Effects of Vibration on Intrastate Bus Drivers

A F Azenan¹, Jalil Azlis-Sani²
¹² Faculty of Mechanical Engineering & Manufacturing Universiti Tun Hussein Onn Malaysia (UTHM), 86400 Parit Raja, Johor.
E-mail: azlis@uthm.edu.my²

Abstract. Lower back pain is a common effect of whole body vibration on bus drivers. Therefore, this study was carried out to identify effects of whole body vibration on intrastate bus drivers including lower back pain. A total number of 161 respondents in Putrajaya Sentral and 92 respondents in Larkin Sentral were selected and the data were analysed using Statistical Package for Social Science (SPSS). A total of Sand 7 bus drivers from Putrajaya Sentral and Larkin Sentral respectively were selected for the measurement. HVM 100 Larson Darvis and a seat pad accelerometer were being used. Based on the data collected, measurements of whole body vibration of two locations were conducted to investigate on the exposure level. Several pain areas faced by the drivers were identified at both terminals i.e: neck, upper back, lower back and shoulder. Based on the correlation analysis, upper back and lower back pain were identified as significant effect of the vibration. The results showed positive, strong and significant relationship between daily vibration exposure, A(8) with upper and lower back pain. In conclusion, the vibration exposed to the drivers at Larkin Sentral were significantly higher and exceeds the exposure limit compared to those at Putrajaya Sentral.

1. Introduction

Presently, there are varieties of public transports in Malaysia especially in Kuala Lumpur such as bus, light rapid train and also monorail. Public bus operation has play an important role across the world for commuting passengers [1]. Vibration has become an important consideration in engineering as the development of industries and vehicles become aggressive [2]. Investigations have shown that bus drivers are exposed to high-intensity vibrations [3]. There are two types of human vibration exposure which are hand arm vibration (HAV) and whole body vibration (WBV). This study will be focussing on WBV on a person is supported on a vibrating surface. It can be seen while driving a bus, the seat will receive or expose to vibration and then the whole body of the drivers will expose to WBV. WBV is an occupational issue of concern due to adverse health effect or simple discomfort and annoyance [4] and can be measured in three orthogonal axes which are x-fore and aft, y-lateral and z-vertical [5]. The amount of vibration exposures depends on a number of factors, including the type and design of the vehicle, the speed at which the vehicle is travelling, the body posture, and the environmental conditions [6]. This sector (bus) also could lead to an issue such as musculoskeletal disorder apart from contributing to the economic growth and job opportunities [7].WBV can cause so many health problem such as back pain problem. One group of workers that have been recorded as being at an increased risk for lower back pain (LBP) is occupational drivers such as bus drivers [8]. Furthermore,
there are four primary harmful effects of the vibration are motion sickness, impaired comfort, impaired activities and degraded health [9]. Efficient and proper process are needed in this study as to gain a better and accurate result. In order to do that, there are several objective in this study that have been focused which is to identify the level of whole body vibration among bus drivers and evaluate whether the vibration exposure have been already exceed the exposure limit based on ISO 2631-1(1997). Then, correlation analysis will be done between two variables which are daily vibration exposure, A(8) from vibration measurement and pain areas caused by whole body vibration from questionnaire as to investigate the effects of whole body vibration instead of lower back pain.

2. Methodology

This research was a cross-sectional study conducted among bus drivers in Rapid Bus Sdn Bhd (Putrajaya Central) and Syarikat Pengangkutan Maju (Larkin Central). The first method of this study was by using vibration instruments which were human vibration meter analyzer (HVM100) and a Tri-axial seat pad accelerometer. For the measurement of whole body vibration, there were 5 bus drivers from Putrajaya Central and 7 bus drivers from Larkin Central were selected to measure the whole body vibration exposure. While performing their normal driving condition, drivers must not be disturbed including researcher in order to get an accurate measurement of whole body vibration. The vibration instruments needed to be calibrated before collecting data in order to get an ideal sensitivity. The value for both weighting- frequencies (Wd and Wk) was (Wd=1.4wx, Wd=1.4wy and Wk=1.0wz) and the sensitivity in this study was (x=1.040 mV/g, y=1.024 mV/g and z=1.016 mV/g) with gain 20 dB each axes. HVM 100 could only recorded a data or register up to only 4 minutes and the next 4 minutes will be recorded in another register. Importantly, the seat pad accelerometer must in proper position (axes).

After getting the data, it will be transferred to Blaze software for further report, analysis on whole body vibration exposure which was correlation analysis for identifying the effects of vibration and calculated daily vibration exposure A(8) and vibration dose value (VDV) by using formulas given.

\[ A_W = \left[ \frac{1}{T} \int_0^T a_w^2(t) \, dt \right]^{1/2} \]

(1)

Where, \( A_w (t) \) is the vibration data and the average weighted vibration in \( m/s^2 \).

\[ VDV = \left[ \int_0^T a_0^w(t) \, dt \right]^{1/3} \]

(2)

Where, VDV is the vibration dose value in \( m/s^{1.75} \)

Measurement time for each drivers in Putrajaya Central was 36 minutes while for Larkin Central was 40 minutes. By using the Blaze software, the four minutes of each register were merged together and the value of A(8) in a merged file were converted to an 8-hour daily value by using HSE calculator to calculate the A(8) and VDV. Then, the results needed to be compared with Exposure Action Value (EAV) and Exposure Limit Value (ELV) for both A(8) and VDV based on Health Guidelines Caution Zone (HGCZ). The details was shown in Table 1.

Second method of this study was by using Modified Nordic Questionnaire. All selected respondents were required to fill up the questionnaires. The Modified Nordic Questionnaire consists of three major parts; personal details, drivers comfort and drivers health with objectives to screen the musculoskeletal disorders in an ergonomics context and for occupational health care service [10]. Each of the drivers were briefed nicely and wisely about the questionnaire and the importance of getting actual data from each of them. The data collected from the questionnaires were keyed in into SPSS for further statistical analysis such as the correlation analysis. The purpose of the analysis was to identify the relationship between two variables while the Pearson correlation was selected for the
statistical analysis. Generally, there are three conditions of the analysis that were positive or negative relation, strength of the relation (\(-value\)) and significant of the relation (\(p\)-value). The \(-value\) and \(p\)-value were shown in Table 2.

| Table 1: EAV and ELV details |  |
|-----------------------------|--|
| EAV                         | ELV                   |
| EAV for A(8)                | 0.50 m/s²             |
| ELV for A(8)                | 1.15 m/s²             |
| EAV for VDV                 | 9.1 m/s²¹⁷⁵           |
| ELV for VDV                 | 21.0 m/s²¹⁷⁵          |

3. Results and Discussion

Based on Figure 1, the painful area caused by vibration on intrastate drivers in Putrajaya Central were presented and the most painful area was neck with percentage of 81.4%. The rest followed by lower back, shoulder, upper back, knee and hips. On the other hand, painful areas experienced by bus drivers in Larkin Central were more compared to Putrajaya Central. The highest percentage of painful areas in Larkin Central was lower back with 87% of 92 respondents. This finding was in lined with previous study on the relationship between back disorders and vehicle operation with vibration exposure [11]. Researchers agreed and recognized that low back pain is the most leading pain due to vibration. The other painful areas having by the bus drivers in Larkin Central were upper back, shoulder, neck, knee, hips, thigh and ankle.

| Table 2: \(\alpha\)-value and \(p\)-value | Strength and Significance |
|----------------------------------------|--|---------------------------|
| \(\alpha\)-value \& \(p\)-value          | Strength and Significance |
| \(\alpha\)-value < 0.5                  | Moderate-weak             |
| \(\alpha\)-value > 0.5                  | Strong-very strong        |
| Sign (\(p\)-value) < 0.05               | Very significant          |
| Sign (\(p\)-value) > 0.05               | Not significant           |
According to Figure 2 shows the A(8) for bus drivers in Putrajaya Central was obtained from Blaze Software and after calculating by using HSE calculator. Yellow line represented the value of EAV which was 0.5 m/s². Based on the figure below, there were no bus drivers who reach the limit of EAV. Only two bus drivers almost reach the EAV limit which was bus driver C and D with equal values of daily vibration exposure that were 0.48 m/s². The rest were bus driver B, E and the lowest was driver A (0.42 m/s², 0.40 m/s² and 0.34 m/s²). Otherwise, the rest was safe to be used and might not harm the bus drivers, but safety precautions must be taken by the employer.

![Figure 3](image-url)

**Figure 3.** Daily vibration exposure, A(8) in Putrajaya Central.

Daily vibration exposure, A(8) in Larkin Central was shown in Figure 4 below. As been mentioned earlier, the yellow line represented the value of EAV while red line shows the value of ELV which was 1.15 m/s². Based on the figure, daily vibration exposure, A(8) of all these 7 different bus drivers surpasses the breaking point of EAV. The highest A(8) is from driver G which was 1.14 m/s² where it needed only 0.01 m/s² to reach the limit of ELV. Generally, the employer should consider all these buses to undergo maintenance as the buses are not fit for driving. Based on ISO 2631-1, the employer need to implement the health monitoring and also control measures. Otherwise, continuous monitoring and assessment on the buses and drivers should be done by employer to overcome the problem.

![Figure 4](image-url)

**Figure 4.** Daily vibration exposure, A(8) in Larkin Central.

VDV was the use of the time integrated fourth power of acceleration. The VDV analysis will be considered as there have shocks and impacts on these bus drivers. Based on ISO 2631-1, when crest factors are above 9, VDV analysis is recommended for evaluation when impulsive exposures are present [4]. Based on Figure 5, the drivers in Putrajaya Central were already exceed the EAV daily VDV exposure level which is 9.1 m/s¹. The value of VDV exposure level in highest and lowest order for drivers E, D, A, C and B were 10.5 m/s¹, 10.2 m/s¹, 10.1 m/s¹, 10.0 m/s¹ and 9.6
According to the VDV exposure level, there were several action needed to be done by the employer as being mentioned in A(8) analysis. Employee need to assess exposure levels, health surveillance for operators exceeding the action level or caution zone and training for management and operators [13].

![Figure 5. Daily VDV exposure (m/s1.75) in Putrajaya Central.](image)

Referred to Figure 6 below, the daily VDV exposure of these 7 drivers in Larkin Central had exceeded the EAV level, meanwhile, there were three drivers(C, E and G) which were now surpassing the ELV level (21.0 m/s1.75) with value of VDV exposure level 21.6 m/s1.75, 21.0 m/s1.75 and 28.1 m/s1.75. The rest are driver B with 20.1 m/s1.75, driver F with 19.2 m/s1.75, driver A with 17.5 m/s1.75 and driver D with 17.2 m/s1.75. The VDV exposure level in Larkin Central was very dangerous and in critical situation. Several requirements were compulsory to be done such as full assessment of vibration levels and engineering to lower down the exposure levels.

![Figure 6. Daily VDV exposure (m/s1.75) in Larkin Central](image)

Table 3 shows the statistical analysis which was correlation analysis. There was no significant correlation analysis that can be done in Putrajaya Central because the daily vibration exposure, A(8) was on the best level. Even though the Pearson correlation showed positive and strong correlation but it was not significant. Effects of vibration on intrastate bus drivers were identified from the Pearson correlation analysis in Larkin Central. The correlation showed positive, strong correlation and significant at p-value was less than 0.05 for Larkin Central. Therefore, the effects of vibration on intrastate bus drivers were identified in Larkin Central which were upper back pain and low back pain.
Table 3: Pearson correlation daily vibration exposure, A(8) with upper and low back pain in Putrajaya Central and Larkin Central

| Sample Size (N) | Upper back pain | Lower back pain |
|-----------------|-----------------|-----------------|
| Putrajaya Central | 5 .720          | .728            |
|                  | .155            | .163            |
| Larkin Central   | 7 .807*         | .745*           |
|                  | .028            | .050            |

*Correlation is significant at the 0.05 level (2-tailed)

Scopes compared were daily vibration exposure, A(8), discomfort and correlation analysis. In Putrajaya Central, no drivers exceeded the EAV or ELV, which meant the overall operation was good in terms of maintenance progress, bus condition and road condition. Meanwhile, all the drivers in Larkin Central surpassing the EAV and one of them was very close to exceed the ELV. Thus, the locations should be identified, marked out, indicated and engineering measures should be taken to control vibration. There were many discomforts faced by the drivers in Larkin Central compared to Putrajaya Central. These discomforts were due to the driving technique, improper manual handling, road surface, suitability of vehicle and also driver age. On the other hand, there were no significant correlation analysis that was done in Putrajaya Central because the daily vibration exposure, A(8) was on the best level. Even though the Pearson correlation showed positive and strong correlation but it was insignificant. However, the Pearson correlation showed positive, strong correlation and significant for Larkin Central. Therefore, the effects of vibration on intrastate bus drivers were identified in Larkin Central which were upper back pain and low back pain.

4. Conclusion

In conclusion, there were several causes to vibration such as speed, design of the vehicles and environmental conditions. Furthermore, the posture of the driver body also was one of the caused that lead to WBV. Awkward postures combined with vibration will amplify the WBV exposure. Other causes such as vehicle maintenance, suspension, seat design and also driver’s skills were known as the caused that lead to WBV. In addition, the results of daily vibration exposure A(8) in Putrajaya Central shown that the drivers did not exceed the exposure action value while the drivers in Larkin Central were surpassing the exposure action value. Meanwhile for VDV exposure, all the drivers surpass the EAV and three drivers in Larkin Central which were C, E and G exceeds the ELV. According to Blaze and SPSS software analysis, the effects of WBV on bus drivers were upper and lower back pain. Several control measures can be implemented by employer to prevent unnecessary exposure by assessing the vibration, review the safe working system previously as far as practicable and organize training to impart knowledge and awareness and to implement health monitoring. Engineering control like proper maintenance or regular servicing of equipment may minimize exposure levels. Hence, this study and future study will unbox perceptions on the importance of lowering down the level of vibration and knowing the effects of it because there are risks and consequences if they neglect it and have no awareness regarding this matter.

5. References

[1] Rohani, M. M., Wijeyesekera, D. C., & Karim, A. T. A. 2013 Bus Operation, Quality Service and The Role of Bus Provider and Driver. Procedia Engineering, 53, 167–178
[2] Katu, U. S., Desavale, R. G., & Kanai, R. A. 2005 Effect Of Vehicle Vibration On Human Body – RIT Experience, 1–9.
[3] Sekulić, D., Dedović, V., Rusov, S., Šalinić, S., & Obradović, A. 2013 Analysis of vibration effects on the comfort of intercity bus users by oscillatory model with ten degrees of freedom. Applied Mathematical Modelling, 37(18-19), 8629–8644
[4] Blood, R. P., Ploger, J. D., Yost, M. G., Ching, R. P., & Johnson, P. W. 2010 Whole body vibration exposures in metropolitan bus drivers: A comparison of three seats. Journal of Sound and Vibration, 329(1), 109–120

[5] Okunribido, O. O., Magnusson, M., & Pope, M. H. 2006 Low back pain in drivers: The relative role of whole-body vibration, posture and manual materials handling. Journal of Sound and Vibration, 298(3), 540–555

[6] Cheung, A. N. and B. 2006 The effects of vibration frequencies on physical, perceptual and cognitive performance physical, perceptual and cognitive, (October).

[7] Taib, M. Y., Ismail, A. R., & Yusoff, A. R. 2010 A Review on Whole Body Vibrations towards Human, (December), 597–602.

[8] Okunribido, O. O., Shimbles, S. J., Magnusson, M., & Pope, M. 2007 City bus driving and low back pain: A study of the exposures to posture demands, manual materials handling and whole-body vibration. Applied Ergonomics, 38(1), 29–38

[9] Kang, T.-H., & Kaizu, Y. 2011 Vibration analysis during grass harvesting according to ISO vibration standards. Computers and Electronics in Agriculture, 79(2), 226–235

[10] Kuorinka, I., Jonsson, B., Kilbom, a., Vinterberg, H., Biering-Sørensen, F., Andersson, G., & Jørgensen, K. 1987 Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Applied Ergonomics, 18(3), 233–237

[11] Granlund, J., & Brandt, A. Bus Drivers ‘ Exposure To Mechanical Shocks Due To Speed Bumps, 8, 1–10.

[12] Foster, G., & Leeuwen, M. Van. 2007 Queensland Mining Industry Health and Safety Conference 2007 Managing Vibration Exposure More recent Standards for WBV exposure