Centralized Multi Carrier Collaborative Transportation Planning with Pickup and Delivery Requests and Time Windows

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1 Introduction

The number of freight vehicles moving within a city is growing and expected to continue to grow at a steady rate particularly due to the current distribution practices with timely deliveries and the explosive growth of business-to-customer electronic commerce that generates significant volumes of personal deliveries. Carrier collaboration, which can reduce the number of freight vehicles moving in the city, improve the efficiency of freight movements, and reduce the empty vehicle-km, is emerging as a key strategy for realizing efficient urban distribution. By exchanging transportation requests among carriers in a transportation network, carriers can reduce their transportation costs, improve their profitability, and capture more business opportunities. The objective of this study is to develop a mathematical model and solution method for carrier collaboration in urban distribution.

We focus on the horizontal collaboration among carriers via order sharing. Through order sharing, carriers can improve their efficiency and profitability because of an increase in vehicle capacity utilization, a reduction in empty vehicle repositions, and a reduction in total transportation costs due to improved transportation planning. This order sharing or request exchange among carriers can be realized by using a centralized approach based on a global mathematical programming model or by using a decentralized approach such as combinatorial auctions or exchanges ([1], [2]). Centralized planning for order sharing means that customer orders from all participating carriers are combined and collected in a central pool and efficient routes are set up for all requests. We consider carriers in less than truck load transportation where each request is a pick and delivery request with a time window for performing each pickup or delivery operation. Each carrier has a limited number of vehicles initially located at its own vehicle depot. These depots may be in different locations. We assume each carrier has both reserved requests which must be served by itself because of its commitments to its customers (shippers) and shareable (exchangeable) requests which can be outsourced to other carriers. The collaborative transportation planning problem with pickup and delivery requests and time windows is NP-hard, so metaheuristic algorithms may be necessary for solving large instances of theproblem. The algorithm developed in this work is based on Adaptive Large Neighborhood Search proposed by Ropke and Pisinger ([3]), one of the prominent metaheuristic algorithms.

2. Methodology, Experiment and Results

In view of its advantage in achieving global optimum of carrier collaboration, we adopt the centralized planning approach. For the multi carrier collaborative transportation planning problem with pickup and delivery requests and time windows, we have developed a mathematical model. The objective of the model is to minimize the total transportation cost of all carriers subject to some constraints. In addition to the constraints related to the classical pickup and delivery problem such as vehicle capacity constraints, time window constraints, precedence constraints between the pickup operation and delivery operation of each request, there are special constraints imposed on the routes of each carrier and on its shared and reserved requests. Each route of a carrier must start from and return to its vehicle depot. Each reserved request must be served by a route of its own carrier, whereas each shareable request can be assigned to any route of any carrier. For small instances, this model can be solved using a MIP solver such as that in GAMS. To solve the model in a reasonable computation time for large instances, we have developed a metaheuristic algorithm. The development of this algorithm was inspired by the Adaptive Large Neighborhood Search (ALNS) heuristic proposed in [3]. In the heuristic, removal and insertion operators are chosen according to their weights and these two types of operators are alternatively applied to the current solution. The weights of the operators are adaptively adjusted according to their historical performances. To preventing from being trapped in a local optimum, simulated annealing is used at a high level of the ALNS.

In our implementation of the ALNS, we use a sequential insertion heuristic to quickly provide a high-quality initial solution in which all reserved requests of each carrier are served by the carrier itself whereas a sharable request may be served by another carrier according to its cost to be served by each carrier. That is, to choose the carrier and its route to serve a shared request , we calculate the transportation cost increment of each route of each carrier to serve the request. This request is then assigned to the carrier and its route with the lowest transportation cost increment for serving the request. At each iteration, our ALNS algorithm employs one removal operator to partially destroy the current solution and then repairs it to a feasible solution by utilizing one insertion operator. Five removal and two insertion operators are proposed and used, including Shaw's removal, price similarity removal, least paid removal, random removal and most expensive removal, greedy insertion, and regret insertion. One question is how to effectively select a removal and an insertion operator in each iteration. Like all ALNS implementations, our algorithm chooses the most suitable combination of operators according to their past performances. For diversification purpose, operators with poor performance still have a low probability to be selected during the large neighborhood search. We use a roulette-wheel mechanism to select an operator among multiple operators. When applying any operator to the current solution, all constraints imposed on reserved request and sharable requests must be satisfied.

We tested our ALNS algorithm on 10 instances with 3 carriers and 30 pickup and delivery nodes. Each carrier has 5 requests, among them some are reserved requests and the others are sharable requests. These instances were taken from [1]. As mentioned early, due to the NP-hard nature of the problem, for these instances, it is time-consuming to get their optimal solutions by a MIP solver, whereas our algorithm can obtain a solution close to the optimal one in a small fraction of time with the relative gap smaller than six percent in terms of cost. Further improvement of the algorithm and its performance evaluation on large instances are underway.

References

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