Analyzing the impact of integrating inventory and routing decisions in a city logistics context

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City logistics refers to the movement and distribution of goods within urban areas. Vehicle routing problem (VRP) solutions are the most frequently addressed topic in city logistics by researchers [3]. However, only a few studies consider inventory aspects along with the routing decisions, although integrating these decisions can be highly beneficial [2]. The Inventory Routing Problem (IRP) provides integrated logistics solutions by simultaneously optimizing inventory management and vehicle routing decisions. In IRP, three main decisions have to be taken: when and how much to deliver to each customer and the travel routes at each time period. Therefore, the IRP adds some complexity due to the integration of inventory and routing elements into a multi-period decision process, but may lead to better overall decisions.

While the IRP has been studied extensively, only a few studies consider inventory aspects along with the routing decisions in a city logistics context, with its specific characteristics. Examples of such characteristics include time windows, multiple vehicle trips per day, the use of heterogeneous vehicles, etc. This work addresses this gap by modeling and solving an IRP in an urban context.

This project considers and compares two scenarios: a traditional one in which inventory and routing decisions are made sequentially and an integrated one in which both decisions are made simultaneously. In the first scenario, each retailer defines its orders based on a replenishment strategy over the multi-period planning horizon. Then, the suppliers deliver their products to the city hub on the requested days, and the city hub handles the delivery process of all suppliers' products to the retailers. This involves a VRP with time windows, heterogeneous fleets, and multiple trips on each day of the planning period. In the second scenario, the city hub simultaneously determines how many products of each type will be delivered to the retailers and the delivery routes while ensuring sufficient inventory at the retailers. Therefore, the city hub simultaneously optimizes inventory and routing decisions. This results in a multi-period IRP with multiple products, time windows, a heterogeneous fleet, and multiple trips.

For the first scenario, the inventory and routing parts are solved sequentially. The retailers decide when and how many products to receive from the suppliers in the inventory part. The retailers are assumed to use one of five different replenishment methods to determine the delivery amount for each period. For the routing part, a Large Neighbourhood Search (LNS) meta-heuristic algorithm is then used to solve the route optimization problem.

In scenario 2, the inventory and routing parts are optimized simultaneously. In addition to the delivery routes, the city hub must also specify how many products to deliver to the retailers in order to minimize the total cost. A matheuristic algorithm based on the one presented in [1] is proposed to solve this problem. We extend the algorithm to incorporate the multi-trip aspect in our problem. The matheuristic method consists of two phases: a route generation phase and an optimization phase. A set of potential delivery routes is created during the route generation phase. For this purpose, we run our LNS algorithm on the daily routing problems that result from applying the different replenishment policies considered in scenario 1 and store the routes found during the search. For the optimization phase, we present a mixed integer linear programming model to simultaneously select routes from the route pool for every period and determine the delivery quantities to the retailers for each of these selected routes. The model minimizes the total routing and inventory cost, and is solved using CPLEX. Our preliminary results show that the number of variables increases exponentially with the size of the problem, and therefore it takes a long time to solve some instances optimally using CPLEX. Hence, a column generation approach is also applied to the model.

An experimental study is conducted to compare the two scenarios. In this study, several problem characteristics are varied, including the number of suppliers, the number of retailers, the holding costs, and the replenishment method used by the retailers in scenario 1. Artificial instances that correspond to each combination are generated and solved for both scenarios. In addition to the total cost, some performance measures related to the city perspective are used for the evaluation process. With this experimental study, we aim to investigate the impact of integrating inventory and routing decisions in an urban logistics context.

References

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