# Characterization of traffic dynamics in non-equilibrium ride-hailing mobility networks: A mesoscopic approach

**Abstract** Ride-hailing services have already become an indispensable component in urban mobility systems in many cities overall the world owing to its effective online mating between idle vehicles and waiting passengers using real-time information. Characterizing traffic dynamics accurately in ride-hailing mobility networks is crucial to support the short-term operational decision-making of platforms, such as fleet size management and optimal matching design. Therefore, in this paper, we develop a multi-class cell transmission model with a detail representation of the actual network topology to characterize the spatio-temporal traffic dynamics in non-equilibrium ride-hailing mobility networks. Using CTM as a tool for propagating traffic flows within the spatio-temporal domain effectively, we embed the core process, namely, matching between passengers and vehicles, and decision-making behaviors of individuals into the framework. While being an integrated model, it boasts high spatial and temporal resolution. At the individual level, it can capture the entire travel chain of passengers, including issuing orders, matching with ride-hailing vehicles, waiting to be picked up, and traveling to their designated destinations. Meanwhile, it can also describe the decision-making behaviors of drivers, including how to cruise for idle ride-hailing vehicles, how to approach the designated destinations for reserved or occupied ride-hailing vehicles. At the network level, it can depict the real-time distributions of traffic flows for both ride-hailing and private vehicles throughout the ride-hailing mobility network. Then, we use empirical data, including road network density data from annual report, and ride-hailing order and trajectory data from ride-hailing platforms, to calibrate and verify the proposed simulation model. Following up is a series of parameter sensitivity analysis based on simulation experiments to investigate how important factors, such as matching strategies, fleet size and background traffic, affect the operational performance of the ride-hailing service in a multi look. Our findings indicate that increasing the fleet size benefits passengers by reducing trip time consumption but harms drivers by intensifying competition. On the other hand, increasing maximum matching radius always has a positive effect on both passengers and drivers. Moreover, background traffic implements a non-linear influence on the operational performance of ride-hailing services: there exists a threshold of background traffic flows, beyond which the operational performance of the ride-hailing mobility network undergoes a significant decline, ultimately resulting in a collapse. Our presented simulation model, which directly addresses characterization of traffic dynamics in large-scale and none-equilibrium ride-hailing mobility networks, offers valuable insights for developing efficient management strategies to alleviate urban congestion and promote sustainable mobility.

***Keywords:*** ride-hailing mobility network; traffic dynamics; spatio-temporal characterization; cell transmission model