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Safety-Aware Traffic Assignment in Mixed AV-HV Networks: A Multi-Player Perspective

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Abstract

This study proposes a safety-based multi-criteria traffic assignment problem (SMM-TAP) model for mixed traffic networks consisting of human-driven vehicles (HVs) and autonomous vehicles (AVs). The model captures route choice behavior by jointly considering travel time and both the reliability and variability of traffic safety. Safety is modeled through the mean and variance of crash risks, which differ across intersections and road segments. At intersections, crash risk distributions depend on the AV proportion and turning movements; on road segments, they are determined by traffic speeds derived from the mixed traffic composition. To reflect user heterogeneity in AV usage, the model adopts a multi-player framework: individual travelers act as user equilibrium (UE) players, transportation network companies follow Cournot-Nash (CN) strategies, and transportation planners pursue system optimal (SO) outcomes. HVs are assumed to follow a stochastic user equilibrium (SUE) principle. The problem is formulated as a general variational inequality (VI), with CN and SO route choices derived from marginal utility computations. Numerical experiments are conducted on the Nguyen Dupuis and Sioux Falls networks. The SMM-TAP model is benchmarked against a conventional mixed traffic assignment problem (M-TAP) that considers travel time only. Results demonstrate that SMM-TAP effectively captures the spatial distribution of mixed traffic under various scenarios and better reflects safety-influenced route choices. Sensitivity analyses on AV penetration rates and time-safety trade-offs further illustrate how total travel cost, travel time, and safety-related costs evolve with increasing AV adoption, highlighting the model's potential for supporting safer and more efficient traffic management in mixed autonomy environments.

Keywords
Traffic Safety Modeling, Mixed Traffic Flows, Traffic Network Equilibrium, Intersection Turning Risk.