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Parking selection in vehicle routing

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This paper presents a variant of the vehicle routing problem considering the delivery of customers in cities with a combination of walking and driving. The objective is first to offer a better model for actual delivery problems where drivers are usually assumed to have a single parking location to deliver each customer. Second, we show that serving some customers through walking trips is more efficient in congested areas. We introduce the *Park-and-Loop Routing Problem with Parking Selection (PLRP-PS)*, which extends the work of [3, 1]. We investigate the case where parking locations should be selected among a large set of parking areas in a variant of Large Neighborhood Search (LNS).

1 The park-and-loop routing problem with parking selection

We consider a set of customers N with non-unitary demand q_i , $\forall i \in N$ who have to be served using a homogeneous vehicle fleet K . We consider that each vehicle starts from and return to a depot 0. It is assigned to a driver who will perform deliveries by walking from a parking location to the customers. We consider a large set P of parking locations. Each parking location $i \in P$ is associated with a parking time pt_i . For each pair of nodes i, j in $\{0\} \cup P$, we assume a driving time t_{ij}^d and distance d_{ij}^d are determined, while a walking time t_{ij}^w and distance d_{ij}^w are defined for each $i, j \in P \cup N$.

A *vehicle route* starts from the depot, visit a sequence of parking locations in P , and returns to the depot. The sum of customers demands served by a vehicle route must not exceed the vehicle capacity Q_d and a vehicle route duration must not exceed a maximum value h_{max} . A *walking-trip* starts from a parking location in P , visits a sequence of customers, and returns to the parking location. It must not serve more than the walking capacity denoted Q_w . The overall walking distance of each driver should not exceed a given limit w_{max} . At a parking location, a walking-trip can start after the vehicle is parked. Then the driver may perform several walking-trips from his vehicle.

The PLRP-PS consists of designing vehicle routes and walking-trips, respecting vehicle capacities, maximum route duration and the maximum walking distance of each driver, such that each customer is served with its demand by exactly one driver, lexicographically minimizing the number of vehicles and the sum of driving times, walking times and parking times. This problem is illustrated on Figure 1, with three vehicles routes (green, grey and blue) starting from the black depot on the left. Walking paths are in red. Red points indicate customers and the dark blue points indicate the selected parking locations. Light blue points indicate unused delivery areas.

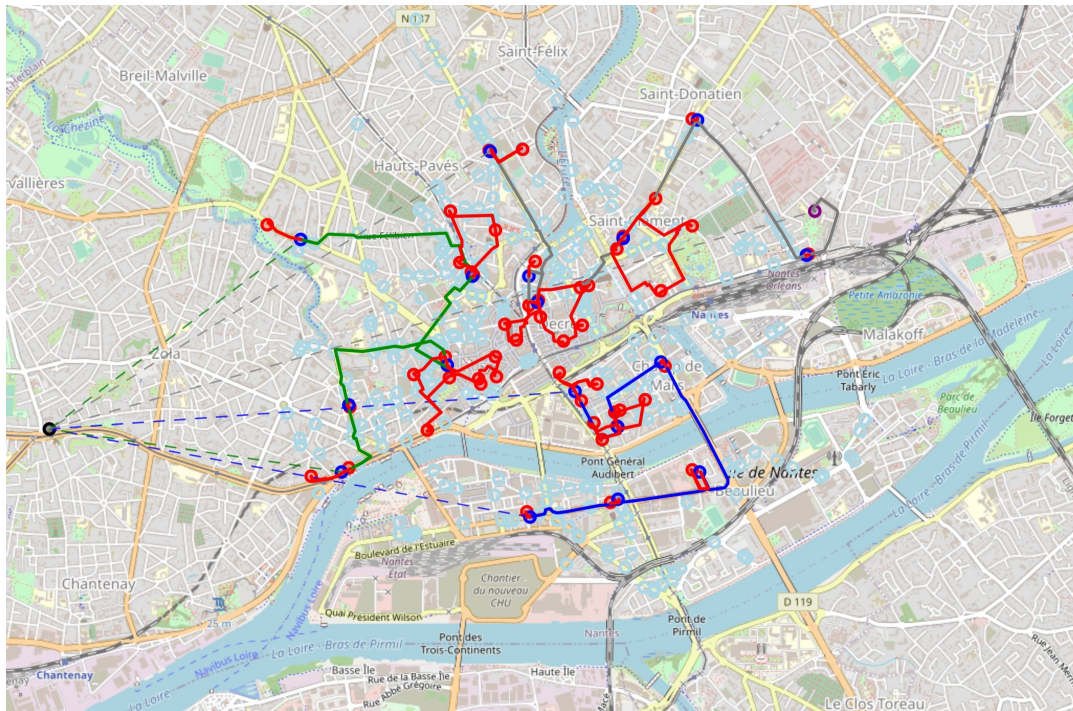


Figure 1: Best found solution for instance “nantes-50-1” with 50 customers. Map created using Open Street Map ©: www.openstreetmap.org/copyright, travel time and distances with OpenRouteService ©: www.openrouteservice.org

2 Solution approach

To solve the PLRP-PS, the proposed algorithm is based on a variant of LNS called Small and Large Neighborhood Search (SLNS). We investigate different strategies that can be used in the SLNS repair operators to select parking locations.

2.1 Small and Large Neighborhood Search

The principle of SLNS where first introduced in [4]. It combines ingredients from the seminal paper of [5] and the recent paper of [2]. In this algorithm, most iterations perform

small destroy and repair operations on the current solution, using in particular, fast list heuristics to re-insert customers. On a regular basis, large destructions are performed, involving additional operators to bring diversification in the search.

Classical destroy and repair operators were tailored to the problem and extend to integrate parking selection. To create the vehicle routes and walking trips, we introduce three types of insertions, namely *insertion in a new route*, *insertion through a new parking location* and *insertion through a served parking location*, which allows customers to be inserted in existing walking-trips.

2.2 Insertion strategies for parking selection

Considering a huge number of parking locations may be available in a city, independently of the number of customers, we are interested in reducing the possibilities that are evaluated when selecting a parking location. Let us presume that a customer has been selected and we aim at evaluating its insertion in a new route or through a new parking location. We propose different parking selection strategies. A *parking selection strategy* is composed of a *parking selection criterion* and *parking selection method*.

We consider two criteria to select parking locations from each customer: The first criterion is the walking time between the parking and the customer (*radius-r* criterion). The second criterion is the ranking of the parking in the list of parking ordered by non-decreasing distance to the considered customer (*k-nearest* criterion). In addition, two approaches involve these criteria to reduce the set of evaluated parkings: The first one *filters* the parking set from which each customer can be served a priori, keeping the locations below a given threshold on the chosen criterion. In the second approach, for each customer a *sorted* list of parking locations is designed based on the selected criterion. The locations are then evaluated according to this order, with a given probability to stop after each location evaluation.

3 Experiments and case study

The efficiency of the approach is demonstrated on the Park-and-Loop Routing Problem (PLRP), with 13 new best solutions found on an existing benchmark solved by [3] and also solved by [1]. Realistic instances were generated based on open data from the city of Nantes. The proposed parking selection strategies are compared and tuned on these instances. Figure 2 presents experiments on problem variants, where the average driving, walking and parking times per customer is represented for different problem sizes. In this figure, the CVRP supposes parking at each customer, the PLRP allows drivers to perform walking trips while parked at customers, the PLRP-PS(C+DA) adds parking at delivery areas, while the PLRP-PS(DA) includes only delivery areas. Comparing the CVRP and

the PLRP-PS(DA), we find that combining walking and driving in urban delivery can save 19% of working time on average compared to the classical vehicle routing approach. In addition, parking at customers saves walking time when this is possible, and serving several customers from one parking is even more profitable in this case.

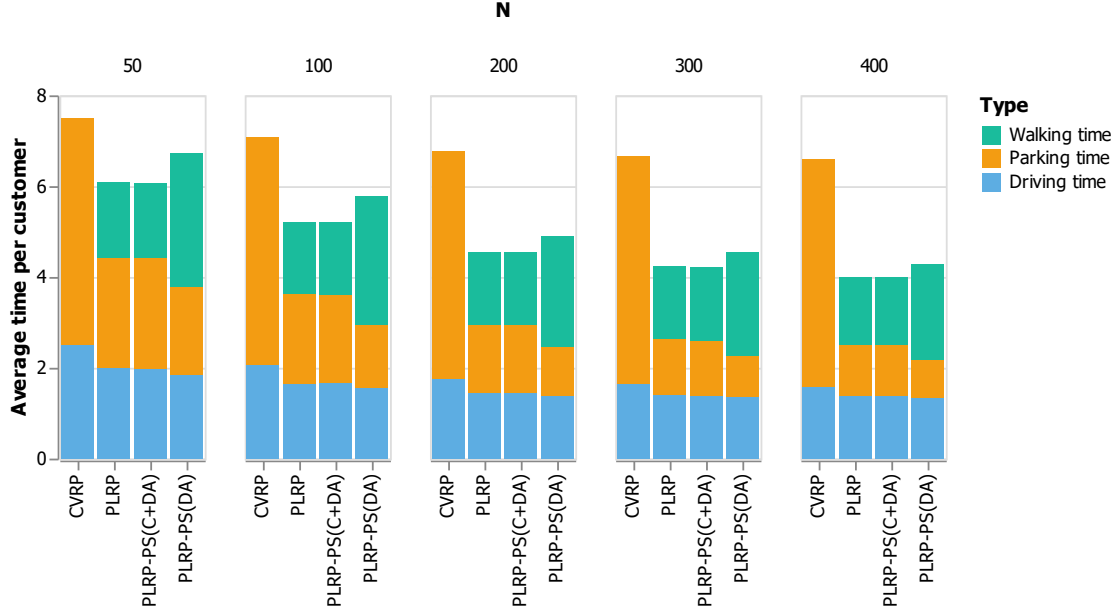


Figure 2: Objective function value decomposition for each type of time and per customer

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