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Robustness of a production schedule to inventory cost calculations

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Abstract

Minimizing the cost of capital tied up by inventory is frequently an important management objective of production scheduling. The paper determines the optimal production schedule of a single machine sequencing problem for two cases; first when the cost of capital is calculated by periodic interest calculation, and second, when the cost of capital is determined by continuously compounded interest calculation. The results are derived for common due date and for different due dates situations as well. The robustness of the suggested production schedules to the method of interest calculation is proved theoretically and demonstrated with the example of a calendar manufacturer.
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1. Introduction

In practice, operations management objectives frequently contradict financial objectives. For example, operations management might be interested in high inventory level to satisfy fluctuating demand while financial management might be interested in low inventory level to reduce inventory holding cost. At times, operations management is interested in low capacity utilization of service facilities to reduce waiting time of customers while financial management is interested in high machine utilization to show high return on investment of expensive resources. There are cases, however, when the contradiction between operational and financial objectives is only apparent. This paper presents a production programming situation in which scheduling decision is relatively insensitive to certain financial considerations.

The paper was motivated by the production scheduling problem of a small calendar manufacturer. Raw materials for calendars arrive to the production process at the required time, and their cost has to be paid to the supplier upon arrival. Income, however, is received only at the delivery time of finished products. All calendars are prepared for a fixed common due date around the last quarter of the year. Delay is not allowed because calendars are perishable items, generally can only be sold around the beginning of the New Year. Based on the analysis of the production process the cutting machine was identified as the bottleneck of the system. Since the company manufactures without

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any income in the first three quarters of the year minimization of inventory holding cost is a major objective for production scheduling.

The objective of this paper is to provide production schedules, which minimize inventory holding cost of the calendar manufacturer and to analyze how the optimal schedule is influenced by the method of interest calculation.

The problem outlined above is a single machine scheduling problem with fixed common delivery date and sequence independent setup times. The scheduling criterion is to minimize a function of total lateness. However, since all calendars are shipped on time, an earliness related cost function must be minimized (Baker and Scudder, 1990). Depending on the calculation of the cost of financing raw materials a linear or a non-linear objective function is appropriate.

Sequencing jobs on a single machine is a well-studied problem in the literature. Since the appearance of the classical sequencing rules of Smith (1956) several other special cases for optimizing flow time and tardiness related objective functions have been solved (e.g. Baker, 1974; Conway et al., 1976). However, as a consequence of the combinatorial nature of sequencing problems most of the practically relevant situations can only be handled by heuristics.

Sequencing with a common due date for all jobs is an important set of sequencing problems (Bector et al., 1991). If the common due date is fixed in advance, then the problem is more tractable but still most of the problems are NP hard. When the due date is fixed in advance and it is higher than the completion time of each job, the problem is reduced to an earliness related single machine sequencing problem.

In most cases, the objective of scheduling is to improve some cost related performance measures. If inventory holding cost is minimized, the cost of capital is an important element of the calculation. Inventory holding cost is generally calculated by the use of inventory holding rate. (see e.g. Anderson, 1994; Vollmann et al., 1997; Waters, 1996) This rate expresses the percentage of the cost of materials which should be considered as holding cost. The application of inventory holding rate is a pragmatic approach. Generally, there are several reasons for the change of inventory holding cost with respect to the change of inventory level. Instead of identifying all these reasons and determining the effect of each reason, an aggregate measure, the inventory holding rate is applied. Sometimes, the cost of capital tied up by inventory can be simply calculated, especially if inventory is financed from credit. In this case, a more accurate inventory holding cost calculation can be given by calculating the exact value of the interest. There are several ways of determining this interest. All these methods can be approximated by two extreme situations: interest is not compounded, and interest is continuously compounded. In the first case, the objective function is a linear function of flow time while in the second case the objective function is non-linear (exponential). Inventory holding cost approximated by these two situations provides a lower and an upper approximation of the exact value of interest for all practically relevant situations.

If the inventory cost is financed directly and completely from credit, and credit conditions are known, then the appropriate cost should be calculated using the actual credit payment. If, however, conditions are not known at the time of the inventory holding cost estimation, or it is not decided yet, how inventory school be financed, then the lower and upper approximation of inventory holding cost is equivalent to the estimation of opportunity cost.

Scheduling based on a non-linear objective function is widely discussed in the literature (e.g. Rinnooy Kan et al., 1975; Sung and Joo, 1992; Alidaee, 1993). Since most of these problems are also NP hard, generally branch and bound based heuristics are suggested for the solutions. In some special cases (like the one presented in this paper), efficient algorithms using the adjacent pair interchange (API) principle can be applied.

Successful applications of classical scheduling theory results are constrained, on the one hand, by several restricting conditions and, on the other hand, by the complex and dynamic nature of reality (McKay et al., 1988). However, in some simple situations, the application of scheduling rules can lead to better results than random or habit-driven sequencing of jobs. When the situation is complex, sensitivity analysis can help to outline the validity of a simple approach by filtering out the non-relevant complicating factors (constraints, parameter). For this reason, sensitivity analysis is used frequently in various areas of management when the complexity of a problem must be reduced (see for example, Borgonovo and Peccati, 2004, 2006; Koltai and Terlaky, 2000).

In the following, two scheduling rules for minimizing inventory holding cost are derived in

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