Meta-heuristics for Synchronized Multi-zone Multi-trip Pickup and Delivery Problems

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We study the *Multi-zone Multi-trip Pickup and Delivery Problem with Time Windows and Synchronization* (*MZT-PDTWS*). In this setting, a homogeneous fleet of vehicles operates out of a single garage to perform multiple sequences of delivery and pickup of customer-specific loads. Loads to be delivered are available at particular facilities during particular operating time intervals, and service at the corresponding customers must be performed within their specified hard time windows. Similarly, loads available at (the same or different) customers within their particular hard time windows, must be collected and brought to one of the available facilities during its particular operating time interval. Vehicles must synchronize their arrivals at facilities with the respective operating time periods, that is, time windows at facilities are hard and vehicles are not permitted to arrive in advance and wait. A number of waiting stations may be used by the vehicles to wait for the next visit at a facility. We assume a *pseudo-backhaul* operating policy (Crainic et al., 2012a) in this paper, i.e., all loads collected at a facility must be delivered before a pickup sequence may be initiated. The goal of the MZT-PDTWS is to determine when and where to deliver the loads present at customers, as well as construct the set of routes and assign them to particular vehicles, providing timely customer service and synchronized arrival at facilities, minimizing the total cost made up of the (variable) costs of operating vehicles and the (fixed) costs of using them.

The time-dependency characterizing demand in the MZT-PDTWS translates into two phenomena. The first concerns facilities, which become available for work at particular time periods only, with a set of loads destined to specific customers and ready to receive collected loads. A given facility may be available at several periods during the planning period considered, with a different operating time and set of loads at each occurrence. To model this time dependency, we define *supply points* as particular combinations of facilities and availability time periods. A supply point is characterized by a set of loads to be delivered to particular customers, and by a no-wait hard time window, meaning that vehicles cannot arrive before the beginning of the time window and wait for the opening of the facility, nor after the end of the time window by paying a penalty. This synchronization requires that vehicles that would arrive earlier than the appointed time go to a *waiting station* (e.g., a parking lot) and wait for the appointed time. When this waiting is deemed uneconomical or no waiting station is available, the vehicle returns to the garage to finish its route.

The second phenomenon concerns customers, which may receive several loads, at different time periods from different facilities, or ship loads at various points in time through a facility to be chosen within a given set, or perform both activities during their operations. We model the type of activity and time dependency associated to each particular load by identifying it as either a *delivery-customer demand* or a *pickup-customer demand*. A delivery-customer demand is characterized by the supply point where it is available for delivery, the customer it must be delivered to, and the time window when the delivery must be performed. A pickup-customer demand is characterized by the customer shipping it and the time window within which the pickup must be performed, as well as by a set of facilities to which the load can be delivered, the choice of a particular one being part of the decisions characterizing the MZT-PDTWS.

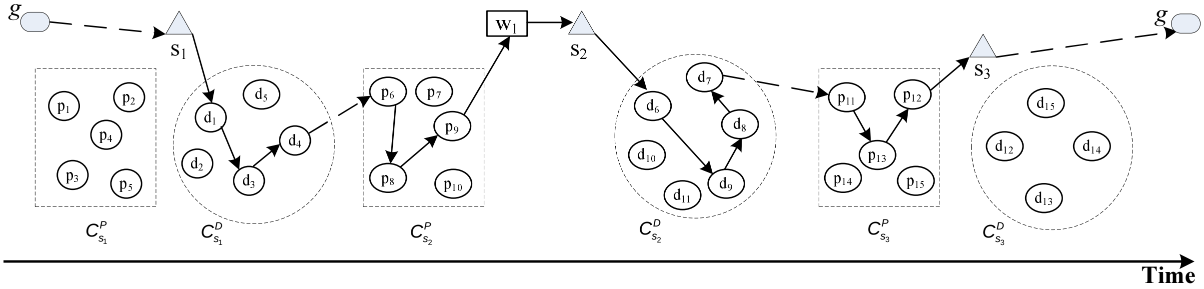

Figure 1: A four-trip route illustration

A vehicle route, illustrated in Figure 1 thus leaves the garage to visit a first facility (S_1 in the figure) within its operating time period (from the garage to the facility, the vehicle could have picked up loads destined to that particular facility) and load (and unload, possibly) freight, proceeds to deliver it to customers within their time windows (Set $\mathcal{C}^D_{s_1}$ of delivery-customer demands), then either moves directly to its next appointment to a facility (S_2), possibly stopping to wait for the appropriate time at a waiting station (w_1), or first moves to a pickup-demand customer and starts a pickup sequence (Set $\mathcal{C}^P_{s_2}$) before going to the facility. The route continues until either there are no more loads to deliver or its cost becomes noncompetitive compared to other routes. The vehicle returns to the garage in both cases. The MZT-PDTWS generalizes the Synchronized Multi-zone Multi-trip VRPTW (Crainic et al., 2009; Nguyen et al., 2013) and the VRP with Backhauls (e.g., Berbeglia et al., 2007). It is encountered in several settings, in particular when planning the operations of two-tiered City Logistics systems (Crainic et al., 2009) accounting for both the inbound and outbound traffic (Crainic et al., 2012a).

We propose a tabu search meta-heuristic for the MZT-PDTWS integrating multiple neighborhoods grouped into two classes. A first set of neighborhoods targets the construction of multiple-trip routes by modifying the supply points a vehicle visits. A second set focuses on improving the routing within sequences of delivery- and pickup-demand customers through intra- and inter-route neighborhoods dedicated to each type of sequence. The neighborhood selection rule is dynamically modified during the search, and a diversification strategy guided by an elite set of solutions and a frequency-based memory is called upon when the search begins to stagnate.

Extensive computational experiments (on instances with up to 72 supply points and 7200 customer demands) will be reported to qualify the impact of a number of major problem characteristics, parameters and search strategies on the behaviour of the solutions and to underline the good performance of the proposed algorithm. As no previous results are available in the literature for the MZT-PDTWS, we also evaluate the performance of the method through comparisons with currently published results on the VRP with Backhauls.

References

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