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Lot sizing and scheduling with sequence-dependent setup costs and times and efficient rescheduling opportunities

Knut Haase, Alf Kimms*

Institut für Betriebswirtschaftslehre, Christian Albrechts University of Kiel, Olshausenstr. 40, 24118 Kiel, Germany

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Abstract

This paper deals with lot sizing and scheduling for a single-stage, single-machine production system where setup costs and times are sequence dependent. A large-bucket mixed integer programming (MIP) model is formulated which considers only efficient sequences. A tailor-made enumeration method of the branch-and-bound type solves problem instances optimally and efficiently. The size of solvable cases ranges from 3 items and 15 periods to 10 items and 3 periods. Furthermore, it will become clear that rescheduling can neatly be done.

Keywords: Lot sizing; Scheduling; Production planning and control; Rescheduling; Sequence-dependent setup times

1. Introduction

For many production facilities the expenditures for the setups of a machine depend on the sequence in which different items are scheduled on the machine. Especially when a machine produces items of different family types setups between items of different families are substantially more costly and time consuming than setups between items of the same family. In such a case a just-in-time philosophy will cause frequent setups, i.e. large total setup costs and long total setup times. To reduce the expenditures for the setups items may be produced in lots which satisfy the demand of several periods. The amount of a production quantity in a period which will be used to satisfy demand in later periods must then be held in inventory. This incurs holding costs. Therefore, we have to compute a schedule in which the sum of setup and holding costs is minimized. In the case of sequence-dependent setup costs the calculation of the setup costs requires the computation of the sequence in which items are scheduled, i.e. we have to consider sequencing and lot sizing simultaneously.

Despite its relevance only little research has been done in the area of lot sizing and scheduling with sequence-dependent setups. Some papers have been published which are related to the so-called discrete lot sizing and scheduling problem [4], denoted as DLSP. In the DLSP the planning horizon is divided into a large number of small periods (e.g. hours, shifts, or days). Furthermore, it is assumed that the production process always runs full periods without changeover and the setup state is not preserved over idle time. Such an "all-or-nothing" policy implies that at most one item will be

* Corresponding author.

E-mail address: Kimms@bwl.uni-kiel.de (A. Kimms).

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produced per period. In [1] a DLSP-like model with sequence-dependent setup costs was considered first. For the DLSP with sequence-dependent setup costs (DLSPSD) an exact algorithm is presented in [2]. There the DLSPSD is transformed into a traveling salesman problem with time windows which is then used to derive lower bounds as well as heuristic solutions. An exact solution method for the DLSP with sequence-dependent setup costs and times (DLSPSDCT) is proposed in [3]. The optimal enumeration method proposed by [4] is based on the so-called batch sequencing problem (BSP). It can be shown that the BSP is equivalent to the DLSPSDCT for a restricted class of instances. The solution methods for the DLSPSDCT and the BSP require large working spaces, e.g. for instances with six items and five demands per item a working space of 20 megabytes is required. Recently, another new type of model has been published which is called the proportional lot sizing and scheduling problem (PLSP) [5]. The PLSP is based on the assumption that at most one setup may occur within a period. Hence, at most two items are producible per period. It differs from the DLSP regarding the possibility to compute continuous lot sizes and to preserve the setup state over idle time. A regret-based sampling method is proposed to consider sequence-dependent setup costs and times. In [6] an uncapacitated lot-sizing problem with sequence-dependent setup costs is considered. A heuristic for a static, i.e. constant demand per period, lot-scheduling problem with sequence-dependent setup costs and times is introduced in [7]. In [8] the so-called capacitated lot-sizing problem with sequence-dependent setup costs (CLSD) is presented. As in the PLSP, the setup state can be preserved over idle time. But in contrast to the DLSP and PLSP many items are producible per period. Hence, the DLSP and PLSP are called small-bucket problems and the CLSD is a large-bucket problem. For a review of lot-sizing and scheduling models we refer to [5]. A large-bucket problem with sequence-dependent setup costs and times is not considered in the literature so far. In this paper we will close this gap.

The text is organized as follows: in the next section we briefly describe the practical background that inspired our work on this subject. In Section 3, we give a mathematical formulation of the problem under concern. Afterwards, rescheduling is discussed in Section 4. In Section 5, an optimal enumeration method is outlined. The efficiency of the algorithm is tested by a computational study in Section 6.

2. A real-world case

Linotype-Hell AG, Kiel (Germany), manufactures high technology machines for the setting and printing business. A case study coauthored by one of the authors and provided in [9] informally describes the situation up to 1995 as follows. Although a commercial Siemens software package already is in use for production planning and control, demands are usually not met right in time. A milling machine, a so-called BZV07-2000, is identified as being the bottleneck. Hence, one searches for alternatives out of this situation. Buying an additional milling machine is considered to be too expensive. And using outside capacities is not wanted, because the know-how should be kept inside the firm. Hence, one of the authors suggests using the available capacity of the milling machine more efficiently by improved production planning.

The production planning problem for the milling machine indeed is a lot-sizing and scheduling problem with sequence-dependent setups. Setting the milling machine up actually means to load a specific program into memory that runs the numerically controlled milling machine, and to mount specific tools and holders. The sequence-dependent setup time consists of taking off tools and holders, loading another program, and mounting other tools and holders. The shortcoming of the planning software already in use is that average data for setup times are used as input for planning, and sequence dependencies are not considered. But, in practice, total setup times result from planning. As a consequence, the idea is near to formulate and to solve a model for this particular problem.

This case actually inspired the work on this paper and may thus serve for validating the work. Unfortunately, from our point of view, in 1996 Linotype-Hell AG started using SAP software and