It can be expected that connected and automated vehicles (CAVs) and human-driven vehicles (HVs) will co-exist on the transportation network in a long period. Hence, to support many traffic operation tasks, it is critical to develop a reliable traffic state estimation model under the CAHV-mixed environment. One of the most challenging issues in modeling traffic is to capture the traffic flow characteristics of a mixed traffic environment. To address this issue, this study introduces an extended macroscopic traffic flow model which models CAVs and HVs in dedicated groups.

### METHODS

The sensitivity analysis shows EKF with the proposed model has RMSPE lower than 17% regarding the predicted flow and speed. The proposed method shows stable in predicting the traffic state.

This study introduces an extended macroscopic traffic flow model which models CAVs and HVs in dedicated groups. Assuming CAVs are operated with optimal speed guidance, the proposed model captures the interaction between CAV and HV. A new set of key factors are introduced to represent the acceleration and deceleration behavior of HVs due to following CAVs in the mixed traffic stream. To contend with the uncertainty in drivers’ behaviors, this study further adopts the Extended Kalman Filter (EKF) to enhance the estimation on each segment. Numerical cases on a freeway segment involving CAV speed control are tested to evaluate the proposed model. The results show that:

(a) the proposed model can capture the CAV impacts and estimate the mixed traffic states accurately, and

(b) EKF can greatly improve the estimation accuracy contending simulated noise sensors. The sensitivity analysis shows the proposed model is more robust than the conventional method on various CAV penetration rates ranged from 5% to 70%.

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**RESULTS/DISCUSSION**

**Scenario configuration**

**Figure 2** The network representation of the studied case

**Figure 3** Arrival flows of the freeway segment

The detectors on the boundary of Segment 4 and Segment 5 collect the flow and mean speed of both CAVs and HVs vehicles. These data are transmitted to CAVs for optimizing the guided speed. In the base case, the penetration rate of CAVs is set to 20%.

**Table 1** Flow errors of the proposed model with EKF

**Table 2** Speed errors of model prediction with EKF

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**INTRODUCTION**

The availability of the observed traffic flow and speed of HVs is limited by the stationary detector, which is highlighted in blue in Figure 1. To obtain a reliable traffic flow estimation, this study further adopts the extended Kalman filter (EKF) for improving the estimation accuracy. EKF is an optimal state estimator applied to dynamic systems that involve random noise (e.g., sensor errors). It takes a limited amount of noised real-time measurements for correcting the prior estimates.

**Figure 1** Traffic state estimation with extended Kalman filter

**Figure 4** Speed comparison between the ground-truth, EKF, and non-EKF

**Figure 5** Flow comparison between ground-truth, EKF, and non-EKF

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**CONCLUSIONS**