

Development of Real-World-Emission Reduction Technologies (3rd Report)

-Study on Emission Reduction by Vehicle Control Using V2X Information-

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Driven by stricter Euro 7 RDE requirements and the introduction of On-Board Monitoring (OBM), reducing real-world emissions has become increasingly important. Real-world exhaust emissions are influenced not only by powertrain and aftertreatment performance but also by traffic conditions and driver behavior. This study, the third report in a series, investigated the emission-reduction potential and practical applicability of vehicle-to-infrastructure (V2I) assistance using Green Light Optimal Speed Advisory. Building on a previously developed digital twin evaluation environment that integrates traffic simulation, a driving simulator, vehicle simulation, actual vehicle control systems, and an emission model, the interactions among vehicles, drivers, and traffic flow were assessed with a focus on NO_x.

First, a traffic simulation was conducted using PTV Vissim on an approximately 3 km urban route near Tokyo Station containing 34 signalized intersections. An enhanced advisory algorithm calculated an optimal speed for passing the next two traffic signals during green phases while maintaining a minimum speed of 20 km/h. Vehicles following the recommended speed were defined as V2I-assisted vehicles. Compared with vehicles without assistance, the assisted vehicles reduced simulated NO_x emissions by approximately 23%. Spatial analysis showed lower emissions around intersections because the advisory reduced speed fluctuations, unnecessary acceleration, and stopping. However, assisted vehicles sometimes traveled at approximately 20 km/h to avoid red signals, causing surrounding vehicles to overtake and indicating a potential traffic-flow and driver-acceptance issue.

Practical effectiveness was then evaluated with 21 participants in their twenties to fifties, after approval by the research ethics committee of Toyota Motor Corporation. Participants drove the simulated route under three conditions: without V2I assistance, with surrounding V2I-assisted vehicles, and with both surrounding vehicles and a recommended-speed display. The presence of controlled surrounding vehicles was not disclosed until after the tests. Relative to the baseline, average NO_x emissions decreased by 30% when only surrounding vehicles received assistance, because preceding V2I-assisted vehicles constrained the participant vehicle speed, and by 64% when participants also received speed guidance. The recommended-speed display reduced average acceleration for drivers who achieved emission reductions, demonstrating that smoother driving was the principal mechanism. Possible tradeoffs, including lower catalyst temperature and increased motor work, showed no substantial adverse effect in vehicle tests.

Driver response varied considerably. Some participants regarded the slower assisted vehicles as obstructing traffic and wanted to overtake them, and one participant produced 10% more NO_x with speed guidance, accompanied by increased acceleration. Thus, the environmental benefit depends on whether drivers understand and accept the assistance and whether the advised behavior is compatible with surrounding traffic.

The results demonstrate that V2I-based speed guidance can reduce real-world NO_x emissions from both assisted vehicles and nearby traffic by suppressing unnecessary acceleration and deceleration. For implementation, advisory algorithms and interfaces should balance emission reduction, travel efficiency, and traffic harmony. Communicating the system's purpose, improving recommended-speed displays, and indicating assisted operation to surrounding drivers may increase acceptance and ensure consistent benefits under diverse traffic conditions and driver populations.

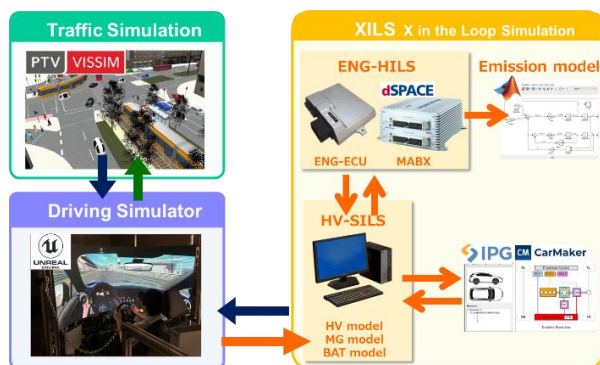


Fig.1 System architecture of the digital twin environment

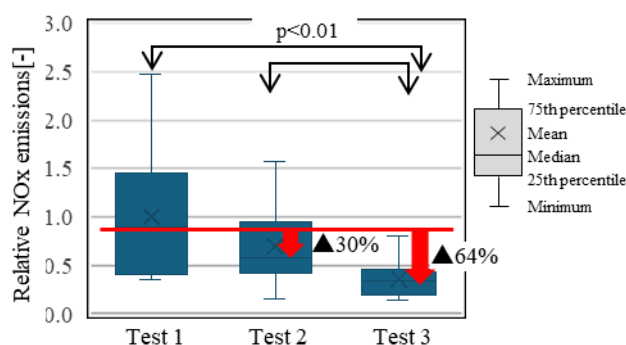


Fig.2 Comparison of NO_x emissions (Welch's t-test)