In this study, a simulated driving simulator setup was carried out on a high-fidelity driving simulator. A design stage four-lane mountainous expressway was implemented geo-based on the basis of the detailed road design blueprint. We attempted to establish a practical approach for evaluating its design consistency through investigating operating speed consistency, vehicle stability and vehicle lateral offset (vehicle trajectory). Specifically, the speed consistency is studied using the classic indicators—15th speed reduction and 85th maximum speed reduction. The vehicle stability was evaluated using lateral acceleration, rebound coefficient and the conventional side-friction parameter. The adjusted lateral offset was newly proposed, which is defined as the lateral offset from ideal vehicle trajectory. Utilizing the adjusted lateral offset that can reflect the trajectory variation dependent on the characteristics of road geometry, which leads to the discovery of the inconsistencies in the studied mountainous expressway.

Method

Participants: A total of 18 males and 4 females were recruited through Internet and posters placed around Tongji University. Each of them has a total mileage driving over 100,000 kilometers and an average annual driven distance of 3,000 kilometers.

Procedure: consists of two sub-courses – on West Bound (WB) profile and East Bound (EB) profile. Dry pavement conditions in daylights, with the free flow traffic on two driving lanes and a low traffic density distributed randomly on the opposing lanes.

- Experiment instruction & questionnaires.
- Trainings on a specific alignment for 10 minutes are then provided so that they can get familiar with the driving simulator.
- Drive on the alignment of the mountainous expressway in consideration for the first test course, from east to west.
- After 5-min break, begin the 2nd test course in the expressway from west to east, and fill the questionnaires.

Roadway Configurations: The driving scene was reproduced in virtual reality, including the profile, cross-section and road-tube elements from the design blueprint.

The road section is about 2.4km long with 2 lanes in each direction, a typical mountainous expressway containing continuous small radius curves and long down-slopes.

The longitudinal grade of this alignment ranged from -6.0% to 4.0% (from east to west), and the cross-section was 10.50 m wide (lane width 3.75 m and shoulder width 1.75m). This alignment was separate subgrade designed due to the geographical environment. Considering dissimilarities in the horizontal and vertical features, 103 configurations in total were made up of 34 tangent and 71 curve configurations.

Design Consistency Evaluation

Operating Speed Consistency: The speed difference from design speed (Safety Criterion I) and operating speed difference (Safety Criterion II) were assessed to evaluate the performance of AVS5 and 85MSR. The paired t-test showed the difference between AVS5 and 85MSR was 7.67 km/h (p=0.001).

Vehicle Stability: Vehicle stability was examined by the following three measures: 85% MSR, lateral acceleration and driver coefficient.

It should be pointed out that the smooth curve should be considered as an "ideal consistent trajectory" when the driver negotiates horizontal curvature. The deviation of the raw data from the ideal trajectory and standard deviation from its ideal vehicle trajectory would then reflect to some extent the impact of the road properties, especially the curvature radius and super-elevation rate, on the responsiveness of drivers. This means that the drivers need to do more steering adjustment in order to compensate for these observed lateral deviation deviations from its ideal vehicle trajectory.

In order to quantify the "adjusted lateral offset" along the test mountainous freeway alignment, the standard deviation from its ideal vehicle trajectory of lateral offset and maximum adjusted lateral offset were computed for each configuration.

The current study demonstrated the capability of driving simulator in evaluating design consistency for design stage roadways. Specifically, the high-fidelity driving simulator can provide consistent driving performance measures such as speed-profile and lateral acceleration, in addition to the data at the predefined fixed locations that were commonly relied on to conventional consistency studies.

- speed reduction AVS5 and maximum speed reduction 85MSR were examined as robust measures to evaluate the consistency of driving performance, and a significant difference of 7.67 km/h was found.

- The proposed "adjusted lateral offset" could be a task-dependent index that would reflect the consistency of driving performance. And the standard deviation of it was able to reflect the actual trajectory variation induced by the driving performance.