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Study of noise hazard in bus interior in Dhaka city

Riyajul Haq, Nashid Mirza and Tanvir Ahmed

Department of Civil Engineering
Bangladesh University of Engineering and Technology, Dhaka 1000, Bangladesh

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Abstract

In a mass transport system, the interior noise environment of the vehicle not only affects the comfort of travel of the passengers but also, most importantly, the health and well-being of vehicle operators. It is widely suspected the operators of mass transit vehicles are at the risk of noise induced physiological and psychological ailments due to long exposure periods or high noise episodes during the course of their daily activities. Here we assess the interior noise level of buses in Dhaka city by carrying out noise surveys inside different types of buses in 29 bus routes. Temporal noise level recording over the trip duration (from origin to destination of the route) was used to determine route-wise noise intensity-duration relationships, equivalent noise levels over typical exposure periods and spatial hotspots of noise pollution. After correction for working shift of the bus operators, the equivalent noise exposure level ranged from 79.8 dBA to 92.9 dBA indicating that there is some degree of variability in experienced noise levels for the different types of buses operating in different routes. The actual working shift hours of the operators of 24 out of the 29 buses exceeded the permissible shift length for an occupational setting as per NIOSH guidelines. Buses in several route-segments were identified to have a higher interior noise compared to others which may be due to high traffic congestion, presence of densely populated areas, poor quality of the bus or lack of engine maintenance. Also, given sufficient exposure duration, noise level in bus interior environment has the potential to exceed recommended WHO/EPA community-level exposure guidelines which might affect the huge number of passengers availing the bus service every day. Findings of this research work shows that level of noise exposure in bus transport system in Dhaka city is high enough to adversely affect the health and productivity of bus operators.

Keywords: Noise exposure, mass transit noise, occupational health and safety, noise induced hearing loss.

1. Introduction

The quality of life of urban dwellers is intricately linked with the roadway noise environment which is continuously under a state of degradation due to expansion of road network and growth in vehicular traffic particularly in developing countries. In both the industrialized and non-industrialized nations, noise in urban areas is a major health and environmental concern for the public as well as for policy-makers. Noise pollution can cause annoyance and aggression, hypertension, high stress levels, tinnitus, hearing loss, sleep disturbances (ANSI 1996) and profound physiological and social impact on affected individuals which may eventually affect work performance, efficiency and reduces the quality of life (Hossain et al. 2013). In a mass transport system, the interior noise environment of the vehicle not only affects the comfort of travel of the passengers but also, most importantly, the health and well-being of vehicle operators who have to work long hours within that environment. In an occupational setting, OSHA and NIOSH workplace noise exposure limits restrict 8-h work shift exposure to 90 and 85 dBA, respectively, in order to protect most workers from compensable hearing loss over a 40-year lifetime working period (NIOSH 1998; OSHA 1983). Abundant literature is available regarding the characterization of urban traffic noise, quantification of outdoor noise and the impact of urban traffic noise on the health and welfare of exposed individuals (Dinno et al. 2011; Ozer et al. 2009; Mangalekar et al. 2012; Mishra et al. 2010; Dursun et al. 2006; Rosenhall et al. 1990; Belojevic 2008). A large body of studies has addressed noise pollution levels at indoor locations adjacent to busy roadways (Mishra et al. 2010; Gershon et al. 2006). However, the quantification of noise pollution levels inside mass transport vehicles as experienced by the operators of the vehicles and the potential effect on their occupational health and safety have received very limited attention (Koushki and Ali 2001, Nadir et al. 2011, Zannin et al. 2003, Mukherjee et al. 2003).

Dhaka is one of the most heavily populated metropolitan cities of the world with significant commuter flows. Approximately 16 million people currently live in the capital city which has a large public transportation system comprising of 7100 buses (STP 2005). Buses are the most dominant mode of public transport and among the mechanized modes of transport buses run the highest passenger-km per day (Rahman and Nahrin 2012). With the rapid increase in traffic, the noise pollution level in Dhaka has increased which has been highlighted in several studies (Haq et al. 1999; Hassan et al. 2013; Ayaz et al. 2011). Noise emitted from the engine, gear, clutch, hydraulic horn, accelerator, brake, etc. during operation of the bus are the main noise sources within and outside the bus (Mukherjee et al. 2003). It is widely suggested that people involved in the operation of buses may be suffering from Noise-Induced Hearing Loss (NIHL) and related ailments (Hossain et al. 2013).

Limited studies are available which have qualitatively assessed the effect of noise on urban dwellers and public transport users (Koushki and Ali 2001). Occupational noise hazard in selected buses and traffic intersections has been studied in a very limited scale in Dhaka city in a recent study (Hossain et al. 2013). This study attempts to expand the previous work through comprehensive noise sampling to gain an understanding of the overall noise environment inside the buses of Dhaka city. Continuous noise level measurements were done over the entire duration of a one-way trip in all 29 bus routes of Dhaka city covering the major portion of the city's road network. Standard noise metrics were used to assess the severity of noise exposure and assess the suitability of the interior noise environment in the bus with respect to NIOSH guidelines. A Noise intensity map delineating hotspots for noise pollution over the bus routes has also been prepared.

2. Methodology

2.1 Route selection and data collection

There are around 39 local (intra-city) buses routes in Dhaka city over which 60 different companies (both public and private) operate their buses. Also, there are several routes which are covered by multiple bus operators. Although the bus routes altogether cover the major roads of the city, the routes do overlap and going from one point to another may require availing multiple bus service options. In order to determine the interior noise environment of these buses and to assess the noise exposure level of the bus operators, 29 different bus service routes were selected for noise level measurements. These routes were chosen in such a way that it covers the entire road network of Dhaka city that are served by the different bus operators. A summary of the bus routes surveyed is provided in Table 1.

Table 1
Summary of the bus routes surveyed and their salient features

Bus Operator Name	Origin	Destination	Trip Distance (km)	Number of intermediate stoppages	Duration of Noise measurement (minutes)
3 no local bus	Abdullapur	Gulistan	21.4	11	110
7 no local bus	Gabtoli	Sadarghat	13.2	10	102
Ashirbad	Azimpur	Mirpur-1	9.7	5	52
Azmiriglori	Sadarghat	Abdullapur	21.5	10	163
Bengal Motors	House-building	Kollanpur	19.4	6	91
Bikolpo	Azimpur	Mirpur-12	13.5	8	91
BRTC	Mirpur-12	Motijheel	15	10	93
BRTC AC	Motijheel	Abdullapur	22.6	12	75
BRTC Double Decker	Abdullapur	Gabtoli	20.3	9	76
Dipon Transport	Motijheel	Mohammadpur	8.8	5	47
DishariPoribahan	Mirpur-1	Gulistan	12.3	7	52
Falgun	House-building	Azimpur	21.4	13	118
JatrabariPoribahan	House-building	Jatrabari	22.8	8	107
KonokPoribahan	Abdullapur	Mirpur-1	16.7	7	49
Midway	Taltola	Mohammadpur	15.3	9	102
MoitriPoribahan	Motijheel	Mohammadpur	8.8	7	51
New Dhaka Link	Azimpur	Mirpur-1	9.4	5	36
New Vision	Mirpur-1	Motijeel	13.3	8	94
Nishorgo	Azimpur	Mirpur-14	16	8	87
ProbatiBonosri	Gulistan	Abdullapur	19.9	9	90
Salsabil	Jatrabari	Abdullapur	21.8	9	89
Shuprobat	Sadarghat	Abdullapur	20.9	10	95
Shotabdiporibahan	Mirpur-14	Motijheel	19.8	11	113
Shuchonaporibahan	Nilkhet	Abdullapur	21	8	73
Transilba	Mirpur-1	Jatrabai	20	11	101
Turagh	Jatrabari	Abdullapur	21.8	7	78
VIP	Azimpur	Abdullapur	21.6	13	73
Winner	Nilkhet	Kuril	16.5	9	94
Cantonment mini service	Mirpur-14	Kakoli	2.6	2	17

Continuous noise level readings were recorded over the entire duration of the one-way trip for a specific route using a data logging noise level meter (Extech HD600). Measurements were carried out by placing the noise level meter near the ear level of the bus driver and conductor over the entire length of a one-way trip of the selected routes under normal operating conditions, that is, within working hours of the day (9:00 am to 7:00 pm)but avoiding rainy conditions, weekends or holidays. Noise level was recorded in decibels (A-weighted) at 30-second intervals. During noise level measurements, a GPS (Etrex-10) was used to track the real-time position of the bus and obtain the travel distance and travel time of the one-way trip. The recorded data was later downloaded in a personal computer and post-processed in Microsoft Excel and MATLAB.

2.2 Basic noise calculation

In order to determine the characteristics of noise and its exposure level, it is necessary to determine the Equivalent Continuous Noise Level (L_{eq}), Noise exposure level (L_{EX}) and Noise Dose. L_{eq} is the equivalent steady sound level of a noise energy-averaged over time. Equivalent continuous noise level can be calculated from the following equations:

$$L_{eq} = 10\log\frac{1}{t}\int_0^t 10^{L(t)/10}dt \tag{1}$$

Where, t = the time over which L_{eq} is determined, $L(t)$ = the time varying noise level (dBA) and L_{eq} = Equivalent Continuous Noise Level (dBA)

Usually $L(t)$is measured in discrete time intervals. This modifies the equation (1) to:

$$L_{eq} = 10\log\frac{1}{t}\sum_{i=1}^{i=n}10^{L_i/10}t_i \tag{2}$$

Where, n = the total number of samples taken, L_i = the noise level (dBA) of the i-th sample and t_i = fraction of total sample time (Davis and Cornwell 2012).

L_{EX} is the sound level, energy-averaged over 8 hours, which would give the same daily noise exposure dose as the varying noise over typical full shift. It is closely related to the L_{eq} which can be calculated using equations (1) or (2) using discrete sound level measurements. In fact, L_{EX} can be regarded as being the measured L_{eq} with a small correction for shift length (Work Safe BC 2007).

$$L_{EX} = L_{eq} + \text{correction for shift length} \tag{3}$$

The decibel correction with which the L_{eq} needs to be adjusted can be obtained from the shift correction chart (WorkSafeBC 2007). Interview with the local bus drivers and conductors revealed that they generally work four days per week with approximately 18 hours (6:00AM to 12:00PM) in a day. Assuming this workload, the shift length duration can be estimated to be 14.4 hours (distributed over a hypothetical 5-day working period) and the shift length correction to L_{eq} can be estimated to be+2.5 dBA.

Noise dose is another single descriptor for noise exposure and may be given in terms of a value relative to unity or 100%. An exposure to sound level 85dBA for 8 hours corresponds to a 100% noise dose which is termed as an “acceptable” amount of noise as per NIOSH guidelines. Noise dose can be calculated using the following equation:

$$ND = 100\times\frac{T}{8}\times 10^{\frac{L_{eq}-85}{10}}\% \tag{4}$$

Where, T = shift length or sampling time, in hours and L_{eq} = A-weighted, sound level linearly energy averaged over T hours.

As per NIOSH guidelines, occupational noise exposure should be controlled so that worker exposures are less than the combination of exposure level (L) and shift length duration (T) as calculated by the following formula (NIOSH 1998).

$$T(\text{min}) = \frac{480}{2^{(L-85)/3}} \tag{5}$$

3. Result and discussion

3.1 Noise intensity-duration relationship

In order to characterize the internal noise environment within different buses in Dhaka city, cumulative noise distribution curves were constructed from the temporal noise measurements from within these individual buses. These distributions indicate the percentage of time a certain noise level is equaled or exceeded within the sampling time in the bus interior. The parameter L_N (L_{90}, L_{50} and L_{10}), a statistical measure which indicates the noise level that is exceeded during N% times, was also determined from the graphs in Table 2. The equivalent level of noise was calculated using Equation 2. The cumulative noise distribution curves of the interior of the 29 buses surveyed are shown in Figure 1. It can be seen that there is a significant variation in the levels of noise exposure within the individual buses serving different routes. The maximum L_{90} (77.3 dBA) was found in Midway bus that operates on the Taltola to Mohammadpur route whereas the minimum L_{90} (65.8 dBA) was found in Azmiriglori bus that operates on the Sadarghat to Khilkhet route.

Table 2
Noise level metrics calculated from interior noise measurements for 29 different bus services

Bus Company	L_{min} (dBA)	L_{avg} (dBA)	Lmax (dBA)	L_{90} (dBA)	L_{50} (dBA)	L_{10} (dBA)	L_{eq} (dBA)
3 no local bus	69.8	78.5	92	72	78.7	85.2	81.3
7 no local bus	69.3	79.3	91.5	74	79.6	84.3	81.3
Ashirbad	71.8	79.6	95.8	72.8	79.2	88.5	83.7
Azmiriglori	61	73.1	89.6	65.8	73.2	81	77.3
Bengal Motors	64.2	77.1	93.7	69	77.7	84.8	81
Bikolpo	60.1	74.6	89	67.2	73.7	82.6	78.4
BRTC	69	78.1	111	72	78	84	89
BRTC AC	68.2	73.6	95.2	69.5	72.9	79	77.6
BRTC Double Decker	70.6	79.2	94.7	74.4	78.9	84.5	81.8
Dipon Transport	74.9	83.1	106.4	77.2	82.2	89	90.4
DishariPoribahan	66	78.3	96	69	80.1	85.3	82.5
Falgun	69	78.5	109	73	77.4	85	86.9
JatrabariPoribahan	70.8	79	88.8	73.8	79.2	83.8	80.8
KonokPoribahan	71.1	82	105.8	76	82.2	88.2	88.3
Midway	72.2	81.4	99.9	77.3	81.2	86.7	83.6
MoitriPoribahan	68.7	77.2	88.8	71.9	77.4	81.5	78.9
New Dhaka Link	66.3	78.2	89.3	71.5	78.6	84.3	80.6
New Vision	49.3	76.8	101.2	67.4	76.8	85.3	83
Nishorgo	65.4	79.9	95.2	74.3	79.5	87.5	83.6
ProbatiBonosri	59.4	74.1	97.2	68	74	81	80.6
Salsabil	73	79.8	101.5	75.2	79.5	83.8	83.8
Shuprobat	70.2	79.1	93.3	73.4	78.8	85.3	81.7
Shatabdiporibahan	66.1	80.9	104.6	72.4	80.3	90	88.8
Shuchonaporibahan	56.2	75.3	96.7	66.2	73.9	81.4	79.6
Transilba	67.7	79.5	90.9	74	79.6	85.3	81.7
Turagh	72.2	79.9	89	75.3	80	85	81.2
VIP	63	78.9	92	72	80.1	84.2	81.3
Winner	63	75.6	96	68	75.4	82	81
Cantonment mini service	68.7	76.9	93.7	71.4	76.3	82.6	81.1

The average value of L_{90} was found to be 71.8 dBA with a standard deviation of 3.1 dBA. The maximum L_{50} (82.2 dBA) was experienced in Dipon transport and Konokporibahan whereas the minimum L_{50} was 72.9 dBA that was experienced in BRTC AC bus which operates on Motijheel to Abdullapur route. The maximum L_{10} (90 dBA) was experienced in Shatabdi poribahan which operates on Mirpur-14 to Motijheel route whereas the minimum L_{10} (79 dBA) was experienced in BRTC AC bus which operates on Motijheel to Abdullapur route. In general, the highest equivalent continuous noise level (90.4 dBA) was found in Dipon transport bus and the lowest equivalent continuous noise level (77.3 dBA) was found in Azmiriglori bus. The lowest minimum noise level was experienced in New Vision bus which was 49.3dBA and the highest maximum noise level was found in BRTC bus which was 111 dBA.

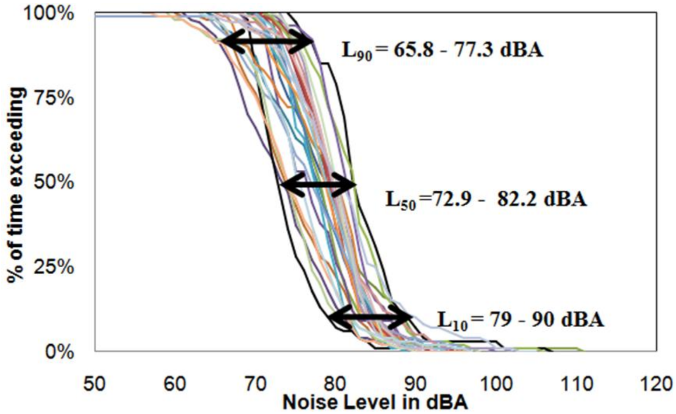

Fig. 1. Noise intensity - duration relationship of interior noise measurements for 29 different bus services. Each line represents the intensity-duration relationship for a single bus operator.

The highest average noise level (83.1 dBA) was experienced in Dipon transport that operates on the Motijheel to Mohammadpur route. The reason for this variance in noise metrics among different routes can be attributed to a number of factors both internal (bus engine type and age, noise insulation, bus type and size) and external (traffic congestion, uncontrolled honking, travel speed, road condition etc.). For example, Dipon transport operates buses with old engines and has a route through most congested areas in the city which might contribute to its high levels of noise. On the other hand, the Air-conditioned BRTC bus, being somewhat insulated from the noise of the exterior environment, has a more acceptable level of noise inside the bus.

3.2 Assessment of occupational noise hazard

Estimated noise exposure level and noise dose were compared with NIOSH guidelines to determine the severity of noise hazard level in the bus interior. An exposure to sound level of 85 dBA for 8 hours corresponds to a 100% noise dose which is perceived as an "acceptable" amount of noise according to the NIOSH guidelines. In fact, L_{EX} could be regarded as being the measured L_{eq} with a small correction. Noise dose and permitted shift length were calculated using Equations 3 and 4. From Table 4 it can be seen that the shift length of 24 among the 29 buses exceeded the permitted shift length as per NIOSH guidelines which indicates that the bus conductors and drivers have been operating buses beyond their safe shift hours with respect to noise exposure. Besides this, the interior noise of 9 buses among 29 buses exceeded Noise Dose as per NIOSH guidelines. According to NIOSH guideline the most severely noise polluted bus services were BRTC (non-air-conditioned) bus which operates in the Mirpur-12 to Motijheel route, Dipon transport which operates in the Motijheel to Mohammadpur route and Konok Poribahan which operates in the Abdullapur to Gabtoli route. Experienced Noise Exposure Levels (L_{EX}) in BRTC bus, Dipon Transport and Konok Poribahan bus were 91.5 dBA, 92.9 dBA and 90.8 dBA respectively. At these exposure levels the permitted shift length according to NIOSH guidelines are 1.78 hours, 1.3 hours and 2.1 hours respectively but actual average shift length for these buses is on an average 14.4 hours which is exceeding that limit. It is estimated that a 30 min daily exposure to 90 dBA of noise (equivalent to a daily 8-h exposure of 78 dBA) for 5 days per week over a 40 year period would be expected to produce a 4 dB loss of hearing at 4 kiloHertz (kHz) in the median individual and an 11 dB loss in the90th percentile individual (EPA 1979, Gershon et al. 2006). Also, a loss of as little as 10 dB averaged across 2 and 4 kHz over both ears may affect speech comprehension (Gershon et al. 2006). In most of the bus routes surveyed, that threshold of noise exposure has been exceeded. This indicates that there is a concern for occupational hazard in this work environment and persons involved in operating buses in roadways of Dhaka city are at the risk of noise-induced ailments due to elevated noise exposure. This can adversely affect the health and productivity of bus drivers and conductors in the long run.

Table 3
Comparisons of noise exposure level of the interior of 29 buses surveyed with NIOSH guidelines

Bus Operator Name	L_{EX} (dBA)	Noise Dose, ND (%)	Permitted Shift Length, (hr)/day	NIOSH Guideline Compliance*
3 no local bus	83.8	77	10.56	Exceeded
7 no local bus	83.8	77	10.56	Exceeded
Ashirbad	86.2	133	6	Exceeded
Azmiriglori	79.8	31	26.6	Not exceeded
Bangole Motors	83.5	72	11.3	Exceeded
Bikolpo	80.9	40	20.67	Not exceeded
BRTC	91.5	452	1.78	Exceeded
BRTC AC	80.1	33	24.8	Not exceeded
BRTC Double Decker	84.3	86	9.4	Exceeded
Dipon Transport	92.9	624	1.3	Exceeded
Dishari Poribahan	85	108	8	Exceeded
Falgoan	89.4	279	6.3	Exceeded
Jatrabari Poribahan	83.3	68	11.8	Exceeded
Konok Poribahan	90.8	385	2.1	Exceeded
Midway	86.1	130	6.2	Exceeded
Moitri Poribahan	81.4	44	18.4	Not exceeded
New Dhaka Link	83.1	65	12.4	Exceeded
New Vision	85	100	8	Exceeded
Nishorgo	86.1	130	6.2	Exceeded
Probati Bonosri	83.1	65	12.4	Exceeded
Salsabil	86.3	137	6	Exceeded
Shuprobat	84.2	84	9.5	Exceeded
Shotabdi poribahan	91.3	432	1.87	Exceeded
Shuchona poribahan	82.1	52	15.6	Not exceeded
Transilba	84.2	84	9.5	Exceeded
Turagh	83.7	75	10.8	Exceeded
VIP	83.8	77	10.5	Exceeded
Winner	83.5	72	11.3	Exceeded
Cantonment mini service	84.3	86	9.4	Exceeded

For 8 hr working hour/day NIOSH limits 85 dBA LEX value and noise dose of 100%

3.3 Variability in noise levels in routes and route-segments

The survey data of 29 bus services was consolidated into nine major routes (which are divided into several route-segments) to portray the interior noise hazard level in buses along specific bus routes. Since the measurement was taken along the travel path of individual buses, it is possible that in some of the routes or route-segments there were multiple samplings of noise since several buses operated over that particular route or route-segment. In order to get a general idea of noise exposure over that route segment, the arithmetic mean of equivalent continuous noise level (L_{eq}) over that particular route-segment was calculated. Figure 2 shows the equivalent continuous noise level (L_{eq}) of 5 out of the 9 major Dhaka city bus routes over which the 29 bus service companies operated.

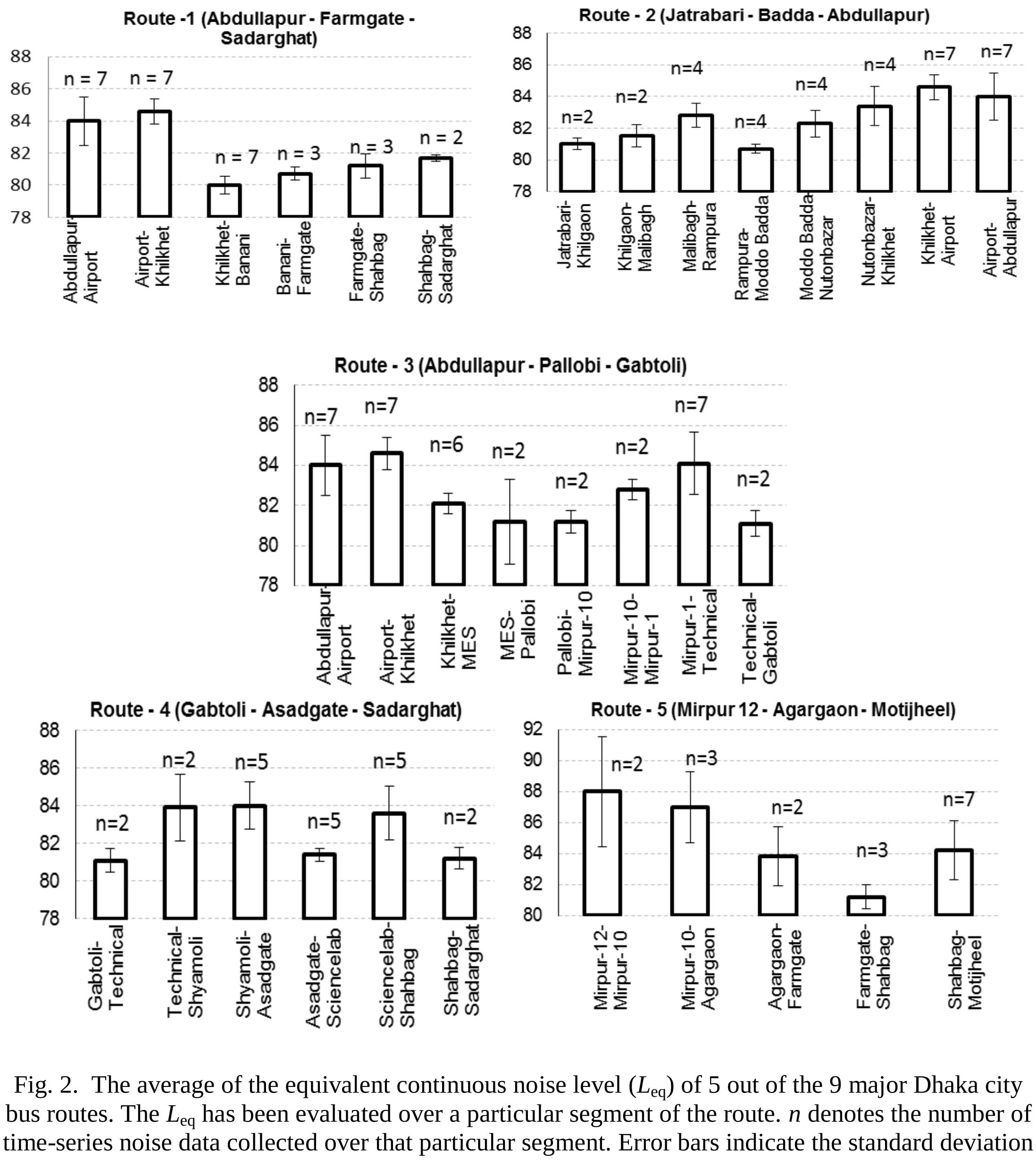

Fig. 2. The average of the equivalent continuous noise level (L_{eq}) of 5 out of the 9 major Dhaka city bus routes. The L_{eq} has been evaluated over a particular segment of the route. *n* denotes the number of time-series noise data collected over that particular segment. Error bars indicate the standard deviation of L_{eq} over the *n* samples. The vertical axis in the figure represents the equivalent noise levels in dBA.

It can be seen from the figure that there is significant variability in noise exposure in different segments along a particular route which can also be attributed to different factors stated in section 3.2. For example, in route 1, the highest average equivalent continuous noise level (84.6 dBA) was found in the 2.8 km long Airport to Khilkhet route segment. This can be attributed to the high velocity in which the vehicle moves (consequently generating more noise) in this segment since it is comparatively less congested compared to other segments. The presence of major road intersections and mixed and commercial areas within a segment can also contribute to the interior noise from external sources. This may be true for the case of Mirpur-12 to Motijheel route (Route 5 in Figure 2) which has a relatively higher average noise level compared to the other routes. This route goes through mixed and commercial areas as well as busy intersections. Using the information of individual route segments, a bus interior noise level map of the average experienced L_{eq} for Dhaka city is prepared as shown in Figure 3. From this map it can be seen that the 85 dBA average equivalent continuous noise level is exceeding in Mirpur-12 to Mirpur-10, Mirpur-10 to Agargaon and Mohammadpur to Sciencelab route segments.

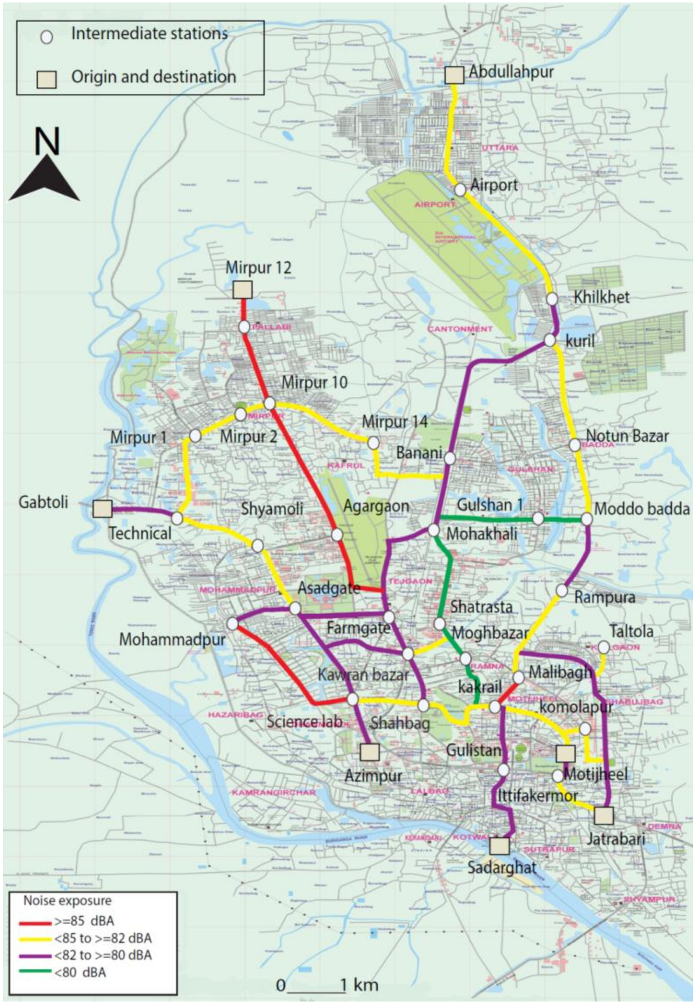

Fig. 3. Interior Noise (Average L_{eq}) Level Map of Buses in Dhaka City

From the bus interior noise level map, hotspots of noise pollution were identified in Dhaka city bus routes (Figure 4). In this study, the route segments considered as hotspots of noise pollution are those segments that have average equivalent continuous noise level above 84 dBA. The hotspots of noise pollution are generally coincident with areas having high population density, high number of commercial establishments and high number of road intersections.

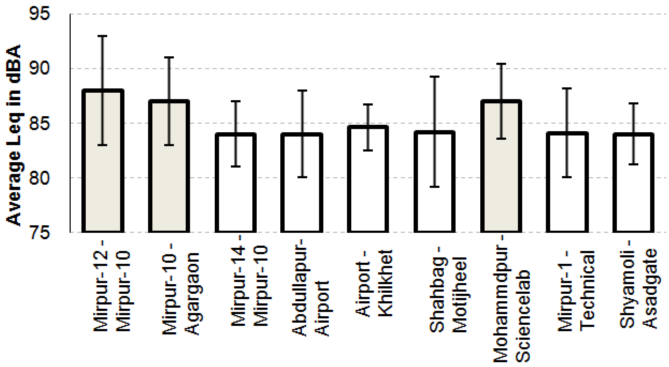

Fig. 4. The major hotspots of noise pollution in Dhaka city bus routes. Among these, the Mirpur-12 to Mirpur-10, Mirpur-10 to Agargaon and Mohammadpur to Sciencelab route segments have the highest levels of noise with the average exceeding 85 dBA.

4. Conclusion

With the increase of industrialization and urbanization, noise pollution has become more pervasive in urban settings of Bangladesh especially in Dhaka city. Findings of this research work has shown that level of noise in bus interior in Dhaka city urban area is high enough to adversely affect the health and well-being of people operating these buses in the road environment. The assessment is based on the analysis from continuous noise level measurements carried out over the entire trip duration over several bus routes. The bus drivers and conductors are the most vulnerable working groups since their profession compels them remain inside the vehicle at all times over long hours in a very noisy environment and often cutting short the working hours is not a decision they will decisively make on their own. It is imperative that a separate study should be initiated in assessing the extent of NIHL that this working group is suffering. Loss of hearing test, determined by audiometric measurements of hearing threshold levels at various frequencies, may be conducted for this purpose.

While the interior noise of the buses poses a risk to occupational safety of the bus operators, the exposure to passengers can also be a cause for concern, given sufficient exposure duration. EPA and WHO recommend lower daily exposures compared to the NIOSH/OSHA guidelines (75 dBA for 8 h, or 85dBA for 47.5 minutes) to prevent any hearing loss among exposed individuals in a community setting (EPA 1974). Depending on the amount of time being spent travelling, there is a possibility that these thresholds may be exceeded in most of these bus routes. Additional studies are required to fully characterize this risk and devise effective risk management strategies. The bus transportation system in Dhaka is plagued with many problems such as poor quality of service, private sector monopoly on the bus sector with poor government oversight on them, buses operating without fitness certificates, lack of maintenance of engines etc. All or some of these problems may be directly contributing to the poor noise environment inside the bus. A thorough investigation into the factors causing high interior noise in the bus needs to be done which may be useful in designing mitigation measures to attenuate the noise. With the rapidly growing rate of infrastructural development, unplanned urban land-use change and weak transportation system it is almost certain that problems associated with noise pollution in bus interiors will become more prominent. A concerted effort involving all stakeholders is required to devise practical solutions to the problem.

References

ANSI (1996).Determination of occupational noise exposure and estimation of noise-induced hearing impairment (S3.44-1996). New York, NY: American National Standards Institute. Report No.: S3.44-1996.

Ayaz, S. B. and Rahman, M. M. (2011), Assessment of Roadway Noise Level and Potential Mitigation Measures, DUET Journal, 1(2).

Belojevic, G. (2008). Urban Road Traffic Noise and Blood Pressure and Heart Rate in Preschool Children, Environment International,34 (2): 226–231.

Davis, M. and Cornwell, D. (2012), Introduction to environmental engineering, McGraw Hill Publication.

Dinno, A., Powell, C. and King, M. M. (2011), A Study of Riders' Noise Exposure on Bay Area Rapid Transit Trains, Journal of Urban Health: Bulletin of the New York Academy of Medicine, 88(1): 1007-1011.

Dursun, S., Ozdemir, C., Karabork, H. and Kocak, S. (2006), Noise pollution and map of Konya city in Turkey, Int. Environmental Application & Science, 1(1-2): 63-72.

EPA (1978). Noise: A Health Problem United States Environmental Protection Agency, Office of Noise Abatement and Control, Washington, D.C. 20460, August, 1978.

Gershon, R. R. M., Neitzel, R., Barrera, M. A. and Akram, M. (2006), Pilot Survey of Subway and Bus Stop Noise Levels, Journal of Urban Health: Bulletin of the New York Academy of Medicine, 83(5).

Haq, M. A., Islam, M. M., Ali, M. S., Haque, M. F. and Akhand, M. M. R. (2012), Status of Noise Pollution in Mixed Areas of Dhaka City: a GIS Approach, J. Environ. Sci. & Natural Resources, 5(1): 09-17.

Hassan, A. and Alam, J.B. (2013), Traffic Noise Levels at Different Locations in Dhaka City and Noise Modeling for Construction Equipment, International Journal of Engineering Research and Applications (IJERA), 3(2): 1032-1040.

Hossain, M. I., Rashid, K. N. and Ahmed, T. (2013), Assessment of Occupational Noise Hazard in Road Ways and Traffic Intersections in Dhaka city, Journal for Civil Engineering, IEB, 41(2): 111-122.

Koushki and Ali, (2001), Exposure to noise inside transit buses in Kuwait: measurements and passenger attitudes, Transport Reviews: A Transnational Tran disciplinary Journal, 22(3): 295-308.

Mangalekar, S.B., Jadhav, A.S. and Raut, P.D. (2012), Study of Noise Pollution in Kolhapur City, Maharashtra, India, Universal Journal of Environmental Research and Technology, 2(1): 65-69.

Mishra, R. K., Parida, M. and Rangnekar, S. (2010), Evaluation and analysis of traffic noise along bus rapid transit system corridor, Int. J. Environ. Sci. Tech., 7 (4): 737-750.

Mukherjee, A. K., Bhattacharya, S.K., Ahmed, S., Roy, S.K., Roy chowdhury, A. and Sen, S. (2003), Exposure of drivers and conductors to noise, heat, dust and volatile organic compounds in the state transport special buses of Kolkata city, Transportation Research Part D 8: 11–19.

Nadir, F., Monazzam, M. R., Khanjani, N., Ghotbi, M. R., Rajabizade, A. and Nadir, H. (2011), An Investigation on Occupational Noise Exposure in Kerman Metropolitan Bus Drivers, International Journal of Occupational Hygiene, 4(12): 5435-5440.

NIOSH (1998). Criteria for a recommended standard: occupational noise exposure, revised criteria 1998. Cincinnati, OH: US Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. Report No.: DHHS (NIOSH) 98- 126.

Ozer, S., Yilmaz, H., Yeil, M. and Yeil, P. (2009), Evaluation of noise pollution caused by vehicles in the city of Tokat, Turkey, Scientific Research and Essay, 4(11): 1205-1212.

Rahman, S. R., and Nahrin, K. (2012), Bus Services in Dhaka City – Users, Experiences and Opinions, Journal of Bangladesh Institute of Planners, 5: 93-105.

Rosenhall, U., Pedersen, K. and Svanborg, A. (1990). Presbycusis and noise-induced hearing loss, Ear Hear,11 (4): 257–263.

WorkSafeBC, (2007). Occupational Noise Surveys and Basic Noise Calculations, Workers. [http://www.worksafebc.com/publications/health_and_safety/by_topic/assets/pdf/occupational_noise_surveys.pdf]

Zannin, P. S. T., Diniz, F. B., Giovanini, C. and Ferreira, J. A. C. (2003), Interior noise profiles of buses in Curitiba, Transportation Research Part, 8: 243–247.

EPA (1979). Protective noise levels: condensed version of EPA levels document. U.S. Environmental Protection Agency Report No. 550/9-79-100. Washington, District of Columbia, U.S.

WHO (1999). In: Berglund B, Lindvall T, Schwela D, eds. Guidelines for Community Noise. Geneva: World Health Organization; 1999.

EPA (1974). Information on levels of environmental noise requisite to protect public health and welfare with an adequate margin of safety U.S. Environmental Protection Agency Report 550/9-74-004, Washington, District of Columbia, U.S.

OSHA (1983). Occupational Noise Exposure: Hearing Conservation Amendment; Final Rule. Fed Reg Washington, District of Columbia: U.S. Department of Labor, Occupational Safety and Health Administration.1983:9738–9785.

STP (2005). Urban transport policy: the strategic transport plan (STP) for Dhaka. Dhaka Transport Coordination Board (DTCB).