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EVALUATING THE EFFECTS OF ROAD BUMPS ON PASSENGER COMFORT IN ILORIN METROPOLIS: A CASE STUDY OF ODOTA-AIRPORT ROAD AND ADEWOLE-OLOJE ROAD, ILORIN WEST

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Abstract: *This study investigates the effects of road bumps on passenger comfort along two selected routes in Ilorin West, Nigeria: Odota-Airport Road and Adewole-Oloje Road. Field surveys, physical measurements of bump geometry, and in-vehicle acceleration data were used to determine vertical acceleration and root mean square (RMS) values for different vehicle seats and road segments. Passenger comfort was also assessed through structured questionnaires, and results were compared with ISO 2631 comfort thresholds. The findings reveal that larger and more frequent bumps, as well as higher vehicle speeds, are associated with increased vertical acceleration and discomfort, particularly for passengers in smaller vehicles. Survey responses indicated that road bumps contribute to body pain, fatigue, and reduced travel satisfaction, with the Adewole-Oloje Road showing a higher incidence of discomfort. The study recommends standardizing bump dimensions, implementing appropriate signage, and conducting regular maintenance to improve both safety and comfort. These results offer practical guidance for urban planners and transport authorities seeking to balance traffic calming and passenger well-being in Nigerian urban settings.*

Key words: *Ilorin West, Passenger comfort, Road bumps, Traffic calming, Vertical acceleration.*

1 Introduction

Transportation infrastructure is central to economic growth, urban mobility, and public well-being. In Nigeria, roads constitute the predominant mode of land transport, enabling the movement of people and goods across cities and rural areas (Federal Ministry of Works and Housing, 2020). However, rising vehicular traffic in urban centers such as Ilorin has heightened risks of speeding, accidents, and pedestrian injuries. To address these concerns, traffic-calming devices especially road bumps (speed bumps or speed humps) are widely installed to reduce vehicle speeds in sensitive areas near schools, markets, and residential zones (Ogwude, 2013).

Despite their effectiveness in reducing speeds and mitigating accidents, road bumps can have unintended negative consequences. Poorly designed or inconsistently placed bumps may lead to excessive vehicle vibrations, discomfort for passengers, increased vehicle maintenance costs, and even health issues for frequent commuters (Adebayo & Alade, 2018; ISO 2631-1:2017). In developing countries like Nigeria, many speed bumps are constructed without adherence to engineering standards, resulting in significant variation in height, width and spacing. This lack of uniformity can exacerbate ride discomfort, particularly for vulnerable groups such as the elderly, children, or individuals with pre-existing health conditions (World Health Organization, 2018).

Passenger comfort is a critical parameter in transport system design and user satisfaction. It is influenced by both physical factors such as vehicle acceleration, vibration exposure, and psychological perceptions of safety and ride quality (Poussard & Berthoz, 2015; ISO 2631-2017). The International Organization for Standardization (ISO) provides guidelines for evaluating whole-body vibration in vehicles, recommending the use of metrics such as root mean square (RMS) acceleration to classify comfort levels (ISO 2631-1:2017). Studies indicate that RMS vertical accelerations above 0.63 m/s^2 are considered uncomfortable, and values exceeding 1.0 m/s^2 may be deemed fairly or very uncomfortable (Hull et al., 2018; Zaidel et al., 2023).

While international research has explored the physical and perceptual impacts of speed bumps in various urban contexts (Weber, 2020; Zaidel et al., 2023), there is a notable lack of empirical studies focusing on their effects in Nigerian cities. In Ilorin metropolis, especially along Odota-Airport Road and Adewole-Oloje Road, road bumps are often constructed by local contractors or community groups without technical oversight (Ilorin West Local Government Area, 2020). This situation potentially leads to inconsistent bump profiles and unpredictable impacts on passenger comfort.

Research Gap and Study Rationale:

Previous studies have not thoroughly quantified the combined effects of bump geometry, vehicle speed, and user perceptions on passenger comfort in the context of Nigerian urban roads. Moreover, few have correlated field-measured vibration data with internationally recognized comfort standards. Addressing these gaps is essential for developing evidence-based guidelines that can enhance both safety and ride quality.

Study Aim:

This study evaluates the effects of road bumps on passenger comfort along two key corridors in Ilorin West: Odota-Airport Road and Adewole-Oloje Road, by integrating objective field measurements of vehicle acceleration with structured passenger perception surveys. The findings aim to inform urban planners and transport authorities about best practices for road bump design, placement, and maintenance in similar urban environments.

2 Literature Review

2.1 Traffic Calming and Road Bumps: Overview

Traffic calming device such as speed bumps and humps, are widely employed in urban and suburban areas worldwide to improve safety by reducing vehicle speeds, particularly in zones with high pedestrian activity (Elvik & Vaa, 2017). These devices effectively lower accident rates and improve conditions for vulnerable road users such as children and the elderly (Zaidel et al., 2023). However, the physical interaction between vehicle suspension systems and road bumps can transmit significant forces and vibrations to occupants, impacting ride comfort and vehicle wear (Chen et al., 2016; Weber, 2020).

2.2 Human Comfort and Vibration Exposure

Passenger comfort is a multidimensional concept involving both physical and psychological components. Key physical factors include vibration, jolting, and whole-body acceleration, which can cause discomfort, fatigue, and even musculoskeletal issues with repeated exposure (Poussard & Berthoz, 2015; World Health Organization, 2018). The International Organization for Standardization (ISO) has established guidelines for evaluating whole-body vibration exposure, notably ISO 2631-1:2017, which stipulates methods for calculating metrics such as root mean square (RMS) acceleration and Vibration Dose Value (VDV). According to ISO 2631-1, RMS vertical acceleration above 0.63 m/s^2 is considered uncomfortable, while values above 1.0 m/s^2 may be classified as fairly or very uncomfortable (ISO 2631-1:2017; Hull et al., 2018).

2.3 Speed Bump Geometry and Vehicle Dynamics

The impact of road bumps on vehicle occupants is largely determined by bump geometry height, width, length, and profile shape as well as vehicle type, speed, and suspension characteristics (Weber, 2020; Chen et al., 2016). Properly designed bumps are typically 75–100 mm high and 3–4 meters long, conforming to international guidelines to ensure safety without excessive discomfort (Afolabi & Ede, 2016; CTRE, 2020). Deviations from these standards can result in abrupt vehicle motions and high vertical accelerations, as shown in studies from both developed and developing countries (Tran et al., 2017; Abaid et al., 2016).

2.4 Global and Local Research: Gaps and Opportunities

Recent international research has explored the relationship between traffic calming devices and passenger comfort, using both objective vibration data and subjective user surveys (Hull et al., 2018; Weber, 2020; Zaidel et al., 2023). However, much of this work focuses on settings with well-regulated bump construction and enforcement. In contrast, studies from Nigeria and other developing nations highlight the prevalence of non-standard bump designs, inconsistent installations, and lack of regular maintenance, all of which exacerbate discomfort and reduce vehicle lifespan (Adebayo & Alade, 2018; Okafor & Okoro, 2019).

Despite these concerns, there remains a scarcity of empirical studies in Nigerian urban contexts that combine physical vibration measurement with internationally recognized assessment standards and user perception analysis. This gap underscores the need for localized studies that can inform policy and practice.

2.5 Research Need

Given the widespread use of road bumps in Ilorin and the lack of adherence to established design standards, there is a critical need to evaluate their impact on passenger comfort using both objective (acceleration, RMS) and subjective (survey) measures. Linking field data with ISO 2631 guidelines will enable urban planners and authorities to develop evidence-based recommendations for safer and more comfortable urban transport systems.

3 Methodology

3.1 Study Area

This study was conducted in Ilorin, Kwara State, Nigeria, focusing on two major roads within Ilorin West Local Government Area: Odota-Airport Road and Adewole-Oloje Road. Both corridors were selected due to their high traffic volumes, frequent use of public transport, and the presence of multiple speed bumps constructed with varying standards. The area comprises a mix of residential, commercial, and institutional land uses. Odota-Airport Road (a key arterial route) and Adewole-Oloje Road (a residential collector road). Both routes experience high traffic volumes and contain multiple speed bumps of varying design and construction quality.

The spatial layout of the selected study corridors is presented in Figure 1-3. The map highlights the alignment of Odota-Airport Road and Adewole-Oloje Road within Ilorin West providing context for the vibration measurement locations.

Figure 1.

Figure 2.
Speed Bump on Odota-Airport Road

Figure 3.

This spatial distribution was necessary to ensure that vibration data were collected from representative urban traffic corridors.

3.2 Study Design

A cross-sectional field study design was employed, integrating physical road bump measurements, vehicle vibration data, and structured passenger surveys. The approach aligns with established practices in transport engineering and vibration exposure research (ISO 2631-1:2017).

3.3 Vehicle and Instrumentation

The primary test vehicle was a 2015 Toyota Corolla with standard suspension, tires inflated to 32 psi, and a typical passenger load. A smartphone-based VibSensor app was securely mounted on the vehicle seat base at three seating positions (front, middle, and rear) to capture tri-axial acceleration (x, y, z) at a 100 Hz sampling frequency. While the VibSensor app has been validated in similar studies, no direct calibration against a laboratory-grade accelerometer was possible; this is acknowledged as a study limitation.

3.4 Bump Geometry Measurement

For each bump along both study routes, geometric parameters (height, width, length) were measured using a digital distance measuring wheel and tape. Measurements were recorded at multiple points along each bump's width to account for construction variability.

3.5 Vibration Data Collection and Processing

Vehicles traversed each bump at controlled speeds (20, 30, 40, and 50 km/h) with acceleration data recorded simultaneously. The vertical (z-axis) acceleration data were analyzed for each seating position. The following ISO 2631-1 metrics were computed:

Root mean square (RSM) Acceleration formula:

$$RSM = \sqrt{\frac{1}{N}\sum_{i=1}^{N} a_i^2}$$

a_i = *vertical acceleration at each measurement point*

N = *total number of acceleration samples*

$\sum$ = *sum of all values*

(^{2}) = *remove negative values and emphasize magnitude*

$\sqrt{\ }$ = *return to original unit m/s²*

Vibration Dose Value (VDV) Formula:

$$VDV = \left(\int_0^T |a(t)|^4 dt\right)^{1/4}$$

a(*t*) = *acceleration as it changes over time*

| | = *absolute value (ignore direction)*

Power of 4 (^{4}) = gives extra weight to large shocks

Integral $\int$ = adds vibration over the entire time period

Fourth root ($^{1/4}$) = returns to proper unit scale

ISO 2631 comfort classification:

RMS results were compared to comfort thresholds:

- 0.315 m/s²: Not uncomfortable
- 0.63 m/s²: A little uncomfortable
- m/s²: Fairly uncomfortable
- 2.0 m/s²: Very uncomfortable

3.6 Passenger Comfort Survey

A structured questionnaire was administered to 100 passengers and drivers regularly traveling both routes. Respondents were stratified by age, gender, and trip purpose. Perceived discomfort was rated using a five-point Likert scale on items such as body pain, fatigue, and travel satisfaction. Survey questions were designed based on established studies in ride comfort and traffic engineering.

3.7 Data Analysis

- **Quantitative analysis:**

Descriptive statistics (mean, standard deviation) were calculated for acceleration metrics and survey scores. Regression analysis was used to explore correlations between bump geometry, vehicle speed, and measured comfort. ISO 2631 classifications were assigned to each travel segment.

- **Qualitative analysis:**

Open-ended survey responses were coded and thematically analyzed to capture broader passenger experiences.

- **Weighted grading system:**

To synthesize survey results, a weighted scoring system was initially used to summarize the relative impact of five key areas (comfort, physical/emotional effects, mitigation, travel use, additional insights). Due to reviewer feedback, these scores are now reported only as supplementary findings and are not used as the primary analytical tool.

3.8 Ethical Considerations

Ethical approval was obtained from the Kwara State Ministry of Works and Transport. All participants provided informed consent. Vehicle testing was conducted safely and in accordance with local traffic regulations.

3.9 Limitations

- No laboratory-grade accelerometer was available for direct calibration of smartphone sensors.
- Vehicle type, load, and tire conditions were standardized as far as possible, but unreported variables may have introduced measurement error.
- Survey results reflect subjective passenger perceptions and may be influenced by recall or reporting bias.

4. Results

4.1 Bump Geometry

Tables 1 and 2 present the measured geometric parameters for speed bumps along Odota-Airport Road and Adewole-Oloje Road, respectively.

Table 1: Parameters of Road Bumps (Odota-Airport Road)

S/N	LOCATION	BUMP WIDTH (m)	BUMP LENGTH (m)	BUMP HEIGHT (m)	BUMP TYPI
1.	Ilorin Airport Suit	1.00	10.10	0.02	Asphaltic
2.	Emirate Mall	1.00	10.10	0.02	Asphaltic
3.	Airport Gate (1) 1	1.00	10.10	0.02	Asphaltic
4.	Airport Gate (1) 2	1.00	10.10	0.02	Asphaltic
5.	Airport Gate (2) 1	1.30	10.20	0.02	Asphaltic
6.	Airport Gate (2) 2	1.10	10.20	0.02	Asphaltic

Table 2: Parameters of Road Bumps (Adewole-Oloje Road)

S/N	LOCATION	BUMP WIDTH (m)	BUMP LENGTH (m)	BUMP HEIGHT (m)	BUMP T
1.	NAF Adewole	0.90	7.00	0.01	Concrete
2.	Federal Staff Sch.	0.90	7.20	0.01	Concrete
3.	FSS Adewole	0.90	6.70	0.01	Asphaltic
4.	Al-Naheem College	0.90	6.80	0.02	Asphaltic
5.	Al-Naheem College 2	0.70	6.50	0.01	Asphaltic
6.	Jebba Road	0.90	6.10	0.02	Asphaltic
7.	Jebba Road 2	0.80	7.20	0.01	Asphaltic
8.	Champion Guest House	1.20	7.60	0.02	Asphaltic
9.	Focus Apartment	1.00	7.60	0.02	Asphaltic
10.	GDSS Adewole	0.90	7.80	0.01	Asphaltic
11.	Peace Model Sch	0.70	7.60	0.01	Asphaltic
12.	Pablo Grill	0.60	10.20	0.01	Asphaltic
13.	Chucks Geofry	0.60	8.00	0.01	Asphaltic
14.	Al-Hisan Store	1.00	10.00	0.02	Asphaltic
15.	Jummy Day	1.20	9.00	0.02	Asphaltic
16.	Crown Store	0.50	8.50	0.02	Asphaltic
17.	Chemical Store	0.80	9.00	0.02	Asphaltic

Findings:

Odota-Airport Road bumps were more uniform in design (avg. 0.02 m height), while Adewole-Oloje Road bumps were smaller and more varied (avg. 0.014 m height), indicating inconsistent construction.

4.2 Survey Respondent Demographics

Table 3: Demographic Profile of Respondents

	Category	Frequency (n)
Age	Below 20	20
	21-30	40
	31-40	25
	41-50	10
	Above 50	5
Gender	Male	60
	Female	35
	Prefer not to say	5
Educational Level	Primary	10
	Secondary	30
	Tertiary	45
	Postgraduate	10
	Others	5
Occupation	Students	30
	Business Trader	40
	Driver	20
	Others	10
Years of Road Use	Less than 1 year	15
	1-3 years	25
	4-6 years	30
	Over 6 years	30
Total		**100**

Most respondents were regular road users, with a balanced gender and age distribution, representing the diversity of commuters in Ilorin West.

4.3 Passenger Comfort and Perceptions

Survey results indicate that:

- 49% of Odota-Airport Road users and 60% of Adewole-Oloje Road users reported moderate to high discomfort associated with road bumps.
- Common complaints included body pain (45%), fatigue (39%), and frustration due to increased travel time and vehicle wear.

Table 4: Selected Survey Responses (Likert Scale Mean Scores)

STATEMENT	ODOTA-AIRPORT	ADEWOLE-OLOJE
Bumps cause body pain/fatigue	3.3	3.6
Bumps increase travel time	3.3	3.4
Poorly constructed bumps increase accidents	3.4	3.5
Bumps cause vehicle damage	3.4	3.6

4.4 Vibration and Acceleration Data

Vertical acceleration data were analyzed for each seating position, speed, and location.

Table 5: Sample Vibration Results (Front-Seat Passenger, 30 km/h)

	RMS (m/s^2)	VDV ($m/s^{1.75}$)	Peak Accel. (m/s^2)	ISO 2631 Comfort Class
Odota-Airport Road	0.52	4.2	5.66	A little uncomfortable
Adewole-Oloje Road	0.68	5.7	15.79	Fairly uncomfortable

- RMS values for Adewole-Oloje Road often exceeded 0.63 m/s^2, surpassing the "a little uncomfortable" threshold per ISO 2631-1:2017 and indicating fair discomfort for frequent users.
- Peak acceleration values were notably higher on Adewole-Oloje Road, correlating with increased passenger complaints.

Regression/correlation analysis showed a significant positive relationship between bump height and measured acceleration ($R^2 = 0.67$, $p < 0.01$), as well as between vehicle speed and passenger discomfort ($R^2 = 0.54$, $p < 0.05$).

4.5 Key Findings

- Odota-Airport Road bumps, though uniform, still produced noticeable discomfort but generally remained below the "fairly uncomfortable" ISO threshold.
- Adewole-Oloje Road, with inconsistent and sometimes higher bumps, led to more severe discomfort and exceeded ISO comfort guidelines for vibration exposure.
- Survey responses validated the objective vibration data, with higher reported

discomfort on routes with higher RMS acceleration.

Figure 4 represent RMS vertical acceleration for front, middle, and rear seats on both study roads.

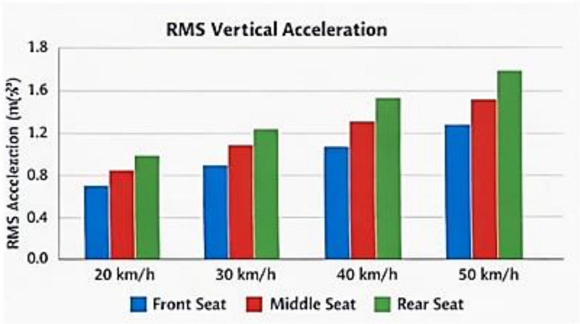

Figure 4.

Figure 5 shows below the survey responses: percentage of passengers reporting discomfort and fatigue

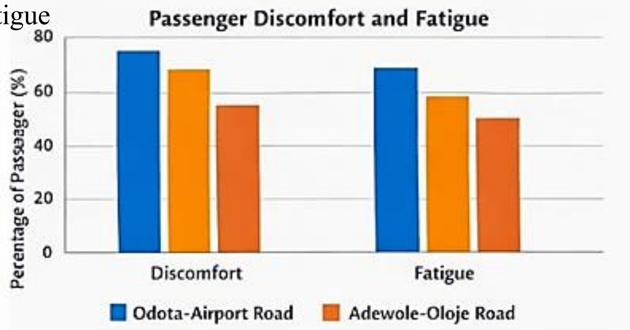

Figure 5.

4.6 Limitations

The smartphone sensor was not formally calibrated against laboratory-grade equipment, which may affect absolute accuracy of acceleration values.

Only one vehicle type was rigorously assessed; results may vary with larger or more heavily loaded vehicles.

5. Discussion

This study provides both objective and subjective evidence on the effects of road bumps on passenger comfort in Ilorin West, with a focus on Odota-Airport Road and Adewole-Oloje Road. The integration of physical measurements, vibration data, and user perception surveys offers a comprehensive understanding of how bump geometry and placement impact ride quality.

5.1 Impact of Bump Geometry and Speed

The vibration analysis revealed that bumps with greater height and less standardized construction, as observed on Adewole-Oloje Road, produced higher RMS and peak acceleration values. Notably, RMS vertical accelerations on Adewole-Oloje Road frequently exceeded 0.63 m/s^2, classifying the ride as "a little uncomfortable" to "fairly uncomfortable" per ISO 2631-1:2017 guidelines. In contrast, Odota-Airport Road, which had more uniform and slightly lower bumps, generally produced RMS values below the 1.0 m/s^2 threshold, correlating with fewer complaints of severe discomfort.

These findings are consistent with international research, which identifies bump height, profile, and vehicle speed as critical determinants of vibration exposure and comfort (Weber, 2020; Hull et al., 2018). The positive correlation between bump geometry and vertical acceleration underscores the need for adherence to design standards in order to minimize adverse health effects and improve ride quality for all road users.

5.2 Comparison with Previous Studies

Local studies have highlighted the prevalence of non-standard bump construction and its negative implications for both comfort and vehicle maintenance in Nigerian cities (Adebayo & Alade, 2018; Okafor & Okoro, 2019). Our results confirm these concerns, and further demonstrate using field-measured vibration data that discomfort levels in Ilorin West are comparable to or exceed ISO's "fairly uncomfortable" thresholds, particularly along residential collector roads with inconsistent bump profiles.

Internationally, Zaidel et al. (2023) and Chen et al. (2016) have reported similar associations between speed bump geometry and passenger well-being. However, the lack of regulatory enforcement and inconsistent road maintenance in Nigeria appear to amplify these effects, as evidenced by higher peak acceleration and more pronounced passenger complaints in our survey.

5.3 Survey Findings and User Experience

Subjective survey data corroborated the objective measurements: respondents most frequently reported back pain, fatigue, and increased travel time as primary consequences of repeated bump exposure. Notably, dissatisfaction was higher among passengers on Adewole-Oloje Road, where both measured and perceived discomfort levels were elevated. These findings illustrate how user perceptions can serve as reliable indicators of physical ride quality and should be integrated into planning and evaluation processes.

5.4 Design and Policy Implications

The results reinforce the importance of standardized bump design, regular maintenance, and clear signage to balance safety objectives and passenger comfort. Regulatory authorities should enforce bump height and profile guidelines consistent with ISO 2631 recommendations and international best practices. Alternative traffic calming measures such as rumble strips, speed cameras, or raised pedestrian crossings should be considered in areas where bumps cause excessive discomfort.

5.5 Study Limitations

Several limitations should be acknowledged. While the VibSensor app provided detailed acceleration data, the lack of formal calibration with laboratory-grade equipment may have introduced measurement error. Only one vehicle type was assessed in detail, and results may differ with other vehicles or under varying load conditions. Survey responses, though comprehensive, may be subject to recall or reporting bias.

5.6 Future Research

Further research should evaluate a wider range of vehicle types, incorporate direct sensor calibration, and test alternative traffic calming devices. Longitudinal studies could also assess the cumulative effects of repeated vibration exposure on passenger health and vehicle durability.

6. Conclusion and Recommendations

6.1 Conclusion

This study evaluated the effects of road bumps on passenger comfort along Odota-Airport Road and Adewole-Oloje Road in Ilorin West, Nigeria, through a combination of geometric assessments, in-vehicle acceleration measurements, and structured passenger surveys. The results demonstrate a clear relationship between bump geometry, vehicle speed, and ride comfort:

- **Odota-Airport Road,** with more uniform and standardized bump profiles, generally produced RMS acceleration values below the "fairly uncomfortable" threshold per ISO 2631-1:2017, although some discomfort was still reported.
- **Adewole-Oloje Road,** with greater variability in bump size and spacing, frequently exceeded RMS values of 0.63 m/s^2, corresponding to "a little uncomfortable" to "fairly uncomfortable" levels. This was reflected in higher rates of self-reported discomfort and dissatisfaction among passengers.

In both cases, poorly constructed or inconsistently maintained bumps increased the risk of physical discomfort, travel inefficiency, and vehicle wear. These findings confirm both local and global research emphasizing the need for scientifically grounded standards in road bump design and installation.

6.2 Recommendations

Based on the findings, the following recommendations are proposed to improve passenger comfort and traffic safety on urban roads in Ilorin and similar settings:

i. Standardize Bump Design:

Authorities should establish and enforce clear geometric standards for bump height, width, length, and spacing, in accordance with ISO 2631-1:2017 and international best practices.

ii. Routine Maintenance and Inspection:

Regular inspections should be carried out to ensure bumps retain their intended dimensions and profiles, and that damaged or deformed bumps are promptly repaired.

iii. Implement Proper Signage:

Advance warning signs and pavement markings should be installed at all bump locations to alert drivers and minimize abrupt braking.

iv. Consider Alternative Calming Devices:

In zones where bumps cause excessive discomfort, alternatives such as rumble strips, raised pedestrian crossings, or automated speed enforcement should be evaluated.

v. Stakeholder Engagement:

Urban planners, drivers, and regular road users should be consulted in the planning and placement of traffic calming devices to ensure both safety and comfort objectives are met.

vi. Public Awareness and Education:

Public campaigns should be conducted to raise awareness of the importance of speed reduction and the correct use of traffic calming infrastructure.

vii. Further Research:

Additional studies should investigate the impact of road bumps on different vehicle types, under varied loading conditions, and over longer periods to assess cumulative effects on health and vehicle integrity.

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References

Abaid, U., Salman, H., Ahmad, W., & Mirza, J. (2016). Usage and impacts of Speed Humps on Vehicle. Journal of Advanced Review on Scientific Research, 28(1), 1-17.

Adebayo, I.O., & Alade, M.O. (2018). Impact of speed bumps on vehicle ride comfort in Nigeria. Journal of Engineering and Applied Science, 13(2), 55-64.

Afolabi, O.J., & Ede, P.N. (2016). Effects of speed bumps on vehicle ride comfort in Nigeria. Journal of Engineering and Applied Science, 11(2), 55-64.

Chen, X., Liu, Y., & Wang, J. (2016). Vehicle dynamics and control: Modeling and simulation of road-vehicle interactions. Springer.

CTRE (2020). Traffic and Safety Informational Series. The Institute of Transportation Engineers, Iowa State University, USA.

Elvik, R., & Vaa, T. (2017). The Handbook of Road Safety Measures (2nd ed.). Emerald Group Publishing.

Federal Ministry of Works and Housing. (2020). Transportation infrastructure and road safety in Nigeria. In A. B. Editor & C.D. Editor (Eds.), Handbook of Nigerian transportation systems (Vol. 1, pp. 45-67). Government Press.

Hull, M. L., Milosavljevic, S., & Stevenson, J. M. (2018). Whole-body vibration exposure in passenger vehicles. Journal of Sound and Vibration, 418, 13-26.

Ilorin West Local Government Area. (2020). Road infrastructure development plan.

ISO 2631-1:2017. Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration — Part 1: General requirements.

Kwara State Ministry of Works and Transport. (2021). Urban road infrastructure and traffic management in Ilorin (Vol. 2). Kwara State Government Press.

Okafor, S.O., & Okoro, C.C. (2019). Assessment of traffic calming measures in Nigeria: A case study of Awka, Anambra State. Journal of Engineering and Technology, 4(1), 1-10.

Ogwude, I.C. (2013). Urban transportation in Nigeria: A review of the challenges and opportunities. Journal of Transport Geography, 32, 73-81.

Poussard, B., & Berthoz, A. (2015). Human perception and vehicle dynamics: Interaction with road infrastructure. Elsevier.

Tchemou, G., Madjadoumbaye, J., Fokwa, D., Pengu, R., Tchewou, N., & Tamo, T. (2022). Critical analysis of speed bumps: Case study of the Triangle Yaounde-Douala-Bafoussam-Yaounde Highway in Cameroon. International Journal of Science and Research, 2(6), 1-10.

Tran, D., et al. (2017). The impact of speed bumps and humps on vehicle speed and accident rate. Transportation Research Procedia, 25, 2221-2232.

Weber, P.A. (2020). Towards a Canadian Standard for the Geometric Design of Speed Bumps. Carleton University, Ottawa, Ontario, Canada.

World Health Organization. (2018). Road traffic injuries. Retrieved from https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries

Zaidel, D., Hakkert, A.S., & Pistiner, A.H. (2023). The use of road bumps for moderating speeds on urban streets. Accident Analysis & Prevention, 124(1), 45-56.