Statistical Analysis of Traffic Noise Status at Selected Junctions in Port Harcourt Metropolis

Abstract

Traffic noise is one of the dominant forms of environmental pollution in most urban cities that adversely affect human health globally. The traffic noise emanating from motor vehicles has become a common health problem in many metropolitan cities in developing countries of the world. This study evaluated traffic noise at selected major junctions (Rumuola, Garisson, Boro Pack, and Lagos Bus stop) in Port Harcourt Metropolis. Traffic noise levels at four congested junctions and a control junction in the Metropolis were monitored using a digital sound level meter. Noise indices, L_{10}, L_{50}, L_{90} equivalent noise levels (L_{eq}), noise climate (NC), noise pollution index (NPI); traffic noise index (TNI); noise pollution level (L_{np}); day-evening-night equivalent metric (L_{DEN}) and percentage highly annoyed (%HA) were statistically determined. Traffic noise at Rumuola junction showed traffic noise ranging from 51.9 to 107.9dBA with a mean deviation of 91.3±8.4dBA; traffic noise at Garrison junction ranged from 52.8 to 107.6dBA with a mean deviation of 88.5±9.7dBA; Boro Park junction showed traffic noise ranging from 48.9 to 106.4dBA with a mean deviation of 83.7±10.1dBA; Lagos Bus Stop junction ranged from 45.4 to 94.9dBA with a mean deviation of 81.5±10.8dBA; while the Control junction (Ibadan Street junction)showed a traffic noise ranging from 48.4 to 61.3dBA with a mean deviation of 51.6±5.3dBA. Noise levels at the studied junctions were significantly high and exceeded permissible limit compared to the control junction *(p-value = 0.00485; 95%CI).* L_{10} (94.8dBA), L_{50} (86.8dBA), L_{90} (76.1dBA) and L_{eq} (92.4dBA) were highest at Rumuola junction and lowest at Control junction (with 57.3dBA, 52.8dBA, 48.4dBA and 54.1dBA, respectively). Computed NPI values (1.25-1.34) indicated high traffic noise levels at the four junctions and low (0.77) at the control junction; L_{np} values (105.0-116.6dBA) indicated high traffic noise pollution at the four junctions and low (63.0dBA) at the control junction; TNI values (120.9-138.5) indicated high traffic noise impacts at the four junctions and low (54.0) at the control junction. Computed L_{DEN} and %HA indicated high level of traffic noise annoyance to the four junctions. The study revealed high traffic noise pollution at the four junctions that may significantly affect public health and therefore requires further investigation by concerned authorities to assess the health effects of traffic noise on the surrounding residents and traders at the studied junction.

Key words: equivalent noise level, noise climate, noise pollution index, traffic noise index, noise pollution level, day-evening-night.

1. Introduction

Noise pollution is a significant environmental problem in many rapidly growing urban cities of developing countries [1, 2]. Recently, road traffic noise has been recognized as one of the main sources of environmental pollution in urban cities and a common characteristic of improperly planned urban cities in developing countries such as the metropolitan city of Port Harcourt in Nigeria [1, 3]. The fast expansion of Port Harcourt metropolis in recent times due to urbanization has led to the growth of residential settlements, commercial businesses and a number of industries. This has resulted in rapid population growth in the City of Port Harcourt and has consequently led to the increase in the means of transportation in the City, thereby putting more pressure on the available infrastructures such as roads [4, 5]. In an attempt to provide social amenities and infrastructures in the Metropolis, the government has embarked on the construction of some road networks, most of which often experienced heavy vehicular flow and have also been overtaken by traders carrying out different activities along the roads resulting in traffic congestion with enormous amount of noise generated by motor vehicles.

Nowadays, traffic noise has become a serious problem in Port Harcourt metropolis of Rivers State because of lack of proper urban planning. People living around these roads and those doing business in close proximity to the roads are often exposed to noise pollution emanating from vehicular traffic, which may negatively affect their health [4, 5]. It is well established that noise pollution portends potential hazard to human health and the enjoyment of social life [6, 7]. The problem is further compounded by increase in traffic volumes (heavy trucks, light motor vehicles and motor cycles/tricycles) far beyond the expectations of the early urban planners in the State [8, 9, 10, 11]. The negative effects of noise pollution due to road traffic is enormous ranging from psychological effects such as irritability, annoyance, sleeplessness to physical effects such as hearing loss, physiological effects such as blood pressure [6, 12, 13]. Notwithstanding the few previous studies carried out on noise pollution in the city of Port Harcourt, traffic noise at major junctions in the City has not been appropriately characterized and analyzed using a combination of noise descriptors. To mitigate noise pollution in developing urban cities such as Port Harcourt Metropolis, analysis and evaluation of traffic noise descriptors is required so that the noise impacts at busy junctions can be predicted in advance during the planning and design process of roads. In this study, empirical mathematical models based on statistical regression approach were employed for predicting road traffic noise descriptors in Port Harcourt metropolis of Rivers State, Nigeria. The noise descriptors evaluated in this study include logarithm average (L_{avg}), L_{10}, L_{50}, L_{90}, equivalent noise level (Leq), Noise climate (NC), noise pollution level (L_{np}), traffic noise index (TNI) and traffic noise pollution index (NPI).

Due to the fluctuating nature of sound pressure levels, various indices have been developed to describe the variations of noise levels over time [14, 15, 16]. In certain cases, it may not be adequate to describe the fluctuation in noise levels using Leq only. Thus, the need to use other noise descriptors. The noise descriptors used to describe the variations or fluctuations in measured sound pressure levels are L_{10}, L_{50} and L_{90}; while the noise indices or metrics used to describe the pollution levels or impacts of noise levels in an area include equivalent noise levels, noise climate, noise pollution index, traffic noise index and noise pollution levels. The equivalent sound level known as L_{eq} is used to describe the fluctuating sound heard over a specific time period as if it is a steady, unchanging sound. L_{10}, L_{50}, and L_{90}, and L_x, are statistical sound level descriptors also used to indicate noise levels that exceeded10, 50, 90, and x percent of the time, respectively [14, 15, 17]. The maximum sound pressure level (L_{max}) is the highest A-weighted noise level obtained at a particular event during the fluctuation of sound pressure with time [14, 15, 17].

2. Materials and Methods

2.1 Study Area

Port Harcourt metropolis is the capital of Rivers State and lies between Latitudes 4^o45’N and 4^o55’N and Longitudes 6^o55’E and 7^o05’E along the coastal area of the State. The Metropolis is also a major industrial and commercial centre in Rivers State with fast growing population density. It is a developed City with several networks of roads and intersect junctions (Figure 1). The roads are often congested by heavy vehicular traffic. The studied junctions are Rumuola junction, Garrison junction, Boro Park junction, Lagos Bus Stop junction, and Control (Ibadan Street) junction. The coordinates of the study junctions are shown in Table 1; while the detail of the locations of the junctions is shown in Figure 1.

Table 1: Coordinates of studied junctions

s/n	Junction	Latitude (N)	Longitude (E)
1	Rumuola	$4^0$49’56.28’’	$7^0$00’16.18’’
2	Garrison	$4^0$48’21.29”	$7^0$00’33.33”
3	Boro Park	$4^0$47’18.23”	$7^0$00’11.91”
4	Lagos Bus Stop	$4^0$45’42.29”	$7^0$01’07.87”
5	Ibadan street (Control)	$4^0$45’25.06”	$7^0$01’57.00”

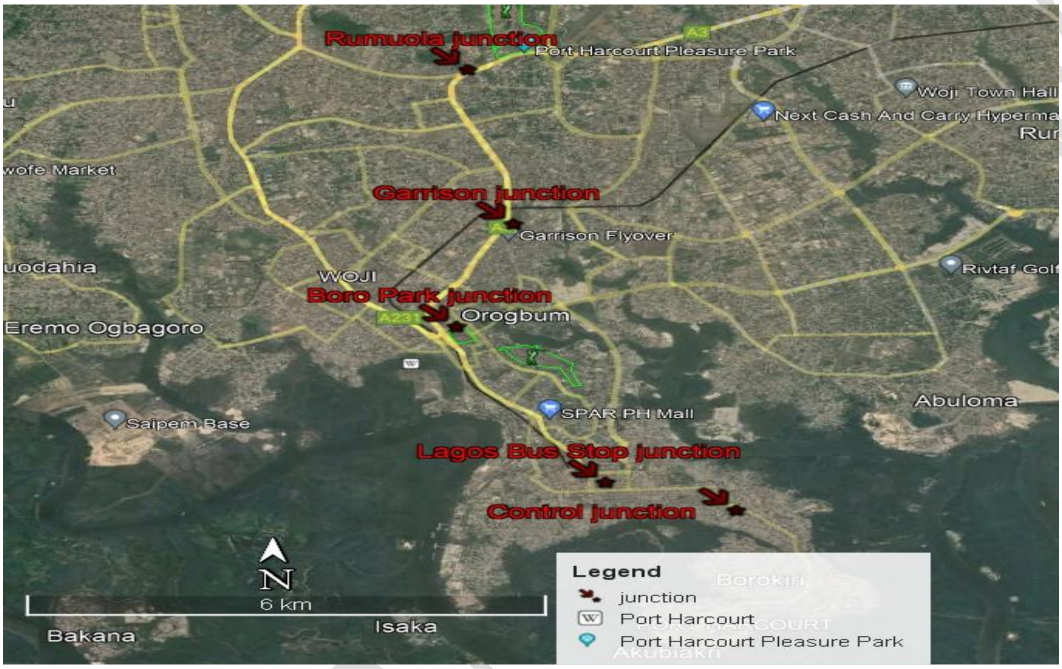

Figure 1: Google map of the study area

2.2 Noise measurement

Traffic noise monitoring of the study area was conducted within a duration of seven days (from Monday to Sunday). A systematic monitoring of traffic noise was conducted from 7:00am to 12 midnights (16hours). Values of sound pressure levels at each monitoring location were obtained and recorded using an Extech digital sound level meter (Model 407730), Smart Sensors digital sound level meter (Model AR854) and a TES (Model 1352H) sound level meters. The noise meters was placed at 1.5 meters above ground level in accordance with ISO 9613 noise measurement procedure [18]. The instrument were set on fast response and maximum position to enable the capturing of vehicular noise. They were calibrated in the field using a noise calibrator. Recording of sound pressure levels was carried out at 10-minutes intervals. Subsequently, the values of the logarithm average (L_{avg}) and noise indices (L_{10}, L_{50}, L_{90}, NC, Leq) were determine for each study junction.

2.3 Calculation of Relevant Noise Indices

The logarithm average of measured sound pressure levels were computed using Equation (1) as contained in Davis and Cornwell [15].

$$L_{avg} = 20\log\frac{1}{N}\sum_{j=1}^{N}10^{L_j/20} \qquad (1)$$

Where, Lavg is the logarithm average sound pressure level in dB (reference 20µPa), N is the number of measurements, L_j is the j^{th} sound pressure in dB (reference 20µPa) for j = 1, 2, 3, ……, N.

The equivalent continuous sound level (Leq) for the measured discrete noise values was computed using Equation (4) as expressed in (Kiely [14], Davis and Cornwell [15] and Sincero and Sincero [17].

$$L_{eq} = 10\log\sum_{i=1}^{i=n} 10^{L_i/10} t_i \qquad (2)$$

Where n is the total number of measured noise levels, L_i is the noise level in dBA of the i^{th} sample and t_i is the fraction of the total sample time.

Noise climate (NC), noise pollution level (L_{np}), traffic noise index (TNI) and traffic noise pollution index (NPI) were determined using empirical equations (3) to (8) found in Nwaogazie [19], Swain and Shreerup [20], Selman [21] and Ramakrishna et al [16].

$$NC = L_{10} - L_{90} \qquad (3)$$

$$L_{np} = L_{50} + (NC) + \frac{(NC)^2}{60} \qquad (4)$$

$$TNI = 4*(NC) + L_{90} - 30 \qquad (5)$$

$$NPI = \frac{L_{eq}}{\text{Ref. value}} \qquad (6)$$

The World Health Organization (WHO) has provided an empirical mathematical equation for the calculation of day-evening-night equivalent metric (L_{DEN}) as shown in Equation (7) [6]. Equation (7) was used to compute and predict noise exposure during morning, evening and night hours. Also, the percentage of people who are highly annoyed (%HA) because of road traffic noise was computed using Equation (8) [6]. According to the WHO [6] L_{DEN} and %HA are useful noise indicators, which can be used to assess and predict the levels of noise annoyance and other noise effects in the exposed population. The measured noise values were scaled up o 24hours for the determination of day-evening-night equivalent metric.

$$L_{DEN} = 10*\log\frac{1}{24}\left(12*10^{\frac{L_{day}}{10}} + 4*10^{\frac{L_{evening}+5}{10}} + 8*10^{\frac{L_{night}+10}{10}}\right) \qquad (7)$$

Where, L_{day} is the 12 hours, computed day time L_{eq} , $L_{evening}$ is the 4 hours computed evening time L_{eq}, and L_{night} is the 8 hours computed night time L_{eq}.

$$HA(\%) = 0.5118(L_{DEN} - 42) - 1.436*10^{-2}(L_{DEN} - 42)^2 + 9.868*10^{-4}(L_{DEN} - 42)^3 \qquad (8)$$

2.4 Data Analysis

Collected data were analyzed using Microsoft Excel. Logarithm average (L_{avg}) and standard deviations (SD) values of the noise values were computed for each sampling junction. The equivalent continuous sound level (Leq) and noise pollution level (Lnp) of the traffic noise levels were mapped using inverse distance weighting (IDW) interpolation method in ArcGIS software. This was performed to determine the spatial distribution L_{eq} and L_{np} across major junctions within Port Harcourt Metropolis.

3. Results and discussion

The statistical summary of noise levels at the junctions are shown in Table 2. The computed traffic noise descriptor metrics for the study area are presented in Table 3. The computed day-evening-night equivalent noise metrics are shown in Table 4. The test of significance comparing noise levels in the study area and the control junction is shown in Table 5. The plots of L_{max}, L_{avg} and L_{eq} values in comparison with the National Environmental Standards and Regulatory Enforcement Agency (NESREA) and World Health Organization (WHO) permissible standards are shown in Figure 2.

The summary result shown in Table 2 shows that noise levels at Rumuola junction ranged from 51.9dBA to 107.9dBA with a mean deviation of 91.3±8.46dBA; noise levels at Garrison junction ranged from 52.8dBA to 107.6dBA with a mean deviation of 88.5±9.7dBA; noise levels at Boro Park junction ranged from 48.9dBA to 106.4dBA with a mean deviation of 83.7±10.1dBA; noise levels at Lagos Bus Stop junction ranged from 45.4dBA to 94.9dBA with a mean deviation of 81.5±10.8dBA; while noise levels at the control junction ranged from 48.4dBA to 61.3dBA with a mean deviation of 51.6±5.3dBA. Figure 2 indicates that the maximum, arithmetic mean and Leq values at all the junctions exceeded WHO/NESREA permissible limit of 70dBA [6, 22]; while these values fall below the limit at the control junction.

Table 2: statistical summary of noise levels measured in the study area

Location/noise statistics	L_{Min} (dBA)	L_{Max} (dBA)	Logarithm Mean (dBA)	SD (dBA)
Rumuola junction	51.9	107.9	91.3	8.4
Garrison junction	52.8	107.6	88.5	9.7
Boro Park junction	48.9	106.4	83.7	10.1
Lagos Bus Stop junction	45.4	94.9	81.5	10.8
Control junction	48.4	61.3	51.6	5.3

SD = standard deviation

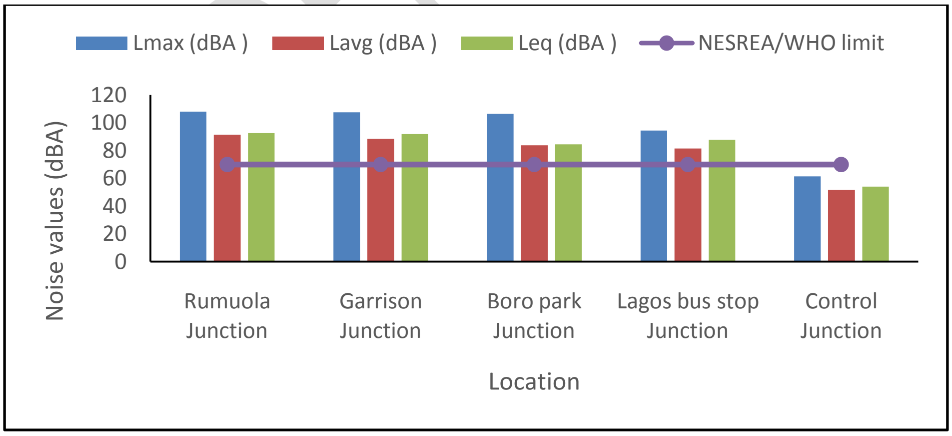

Figure 2: Computed average L_{max}, L_{avg}, and L_{eq} values in comparison with permissible limit

Table 3: Results of computed traffic noise descriptors

Location	L_{10} (dBA)	L_{50} (dBA)	L_{90} (dBA)	NC (dBA)	L_{eq} (dBA)	L_{np} (dBA)	TNI	NPI
Rumuola junction	94.8	86.6	76.1	18.7	92.5	111.2	120.9	1.32
Garrison Junction	91.7	82.7	68.5	23.2	91.7	115.0	131.3	1.31
Boro park Junction	87.9	77.7	68.3	19.6	84.1	104.0	116.7	1.21
Lagos Bus Stop junction	86.3	74.9	58.9	27.4	87.6	105.0	138.5	1.25
Control junction	57.3	52.8	48.4	8.9	54.1	63.0	54.0	0.77

Table 4: Computed day-evening-night equivalent metric

Location	L_{egDay} (dBA)	$L_{egEvening}$ (dBA)	$L_{egNight}$ (dBA)	L_{DEN} (dBA)	%HA
Rumuola junction	102.9	104.9	86.5	104.4	215.8
Garrison junction	98.3	114.3	77.5	111.63	299.1
Boro Park junction	95.1	99.4	76.7	98.04	157.2
Lagos bus stop junction	91.7	95.1	67.2	93.91	125.9
Control junction	53.2	49.8	47.9	51.3	27.3

Table 5: Analysis of variance (ANOVA) test of significance

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	22215.2	1	22215.2	9.406674	**0.0048522**	9.317655
Within Groups	32870.78	8	4108.847			
Total	55085.98	9				

The results (shown in Table 3) indicate that the average L_{10} and L_{50} values exceeded NESREA and WHO permissible limit of 70dBA at all the junctions in the study area; while average L_{90} values exceeded the permissible limit at Rumuola junction, indicating high traffic noise levels at the junctions. In a similar study Okeke and George [23] obtained average L_{10}, L_{90} and L_{50} values of 94dBA, 87dBA and 78dBA respectively around Rumuola junction. The high values of L_{10} and L_{50} show evidence of high noise levels around the study junctions, which may negatively affect human health and should be of health concern to decision makers in the City.

It is clear from Table 3 that the average noise climate at the studied junctions ranged from 8.9dBA at Control junction to 27.4dBA at Lagos Bus Stop. In a similar study Okeke and George [23] obtained an average noise climate value of 16.0 at Rumuola junction. The noise climate obtained at Rumuola junction suggests less fluctuation of traffic noise levels, indicating steady traffic congestion at the junction [24]. Rumuola and Lagos Bus Stop junctions are located in densely populated areas within Port Harcourt metropolis with many residential and commercial buildings. The clustering of buildings around these junctions may cause a reflection of traffic noise, thereby increasing the levels of noise climate within these areas.

L_{eq} values at the studied junctions ranged from 54.1dBA at the control junction to 92.5dBA at Rumuola junction. The computed mean L_{eq} values at the studied junctions exceeded NESREA and WHO permissible limit of 70dBA, suggesting high levels of noise pollution around the junctions, which may be injurious to human health. The L_{eq} value at the control junction is below permissible limit, indicating low traffic noise pollution at control junction that poses no risk to public health.

The computed average noise pollution levels (Table 3) showed minimum value of 63.0dBA at the control junction and maximum value of 115.0dBA at Garrison junction. In a similar study, Okeke and George [23] obtained an average noise pollution levels value of 108dBA around Rumuola junction. Computed average noise pollution levels exceeded the recommended threshold value of 88dBA [25], indicating high level of noise pollution in the study area. This is as a result of the influence of high traffic volume observed around the junctions. The noise pollution levels are also determined by the equivalent continuous noise (L_{eq}) and the noise climate (NC) of the around junctions [21, 26]. Comparatively, computed average noise pollution levels were observed to be higher than computed average traffic noise index, which is due to high levels of noise climate obtained surrounding the junctions. This finding is contrary to the finding of Nassiri et al. [26] who in their study obtained noise pollution levels that were higher than traffic noise indices.

Traffic noise index was minimum (54.0) at the control junction and maximum (138.5) at Lagos Bus Stop junction. In a similar study, Okeke and George [23] obtained an average traffic noise index value of 117.0 at Rumuola junction. The high TNI values indicates that there are high noise pollution levels around the junctions in the study, resulting from heavy traffic volume around the junctions [5, 8, 16, 23, 27]. According to Shalini and Kumar [25], Chiedu et al. [27] and Kumar and Srinivas [28], a TNI value above 74dBA has been considered a threshold of annoyance in people. Traffic noise index also shows the psychological and physiological effects of noise [21, 29]. The computed high average values of traffic noise indices for all study junction are capable of causing annoyance to the exposed population around the road junction, particularly, business owners or shop owners.

The computed noise pollution index showed minimum (0.77) at the control junction and maximum (1.32) at Rumuola junction. In a similar study, Nassiri et al. (2016) reported a traffic noise impact index of 1.5 in a District of Tehran City, Iran. The range of noise pollution index values indicate high noise pollution levels around the study junctions, which are hazardous to human health. The study shows that the noise levels around the study junctions is significantly high compared to the control junction *(p-value = 0.00485; 95%CI)* as indicated in Table 5. This finding also agrees with the study by Ajoku and Amadi-Wali [4] and Fred-Nwagwu et al. [5] who in their studies reported high noise pollution around some junctions in Port Harcourt metropolis, caused chiefly by heavy traffic. The finding also corroborated the study by Iwuoha and Avwiri [11] who reported significant level of noise pollution within Port Harcourt Metropolis.

L_{eq} and L_{np} provided a general assessment of noise pollution status at the junctions. NPI assesses that degree of traffic noise pollution at the junctions; while TNI assesses the impact of noise at the junctions. Judging from the fact that noise climate is computed as the difference between L_{10} and L_{90} (the residual), noise climate can be considered as the predicted contribution of vehicular traffic to noise at the junctions. It is evidently clear from the noise climate values (shown in Table 4) that vehicular traffic contributes substantially to noise pollution at the junctions. Other potential sources of noise at the junctions may be due to commercial activities with the use of electric generators, sound from mobile sellers and the used of sound systems by advertisers around the study junctions [4, 5, 10, 11, 24]. These sources contribute to the residual or background noise levels at the junctions.

The computed day-evening-night equivalent metrics (L_{DEN}) for each of the junctions are shown in Table 5. Table 5 shows that the day time, L_{egDay} values ranged between 53.2dBA at the control junction and 102.9dBA at Rumuola junction. The evening time, $L_{egEvening}$ values ranged between 49.8dBA at the control junction and 104.9dBA at Rumuola junction; while the night time, $L_{egNight}$ values ranged between 47.9dBA at the control junction and 92.3dBA at Rumuola junction. The overall day-evening-night equivalent metric (L_{DEN}) for the study junctions ranged from 51.3dBA at the control junction and 111.63dBA at Garrison junction.

The percentage of highly annoyed persons (%HA) as a function of noise exposure indicated by L_{DEN} was found to range from 27.3% at the control junction to 299.1% at Garrison junction. The exposure assessment from computed day-evening-night equivalent metric (Table 5) showed high L_{DEN} and %HA values, suggesting high levels of traffic noise pollution at the junctions. This is capable of causing high level of annoyance and evoking acute responses in the exposed population, which may lead to sleep disturbance or sleep awakenings or changes in sleep stage [6, 30].

Computed L_{10}, L_{50}, Leq and L_{np} indicated high noise pollution at the study junctions compared to the control junction. A test of significance also revealed that the noise levels at the study junctions is significantly high compared to the control junction *(p-value = 0.00485; 95%CI).* This finding also agrees with the study by Ajoku and Amadi-Wali [4] and Fred-Nwagwu et al. [5] who in their studies reported high noise pollution around some junctions in Port Harcourt metropolis, caused mainly by heavy traffic. The finding also corroborated the study by Iwuoha and Avwiri [11] who reported significant level of noise pollution within Port Harcourt Metropolis.

4. Conclusion

This study has shown that there is high traffic noise pollution at major junctions in Port Harcourt metropolis, thus not conducive for prolong human exposure. The logarithm average values (81.5 - 91.3dBA) are above the minimum permissible limits of 70dBA. Computed L_{eq} values (84.1- 92.5dBA) and noise pollution levels, L_{np} values (104.0 - 115.0dBA) are indication of high noise pollution at the junctions, which is hazardous to the exposed population. Computed noise pollution index, NPI (1.21 to 1.32) indicated very high traffic noise levels at the junctions that may pose risk to human health. Computed traffic noise index, TNI (116.7 – 138.5) indicated traffic noise at the junction may have high impact on exposed vulnerable individuals. The percentage of annoyance levels (125.9 - 299.1%) indicated that traffic noise at the junctions may induce high level of annoyance in the exposed individuals, however, they may not be aware of this noise effect. Generally, the study has revealed high traffic noise pollution at the study junctions compared to the control junction ($p < 0.05$, 95% CI). This is capable of causing high level of annoyance and evoking acute responses in the exposed population. Further study is needed to assess the health effects of traffic noise on the surrounding residents and traders at the studied junction.

5. Conflict of interest

The authors have declared that no competing interests exist.

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