An ELS for the Dial-A-Ride Problem with private vehicles

David Brevet \(^1\), Christophe Duhamel \(^1\), Philippe Lacomme \(^1\)

\(^1\) Université Clermont Auvergne, LIMOS, UMR CNRS 6158, Campus des Cézeaux, 63177 Aubière Cedex, France.

(david.brevet, christophe.duhamel, placomme)@isima.fr

**Keywords:** transportation, DARP, metaheuristic, ELS.

1 Introduction

In modern transport services, clients have the opportunity to choose between several transportation type including public transportation, private society or carpooling. Currently, routing problems in operational research are based on heterogeneous fleets from one or several companies. For instance, the well-known Dial-A-Ride Problem (DARP) \([1]\) aims at defining routes for a fleet of vehicles in order to transport each customer from his pickup node to his delivery node, considering a number of operational constraints and taking into account the Quality of Service (QoS). Earliest publications from the 80s were focusing on the single vehicle case. A survey of recent works dedicated to the DARP can be found in \([2]\). We consider here an extension of the DARP, referred to as DARP-PV, which addresses a proper coordination between a heterogenous fleet of vehicles located at a depot node and a set of private vehicles. An Evolutionary Local Search (ELS) metaheuristic is used to compute solutions.

2 The ELS metaheuristic

The DARP is formally defined on a complete weighted digraph \(G = (N, A)\), with a heterogeneous fleet \(F\) of \(K\) vehicles and a set \(R = \{1, ..., n\}\) of transportation requests. \(N = \{0,1, ..., 2n, 2n + 1\}\) is the set of nodes. The depot is split in two copies, 0 and \(2n + 1\), for, respectively, the beginning and the end of the trips. Given a transportation request \(i\), its pickup point is \(i\) and its delivery point is \(n + i\). Thus \(P = \{1, ..., n\}\) and \(D = \{n + 1, ..., 2n\}\) are, respectively, the pickup and the delivery subsets. For each node \(i\), \([e_i; l_i]\) is its time windows (\(e_i\) is the earliest starting time and \(l_i\) is the latest starting time), the service duration is \(d_i\) and the demand is \(q_i\). Given an arc \((i, j) \in A\), \(t_{ij}\) is the transportation time and \(c_{ij}\) is the transportation cost. Vehicle \(k\) of the fleet has capacity \(Q_k\).

In the DARP with Private Vehicles (DARP-PV), a subset \(R' \subseteq R\) of customers can use their own vehicle, for their request and for handling the requests of other customers. In case customer \(r \in R'\) uses its vehicle, the trip starts at \(r\), stops at \(n + r\) and the vehicle’s capacity is \(Q_r\). DARP-PV reduces to DARP when \(R' = \emptyset\) and thus it is NP-hard.

As \([3]\), we created an ELS based metaheuristic. A randomized heuristic is used to create an initial solution, using the fleet \(F\). Then, at each iteration of the ELS, several copies of the incumbent solution are built. Each copy is randomly modified before being improved by a local search using several neighborhood structures and considering a dynamic probability to call each one. Each neighborhood considers the private vehicles and allows an interplay between \(F\) and \(R'\).
3 Numerical experiments

The ELS is more scalable than exact methods to address medium to large instances from the literature. Some results are presented on Table 1. The solutions are evaluated on the total travel distance. Since the BKS is only known when no private vehicles \( i.e. R' = \emptyset \) are used, the average gap the BKS permits to evaluate the impact of using private vehicles. 5 runs of the ELS are done for each instance. The best (Best) and average (Avg) value found, the gap between BKS and our best (Gap*) and our average (Gap) value, the average time to reach solutions (T*) and the total time limit (T) are reported. All experiments have been carried on an Intel i7-4790 processor, scaling around 4.21 GFLOPS.

| \(|N|\) | \(|F|\) | \(|R'|\) | BKS | ELS (5 runs) |
|---|---|---|---|---|
| \(R1a\) | 48 | 3 | 0 | 190.02 | 190.02 | 190.02 | 0.00 | 0.00 | 0.00 | 0.25 |
| \(R1a_1p\) | 48 | 3 | 1 | None | 190.02 | 190.02 | 0.00 | 0.00 | 0.00 | 0.25 |
| \(R1a_2p\) | 48 | 3 | 2 | None | 190.02 | 190.02 | 0.00 | 0.00 | 0.00 | 0.25 |
| \(R1a_3p\) | 48 | 3 | 3 | None | 187.81 | 187.81 | -1.16 | -1.16 | 0.12 | 0.25 |
| \(R2a\) | 96 | 5 | 0 | 301.34 | 301.34 | 301.34 | 0.41 | 0.19 | 1.00 |
| \(R2a_1p\) | 96 | 5 | 1 | None | 297.29 | 298.10 | -1.34 | -1.08 | 0.56 | 1.00 |
| \(R2a_2p\) | 96 | 5 | 2 | None | 293.82 | 294.85 | -2.50 | -2.15 | 0.69 | 1.00 |
| \(R2a_3p\) | 96 | 5 | 3 | None | 293.66 | 294.13 | -2.55 | -2.39 | 0.66 | 1.00 |
| \(R3a\) | 144 | 7 | 0 | 532.00 | 532.00 | 533.82 | 0.34 | 1.15 | 2.50 |
| \(R3a_1p\) | 144 | 7 | 1 | None | 529.23 | 531.49 | -0.52 | -0.10 | 1.36 | 2.50 |
| \(R3a_2p\) | 144 | 7 | 2 | None | 527.77 | 531.83 | -0.80 | -0.03 | 1.85 | 2.50 |
| \(R3a_3p\) | 144 | 7 | 3 | None | 522.09 | 525.16 | -1.86 | -1.23 | 1.93 | 2.50 |

In general, allowing private vehicles to be used in conjunction to the fleet \( F \) can lead to better solutions than in the pure DARP context (see for instance \( R2a \) and \( R3a \)): minimizing the total distance improve the riding time for each client. The larger the number of private vehicles, the better the solution (see \( R2a \) and \( R3a \)). However, this does not always holds and sometimes additional private vehicles may not help (\( R1a_1p, R1a_2p \)). It depends on both the instances and on the number of private vehicles. In addition, the more the number of private vehicles, the smaller the stability of the results.

4 Concluding remarks

An extension of the DARP in which private vehicles can be used in conjunction with the fleet is presented. An ELS metaheuristics is proposed to compute solutions of good quality. Results are presented on a set of small to medium instances to assess the impact of these vehicles in the solution. These preliminary results push us into considering that private vehicle are of great interest for minimization of the routing cost. Future work is currently done to evaluate the economic impact of incenting global vs. individual transportation mode. In addition, work is currently done to integrate customer’s privacy constraints to improve customer’s safety.

References