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Full truckload vehicle routing problem with profits

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Abstract: A new variant of the full truckload vehicle routing problem is studied. In this problem there are more than one delivery points corresponding to the same pickup point, and one order is allowed to be served several times by the same vehicle or different vehicles. For the orders which cannot be assigned because of resource constraint, the logistics company outsources them to other logistics companies at a certain cost. To maximize its profits, logistics company decides which to be transported by private fleet and which to be outsourced. The mathematical model is constructed for the problem. Since the problem is NP-hard and it is difficult to solve the large-scale problems with an exact algorithm, a hybrid genetic algorithm is proposed. Computational results show the effectiveness of the hybrid genetic algorithm.

Key words: full truckload; vehicle routing problem; genetic algorithm; profit

1 Introduction

Vehicle Scheduling Problem (VSP) has attracted a great deal of attention because of its complexity in computation and wide applications in the field of logistics and transportation. According to the relation of customer demands and vehicle capacity, VSP can be divided into the less than truckload vehicle routing problem (also called VRP) and the full truckload vehicle routing problem (denoted by FTVRP). Compared with the former, the full truckload vehicle routing problem is much less studied.

The full truckload vehicle routing problem is firstly tackled by Ball et al. (1983), who presented a heuristic algorithm. Desrosiers et al. (1988) assumed that the vehicles must return to the depot after accomplishing the transportation tasks, and turned the problem into an asymmetric traveling salesman problem. Skitt and Levary(1985) proposed a method to generate new routes, based on an LP sub-problem. Wei et al. (2005) used genetic algorithm to solve FTVRP with a driving distance restriction. Huo and Zhang (2006) and Gronalt et al. (2003) presented an improved saving algorithm for the problem, considering both the fixed and variable cost of vehicles. Liu et al. (2010) introduced a task selection and routing problem in which a truckload carrier received tasks from shippers and other partners, and made a selection be-

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tween a private vehicle and an external carrier to serve each task. Sun (2012) dealt with a variant of FTVRP in which vehicles were not required to return the depot after it completed the task. He proposed an adaptive genetic algorithm and PSO algorithm with near neighbor interactions to solve it.

However, there are some shortages in the existing literature: 1) their objectives are to minimize the cost, lacking in the research with the objective of maximizing the profits. Since logistics enterprises barely reject orders from customers to protect their own reputation during the practical operations, it results in a situation where orders cannot be completed on time under limited resources when the peak demand occurs. In order to deal with the situation, the logistics company will outsource some orders to other logistics companies at a certain cost. To maximize its profits, logistics company will decide which to be transported by private fleet and which to be outsourced. 2) the problems studied are assumed that one pickup point only corresponds to one delivery point, meanwhile, one order is only served by the same vehicle. This is not practical as a factory or warehouse may delivery goods to many customers. When the demand of a customer is more than the capacity of vehicles, in addition, it is not necessary to require to be served by the same vehicle.

To overcome these shortages, this paper analyzes the more general full truckload vehicle routing problem with profits. In this problem, it is allowed that there are more than one delivery points corresponding to the same pickup point, and one order is served several times by the same vehicle or different vehicles. The objective is to maximize the profits of the logistics company. We call the problem the full truckloads vehicle routing problem with profit (denoted by FTVRPP). Since the problem includes Chinese Postman Problem, it is also NP-hard. It is difficult to solve the large scale problem with an exact algorithm, therefore, a hybrid genetic algorithm is proposed to solve it.

2 Problem definition and formulation

The full truckload vehicle routing problem with profit can be defined as follows: Let $G=(V,A)$ be the logistics distribution network in the problem, where vertex set V includes the depot 0 and the customer set $V_c=\{1,2,3,\cdots,n\}$, and A is arc set. Orders of the logistics company constitute arcs subsets A_o and $A_o \subset A$, with the order demand q_{ij}. Each order o_{ij} has both a pickup point i and a delivery point j. Let $K=\{1,2,\cdots,m\}$ be the vehicle set, where m is the number of available vehicles. The capacity of the vehicles is denoted by Q; loading time and unloading time at node i are denoted by p_i and d_i, respectively; F_{ij} presents visit times of order o_{ij}; c_{ij} means the travel cost of vehicles on the arc(i,j), which is equal to the distance of arc(i,j) in this study; the average speed of the vehicles is represented by S_p, and the maximum duration of a vehicle is T. The logistics company accepts an order at a certain price w, and outsources an order at the cost w'. The objective of the logistics company is to maximize its profit.

The vehicles are required to satisfy the following constraints: 1) the number of vehicles is limited; 2) the maximum load of each route does not exceed the vehicle capacity at each node; 3) the total duration of each route does not exceed the maximum duration.

To construct the formulation, we use n_k to represent the number of customers served in route (vehicle) k, and r_{ki} to represent the ith customer in the route(vehicle) k, where $r_{k0}=r_{k(n_k+1)}=0$. z_{ij} is a decision variables, and sign(x) is an auxiliary variable. We propose the formulation based on routes which was ever used for VRP by Jiang et al. (1999). Formulations for FTVRPP are as follows:

Maximize:

$$\sum_{i=1}^{n}\sum_{j=1}^{n} z_{ij}w - \sum_{k=1}^{m}\Big(\sum_{i=1}^{n_k} c_{r_{k(i-1)}r_{ki}} + c_{r_{kn_k}r_{k(n_k+1)}} \times \operatorname{sign}(n_k-1)\Big) - \sum_{i=1}^{n}\sum_{j=1}^{n}(1-z_{ij})w' \tag{1}$$

Subject to:

$$F_{ij} = \operatorname{int}\Big(\frac{q_{ij}}{Q}\Big)+1 \quad i,j \in V_c \tag{2}$$

$$z_{ij} - \sum_{k=1}^{m}\Big(\sum_{l=2,i=r_{k(l-1)},j=r_{kl}}^{n_k} o_{r_{k(l-1)}r_{kl}}\Big)/F_{ij} = 0 \quad i \in P,\ j \in D \tag{3}$$

$$load_{r_{ki}r_{k(i+1)}} \leqslant Q \quad k \in \{1,2,\cdots,m\},\ i \in \{1,2,\cdots,n_k\} \tag{4}$$

$$\Big(\sum_{i=2}^{n_k}(p_{r_{k(i-1)}} + d_{r_{ki}})o_{r_{k(i-1)}r_{ki}}\Big) +$$