A real life batch-sizing and sequencing problem with capacitated buffer and setup times

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1 Introduction

This work deals with a real-life batch sizing and sequencing problem where sequence-dependent setup times are necessary when changing the production from one type of product to another. This problem arises in the automotive industry and concerns an injection machine that is able to produce several types of products, such requiring a specific injection tool. Due to a long heating time of the injection tool, a minimum batch size is required. There is a limited buffer for each type of product. The problem is to determine the starting time and the duration of each batch so that a given demand is satisfied while the inventory level of each buffer falls into a predefined interval. This buffer is necessary because the injection process is an upstream manufacturing operation feeding a downstream assembly operation that should never stop. Considering simultaneously batch sizing and scheduling is a crucial issue for planners, especially when setups are sequence-dependent [1].

One of the related problem in the literature is the general lot-sizing and scheduling problem (GLSP) which aims to minimise setup, production and inventory holding costs. Different variants of the problem have been studied in the literature [2] while considering several parameters such as planning horizon and resource constraints. In discrete lot-sizing and scheduling problems (DLSP), the planning horizon is divided into periods with a demand to be fulfilled in each period. The DLSP is a small bucket model with the so-called all-or-nothing assumption which means, in each period, there is only the choice to produce during the entire period or not to produce at all. Thus, a batch size always corresponds to an integer number of consecutive periods. Many studies have addressed the same planning problem with a different approach known as batch sequencing problem (BSP). In the BSP, each job has a due date and a processing time and the objective function is related to completion times such as total tardiness or makespan. In the DLSP, decisions concerning production or setup have to be taken at each time period, while in the BSP, decisions are related to schedule jobs, i.e. to determine their completion times [4]. The studied problem falls on the border of these two streams of research, since starting from a demand to be satisfied, we must simultaneously determine batch sizes and the sequence of these batches. The main difference from lot-sizing lies in lengths of periods which are very short in our problem compared with the setup times.

2 Problem description

This study investigates simultaneous batch sizing and sequencing to produce some coloured plastics over a discrete horizon of T time periods. Given a demand $d_{k,t}$ for item k at period t to be fulfilled from buffers, one has to organize the production to replenish the buffers so as to keep the inventory levels between predefined bounds at any time. For each item k, the safety window (SW_k) represents a threshold quantity of the buffer to be maintained for contingencies.

Moreover, backlogging is allowed but penalized, while holding cost are ignored by the company given the short planning horizon considered. From an operational point of view "the goal is to schedule batches as large as possible without crossing the safety window and without exceeding the buffer capacity." For each type of product, a nominal production rate q_k represents the quantity of products k that can be produced and released in the buffer at each period, without waiting for the completion of the batch. In fact, each batch is composed of identical products which require a particular configuration (tool) to be set up on the machine. Control theory-based models have been developed to address these types of scheduling problems but in general their limitation is that the optimal decisions (machine states at each period) are not globally computed and then applied, but are generated during the evolution of the system based on predetermined control strategies [3]. Because of these limitations, we propose an Integer Linear Programming (ILP) formulation which determines the optimal sequence of machine states over the planning horizon. We distinguish three possible states : production, setup or changeovers and idle states. Therefore, the set of all possible states consists of : K product *configurations* plus K*(K-1) possible *changeovers* between configurations plus K fictive dummy configurations which are used to indicate *idle* periods of the machine even if a certain configuration is set. We seek a feasible schedule that minimizes the total cost due to shortages, to SW units used to satisfy demand, and to idleness of the machine. The machine idleness involves *changeover* periods, i.e., the time of setting up a new configuration and purely *idle* periods.

The above mentioned objectives have been considered simultaneously with weights that are consistent with the company's priorities. We introduce a matrix which regulates machine state transition and some constraints ensuring the minimum batch sizes, the correct duration of changeovers and the evolution of inventory levels over the planning horizon. We test our model on small-size instances and obtain encouraging results for solving larger-size instances.

3 Conclusions & future works

We consider a simultaneous batch-sizing and sequencing problem which was extracted from a real life problem in the automotive industry where the production has to be organized on the injection machine in order to ensure the coloured plastics (internal demand) required from the assembly phase, considering a limited intermediate buffer between them. Buffer capacity, batches' minimum size and sequence-dependent setup times lead to a very challenging optimization problem. An ILP is proposed aiming to ensure demand satisfaction and increase machine efficiency. The first experiments are carried out on small-size instances, using Cplex solver.

As future work, we firstly aim to extend our study to represent the real case where several parallel injection machines share resources for the setup operations. Afterwards we are going to develop a meta-heuristic approach to deal with large-size instances based on real data and finally consider demand uncertainties as in the practice.

Références

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