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An unpaired pickup and delivery vehicle routing problem with multi-visit

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ABSTRACT

This paper studies an unpaired pickup and delivery vehicle routing problem allowing for multi-visit. The problem consists of two interacted decisions: the pairing of supply and demand and the vehicle routing. Given the complexity of the problem, a novel unified model is formulated to decouple the interactions between the two decisions. Based on the unified model, some valid inequalities are derived and a tabu search algorithm is proposed. The computational results show that the tabu search algorithm can provide high quality solutions to the problem under investigation and the closely related problem studied in Chen et al. (2014).

1. Introduction

This research has been motivated by a consulting project we have done for one of the major tobacco companies in central China, who claims to have very high transportation costs to transfer various raw materials among its plants. For historical reasons, these plants are geographically dispersed. Since there is no central warehouse, each plant has its own (local) warehouses to store certain raw materials. Moreover, to ensure quick response and smooth production, upon receiving the 10-day production schedule from the central planning department of the company, each plant needs to make its own inter-plant raw material transfer decision for prevention of the stockout. For a long time, the raw material has been transferred with the following mode: when Plant 1 has a delivery request (i.e., demands a certain quantity of raw material of a certain type), it will send the delivery request to its nearest plant (e.g., Plant 2); upon receiving the delivery request, Plant 2 will deliver the requested raw material to Plant 1 and the vehicle will return empty; in case Plant 2 cannot fully meet the demand of Plant 1 (i.e., with limited supply), other plants will be chosen successively in a non-decreasing order of its distance (to Plant 1) till the demand is completely satisfied. Each plant might be in need of one/several type(s) of raw material(s) but able to supply other type(s) of raw material(s) at the same time.

Under the current transferring mode of the tobacco company, the decision-making rights are decentralized. Whenever there is a delivery request, the pairing decision is made locally by designating pickup points and pickup quantity for the delivery. Moreover, the routing decision is made locally as well, without considering the routing decisions of all plants as a whole. Thereby, the annual total transportation costs of the tobacco company end up high with hundreds of raw material types transferred and thousands of delivery requests. Furthermore, vehicles often return empty, which is a waste of vehicle

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resources. With the problems identified above, the tobacco company has started to establish a central logistics management department, aiming to tackle the problem from a global perspective.

Similar problems also exist in the retailing industry. For example, a product might have been sold out in a store when it is requested by a customer. To increase sales, transshipment is normally made from the nearest store to meet the customer's demand in the quickest possible way. It is clear that, under such a transshipment mode, both the pickup and delivery pairing decision and the routing decision are made with no consideration for the transshipment requests of other stores. To reduce total transshipment costs for all stores, it is more desirable to reposition the inventories of all stores globally before a stock-out happens.

One possible way to optimize the vehicle routing problem mentioned above is to allow a vehicle to visit a customer multiple times (i.e., multi-visit). Generally, research on vehicle routing assumes that a vehicle can only visit a customer once at most (i.e., single-visit), which is also the case of the tobacco company we consulted. Intuitively, it is more cost effective to allow for multi-visit. For example (refer to Fig. 1), suppose there are 3 plants, four types of raw materials and the vehicle capacity is 3. The supply/demand information of each plant is shown in the "supply"/"demand" column, where the numbers in parentheses are the supply/demand quantity of the materials. Depot is the place where each vehicle leaves empty to carry out a transportation task and returns empty with its task done. Each vehicle is used only once, which indicates that a vehicle cannot be dispatched again when it returns to the depot. Under the single-visit mode (Fig. 1(a)), two vehicles are needed to meet the demand of all the 3 plants and the routings are: Depot - Plant 1- Plant 2 - Plant 3 - Depot (solid line) and Depot - Plant 3- Plant 1 - Plant 2 - Depot (dashed line). The corresponding load information, when a vehicle travels from one plant to another, is given above the edge between the two plants. However, if multi-visit is allowed (Fig. 1(b)), the above two routings can be merged. Thus, only one vehicle is needed and the corresponding routing is: Depot - Plant 1 - Plant 2 - Plant 3 - Plant 1 - Plant 2 - Depot. Contrary to single-visit, Plant 1 and Plant 2 are visited twice by the same vehicle. It is quite obvious that the multi-visit arrangement outperforms the single-visit arrangement with fewer vehicles engaged and lower transportation costs.

The vehicle routing problem above can be further optimized by means of better pairing pickup and delivery. Contrary to locally paired pickup and delivery, unpaired pickup and delivery is expected to have a better performance in terms of the number of vehicles needed and the transportation costs incurred, since the pickup and delivery decision can be made from the global perspective. With unpaired pickup and delivery, for a delivery request, the pickup points and the corresponding pickup quantity from every pickup point are unknown beforehand. Obviously, both the routing decision and the pairing decision need to be made in the transportation network; moreover, the two decisions are interacted, which means, given a routing decision, the corresponding optimal pairing decision can be uniquely identified and vice versa. In addition, time windows on pickup and delivery in the network can be neglected since, the production schedule is released quite a period (e.g., at least 10 days as in the case of the tobacco company) in advance, which gives every plant enough time to pick up and deliver the raw material to serve the production.

This research aims to minimize the transportation costs for pickup and delivery of various products within the network with multi-visit to satisfy demands of all customers. As a matter of fact, the problem in this paper can be referred to as multi-commodity unpaired pickup and delivery vehicle routing problem with multi-visit. Also, it can be seen as an extension to the many-to-many pickup and delivery problem (Battara et al., 2014) with multi-visit. Our research is closely related to Chen et al. (2014), in which unpaired pickup and delivery with single-visit is studied. To solve our problem, a unified model is formulated.

The remainder of the paper is organized as follows. Section 2 presents a review of relevant works. In Section 3, unified method is discussed first, based on which a unified model is developed. In Section 4, some valid inequalities are derived. A heuristic algorithm is developed in Section 5. Computational experiments are shown in Section 6. In Section 7, the main conclusions, contributions and possible future research are discussed.

2. Literature review

Our problem combines the unpaired pickup and delivery problem with the multi-visit routing problem. From this perspective, our problem is closely related to Maritime Routing and Scheduling Problem (MRSP). In MRSP, many works focus

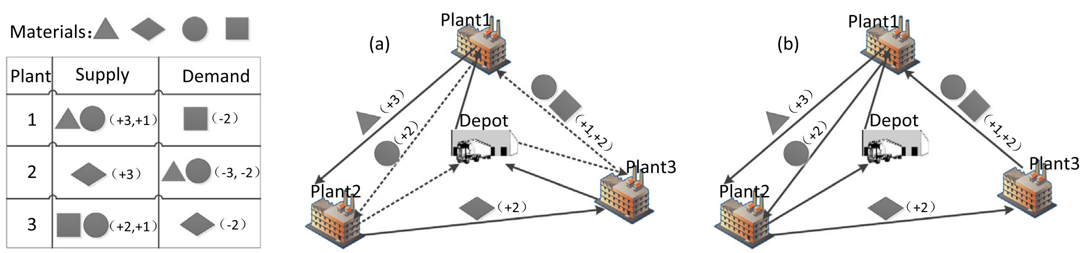

Fig. 1. (a) Single-visit routing. (b) Multi-visit routing.