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Economic due-date setting in job-shops based on routing and workload dependent flow time distribution functions

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Abstract

The trade-off between the length of the lead times quoted to the customers and the delivery reliability has been investigated by many authors. However, only a few studies do this in an economic setting. In this study, the setting of cost optimal due dates taking into account lead-time related and tardiness related costs is investigated. More specifically, in setting the internal due dates, which are used for determining the priorities on the shop floor, and in determining the expected order flow time probability density functions which are used for setting the external due dates, the work load is taken into account. From this study, it follows that this approach leads to (much) lower costs as compared to the situation with workload independent order flow time p.d.f.'s.

Keywords: Lead times; Cost optimal; Delivery performance; Due date

1. Introduction

For many firms it is crucial to have short lead times and a good due date performance [1–3]. With the latter it is meant that orders are delivered as close as possible to their due dates. Two decision functions play an important role in this respect: the *order acceptance* function where, amongst others, a lead time is promised to the customers and the *order realisation* function which influences the order completion time. In quoting lead times to the customers a trade-off has to be made between the length of the lead times and the reliability of the lead-time. Promising a short lead time might lead to an impossible task for the order realisation function with regard to delivering the order close to the order due date. On the other hand long lead times make it easy for the order realisation function to obtain a good due date performance but these lead times are, in general, not acceptable for the customers. Many authors (e.g. Cheng [4]; Vig and Dooley [5]; Lawrence [6]; Enns [7]) have studied this trade-off between the length of the lead times quoted to the customer and the delivery reliability (or due date performance). In these studies, lead times are determined such that a certain delivery reliability (in terms of lateness or tardiness) is obtained. However, a number of production situations are characterised by the fact that customers are willing to pay more for short lead times while, at the same time, there are penalties for the manufacturer for late deliveries. Short lead times lead to

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high prices but also to high penalties. Long lead times lead to lower prices paid by the customers but also to (very) low penalties to be paid by the manufacturer. In these situations the question is not which lead times lead to a certain delivery reliability but which lead times lead to the highest profit. Up to now only a small number of studies have taken this into account in determining optimal lead times ([8–11]). Gong et al. use the equivalence between the production lead-time model and the inventory model ('newsboy' problem) for a serial production line where all orders have the same number of operations.

This paper concentrates on job-shop like production systems where orders might have quite different routings and routing lengths and on the effect of using (operation) due date sequencing. Enns uses the *overall* lateness distribution function in setting economically optimal due dates. Bertrand and Van Ooijen [12] show that the flow time distribution functions might have quite different shapes for orders with different numbers of operations. The order flow time p.d.f.'s they use in setting the cost optimal external due dates, which determine the delivery performance, are the long term p.d.f.'s that are correct for the average utilisation. However, on the short term the utilisation (workload), in general, will deviate from the average utilisation (workload).

In this study the approach of Bertrand and Van Ooijen [12] is followed. Their research is extended by taking into account the work load in setting the internal due dates, that are used for determining the priorities on the shop floor, and in determining the external due dates, that are quoted to the customer. The latter are based on different flow time p.d.f.'s for orders with different numbers of operations. The rest of this paper is organised as follows. In Section 2, a detailed description of the economic lead times determination problem is given. Next, in Section 3, it is discussed how order flow time probability density functions can be used to determine the economically optimal lead times. Section 4 discusses in more detail the production situation that is considered and the simulation study that has been used to investigate the effects of the policies discussed in Section 3 after which in Section 5 the results of this simulation study are presented and discussed. Finally, Section 6, summarizes the findings of this study.

2. Economically optimal lead times

In this study it is assumed that quoting long lead times leads to economic costs, for instance by getting orders with lower margins. The fact that customers value short lead times over long lead times has been modelled as a piecewise linear order cost function. In the market there is an accepted order lead time m. Quoting a lead time shorter than m has no influence on the lead time related costs. Quoting a lead-time longer than m results in an increase of the order costs proportional to the lead-time.

In formula

$$p(l_j) = 0, \qquad 0 \leqslant l_j \leqslant m,$$
$$p(l_j) = b(l_j - m), \qquad l_j \geqslant m,$$

with

l_j: lead time of order j;

$p(\cdot)$: the part of the order costs that depends on the quoted lead-time;

m: the lead-time that is generally accepted by the market; lower lead times do not lead to a decrease of the costs;

b: constant.

On the other hand it is assumed that there is a penalty for late deliveries. It is assumed that the tardiness costs are proportional to the amount of tardiness. If an order finishes later than its customer due date, the order is tardy and a tardiness cost is incurred. Each unit of tardiness leads to a penalty of c monetary units. The tardiness depends on the due date and the completion time of the order. The completion time C_j is equal to the arrival time r_j plus the order flow time f_j: $C_j = r_j + f_j$.

For most situations holds that upon arrival of an order its flow time cannot be known with certainty. Therefore it is assumed that the distribution function of the order flow time is known, for instance determined from historical data. Let $H(f)$ denote the distribution function of the order flow time and $h(f)$ the density function of the order flow time. Now the question is which lead-time (or due date)