Impact of Competition on Quality of Service in Demand Responsive Transit

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28 Septembre 2010@MATES-Leipzig

Outline

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Introduction

Demand-Responsive Transit (DRT) services

DRT are a form of transport that is a compromise between public transportation and individual taxis

Principle

- Define the itineraries and schedules of the vehicles based on the requests of the users
- Customers are 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

Problem

Problem

- Competition on a three years contract
- The quality of service (QoS) cannot be guaranteed over longer periods of time

Idea

- Let companies compete on QoS on a day to day basis
- 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 ?

Background

Dial-a-Ride Problem with Time Windows (DARPTW)

- 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 (earliest possible time and latest possible time)

Approaches

- DARPTW can be solved exactly by modeling it as a Mixed Integer Program (MIP), or by applying heuristics
- Exact algorithms : high computation time
- Heuristics : distance from the optimal solution

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Quality of Service

QoS

- QoS is the ratio of the actual ride time to the direct ride time
- E.g. The time to travel from A to B directly $=$ 5 min, and the vehicle drives from A to B via C, in 7 minutes, $QoS = \frac{5}{7}$

Bidding Service Quality

- Usually
  1. the additional costs needed to serve a request is used as a bid
  2. the request is assigned to the vehicle that has announced the bid with the lowest additional costs
- Here, we let the companies compete on the QoS for an incoming request

The Multi-Company DARPTW

Mechanism Overview

1. A customer announces its request to all companies
2. Each company checks for insertion possibilities
   - If possible, a bid value is calculated for this request
   - Otherwise, the company will not place a bid in the current auction
3. When all bids are received
   - The best one (the highest QoS) is determined
   - The conditions that have to be met by the winning company in serving the request are set
4. The winning company is informed of the conditions
5. The winning company inserts the request into the schedule of one of its vehicles

Reversed sealed-bid second-price auction

Reversed sealed-bid second-price auction

- Each bid is private to the company that submits it
- *Reversed*, because there are multiple sellers (the companies) and a single buyer (the customer)
- The winner of the auction has to meet the details of the second-highest bid value

Payments

Payments

- Profit = total *income* - total *costs*
- Payment = *price per kilometer* C_{km} $\times$ the direct distance between the pickup and the delivery location of the customer's request
- The lower bound for $C_{km} = \frac{OPT(R)}{\sum_{(i,j)\in R} t_{i,j}}$
- The upper bound for $C_{km} \frac{OPT^{1.0}(R)}{\sum_{(i,j)\in R} t_{i,j}}$

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Companies' Behavior

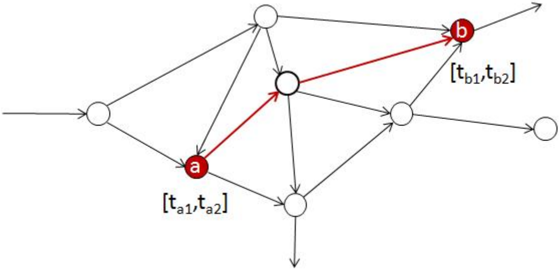
Online Optimization

- The computations of the transport companies are based on online optimization for the insertion of rides

Bid Calculation

- There are different costs associated with the different QoS values that a company can bid
- If each company bids the highest QoS possible, all rides will be transported at QoS of 1
- To avoid this, we allow the companies to incorporate knowledge about future requests in their bid calculation

Companies' Behavior



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Hypothesis

Hypothesis

1. When multiple companies compete on QoS, the average QoS is higher than in a situation with a single company which minimizes costs. Transportation costs are also higher
2. For a single company, a higher required QoS is more expensive
3. When multiple companies compete on QoS, the costs are not significantly higher than in a situation with a single company which minimizes costs with the same average QoS

Experimental Setup

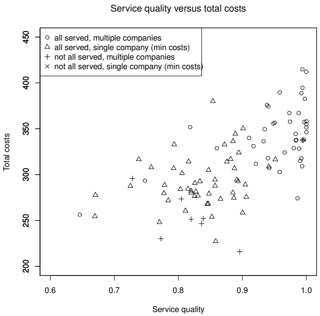
Experimental Setup

1. 100 problem instances, each containing 16 customers
2. Network : continuous map (square area of 20 by 20 km)
3. Coordinates and pickup and delivery times distributed uniformly
4. With each customer, we add its availability time
5. Jade & SCIP

Tests

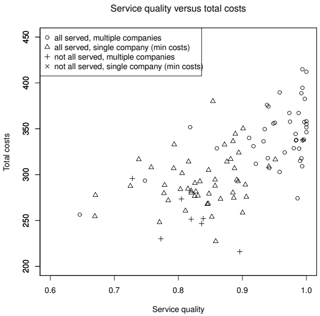
1. First setting : two companies competing on QoS
2. Second setting : a single company minimizing costs

First Experiment



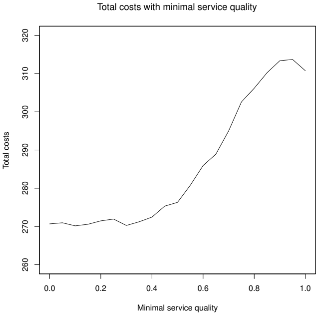
1. QoS about 12% higher in the multi-company setting than in the single-company setting
2. Total costs about 13% higher in the multi-company setting than in the single-company setting

First Experiment



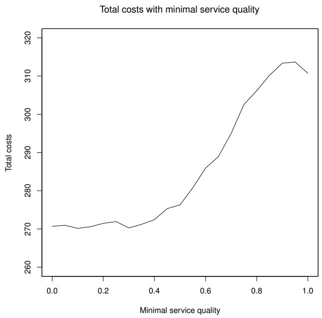
1. QoS about 12% higher in the multi-company setting than in the single-company setting
2. Total costs about 13% higher in the multi-company setting than in the single-company setting
3. Hypothesis 1 valid

Second Experiment



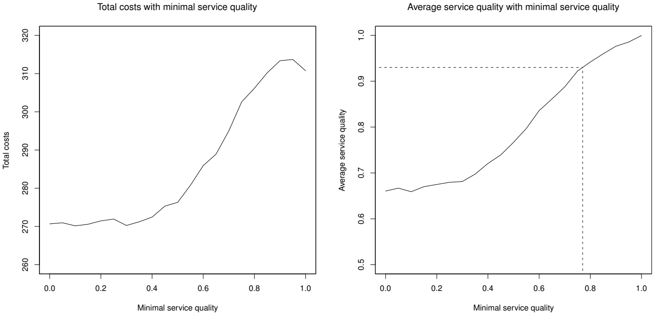
1. Average total costs increasing as from a QoS level of 0.4
2. Strong correlation between total costs and minimal QoS (93%)

Second Experiment



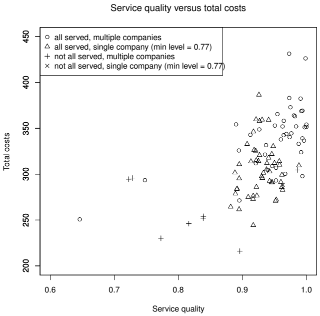
1. Average total costs increasing as from a QoS level of 0.4
2. Strong correlation between total costs and minimal QoS (93%)
3. Hypothesis 2 valid

Second Experiment



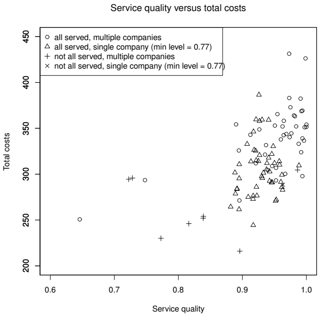
1. Average total costs increasing as from a QoS level of 0.4
2. Strong correlation between total costs and minimal QoS (93%)
3. Hypothesis 2 valid
4. Average QoS in the multi-company setting is 0.93 and when we search for the corresponding minimal QoS level we find a value of 0.77

Third Experiment



1. Same QoS
2. Total costs 7% higher in the multi-company setting

Third Experiment



1. Same QoS
2. Total costs 7% higher in the multi-company setting
3. Hypothesis 3 not valid

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Conclusion & Perspectives

Conclusion

1. It is possible to obtain a higher QoS in door-to-door transportation by letting multiple companies compete on QoS
2. The costs are about 7% higher than in a single company setting with an appropriate required QoS

Perspectives

1. Other definitions of QoS, e.g. taking into account deviations from desired departure/arrival time
2. Define mechanisms where companies compete both on QoS as well as on costs
3. Define mechanisms allowing for bidding on combinations of requests
4. Consider more realistic generation of requests, based on real data

Conclusion & Perspectives

Thanks