UCR College of Engineering- Center for Environmental Research & Technology

Traffic Abnormality Predication Application for Connected Automated Vehicles (CAVs) in a Mixed Traffic Environment

Fei Ye (fye001@ucr.edu), Guoyuan Wu (gywu@cert.ucr.edu), Kanok Boriboonsomsin (kanok@cert.ucr.edu), Matthew J. Barth (barth@ece.ucr.edu), Samer Rajab (SRajab@hra.com) and Sue Bai (SBai@hra.com)

Introduction

The emergence of Connected Vehicle (CV) technologies enables a number of onboard advanced driver assistance systems (ADAS) applications to enhance vehicle's safety, mobility, and environmental sustainability. A rapid growth of occurrence of traffic accidents or hazards on road leads to huge time cost and economic loss. By crowdsourcing traffic data (e.g. vehicle position, speed, heading, etc.) through vehicle-to-vehicle (V2V) communication, upcoming hazards at lane level can be detected with reasonable lead time. The work described in this paper aimed to develop and simulate an innovative V2V-based application, called Lane Hazard Prediction (LHP), to perform lane-level hazard prediction, and a corresponding driver response model. The purpose is to improve the mobility and safety of both individual users and the entire traffic system. LHP identifies the position of a downstream lane-level hazard (within seconds after it occurs) based on a spatial and temporal data mining and machine learning techniques. It then guides the LHP-equipped vehicles with recommended lateral maneuvers to avoid traffic jams resulting from the hazards. Simulation results demonstrate reliable hazard prediction, even when the V2V penetration rate is as low as 10%. A comprehensive evaluation of the developed LHP application from the perspectives of both user benefits and system benefits has been conducted over different CV penetration rates and traffic congestion levels. The evaluation of the proposed LHP system is conducted using a well-calibrated real world network Freeway I-270N, Columbus, OH in a microscopic traffic simulation software called VISSIM. The results demonstrate that the proposed LHP application can significantly improve both the safety and mobility performance of the equipped vehicles without compromising the mobility and safety performance of the overall traffic.

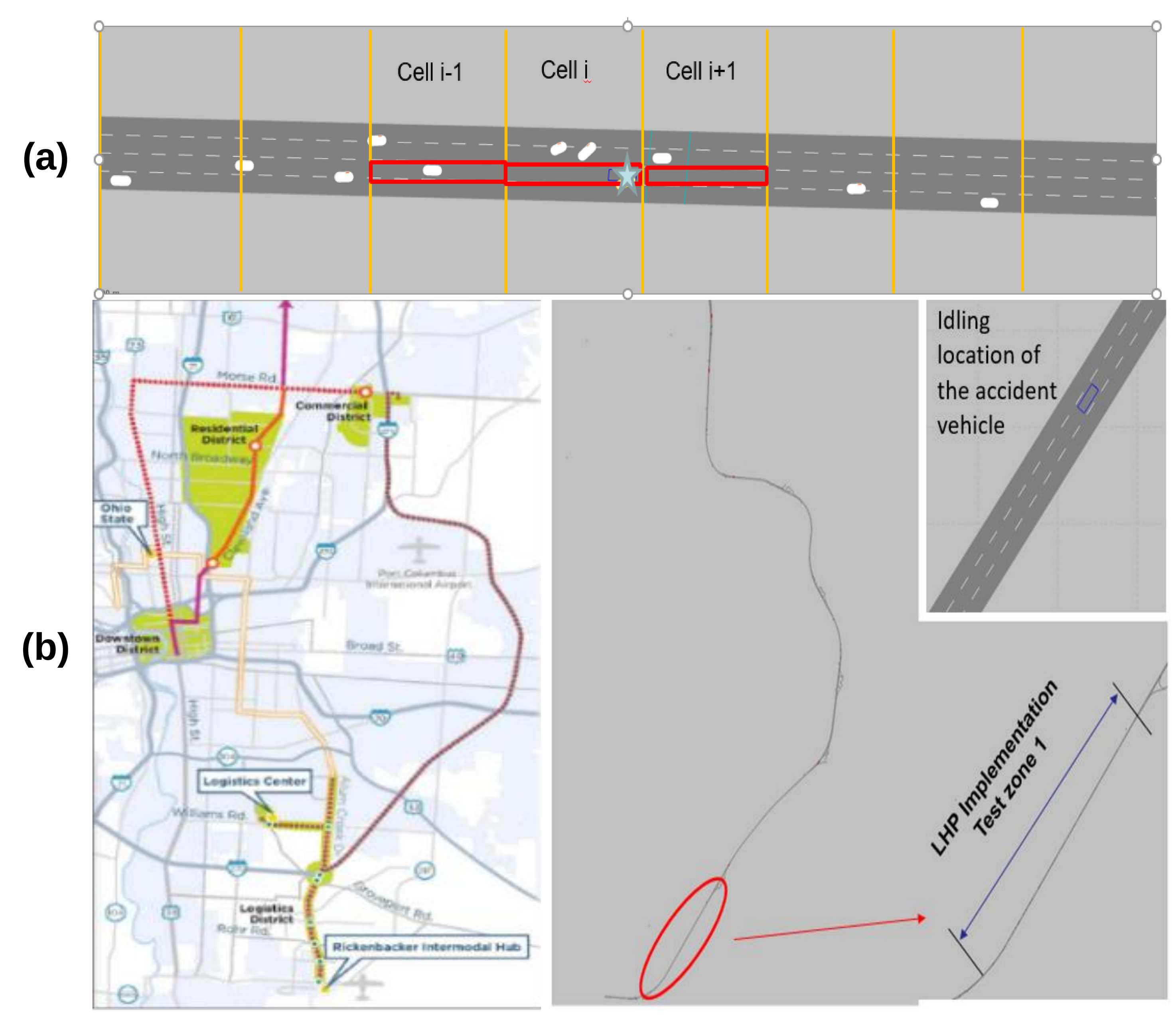


Figure 1. (a) Illustration of spatial partitioned cell on a network segment; (b) Road network of I-270N in real world and VISSIM

Methodology

To perform lane-level hazard prediction, the traffic network was partitioned into spatial lane-level cell segments. Data crowdsourcing on lane-level longitudinal segment cells, performing integration over multiple time steps. For each cell (i,j) in the traffic network (i represents the longitudinal segment, and j indicates the lane number), measurements were considered from the ego-cell as well as its adjacent cells in both the upstream and downstream segments, as shown in ***Figure 1a***. The real-world network used in this study was a calibrated 17-mile stretch of I-270 North in Ohio, with seven on-ramp/off-ramp pairs (see ***Figure 1b***).

The framework of the proposed LHP application is shown in ***Figure 2***. The developed LHP application contains four major modules. The lane hazard prediction

We identified eight key features that are deemed to be representative and critical for detecting a potential downstream hazard or abnormality in traffic. The binary logistic regression-based LHP model is described in Equation (1).

$$logit(P_{ij}) = ln\left(\frac{P_{ij}}{1-P_{ij}}\right)$$
$$= \beta_0 + \beta_1 \times \overline{V}_{ij} + \beta_2 \times \frac{\overline{V}_{ij}}{\overline{V}_i} + \beta_3 \times \frac{\overline{V}_{ij}}{\overline{V}_{i-1}} + \beta_4 \times \frac{\overline{V}_{ij}}{\overline{V}_{i+1}} + \beta_5 \times \frac{m_1}{m} + \beta_6 \times \frac{m_2+m_3}{m} + \beta_7 \times \frac{m_4+m_5}{m} + \beta_8 \times \sum_{i=1}^{n} \frac{m_i}{m} log\left(\frac{m_i}{m}\right) \quad (1)$$

Therefore, the probability of a hazard in cell (i, j) can be obtained by

$$P_{ij} = \frac{1}{1+\exp(-\text{logit}(P_{ij}))} \quad (2)$$

Based on the LHP results, lane recommendation module suggests a lane change out of the hazard lane for LHP-equipped vehicles. Alternatively, it suggests that the vehicle keep moving in the current, non-hazard lane when approaching the hazard location to avoid joining the associated queue behind it.

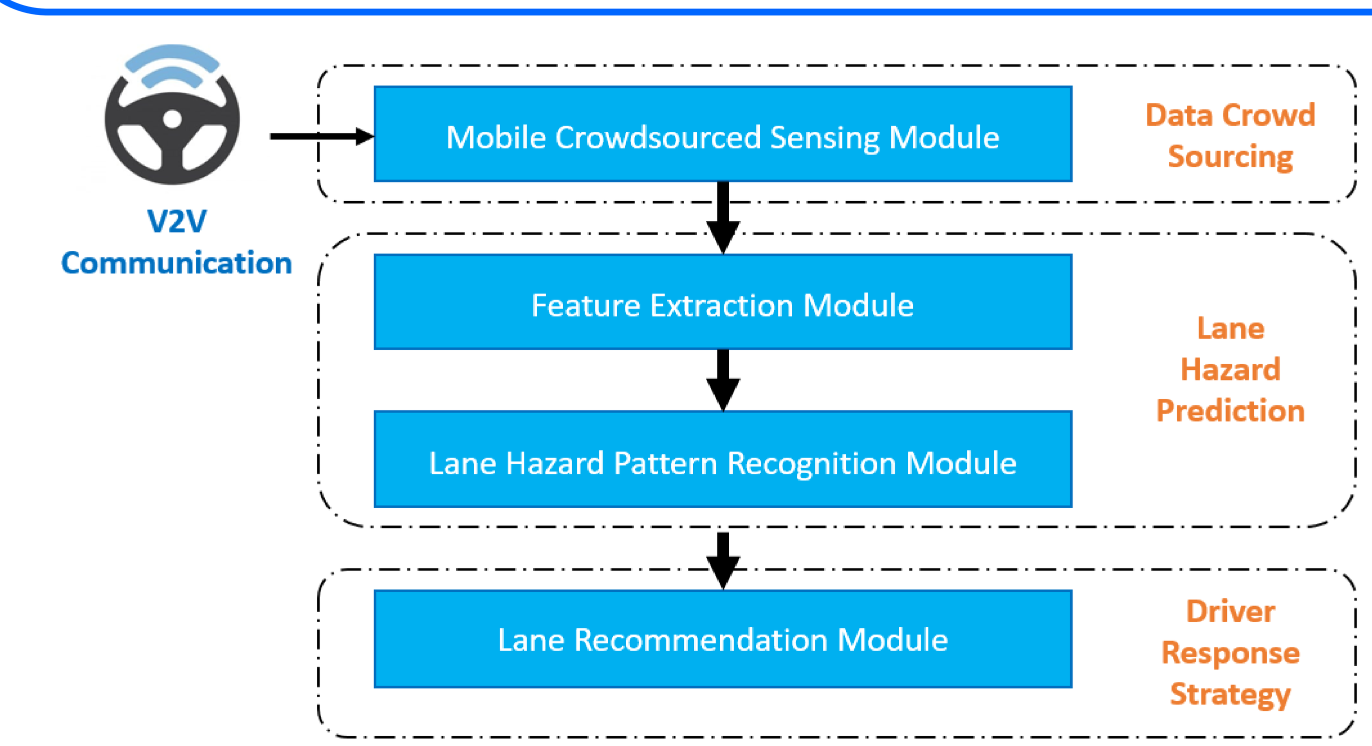


Figure 2. Results of forecasting the position and time vehicles joining the queue

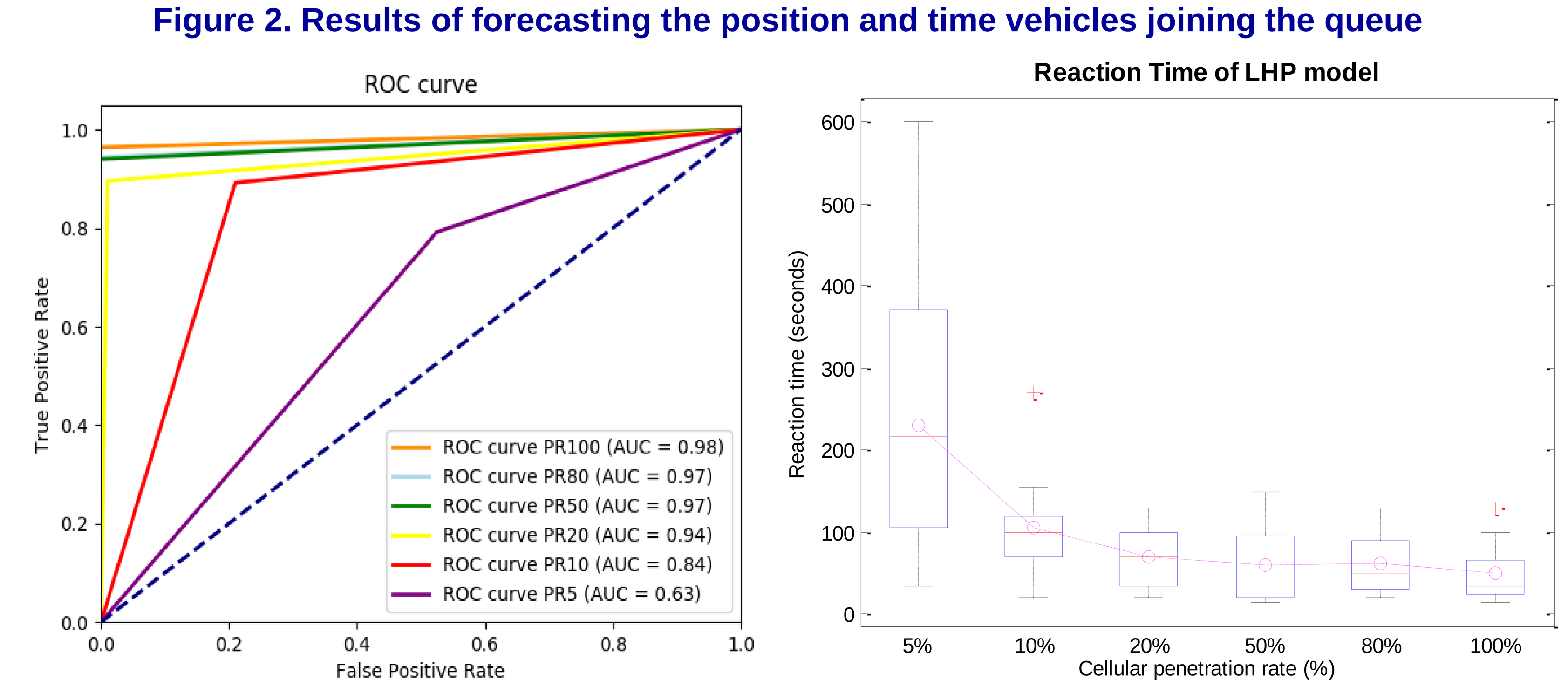
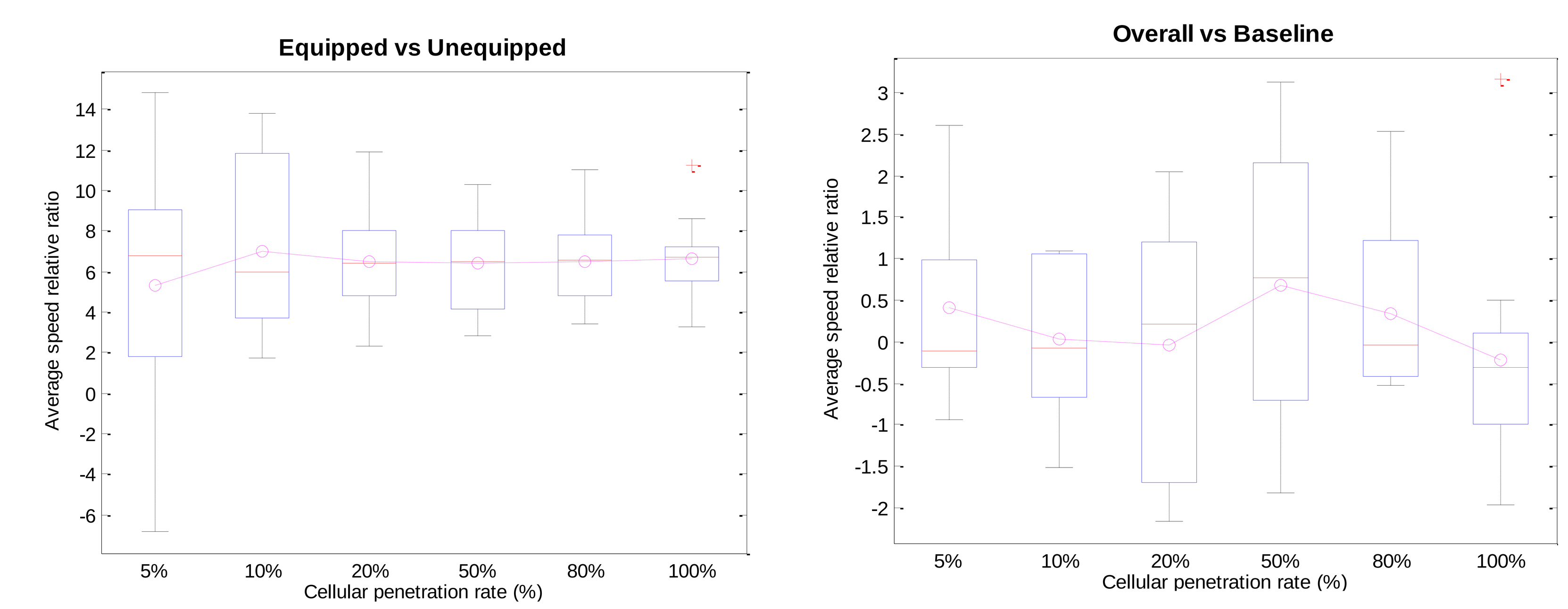
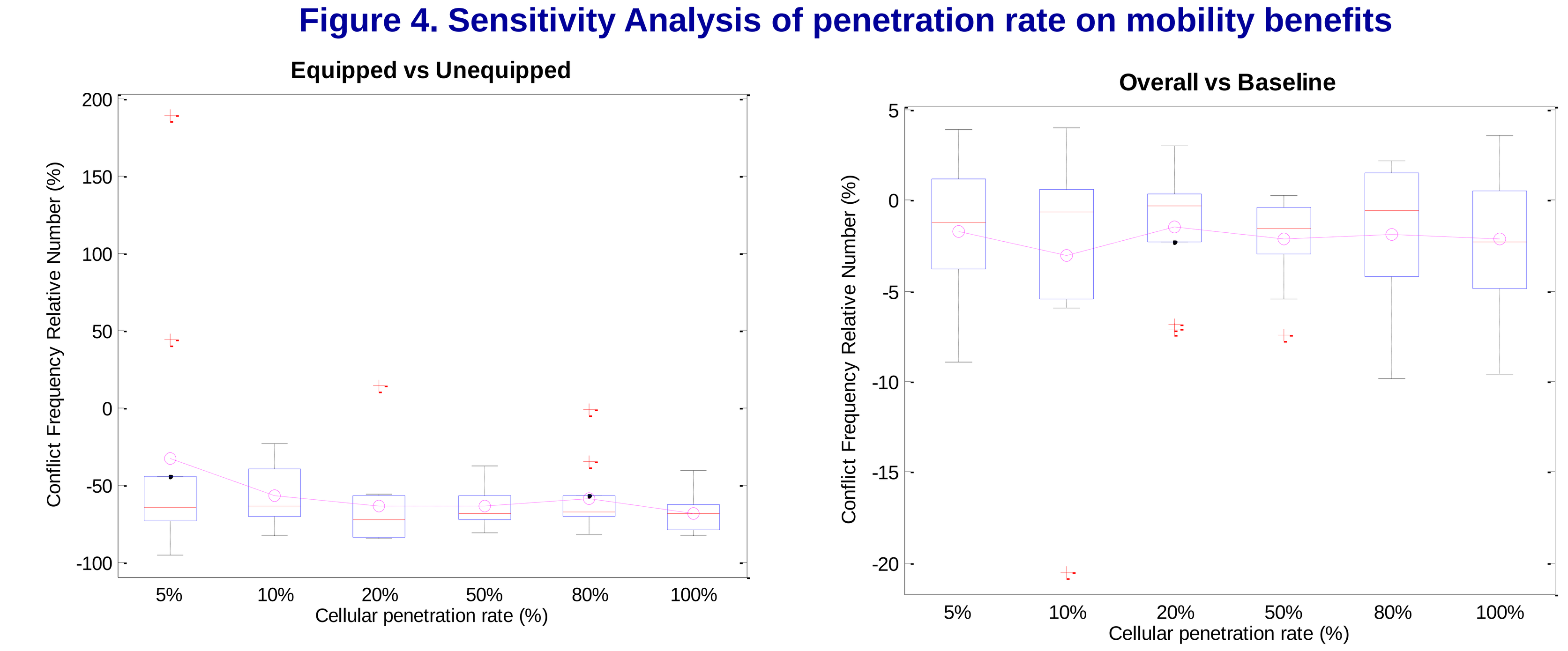


Figure 3. Sensitivity analysis of prediction accuracy and efficiency of LHP under different penetration rates



(a) User benefits (b) System benefits

Figure 4. Sensitivity Analysis of penetration rate on mobility benefits



(a) User benefits (b) System benefits

Figure 5. Sensitivity Analysis of penetration rate on safety benefits

Results and Discussion

- For prediction accuracy, with 100% penetration rate of connected vehicles, the LHP algorithm provided the best performance with **0.98** AUC. (see ***Figure 3***)
- For the application efficiency, the average reaction time of LHP was less than **60 seconds** across the penetration rates between 20% and 100% (see ***Figure 3***).
- The average speed improvements for LHP-equipped vehicles (up to **7%**) were witnessed across all penetration rates. (see ***Figure 4a***)
- Overall, the applied LHP model had negligible effects on the system-level mobility, regardless of the penetration rates. (see ***Figure 4b***)
- Significant user benefits in terms of safety could be achieved across all simulated penetration rates. The average conflict frequency difference was decreased by a factor of **-32.8% ~ -68.1%** for LHP-equipped vehicles (see ***Figure 5a***)
- As indicated in ***Figure 5b***, positive effects on system benefits in terms of safety were also witnessed across all penetration rate levels. The average conflict frequency ratio varied between **-1.4% and -3.0%.**
- Results demonstrate that LHP-equipped vehicles may gain significant mobility and safety benefits without compromising the mobility and safety performance of the overall traffic.
- An attractive feature of the proposed LHP application is that accurate prediction within seconds and noticeable benefits in safety and mobility can be achieved, even under a relatively low V2V penetration rate.

Acknowledgement

This research was funded by Honda R&D Americas, Inc. The contents of this study reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views of Honda R&D Americas, Inc.