A Shipper Perspective to Transport Optimization: a subcontracted Pickup and Delivery Problem with Transshipment Facilities

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We propose a vehicle routing problem faced by companies that ship their goods from several production centers to multiple customers either directly or through a set of intermediate facilities where goods can be transshipped. The main contribution of this work is the modeling and solving of a Pickup and Delivery variant of the VRP with Transshipment Facilities where transport is operated by several carriers proposing various transportation rates. We define the Pickup and Delivery Problem with Transshipment Facilities (PDP-TF), propose a Large Neighborhood Search method to solve this problem and assess the performance of this method on a set of related optimization algorithms. Finally, we describe a real-life case study provided by a major food company in France.

1 Problem Statement

We consider a transportation problem faced by a manufacturing company that ships goods through a logistics network with four layers: a single vehicle depot, a set of production centers, a set of transshipment facilities called Collaborative Routing Centers (CRC) and a set or customers. All vehicles start from the depot, load goods at production centers, then visit and deliver a subset of customers and CRCs.

We consider a set of transportation requests representing homogeneous products ordered by a given customer. Depending on the products, a request can be shipped from multiple production centers. In addition, a request can either be delivered directly to its customer or be delivered via a CRC. In the latter case, the request is collected later at the CRC by another vehicle that delivers it to the customer. This delivery has a known fixed cost that depends of the size of the request and the distance between the CRC and the customer.

Transport operations are operated by several carriers using a heterogeneous fleet of vehicles. Carriers impose varying feasibility constraints on the routes such as a maximum detour, duration, or site-dependency constraints. They propose various types of rates: in Full-Truckload (FTL) rates, the price is determined by criteria such as route length, route duration, or the number of route stops; in Less-Than-Truckload (LTL) rates, the cost depends on the distance between the pickup site and the delivery site as well as the size or weight of the request.

Depending on the selected pickup facility, the possible transshipments at a CRC and the time windows, several scenarios (called *options*) are considered to carry each request. The cost of an option reflects the transshipment and delivery cost from the CRC to the client. A *route* is defined by a set of options and a sequence of pickups followed by a sequence of deliveries. It satisfies the time windows of each visited facility as well as carrier specific constraints.

The Pickup And Delivery Problem with Transshipment Facilities (PDP-TF) consists in selecting one option for each transportation request, designing a set a routes to serve these requests while respecting the time windows of the options, and assigning a vehicle to each route. The objective is to minimize the sum of the routing costs and the sum of the selected options costs.

2 Solution method

We propose to solve the PDP-TF with a metaheuristic based on Large Neighborhood Search (LNS). LNS was introduced in [1]. It consists in exploring large neighborhoods by iteratively applying destroy and repair operators. Destroy operators remove a subset of requests from their route and place them in a *request bank*. Repair operators inserts the requests of the request bank in routes by evaluating each of their options and their possible insertion positions in existing routes.

As in [4], we perform a combination of small and large removals operators. Small removals remove only a few requests from the current solution, so they can be quickly repaired. When performing small removals, we use fast repair operators, inspired by [3], that sort the request bank according to some criteria, then insert requests according to their order in the sorted request bank. The considered criteria are the size of the request, the number of times the request couldn't be inserted in any route, or random. This type of *list operator* is particularly suitable for our application because a black box approach is used for cost evaluations due to the diversity of transportation rates. Large removals diversify the search. They are called after a certain number of iterations without improvement of the best found solution. When performing large removals, solutions are repaired with a greedy or a 2-regret operator.

The LNS is hybridized the solving of a Set Partitioning Problem that recombines routes produced by the LNS at different iterations.

3 Experiments

The LNS algorithm is evaluated on two related optimization problems introduced in [5]: the VRP with Transshipment Facilities and Time-Windows (VRPTWTF) and its Fleet-Size and Mix variant (FSMTWTF). Our algorithm improves the results of [5] on 8 instances out of 56 VRPTWTF instances and on 7 instances out of the 56 FSMTWTF instances. The average gap on all VRPTWTF instances is 0.13%. The average gap on all FSMTWTF instances is 0.43%. The algorithm is used to solve a real-life case study provided by a major food company in France. Further work includes tuning of the LNS parameters and extending the VRPTWTF and FSMTWTF instances to allow requests to be picked up from multiples supplier sites.

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