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Comparative Assessment Of Heavy Vehicle Bus Driver Experience In Real And Simulated Environments

M.Pandarinath[1*], T. Ramamohan Rao[2], SriramVenkatesh[3]
[1] Department of Mechanical Engineering, Maturi Venkata Subba Rao Engineering (M.V.S.R) College, India.*
[2] Department of Mechanical Engineering, Vasavi College of Engineering, India.
[3]Department of Mechanical Engineering, Osmania University, India.

Abstract:
Background: *Driving simulators, serving as interactive virtual reality instruments, play a crucial role in human factors studies. The study evaluates the driver's experience in real-road conditions and simulator-based scenarios.*
Materials and Methods: *The study involves on-road testing, which evaluates vehicle performance and ride comfort in real-world conditions. Three distinct road types, including smooth, rough, and roads with speed breakers, are chosen to represent various road conditions. The selected vehicle is an Ashok Leyland bus, a standard mode of public transportation in India. A qualified driver with significant experience is selected to ensure the reliability of the assessment. The study employs a vibration tester (AVD-80 model) and magnetic vibration transducer to measure vibrations beneath the driver's seat. Data is collected from both on-road testing and simulator-based scenarios, ensuring consistency in data collection setup and process. The study evaluates acceleration RMS values under these conditions.*
Results: *The results consistently demonstrate differences between real-road and simulator-generated data, with real roads consistently producing higher acceleration values. Smooth roads yield acceleration values of 0.8 to 0.9 m/s^2 (actual) compared to 0.5 to 0.6 m/s^2 (simulator). For rough, unpaved roads, the actual scenario records values between 8 to 9 m/s^2, while the simulator shows values between 5 to 6 m/s^2. Roads with speed breakers exhibit acceleration values ranging from 5 to 7 m/s^2 (actual) and 3 to 5 m/s^2 (simulator).*
Conclusion: *This study underscores the disparities in driver experience and acceleration values between real-road and simulator conditions, emphasizing the limitations of simulators in replicating road vibrations accurately.*
Key Word: *Driver seat simulator; Smooth road; Rough road; Bump road.*

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I. Introduction

Driving simulators, serving as interactive virtual reality instruments, play a crucial role in human factors studies. The challenge of replicating certain real-world road scenarios, often due to safety and replicability concerns, has heightened the relevance of these tools. However, validating experiments conducted on driving simulators is intricately linked to infusing a sense of authenticity into the virtual driver's experience. Expanding the scope of validity for such tools necessitates the incorporation of haptic feedback, with particular emphasis on simulating inertia effects. Malte et al.[1] highlight the value of driving simulators in driver behavior research, emphasizing their safety and cost-effectiveness. The study's comparison of driver headway choices in real and virtual environments reveals no significant differences, supporting the use of simulators for headway choice studies. Calvi et al. [2]validate the University of Rome Tre's driving simulator for assessing speed change lanes. With 90 participants, the study confirms its validity for replicating real-world driving behavior and trajectory data. This supports designers in identifying optimal solutions for operational, safety, and cost-effective speed change lane designs. Yunfei et al.[3] successfully integrated Traffic Simulation models and Driving Simulators to broaden their applications, with validation demonstrating similar driving behavior between the virtual and real world. Future extensions include integration with a networking simulator for Connected Vehicle studies and a multiple participant component for interactive simulations. Shechtman et al.[4] assess driver response validity by comparing behavioral errors in a simulator and on the road, finding no significant differences in various error types, thus suggesting relative and absolute validity for the simulator. Further research with a larger sample size is warranted to confirm if simulator performance predicts real-world driving behavior. Jan Torneros[5] aimed to validate driving behavior in a simulated road tunnel, finding differences in speed and lateral position between real and simulated tunnels. Absolute validity was somewhat unsatisfactory for speed choice, but relative validity was good for both speed and lateral position. Daniel et al.[6] conducted two studies to assess the validity of a driving simulator for measuring driving performance. The first study demonstrated relative validity by comparing on-road and simulator errors, while the second study confirmed discriminant validity by distinguishing performance levels among driver groups. These findings support the use of simulators in research and suggest potential applications in driver education and training evaluation. C.F. de Winter et al.[7] investigate the relationship between simulator-based driver proficiency and on-road driving test results, highlighting the importance of assessing these relationships for driver training and virtual reality industries. The study offers insights into individual differences in young drivers' behavior and suggests the need for further research to establish the reliability and validity of simulator measures and on-road tests. Samantha et al.[8] examined the validity of a low-cost simulator for assessing driver distraction from in-vehicle information systems. Their study found that although there were differences in driver behavior compared to a medium-cost simulator, low-cost simulators still have value in the initial design and evaluation of in-vehicle information systems. Yan et al.[9] investigate the use of a driving simulator for assessing traffic safety at signalized intersections. Their study validates the simulator through speed behavior comparisons and innovative surrogate safety measures, establishing its relative validity for traffic safety studies at signalized intersections. Ying et al.[10] compared on-road and simulation studies to validate simulator-generated measures. They found that visual attention and task engagement closely matched between the two environments, suggesting that medium fidelity simulation is effective for evaluating the effects of in-vehicle information systems designs on driver behavior.

II. Materials and Methods

On-road testing

In this study on-road testing is used to identify different vibrations excited by the road conditions to the vehicle and occupants and the following parameters were used to perform the on-road testing.

- Selection of roads
- Selection of vehicle
- Selection of driver
- Selection of testing equipment

Selection of roads

In Hyderabad, India, three roads were chosen to assess public transport vehicle comfort based on the driver's discomfort. The selected roads included smooth highways, unpaved rough roads, and bumpy roads with speed breakers.

Smooth Road (highway)

Highways are top-tier roads with smooth surfaces, no potholes, or ditches. They link major urban centers, minimize bumps, suit all vehicle types, and endure heavy loads with little deformation as shown in figure 1.

Figure. Error! No text of specified style in document. **1** Smooth Road(highway)

Rough Road (unpaved)

A rough road is unpaved, made from natural materials and gravel. These narrow paths are shared by pedestrians, animals, and small vehicles, featuring uneven, bumpy surfaces (see Figure 2). Vehicles on these roads may experience instability and pitching due to the rough terrain.

Figure.2 Rough Road (unpaved)

Bump Road (Speed Breaker)

A speed breaker, or speed hump, is a road feature designed to slow down vehicles and enhance road safety. Typically constructed from materials like asphalt, concrete, or rubber, it's positioned perpendicular to traffic flow (see Figure 3).

Figure.3 Bump Road (speed breaker)

Selection of vehicle

Public transport is a critical part of India's transportation system, offering affordable and accessible services to millions. This includes buses, trains, metros, and taxis, with buses being the most prevalent. India's market possesses numerous domestic and international vehicle brands like Ashok Leyland, Tata Motors, and Volvo Bus. In this study, the Ashok Leyland bus was chosen for evaluation as shown in figure 4.

Figure. 4 Ashok Leyland vehicle

Selection of driver

To evaluate vehicle ride comfort via on-road testing, a suitable driver must be chosen. Initially, volunteers were screened based on a consent form that included gender, age, and weight. The selected driver needed at least five years of driving experience, a valid state-issued license, and a clean accident history.

Prior to the formal test, drivers received training to understand the test's purpose, familiarize themselves with the test vehicle and process, and trained in real urban road traffic scenarios. Their health conditions were assessed to ensure fitness. During the formal test, drivers performed various driving operations on different roads to meet the test requirements. In this study, N. Yadaiah (age 42, weight 65.3 kg, height 172.2 cm, 20 years of driving experience, BMI 22) was chosen for the investigation.

Selection of testing equipment

To assess seat vibration in vehicles, acceleration on the driver's seat is typically measured using accelerometers to calculate floor vibration below the seat. Magnetic vibration transducers are installed at the seat interface to capture measurements. The transducer signals are then recorded with a vibration tester, noting the maximum values.

In this study, the AVD-80 model MCM instrument and magnetic vibration transducer were employed for measuring seat vibrations as shown in figure 5. For specific details and specifications of the accelerometers and vibration meter, refer to Table 1.

Figure.5 Accelerometer and transducer

Table 1 . Specifications of accelerometer equipment

S. No	Description	Specifications
1	Model Number	AVD-80
2	Measurement Accuracy	(± 5%)
3	Velocity Measuring Range	0.1 – 199.9 mm/s True RMS & 565 mm/s PK – PK
4	Acceleration Measuring Range	0.1 – 199.9 m/s^2 True RMS & 565 m/s^2 0.2 PK – PK
5	Displacement Measuring Range	1.0 - 1000 µm True RMS & 2828 µm 2.0 PK - PK
6	Display	2 x 8 Dot Matrix LCD
7	Frequency Range	10HZ - 1KHZ
8	Vibration Transducer	Magnetic Base - Hand Held Probe Rod - Low Noise Cable with Connectors (1.5 Mtrs)
9	Battery Type	9V Battery (Alkaline)

Procedure for data collection on real road conditions

The data collection procedure commenced with a briefing for the driver, providing insights into the research's purpose and significance. The driver was informed that the study aimed to evaluate the vibrations encountered in the driver's seat while navigating diverse road surfaces. The subsequent step involved a detailed explanation of the testing process for measuring seat vibrations and clarifying the data collection protocol for different road conditions.

The data collection process was extended systematically, with tests conducted on smooth, rough, and bumpy roads with speeds of 40 km/h, 20 km/h, and 10 km/h, respectively.

Figure. 6 Placement of accelerometer transducer

Procedure for Data Collection on the Simulator:

The simulator session commenced with an introductory overview of its operational principles, emphasizing its capability to simulate diverse real-world road conditions. The detailed explanation covered the simulator's ability to replicate vibrations to simulate actual road scenarios closely. The driver was then guided to assume a position in the simulator's seat with that same posture during actual driving conditions. An accelerometer was positioned beneath the simulator's driver seat, as the setup employed during road tests, as shown in the figure 6.

III. Result and Discussions

For the present research study, the performance evaluation compared the following aspects of driver's behaviour between the real-road conditions and the driver seat simulator. The acceleration RMS values were collected by placing magnetic vibration transducer beneath the driver seat with vibration tester equipment on three different roads conditions as shown in Table 2.

Table 1 . RMS acceleration ranges of different roads

S. No	Acceleration values	Smooth Road (m/s^2)	Rough Road (m/s^2)	Bump Road (m/s^2)
1	Real road conditions	0.8-0.9	8-9	5-7
2	Simulators	0.5-0.6	5-6	3-5

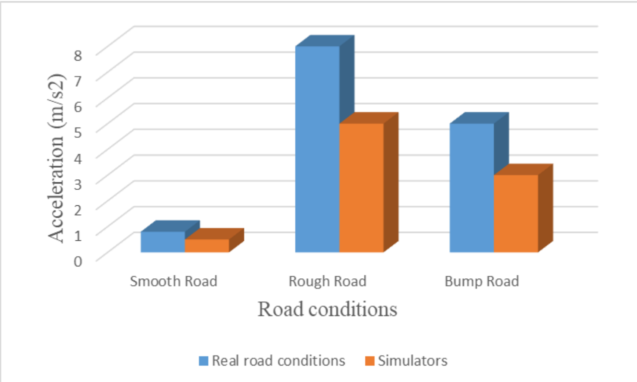

Figure.7 Comparisons of acceleration values in different road conditions

On actual smooth roads, the driver experienced acceleration values within the range of 0.8 to 0.9 m/s^2, whereas the simulator produced acceleration values ranging from 0.5 to 0.6 m/s^2, on rough roads, the driver recorded acceleration values of 8 to 9 m/s^2, while the simulator's values ranged from 5 to 6 m/s^2. In the case of real roads with bumps, the driver encountered acceleration values spanning from 5 to 7 m/s^2, while the simulator's data exhibited values between 3 and 5 m/s^2 as shown in figure 7.

Consistently, the study findings across various road conditions, including smooth, rough, and bumpy road scenarios, underscore the higher acceleration values observed in actual road conditions compared to the simulator-generated data, a critical consideration arising from these results is the potential health risks associated with continuous exposure to simulated conditions. In response to this concern, our study has taken a precautionary approach by standardizing the simulator to generate reduced vibration values compared to real-world scenarios. This adjustment is a fundamental step in prioritizing driver safety and well-being during testing, as extended exposure to excessive vibrations can adversely affect health.

V. Conclusion

This research compared driver behaviour in real-road conditions and a driver seat simulator, focusing on acceleration Root Mean Square (RMS) values. Notably, the data revealed consistent differences between actual road experiences and simulator-generated data.

Real roads consistently resulted in higher acceleration values:

- Smooth roads: 0.8 to 0.9 m/s^2 (real) vs. 0.5 to 0.6 m/s^2 (simulator).
- Rough, unpaved roads: 8 to 9 m/s^2 (real) vs. 5 to 6 m/s^2 (simulator).
- Roads with speed bumps: 5 to 7 m/s^2 (real) vs. 3 to 5 m/s^2 (simulator).

These disparities underscore the simulator's limitations in replicating real-world road vibrations accurately, potentially posing health risks due to prolonged exposure to simulated conditions. As a proactive safety measure, the simulator has been standardized to produce reduced vibration values. Combining real-road and simulator data while prioritizing safety measures enhances our understanding of driver behaviour, leading to a safer and more comfortable driving experience.

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