Optimizing the service level of regular criteria for the stochastic flexible job-shop scheduling problem

Mario Flores-Gómez Stéphane Dauzère-Pérès

Mines Saint-Etienne, CNRS, UMR 6158 LIMOS, Gardanne, France
{mario.flores, dauzere-peres}@emse.fr

Mots-clés : *Flexible job shop, stochastic processing times, service level, tabu search*

1 Introduction

The Flexible Job-shop Scheduling Problem (FJSP) is a generalization of the classical Job-shop Scheduling Problem (JSP). In the JSP, each job requires a series of operations (route) to be processed on a set of machines. A machine can only perform one operation at a time, and each operation cannot be interrupted. In the FJSP, the machine on which an operation is processed is not given but must be selected in a subset of machines that are eligible to perform the operation. The processing times can be machine-dependent. Hence, solving the FJSP means determining both an assignment of operations to machines, and a sequence of operations on the machines, while respecting the constraints and optimizing a criterion.

The Stochastic FJSP (SFJSP), where the processing times of operations on the machines are stochastic, has been considerably less studied than its deterministic version. [2] define, for a single-machine scheduling problem, a β-robust schedule to model the likeliness of the total flow time across all jobs to be no worse than a given target level. This notion is extended by [1] to deal with the stochastic JSP. They propose a number of techniques combining Monte Carlo simulation with solution approaches dedicated to the deterministic JSP (e.g. constraint programming or tabu search). In continuation of our work in [6] and [7], we extend the study on the relevance of the notion of *makespan service level* as defined in [3] and [4]. Instead of considering that the uncertainty of the processing times is job-related, we focus on the case where the processing times of the operations that can be processed by one machine are stochastic, i.e. the uncertainty of the processing times is machine-related. Moreover, we propose and evaluate the impact of other regular criteria than the makespan when defining service levels.

2 Problem statement

As already stated, processing times are random variables. As a consequence, the makespan of a sequence is also a random variable. Our first criterion is the maximization of the *makespan service level*, i.e. the probability that the makespan is lower than or equal to a given threshold T :

$$\alpha(S, T) = \mathbb{P}(C_{max}(S, \xi) \leq T),$$

where ξ is a multivariate random variable of dimension n.

To determine the service level of a sequence, a set of scenarios Ω is generated and an algorithm based on Monte Carlo simulation is implemented, as described in [7]. The service level is denoted $\alpha(S, T, \Omega)$. The proposed solution method is based on a competitive tabu search approach [5], including a Monte Carlo sampling procedure to represent and deal with uncertainties. The results of computational experiments as well as the outline of the proposed method can be found in [7]. Note that minimizing the makespan does not mean maximizing the service level.

Another extension of our previous work is to consider other service levels that can be more relevant in practice, for instance maximizing the probability of completing jobs on time :

$$\max \sum_j w_j \Big(\mathbb{P}(C_j \leq d_j) \Big).$$

$\mathbb{P}(C_j \leq d_j)$ is the probability that the completion time C_j of job j is smaller than or equal to its due date d_j, and w_j is the weight of job j where the larger w_j, the higher the priority of j. Although the value of the service level changes depending on the weights of jobs, the joint probability is not directly affected by the weights.

3 Conclusion

In continuation of our work in [7], we extend the analysis on the relevance of the notion of *makespan service level* by considering the case where the uncertainty of the processing times is machine related. Moreover, we introduce other service levels that rely on deterministic regular criteria from the literature. Computational experiments will be presented and discussed in the conference. Scenarios obtained from historical data from an industrial partner will also be used to present new results and further motivate the relevance of service levels in scheduling problems.

Références

[1] J Christopher Beck and Nic Wilson. Proactive algorithms for job shop scheduling with probabilistic durations. *Journal of Artificial Intelligence Research*, 28 :183–232, 2007.

[2] Richard L Daniels and Janice E Carrillo. β-Robust scheduling for single-machine systems with uncertain processing times. *IIE transactions*, 29(11) :977–985, 1997.

[3] S. Dauzère-Pérès, P. Castagliola, and C. Lahlou. Niveau de service en ordonnancement. In J.C. Billaut, A. Moukrim, and E. Sanlaville, editors, *Flexibility and Robustness in Scheduling*, chapter 5, pages 97–113. Hermes Science Publications, 2005.

[4] S. Dauzère-Pérès, P. Castagliola, and C. Lahlou. Service level in scheduling. In J.C. Billaut, A. Moukrim, and E. Sanlaville, editors, *Flexibility and Robustness in Scheduling*, chapter 5, pages 99–121. Wiley, 2013.

[5] Stéphane Dauzère-Pérès and Jan Paulli. An integrated approach for modeling and solving the general multiprocessor job-shop scheduling problem using tabu search. *Annals of Operations Research*, 70 :281–306, 1997.

[6] Mario Flores-Gómez, Valeria Borodin, and Stéphane Dauzère-Pérès. A Monte Carlo based method to maximize the service level on the makespan in the stochastic flexible job-shop scheduling problem. In *2021 IEEE 17th International Conference on Automation Science and Engineering (CASE)*, pages 2072–2077. IEEE, 2021.

[7] Mario Flores-Gómez, Valeria Borodin, and Stéphane Dauzère-Pérès. Maximizing the service level on the makespan in the stochastic flexible job-shop scheduling problem. *Computers & Operations Research*, 157 :106237, 2023.