



HAL
open science

Data-Driven Approach for the Job Sequencing and Tool Switching Problem with Non-Identical Parallel Machines and Stochastic Processing Times

Khayati Khaled, Khadija Hadj Salem, Lardeux Benoit, Safa Bhar Layeb, Jridi Maher

► To cite this version:

Khayati Khaled, Khadija Hadj Salem, Lardeux Benoit, Safa Bhar Layeb, Jridi Maher. Data-Driven Approach for the Job Sequencing and Tool Switching Problem with Non-Identical Parallel Machines and Stochastic Processing Times. ROADEF 2025 - 28ème Congrès Annuel de la Société Française de Recherche Opérationnelle et Aide à la Décision, École nationale des ponts et chaussées, Feb 2025, Champs Sur Marne, France. ⟨hal-05060581⟩

HAL Id: hal-05060581

<https://hal.science/hal-05060581v1>

Submitted on 8 May 2025

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



HAL Authorization

Data-Driven Approach for the Job Sequencing and Tool Switching Problem with Non-Identical Parallel Machines and Stochastic Processing Times

Khaled Khayati^{1,3}, Khadija Hadj Salem¹, Benoit Lardeux¹, Safa Bhar Layeb^{3,4}, Maher Jridi¹

¹ L@bISEN, Usine du Futur, ISEN Yncréa Ouest, 33 Quater Avenue du Champ de Manœuvres, Carquefou 44470, France;

{Khaled.khayati, khadija.hadj-salem, benoit.lardeux, maher.jridi}@isen-ouest.yncrea.fr

² LR-OASIS, National Engineering School of Tunis, University of Tunis El Manar, Tunis, Tunisia

safa.layeb@enit.utm.tn

³ Industrial Engineering Center, Toulouse University, IMT Mines Albi, Albi, France

Keywords : *Job sequencing, Tools switches, Stochastic processing times, Simulation.*

1 Problem description

In this work, we address the *Job Sequencing and Tool Switching Problem with Non-identical Parallel Machines and Stochastic Processing Times* (SSP-NPM-SPT), a significant challenge within Flexible Manufacturing Systems (FMS). The SSP-NPM extends the classical SSP, which is known to be an \mathcal{NP} -hard optimization problem. Recent contributions to the deterministic SSP-NPM, notably by [1], have proposed three Mixed Integer Linear Programming (MILP) models—precedence-based, position-based, and time-indexed—aimed at optimizing performance metrics such as makespan and total flow time. Furthermore, incorporating stochastic processing times accounts for real-world constraints, where performance fluctuations or delays may arise, highlighting the need for robust optimization methods to ensure reliable solutions under uncertainty.

Formally, the SSP-NPM involves scheduling a set of jobs J on a set of non-identical parallel machines M , each with a limited tool magazine capacity C_m . Each job j has a processing time p_{jm} on machine m , which depends on the specific job-machine pairing. Additionally, let T represent the set of tools required for processing all jobs in J , where each job j requires a subset of tools $T_j \subseteq T$ to be loaded onto the machine before its processing. Each tool t occupies one slot in a machine's tool magazine. Due to variations in tool requirements and the constrained magazine capacity, tool switches are unavoidable to complete all jobs. The time required to switch a single tool on machine m is denoted as sw_m . Notably, the initial tool loading is not treated as a tool switch, and tool switching on machine m cannot occur while a job is being processed on that machine. The SSP-NPM seeks to determine both the job sequence and the tool switching schedule while respecting tool magazine capacity and tool requirements constraints, to minimize the makespan C_{max} .

An illustrative example of the deterministic SSP-NPM is shown in Fig. 1, involving 5 jobs and 14 tools allocated to 2 machines with different capacities $C_1 = 6$, $C_2 = 5$, and identical switching times $sw_1 = sw_2 = 2$. The table on the right side displays the processing times p_{jm} and tool requirements T_j for each job j .

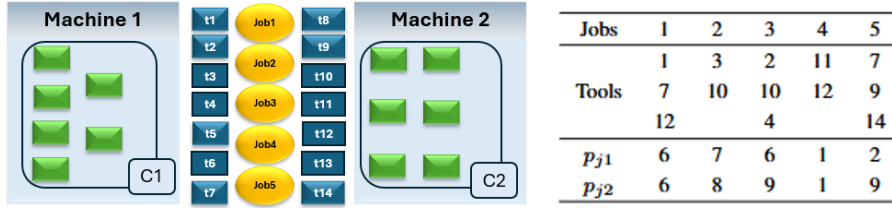


FIG. 1: SSP-NPM environment

2 Proposed Approach

To address the SSP-NPM-SPT, we propose a data-driven approach leveraging Monte Carlo simulation. This approach consists of two main phases: first, a Monte Carlo Simulation (MCS) to generate scenarios with processing time variation and identify the most likely values for decision variables. In the second phase, these identified values are fixed using various thresholds, and the remaining decision variables are determined to construct the final solution. According to [2], MCS effectively represents processing time uncertainty by generating manageable scenario samples. In [3], processing times p_{jm}^ξ are modeled using a Normal Distribution with mean p_{jm} and variance σ^2 , where $\sigma = \theta \cdot p_{jm}$, with different variability levels and number of scenario sets. The Position-based MILP from [1] is used to calculate the makespan C_{max}^ξ for each scenario ξ .

Building on the scenario results derived from the approach in [3], we begin with a statistical analysis of the decision variable outcomes. Decision variables that exhibit consistent patterns across scenarios and exceed a predefined threshold are then fixed to simplify the problem. Next, we proceed with determining the remaining decisions to minimize the makespan C_{max} while ensuring compliance with operational constraints. The proposed framework is designed to achieve a balance between solution quality and computational efficiency.

The proposed approach is evaluated through computational experiments on benchmark instances from the SSP-NPM literature. The obtained numerical results are compared against those reported in [3]. By leveraging statistical analysis and a decision variable fixing strategy, our approach streamlines the problem-solving process by reducing the search space, thereby enhancing computational efficiency. This comparison, based on key metrics such as makespan and CPU time, highlights the effectiveness of the proposed approach in addressing uncertainty in the SSP-NPM-SPT. Moreover, each solution generated for a given instance can be easily applied to other instances or scenarios with similar parameter and variable structures, emphasizing the adaptability of the proposed approach.

References

- [1] Dorothea Calmels. A comparison of different mathematical models for the job sequencing and tool switching problem with non-identical parallel machines. *International Journal of Operational Research*, 2021. Advance online publication.
- [2] Tito Homem-de Mello and Güzin Bayraksan. Monte carlo sampling-based methods for stochastic optimization. *Surveys in Operations Research and Management Science*, 19(1):56–85, 2014.
- [3] Khaled Khayati, Khadija Hadj Salem, Benoit Lardeux, and Safa Bhar Layeb. On solving the job sequencing and tool switching problem with non-identical parallel machines and stochastic processing times. In *The 2024 International Conference of the African Federation of Operational Research Societies*, Tlemcen, Algeria, November 3-5 2024.