Modeling e-hailing and car-pooling services in a coupled morning-evening commute framework

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Project Objective

The objective of this research is to understand the impact on traffic congestion and travelers' behavior when integrating the new shared mobility services to the coupled morning and evening commute problem.

Problem Statement

The emerging shared mobility services, such as e-hailing services provided by Uber, Lyft, Didi, Grab, and Ola or rideshare services enabled by SCOOP, WAZE, Zipcar, and Turo provide more travel mode choices for commuters in both morning and evening commutes. For example, a person can combine a rideshare service in the morning, but use an e-hailing service for the evening return trip to reduce the pairing cost, and provide more flexibility in evening trips There is a clear need to not only understand the nature and effect of these new shared mobility transportation services better, but also to understand, model, and study the interactions between the various modes of transportation, and integrate them in a unified transportation planning model that includes both morning and evening commute trips.

Research Methodology

In this research project, we propose a general equilibrium modeling framework, which is capable of capturing the complex interactions between solo-driving, rideshare, and e-hailing, and allows travelers to switch between different transportation modes in a coupled morning-evening commute. Formulated as a mixed complementarity problem, the main constraints of the general equilibrium model include user equilibrium conditions, flow conservation equations, rideshare capacity and a minimum fare threshold.

Then we prove that an equilibrium exists for the proposed model. Also, we show that when the model reaches an equilibrium, (1) the morning (evening) commute also reaches an equilibrium; (2) if travelers' mode choice is fixed, the morning (evening) commute is equivalent to a traditional traffic equilibrium problem; (3) travelers are rational to mode choice, which means that no traveler will choose a more expensive travel mode combination.

Results

Solved using the PATH solver, the proposed model is validated using the well-studied Sioux-Falls network. The results show that the proposed coupled morning-evening model is effective in capturing the mode switches between morning and evening, which eventually leads to better system performance (e.g., number of drivers, total VMT) compared with a decoupled morning (evening) commute model. For example, as can be seen in Table 1 below in the Sioux-Falls network, the coupled model produces 24.2% fewer drivers and 8.4% less VMT in the system compared with the decoupled model when the inconvenience cost due to ridesharing is higher during the evening commute than in the morning commute. This is due to the fact that the coupled model can capture the behavior of travelers' capability to switch to e-hailing in the evening commute when ridesharing in the morning commute. A decoupled model cannot capture this effect and most likely will predict that the traveler will drive to work for the given parameter settings.

Table 1. Comparisons between coupled model and decoupled model in the Sioux-Falls network.

	Coupled Model	Decoupled Model
VMT (am)	29862	37102
VMT (pm)	38576	37102
VMT (total)	68438	74204
# Drivers	1357	1686
# Rideshare Passengers (am)	1643	1314
# Rideshare Passengers (pm)	1247	1314
# E-hailing Passengers (am)	0	0
# E-hailing Passengers (pm)	396	0