Evaluating the value of information on the revenue performance of mobility on-demand systems

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Abstract

This paper presents an approach to incorporate demand prediction in flexible mobility on-demand revenue management system. This system has to deal with real-time management of ride services as well as customers demand in order to maximize the profit. We formulate the problem as a mixed-integer linear optimization model and present a math-based rolling horizon algorithm to solve it. We first compare our algorithm against the case in which no forecasted demand is considered. Thereafter, we present various scenarios with different demand forecasting error. Our results indicate that taking into account the future demand can dramatically increase the revenue performance of the system; however, this improvement does not linearly increase with forecast accuracy.

Introduction

The Flexible Mobility On-Demand (FMOD) is a demand responsive system in which a customized travel service is offered to each passenger [1]. When a passenger arrives to the system, he/she requests a ride service. Each request contains information about the pickup/delivery locations and preferred pickup time. The system then generates a set of ride options (i.e. travel menu) to the passenger. Ride options are created based on the proposed pickup time, type of service (taxi/shared taxi), charging fare and maximum duration of the trip (in case of shared-taxi). For each customer, the travel menu is constructed in a way that maximizes the expected profit of the company.

In on-demand systems, the revenue management problem requires to find an equilibrium between customers demand and fleet operating cost. In these systems ignoring future demand could result in an unbalanced situation in which either the operating cost increases or the satisfaction of customers from the service decreases, both resulting in significant revenue loss. Here the central questions are how to incorporate the future demand into revenue management system and how we can improve the accuracy of forecasted demand.

The purpose of this paper is to present an optimization model that maximizes the revenue of on-demand systems taking into account the forecasted demand. More specifically, we determine a look-ahead strategy to perform fleet management as well as constructing the travel menu (demand management) to maximize the revenue. Moreover, we investigate the impact of forecasting accuracy on revenue performance to determine their trade-off.

Solution approach

In this problem, we study a case in which a company owns a set of identical vehicles that can operate either as taxi or shared taxi. We assume that all trips are performed inside a given geographical area. For this area, we use a time-space demand prediction model. The geographical area is partitioned into a set of zones and time is discretized into intervals. For each zone and time interval the forecasting model predicts the expected number of requests as well as the preferred service type (taxi/shared taxi). The revenue management model uses this information to maximize the profit.

To maximize the revenue one has to simultaneously solve two interrelated problems. On fleet management side, it has to solve a special case of dynamic pickup and delivery problem with time window. More specifically, it has to re-assign vehicles to serve registered request (those that will serve in future) and determine a set of minimum-cost rides that can be offered to the customer (each ride has a specific pickup time, service type and trip duration). On demand management side, it has to solve a choice-based assortment optimization. Here, first a charging fare to each alternative has to be calculated based on which a utility value is computed. We measure the utility of each alternative as a generalized value of time which consists of the in-vehicle time, waiting time, schedule delay and charging fare. Choice of customers are modeled as multinomial logit. The assortment optimization is then determined by a sub-set of rides that can be offered to the customer in order to maximize the expected profit. All information regarding the forecasted demand is also incorporated in the model.

We define a state as an arrival time of the new customer into the system. For each state we formulate the revenue maximization problem as a mixed-integer linear programming model. The output of the mode is a customized travel menu maximizing the expected revenue. Thereafter, a rolling horizon algorithm is used to re-optimize the model whenever a new customer arrives to the system.

Results

The described methodology is coded with C++ and we use CPLEX to solve the optimization problem. To evaluate the value of information, we generate various scenarios between two extreme cases. On one side of the spectrum, we consider a scenario in which no future demand is available (myopic solution). On the other hand, we consider a case in which the future demand is known with certainty. In between, we define various scenarios which are distinguished by forecasting error. The results indicate the revenue significantly increase (around 20%) while incorporating future demand compare with the case where no future information is considered.

Conclusion

In this study, we present a mathematical model which incorporates future demand in revenue management model of flexible mobility on-demand system. We develop a rolling horizon algorithm which can solve the problem. Moreover, we investigate the value of information on the revenue performance of these systems. We show the advantage of considering forecasted demand on the revenue performance of the system.

[1] Atasoy, Bilge, et al. "The concept and impact analysis of a flexible mobility on demand system." Transportation Research Part C: Emerging Technologies 56 (2015): 373-392.