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Acoustic Environment in the Bus: an Empirical Study

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ABSTRACT: Traffic snarl-up or traffic jam is a common phenomenon in Puri, one of the imperative pilgrimage sites for Hindus as well as a popular tourist destination in India. Traffic congestion inevitably produces traffic noise, in turn annoying the drivers, leading to road rage. Keeping this in mind, the present article has monitored and assessed different noise descriptors in 7 different types of buses, totally involving 35 buses in and around Puri, for three years, from 2014 to 2016. The minimum and maximum noise levels have been more than 65.3 dB and 90 dB, respectively. Also, Leq is beyond 80dB, demonstrating a noisy environment inside the bus. The result of Karl Pearson's Correlation Co-efficient clearly indicates that in general, the noise levels have gradually increased from 2014 to 2016. Furthermore, it has conducted a survey to reveal opinions of 156 passengers and 50 drivers of the buses concerning their annoyance from noise pollution.

Keywords: Traffic Noise, Noise in Buses, Acoustic environment, Questionnaire, Puri

INTRODUCTION

The most harmful environmental pollution in today's world is noise pollution. Researchers have been studying the impact of urban road traffic noise on human health. The significant and relatively-recent rise in noise levels has been studied in terms of both magnitude and extent within the congested and poorly-urbanized city of Puri, home to the famous 12th Century Jagannath Temple. It has also been observed that even the remote sea beach area of the city is not free from anthropogenic noise.

As such, the present study has made an attempt to monitor noise levels inside several types of buses in Puri and assess the extent of their noise pollution. This study also demonstrates the perception of bus passengers and drivers about the annoyance they feel from noise pollution. The drivers, who drive the buses within the urban area, are more prone to noise pollution. With the exception of a few studies (Zannin, 2008; Zannin et al., 2003), there has been no similar work to address noise levels inside heavy vehicles; therefore, the present study aims at demonstrating the noise level inside the buses, revealing the impact of noise on bus drivers and passengers.

MATERIALS AND METHODS

Noise levels in 35 buses were equally sampled in seven separate sub-samples: (1) AC deluxe buses, (2) pushback buses, (3) city-ride buses, (4) non-AC buses, (5) (AC) governmental city buses, (6) (non-AC) governmental city buses, and (7) Volvo buses. Capable of carrying up to 40-70 passengers, all of these buses stop at specific bus stop for passengers to get on or get off and can. Diesel is the type of fuel they use.

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Measurements have been carried out in 35 buses in several lines during the whole ride, from the first station to the last one. The measurements were made with the buses, loaded with passengers during the normal working hours, and meteorological conditions, ideal.

Noise levels were measured by means of Model LUTREN, SL-4010 and Model HD2110L sound level meters (De et al., 2017; Goswami, 2009; 2011; Goswami and Swain, 2011; Goswami et al., 2011; 2012a; 2012b; 2013; 2017; Goswami et al., 2013a; 2013b; Pradhan et al., 2012a; 2012b; Sahu et al., 2014; Swain and Goswami 2013a; 2013b; 2014a, 2014b; in press; Swain et al., 2012 a, 2012b; 2013; 2014; 2016; and Mohapatra and Goswami 2012a, 2012b). The equipment got calibrated in accordance with the recommended procedures of the manufacturers. The microphone of the sound level meter was installed 20cm away from the bus driver. Noise exposure level was nominally normalized to eight hours in a working day. The present study was conducted at Puri (Fig. 1) during May, 2014; May, 2015; and March, 2016. Puri is located at 19° 48'North Latitude and 85°52' East Longitude.

Fig. 1. Map of India showing the study area (Puri)

This study measured the A-weighted continuous equivalent sound level values (Leq), Lmax, Lmin, and statistical levels of L_{10} (peak noise), L_{50}, and L_{90} (background noise) for each bus. Equivalent noise levels (Leq) represent the equivalent energy sound level of a steady state as well as invariable sound, including both intensity and length of every sound that occurs within a given period. The value of Leq in dB (A) unit is calculated from the following formula:

$Leq = L_{50} + (L_{10}-L_{90})^2 / 56$ (Robinson, 1971).

Again a comprehensive questionnaire survey (Aslam et al., 2008; Patel and Ingle, 2008; Nassri et al., 2008; Mohammadi, 2014) with different types of information from bus drivers and passengers (their socio-demographic characteristics such as their age, education, experience, and the accidents they had faced for the last five years prior to the interview) was undertaken. The questionnaire also included questions regarding their levels of annoyance due to vehicular noise as well as their attitudes/awareness, concerning the impacts of noise. In total 156 passengers and 50 male drivers were interviewed in one-to-one fashion, using the above-mentioned questionnaire.

The questionnaire contained four sections: the first two sections for the bus drivers and the other two for the passengers. Section A and C included general information about the bus drivers and passengers, respectively, while Section B and D contained different health-related problems of drivers and passengers, respectively. There was no refusal from the selected subjects for answering the questionnaire. Pearson's correlation coefficient was used to know the correlation between the Leq values of all three years (i.e., 2014, 2015, and 2016).

RESULTS AND DISCUSSION

Exposure to continuous noise above the 85 dBA may result in loss of hearing. Based on the frequency of the noise and duration of exposure, this loss varies from person to

person (Melamed et al., 2001). To drive a bus is a stressful job. Ewans and Johansoon (1998) studied health status of these persons, who are always exposed to loud noise and vibration, more often than not encountering collisions and accidents (Rydstedt et al., 1998). Drivers are exposed to high noises levels while driving old, faulty buses on uneven and potholed roads, and filled with passengers. The noise exposure level in a bus depends on factors like the noise from high-speed motors, the traffic sound, the bus route, and the number of people transported. It is generally created by the bus' engine, gear, accelerator, and breaks. Not only does this noise disturb the driver, but it also annoys the passengers as well as other surrounding people (Mukherjee et al., 2003). High noise levels may cause high blood pressure, high pulse rates, enhanced muscle reflexes, and sleep disturbances (Cheung, 2004). Their impact on hearing depends on factors such as noise levels, exposure time, noise frequency, and individual sensitivity, not to mention environmental and physiological factors. Frequencies between 500 kHz and 4000 kHz are important to understand human speech and high noise levels in these frequencies may cause speech interruption (Maltby, 2005).

Noise levels was assessed in 7 different buses, i.e., AC deluxe bus, 2x2 pushback bus, city-ride bus, non-AC bus, governmental city bus (both AC and Non-AC), and Volvo bus, which made up 35 buses in total, for three consecutive years (from 2014 to 2016), which can be seen in Tables 1,2, and 3, respectively. The measured noise levels ranged between 65.7 and 101.5 dB in 2014 (Table 1), between 65.8 and 102.7 dB in 2015 (Table 2), and between 65.3 and 104.6 dB in 2016 (Table 3), with the minimum amount being more than 65.3 dB and the maximum, more than 90 dB. Bus drivers perform their duties in acute noisy environments. Such high amount of noise was mainly generated from the engines as well as honking of horns. In most cases, the episodic noise level of the bus was beyond 90dB. As for all buses, the equivalent noise level was more than 80 dB with the equivalent noise level ranging from 81.6 to 85.7 dB in 2014 (Table 1), from 84.2 to 85.4 dB in 2015 (Table 2), and 84.5 to 86.4 dB in 2016 (Table 3). In these three years, the maximum equivalent noise level was 85.7 dB in 2014 for governmental city bus (AC), 85.4 dB in 2015 for push back bus, and 86.4 in 2016 for volvo bus. The background noise level (L_{90}) of all buses in all three years was beyond 70 dB, which indicates that the bus drivers were greatly annoyed with noise pollution, the extent of which depends on the engine type as well as its maintenance level, not to mention the bus' age. Most of the buses that traffic these roads were more than 5 years old. The highest noise level belonged to 2016.

Figure 2 demonstrates the mean noise level for different buses, showing that the noise level was more or less the same for all three years. There is a positive correlation (r = 0.761) between the year 2014 and 2015, while a negative one exists between 2014 and 2016 (r = -0.463), as well as 2015 and 2016 (r = - 0.493). The correlation coefficient also indicated a good relation between 2014 and 2015.

Table 1. Noise level (dB) variations of different buses at Puri in 2014 (2-5 pm)

Sl. No.	Name of the Buses	Lmax	Lmin	L10	L50	L90	Leq
1	AC deluxe bus	93.9	65.7	85.2	81.3	71.6	84.6
2	2x2 push back bus	99.7	67.3	85.6	81.9	74.1	84.3
3	City-ride bus	101.5	66.5	85.8	80.7	72.5	83.9
4	Non-AC bus (3x2)	100.3	68.3	85.6	81.6	73.7	84.1
5	Governmental city bus (AC)	100.7	69.8	86.1	82.5	72.8	85.7
6	Governmental city bus (non-AC)	100.1	69.1	84.3	80.9	71.6	83.8
7	Volvo bus	99.5	66.5	84.6	79.1	72.8	81.6

Table 2. Noise level (dB) variations of different buses at Puri in 2015 (2-5 pm)

Sl. No.	Name of the Buses	Lmax	Lmin	L10	L50	L90	Leq
1	AC deluxe bus	95.7	66.9	85.5	82.4	73.8	84.8
2	2x2 push back bus	100.1	66.8	85.4	82.3	72.1	85.4
3	City-ride bus	101.1	67.9	84.6	81.9	71.6	84.9
4	Non-AC bus (3x2)	102.7	68.4	86.3	82.6	74.7	85
5	Governmental city bus (AC)	101.1	70.3	86.7	83.3	76.2	85.3
6	Governmental city bus (non-AC)	97.8	68.9	85.9	81.6	72.9	84.6
7	Volvo bus	98.8	65.8	85.3	80.8	71.5	84.2

Table 3. Noise level (dB) variations of different buses at Puri in 2016 (2-5 pm)

Sl. No.	Name of the Buses	Lmax	Lmin	L10	L50	L90	Leq
1	AC deluxe bus	98.9	65.7	87.9	82.8	75.5	85.5
2	2x2 push back bus	101.4	67.2	86.9	82.7	74.9	85.2
3	City-ride bus	103.7	68.7	86.4	82.5	73.8	85.3
4	Non-AC bus (3x2)	104.6	65.3	86.6	82	74.7	84.5
5	Governmental city bus (AC)	100.1	66.8	86.7	83.5	75.6	85.7
6	Governmental city bus (non-AC)	100.5	65.5	87.1	82.6	74.8	85.3
7	Volvo bus	100.1	69.4	86.8	83.3	73.6	86.4

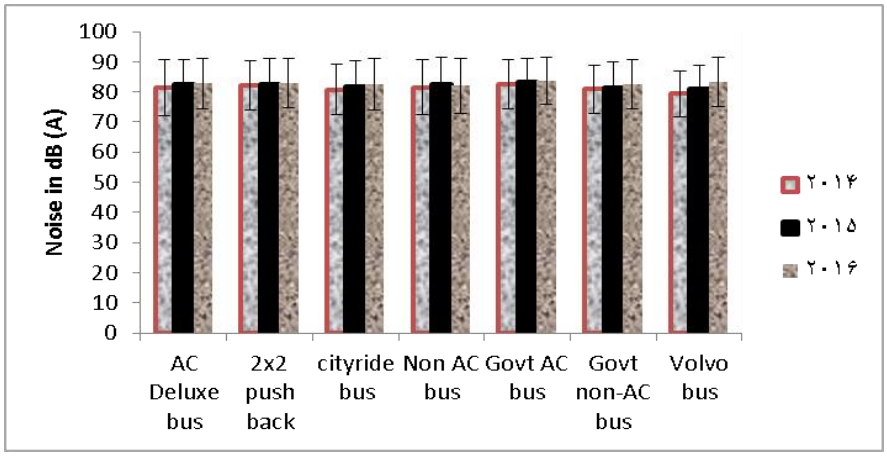

Fig. 2. Mean noise level along with standard deviation of different buses in all three years

The researcher was not able to measure the exact amount of noise exposure in dB but the drivers were certainly exposed to high amount of noise in all roads of Puri. Patwardhan et al. (1991) conducted a study on bus drivers, showed that drivers' noise exposure inside the buses were between 89 to 106 dB. The audiograms of these drivers showed that 89% of them had hearing impairments (Patwardhan et al. 1991). The study of Mukherjee et al., (2003) demonstrated that in case of 49.6% to 55% of the measurements, drivers' noise level was 85 dB or higher in Kolkata, India.

Zannin (2008) showed in his study that among all buses the noise exposure levels were above 65 dB with 56 buses out of the total 60 buses evaluated, having levels, equal to or less than 82 dB. According to Zannin (2008) and Zannin et al. (2003); the age and the location of the engine were relevant factors in determining noise exposure level. Another study, conducted in Brazil in 2010, showed that there was a significant difference in the generated noise among types of buses, with the older ones causing greater noise (Portela and Zannin, 2010). According to the Brazil national standards

(NR-17), a level of exposure exceeding 65 dB (A) within 8 hours of work is considered uncomfortable (Portela and Zannin, 2010; Zannin et al., 2003). Nadri et al. (2012) found that the drivers' level of noise exposure was 79 dB for 8 hours of work in the metropolitan area of Kerman, Iran. In this study, however, the noise exposure levels in all bus types was relatively similar, having just a slight variation. According to Brazilian national standard, drivers' eight hours of work at such noise exposure level is highly detrimental for their health. Although the researchers did not conduct an audiometric study in this study, it can be said that the drivers' hearing ability was in danger. Organization of training, workshops, and awareness programs in order to use of ear muff are some necessary measures to be taken for the drivers.

To reveal the impact of noise exposure on drivers' health; a public survey was conducted in 2015, to which 50 drivers and 156 passengers responded. All drivers were male, between 25 and 45 years old. Forty two (42) of the drivers were matriculate and rests, under-matriculate. Their work experience as a driver was more than 5 years. After a personal discussion with the drivers, the researcher realized that some drivers were working as helper in the same bus before starting to drive it. They did so merely with practice, having had no proper training on driving. But the researcher thinks that if a professional driver does this job after receiving requisite qualification, then their exposure level could be minimized. Twenty (20) drivers replied that their hearing ability was good, while 15 drivers replied that their hearing ability was gradually worsening day by day. Twenty one (21) drivers believed that they could not hear properly while speaking over the phone, 11 could hear without any difficulty, while 12 remained silent on this question. As many as 43% of the drivers said that they felt difficult hearing in the crowd. Thirty two (32) drivers agreed that people often told them that they were talking too loudly. Also, 35 drivers believed that the sound from the bus engine was greatly annoying and irritating. Only 4 drivers responded to the question on how many accidents they had in one year. Thirty three (33) drivers stated that due to the loud noise from the engine as well as the horns, they were suffering from chronic headaches. Among the passengers, 60% stated that the sound produced when honking the horns along with the one from the bus engine was very annoying and said their impotency to do something, as they could not help travelling by bus.

CONCLUSION

It can be concluded that the noise exposure level to the bus driver is directly related to the engine. The engine is the first and honking is the second source of noise for the bus driver, as his is very close to the bus engine. Zannin (2006) has already reported that bus drivers, exposed to noise levels above 85 dB, are prone to hearing loss. In Iran as well as other countries, such as the United Kingdom, Switzerland, Germany, Australia, Brazil, Japan, and India, maximum permissible noise levels for occupational noise exposure is 85dB (A). In the present study, the observed noise level was very close to the 85 dB level, though this noise level was also very uncomfortable for bus drivers as it exceeded 65 dB (Portela and Zannin, 2010; Zannin et al., 2003).

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