One-warehouse multi-retailer problem

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Introduction

In this project we are focusing on special cases of the one-warehouse multi-retailer (OWMR) problem. It is a multi-level logistics problem where we have \( N \) retailers having deterministic demands of a single product over \( T \) time periods. Each demand needs to be ordered and then delivered from the main warehouse, inducing a fixed setup cost whenever an order at the warehouse or a delivery from the warehouse to one of the retailers occur. Decisions can be taken at the warehouse or at the retailers as inventories can happen at both levels. The OWMR problem is a generalization of one of the most well-known and studied problem in logistics, the joint replenishment problem (JRP), in the special case where the warehouse can also stock inventory. A formal definition of this problem can be found in [5].

Several MIP formulations already exist ([1,4]) to solve the unconstrained OWMR problem. Features such as market Selection, backlog or capacity constraints were added to these formulations. The limits of each formulation were tested and then compared. To solve the most problematic cases an iterative heuristic has been implemented.

Addition of features to the OWMR problem

The first feature we added to the OWMR problem was a restriction on the orders at the warehouse. This makes sense in real life as most likely the warehouse is not able to order a product with no limitation at every time period. The specific structure of an optimal solution for the unconstrained OWMR problem does not hold in the constrained case, which makes the MIP running times subsequently longer.

A second feature, market selection, consists in attributing a revenue to each retailer. In the classical OWMR problem, the demand has to be fulfilled at each time period. Here we added flexibility in the problem as depending on whether the retailer is profitable or not during a given set of time periods the retailer seen as a market can have its demand either entirely satisfied or entirely rejected during this set. These time intervals can be seen as seasons and represent the fact that sometimes deliveries or orders costs can greatly vary within the total duration time.

In classical lot-sizing problems a demand made at time \( t \in [1,T] \) cannot be satisfied after time \( t \). However it often leads to infeasibility when combined to a constrained capacity. To that end the possibility of backlog, which corresponds to the satisfaction of demand with a delay, and the
possibility of having lost sales have been added. The longer the satisfaction of the demand is delayed the more it will weight on the objective function of the problem.

Fix-and-optimize heuristic

To solve the constrained OWMR problem with market selection a heuristic was developed. This heuristic works in two parts:
- first we create an initial feasible solution by rounding the optimum obtained after solving the LP-relaxation of one of the MIP formulations
- then this initial solution is improved by the fix-and-optimize algorithm, an iterative algorithm which only optimizes the boolean variables on a given set of time periods, fixing all other boolean variables ([2,3])

This heuristic gave good results, especially for the biggest instances as within a time limit of an hour it managed to return good solutions when CPLEX could not find non-trivial ones and improved the non-trivial solutions returned by CPLEX.

Conclusions

The different formulations reacted differently to the new features but were all limited in the sizes of the instances it could solved within a time limit of an hour. Specifically, the running times are very dependent on the number of time periods. The efficiency of the heuristic depends a lot on the choice of parameters, but it managed to find good solutions when the MIP could not find one.

Further researches can be made on the heuristic by adding local search during the iterative process or by studying the structure of an optimal solution with the parameters values.

Bibliography


