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Research Article

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Health and Safety Effect of Road Bumps on Vehicle Occupants in Nigeria

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Abstract On most roads in the developing countries road bumps are traffic calming measures to promote orderly traffic moment, control speed and improve safety. However, their presence constitutes great discomfort to drivers while climbing over them. Most of them are not well placed and their irregularity cause vibration of vehicles wheels and tilting impacts on passengers. The objective of this study is to examine the efficiency of road bumps and their contributing factors on the discomfort and safety of motorists. This paper concentrates on the 14 km stretch of the highway linking the State capital; Ilorin city to the Kwara State University, Malete. The Vibsensor software was used to collect data on thirty-two (32) bumps existing along the study road. Questionnaires were also assessed to enquire from road users on the impact of the vibration on their health. The obtained result indicates possible health hazards to various human body organs such as inner ear, eye oscillation and motion sickness. The study also found that sudden hard braking of most speeding drivers on sighting the bumps result in pitching and tilting of occupants and/or may even lead to driver's loss of control to cause serious accidents when the vehicle run off the road.

Keywords Road bumps, Vibration and tilting, Health and Safety

1. Introduction

The purpose of placing road bumps in most developing countries such as Nigeria is to calm traffic by reducing the travel speed. Thus, it is defined as a short distance elevation placed on stretch of road to physically force drivers to reduce travel speed [1].

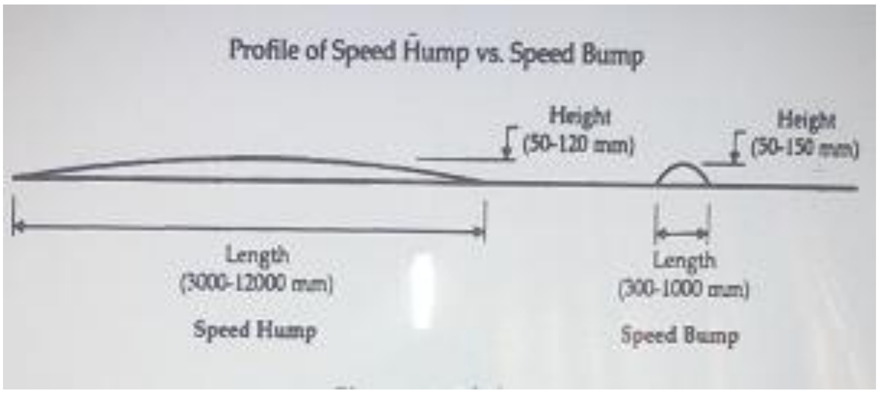

Figure 1: Comparing Speed Humps with Speed Bumps Profiles [5, 6]

Although speed bumps cause vertical acceleration causing discomfort to the occupants of the vehicle, it serves as means of discipline drivers by significantly impairing his riding comfort when climbing these bumps with excessive speed [1]. Consequently, the speed bumps are for the reduction in the amount of cut-through traffic [2]. However, the effects of speed bumps range from driver and passenger discomfort, damage vehicle suspension system, to loss of control if encountered at high speed [3]. The vehicle wheel impact due to speed bumps also affects the comfort, performance, and health of individuals [4]. Figure 1 [5, 6] illustrates the difference between speed bump and speed hump. A speed hump is much wider than the speed bump.

Due to irregularity of road surface, vehicle wheels on speed bumps at high speed causes bounce, pitch and roll on the suspension system while discomfort is exerted on the driver and passengers through vehicle body vibration [5]. The exposure of driver and passengers to vibration result in long term physiological damage [2] and vibration sensitivity of individual organs as depicted in Figure 2 [6].

This study attempts to estimate the level of discomfort to drivers and passengers when crossing the speed bumps due to the vibration of the vehicle body from the reaction of the vehicle wheel suspension system. The evaluation of vibro-acoustical comfort inside the vehicle compartment is considered.

Human responses to whole-body vibration were evaluated by the International Standard 2631 (ISO 2631) (1997) [9, 11, 13]. The ISO 2631 suggests vibration measurements in the three translational axes on the seat pan, but only the axis with the greatest vibration is used to estimate vibration severity [13, 14]. The driver and the passengers in the vehicle tends to tilt in X, Y, and Z axis which increases the discomfort rate [2]. Drivers are prepared to experience more discomfort if it will decrease their travel time, at least to some level [6].

The vibration caused by the effect of speed bumps on vehicle suspension is transmitted to the passengers, and has large influence on comfort, performance, and health [8]. The factors that influence the transmission of vibration to and through the body depend on the frequency and direction of the input motion and the characteristics of the seat from which the vibration exposure is received [9].

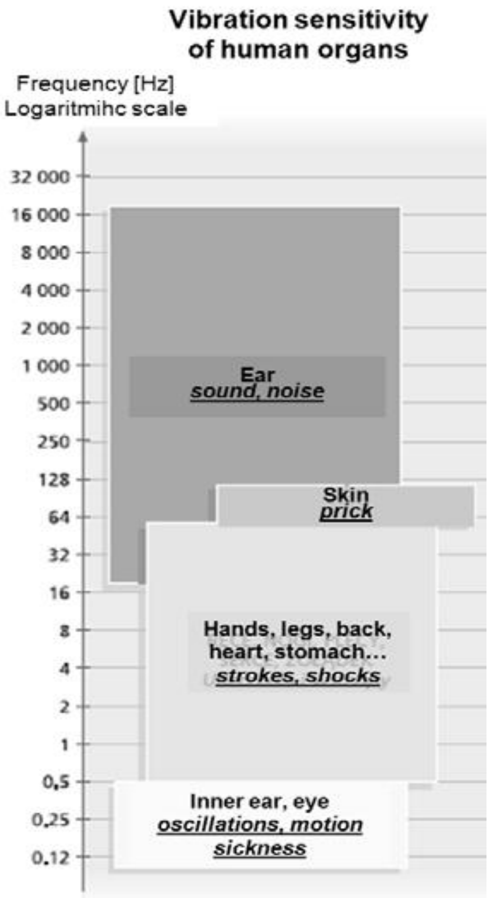

Figure 2: Vibration sensitivity of chosen human organs [6]

Vibrations up to 12 Hz affect all of the human organs, while those above 12 Hz have local effects. [8, 10] Speed bumps on the study road could cause cyclic motion of low-frequency (4-6 Hz) due to tires rolling over an uneven road to resonate the body. Just one hour of seated vibration exposure may cause muscle fatigue and make the user more susceptible to back injury [9, 12].

2. Description of VibSensor Software Application [15]

VibSensor has four main functions of visualizing, acquiring, analyzing and exporting of data. It consists of an accelerometer that is used to measure the mobile data along each of the main axes of the device as shown in figure 3 below. The device measures effect of gravity and other acceleration experience during vehicle movement on the bumps. As the vehicle occupants experience slowly varying tilt and quickly varying vibration, any net acceleration exceeding the activation level of vibration in one to ten second's interval are recorded. The data are then reported as root-mean-square amplitude of the vibration (RMS) and as average tilt over the duration of the acquisition. The device also has capacity to plot and print out the report.

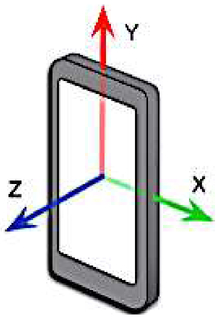

Figure 3: The main Axes of Device [15]

3. Methodology

Thirty-two (32) speed bumps of various shapes and sizes were identified at all the seven (7) communities along the study roadway. Most of them are asphalt while only few are concrete type. Their shapes and dimensions allowed for obtaining the measurable range of vibration and titlting for front, middle and back seat points. Commercial cars and buses which are the most common modes of transport along this road were used.

A vibsensor application was used to measure the vibration and tilting of human body in the form of acceleration at three seating positions; front, middle and back seats at x, y, and z directions as vehicles climb over the speed bumps. During this study, the device was firmly resting on the vehicle seat platform near the observer in order to measure only the true acceleration. This method enables the measure of vibration frequency which determines the vibration effects on health, comfort, perception and motion sickness [10].

Summary of the acceleration data for each axis as the vehicle climbed over the bumps in sessions was reported. Resonances from the calculated power spectra density were identified. These values are equal to RMS vibration level for a constant vibration level with a unit of acceleration squared per frequency [15].

4. Results and Discussion

The data collected are analysed to obtain the following results which address the study objectives:

4.1. Speed Bumps' Parameters

Speed bumps are described in this study using geometric design parameters such as length, height, and width as well as spacing between them (Table 1). Speed bumps span the entire width of a road and road width was recorded as the bump's width while the width and height of bump's cross section represent length and height of the bump respectively.

Table 1: Average speed bumps dimensions for each community

No. of Bumps	Community	Bump width (m)	Bump length (m)	Bump height (m)	Bump spacing (m)
11	Malete	7.86	0.93	0.69	156.93
3	Okete Tuntun	6.88	0.94	0.57	61.46
5	Elemere	7.07	1.11	0.68	120.26
5	Ore/Asomu	6.57	0.87	0.76	106.82
3	Akorede	6.83	0.84	0.58	122.73
3	Ogbagba	6.02	0.87	0.72	46.03
2	Shao Junction	6.91	1.09	0.92	24.06

Results presented in Table 1 can be compared with the general specification of speed bump design parameters ranging from 300 – 1000mm for length and 50 – 150mm for the height as shown in Fig. 1[6]. It was observed that all the bumps heights are outrageously higher than the specification while the bump lengths are at the maximum limit of the range. Although, length of speed bumps is the most important parameter, bump heights can influence the magnitudes of vertical accelerations and the maximum levels of perceived discomfort [10]. This explains why exposure of human body to vibration can cause discomfort to the motorists. This is an indication that the driver and passengers' bodies will be exposed to vibration and tilting as their vehicles wheels' pitching and rolling on sharp bumps.

Previous research from several countries suggests that to achieve overall speeds of 25 to 30 km/h, speed bumps should be placed between 40 and 60 meters apart. Greater spacing, up to 100 meters, can be used for speeds of 50 km/h [6]. Irregularity in spacing of speed bumps affects the average speed on this road and could even constitute confusion to drivers' decision to move on their willing speed. This action may lead to stress and fatigue that may eventually result in serious accident for sudden braking and high speed vehicle. Thus, the health and safety of the drivers are at risk.

4.2. Vibration and Tilting of Human Body

The vibration reading was obtained in acceleration (m/s^2) using vib-sensor application in Android with 3 dimensional axis x, y, z, where x represents the forward or backward movement, y represents the sideways movement and z represents the upward and downward movement (bounce and pitch). The result was obtained for the front seat, middle seat and back seat for each speed bump and the respective graph was plotted as shown in figures 4–6. Only the critical speed bump's effects at Shao junction was selected as the representative community and presented in this paper because of its highest height and shortest spacing. This agrees with the ISO 2631 which recommends the use of only axis with the greatest vibration to estimate vibration severity [9].

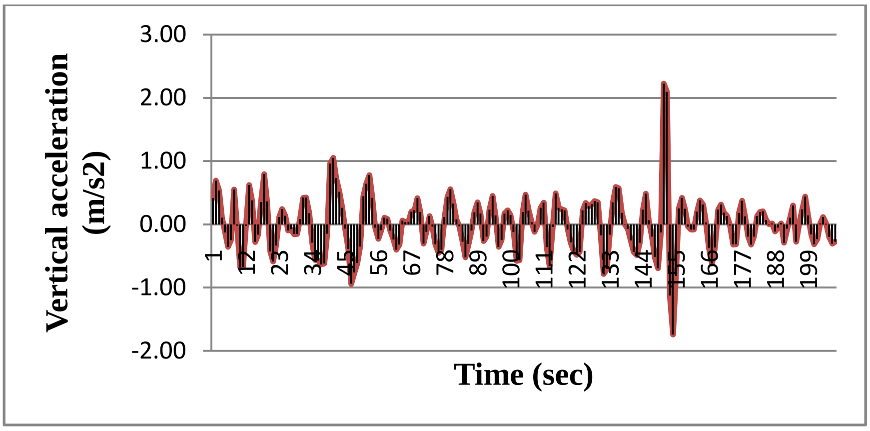

Figure 4a: Vibration Effect on Front Seat Passenger

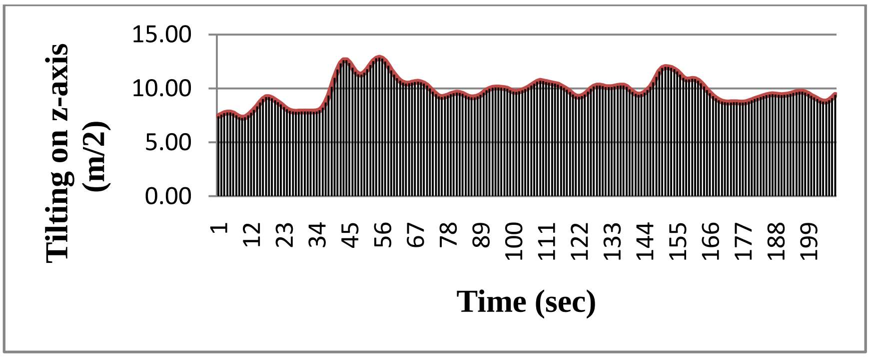

Figure 4b: Tilting Effect on Front Seat Passenger

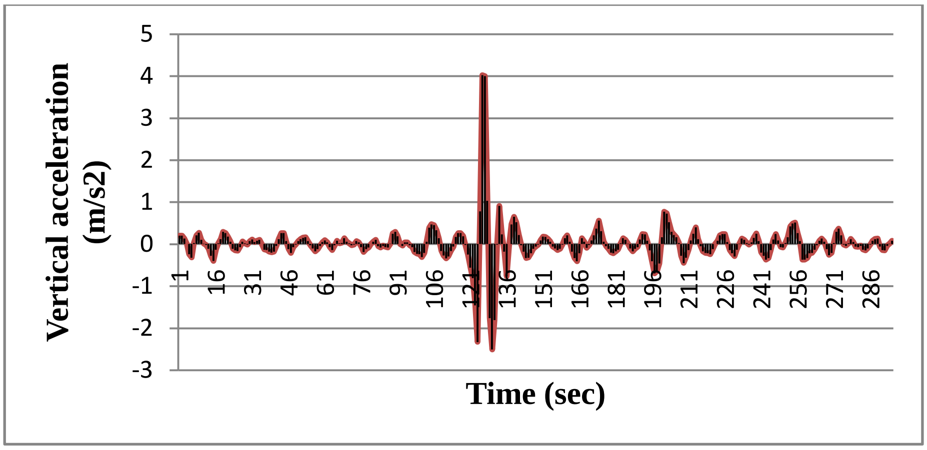

Figure 5a: Tilting Effect on Middle Seat Passenger

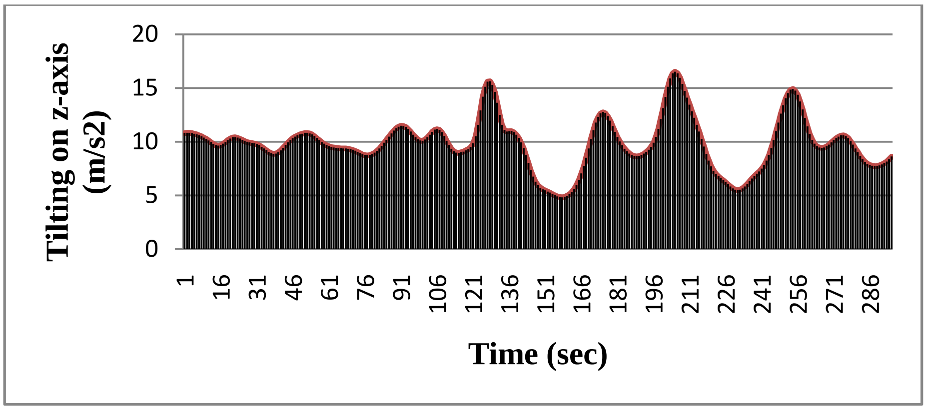

Figure 5b: Tilting Effect on Middle Seat Passenger

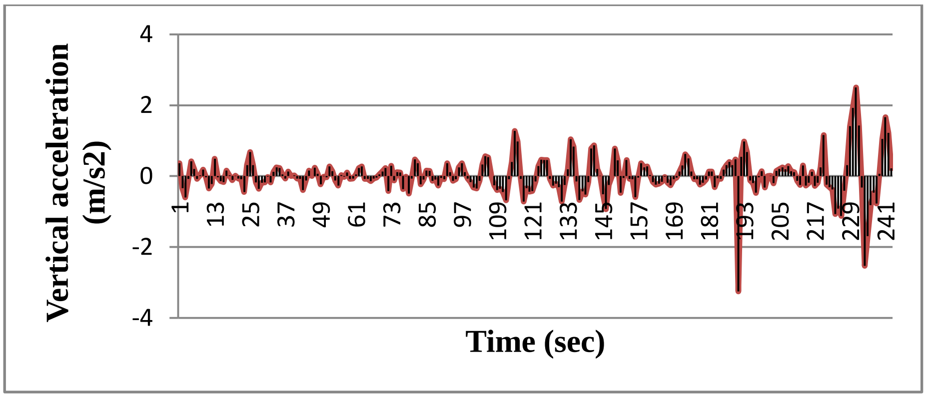

Figure 6a: Vibration Effect on Back Seat Passenger

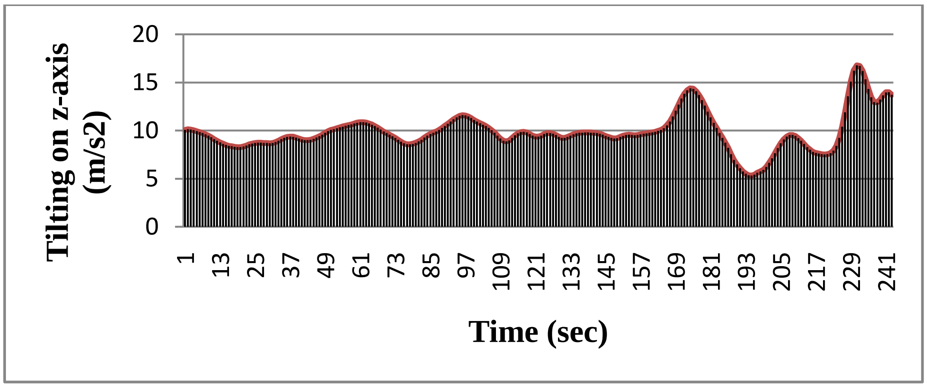

Figure 6b: Tilting Effect on Back Seat Passenger

Results in Figures 4 to 6 above show some similarities in the magnitude of vibration and tilting accelerations. The highest magnitude corresponds to the position of passenger seating in the middle of vehicle. There is steady vibration as vehicle climbs the bump for the passenger seating in the front with the peak towards the point of descending of vehicle from the bump. The passenger on the middle seat suffer the severe vibration effect as the front wheels are descending from the bump while severity of vibration is only felt by the time vehicle is finally descending from the bump. This result implies that the passenger seating at the middle seat feels more sever vibration than other passenger seating at the front seat and the back seat due to upward body motion. Also, the passenger at the back seat will suffer higher discomfort due to downward body motion. Similarly, tilting effect is higher on both the middle and back seats passenger. This is an indication of less discomfort for front seat passenger and driver compared to the middle and back seat passenger.

4.3. Estimation of Vibration Sensitivity on Human Organ

By the user guide of Vibsensor, Root-square-mean, RMS vibration is estimated with acceleration square divided by the frequency [15]. Therefore, the reported rms values by the application for each point (front, middle and back seats) of z-axis were used to estimate frequency for the peak acceleration as follows:

Table 2: Effect of Vibration Sensitivity on Human Organ

Seating Position	RMS (m/s^2)	Peak Vertical Acceleration (m/s^2)	Frequency (Hz)	Health Safety Implication (ISO 2631-1, 1997). [Fig 2]
Front	0.38	2.09	0.18	Inner ear, eye oscillation, motion sickness
Middle	0.44	4.02	0.11	---ditto --
Back	0.33	2.5	0.13	---ditto --

Table 2 indicates why both driver and passenger complain of stress and tiredness after daily usage of this road and this corresponds to the responses assessed from the questionnaire.

4.4. Evaluation of Questionnaire Response

Two hundred (200) questionnaires were distributed among the selected commuters along the study route. The following critical questions were asked aside other general questions and their responses are as presented in Tables 3 to 5 below.

4.5. What is your estimated Travel Speed?

The respondent were purposely asked about their estimated speed examine the necessity for the installation of speed bumps on the road. Although the road is a two lane, two way rural roads with expected speed limit of 80 km/hr, 58 percent of drivers' desired speed is above the speed limit. Considering the road condition and the life span of the road which is already exceeded, a reasonable speed should not have exceeded 60 km/hr (Table 3). This explains why commuters should be uncomfortable and unreported run off and rear collisions are possible, especially t or near road bumps locations.

Table 3: Estimated travel speed

	Frequency	Percent	Valid Percent	Cumulative Percent
30-60kmph	20	10.0	10.0	10.0
60-80kmph	64	32.0	32.0	42.0
80-100kmph	58	29.0	29.0	71.0
100-120kmph	56	28.0	28.0	99.0
above 120kmph	2	1.0	1.0	100.0

4.6. What are the effects of Bumps on Human Feelings?

Commuters were asked how they feel after ravelling on the road with bumps daily. Majority of the commuters responded that they have strong and average feeling for motion sickness, fatigue, headache and insomnia. Only 15% of commuters has no feeling for insomnia (Table 4).

These feelings can eventually affect the driving attitudes which may lead to serious accident. However, it is advisable to avoid driving whenever any of these feeling are encountered.

Table 4: Percentage Effects of Bumps on Human Feelings.

	Effects of Bumps on Human Feeling in (%)			
	Motion Sickness	**Fatigue**	**Headache**	**Insomnia**
Strong	45.0	53.5	49.5	35.0
Average	50.0	43.0	45.5	30.0
Weak	4.0	3.0	5.0	20.0
None	1.0	1/0	1.0	15.0
Total	100	100	100	100

4.7. What are the effects of road bumps on human organ?

Consequently, the above feeling can lead to pain in human organ such as chest and abdomen, backache, intestine and bladder. This pain can even cause damage to any of these organs. As shown in Table 5 only intestine and bladder are less significant. The effect of chest & abdomen and backache may not be felt immediately but if not treated on time may cause death.

Table 5: Percentage Effects of Bumps on Human Organs

	Effects of Bumps on Human Organs		
	Chest& Abdomen	**Backache**	**Intestine & bladder**
Strong	35.5	57.5	14.5
Average	32.0	34.0	27.5
Weak	24.5	7.5	35.5
None	8.0	1.0	22.5
TOTAL	100	100	100

5. Conclusion

This paper studied the efficiency of speed bumps as it affects the riding comfort and health safety of drivers and passengers. The study area consists of seven (7) communities strategically spread along roadway, from Malete up to Shao junction with 32 numbers of speed bumps. It was found that the presence of speed bumps causes highest severity of discomfort and health to passengers at middle seat and least to front seat passengers as a result of whole body vibration. Despite the application of this type of bumps at the respective locations along the study road, there is abrupt reduction in speed as vehicles approach the bumps due to emergency braking. This action is not appropriate as it leads to discomfort resulting from vibration of vehicle wheels on bumps.

The measured vertical accelerations were found to be comparable with the corresponding tilting acceleration for front, middle and back seats. It has been found that the maximum acceleration of 2.09 m/s^2 for front seated passengers, 4.02 m/s^2 for middle seat while 2.5m/s^2 for the back seat vibration measurement. Finally, the discomfort evaluated due to vibration was related to human body tilting and the effects on human organs such as inner ear, eye oscillation and motion sickness are significant on the study road [6].

This study has demonstrated that proper evaluation based on data collection, local knowledge, and application of appropriate devices can help in providing a viable traffic calming mechanism. Therefore, the study recommends further study on the appropriate speed bumps that will be safe and less discomfort to road users.

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