Dynamic Algorithms for Order Acceptance and Capacity Planning within a Multi-Project Environment

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We consider the dynamic order acceptance and capacity planning problem under limited regular and non-regular resources. The goal consists of maximizing the expected profits of the accepted projects within a finite problem horizon. Capacity planning is a useful tool to support tactical decisions such as due-date quotation, price quotation and hiring non-regular capacity. The way the projects are planned affects their payout time and as a consequence, the reinvestment revenues, as well as the available capacity for future arriving projects. Since actual characteristics of project proposals are only revealed upon arrival, dynamic solution approaches are more likely to obtain good results. For this reason, this paper considers dynamic heuristics, such as approximate dynamic programming algorithms and investigates their suitability to solve the problem. We perform simulation experiments to compare the performance of our algorithms to methods commonly used in practice.

Keywords: approximate dynamic programming, order acceptance, capacity planning, simulation, multi-project.

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1 Introduction

Acknowledging the fact that companies have limited resources at their disposal implies that a profit-maximizing company would not accept all project proposals, but would be willing to reject some in order to increase its overall profits. This contrasts sharply with the common practice in project management of accepting all project proposals with a positive net present value (NPV) and to plan them on a first-come, first-served (FCFS) basis, without consideration of future arrivals.

In this paper we examine the order-acceptance and capacity-planning decision facing multi-project organizations upon project arrival. *Capacity planning* determines the allocation of the available (regular and non-regular) resources to the candidate projects, while *order acceptance* is concerned with the accept/reject decision of these projects. In a multi-project environment, projects typically share common resources, so that adequate management of these scarce resources is of crucial importance. Consequently, the development of good acceptance rules and capacity-planning tools is extremely relevant, as they can support decisions such as due-date quotation, price quotation and hiring non-regular capacity. Appropriate order acceptance and capacity planning allows to gain a larger control over the use of non-regular capacity, increase profits and improve delivery performance, which creates a competitive advantage to the company. These benefits constitute the motivation for this research.

Our research adheres to different research domains, one of which is *revenue-based capacity management*, which studies the problem of satisfying customer demand with limited resources while maximizing the company's revenue and profitability [1]. Secondly, the research is related to *portfolio planning and scheduling*, which involves the selection and scheduling/planning of projects. Most of this literature has been dedicated to *static* environments, in which project selection is performed only once, at the beginning of the problem horizon [9], [13]. An example of operational project selection can be found in [15]; within *job-shop planning*, job selection has been a topic of growing interest in the last decade. In [5] and [12] a number of jobs are considered for selection and subsequently the job sequence is determined for the retained jobs. As for the *dynamic* context, where orders arise dynamically to the organization and require immediate response, the existing work is relatively scarce, although there has been a growing interest in recent years [10], [11]. In [7], *simulation* was used to compare different order-acceptance strategies in a job-shop environment. The same methodology was used in [1] and [14] for production-to-order environments; in addition, heuristics for scheduling the accepted work orders were developed. In a completely different context, a *decision-theory-based approach* was implemented in [2] that reserves parts of the capacity for specified order types through a capacity allocation policy. For a more elaborate survey of the literature on both static and dynamic problems, we refer to [8].

2 Model and solution approach

In this paper, we develop dynamic order acceptance and planning algorithms that aim to maximize the expected profits from accepted orders under finite regular per-period capacity. If needed, non-regular capacity units can be brought in at per-unit costs. Only one resource type is considered, which is taken to represent the *bottleneck* resource of the company, for instance in a manufacture-to-order (MTO) environment it might represent a single machine or a team of engineers. We assume that the company owns a limited number of bottleneck capacity units. The amount of *regular* capacity units is the result of a long-term strategic decision that cannot be revised within the time horizon considered in our planning framework. In contrast, the amount of *non-regular* capacity units can be altered as a result of working overtime, hiring temporary labor or outsourcing.

Upon completion of a project, the project payoff is received; from this point on reinvestment revenues are reaped. The way the projects are planned affects their payout time and as a consequence, the reinvestment revenues, as well as the available capacity for future arriving projects. In our model, each project consists of an aggregated workload on the bottleneck resource, expressed as a discrete number of work packages. Obviously, accepted orders can only be executed between their release time and the project's due date, which is regarded here as a deadline. We assume that the company has forecasts for the main features (workload, pay-off and deadline) of the incoming projects, which are obtained using forecasting techniques.

In [8], we modeled the problem as an extension of the optimal stopping problem, a well-known problem within dynamic programming (DP) [4]. We also presented a stochastic dynamic-programming (SDP) approach that maximizes the expected revenues of the dynamic-order acceptance and capacity-planning problem. Since SDP suffers from Bellman's [3] *curse of dimensionality*, approximate methods are needed to solve real-life problems.

Because actual characteristics of project proposals are only revealed upon arrival, dynamic solution approaches are more likely to obtain good results. For this reason, this paper considers dynamic heuristics in general. More particular, the suitability of approximate dynamic programming algorithms [4] to solve the problem will be investigated. Simulation experiments compare the performance of our procedures to a first-come, first-served policy that is commonly used in practice.

Our algorithms are particularly relevant for environments in which a scarce resource acts as a single static bottleneck and where at least rudimentary information about the work content of the proposed and future projects is available. Examples of such environments are MTOs with a single static bottleneck resource [11], construction environments and maintenance projects [6].

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