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Resource constrained scheduling problems with general truncated sum-of-processing time dependent effect under single machine and unrelated parallel machines

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ABSTRACT

This paper studies some scheduling problems with general truncated sum-of-processing time dependent effect under single machine and unrelated parallel machines. Under the single machine, we consider that the actual processing time of a job is bivariate, continuous and non-increasing convex function of the total processing time of the processed jobs, its position, the amount of resource allocation and control parameter. SLK due date assignment models are involved, in which the length of due window is the same. We present the polynomial time algorithms to find the optimal job sequence, the due date and resource allocations that minimizing including the slack due date, earliness cost, tardiness cost, resource consumption costs and makespan. Under the unrelated machines, we only consider no resource locations scheduling problems. Minimizing the total the machine load and minimizing the total completion time can also be solved in a polynomial time when the number of machines is fixed, respectively.

1. Introduction

In supply chains and modern manufacturing systems, Just-in-time (JIT) has received more and more attention in the past decades. Especially, due-window assignment scheduling problems have also been addressed by many published papers. Adamopoulos and Pappis (1996) were some pioneers who addressed machine scheduling problems with the SLK due window assignment model. The comprehensive reviews with the slack due date (SLK) assignment models are first given by Gordon, Proth, and Chu (2002), which they summarize various due date assignment methods on machine scheduling since 2002. For more literatures studies involving the SLK due-window assignment, readers can refer to Janiak (2004), Bai, Li, Wang, and Huang (2014) and Li, Ng, and Yuan (2011).

This paper considers resource constrained scheduling problems with general truncated sum-of-processing time dependent effect under single machine and unrelated parallel machines. We will formally describe the presented problems. Jobs set $N = \{J_1, J_2, \dots, J_n\}$ will be operated independently on m unrelated parallel machines $M = \{M_1, M_2, \dots, M_m\}$. Assume that the job sequence π is $\{J_1, J_2, \dots, J_n\}$. Note that $C_j = C_j(\pi)$ is the completion time of job J_j. Then $C_{\max} = \max\{C_j | j = 1, 2, \dots, n\}$ and $TC = \sum C_j$. Let $[d_j^1, d_j^2]$ be due window of job J_j, where $d_j^1 \geqslant 0$ and $d_j^2 (d_j^2 \geqslant d_j^1)$ are the starting time and finishing time of due window of job J_j, respectively. Define that $D_j = d_j^2 - d_j^1$ is the length of due window of job J_j. Furthermore, the penalties will be incurred if the jobs are completed before d_j^1 or after d_j^2. But there does not exist cost for those jobs finished within the due window. Let $E_j = \max(d_j^1 - C_j, 0)$ and $T_j = \max(C_j - d_j^2, 0)$ be the earliness cost and the tardiness cost of job J_j.

Note that the jobs will be generated inventory penalty or tardiness penalty if they are completed early or tardily. It is necessary that the jobs are completed in due window or as close to their due dates as possible. Finding a proper due window is an important problem. Because of the possible loss of profit, the larger size due window may not be accepted by customers. Moreover, the small size due window may lesson production elasticity and weaken delivery capacity for the manufacturers. However, trade-off between the gain and the loss must consider for the decision makers. The due window assignment problems often are

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considered in manufacturing systems covering common due date (CON, $d_j^1 = d_j^2$), equal slack due date (SLK, $d_j^1 = p_j + q_1, d_j^2 = p_j + q_2$) and different due date (DIF). This paper only refers to the SLK due window assignment(SLK), i.e., the starting time d_j^1 and the finishing time d_j^2 of the due window of job J_j are denoted by its processing time p_j plus a given parameter q, and a common due window D is shared by all jobs. Recently, Mosheiov and Oron (2010) examined minimization of the earliness cost E_j, the tardiness cost T_j, the starting time d_j^1, and the length D of due window on a single machine. Janiak, Janiak, Krysiak, and Kwiatkowski (2015) presented comprehensive discussions of due window assignment problems on various scheduling sets. Zhao and Tang (2015) examined a scheduling model with time-dependent and position effect by using the SLK due-window assignment method. The position effect means that the actual processing time of the job is $p_{jr} = (p_j + kt)g(r)$, where $g(r)$ is a function of the position r. However, Yang, Wan, and Yin (2015) fixed the incorrect solution methods in the published paper of Wang, Liu, and Wang (2013) under the SLK due-window assignment model, and presented a corresponding revised algorithm to obtain the values of optimal starting time d_j^1 and the finishing time d_j^2 of job J_j, where Wang et al. (2013) studied the two due-window assignment models: SLK due window and DIF due window with deterioration jobs and learning effect. The involved objective function is the weighted combination of the earliness costs, the tardiness costs, the length and size of due window, and makespan. Yue and Wan (2016) presented jobs deterioration and SLK/DIF due-window assignment on a single machine, where the actual processing time of job J_j is $p_j = a_j t$ if its starting time is t. They presented the optimality properties and developed some algorithms to solve the following two scheduling problems in a polynomial time. One is to minimize the objective function $\sum \alpha E_j + \beta T_j + \gamma d_j^1 + \delta D$. The other is to minimize the objective function $\sum \alpha V_j + \beta U_j + \gamma d_j^1 + \delta D$.

The learning effect is that the actual processing time of a job scheduled in the later sequence will be shorter. The first comprehensive survey with learning effects on machine scheduling problems is provided by Biskup (2008). However, owe to the limited learning of the human activity, scheduling models with the truncated learning effect overcome the following shortcoming: the actual job processing time will reduce fast to zero under the uncontrolled learning effect. More recently, Cheng, Cheng, Wu, Hsu, and Wu (2011) considered two-agent scheduling problems with the truncated sum-of-processing-time-based learning effect. Wu, Yin, and Cheng (2013) addressed two scheduling problems with the truncated-position-based learning effect on a single machine and two-machine flow shop. The authors provided the polynomial time algorithms for the makespan minimization problem and the total completion time minimization problem, respectively. For more references with truncated learning effect, readers may refer to Cheng, Kuo, and Yang (2013), Lu, Li, Wu, and Ji (2014), Niu, Wan, and Wang (2015), Rudek (2012), Zhang, Yan, Huang, and Tang (2012), etc. Additionally, we refer readers some recent works with time-dependent processing times by Qin, Zhang, and Bai (2016), Lee and Wang (2017), Wu et al. (2017), Zhang, Wu, Lin, and Wu (2017a), Zhang, Lin, Wu, and Wu (2017b), and two parallel-machine makespan minimization papers with time-dependent processing times by Rudek (2017a, 2017b).

For the combination of learning effects and resource allocation cases, Wang, Wang, and Wang (2010) listed many real-life situations to explain the background of the proposed scheduling problem. Recently, Wang and Wang (2014) introduced a common due-window assignment model with learning effects and resource allocations; Next year, they presented convex resource-dependent and job-dependent processing times. The objective function is to minimize the total compression cost under the total compression cost constraints effect. Li, Luo, Zhang, and Wang (2015) and Lu et al. (2014) studied the same scheduling model: combination of the due-window assignment method and processing time functions. Their technology is to transform the linear function and convex function models to the assignment problem under some specific regular objective functions. He, Liu, and Wang (2017) considered two scheduling models on a single machine: the actual processing time of job J_j if it is scheduled in the rth position in the sequence is $p_{ju}^A(u_j) = p_j \max\{f_j(r), a_j\} - b_j u_j$ and $p_{ju}^A(u_j) = \left(\frac{w_j \max\{f_j(r), a_j\}}{u_j}\right)^k$, where $0 < a_j < 1, b_j(>)0$ is a compression rate and $u_j(>0)$ is resource allocation. The objective function is denoted by $Z = \alpha C_{\max} + \beta \sum C_j + \gamma \sum_i \sum_j |C_i - C_j| + \delta \sum v_j u_j$. Based on the linear assignment method and the Lagrange function, some polynomial time algorithms and the branch-and-bound algorithm are also presented to obtain the optimal job sequence of the corresponding problems.

Based on above motivations, this paper studies some scheduling problems with a general truncated sum-of-processing-time dependent effect under a single machine and unrelated parallel machines. The reminding of the paper is stated as follows. The problem formulation will be addressed in next section; Section 3, we consider some single-machine scheduling problems. The actual processing time of a job is a bivariate continuous non-increasing convex function of the total completion time of processed jobs, the amount of resource allocation and the control parameter. For the SLK due-window assignment problem, we provide the polynomial time algorithms to determine the optimal job sequence, due date values and resource allocations that minimizes including the slack due date, earliness cost, tardiness cost, resource consumption costs and makespan; Section 4, we consider that the convex combination of processing time and resource allocation will be demonstrated under some limit set on a single machine; Section 5, we only consider no resource location scheduling problems under the unrelated parallel machines. The aim is to solve the two objective functions: the total machine load criterion and the total completion time criterion. If m is a constant, the two problems can be confirmed in polynomial solvable time, respectively; The brief conclusion will be listed in last section.

2. Problem statement

Note that jobs set $N = \{J_1, J_2, \ldots, J_n\}$ will be operated independently on m unrelated parallel machines $M = \{M_1, M_2, \ldots, M_m\}$. Assume that the number of jobs in machine M_i is $n_i, i = 1, 2, \ldots, m$, and $\sum_{i=1}^m n_i = n$. The actual job processing time of J_j placed in the rth position under machine M_i is defined as follows:

$$p_{ijr}^A = p_{ij} \max\{f_{ij}\left(\sum_{l=1}^{r-1} p_{il}, r\right), a_{ij}\},$$

where p_{ij} and a_{ij} denote the normal processing time and the truncation parameter of job J_j under machine M_i, and $f(x, y)$ is a bivariate continuous non-increasing convex function on x and y.

Specially, if $m = 1$, i.e., single-machine case, then the actual job processing time of J_j if it is placed in the rth position of the schedule can be denoted by:

$$p_{jr}^A = p_j \max\left\{f_j\left(\sum_{l=1}^{r-1} p_l, r\right), a_j\right\}.$$