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A vehicle routing problem with multiple overlapped batches

Mingzhu Yu [a,*], Xiangtong Qi [b]

[a] Department of Transportation Engineering, College of Civil Engineering, Shenzhen University, Shenzhen 518060, China
[b] Department of Industrial Engineering and Logistics Management, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong

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ABSTRACT

This paper considers a vehicle routing problem faced by an express company which tackles complicated operations involving time window constraints, multiple delivery and pick-up customer visits per day, multiple trips per vehicle, and latency cost for each delivery. It is challenging in that it involves multiple delivery and pick-up batches and the time spans of the batches are overlapped. We formally define the problem and develop two tabu search algorithms. By computational experiments, we find one algorithm outperforms the other by getting better solution in much shorter time. Moreover, our approach produces a significant cost saving for the company.

1. Introduction

The main concern of distribution management is to determine the optimal set of vehicle routes for customer service. The classic vehicle routing problem (VRP) designs the optimal set of routes, starting and ending at a central depot, to be performed by a fleet of vehicles. The typical characteristics of VRP are that there are a set of customers with given demands or supplies, and that each customer has to be served exactly once such that the capacity constraints of vehicles are met. The objective can be to minimize the total distance traveled, the number of vehicles used, or a combination of them.

In today's business environment, managers are constantly facing the pressure of not only making the operations more efficient but also providing better service to customers. Logistics companies need to cut costs by reducing the vehicle traveling distance or the number of vehicles to be used. Meanwhile, customers demand a better service level, which can often be translated to shorter customer waiting time. This is especially important in the express package delivery industry where service providers need to strengthen their competitiveness by delivering packages to customers as early as possible.

Our research is motivated by a large express delivery company in Hong Kong. The company runs the packages pick-up and delivery operations over a distribution network which contains a central hub and a set of transfer stations (refer to Fig. 1). There are ten transfer stations (TM/YL/SS/FL/TP/FT/SLY/YSW/TW/C) and one hub. The station allocation areas are marked with circles in the figure. Our research mainly focuses on the company's express business with mainland China. Inbound packages from mainland China arrive at the hub where the packages are first unpacked and sorted, and then delivered to the designated stations by a fleet of vehicles. Each station has a group of staff who will further send the packages to individual customers. Outbound packages are first collected by the station staff and gathered at the stations, and then picked up and transported to the hub by the same fleet of vehicles. Packages will finally be sent to mainland China. When a vehicle visits a station, it may only do delivery, only do pick-up, or do both delivery and pick-up.

* Corresponding author. Tel.: +86 755 86670364.
E-mail addresses: mzyu@szu.edu.cn (M. Yu), ieemqi@ust.hk (X. Qi).

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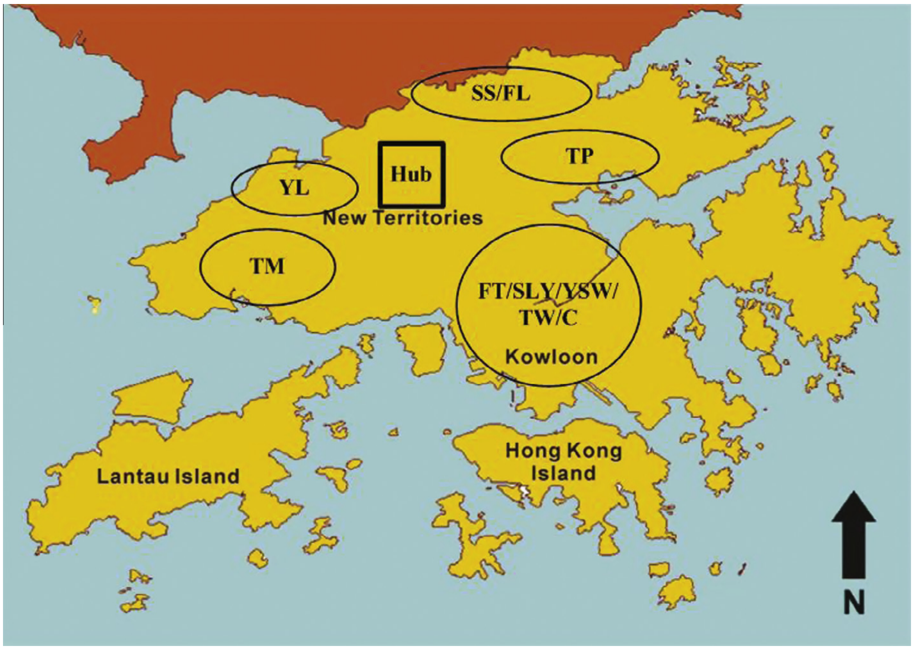

Fig. 1. Geographical representation of the stations and hub (depot).

Table 1
Batch time setting.

Batch no.	Batch starting time	Cut-off time	Batch deadline
1	5:30	10:30	11:30
2	9:00	11:30	12:30
3	12:30	14:30	16:30
4	14:00	17:00	19:30
5	15:00	19:00	20:00

To provide competitive services with respect to timeliness, the company needs to visit the transfer stations in multiple rounds every day for package delivery and pick-up, where each round is called a batch. The daily operation of the company involves five batches. Every transfer station has both package pick-up and delivery demands in each batch. Therefore, the company visits every transfer station in every batch. What makes the problem challenging is that *the time spans of two consecutive batches are overlapped*. This causes the problem of assigning and reusing vehicles among different batches, in addition to vehicle routing. Depending on the routing decision of one batch, a specific truck may or may not be available to use for the next batch, due to the following reasons.

First, each batch has a batch starting time by which the inbound packages have been processed at the hub and are ready for delivery. Any vehicle for the delivery of a batch cannot leave the hub before the starting time of the batch; otherwise there may still be some packages not ready for delivery. In this way, the inbound packages arrived at the hub before the batch starting time could be sent out timely. Second, each batch also has a common pick-up cut-off time at all stations. It is required that all outbound packages received at the station by the corresponding cut-off time should be picked up in that batch. In other words, the pick-up vehicle cannot leave a station earlier than that cut-off time. Otherwise, the orders placed in this batch could not be promptly collected and the following schedules in the hub, border and the company's mainland China branch will be affected. Finally, each batch has a deadline by which all pick-up vehicles must return to the hub so that the outbound packages collected before the cut-off time can be sent out in time to the border and catch up with the arrangement in the mainland China side. The batch cut-off times and batch deadlines are usually published by the company. Knowing about these time settings, customers have better expectation and planning on arranging their package orders. In this way, the company provides a transparent and prompt service.

A real example of five batches with different time spans is given in Table 1. Taking the first batch for example, a vehicle could leave the hub to deliver inbound packages after 5:30. On the route, the vehicle could also pick up outbound packages collected in this batch if it leaves a station later than 10:30 and there is enough capacity. The vehicle should send these outbound packages back to the hub before 11:30. In this case, the pick-up package orders placed before 10:30 are collected to the hub before 11:30 and then further sent to Shenzhen across the border.