Two-echelon Multi-depot Inventory Routing Problem with Split Delivery

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1 Introduction

In the last years, the variability of the demands and the development of technologies motivate research against the optimization of supply chains when demands' projection and fluctuating costs make it incredibly difficult. Therefore, the management of inventory and transportation operations at the company level becomes an ongoing issue for business leaders. The optimization problem that incorporates routing decisions under a Vendor Manager Inventory (VMI) system, constitutes the Inventory Routing Problem (IRP). Moreover, IRP is one of the most up-to-date solutions in optimization research field used to reduce logistics cost in practical applications (store chains,gasoline distribution, petrochemical, etc.).

Simultaneously, IRP deals with the management of inventory, such that no customer runs out of stocks, and with the distribution of products to retailers through chosen routes with variable periodic demands [4]. The IRP is more complex than the classical Vehicle Routing Problem (VRP) due to the integration of the inventory component into a multi-period decision process and it could generates about 7.3% of economies regarding to the resolution of the problem in a distinct way [4]. Different variants of the problem have been studied in the literature based on several parameters such as [4] ; the number of products, the number of entities involved in the supply chain, demands and fleet characteristics, etc. In our work, we deal with a complex supply chain structure where a rich version of two-echelon IRP in a multi-depot, multi-product network is considered and split deliveries are allowed. Moreover, many possible product flows, from different sources to different destinations in all echelons should be managed and both upstream and downstream flows need to be controlled.

2 Problem description

We introduce in this work a rich variant of the Inventory Routing Problem (IRP) where suppliers have to deliver a set of products to different depots and they will subsequently be distributed from these depots to a set of customers on a finite time horizon with a capacitated homogeneous fleet of vehicles. Our proposal tries to extend the work of [1, 2] to combine the multi-product and the multi-depot IRP variants in a two-echelon supply chain structure. The aim is to determine for each period of the planning horizon (1) the set of vehicles to allocate to each depot, (2) the quantity of products to assign from suppliers to each depot (3) the quantity of products to deliver to each customer by using the vehicle assigned, and (4) the routes to proceed for deliveries. The objective is to jointly minimize inventory, ordering and transportation costs, while satisfying the customers' demands and avoiding stock outs. Different inventory policies are generally applied at both levels to organise deliveries such as ; the order-up-to level (OU) policy, the maximum level (ML) policy and the optimized target level (OTL) policy.

To tackle this problem, we propose a Mixed Integer Linear Programming (MILP) formulation that combines different IRP variants. Vehicles do not have a fixed assignment to a depot, and in every time period each vehicle departs and returns to one depot at most, but it could be re-assigned to another depot in the next time period. We suppose that the renting fee of a vehicle's re-assignment is null. Each depot has a maximum inventory capacity per product, and its inventory level cannot be negative. In each period, a deterministic demand must be fulfilled at each customer for each product. Since direct deliveries from the supplier to the customers are not allowed, then, suppliers could provide a certain quantity of products to the depots which are responsible to deliver this quantity to the customers, supposing that the total availability of products at each supplier is not constrained (unlimited capacity). A given customer could be visited by different vehicles in the time period. Therefore, split delivery is allowed if vehicle capacity is exceeded or if the depot could not satisfy the quantity required by the customers. Consequently, a customer can be visited by two vehicles from the same / different depots during the same period. Very significant cost savings are realized when allowing split deliveries by optimizing the use of vehicles' fleet over the time horizon.

We test our model on the instances of [3] combined with those of [2] to handle the multi-product variant of the problem and several combinations of inventory policies were tested for both depots and customers.

3 Conclusion & future work

In this study, we have introduced the multi-depot, multi-product IRP in its rich variant for the two-echelon logistical system to optimize the trade-off between inventory and routing decisions in an integrated way. Each echelon includes several nodes that lead to a very challenging many-to-many supply chain. A MILP is proposed and different inventory policies (ML/OU/OTL) are considered and applied at both levels of the supply chain. The objective is to satisfy the customer's request by using vehicles assigned to different depots and allowing split deliveries in the routing decisions. The first tests were carried out on small-sized instances. Our modelization is inspired from a real life problem in the healthcare domain within territorial hospital groups where several types of products should be distributed from suppliers to the care units through storage depots.

As a future work, firstly we aim to develop a meta-heuristic approach to deal with large-sized instances, then we opt for testing the model as well as the approach developed on real data outcomes from an existing territorial hospital group, and finally considering uncertainties in customers' demands by using fuzzy numbers and possibility theory.

Références

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