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ECONOMIC SUSTAINABILITY OF DYNAMIC RIDE-SHARING: A SIMULATION-BASED ANALYSIS

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ABSTRACT

Dynamic ride-sharing enables a vehicle to carry two or more passengers with similar schedules and itineraries on each trip, increasing traffic efficiency and vehicle utilization. Existing studies mainly focus on the environmental sustainability of dynamic ride-sharing, such as quantifying the reduced carbon emissions, while overlooking its economic sustainability. This study aims to analyze the economic sustainability of dynamic ride-sharing based on massive simulations. Specifically, this study first develops an agent-based simulation platform that can simulate large-scale ride-sharing and non-ride-sharing services simultaneously. Then, this study conducts a revealed preference survey to calibrate passengers' price and detour elasticity. Finally, using real-world mobility data from ten cities, this study conducts massive simulations on the developed simulator and compares the average revenue of each vehicle under various scenarios with different discounts and detour ratios. This study finds that even a low discount (e.g., 20%) can decrease the average revenue.

1 INTRODUCTION

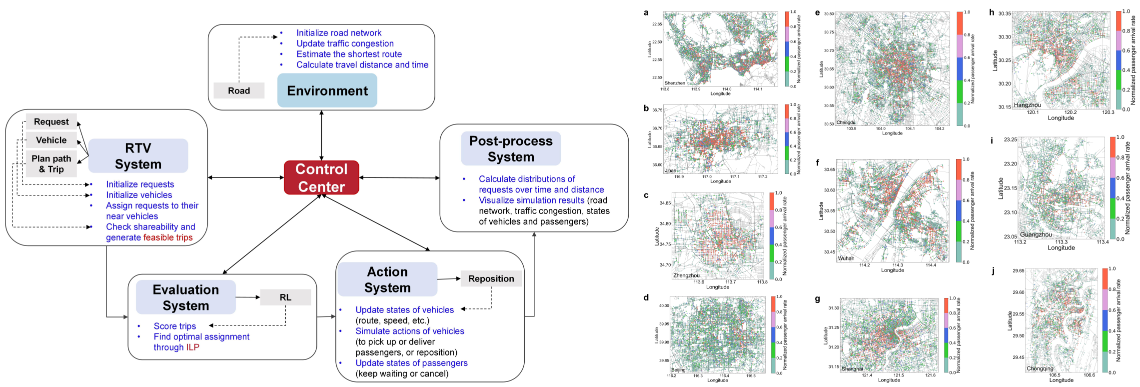
Dynamic ride-sharing systems provide door-to-door services for a few passengers with similar itineraries and schedules and enable them to split the costs. Ride-sharing programs have a high potential to benefit passengers, vehicles, and society, such as saving travel costs, increasing vehicle utilization, alleviating traffic congestion, and reducing carbon emissions. Existing studies mainly focused on the environmental implications of ride-sharing (Chen et al. 2023; Yin et al. 2018; Zhang et al. 2020). This study aims to analyze the economic sustainability of ride-sharing based on numerous simulations using real-world mobility datasets from 10 cities.

2 AGENT-BASED SIMULATOR

The architecture of the simulation platform is shown in Fig. 1. The platform mainly consists of six parts, i.e., control center, environment, RTV system, evaluation system, action system, and post-process system. The control center is designed to integrate all functions, while the environment initializes road networks and updates real-time traffic situations. In the RTV system, each vehicle is regarded as an agent with attributes including the current on-vehicle passengers, the planned route, etc. Agents drive to pick up and deliver their scheduled passengers according to the assignment results of the integer linear programming (ILP) in the evaluation system. Subsequently, agents' movements and speeds, and passengers' states are updated in the action system. Finally, all simulation results are visualized in a post-process system.

3 DATA

The mobility dataset used in this study comes from a Chinese transportation network company (TNC). The dataset records order ID, start and end timestamps, and pick-up and drop-off coordinates of 500,000 transportation trips from November 2015 to November 2016 in ten cities of China, i.e., Beijing, Chengdu, Chongqing, Guangzhou, Hangzhou, Jinan, Shanghai, Shenzhen, Wuhan, and Zhengzhou. The dataset is



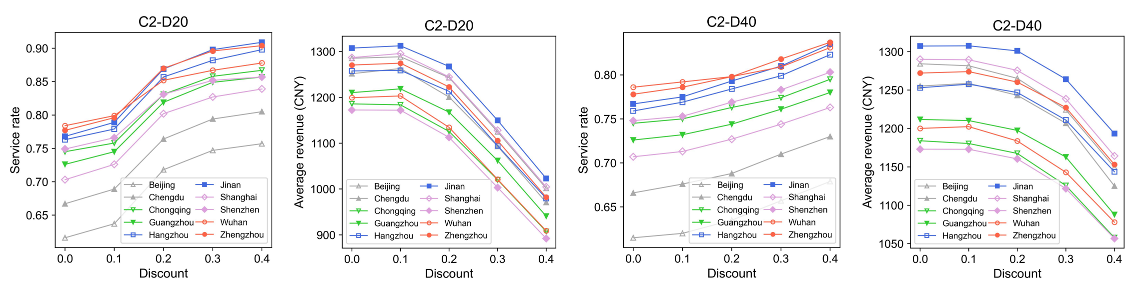
(a) Simulator architecture (b) Mobility data

Figure 1: Architecture of the developed agent-based simulation platform (a) and mobility data (b).

randomly sampled from the company's database, and the spatial and temporal distributions of the trips are the same as the original ones. Fig. 1 (b) illustrates the road networks and spatial distributions of transportation requests in ten cities.

4 EXPERIMENTS AND RESULTS

This study conducts experiments in ten cities with various discounts. This study considers two scenarios: the vehicle capacity of two passengers with the maximum 20% (C2-D20) and 40% detour ratio (C2-D40), respectively. As shown in Fig. 2, the experimental results demonstrate that a low discount (e.g., 20%) can significantly increase the average service rate, while decreasing the average revenue of vehicles compared with non-ride-sharing (i.e., without any discounts).



(a) Service rate (b) Average revenue (c) Service rate (d) Average revenue

Figure 2: Experimental results on service rates and average revenue.

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