Optimization of cart movements between workstations for a production plant

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1 Introduction

In the studied production plant, cart movements must be realized between production and consumption workstations. Logistics operators accomplish these movements driving trains which can each pull a certain amount of carts. As the production line must always be supplied with input products transported by these carts, the management of the logistics operators is crucial. Therefore the management team needs to determine the number of logistics operators required, distribute the parts between these operators and optimize the sequence of operator moves.

2 Optimization problem

In this problem, every production workstations must be provided with a non-full cart. The resulting optimization problems are classified as node sequencing problems with time windows. These problems are modeled to be recognized as two very similar problems: a tour study with a single logistics operator (TSPTW) and a tour study with multiple logistics operators (VRPTW).

The following objectives are ordered by decreasing significance: (1) minimize the number of logistics operators (VRPTW only), (2) minimize ending time, last node visit date, (3) minimize engagement time, total cart moving time and cart handling time by logistics operator(s).

The constraints are the following: (a) the flow constraint (VRP or TSP), (b) the flow of a part is realized by a single logistics operator (VRPTW only), (c) the node precedences, round trip between production and consumption workstations, (d) the train pulling capacity.

3 Heuristics

The category of the outlined problems is regarded as NP-Hard. Hence, a heuristic approach is explored. Unfortunately, heuristic methods based on column generation, which have proven to be efficient for the VRPTW[3], are not applicable in this specific case (notably due to constraint (c)). It appears that Variable Neighborhood Search methods are efficient for VRPTW[4][6] and TSPTW[5] and can be adapted to suit industrial constraints.

3.1 TSPTW - Variable Neighborhood Search

A greedy insertion algorithm returns a first node sequencing solution. In order to improve this solution three node moves are introduced: switch two consecutive nodes, delete and insert one node[5], delete and insert three nodes (these triplets of nodes are characterized by constraint (c)). A simulated annealing using these three moves improves the solution.

3.2 VRPTW - Large Neighborhood Search

A greedy insertion algorithm returns a first solution, setting the number of necessary logistics operators. In order to improve ending and engagement times, two large part moves (with respect to constraint (b)) are introduced: delete all the nodes corresponding to the same part from a tour and insert them into another tour, delete all the nodes corresponding to two different parts from two different tours and insert them exchanged. A Large Neighborhood Search realizing one descent to a local minimum uses these two moves to improve and smooth the solution.

4 Performance, evaluation and perspectives

These heuristics are tested on a configuration of the body shop department in a production plant. This plant employs three logistics operators in order to fulfil between 236 and 330 cart moves in a 7h15 shift for 59 parts located in 19 different zones. The results are compared to a LocalSolver model[1][2].

The TSPTW results are improved by 1% to 13% compared to the LocalSolver solutions on a shift scale (considering the objective (1)). Satisfying results are obtained on a week scale in one hour, while the LocalSolver model obtains its first feasible solution for the simplest instance after two hours of search. The VRPTW results determine that three logistics operators are needed and return a satisfying part distribution between logistics operators with satisfying workstation visitation sequences.

To conclude, an operational prototype of a decision making tool was created in scope of this internship. Unfortunately, the latest plant data was not available for testing and this prototype has not been deployed in the field. Another comparative study using a constraint programming approach and machine learning tools is currently in development.

References

[1] Khatouf Mohamed Amine. Résolution de problématiques industrielles avec LOCALSOLVER. Master's thesis, Université de Bordeaux, 2017.

[2] Estellon Bertrand Gardi Frederic Megel Romain Nouioua Karim Benoist Thierry, Darlay Julien. LOCALSOLVER, de la recherche locale en programmation mathématique. *ROADEF Le bulletin*, 27, 2011.

[3] Wasil Edward A. Golden Bruce L., Raghavan Subramanian. *The vehicle routing problem: latest advances and new challenges*, chapter Chvatal-Gomory Rank-1 Cuts Used in a Dantzig-Wolfe Decomposition of the Vehicle Routing Problem with Time Windows. Springer Science & Business Media, 2008.

[4] Krichen Saoussen Harzi Marwa. Variable neighborhood descent for solving the vehicle routing problem with time windows. *Electronic Notes in Discrete Mathematics*, 58:175–182, 2017.

[5] Amghar Khalid. *Une heuristique de recherche à voisinage variable pour le problème du voyageur de commerce avec fenêtres de temps.* PhD thesis, Université de Montréal, 2016.

[6] Marius M. Solomon. Algorithms for the vehicle routing and scheduling problems with time window constraints. *Operations research*, 35(2):254–265, 1987.