A comparison of proactive and reactive scheduling approaches for the RCPSP with uncertain activity durations

Pedram Saeedi, Erik Demeulemeester

KU Leuven, Faculty of Economics and Business, Department of Decision Sciences and Information Management, Leuven (Belgium)
pedram.saeedi@kuleuven.be
erik.demeulemeester@kuleuven.be

Keywords: RCPSP, proactive and reactive scheduling, uncertain activity durations.

1 Abstract

In this paper, we study the performance of state-of-the-art robust solution approaches towards solving the resource-constrained project scheduling problem (RCPSP) with uncertain activity durations. This study addresses approaches in search of a stable project plan that usually use a two-stage procedure, which first creates an (optimal) baseline schedule and then provides changes in the schedule whenever the realized duration of an activity forces us to deviate from the baseline schedule. We discuss the fundamentals of these approaches and possible directions for future research.

2 Introduction

Although the RCPSP has been studied for decades, most of the work done in this field investigated the problem in a static and deterministic environment (Padalkar & Gopinath 2016). In reality, however, the activity durations in a project are subject to significant uncertainty due to various internal or external factors (Zhu et al. 2005, Atkinson et al. 2006): variations in resource requirements, activities taking more or less time than their initial estimation, changes in the budget, etc. This may result in a considerable project overcost and/or overtime (Flyvbjerg 2013). The efforts to address uncertainty in the study of the RCPSP are relatively small compared to those for the deterministic version. In recent decades there have been several studies discussing project scheduling dealing with uncertainties (one can refer to Herroelen & Leus (2005), Demeulemeester & Herroelen (2011) and Hazir & Ulusoy (2019) for an overview of these studies).

Different approaches are proposed to address the uncertainty in project scheduling (Herroelen & Leus 2005). From a general point of view, we can divide most of these efforts into two categories: the stochastic RCPSP (SRCPSP, also referred to as dynamic scheduling) and proactive and reactive project scheduling. The SRCPSP uses scheduling policies or scheduling strategies to dynamically make certain decisions at certain moments. This implies that no baseline schedule is created prior to the start of the project and the schedule is generated gradually by using the aforementioned policies. This results in a lack of robustness in the SRCPSP approach. In the proactive and reactive approaches, on the other hand, a two-stage process is used. In the first stage, a robust baseline schedule is produced, meaning that this approach tries to generate a baseline schedule that tolerates a certain type of uncertainty as well as possible. In the second stage, reactive measures are taken whenever a conflict occurs that cannot be absorbed by the baseline schedule. The main drawback of this two-stage approach is that the final schedule (and its *quality*) is

heavily based on the initial baseline schedule. However, Davari & Demeulemeester (2019*a*) have recently introduced an integrated proactive and reactive approach for the RCPSP to address this drawback.

3 Methodology

The goal of the research in this paper is to study the performance of the proactive and reactive scheduling approaches towards solving the RCPSP. There have been several robustness measures introduced in the scheduling literature to evaluate the robustness of a project schedule. Herroelen & Leus (2005) divide these measures into the two categories of *solution robustness* and *quality robustness*. Solution robustness (also referred to as schedule stability) is concerned with the difference between the baseline schedule and the realized schedule. Quality robustness, on the other hand, is concerned with the insensitivity of the objective value of the baseline schedule against distortions. For an overview and comparison of different robustness measures used in the literature we refer to (Herroelen 2007) and (Khemakhem & Chtourou 2013).Many papers take advantage of proactive and reactive scheduling to deal with uncertainty in the RCPSP. Leus & Herroelen (2004) developed a linear programming model that allowed an increase in the duration of a single activity with having only a single resource type in the problem. Al-Fawzan & Haouari (2005) studied the optimization of the makespan and the solution robustness by introducing a bi-objective model for the RCPSP. Deblaere et al. (2007) consider the RCPSP with uncertainty in activity durations and try to solve the problem by providing solutions on resource allocation that would maximize schedule robustness. Van de Vonder et al. (2008) developed new heuristics such as the *starting time criticality* heuristic to find solutions to the proactive RCPSP. Lambrechts et al. (2008) focus on uncertainty in resource availability and propose eight proactive and three reactive strategies to solve the problem. They apply two approaches for generating a baseline schedule, including using the highest *cumulative instability weight* (CIW) measure to determine an ordered list of activities for scheduling. Lamas & Demeulemeester (2016) introduced a MIP formulation for the chance-constrained RCPSP (C-C RCPSP). Bruni et al. (2017) take advantage of the adjustable robust optimization approach. In the adjustable robust optimization, part of the variables in the problem are determined before the realization of the uncertainty and the others can be adjusted based on the realization of the uncertainty Davari & Demeulemeester (2019*a*) developed an integrated proactive and reactive approach towards the RCPSP and they continued their study in Davari & Demeulemeester (2019*b*) by investigating different classes of reactions and evaluating their contributions in optimal proactive and reactive policies (PR-policies).

This study is conducted in two phases. In the first phase, a thorough literature review is done to address different proactive and reactive approaches and solutions. This phase also covers different single or composite measures of robustness introduced in the literature as well as different policies on activity starting times and schemes on resource allocation. Considering the various combinations of these factors alongside different proactive and reactive approaches in the RCPSP literature, there has not been a clear comparison of how well different studies perform compared to each other. This is where the second phase of this study comes to action. We will conduct a computational comparison of the proactive and reactive RCPSP approaches to see how well they perform in the same environment and with the same input parameters. This will give us the opportunity to see the current gaps in the literature, for instance, to see on what type of project *settings* proactive and reactive approaches cannot still achieve satisfactory results or cannot provide a good solution in terms of robustness. Another contribution would be getting an overview of promising proactive and reactive approaches and expansions to achieve further better results for dif-

ferent RCPSP problems, for instance, to identify promising (or optimal) scheduling policies for particular versions of the RCPSP and to compare the *quality* of different scheduling policies. This helps us to identify the potential directions towards future studies.

References

Al-Fawzan, M. A. & Haouari, M. (2005), 'A bi-objective model for robust resource-constrained project scheduling', *International Journal of production economics* **96**(2), 175–187.

Atkinson, R., Crawford, L. & Ward, S. (2006), 'Fundamental uncertainties in projects and the scope of project management', *International journal of project management* **24**(8), 687–698.

Bruni, M. E., Pugliese, L. D. P., Beraldi, P. & Guerriero, F. (2017), 'An adjustable robust optimization model for the resource-constrained project scheduling problem with uncertain activity durations', *Omega* **71**, 66–84.

Davari, M. & Demeulemeester, E. (2019*a*), 'The proactive and reactive resource-constrained project scheduling problem', *Journal of Scheduling* **22**(2), 211–237.

Davari, M. & Demeulemeester, E. (2019*b*), 'Important classes of reactions for the proactive and reactive resource-constrained project scheduling problem', *Annals of Operations Research* **274**(1-2), 187–210.

Deblaere, F., Demeulemeester, E., Herroelen, W. & Van de Vonder, S. (2007), 'Robust resource allocation decisions in resource-constrained projects', *Decision Sciences* **38**(1), 5–37.

Demeulemeester, E. & Herroelen, W. (2011), 'Robust project scheduling', *Foundations and Trends® in Technology, Information and Operations Management* **3**(3–4), 201–376.

Flyvbjerg, B. (2013), 'Over budget, over time, over and over again: Managing major projects'.

Hazir, O. & Ulusoy, G. (2019), 'A classification and review of approaches and methods for modeling uncertainty in projects', *International Journal of Production Economics* p. 107522.

Herroelen, W. (2007), Generating robust project baseline schedules, *in* 'OR Tools and Applications: Glimpses of Future Technologies', INFORMS, pp. 124–144.

Herroelen, W. & Leus, R. (2005), 'Project scheduling under uncertainty: Survey and research potentials', *European journal of operational research* **165**(2), 289–306.

Khemakhem, M. A. & Chtourou, H. (2013), 'Efficient robustness measures for the resource-constrained project scheduling problem', *International Journal of Industrial and Systems Engineering* **14**(2), 245–267.

Lamas, P. & Demeulemeester, E. (2016), 'A purely proactive scheduling procedure for the resource-constrained project scheduling problem with stochastic activity durations', *Journal of Scheduling* **19**(4), 409–428.

Lambrechts, O., Demeulemeester, E. & Herroelen, W. (2008), 'Proactive and reactive strategies for resource-constrained project scheduling with uncertain resource availabilities', *Journal of scheduling* **11**(2), 121–136.

Leus, R. & Herroelen, W. (2004), 'Stability and resource allocation in project planning', *IIE transactions* **36**(7), 667–682.

Padalkar, M. & Gopinath, S. (2016), 'Six decades of project management research: Thematic trends and future opportunities', *International Journal of Project Management* **34**(7), 1305–1321.

Van de Vonder, S., Demeulemeester, E. & Herroelen, W. (2008), 'Proactive heuristic procedures for robust project scheduling: An experimental analysis', *European Journal of Operational Research* **189**(3), 723–733.

Zhu, G., Bard, J. F. & Yu, G. (2005), 'Disruption management for resource-constrained project scheduling', *Journal of the Operational Research Society* **56**(4), 365–381.