

# Development of a Mixed Traffic Simulation Environment with Heavy Vehicles Incorporating a Merging Decision Model Based on Empirical Trajectories.

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Evaluating automated vehicle merging behavior in mixed traffic requires advanced traffic simulation. Conventional microscopic traffic simulators focus primarily on network-level traffic flow, making them insufficient for reproducing complex merging interactions and driver decision-making. This study addresses the trade-off between reproducing steady-state car-following behavior and complex merging interactions by proposing a separated modeling framework. By incorporating an empirical trajectory-based decision model, we construct a high-precision simulation environment for heavy-vehicle mixed traffic flows.

To overcome the trade-off, the highway network was separated into two modeling scopes consisting of overall area driving and merging decision-making. The target site was the Higashi-Ikebukuro Interchange on the Metropolitan Expressway No. 5, characterized by a short acceleration lane. High-precision trajectory data from the SAKURA Project collected at this site were preprocessed to extract non-congested merging scenes. As shown in Fig. 1, the merging decision framework integrated into Vissim consists of two sequential models. First, relative spatial-temporal features including speed, acceleration, relative distance, and remaining distance to the merge point were defined to classify merging scenarios into seven distinct scene groups using g-means clustering. Second, vehicles were classified by length into standard and heavy vehicles to construct merging behavior selection models. Machine learning classifiers, including vehicle-type-specific decision trees, scene-group-combined decision trees, vehicle-integrated decision trees, and k-nearest neighbors, were evaluated to predict probabilistic action choices, with optimal models selected based on F1-scores. Consequently, vehicle-type-specific models were selected for all standard vehicle scenes, while the integrated or combined models were adaptively adopted for heavy vehicles to successfully overcome limited data availability.

The decision models were implemented in Vissim, and the upstream road model was extended as a flat, straight road to isolate shockwave propagation from road-geometry effects. A dynamic switching mechanism between free-flow and car-following states with a threshold at 2.8 seconds time headway was introduced to suppress unnatural vehicle clustering and prevent artificial bottlenecking. Traffic flows were configured across four saturation levels with corresponding heavy vehicle ratios and detailed vehicle body classifications. Validation against empirical data demonstrated high reproducibility across both macro and micro indicators. Speed and time headway distributions achieved overlap coefficients exceeding 80% to 90% across most conditions. The distribution of scene groups in the simulation achieved an 87.6% overlap coefficient with empirical data. Overlapping coefficients of action choices exceeded 80% for standard-vehicle interactions and mixed standard-heavy vehicle interactions, while lower coefficients of approximately 60% in heavy-heavy interactions were attributed to limited empirical samples.

The proposed simulation framework based on the separated modeling approach successfully overcomes the trade-off between steady-state driving and merging interactions, establishing a reliable evaluation platform for automated merging systems in heavy-vehicle mixed traffic. In future work, this high-precision platform will be utilized to design and evaluate advanced cooperative driving automation systems, including infrastructure-to-vehicle (I2V) and vehicle-to-vehicle (V2V) cooperative merging support.

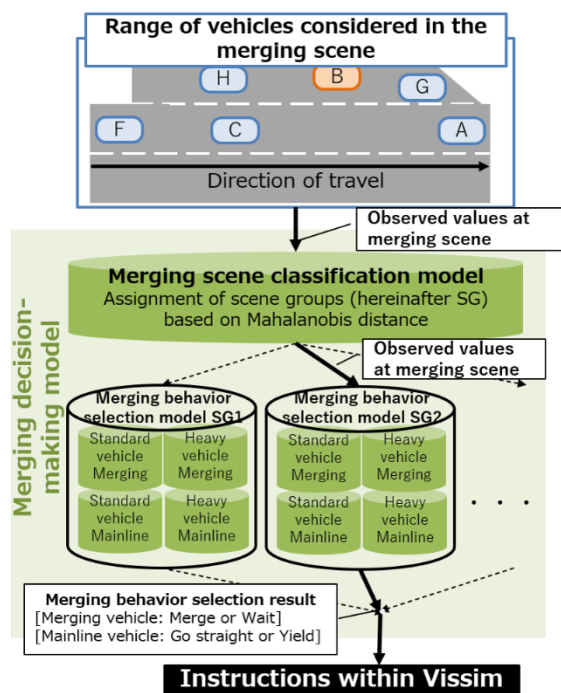


Fig.1 Overall flow of merger decision-making