Impact of Competition on Quality of Service in Demand Responsive Transit

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Abstract. Demand responsive transportation has the potential to provide efficient public door-to-door transport with a high quality. In currently implemented systems in the Netherlands, however, we observe a decrease in the quality of service (QoS), expressed in longer travel times for the customers. Currently, generally one transport company is responsible for transporting all customers located in a specified geographic zone. In general it is known that when multiple companies compete on costs, the price for customers decreases. In this paper, we investigate whether a similar result can be achieved when competing on quality instead. To arrive at some first conclusions, we set up a multiagent environment to simulate the assignment of rides to companies through an auction on QoS, and the insertion of allocated rides in the companies’ schedules using online optimization. Our results reveal that this set-up improves the quality of the service offered to the customers at moderately higher costs.

Keywords: Dial-a-ride, multi-company, quality of service, auction.

1 Introduction

Demand-Responsive Transit (DRT) services are a form of transport that is a compromise between public transportation and individual taxis. The principle of these systems is to define the itineraries and schedules of the vehicles based on the requests of the users. Customers are thus provided with relatively cheap door-to-door transportation insofar as they accept to share their ride with others and tolerate a certain detour from their direct trip. The main problem with current DRT services as organized in the Netherlands is that the quality of service (QoS) cannot be guaranteed over longer periods of time. A strong competition for the right to serve for a period of usually three years promises a reasonable quality at a low price, but has the effect that a company that is too optimistic in the contracting phase receives the assignment, but subsequently cannot meet the quality objectives without incurring serious losses. Heavily penalizing such a company for a low QoS will soon lead to bankruptcy, and therefore an even lower QoS until a new company has been found.
QoS is usually not specifically addressed in the allocation of rides. The minimization of company’s costs is treated as a primary objective, while imposing a minimal QoS [1]. The idea put forward in this paper is to let companies compete on QoS on a day to day basis given a price per kilometer that is fixed in advance. Given known results that competition can reduce the total costs, the question is can we use it to improve the QoS instead, and at what costs? Here we divert from research on using auctions and other price-based mechanisms for task allocation in that not the company with the lowest price receives the task, but the company that guarantees the highest QoS. Our main hypothesis is that this approach significantly increases the QoS without much additional costs.

To test our hypothesis, we implement the proposed approach in a multiagent environment (see Section 3), simulate series of requests, simulate the bidding and scheduling process of the companies (in Section 4), and compute the resulting costs and QoS in Section 5. We compare these results to a single-company setting where the company optimizes costs with and without a guaranteed QoS level.

2 Background

DRT services are usually modeled as a Dial-a-Ride Problem with Time Windows (DARPTW), an extension of the Vehicle Routing Problem. A DARPTW is defined by a set of customers and a fleet of vehicles. Each customer desires to be transported from an origin location to a destination. Customers can impose a time window which includes the earliest possible time and the latest possible time they can be either picked up or delivered. The dynamic DARPTW (D-DARPTW) is NP-hard, which can be proven by a translation from the Traveling Salesman Problem (TSP) [2]. The problem can be solved exactly by modeling it as a Mixed Integer Program (MIP) [3], or by applying heuristics [4]. The disadvantage of using exact algorithms in a dynamic environment is that these algorithms take too much computation time. The disadvantage of using heuristics is that in some cases the solutions are significantly far from the optimal solution.

In a technique called on-line optimization the optimal solution is searched for with exact algorithms, but only taking into account that part of the problem that is relevant for the moment [5]. For instance, when searching for the best departure times of the locations of a request to insert into a current schedule, only that part of the current schedule that can be influenced by inserting the new request needs to be considered in the solution process. This results in smaller problems as input for exact algorithms, which implies less computation time. In our simulations of the multi-company environment we apply this online optimization for the insertion of a ride into the schedule of one of the companies.

3 The Multi-company DARPTW

In this section, we define a DARPTW where multiple companies compete for requests. The general principle is that the companies announce an offer to the customer, who chooses the company that will serve its request. Conditioned on