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# Social benefit of optimal ride-share transport with given travelers' activity patterns

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**Abstract**

"Sharing economy", including car-sharing and ride-sharing, will change our society and transport in the near future. To effectively introduce ride-sharing service into our society, we need to determine route and schedule of vehicles based on users' activity. We also need to understand how users' activity patterns affect the performance of this sharing service, and we have to evaluate social benefit of introducing ride-sharing service. The objective of this study is to investigate how the ride-sharing service would be successfully operated in the above context. The optimal vehicle routing and scheduling problem which satisfies all the users' activities is formulated as an integer linear programming problem. By using the proposed model, numerical experiments are conducted with different types of activity patterns. Then, efficiency of the optimized ride-sharing service is examined by comparing its performance with those of car-sharing service and fully private-owned car transport. The results show spatial and temporal distribution of users' activity patterns will have great effects on the performance of ride-sharing services.


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*Keywords:* Ride-share transport; Optimal vehicle routing problem; Traveler's activity pattern

## 1. Introduction

"Sharing economy"— to share something with someone, instead of owing goods and services for each—has become one of the key concepts in various fields in our modern society. In terms of car transport, car-sharing and ride-sharing supported by advanced information and communication technologies have begun to be accepted. Car-

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sharing, one part of the vehicle-sharing services, attracts people who want to use a car when they need and people whose cars are mostly in their garage or car park. Car-sharing is effective to reduce total number of cars in our society comparing to owning cars for individuals in the society. Ride-sharing is another concept of sharing on car use. It provides a chance to share available seats on a car for users who have similar itinerary. Ride-sharing has been widely studied and commercial services of ride-sharing have been provided in various areas in the world (Furuhata et al. (2013)). Meanwhile, autonomous driving has a potential to make cars as available transport mode for everyone; private cars are often recognized as useful means of transport for only people who have driving license at the moment. In addition, this technology is expected to be an effective way to solve relocation problem, which has been a matter for car-sharing and ride-sharing. Sharing economy combined with autonomous driving will encourage changing transport dramatically in the future. In a society where both of the sharing transport services are widely diffused, autonomous cars are owned by society and people use those cars accepting sharing a ride. In this society, cars can be recognized as public transport mode that carries people from place to place on time as people requested. To introduce such kind of transport service into our society, it is required to know users' demand, which is highly related to user's activity, and then estimate the minimum number of cars to be introduced and determine the optimum route and schedule of each car.

The driver-rider(s) matching problem has been extensively studied for ride-sharing system. In order to efficiently operate the ride-sharing system, the matching problem has been mostly formulated as an optimization problem similarly to the Dial-A-Ride Problem (Cordeau and Laporte (2007)) with different specific aims and objectives such as maximization of the number of users (Agatz et al. (2012)), maximize the number of matches (Masoud and Jayakrishnan (2015)), and combination of them (Herbawi and Weber (2012)). Di Febbraro et al. (2013) have also formulated the optimization model for driver-rider(s) matching, but their objective is to minimize the difference of desired and real departure and arrival time. Martinez et al. (2015) conducted agent based simulation model for shared taxi system. Regue et al. (2016) proposed Car2Work, shared mobility system mainly for commuter trips, and developed model for it. As travelers who can drive and own a car can play either driver or rider roles in ride-sharing system, Agatz et al. (2011) formulated the maximum weight bipartite matching optimization problem for assigning the driver and rider roles that maximize the system travel distance saving. Similarly, carpooling is one of typical system of ride-sharing among both drivers and users have schedule constrain of their travel. Correia and Viegas (2010) proposed simulation model for carpooling. Regarding the autonomous vehicle, Correia and Arem (2016) proposed multi modal user equilibrium traffic assign model for public transport and cars including fully autonomous vehicle. Fagnant and Kockelman (2015) developed model for shared autonomous vehicle with ride-sharing service based on an agent-based framework.

In the sharing transport, it sometimes occurs that users cannot complete their travel as schedule due to longer detour caused by sharing a ride with other users. To reduce this kind of users, two means are adopted in previous studies; one is to maximize the number of pairs of users and drivers, and another is to minimize the difference between scheduled arrival time and that of model solved. The former method has some users removed from the service and the latter causes users to change their schedule. From the stand point to propose sharing-transport for improving mobility for whole members of society with limited resources, transport mode does not prevent no scheduled activity is desirable. Although the characteristics of the society including spatio-temporal travel demand of the society will have a key issue to a successful ride-sharing services, previous studies on the effects of the society on ride-sharing are still very limited.

The aim of this study is to develop a model of ride-sharing service which optimizes route and schedule for shared vehicles and users which satisfies all users' given activities, and investigates dominant factor to the efficiency of the ride-sharing service by conducting numerical experiments. The major difference between previous models for dial-a-ride or ride-sharing is that in this study all scheduled activities of users are not prevented or changed; no users get out from the service because of failure in matching with ride-sharing partner, thus single-rider in one vehicle is allowed. The experiments further contribute to show efficiency of ride-sharing by comparing the performances of car-sharing, ride-sharing and private transportation. Using the model, the optimal route and schedule can be obtained with transport network and travel demands of users as inputs. The result of numerical calculation contributes to the estimation of the efficiency of the service in advance and designing the service as well.