Connected Vehicles: An Integrated Analysis of Safety, Mobility and Environmental Sustainability

Connected Vehicles (CVs) have been exploited as a source of traffic data in some transportation research areas from traffic state monitoring to transportation management and control strategies, due to the low cost, wide coverage, and high accuracy. CV technology also enables a variety of CV-based applications which present an opportunity to provide vehicles and drivers with situational awareness and improve upon the short-sighted behaviors of conventional vehicles. Increasing efforts in the development and deployment of CV-enabled applications are ongoing to improve traffic safety, mobility, environmental sustainability, efficiency, and driving comfort. Among them, Safety, Mobility, and Environmental sustainability (SME) are the three cornerstones of performance measures when evaluating the benefits/impacts of Connected and/or Automated (CAV)-based applications. However, very few studies evaluate the three performance measures at the same time. In this dissertation, an integrated analysis of the SME tradeoffs and co-benefits of some CAV-based applications has been conducted under a proposed Measure of Effectiveness (MOE) analysis framework. Under this analysis framework, a series of innovative CV-based mobility-focused applications have also been proposed, to achieve dynamic application management under various traffic conditions.

All of the proposed CV-based applications, i.e., Lane Speed Monitoring (LSM), Optimal Lane Selection (OLS) application, and Cooperative Smart Lane Selection (CSLS) application, are mainly designed to improve mobility of the individual user and the traffic network. Specifically, LSM guides the vehicle driver to the fastest lane by utilizing short-range downstream vehicle information, helping the vehicle driver achieve a faster travel speed. OLS adopts longer-range connectivity and guides the application-equipped vehicle driver to go through a micro-route (i.e., an optimal lane sequence) to reduce the travel time of each individual application-equipped vehicle, solved by the spatial-temporal model and the dynamic programming method. The CSLS application is designed from the cooperative perspective which can be regarded as an evolved version of LSM, to increase mobility for the overall traffic system. The effectiveness of these CV-based applications have been tested and validated using microscopic traffic simulation tools.

Furthermore, an interdisciplinary concept from the information technology to the transportation field has been proposed, i.e., the Speed Variation-based Entropy (SVE). SVE and SVE distribution provide alternative MOEs for CV applications evaluation in a more holistic way, which otherwise needs to be jointly reflected and evaluated by several conventional MOEs. A variety of CV applications have been tested using SVE/SVE distribution in combination with the three conventional MOEs under various scenarios. Results show that SVE has a strong correlation with conventional MOEs especially under freeway scenarios.