A Multiobjective Model and Simulated Annealing Approach for a Dial-a-Ride Problem

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DARP is a known NP-Hard problem, and several methodologies have been adopted to solve it. However an exact mathematical formulation to solve it is very complex, and unable of being solved in a reasonable time for problems of “real size”.

This work presents a simple and effective alternative to solve a dial-a-ride problem. A general mathematical and multiobjective model is proposed to represent the problem, and the metaheuristic Simulated Annealing is used with other heuristics to treat it, to produce routes to be operationally economical and satisfying the customers' demand keeping a “good” quality level in the realized service.

Considering a classification of vehicle routing and programming problems, those that cover the passengers' transport of their origin places to their destinies are known in literature as problems of “dial-a-ride” type.

Dial-a-Ride - DARP consists of developing routes and scales of vehicles to transport several customers, which specify requests of pick-up and delivery between specific origin and destiny places. The objective of that process is planning a set of routes for some vehicles, with “minimal cost”, holding the largest possible number of customers, always complying a set of constraints.

In deficient people transportation, a pick-up point matches to the address where a certain customer should get into the vehicle, and the associated delivery point matches to the address where the same customer should leave the vehicle. Each pick-up point and its respective delivery point and their respective “time window” define a customer’s *Transportation Request*. A common tendency in DARP models is to let that customers fix a “time window” (time intervals for their attendance) for their departure and arrival, because the customers should be able to specify a time interval for their pick-up and delivery, both in specific places.

The model proposed in this work treats DARP in a static mode (all the requests are known in advance), with multiple vehicles, with heterogeneous fleet (each vehicle has a different capacity) and multiple depots (each vehicle begins and finishes its route in specific depots). This is an approach that includes several others found in literature, and it is very close to real situations.

The objective is to minimize the operational costs and the customers' “inconvenience”, that is, minimizing the “non-essential” requirements of problem. These requirements are related to the total distance traveled by the vehicles, to the number of vehicles used in problem solution, to the routes duration, to customers’ ride time and to waiting times in pick-up and delivery places.

The initial solution is formed through a *distribution heuristic*, that is responsible for routing the vehicles, for forming clusters of places in the routes and determine their attending sequence of these. In the distribution heuristic, m empty routes are created, assigning to each one of them a specific vehicle. Later, all the customers’ transportation requests (pick-up points and its respective delivery ones) are randomly distributed in a uniform mode to these routes, and the n transportation requests are divided equally among the m vehicles. Obviously, sometimes divides n by m won't be an integer, and in these cases the last route should attend a higher number of requests. Selecting requests and routes that will assist them is also random.

The insertion positions in route are also selected in a random mode, but always assisting the precedence constraint originating from the customers' transportation request, (the pick-up place should always be before the delivery place). Finally, due to the fact that all routes begin and finishes at specific depots (regarding the vehicle that will perform it), the places regarding these depots will always be allocated on first and last points in each one of the created routes.

The distribution heuristic just treats the vehicles' routing, but the programming of these vehicles should still be made to determine the arrival times in places, the departure times, and so on. Then, another heuristic, denominated *programming heuristic*, is used.

Three different change moves were used as neighborhood structure: *Re-order route*, *Re-allocate points* and *Change points*. These moves are based in others found often in works about DARP. It is interesting to highlight that in these moves the depots are not considered, because they are "fixed" in all the routes, and thus their positions cannot be changed.

The Re-order route move consists basically in selecting any route from solution, select any point in this route, select a new position for this point and change this point position with the new position. The selected point can be a pick-up or a delivery point.

The Re-allocate points move consists basically in also select two routes from solution, select any transportation request in just one of the two routes, extract it (its pick-up and delivery points) of origin route and add it to the another route, in any position. The pick-up point and its respective delivery point are extracted simultaneously, however its insertion in "another" route can be done in a separate way, in other words, these points are allocated individually in any position of the route, however always keeping the condition that the pick-up point is before the delivery one (precedence constraint).

The Change points move consists of selecting any two routes from solution, select any transportation request (pick-up point and its respective delivery) in each one of two routes, and change them. In this case, transportation requests are changed, so their pick-up and delivery points are changed simultaneously (changes in pairs), and this guarantees that pick-up point will always be before to its respective delivery point.

Starting from this neighborhood structure, SA was implemented in a way that each neighboring solution is generated for just one of these movements, and its choice is done in a random mode, uniformly distributed, making possible a good diversity among the generated intermediate solutions, and consequently a good exploration of the space of solutions.

Several experiments were performed with instances founded in literature (available in: <http://www.hec.ca/chairedistributique/data/darp />) to evaluate the potential of the presented approach. These instances are references in works of great importance for DARP resolution.

The clustering and routing were performed by the distribution heuristic and neighborhood structure, while the vehicles' programming was performed by the programming heuristic.

The Simulated Annealing, integrated with the other heuristics, was able to get, in all the cases, and with low processing time, valid solutions for the problem. Besides, it was shown robust, because the presented deviations were satisfactorily low. The neighborhood structure, through the change moves, had been shown to be appropriate and efficient for space of solutions exploration. The obtained results show that the Simulated Annealing, with the proposed model and the other heuristics, were able to produce solutions of good quality for all the instances in expressively low computational times. These results were compared to two other recent approaches found in literature, and in all of cases, the "quality of service" was significantly better. The customers' inconvenience was significantly reduced, which in practice, on human perspective, it reflects better solutions.

Finally, the results show clearly the potential of the presented approach, where solutions of high quality are obtained, for relatively big problems, in expressively low processing times.

Starting from this work, a great research field is had to be explored, as for instance, the application of this approach to real problems found in Brazilian cities, and to other similar problems.