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Optimization of postal express line network under mixed driving pattern of trucks

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ABSTRACT

Details about the movement of trucks on postal express lines are investigated to improve the performances of mail distribution. A mixed driving pattern of trucks is introduced to minimize the transportation cost of a postal express line network with a service level requirement. We formulate this problem as a mixed p meeting depots location with shipment scheduling problem and build a MINLP model. A two-level tabu search procedure based on shipment grouping method is developed. Through a series of computational experiments and sensitivity analysis on different instances, some managerial insights of the network under mixed driving pattern are revealed.

1. Introduction

General express lines are the connections among hubs without stopovers in the hub-and-spoke network (Yaman et al., 2007), such as the direct routes among mail sorting centers in a general postal distribution network (Grünert and Sebastian, 2000). These direct routes and the sorting centers they connect constitute a postal express line network (PELN). Each sorting center in a PELN collects local outbound mails, sorts them according to their destinations, and delivers them to designated sorting centers. Simultaneously, it also receives inbound mails from other sorting centers. The mail shipments on express lines among sorting centers, which can be named as postal express delivery, play an important role in the whole process of mail distribution.

Due to its convenience and flexibility, road transportation is one of the most common modes in postal express delivery. In each sorting center, there are a huge amount of outbound mails waiting to be sorted and shipped to their destinations daily. The postal service provider has to find an effective way to arrange trucks to implement the mails interchange among sorting centers in time. However, the long distances among sorting centers and specific time limits are two rigorous challenges for decision making. Normally, sorting centers are geographically far from each other and the postal express delivery among them is long-haul transport (for example, in China, road transport which is longer than 200 km can be viewed as long-haul transport). In addition, mail distribution has specific time limits, e.g. the deadline of inbound mails. According to the Next Day Delivery service (Armacost et al., 2002) provided by more and more postal service providers, mails have to be sent to their recipients the next day. A reasonable decision for the postal

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service provider cannot be made without the consideration of the balance between transportation cost and postal service level. However, these two challenges prevent some economical distribution patterns from being applied in postal express delivery, such as pickup-and-delivery (Parragh et al., 2008) which is suitable for less-than-truckload shipping in a small region. In this research, we plan to overcome these two challenges by utilizing the flexible driving patterns of trucks in road transportation.

The long-haul transportation of mails between two sorting centers (named as A and B respectively) can be implemented by different driving patterns of trucks. In this paper, we consider three common driving patterns described as follows:

- *Reciprocation:* Sorting center A dispatches a truck which is loaded with outbound mails to sorting center B. After being unloaded, the truck returns with inbound mails (the outbound mails of sorting center B).
- *Convection:* Each sorting center dispatches a truck which is loaded with outbound mails to each other. After being unloaded, these trucks return respectively.
- *Rendezvous:* Two trucks depart from their own sorting centers to an assigned meeting depot (MD). When they meet at the MD, the two trucks exchange their mails (usually swap containers directly) with each other and then return respectively.

Among these driving patterns, Reciprocation is a widely used driving pattern because of its economy. It is adopted in many types of transportation, such as reverse logistics, and drop-and-pull transportation. Convection is a driving pattern commonly used in fields like automotive logistics and some prior express service in China. Rendezvous is a new driving pattern which is gradually used in the distribution networks of enterprises like DHL and Staples. Moreover, Lee and Qi (2009) provided three types of vehicle trips for direct delivery between two depots. Two of them can be classified into Convection and the other one can be classified into Reciprocation.

These three driving patterns can achieve different performances in transportation cost and service level. The transportation cost considered in this paper is mainly represented by the total travel distance of trucks in a PELN, while the service level discussed is measured by the percentage of shipped mails to total sorted outbound mails in all sorting centers which need to be shipped within a day. In a sorting center, after the outbound sorting starts, the sorted mails are generated continuously and accumulated. Therefore, the volume of a shipment is determined by the departure time of the truck. The sorted mails generated after the truck departs have to be left and wait for the next day's delivery. Ordinarily, to reduce transportation cost and to increase service level are always mutually exclusive and the tradeoff between them has to be considered when using these driving patterns.

Among these three driving patterns, Rendezvous has great complexity and special requirements, especially when used in the postal express delivery among multiple sorting centers. As a significant element in Rendezvous, the MD is a place where trucks meet and swap their containers. In this research, the MDs are chosen from the existing sorting centers for the following two reasons: on one hand, it does not need much fixed cost for building some other special facilities; on the other hand, the necessary equipment and workplaces for handling containers are available at these sorting centers.

Besides how to locate proper MDs, how to allocate trucks to these MDs as well as how to swap containers carried by these trucks have to be determined. According to the definition of Rendezvous, each truck loaded with a container filled with outbound mails (named as *outbound container*) departs from its origin sorting center to the assigned MD. After the outbound container is taken off at the MD, the truck picks up another container filled with inbound mails (named as *inbound container*), which is brought by a truck from another sorting center, and then returns back. The remained outbound container will be loaded on a truck coming from the sorting center which is the destination of the mails inside and then drawn to that sorting center. That is, for a truck carrying an outbound container, there should be two counterpart trucks having matching relationships with it: one brings its inbound container to the MD, named as *in-partner* truck, while the other takes over its outbound container at the MD, named as *out-partner* truck. If these two counterpart trucks are the same, this kind of Rendezvous is named as *symmetrical Rendezvous*; otherwise, it is named as *asymmetrical Rendezvous*.

Fig. 1(a) and (b) illustrates symmetrical and asymmetrical Rendezvous, respectively. As Fig. 1(a) shows, a truck from sorting center A (denoted as truck A) carrying its outbound container I filled with mails whose destinations are sorting center B goes to an assigned MD, while a truck from sorting center B (denoted as truck B) carrying its outbound container II filled with mails whose destinations are sorting center A goes to the same MD. When they meet at the MD, they swap their containers and return respectively. Obviously, for truck A, container II is its inbound container. Because truck B brings container II and also takes over container I, it is both the in-partner and the out-partner truck of truck A. For the same reason, truck A is also the in-partner and the out-partner truck of truck B. But in asymmetrical Rendezvous, the situation is different. As Fig. 1(b) shows, three trucks from sorting center A, B and C (denoted as truck A, B and C, respectively) go to an assigned MD for swapping containers. Their outbound containers, I, II and III, are filled with mails whose destinations are sorting center B, C and A, respectively. In this case, for truck A, container III is its inbound container, meanwhile truck B and C are its out-partner and in-partner truck, respectively.

The concept of counterpart can also be used to describe the matching relationship among shipments. If an outbound truck undertaking a shipment s_a has an out-partner truck undertaking shipment s_b before container swap at a MD, then s_a is *out-partnered* with s_b, and s_b is the out-partner shipment of s_a; if it has an in-partner truck undertaking shipment s_c, then