A Comprehensive Framework for Modelling Taxi Driver Behavior and Centralized Taxi Operation in SimMobility

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ABSTRACT

A majority of past research efforts have been devoted to modelling and optimizing the taxi fleet operations. Much less attention has been made to the decentralized nature of taxi systems [Martinez et al., 2015]. In the context of multi-agent simulation technology, although some facets of taxi operations —such as street pick-ups, taxi queueing, and taxi dispatch—have been modelled, there is no platform that captures the dynamics between decentralized driver's decision-making and the centralized dispatching decision making. Such decentralized perspective is critical in modeling taxi fleets because taxi drivers can only be incentivized or coordinated but not centrally controlled [Cheng and Nguyen, 2011].

This paper aims to fill this gap by introducing a comprehensive framework that models various facets of taxi driver's behavior along with a taxi dispatching system within SimMobility Mid-Term simulator. SimMobility Mid-Term simulator is an agent based, fully econometric, and activity-based demand model integrated with a dynamic traffic assignment model [Lu et al., 2015]. It is capable of simulating daily travel at both the household and individual levels. The traffic dynamics are simulated using a mesoscopic simulator. SimMobility Mid-Term simulator is part of a much larger simulation platform that also contains long term and short term models [Adnan et al., 2016].

Simulating taxis is extremely challenging because of complex interactions between independent taxi drivers, the central controller, and travelers decision processes. To facilitate the study of such a complex and partially decentralized system, we propose an event-based modelling framework. In this framework, the taxi-driver, the controller, and the traveler are represented as separate decision agents. The taxi driver can exist in six states: booked, occupied, queuing, cruising, out-of-service and direct-to-destination. The events that can trigger change in state include pick up, drop off, cruising for too long, queueing for too long, joining a queue, controller request reception, and controller information reception. The specific behaviors of the taxi drivers are modelled within a discrete-choice framework. Specifically, the following decisions will be modeled: (i) *Taxi Driver Decision*, which predicts the probability of a taxi driver to cruise or not to cruise; (ii) *Taxi Stand Choice*, which estimates the probability of a taxi driver to choose a specific taxi stand among taxi stands stations scattered around the network; (iii) *Destination Choice*, which estimates the probability of a taxi driver to choose a specific operation destination among all possible destinations; (iv) *Route Choice*, which estimates the probability of a taxi driver to choose a specific route while she is cruising and her destination is set in advance; and (v) *Compliance/Acceptance Choice*, which estimates the probability of a taxi driver to change her/his initial choices according to the information sent

by the controller regarding a specific destination where the demand for taxis there is high and her/his presence is requested.

On the other hand, the controller will process traveler's service requests and assign the travelers to taxis after considering taxi driver's choices and service costs. The costs include the overall time/distance required to dispatch, pick-up, and drop-off to client's destination, the occupancy of the vehicle, and the demand generation potential of nearby hotspots. The controller captures the taxi service status, updated taxi locations, and movement through real-time communication with supply simulator over the simulation time, to react to the incoming ride and re-directing request accordingly. In this paper we also present the design features of the proposed controller that will allow us to extend the simulation of the operations of multiple on-demand services—Uber, Lyft—in conjunction.

We integrate this taxi framework to the calibrated SimMobility model of Singapore [Lu et al, 2015; Adnan et al., 2016]. In the estimation of SimMobility models, data from multiple sources are used. The variables related to network performance and level of service comes from network skims and GPS data. The GPS-enabled travel time data along with network skims, after application of data fusion techniques, allows generation of more realistic travel time data for the whole day. Land use data, which forms the basis of attraction variables for destination choice models is zonal based. The population was synthesized from household interview travel survey data (HITS 2012). The taxi demand was estimated by the Mid-Term activity-based pre-day model, which generates the day activity schedules for each passenger. The traveler can independently make decision according to controller's suggestions. The suggested model can reflect strategic changes made by the driver such as the decision to stop cruising and move to a known location, the decision to stop queuing and start cruising, the decision to accept booking or not, the decision to move towards a high demand spot according to controller information, etc. Real-world operational data sets for Singapore are used, which allows us to construct a highly realistic simulation environment. For the estimation of each of the proposed taxi decision dimensions, a huge GPS dataset collected from a major taxi fleet operator in 2010 was used, containing position and service status data. This proposed framework will allow researchers and policy makers to study and evaluate potential mechanisms, policies, and new services for improving taxi services.

The current work has three major contributions. (1) Development of a comprehensive event-based framework that addresses complex behaviors and interactions of taxi drivers, fleet controllers, and travelers. (2) Incorporation of the proposed framework within a highly realistic agent-based simulation platform, SimMobility. (3) Evaluation of the suggested framework against real-world data. (4) Evaluation of taxi driver's strategies, policies, and the dispatch mechanisms of the complete taxi eco-system.

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