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An optimization model of automated taxis in trip assignment under elastic demand for the first/last mile problem

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Extended Abstract

1. Introduction

In recent years, advances in information and vehicle manufactory technologies have accelerated the process of vehicle automation. Using automated vehicles (AVs) in transit systems may create an economical and flexible type of mobility since personnel costs in travelling are avoided and empty vehicle relocations between different areas are conducted automatically.

Most efforts have been devoted to studying the impacts of these vehicles on mobility under different driving and infrastructure conditions. It was estimated that only 1/3 of privately-owned vehicles are needed when using shared AVs to satisfy the personal mobility (Spieser et al., 2014). It is expected that in the future, tens of thousands of AVs instead of private cars will travel on the road to satisfy peoples' daily travel demand in an urban area. Therefore, it is essential to consider the impact of traffic congestion generated by this large number of AVs in the strategic planning of AV fleet size and infrastructures.

Some studies have addressed the route design of ATs with dynamic travel time, which is captured by a function of traffic flows. However, they treat the demand of using ATs fixed, indicating that the influence of time delay on travel demand is neglected. In future modelling, automated taxis cannot be treated as an isolated transport mode anymore. They should be regarded as a part of the urban transport system. The interactions between ATs and other travel modes like the public transport, bikes and walk should be taken into account. Yet few studies have considered the strategic planning of ATs in urban mobility, such as the fleet management, the pricing problem, etc. This research is an extension of our earlier work (Liang et al., 2017) on automated taxi routing problem considering the traffic congestion generated by taxis themselves. However, in that model, the influence caused by demand variation was not included, which means it was assumed that the demand is given.

In this paper, we aim to design an automated taxi (AT) system to provide a seamless transport service between the train station and the city area, which is defined as the first/last mile problem. It considers the impact of traffic congestion on mode split. We establish a shared-use vehicle routing model incorporating mode choice that will decide which clients prefer to take an AT or another competing mode. It assumes that the demand for ATs is elastic depending on its service level considering the competition between automated taxis, bikes and walk. We aim to achieve an equilibrium between these three modes when assigning all passengers to finish their trips.

2. Problem setting

We focus on the first/last mile problem of the train station with considering ATs, bikes and walk as three travel modes for these trips. The AT operators design the system by determining the fleet size

and price rates of ATs, which is based on the potential demand of the AT service. The passengers choose one of these three modes as a travel mode to satisfy their travel demand. The mode choice is based on the utilities of these modes, which is obtained by a logit model. The utilities of bikes and walk are benchmarks and do not change in this model, while the AT's utility is influenced by the price of this service, travel time, etc. Travel time by ATs depends on the traffic flows on road links, which is calculated by a standard traffic assignment model under user equilibrium (UE) or system optimal (SO) flows. Therefore, AT's travel time is linked with the fleet size and the number of users who choose and use ATs, which will feedback in the demand for ATs. In this paper, we aim to find the optimal solution for the fleet size and price rates to maximize the system profit while taking users mode choice and route choice into consideration.

The utility functions of three travel modes embedded in the model which makes it a non-linear programming model. We plan to design a customized gradient procedure to solve this problem(Huang et al., 2018). This method cannot guarantee the global optimality of the solution, but it ensures that the solution quality is improved step by step, until reaching the stopping criteria.

Assumptions:

- The total demand satisfied by ATs, bikes and walk is pre-known.
- Only ATs, bikes and walk are considered as transport modes in this paper.
- ATs are able to move automatically between any OD pairs in the system.
- We use peak time travel demand as the input of the system.
- The ATs only serve travel requests between the train station and the city area. The passenger's requests travelling within the city area are not considered.

3. Expected results

We set the service price and the fleet size of ATs as decision variables. With the objective that the total travel time is minimum, the model will decide the best price rate and fleet size of the AT system. This makes it valuable to explore the demand based automated taxi system optimization. The model is able to do sensitivity analyses on transport demand, which allows the transport planner to conduct demand management of the automated vehicles in the future.

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