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Scheduling problems with past-sequence-dependent setup times and general effects of deterioration and learning

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ABSTRACT

In this paper we consider the single-machine setup times scheduling with general effects of deterioration and learning. By the general effects of deterioration and learning, we mean that the actual job processing time is a general function of the processing times of the jobs already processed and its scheduled position. The setup times are proportional to the length of the already processed jobs, i.e., the setup times are past-sequence-dependent (p-s-d). We show that the problems to minimize the makespan, the sum of the δth ($\delta > 0$) power of job completion times, the total lateness are polynomially solvable. We also show that the total weighted completion time minimization problem, the discounted total weighted completion time minimization problem, the maximum lateness (tardiness) minimization problem, the total tardiness minimization problem can be solved in polynomial time under certain conditions.

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1. Introduction

In classical scheduling problems, the processing times of jobs are assumed to be constant values. However, there are many situations that the processing times of jobs may be subject to change due to deterioration and/or learning phenomena Pinedo [1]. Machine scheduling problems with deteriorating jobs and/or learning effect have been paid more attention in recent years. Extensive surveys of research related to scheduling deteriorating jobs were provided by Alidaee and Womer [2] Cheng et al. [3] and Gawiejnowicz [4]. For research results on other scheduling models with deteriorating jobs and different machine environments, a reader can refer to Wu et al. [5], Shiau et al. [6], Wang [7,8], Wang et al. [9], Wang and Liu [10], Wang and Sun [11], Ng et al. [12], Wei and Wang [13], Wang et al. [14], Wang et al. [15], and Wei et al. [16].

In addition, extensive surveys of research related to scheduling with learning effects and/or ageing effects was provided by Biskup [17] and Janiak et al. [18]. Biskup [19] and Cheng and Wang [20] were among the pioneers that brought the 19 concept of learning into the field of scheduling problems. Biskup [19] considered the following position dependent learning effect model, i.e., if job J_j is scheduled in position r in a sequence, its actual processing time is

$$p_{jr}^{A} = p_j r^{a},$$

where p_j is the normal processing time of job J_j, $a \leqslant 0$ is a constant learning effect. Biskup showed that two single machine scheduling problems can be solved in polynomial time. Janiak and Bachman [21] considered the same model with Biskup [19], and another position dependent learning effect model, i.e., if job J_j is scheduled in position r in a sequence, its actual processing time is

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$$p_{jr}^A = p_j - b_j r,$$

where b_j is a learning ratio for job J_j. For research results on other scheduling models with learning effects and different machine environments, a reader can refer to Eren and Guner [22–24], Eren [25], Wang et al. [26], and Wang and Wang [27–29]. Kuo and Yang [30] claimed that there are situations where "the more you practice, the better performance you obtain", so they proposed time dependent learning effect model, i.e., the actual processing time of job J_j if it is scheduled in position r is given by:

$$p_{jr}^A = p_j\left(1 + \sum_{l=1}^{r-1} p_{[l]}\right)^a,$$

where $a \leqslant 0$ is a constant learning rate. They proved that single machine total completion minimization problem remain polynomially solvable. Koulamas and Kyparisis [31] considered the following model, i.e., the actual processing time of job J_j if it is scheduled in position r is given by:

$$p_{jr}^A = \left(1 - \frac{\sum_{l=1}^{r-1} p_{[l]}}{\sum_{l=1}^{n} p_l}\right)^a,$$

where $a \geqslant 1$ is a constant learning rate. They proved that single-machine makespan and total completion time minimization problems remain polynomially solvable. They also showed that the two-machine flowshop makespan and total completion time minimization problems remain polynomially solvable for some special cases. Cheng et al. [32] considered the following model, i.e., the actual processing time of job J_j if it is scheduled in position r is given by:

$$p_{jr}^A = \left(1 - \frac{\sum_{l=1}^{r-1} p_{[l]}}{\sum_{l=1}^{n} p_l}\right)^{a_1} r^{a_2},$$

where a_1 and a_2 denote two learning indices with $a_1 \geqslant 1$ and $a_2 \leqslant 0$. They proved that some single-machine scheduling and some special cases of the m-machine flowshop problems can be solved in polynomial time. Wang et al. [33] consider a learning effect model, i.e.,

$$p_{jr}^A = p_j\left(\alpha a^{\sum_{i=1}^{r-1} \ln p_{[i]}} + \beta\right),$$

where $\alpha \geqslant 0$, $\beta \geqslant 0$ and $0 < a \leqslant 1$ are parameters obtained empirically, and $\alpha + \beta = 1$. They proved that some single-machine scheduling problems can be solved in polynomial time. Other types of jobs with learning and/or aging effects have also been discussed; the reader is referred to papers by Janiak and Śnieżyk [34,35], Wang and Wang [36], Wu et al. [37], Low and Lin [38], Yang and Yang [39], Lai and Lee [40], Wang et al. [41], and Wang et al. [42]. Most recent studies tend to combine learning effect with deterioration effect (Toksar and Guner [41], Cheng et al. [43], Yang [44], Yin and Xu [45], Lee and Lai [46], Wang and Wang [47], Wang et al. [48], and Bai et al. [49]).

The above works on scheduling with deteriorating jobs and/or learning effects neglect the setup cost or setup times. However, scheduling with setup times or setup cost plays a crucial role in today's manufacturing and service environments where reliable products/services are to be delivered on time Cheng et al. [50]. There are two types of setup time or setup cost: sequence-independent and sequence-dependent. In the first case, the setup time/cost depends solely on the task to be processed, regardless of its preceding task. While in the sequence-dependent type, setup time/cost depends on both the task and its preceding task. For recent results and trends in scheduling problems with setup times or costs, the reader may refer to the recent review paper of Allahverdi et al. [51]. Koulamas and Kyparisis [52] first introduced a scheduling problem with past-sequence-dependent (p-s-d) setup times, i.e., the setup time is dependent on all already scheduled jobs. The objectives are the makespan, the total completion time and the total absolute differences in completion times. They proved that the standard single machine scheduling with p-s-d setup times and any of the above objectives can be solvable in polynomial time. They also extended their results to nonlinear p-s-d setup times. Kuo and Yang [53] considered single machine scheduling with past-sequence-dependent setup times and job-independent (job-dependent) learning effect (i.e., $p_{jr}^A = p_j r^{a_j}$, where a_j is the job-dependent learning rate of job J_j). For the following objective functions: the makespan, the total completion time, the total absolute differences in completion times and the sum of earliness, tardiness and common due-date penalty. They proposed the polynomial time algorithms to optimally solve the above objective functions. Wang [54] considered single-machine scheduling with past-sequence-dependent setup times and time-dependent learning effect $\left(\text{i.e., } p_{jr}^A = p_j\left(1 + \sum_{l=1}^{r-1} p_{[l]}\right)^a\right)$. He proved that the makespan minimization problem, the total completion time minimization problem and the sum of the quadratic job completion times minimization problem can be solved by the SPT rule, respectively. He also proved that some special cases of the total weighted completion time minimization problem and the maximum lateness minimization problem can be solved in polynomial time. Wang et al. [55] considered

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