Muticriteria optimization approaches for a sequencing problem in an automotive paint shop

Alena Melnikava[1], Issam Mazhoud[1], Abdel Bitar[2], Stéphane Dauzère-Pérès[3]

[1] DecisionBrain, Paris
{alena.melnikava, issam.mazhoud}@decisionbrain.com
[2]Smart Flows, Paris
{abitar}@smart-flows.com

[3] Mines Saint-Etienne, Univ. Clermont Auvergne, CNRS, UMR 6158 LIMOS
CMP, Department of Manufacturing Sciences and Logistics, Gardanne, France
dauzere-peres@emse.fr

Key words *: Paint shop, Scheduling, MIP, Local Search, Decomposition, Goal Programming*

Introduction

Paint shop scheduling for plastic automotive parts is nowadays a complex decision process due to numerous technical requirements, a large product variety and rigid deadlines set by automobile manufacturers. Additionally, the competition and falling margins in automotive industries force the different players to seek for opportunities to increase the reactivity of production schedules to the changing requirements and to meet the tight due dates of automotive customers. Improving production efficiency is critical to reduce the production costs, and automated optimized scheduling can answer in different ways to these economic challenges.

Problem Description

The studied real-life paint shop scheduling problem comes from one of the painting plants of a supplier to various automotive manufacturers worldwide. The paint line is a carousel comprised of so-called “masts”. Each mast holds a part carrier, carrying one type of parts. The painting carrousel moves the parts into the painting workshop, where the parts are painted and dried, and then brings the parts to the unloading area. Loading and unloading processes are manual operations. The scheduling is generally determined for the next 24 hours. An efficient painting schedule consists in filling each mast with a part while satisfying various technical constraints. Moreover, the schedule needs to respect storage capacities and to use the resources such as paint and manual operators as well as possible. In particular, it is cost-effective to minimize the number of colour changes, since each colour change might leave paint remains in the painting holder. Although there is some literature (see e.g. [1], [2] and [3]) on the optimization of the sequence of cars in the paint line in car assembly plants, there is to our knowledge very little work on similar problems than ours except [4], where a Constraint Programming approach and a local search metaheuristic are proposed.

Solution Approaches

The scheduling problem is modelled as a multicriteria Mixed Integer Program (MIP). Due to numerous technical constraints and the significant product variety, the MIP of a typical instance includes almost half a million of variables and constraints. This is thus impossible to find a feasible solution in a reasonable computational time. Different decomposition techniques were experimented to significantly

reduce the computational time. The most efficient approach is a fix-and-relax approach, which allows the problem to be decomposed in small sub-problems, by iteratively solving the MIP for a limited number of variables while fixing the remaining variables. Each sub-problem corresponds to a small-time interval.

Another complexity of the problem is that multiple criteria are optimized. This scheduling problem aims at pursuing two main targets: Covering short-term demands and efficiently using production resources. Actually, the second target corresponds to multiple conflictual targets such as paint saving, the minimization of manual operations and the maximization of the use of production capacities. Different multiobjective approaches in linear programming are known to help to handle multiple criteria.

Since our problem has two main priorities, we developed a two-pass approach and a one-pass approach. The two-pass approach is a lexicographic variant of goal programming, where two priorities are considered: the first one considers covering short-term customer needs and the second one maximizes the use of the production capacity. Thus, in the first pass, only the short-term demands are sequenced. In the second pass, the use of the production capacity is maximized. The one-pass approach is a weighted variant of the first approach where all criteria are optimized simultaneously, by associating different weights to the criteria depending on their priority. This results in a more complex MIP, as it is difficult to find the right balance between the different criteria.

Conclusions

This scheduling problem is modelled as a complex Mixed Integer Program, which cannot be solved due to its large number of variables and constraints and its multiple criteria. Local search combined with goal programming techniques proves to give reasonable results in an acceptable computational time. Still, it would be interesting to propose other heuristics, such as greedy heuristics used as stand-alone or combined with the relax-and-fix approach to increase its performance and robustness.

In the presentation, we will introduce the problem and its mathematical formulation, discuss the advantages and drawbacks of the two goal programming approaches, the local search as well as present and comment some optimization results.

Références

[1] Parames Chutima, Sathaporn Olarnviwatchai. *A multi-objective car sequencing problem on two-sided assembly lines*. Journal of Intelligent Manufacturing 29 (7), 1617-1636, 2018.

[2] Bertrand Estellon, Frédéric Gardi, Karim Nouioua. *Two local search approaches for solving real-life car sequencing problems*. European Journal of Operational Research 191 (3), 928-944, 2008.

[3] Mirza M. Lutfe Elahi, Karthik Rajpurohit, Jay M. Rosenberger, Gergely Zaruba, John Priest. *Optimizing real-time vehicle sequencing of a paint shop conveyor system*. Omega 55, 61-72, 2015.

[4] Felix Winter, Nysret Musliu and Emir Demirović, Christoph Mrkvicka. *Solution Approaches for an Automotive Paint Shop Scheduling Problem,* Proceedings of the Twenty-Ninth International Conference on Automated Planning and Scheduling 29 (1), 573-581, 2019.