DISSERTATION PROPOSAL

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"Operational Analysis of Autonomous Vehicles"

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AVs are expected to play a determinant role in shaping the future of mobility. In this thesis, I investigate the potential effects of Autonomous vehicles (AVs) on various aspects of transportation systems. In the first chapter, I characterize the impact of AVs on highway congestion. In the second chapter, I investigate a parking problem in a central business district for morning commuters who own AVs. In the third chapter, I aim to study how blockchain technology can be used to manage a fleet of AVs, focusing on the trade-off between operational efficiency and system robustness.

In the first chapter, I investigate the effects of AVs on highway congestion. AVs have the potential to significantly reduce highway congestion, since they can maintain smaller inter-vehicle gaps and travel together in larger platoons than human-driven vehicles (HVs). Various policies have been proposed to regulate AVs, yet no in-depth comparison of these policies exists. To address this shortcoming, I develop a queueing model for a multi-lane highway, and analyze two policies: the designated-lane policy ("D policy") under which one lane is designated to AVs, and the integrated policy ("I policy") under which AVs travel together with HVs in all lanes. I use a Markovian arrival process to connect the service rate to inter-vehicle gaps and congestion, and measure the performance using mean travel time and throughput. My analysis shows that although the I policy performs at least as well as a benchmark case with no AVs, the D policy outperforms the benchmark only when the highway is heavily congested and AVs constitute the majority of vehicles; in such a case this policy may outperform the I policy only in terms of throughput. These findings caution against recent industry and government proposals that the D policy should be employed at the beginning of the mass appearance of AVs. Finally, I calibrate the model to data, and show that for highly congested highways, a moderate number of AVs can make substantial improvement (e.g., 22% AVs can improve throughput by 30%), and when all vehicles are AVs, throughput can be increased over 400%.

In the second chapter, I investigate the potential of AVs to solve the parking problem that commuters face when traveling to a central business district for work. I characterize the user equilibrium (UE) for commuters by developing a continuous-time traffic model that takes into account parking fees and traffic congestion as the main economic deterrents to driving. In this model, commuters decide their departure time as well as their parking location between the central and external areas. I show that there exist two forms of UE: UE1 under which all commuters choose the external parking area, and UE2 under which commuters are divided between the central and external areas. I demonstrate that, since congestion cost is lower when AVs are divided between two parking areas than that when all AVs choose the same parking location, a commuter incurs a lower total cost under UE2 than he does under UE1. Therefore, UE2 is pareto-optimal. I further consider the case in which a social planner determines the departure time and parking location of all commuters that minimize the aggregate cost of all commuters. I aim to find conditions under which the aggregate cost of all commuters under UE is equal to that of the social planner case.

In the third chapter, I aim to study the use of blockchain technology in managing the dispatch operation for a fleet of AVs. The standard approach to managing a fleet of AVs would involve a central operator to coordinate the dispatch of vehicles to satisfy demand in a manner similar to ride-sharing platforms. While this approach may be appropriate for managing a fleet of cars with human drivers, it may be unsuited to manage a fleet of AVs due to the risk of a centralized system failure resulting in the loss of fleet control. One way to avoid such catastrophe is to use a robust decentralized system to operate the AV fleet so that no single point of failure would lead to a global system failure. Blockchain technology provides a secure means for decentralized system management by enabling peer-to-peer communication and maintaining multiple records of the system state. Although this blockchain system is robust against global system failure, it results in lower operational efficiency and requires greater computational power due to its decentralized nature. My goal is to explore the efficient frontier of the robustness-performance trade-off when blockchain technology is used to manage a fleet of AVs.