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Evaluation of Daily Vehicular Traffic Flows and Noise Levels at Major Junctions in Port Harcourt Metropolis, Nigeria

Itaa C. M. [a], Ugwoha E. [a,b] and Yorkor B. [b*]

[a] Centre for Occupational Health Safety and Environment (COHSE), University of Port Harcourt, Nigeria.
[b] Department of Civil and Environmental Engineering, University of Port Harcourt, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study evaluated vehicular traffic flows and associated traffic noise levels at major junctions in Port Harcourt metropolis. Traffic volume was determined using visual traffic count method. Noise level was determined using an Extech digital sound level meter. Data were statistically analyzed and noise descriptors determined. Average daily traffic flows ranged from 149 to 4224. Average daily total traffic volume was minimum at Eliozu junction and maximum Eleme junction. Traffic noise varied proportionally with traffic flow. The result showed that Average noise levels varied from 70.5dB(A) to 95.9dB(A). The result showed that L_{10} mean values were 89.0, 90.2 91.7, 94.7 and 97.2dB(A) for Eliozu, Choba, Runuokuta, Runuokoro and Eleme junctions respectively; L_{50} mean values were 80.5, 81.2, 83.8, 85.2 and 89.3dB(A) for Eliozu, Choba, Runuokuta, Runuokoro and Eleme junctions respectively; L_{90} mean values were 69.5, 70.1, 70.4, 72.0 and 78.2dB(A) for

**Corresponding author: E-mail: yorkor.banaadornwi@uniport.edu.ng;*

Choba, Eliozu, Runuokuta, Runuokoro and Eleme junctions respectively. Noise climate (NC) aggregated mean values were 18.9, 19.0, 20.7, 21.3 and 22.7 for Eliozu, Eleme, Choba, Runuokuta and Runuokoro junctions respectively; Leq aggregated mean values were 86.5, 88.3, 91.4, 93.8 and 95.3dB(A) for Eliozu, Choba, Runuokuta, Runuokoro and Eleme junctions respectively; noise pollution index (L_{np}) aggregated mean values were 105.4, 109.0, 113.0, 114.3 and 116.6dB(A) for Eliozu, Choba, Runuokuta, Eleme and Runuokoro junctions respectively; traffic noise index (TNI) aggregated mean values were 115.7, 122.3, 124.2, 125.6 and 132.8dB(A) for Eliozu, Choba, Runuokuta, Eleme and Runuokoro junctions respectively. The study showed evidences of high traffic noise pollution at major junctions in Port Harcourt metropolis, which may adversely affect public health and therefore requires intervention by all stakeholgers, including decision makers.

Keywords: Heavy and light vehicles; noise levels; noise climate; traffic noise index; noise pollution index; noise pollution levels; health effects.

1. INTRODUCTION

Noise pollution has been identified as a significant environmental problem often experienced in rapidly developing built-up cities of developing countries. Traffic noise emanating from motor vehicles is also a common characteristic of unplanned urban cities [1] and constitutes one of the most significant sources of environmental noise pollution in urban cities [2,3], particularly in developing countries such as Nigeria. It contributes significantly to the general environmental problems that affect human health [4]. Noise pollution in most urban cities has been found to emanate mainly from vehicular traffic, and increases as the use of motor vehicles continue to increase with increasing population densities, especially in urban cities of developing countries [1,3,5]. Kumar et al., pointed out that over 70% of the total noise in our environment is as a result of vehicular traffic [5]. This has also contributed to elevated level of noise pollution in many cities with potential health implications. Noise has been said to have affected millions of people worldwide on a daily basis [6]. Several studies have shown that traffic noise has severe effects on public health and has become a very serious concern to people living in close proximity to clutter roadways or communities located at major highway passageways [5,7,8]. Research has also shown that noise can result to serious negative health effects for learning as well as task-motivation effects in adults and children exposed to constant noise [9]. The World Health Organization [10] supported this fact and stated that some of the most important repercussion related to extensive noise exposure are: physiological effects, hearing loss, increased risk of accidents and work-related stress.

Few studies have been carried out on noise pollutions and its effects in Port Harcourt metropolis [3,11-15]. The studies employed different methodologies to determine the causes and effects of noise pollution in the City. Omubo-Pepple et al., carried out a social survey of noise in Port Harcourt and to determine the sources, impacts and control of noise in the City [11]. Ugbebor et al., measured and evaluated traffic noise at three junctions in Port Harcourt [3]. George and Okeke applied existing empirical model to predict traffic noise in Port Harcourt [12]. Emenike and Sampson carried out a study on environmental noise levels and its effects on the quality of life in some residential areas of Port Harcourt metropolis [13]. In a recent study, Fred-Nwagwu et al., carried out a spatio-temporal analysis of traffic noise pollution within Port Harcourt Metropolis [14]. In another recent study, Iwuoha and Avwiri evaluated the effects of noise pollution on health in some geographic residential areas within Port Harcourt metropolis [15]. Some of these researchers carried out field data measurement of noise levels, while others performed social survey using questionnaire instrument to investigate the consequences of noise pollution on the people of the City. Only very few of these studies assessed traffic noise and its effects in Port Harcourt metropolis. Also, some failed to determine traffic noise descriptors at the junctions, which are important for proper evaluation of the effects of noise pollution. Therefore, the main aim of this study is to determine traffic flow, measure traffic noise and evaluate traffic noise indices in order to provide a scientific understand of the problems of traffic noise at major junctions in Port Harcourt metropolis. This study evaluated traffic flows and associated traffic noise with the purpose of determining the level of traffic noise pollution at the major junctions and its potential effects on public health. The valuation of traffic noise at these junctions is necessary for proper control and management.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The map of the studied junctions in the Port Harcourt metropolis is shown in Fig. 1. Port Harcourt is the capital of Rivers State located between Latitudes 4°45'N and 4°55'N and Longitudes 6°55'E and 7°05'E with elevations between 2 and 15 meters above sea level. It occupies approximately area of 1811.6 square kilometers. Port Harcourt Metropolis is a major industrial and commercial centre in Rivers State. It is also a hub for oil and gas activities, hosts many international oil companies. It has a high population density that is fast growing and has many road networks with several roads intersect junctions, which often experience traffic congestion [3]. Notably among these junctions are Choba junction, Rumuokoro junction, Eliozu junction, Rumuokuta and Eleme junction (Table 1 and Fig. 1). Choba, Rumuokoro and Eleme junctions are conjugate junctions that serve as gateways into the Port Harcourt metropolis. The Eleme junction is also located at the commercial centre of the Oil Mill Market in the Port Harcourt metropolis and often have congested heavy traffic flow. Also, Eleme junction on the East-West connects the neighboring states of Abia and Akwa Ibom states with Port Harcourt metropolis. Eliozu junction is an intersection junction on the East-West Road that connects Rumuokoro junction, Aba Road and Airport Road; while Rumuokoro junction connects Imo state with Port Harcourt metropolis [16]. Rumuokuta junction is located in a densely populated commercial centre on Ikwerre Road. It serves as an entry junction connecting vehicles from Rumuokoro junctions, Rumuola, NTA roads and Mile 3 Diobu area of Port Harcourt metropolis. There is always a surge in vehicular movement (both heavy and light vehicles) at these junctions. The traffic situation at these major junctions in the metropolis forms the rationale for this study to evaluate the level of traffic flow and noise at the junctions.

Table 1. Coordinates of study junctions

s/n	Junction	Latitude (N)	Longitude (E)
1	Choba	4°53'54.76''	6°54'24.17''
2	Rumuokoro	4°52'01.82"	6°59'50.09"
3	Eliozu	4°51'33.75"	7°01'18.12"
4	Eleme	4°51'21.78"	7°04'01.05"
5	Rumuokuta	4°50'16.38"	6°59'18.08"

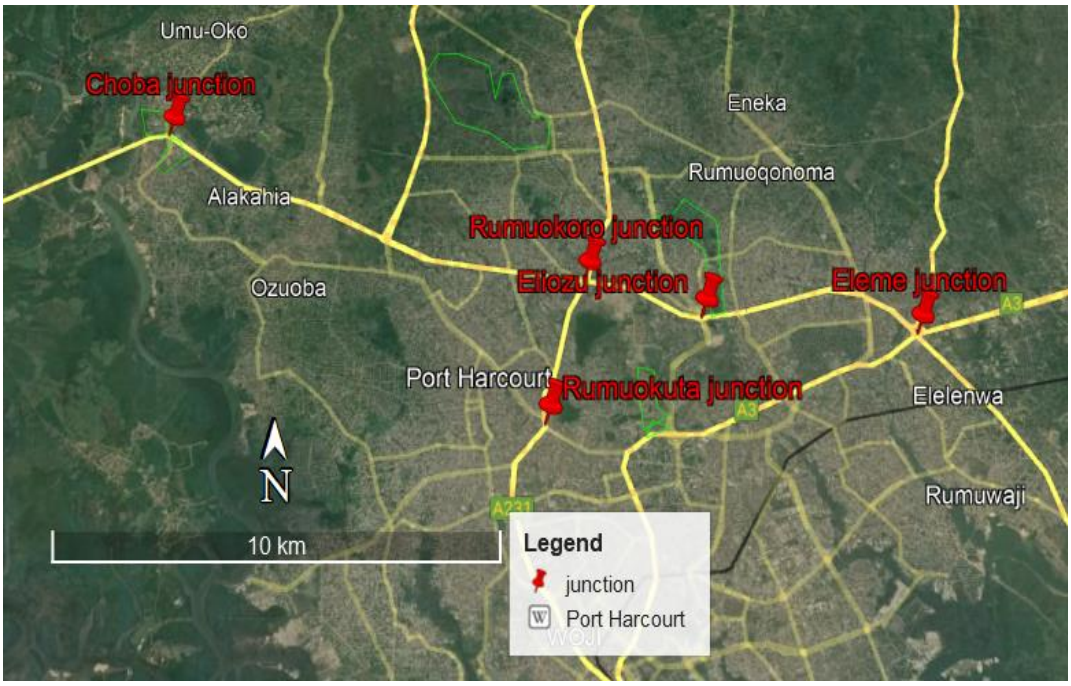

Fig. 1. Map of study area

2.2 Traffic Count

The counting of the number of vehicles passing the junctions was carried out during the monitoring. Visual counting method was used to count the number of light vehicles (cars, buses) and heavy trucks that pass through the junctions per hour [16,17]. The number of vehicles that move through the junctions were counted and averaged at every one-hour interval to give one-hour mean values. The total volume of vehicles (Q) that passed in an hour time is related to the number of vehicles (N) that moved past the junction at time t as shown in Equation (1). The average total volume of vehicles $\overline{Q}$ was computed using Equation (2).

$$Q = \frac{N_t}{t} \quad \textbf{(1)}$$

$$\overline{Q} = \frac{\sum_{t=1}^{n} N_t}{\sum_{i=1}^{n} t_i} \quad (2)$$

where Q is the total volume of vehicles, N_t is the number of vehicles that moved past at time t; and t is the time a vehicle moves past the junction.

2.3 Traffic Noise Measurement

The traffic noise data were acquired via field measurements conducted at nine (9) selected junctions within the study area 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/data loggers. Real time in-situ measurements of traffic noise were conducted at the selected locations as shown in Fig. 1. Measurements were carried out in compliance with ISO 9613 noise measurement procedure [18]. The instruments were situated on tripod stands at heights between 1.2 and 1.5 meters above ground level. Appropriate precautions were taken when setting up the instruments for the onsite measurements of the traffic noise. The sound pressure level meters were set up in an open ground and positioned away from obstacles like buildings, poles, advertisement stands. Protective shield devices were used to shelter the instruments' display, which provided protection from direct sunlight effect. Measurements of traffic noise levels were carried out from Monday to Sunday between 7:00 hours to 00.00 hours (12:00 midnight) and displayed noise values were recorded at every ten-minute interval.

Measurements were made for seven days (Monday to Sunday) from 14th to 20th February 2022.

2.4 Calculation of Noise Indices

The logarithm average of measured sound pressure levels was computed using Equation (3) as contained in Davis and Cornwell [19].

$$L_{avg} = 20\log\frac{1}{N}\sum_{j=1}^{N} 10^{L_j/20} \quad (3)$$

where, L_{avg} 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 Davis and Cornwell [19], Sincero and Sincero, [20] and Kiely [21].

$$L_{eq} = 10\log\sum_{i=1}^{i=n} 10^{L_i/10} t_i \quad (4)$$

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 (5) to (8) found in Nwaogazie [22], Swain and Shreerup [23], Selman [24] and Ramakrishna et al. [25].

$$NC = L_{10} - L_{90} \quad (5)$$

$$L_{np} = L_{50} + (NC) + \frac{(NC)^2}{60} \quad (6)$$

$$TNI = 4*(NC) + L_{90} - 30 \quad (7)$$

$$NPI = \frac{L_{eq}}{Ref.\ value} \quad (8)$$

2.5 Statistical Analysis

Collected data were analyzed using Microsoft Excel and Statistical Product and Service Solutions (SPSS) software version 26. Mean values and standard deviations of the noise values were computed for each sampling junction. Analysis of variance (ANOVA) was carried out to check for difference in results from the different junctions.

3. RESULTS AND DISCUSSION

3.1 Traffic Volume

The statistical summary of traffic volume obtained at the junctions is presented in Table 2. The variations of daily traffic flow with time are shown in Fig. 2. The statistical summary of daily traffic noise levels measured at the junctions is shown in Table 3; while the trends in the daily variations of traffic noise levels at the junctions are presented in Figs. 3 to 7.

Table 2. Statistical summary result of traffic volume of the study area

Location	Statistic	Light vehicles, v	Heavy vehicles, q	Total vehicles, Q	Average speed, S (km/h)	P (%)
Choba junction	Min	618	159	848	5	13.2
	Max	1825	440	2231	15	27.1
	Mean	1305	286	1592	10	18
	SD	365	93	440	4	4
Rumuokoro junction	Min	893	233	1143	5	15.1
	Max	2479	451	2930	25	27.8
	Mean	1393	353	1746	15.4	21
	SD	460	78	503	6	4
Eliozu junction	Min	87	32	128	5	23.7
	Max	147	67	214	10	33.6
	Mean	105	43	149	8.9	29
	SD	19	9	26	4	3
Eleme junction	Min	1685	876	2561	5	32.3
	Max	5239	3741	8612	10	43.4
	Mean	2618	1606	4224	6.4	37
	SD	1250	987	2226	2	3
Rumuokuta junction	Min	573	58	658	5	5.8
	Max	1725	256	1981	25	14.6
	Mean	1191	147	1337	13.6	11
	SD	362	64	419	7	2

SD = standard deviation

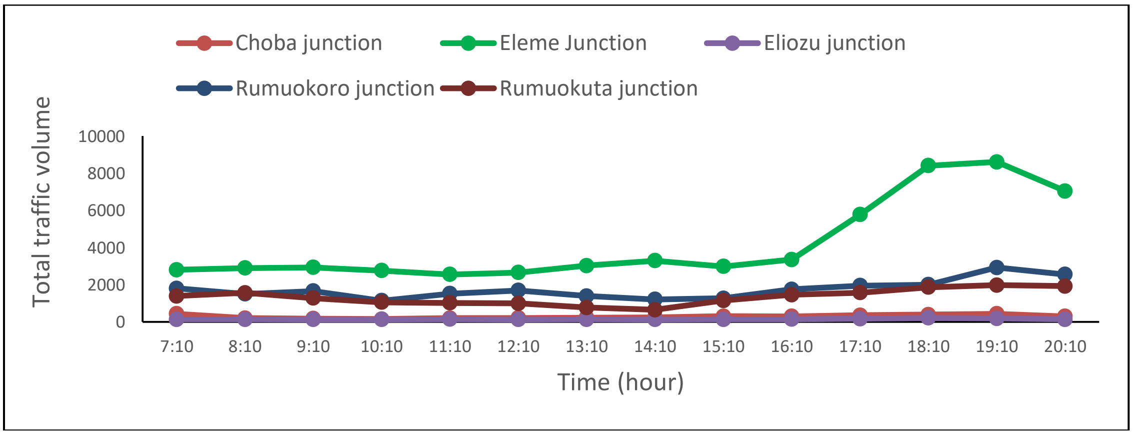

Fig. 2. Time variations daily traffic flow

3.2 Traffic Noise

Table 3. Statistical the summary of the result of traffic noise levels measured within the study area (Result shown in dB (A))

Location	Statistic	Mon.	Tues.	Wed.	Thur.	Fir.	Sat.	Sun.
Choba junction	Min	57.7	50.3	50.4	51.7	48.5	51.3	44.5
	Max	106.1	101.8	106.7	105.1	102.5	94.7	89.7
	Mean	88.7	87.4	88.6	88.0	87.0	79.3	70.5
	SD	10.2	10.1	11.1	11.3	9.7	7.6	8.7
Rumuokoro junction	Min	56.7	52.6	61.3	58.7	65.8	53.8	47.5
	Max	108.8	103.6	108.4	103.6	108.4	96.7	94.5
	Mean	91.3	90.8	91.1	90.2	89.0	83.8	80.0
	SD	10.9	11.1	9.0	8.5	8.3	8.8	9.0
Eliozu junction	Min	58.4	60.8	62.9	63.5	70.3	61.1	45.2
	Max	105.2	96.2	101.7	105.3	104.2	93.4	90.3
	Mean	85.5	86.2	88.8	89.0	87.4	76.0	71.0
	SD	9.1	8.4	7.0	7.4	7.2	7.8	8.4
Eleme junction	Min	72.9	73.3	72.8	71.9	70.5	64.3	58.6
	Max	103.8	107.1	106.3	108.6	101.2	104.5	94.7
	Mean	93.7	93.6	94.9	95.9	92.5	86.8	81.3
	SD	6.6	7.1	6.8	7.3	6.1	9.9	10.1
Rumuokuta junction	Min	52.8	53.7	61.2	58.7	70.2	50.8	48.6
	Max	99.3	99.4	98.5	99.1	98.8	93.5	92.8
	Mean	87.9	87.1	88.0	88.1	87.1	82.6	78.0
	SD	11.5	9.7	8.5	7.8	7.9	9.0	8.9

SD = standard deviation

The volume of traffic flow at the selected junctions was evaluated to determine the number of vehicles passing at each junction per day as shown in Table 2. Table 2 indicates that the computed mean volume of light vehicles at Choba junction was 1305 with a standard deviation 365; the computed mean heavy vehicles at the junction was 286 with a standard deviation 93; the computed mean value of total traffic volume at the junction was 1592 with a standard deviation of 440. Similarly, the computed mean speed of the vehicles at the junction was 10km/h with a standard deviation 4km/h; while the computed mean percentage ratio of heavy vehicles to light vehicles was 18 with a standard deviation of 4. Table 2 shows that the computed mean volume of light vehicles at Rumuokoro junction was 1393 with a standard deviation 460; the computed mean heavy vehicles at the junction was 353 with a standard deviation 78; the computed mean value of total traffic volume at the junction was 1746 with a standard deviation of 503. Similarly, the computed mean speed of the vehicles at the junction was 15.4km/h with a standard deviation 6km/h; while the computed mean percentage ratio of heavy vehicles to light vehicles was 21 with a standard deviation of 4. Table 2 indicates that the computed mean volume of light vehicles at Eliozu junction was 105 with a standard deviation 16; the computed mean heavy vehicles at the junction was 43 with a standard deviation 9; the computed mean value of total traffic volume at the junction was 149 with a standard deviation of 26. Similarly, the computed mean speed of the vehicles at the junction was 8.9km/h with a standard deviation 4km/h; while the computed mean percentage ratio of heavy vehicles to light vehicles was 29 with a standard deviation of 3. Table 2 indicates that the computed mean volume of light vehicles at Eleme junction was 2618 with a standard deviation 1250; the computed mean heavy vehicles at the junction was 1606 with a standard deviation 987; the computed mean value of total traffic volume at the junction was 4224 with a standard deviation of 2226. Similarly, the computed mean speed of the vehicles at the junction was 6.4km/h with a standard deviation 2 km/h; while the computed mean percentage ratio of heavy vehicles to light vehicles was 37 with a standard deviation of 3. Similarly, Table 2 also shows that the computed mean volume of light vehicles at Rumuokuta junction was 1191 with a standard deviation 362; the computed mean heavy vehicles at the junction was 147 with a standard deviation 64; the computed mean value of total traffic volume at the junction was 1337 with a standard deviation of 419. Similarly, the computed mean speed of the vehicles at the junction was 13.6km/h with a standard deviation 7km/h; while the computed mean percentage ratio of heavy vehicles to light vehicles was 11 with a standard deviation of 2.

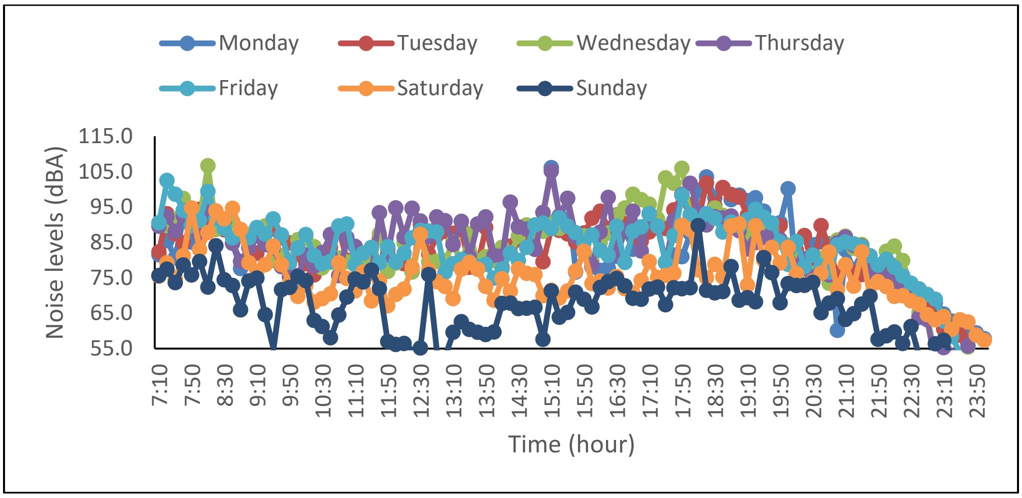

Fig. 3. Daily variations of noise levels at Choba junction

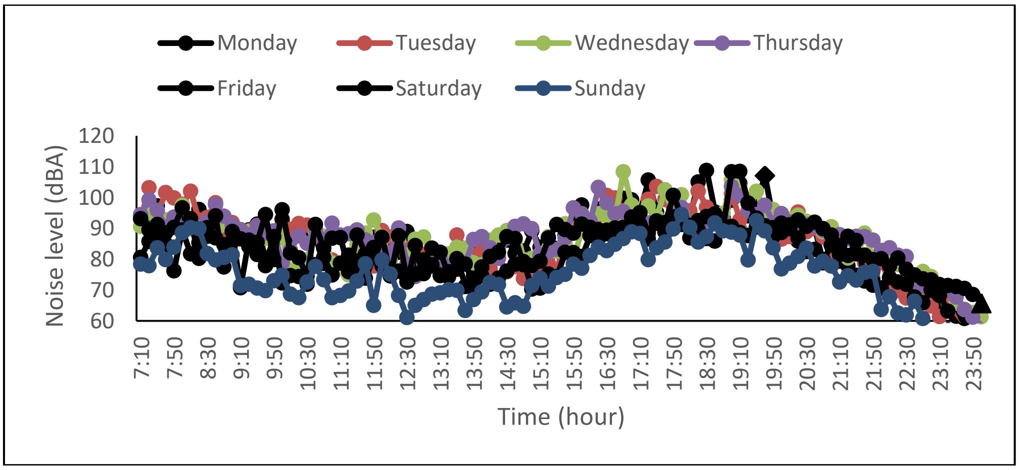

Fig. 4. Daily variations of noise levels at Runuokoro junction

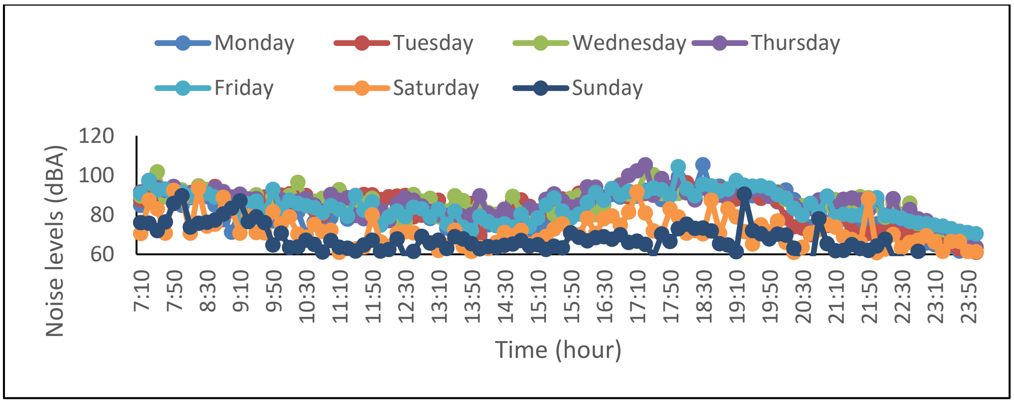

Fig. 5. Daily variations of noise levels at Eliozu junction

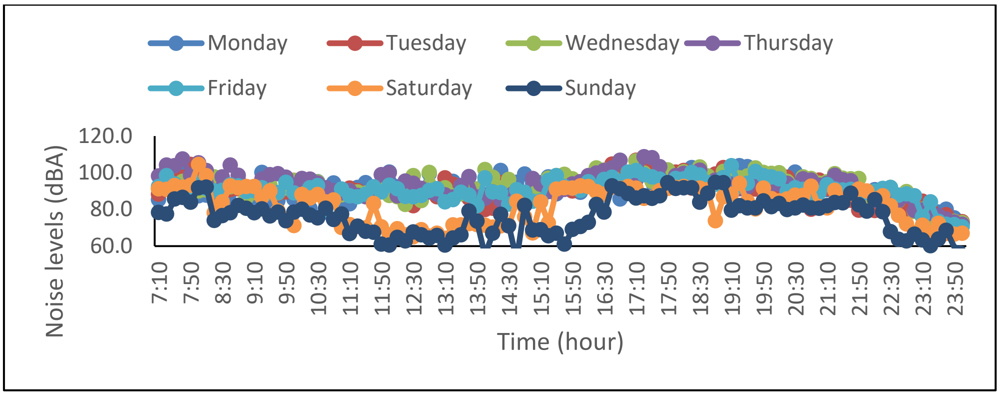

Fig. 6. Daily variations of noise levels at Eleme junction

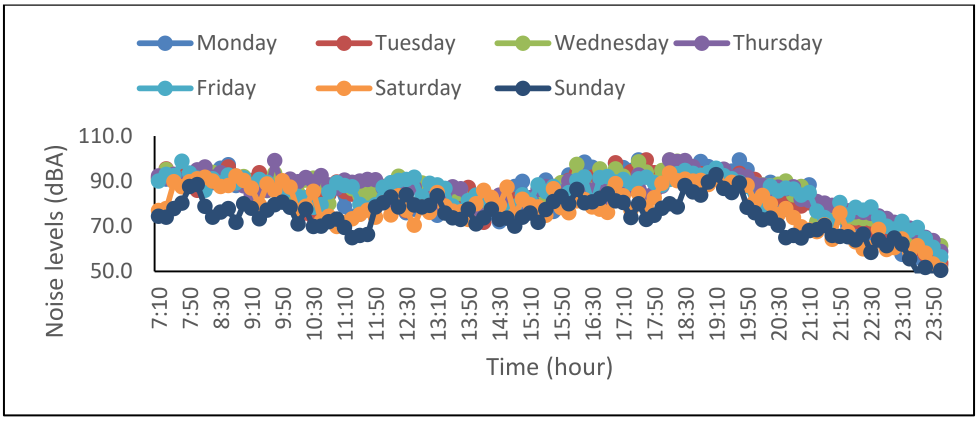

Fig. 7. Daily variations of noise levels at Rumuokuta junction

The result (Table 3) shows that the average traffic noise levels obtained at Choba junction ranged from 70.5dB(A) on Sunday to 88.7dB(A) on Monday, with an overall average value of 84.2dB(A). The average traffic noise levels recorded at Runuokoro junction ranged between 80.0dB(A) on Sunday and 91.3dB(A) on Monday, with an overall average value of 88.0dB(A). The average traffic noise levels at Eliozu junction were between the range of 71.0dB(A) on Sunday and 89.0dB(A) on Thursday with an overall average value of 83.4dB(A). The average traffic noise values at Eleme junction ranged from 81.3dB(A) on Sunday to 95.9dB(A) on Thursday with an overall average value of 90.8 dB (A). The average traffic noise values at Runuokuta junction ranged between 78.0dB(A) on Sunday and 88.1dB(A) on Thursday, with an overall average value of 85.5 dB (A).

It is clearly shown in Fig. 2 that the traffic flows at Eleme Rumuokoro, and Rumuokuta junctions increase gradually from the morning hours (7:00am – 11:00am) towards evening hours (4:00pm – 9:00pm). The traffic flow at Eliozu and Choba junctions showed a relatively even or steady flow from morning hours to evening time. A relatively reduction in traffic flow was observed during the afternoon hours (12:30pm – 3:00pm). This trend in traffic flow may probably be caused by the movement of people and goods to various places of business and rushing back in the evening at the close of business. Kundu et al., in their study also observed similar trend in traffic [26].

Observably, trends in the daily variations of traffic noise levels (Figs. 3 to 7) indicates that traffic noise levels were very high during the morning hours (7:00am – 11:00am), low during the afternoon hours (12:30pm – 3:30pm), high during evening hours (4:00pm – 8:30pm) and then lowest towards midnight (22:00pm – 12:00 midnight). Traffic noise levels decreases gradually from at 10:00pm to 12:00am when there were fewer vehicles and free flow of vehicles at the junctions. Generally, the traffic noise levels observed at the junctions also exhibited similar trend with traffic volume. This characteristic of the traffic noise may probably be due to the rushing movement of people carrying of goods and public transport during the morning and evening hours.

The result (Table 1) indicates that Eleme junction has the highest mean daily traffic volume, this is followed by Rumuokoro junction and Choba junction. It is evident from Fig. 2 that Eliozu junction has the least traffic flow compared to other junctions. Table 2 also shows that Eleme junction has the highest percentage flow of heavy vehicles, followed by Rumuokoro junction and Choba junctions. This is expected as these three junctions are located on the East-West highway that most often experience heavy vehicular movement. This finding corroborated the studies of Ugbebor et al. [3] and Ugbebor et al. [16]. Also, Eleme junction on the East-West connects the neighboring states of Abia and Akwa Ibom states with Port Harcourt metropolis; Eliozu junction is an intersection junction on the East-West Road that connects Rumuokoro junction, Aba Road and Airport Road [16]. The result demonstrated that high volume of traffic has great influence on the traffic noise levels at the junctions. Generally, the findings of this study on the volume of traffic in Port Harcourt metropolis agree with the study by Fred-Nwagwu et al., who also reported high traffic volumes in Port Harcourt metropolis [14].

The traffic noise levels obtained at Choba junction corroborated the study by Ugbebor et al. [3] and Fiberesima [27] who also obtained average noise values as high as 93.39dB(A) and 84.0dB(A) respectively at the junction, which were attributed to vehicular activities at the junction, particularly horns from transportation vehicles. However, it contradicts the study by Emenike and Sampson who reported an average noise value of 64.0dB(A) at the Choba junction [13]. The traffic noise levels obtained at Rumuokoro junction supported the study of Ugbebor et al. [3] and Ajoku and Amadi-Wali [28] who obtained mean noise values as high as 94.9dB(A) and 87.68dB(A) respectively at Rumuokoro junction. The traffic noise levels obtained at Eliozu junction contradicts the study by Emenike and Sampson who reported an overall average noise value of 63.9dB(A) at the Eliozu [13]. Also, the traffic noise levels obtained at Eleme junction bolstered the study of Ajoku and Amadi-Wali who obtained mean noise values ranging 86.0dB(A) and 88.29dB(A) at the junction [28]. Similarly, the traffic noise levels obtained at Rumuokuta junction strengthened the work of Ugbebor et al. and Ajoku and Amadi-Wali who obtained mean traffic noise values as high as 94.1dB(A) and 86.69dB(A) respectively at Rumuokwuta junction [3,28]. The traffic noise levels at the junctions far exceeded the 65dB (A) prescribed by WHO [10,29], as noise pollution, indicating high traffic noise pollution at all the junctions.

The result of the computed statistical daily traffic noise descriptors for the junctions is presented in Table 4.

The result in Table 4 indicates that the noise levels exceeding 10% of the time at Choba junction varied from 75.5dBA on Sunday to 96.8dBA on Monday with a mean value of 90.2dBA. The noise levels exceeding 50% of the time at the junction varied from 68.4dBA on Sunday to 86.0dBA on Tuesday with a mean value of 81.2dBA; while noise levels exceeding 90% of the measurement time at the junction varied from 54.9dBA on Sunday to 75.0dBA on Friday with a mean value of 69.5dBA. The computed noise climate at the Choba junction varied between 16.9dBA on Friday and 24.9dBA on Monday with an average of 20.7dBA. The computed L_{eq} values ranged from 75.6dBA on Sunday to 94.3dBA on Tuesday with a mean value of 88.4dBA. Similarly, the computed noise pollution levels at the junction varied from 96.4dBA on Sunday to 118.9dBA on Monday with a mean value of 109.1dBA. The computed traffic noise indices at the junction varied between 108.1dBA on Sunday and 141.5dBA on Monday with a mean value of 122.3dBA. Choba junction shows a mean noise pollution index of 1.26.

The noise levels exceeding 10% of the time at Rumuokoro junction varied from 88.8dBA on Sunday to 99.3dBA on Tuesday with a mean value of 94.7dBA. The noise levels exceeding 50% of the time varied from 75.5dBA on Sunday to 89.2dBA on Thursday with a mean value of 85.2dBA; while noise levels exceeding 90% of the time at the junction varied from 64.7dBA on Sunday to 77.8dBA on Thursday with a mean value of 72.0dBA. The computed noise climate at the junction varied between 17.9dBA on Thursday and 28.9dBA on Tuesday with an average of 22.7dBA. The computed L_{eq} values ranged from 85.2dBA on Sunday to 101.5dBA on Tuesday with a mean value of 94.0dBA. Similarly, the computed noise pollution levels at the Rumuokoro junction varied from 107.6dBA on Saturday to 130.4dBA on Tuesday with a mean value of 116.6dBA. The computed traffic noise indices at the junction varied between 119.4dBA on Thursday and 156.0dBA on Tuesday with a mean value of 132.6dBA. Rumuokoro junction shows a mean noise pollution index of 1.34.

The noise levels exceeding 10% of the time at Eliozu junction varied from 76.3dBA on Sunday to 93.9dBA on Wednesday with a mean value of 89.0dBA. The noise levels exceeding 50% of the time varied from 65.4dBA on Sunday to 87.9dBA on Wednesday with a mean value of 89.3dBA; while noise levels exceeding 90% of the time at the junction varied from 58.4dBA on Sunday to 77.8dBA on Thursday with a mean value of 70.1dBA. The computed noise climate at the junction varied between 15.9dBA on Wednesday and 22.9dBA on Monday with an average of 18.9dBA. The computed L_{eq} values ranged from 70.7dBA on Sunday to 94.3dBA on Tuesday with a mean value of 86.6dBA. Similarly, the computed noise pollution levels at the Eliozu junction varied from 88.6dBA on Sunday to 115.4dBA on Tuesday with a mean value

Table 4. Result of computed traffic noise descriptors for the junctions

Location	Descriptors	Mon.	Tue.	Wed.	Thur.	Fri.	Sat.	Sun.	Average
Choba junction	L_{10} (dBA)	96.8	93.1	92.7	93.5	91.9	87.7	75.7	90.2
	L_{50} (dBA)	83.7	86	85.5	84.9	85	74.9	68.4	81.2
	L_{90} (dBA)	71.9	70.8	73.5	72.4	75	68.1	54.9	69.5
	NC (dBA)	24.9	22.3	19.2	21.1	16.9	19.6	20.8	20.7
	L_{eq} (dBA)	94	94.3	91.6	92.3	89.8	81.3	75.6	88.3
	L_{np} (dBA)	118.9	116.6	110.8	113.4	106.7	100.9	96.4	109
	TN1 (dBA)	141.5	130	120.3	126.8	112.6	116.5	108.1	122.3
	NPI	1.34	1.35	1.31	1.32	1.28	1.16	1.08	1.26
Eleme junction	L_{10} (dBA)	100.2	99.7	100.1	101	97.7	92.4	88.7	97.2
	L_{50} (dBA)	91.7	90.8	93.9	93.8	91.1	85.5	78.4	89.3
	L_{90} (dBA)	82.9	80.1	85	85.2	84.4	67.2	62.9	78.2
	NC (dBA)	17.3	19.6	15.1	16.1	13.3	25.2	25.8	19
	L_{eq} (dBA)	96.7	97.2	97.7	98.1	94	96.1	89.5	95.3
	L_{np} (dBA)	114	116.8	112.8	114.2	107.3	121.3	115.3	114.3
	TN1 (dBA)	122.1	128.5	115.4	119.6	107.6	138	136.1	124.2
	NPI	1.38	1.39	1.4	1.4	1.34	1.37	1.28	1.37
Eliozu junction	L_{10} (dBA)	91.9	91.2	93.8	93.9	93.2	82.8	76.3	89
	L_{50} (dBA)	81.3	86.9	87.9	87.5	84.1	70.6	65.4	80.5
	L_{90} (dBA)	69	70.1	78	77.8	74.6	62.8	58.4	70.1
	NC (dBA)	22.9	21.1	15.9	16.1	18.6	20	17.9	18.9
	L_{eq} (dBA)	90	94.3	92.1	91.8	89.9	77.3	70.7	86.5
	L_{np} (dBA)	112.9	115.4	108	107.9	108.5	97.3	88.6	105.4
	TN1 (dBA)	130.6	124.5	111.6	112.2	119	112.8	100	115.7
	NPI	1.29	1.35	1.32	1.31	1.28	1.1	1.01	1.24
Rumuokoro junction	L_{10} (dBA)	97.6	99.3	97.2	95.7	93.7	90.4	88.8	94.7
	L_{50} (dBA)	87.2	87.6	88.7	89.2	86.8	81.1	75.5	85.2
	L_{90} (dBA)	70.7	70.4	76.2	77.8	73.8	70.5	64.7	72
	NC (dBA)	26.9	28.9	21	17.9	19.9	19.9	24.1	22.7
	L_{eq} (dBA)	99.3	101.5	96.1	94.5	93.4	87.7	85.2	93.8
	L_{np} (dBA)	126.2	130.4	117.1	112.4	113.3	107.6	109.3	116.6
	TN1 (dBA)	148.3	156	130.2	119.4	123.4	120.1	131.1	132.8
	NPI	1.42	1.45	1.37	1.35	1.33	1.25	1.22	1.34
Rumuokuta junction	L_{10} (dBA)	95.6	93.4	93.5	93	92.4	89.9	84.4	91.7
	L_{50} (dBA)	84.7	86.2	87.5	86.9	86.7	78.9	75.8	83.8
	L_{90} (dBA)	67.4	70.7	73.2	75.7	73.9	67.1	64.5	70.4
	NC (dBA)	28.2	22.7	20.3	17.3	18.5	22.8	19.9	21.3
	L_{eq} (dBA)	98	94.8	94.4	91.9	92.4	87.6	82.4	91.4
	L_{np} (dBA)	126.2	117.5	114.7	109.2	110.9	110.4	102.3	113
	TN1 (dBA)	150.2	131.5	124.4	114.9	117.9	128.3	114.1	125.6
	NPI	1.4	1.35	1.35	1.31	1.32	1.25	1.18	1.31

of 105.5dBA. The computed traffic noise indices at the junction varied between 100.0dBA on Sunday and 130.6dBA on Monday with a mean value of 115.8dBA. Eliozu junction shows a mean noise pollution index of 1.24.

The noise levels exceeding 10% of the time at Eleme junction varied from 88.7dBA on Sunday to 101.3dBA on Thursday with a mean value of 97.2dBA. The noise levels exceeding 50% of the time varied from 78.4dBA on Sunday to 93.9dBA on Wednesday with a mean value of 89.3dBA; while noise levels exceeding 90% of the time at the junction varied from 62.9dBA on Sunday to 85.2dBA on Thursday with a mean value of 78.2dBA. The computed noise climate at the junction varied between 15.1dBA on Wednesday and 25.8dBA on Sunday with an average of 18.9dBA. The computed L_{eq} values ranged from 89.5dBA on Sunday to 98.1dBA on Thursday with a mean value of 95.6dBA. Similarly, the computed noise pollution levels at the Eleme junction varied from 107.3dBA on Friday to 121.3dBA on Saturday with a mean value of 114.5dBA. The computed traffic noise indices at the junction varied between 107.6dBA on Friday and 138.0dBA on Saturday with a mean value of 123.9dBA. Eleme junction shows a mean noise pollution index of 1.37.

The noise levels exceeding 10% of the time at Rumuokuta junction varied from 84.4dBA on Sunday to 95.6dBA on Monday with a mean value of 91.7dBA. The noise levels exceeding 50% of the time varied from 75.8dBA on Sunday to 86.9dBA on Thursday with a mean value of 83.8dBA; while noise levels exceeding 90% of the time at the junction varied from 64.5dBA on Sunday to 75.7dBA on Thursday with a mean value of 70.4dBA. The computed noise climate at the junction varied between 17.3dBA on Thursday and 28.2dBA on Monday with an average of 21.4dBA. The computed L_{eq} values ranged from 82.4dBA on Sunday to 98.0dBA on Monday with a mean value of 91.6dBA. Similarly, the computed noise pollution levels at the Rumuokuta junction varied from 102.3dBA on Sunday to 126.2dBA on Monday with a mean value of 113.0dBA. The computed traffic noise indices at the junction varied between 114.1dBA on Sunday and 150.2dBA on Monday with a mean value of 125.9dBA. Rumuokuta junction shows a mean noise pollution index of 1.31.

The result shown in Table 4 indicates that the average L_{10}, L_{50} and L_{90} values exceeded NESREA and WHO permissible limit of 70dBA at Eleme and Rumuokro junctions; however average L_{90} values fall on the borderline of the limit at Eliozu and Rumuokuta junction, and below the limit at Choba junction. L_{90} values have been considered as residual or background noise levels [24,30]. Highest noise L_{eq} noise value was observed at the highly congested Eleme junction, followed by Rumuokoro junction (94.0dBA). The computed mean L_{eq} values at the junctions exceeded NESREA and WHO permissible limit of 70dBA, suggesting that there are high noise levels at the junctions, which is injurious to human health.

The values noise climate indicate that traffic noise levels fluctuate less in interval of time at the junctions [16]. This suggests that the junctions have similar uniform traffic flow and hence produced similar traffic noise levels. Rumuokoro and Rumuokuta junctions are located in densely populated areas in the Port Harcourt metropolis, with many residential and commercial buildings. The clustering of buildings at these junctions may cause the reflection of traffic noise thereby increasing the levels of noise climate at these junctions. Judging from the fact that noise climate is computed as the difference between L_{10} (the peak intruding noise levels) and L_{90} (the residual or background noise levels), noise climate can be considered as the predicted contribution of vehicular traffic to the background noise at the junctions. It is evidently clear from the noise climate values that vehicular traffic contributes substantially to noise levels at the junctions.

The computed average traffic noise indices for the junctions corroborated the study of Okeke and George [12]. The high TNI values indicates that there are high variations of noise levels at the junctions resulting from heavy traffic flow at the junctions [11,12,14,25,31]. According to Chiedu et al., [31], Kumar and Srinivas [32] and Shalini and Kumar [33] 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 [24,30]. The computed high average values of traffic noise indices for all junctions are capable of causing high level of annoyance to the exposed population at the road junctions, particularly, residents and business owners or shop owners. The computed average noise pollution levels for the junctions agreed with the studies of Ugbebor et al. [3] and Okeke and George [12]. The computed average noise pollution levels exceeded the recommended threshold value of 88dBA [33], indicating excessive traffic noise at the junctions, which may be injurious to the exposed population.

Comparatively, computed average noise pollution levels were observed to be lower than the average traffic noise indices, which is contrary to the finding of Nassiri et al., who in their study obtained noise pollution levels that were higher than traffic noise indices [34]. The range of noise pollution indices obtained at the junctions are similar to that obtained reported by Nassiri et al. in a District of Tehran City, Iran [34]. The values indicate high noise pollution levels at the study junctions, which are hazardous to human health.

Generally, the different computed noise descriptor metrics indicated high traffic noise pollution in the study area caused by high traffic volume observed at the junctions. In a similar study, Ugbebor et al. reported high noise levels at some junctions within Port Harcourt metropolis which was attributed to high volume of traffic [3]. Study by Fiberesima reported that high vehicular movement is the principal source of noise pollution at Choba junction in Port Harcourt City [27]. Also, in another related study, Ugbebor et al. reported the prevalence of high noise pollution at Eleme junction, which was also attributed to high vehicular movement [16]. Again, the study by Omubo-Pepple et al., implicated road traffic as one of the major sources of noise pollution within Port Harcourt Metropolis [11]. This was ascribed to high volume vehicles at major junctions in the City. The high noise climate, traffic noise indices and noise pollution levels obtained at the junctions pose serious health hazards to the general public, particularly the exposed residents and individuals who spent long time at the junctions. The possibility of noise-induced annoyance and hearing impairment may exist among these exposed group of people.

This study has shown evidences of unhealthy noise pollution at the junctions. The health inferences of traffic noise pollution in the Port Harcourt metropolis demonstrates high levels of noise pollution hazardous to the public wellness, particularly, people living and transacting businesses at the junctions. Noise pollution exerts a wide range of effects on the exposed population, ranging from social, physical, physiological to psychological effects [12,14]. It is evident that the people living or transacting businesses at the junctions may suffer from diseases associated with noise pollution. This may include hearing impairment due to prolonged exposure high traffic noise levels [10,12,19]. People doing business (traders and shop owners) at Eleme Choba and Rumuokoro junctions may be adversely affected due to prolonged exposure. Noise pollution diseases such as annoyance, headache, hearing impairment, speech interference, irritation, and fatigue may be common among the people living in close proximity to these junctions [10,16,19]. Other possible health effects that may be prevalence among the exposed people at the junctions include cardiovascular disease, muscle constriction, nervousness, elevated blood pressure, and tinnitus, among others [14,34]. Long time exposure to high noise levels such as that obtained at the junctions can contribute to the development of noise induced permanent threshold shift (NIPTS), resulting in irreversible permanent hearing loss [14,15,27,35].

4. CONCLUSION

The evaluation of vehicular traffic volume and associated traffic noise at major junctions in Port Harcourt metropolis has been carried out. The study showed evidences of a high volume of vehicles at the junctions within Port Harcourt metropolis. Traffic noise varied proportionately with traffic flow at the junctions. Average daily traffic flows were between 149 at Eliozu junction and 4224 at Eleme junction; while noise levels were between 71.0dB(A) at Eliozu junction and 93.7dB(A) at Eleme junction. High volume of traffic produced high levels noise at the junctions, which exceeded permissible limit for human comfort. Computed noise climate (18.9 - 22.7) showed that vehicular traffic contributes substantially to noise levels at the junctions.

The traffic noise levels at the junctions exceeded the 65dB(A) prescribed by WHO as noise pollution, indicating high traffic noise pollution at all the junctions. Computed L_{eq} values (86.5 - 95.3dBA), traffic noise index values (115.7 - 132.8dBA) and noise exposure levels (105.4 - 116.6dBA) indicated high noise level at the junctions, which is hazardous to human health. Excessive traffic noise at the junctions, which may be injurious to the exposed public. Residents and traders at the junctions should take precautionary measures to minimize prolong exposure. Long-time exposure to elevated traffic noise level at the studied junctions may also have detrimental psychological and physiological effects on the exposed population, particularly, vulnerable individuals such as the elderly and children. Therefore, the high level of traffic noise pollution at major junctions in Port Harcourt metropolis should be of public health concern to all stakeholders and decision makers (local and state authorities or administrators) in the City. Awareness campaign should be carried out among the exposed individuals, particularly, traders who spent long time transacting businesses at these junctions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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