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Order acceptance and due-date quotation in low machine rates

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ABSTRACT

In real manufacturing environments, some customer orders include multiple jobs. However, a single due-date should be assigned to each order. Further, machine processing rate is not constant at all times. In effect, in many manufacturing operations, the machine processing rate decreases to a subnormal level during time and needs a special type of maintenance to bring the normal state back. Due to this reduction in capacity, production schedulers may decide to reject some orders. In this paper, the novel extensive problem of selecting a subset of orders, assigning due-dates to selected orders, scheduling the selected orders and jobs within each one, and scheduling the rate-modifying maintenance is studied. The objective function is minimizing total cost of lost-sales of rejected orders together with due-date length and maximum of earliness and tardiness of selected orders. The problem is proved polynomial and an optimal approach is developed.

1. Introduction

Make-to-order manufacturers deal with a set of orders, each of which includes a number of jobs. Each customer usually expects to receive his or her order completely. The reasons are reducing the transportation costs, meeting the requirements of assembly operations, minimizing the order reception and processing costs, and so forth. Hence, a common due-date is assigned to jobs within each order. Mosheiov and Oron studied a situation where the number of due-dates is considerably smaller than of jobs [1]. They called the jobs with the same exogenous due-date as a class.

Due-date assignment problems have received more attention in the last two decades [2]. Due-date assignment studies usually disregard the presence of orders that contain multiple jobs. An exception is a recent study by Shabtay et al. [3]. They extended the common due-date assignment notion to a group technology environment in which a constant due-date is assigned to all the jobs within each family. Their main motivation was based on the assumption that each family of jobs corresponds to a single customer order.

In many manufacturing operations, the machine processing time varies during the time. The change in processing time may be due to learning [4], deterioration [5], and usage of some additional resources [6]. In the case of deterioration, the machine production rate gradually decreases. While the machine is in its low rate condition, the production rate can be upgraded by performing a maintenance activity. This kind of maintenance is called rate-modifying activity (RM). This situation is frequent in industry. For instance, in machining processes, the material-removing tool becomes blunt during the time. So, the machining time increases and the tool should be sharpened or replaced. Another real world example is related to electronic industry [7] and is not repeated here for the sake of brevity.

As contrast to other kinds of maintenance [8–11], the consideration of RM in scheduling environments is very recent. Rustogi and Strusevich [12] studied a machine scheduling problem with deteriorating jobs and RMs in which the objective

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function is the minimization of make span. They proved that when the number of RMs is fixed and the deteriorations are dependent to the positions of maintenances and jobs, the problem is formulated as a rectangular linear assignment problem. Gordon and Tarasevich [13] develops polynomial solution algorithms for a machine scheduling problem with RM and due date assignment. Mosheiov and Sarig [14] developed polynomial procedures for machine scheduling problem in which a common due window and an RM should be scheduled. Yang and Yang studied machine scheduling problem with deteriorating jobs and multiple deteriorating RMs [15]. Their problem is determination of the optimal number and positions of RMs and the sequence of jobs to minimize total completion time. They developed polynomial procedures to solve the problem.

In order to quote short and reliable due-dates, production schedulers may consider selecting a subset of orders and rejecting the others [16]. Slotnick reviewed the studies which consider the integrated problem of order acceptance and scheduling (OAS) [16]. Gordon and Strusevich [17] studied the integrated problem of machine scheduling and due date assignment with deteriorating processing times. They assumed that each order either is completed by its due date or must be discarded. They developed polynomial algorithms to solve the problem. Rom and Slotnick [18] developed a genetic algorithm for a machine scheduling problem with the objective of maximization of total revenue of accepted orders minus total tardiness costs. Nobibon and Leus [19] considered a machine scheduling problem with both firm and potential orders. Each potential order can be rejected. Their objective is the maximization of revenue of accepted orders minus the tardiness cost of such orders. They proved that the problem is non-approximable and developed two branch and bound approaches. Cesaret et al. [20] studied a machine scheduling with sequence-dependent setup times and unequal arrivals. They assumed that each order can be rejected at the cost of losing its revenue. Each order has a deadline which cannot be violated. The objective is the maximization of revenues of accepted orders minus their tardiness costs.

In the scheduling context, outsourcing of an order is tackled as rejection. For example, an outsourcing and scheduling problem was studied by Lee and Sung as an OAS problem [21].

In all of the abovementioned studies, each order contains a single job. In practice however, the customer order may include several jobs. Acceptance of one order means accepting all of its jobs.

This paper studies a single machine problem including RM scheduling, OAS, and due-date assignment to selected orders. It is assumed that each order may include a number of jobs. The objective function is minimizing total due-date and maximum of earliness and tardiness costs of selected orders together with the lost-sale cost of rejected ones. To the best of our knowledge, no published paper has tackled the OAS problem with orders including multiple jobs. Also, the authors are not aware of any paper considering OAS in repairable low-machine rate situations. Finally, most of published papers considering OAS deal with exogenous due-dates.

The paper has the following structure. Section 2 defines the problem formally and presents the mathematical notations. Several dominance rules are developed in Section 3. Dominance rules describe the properties which are common among optimal solutions [22]. A solution which matches all the dominance rules is called dominant. On the other hand, a solution which dissatisfies at least one rule is called dominated or non-optimal. The reason of existence of dominance rules is reducing the search space of the problem to the dominant solutions [22]. Consequently, the problem can be solved more efficiently. Based on such rules, a polynomial solution approach is developed in Section 4. Finally, Section 5 summarizes the results.

2. Problem definition and notations

In this paper, an integrated problem of machine scheduling, order acceptance and due date assignment in a low rate situation is studied. The problem is denoted by OASDA&RM.

It is assumed that,

- Processing of each job must be done without preemption.
- The machine can process at most one job at a time.
- Setup times are negligible.
- All jobs are ready for process at time zero.
- The machine is in a low-rate situation at time zero.
- No break down occurs.
- Maintenance activity upgrades the machine processing rate.
- During RM, the machine is turned off and no job can be processed.

There are m orders at hand (O_i:$i = 1,\ldots,m$), each of which includes N_i ($N_i \geqslant 1$) jobs. The jobs of the same order should be delivered simultaneously. Hence, the jobs of each order are scheduled around a common due-date d_i which should be determined. In some studies, it is assumed that the jobs constituting one order must be processed contiguously [23]. In this paper this is not the case.

Low rate of machine decreases the production capacity. Due to this capacity loss, production schedulers may decide to reject some orders at a lost-sale cost. The set of accepted orders and the time of performing modifying maintenance (RM) should be determined.