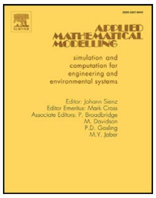
Applied Mathematical Modelling 45 (2017) 982–996

Contents lists available at ScienceDirect

Applied Mathematical Modelling

journal homepage: www.elsevier.com/locate/apm



Algorithms for minimizing the number of tardy jobs for reducing production cost with uncertain processing times

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ARTICLE INFO

Article history:
Received 18 April 2015
Revised 15 December 2016
Accepted 13 January 2017
Available online 20 January 2017

Keywords:
Single machine
Scheduling
Dominance relation
Number of tardy jobs
Algorithm

ABSTRACT

This paper addresses a manufacturing system consisting of a single machine. The problem is to minimize the number of tardy jobs where processing times are uncertain, which are within some intervals. Minimizing the number of tardy jobs is important as on-time shipments are vital for lowering cost and increasing customers' satisfaction for almost all manufacturing systems. The problem is addressed for such environments where the only known information is the lower and upper bounds for processing times of each job since the exact processing times may not be known until all jobs are processed. Therefore, the objective is to provide a solution that will perform well for any combination of feasible realizations of processing times. First, a dominance relation is established. Next, several versions of an algorithm, incorporating the dominance relation, are proposed. The computational analyses reveal that the error of one of the versions of the algorithm is at least 60% smaller than the errors of the other versions of the algorithm. Besides, the performance of this version is very close to the optimal solution, i.e., on average, 1.34% of the optimal solution.

1. Introduction

The number of tardy jobs or equivalently the percentage of on-time shipments is often used to measure the performance of managers. This is because manufacturing managers in developed countries consider the speedy and on-time delivery as vital since they affect costs, profitability, and customer satisfaction which in turn affect the long-run financial performance of a firm by increasing repurchase intentions and building loyalty among existing customers. On-time shipments and delivery is relevant in many manufacturing and production systems, such as semiconductor manufacturing facilities or automobile assembly lines, Seo et al. [1].

Manufacturers frequently have to pay penalty costs for each late job. If the manufacturer employs its workers in the weekends or in late hours to avoid late jobs, then it may end up paying high labor costs which are higher in those periods relative to the normal working hours. In addition, the labor productivity may decrease due to over employment. The two cases result in higher costs and lower profits for the firm. Thus, an important factor in reducing costs is to reduce the number of late or tardy jobs.

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http://dx.doi.org/10.1016/j.apm.2017.01.039
0307-904X/

The customers may easily switch to another manufacturer due to the discontent of late deliveries in today's highly uncertain, global and complex environment with fierce competition among manufacturers. When customers purchase the same brand for long time, they may form habit for that product and this gives her/him incentive to repurchase that product in later periods. Moreover, in today's environment, information is shared easily and quickly. A manufacturer's delay in deliveries could hurt its reputation and may decrease its ability to attract new customers. Therefore, increasing the percentage of on-time shipments is utmost important for building customer loyalty and competing with the other firms worldwide.

Single machine scheduling is commonly applicable in real life. Furthermore, one machine may be bottle neck in many multiple-machine manufacturing environments. Thus, efficient scheduling on the bottle neck machine is essential for in increasing the productivity of the manufacturing environment. Therefore, the single machine scheduling problem is important [2].

We address the problem of scheduling jobs on a single machine with the objective of minimizing the number of tardy jobs. This problem has been addressed with respect to different performance measures including the number of tardy jobs. The vast majority of the research on the performance of the number of tardy jobs though has been devoted to the case of deterministic problem where job processing times and due dates are known fixed values. For this deterministic problem, Moore [3] provided an algorithm, which was later shown to give the optimal solution for the problem by Sturm [4].

The single machine scheduling problem has also been addressed for the stochastic environments where job processing times and/or due dates follow certain distributions. For example, Pinedo [5] provided an optimal policy for minimizing the expected weighted number of tardy jobs when job processing times are exponentially distributed and jobs have a common random due date. Seo et al. [1] considered minimizing the expected number of tardy jobs when processing times have normal distribution and a common deterministic due date.

De et al. [6] addressed the single machine stochastic scheduling problem to minimize the total weighted number of tardy jobs where jobs have random processing times and a common due date which has an exponential distribution.

Some real world scheduling problems cannot be modeled as deterministic. The reason for this is that there are many factors causing uncertainty in the processing times. Such factors are: conditions of the tools, machine operator fatigue or lack of experience, untested processing technology, presence or condition of auxiliary devices for holding the job at the appropriate position on the machine such as fasteners or pallets, and disruptions in manufacturing systems, e.g., Tayanithi et al. [7]. Moreover, activities may take more or less time than originally estimated, material may arrive behind schedule, and workers may be absent. This uncertainty should be incorporated into the planning phase. Production control is charged with accommodating these in advance to avoid a possible chaos. Also, for new jobs, past data are not available, and hence, their duration may be predicted by some bounds only. On the other hand, assuming deterministic due dates is not unreasonable as the due dates are specified by the customers beforehand.

Deterministic scheduling models are used for environments in which the processing time of each job is assumed to be known and constant. However, in some environments the processing times may be uncertain due to changes in the dynamic scheduling environment. In such an environment, processing times could be assumed to be random variables with a known probability distribution function. This assumption may cause difficulties in some scenarios. First, we may not have enough priori information to characterize the probability distribution of a random processing time. Second, even if the probability distribution is known a prior, it is useful only for a rather large number of realizations of similar scheduling environments, but it has little practical usage for a small number of similar realizations. Another drawback of using distributional assumptions is provided in the book written by Kouvelis and Yu [8]. They mentioned that distributional assumptions often are inappropriate for a scheduling environment where a few factors such as machine or tool conditions, supplier yield problems or worker skill levels, determine the uncertainty of processing times. For example, the tool condition might be affecting the processing time of all jobs in the same way. It has been observed that although the exact probability distributions for processing times may not be known before scheduling, upper and lower bounds on processing times are relatively easier to obtain in many practical cases.

In an uncertain model, it is assumed that a processing time may take any real value between the lower and upper bounds. A deterministic model is a special case of this considered model in which the lower and upper bounds are equal. Even if we have no possible perturbations of processing time for some given job, we can set the lower and upper bounds far from each other. It should be noted that for some jobs, we may know the exact values of their processing times in which case their lower and upper bound would be equal.

The described problem is known as scheduling problem with uncertain and bounded (or interval) processing times which has been addressed for the single machine scheduling problem with the performance measure of flow time, e.g., Sotskov et al. [9] and Sotskov and Lai [10]. The problem has also been considered for scheduling environments other than the single machine environment. Allahverdi and Aydilek [11] addressed the two-machine flowshop scheduling problem with uncertain and bounded processing times to minimize makespan. They provided several polynomial time algorithms and showed that one of the algorithms yields close to optimal solution. Allahverdi et al. [12] provided dominance relations for the same two-machine flowshop problem with the same objective of minimizing makespan where processing times are deterministic, but setup times are uncertain and bounded. Aydilek et al. [13] considered the same problem of Allahverdi et al. [12], and they proposed polynomial time algorithms. They showed that one of their proposed algorithms yields a solution which is exceptionally close to the optimal solution. Similar other problems have been addressed in the literature for the case where job processing times are uncertain and are within some intervals, i.e., bounded, for other scheduling environments, such as