Potential of Shared Taxi Services in Rural Areas – A Case Study

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Abstract

Due to modern communication and information technology, shared taxi services are on the rise. While most research and practical projects focus on services operating in densely populated urban areas, the advantages of individual, flexible and shared transportation services in sparsely populated areas have not been well explored yet. Using a constraint programming formulation, this work investigates request management policies to evaluate the economic potential of shared taxi services in rural areas and computational experiments demonstrate the impact of pre-bookings on efficiency and service quality of these services.

Keywords: Degree of Dynamism, Ride Sharing, Dial-a-Ride Problem, Case Study

1. Introduction

In recent years, the protection of our environment has become a ubiquitous topic in politics, business, science and private spheres. With an increase in car ownership, extended car usage and the diminishing size of households, the occupancy rates of passenger vehicles have dropped from around 2.1 to around 1.6 between 1970 and 1990 (European Environment Agency, 2008). One promising field to organize transportation in a more environmental-friendly way could be the revived trend of ride sharing, which constitutes a mode of transport in which passengers with similar journeys share one vehicle rather than everyone driving on his/her own. Modern communication and computation technology have greatly simplified and enhanced this mode of transport by facilitating easier collection of travel requests as well as fast and appropriate matching of travelers. In this paper, we want to explore the performance of these services in sparsely populated rural areas considering that customers can book their seats one day in advance (“pre-bookings”) or on short notice (“spontaneous bookings”). We are especially interested in the optimal distribution of pre-bookings and spontaneous bookings and in getting insights on the effects of the time span between request disclosure and desired pickup time for spontaneous bookings. Contrary to primary intuition, a high proportion of pre-bookings turned out to create significant issues in field trials of such services. The full paper comprises also a literature overview to put the research into context of already existing publications in the field.

2. Problem Description

The shared taxi service at hand works as follows. A service operator provides vehicles and drivers. Additionally, the service operator collects requests from individual travelers that are dispersed around a limited geographical area. Based on every request’s origin and destination as well as the desired pickup time, the service time and the number of passengers, the service provider matches vehicles and travelers and builds a route plan for each vehicle. Travelers will share (fractions of) their trip with other travelers. Requests arrive over the planning horizon of length $T$. Let $t_0$ and $T$ be the start and end of the planning horizon, respectively, and $t_\delta$ be the start of the transportation service with $t_0 \leq t_\delta \leq T$. We define $H = H_p \cup H_s$ such that all requests belong to one of two types: a request $h \in H_p$ is called a pre-booking (request) if it is received at a time $t < t_\delta$. All $h \in H_s$ are considered spontaneous (requests), received at or after $t_\delta$. Spontaneous requests are, therefore, processed after the vehicles have already started their routes. Each request specifies a pickup and a delivery location, a pickup time window of length $u$, the number of travelers to be transported and a maximum ride time that the travelers are willing to spend. Each customer must receive immediate feedback about acceptance of his request. The complete mathematical formulation of the problem is presented in the
full paper. In short, the STP consists of finding a predefined number of closed vehicle routes while ensuring that passengers are transported from their pickup to their drop-off location within the specified maximum ride time. Vehicle capacities and time window constraints must be satisfied and any new spontaneous request cannot undo already executed parts of the route or replace any already accepted request.

Note that in this problem, no request is truly static because even pre-bookings are known before \( t_s \), but not necessarily at \( t_0 \) as would be the case for static requests. Consequently, an environment where all requests are disclosed before the start of the service \( t_s \) will be called pseudo-static. The term \( dod \) will then describe the ratio of spontaneous requests and thus \( dod = 0.0 \) refers to exactly the aforementioned pseudo-static case. Moreover, the notion of \( adv \) and \( r \) describe the advance notice time and the system reaction time (the sum of \( adv \) and \( u \)) of spontaneous requests, respectively. For the operator of a shared taxi business, it is relevant to know the impact of all these values, because the ratio of spontaneous bookings \( dod \) and the system reaction time \( r \) can be influenced to some degree which also has implications on the operational efficiency of the service. To guarantee e.g., that a minimum number of spontaneous bookings can be processed, the operator may set an upper bound on the resources that can be reserved by pre-bookings to avoid pseudo-static situations that contradict the vision of an on-demand transportation service. If the necessary arrangements have been made such that the operator is in control of the \( dod \), \( adv \) and \( u \), a request policy can be determined. A request policy is a triple of values \( \langle dod, adv, u \rangle \) that regulates the disclosure times of incoming requests as well as the system reaction times of spontaneous requests.

### 3. Computational Study

The STP was solved through an implementation in Python 3.7 using Google’s open-source library OR-Tools 7.4. The test instances mimic the EcoBus field trial in the German Oberharz region (www.ecobus.jetzt) and were solved through an insertion algorithm. An extract of computational results is shown in Table 1, highlighting the impact of varying \( adv \) and \( dod \) on traveler rejection rates. An intuitive presumption that more spontaneous bookings generally bring about a greater rejection rate only holds in highly dynamic cases where spontaneous bookings have a very low \( adv \) value. By imposing longer advance notice times (and therefore, longer system reaction times) for these requests, we were able to consistently produce solutions that accommodate more customers than in a setting of only pre-bookings. This is due to the more ordered pickup times of spontaneous bookings that allow a better vehicle assignment for the insertion algorithm. These results will be extended significantly in the full paper, including insights on the vehicle occupancy rates and passenger excess times. Moreover, we present an in-depth analysis of the sensitivity of the rejection rate towards changes in the composition of the reaction time based on different \( adv \) and \( u \) values. One main finding of our research is the non-monotonic behavior of the rejection rate under increasing proportions of spontaneous requests. Additionally, we show that increasing the pickup time window is more effective than increasing the advance notice time when it comes to a minimization of the rejection rate.

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<th>Advanced Notice Time [min]</th>
<th>Degree of Dynamism</th>
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<tr>
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<tr>
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<td>40</td>
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*Table 1. Rejection Rates for Different Policies*

### References


