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Daytime Vehicular Traffic Noise Analysis and Modeling at Selected Roads in Port Harcourt

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Using linear regression techniques, the daytime vehicle traffic noise levels at four significant crossings in Port Harcourt were analyzed and predicted. These are the crossroads of Rumuokwuta, Agip, 1st Artillery, and GRA. These crossroads are often quite active with both traffic and pedestrian activity. The sound levels, relative humidity and wind speed along with temperature were all measured using a sound level meter, relative humidity meter, and anemometer, respectively. Data on traffic volume was also gathered throughout the sample period. This was carried out for a total of 10 hours each day beginning at 7 am throughout the course of three days at each site. For the different sites, noise indices including equivalent noise level (L_{eq}), statistical measure (L_n), noise climate (NC), traffic noise index (TNI), and noise pollution level (NPL) were calculated. With the exception of the GRA junction, statistical analysis reveals that there is no change in the data recorded at the various times of the day ($p>0.05$). The estimated indices from all sites were compared, and there was no discernible difference ($p>0.05$). Agip had the lowest TNI at 44.04 dB(A), while Rumuokwuta junction had the highest at 49.7 dB(A). The maximum L_{eq} of 74.9 dB(A) was observed at 1st Artillery while the minimum of 74.1 dB(A) was recorded at Agip. GRA junction

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recorded the maximum NPL as 76.99 dB(A), while Rumuokwuta had the lowest as 76.3 dB(A). A linear model idea for forecasting noise from independent variables, including the atmospheric conditions and traffic count, was calibrated using multiple linear regression modeling. The coefficient of determination was discovered to vary between 0.5 and 0.95 after dimension reduction by the plotting of standardized charts.

Keywords: Traffic noise; regression; noise indices; modeling; statistical analysis.

1. INTRODUCTION

Traffic noise is now a constant source of noise pollution in metropolitan areas, particularly those with poor urban planning, as a result of a rise in automobile use and the fast development in urbanization. When traffic volume exceeds the cap established by early urban designers, the issue of traffic noise pollution arises. This rise in traffic volume has a detrimental impact on the environment [1]. Traffic noise is a kind of environmental noise pollution. The highest allowable outdoor noise regulation is 75 dB(A). Traffic volume directly influences traffic noise in a favorable way [2]. Due to urbanization, population expansion, and an increase in the number of cars on the road, traffic noise pollution is growing. Traffic noise is the total amount of noise made by all moving cars at the point of observation on a road's pavement [3]. Urban traffic noise interferes with people's ability to communicate, concentrate at work, and sleep. Exposure to traffic noise on a regular basis may be harmful to human health, leading to conditions including hypertension, hyperprotienemia, and hyperlipidosis as well as hearing loss [4]. One international issue is noise nuisance [5]. According to Koelega [6], irritation is a negative emotion connected to any agent or circumstance that a person or group knows about or believes will have a negative impact on them.

It is important to link any irritation that a sound may create to its potential negative consequences on health. This is the case since the stress is determined by both the sound quality and the decibel value in addition to the former. For instance, airport noise is often considered to be more annoying than road noise of the same level [7]. Human traits very little influence how annoying a noise is; instead, sensitivity to and fear of the source of the noise have a significant impact [8]. Noise complaints may result from sound levels as low as 40 dB(A), which is what refrigerators and libraries can monitor, and 45 dB(A) or below is the lower threshold for noise creating sleep disruption [9]. The strength of interpersonal interactions at work and the degree of stress brought on by the task itself may have an impact on how we perceive irritation and how it connects to noise levels and the consequent health issues [10,11]. There is conflicting evidence about the influence of long-term noise compared to changes on annoyance [12]. The degree of irritation and various activities may not always be clearly correlated, and there are instances when the degree of annoyance is modest despite a high level of noise source. The most significant consequences of airplane noise are disruptions to rest and leisure time. Yet the consistent result of traffic noise is sleep disruption [13-15].

Several sources provide various types of traffic noise. Traffic noise is influenced by a variety of factors, including vehicle type, speed, and engine type. Two broad categories may often be used to classify the origins of traffic noise; Source of transmission and power plant noise: Engine noise, exhaust, and cooling systems are included in this category. Source of running gear noise: This category contains differential, propeller shaft, and tire-road interaction noise. The noise produced by the tires becomes louder as you go faster [3]. Traffic volume and noise have a tight relationship that increases exponentially over time [16]. In this research, the amount of traffic noise at four road crossings in Port Harcourt is evaluated. The noise profile at chosen sample sites was identified, together with variables influencing noise levels as traffic volume and meteorological conditions. For the purpose of forecasting traffic noise levels at the chosen sample sites, a multiple regression model was created and verified.

2. METHODOLOGY

2.1 Area of Study

In Rivers state's Obio/Akpor local government area, the research was conducted. The investigation was conducted at four different sites. The four road junctions that were selected were Rumuokwuta, Agip, First Artillery, and

GRA, with coordinates of 4°50'25.9''N, 6°59'17.2''E and 4°49'09.2''N, 6° 58'55.7''E and 4°50'32.4''N, 7°02'08.5''E and 4°49'26.3''N, 7° 00'21.2''E respectively.

With First Artillery and GRA crossings on Aba road heading to Abia state and the other two on Ikwerre road connecting with the East-West Road, these crossroads are among the busiest in the Obio/Akpor local government region. The research region is shown in Fig. 1.

2.2 Equipment and Sampling Methods

The Lantek SL-5868 type 2 sound level meter is the apparatus used for field measurements of sound levels. The Wintact WT816 Anemometer was employed to monitor wind speed and temperature, while the HTC-1 relative humidity meter was used to measure relative humidity in percentage (%).

For each site in the research, which includes a weekend, three days were selected. Daily sampling began at 7am and finishes at 5pm. During 30 minutes by the hour, sound levels were recorded on both sides of the street. The sound level meter was held at 1.5 meters above the ground level, with the microphone pointing towards the road. Readings of the temperature and wind speed were obtained twice per hour. Readings of the relative humidity were only obtained once per hour. At the conclusion of each day, a traffic volume count was performed by capturing a video recording of the road for one minute at peak traffic periods at intervals of 15 minutes. During the recordings, the sound level meter was held in the hand to allow for easy crossing of the highway.

2.3 Mathematical Methods

Equivalent noise levels (L_{eq}), noise climate (NC), traffic noise index (TNI), statistical measure (L_n), and noise pollution level (NPL) are the indicators of interest. The noise indices for the investigation were computed using Equations (1) through (5);

$$L_{eq} = 10 \log_{10} \left[\frac{1}{T} \sum_{i=t}^{i=n} 10^{\frac{L}{10}} t \right] \quad (1)$$

Where L_{eq} is the equivalent noise level in dB(A), T is the total sampling time, L represents recorded noise level in decibels, t is the fraction of total sample time and n is the number of samples.

$$NC = L_{10} - L_{90} \quad (2)$$

Where NC is the noise climate in dB(A), L_{10} and L_{90} are sound levels equaled or exceeded 10% and 90% of the time respectively.

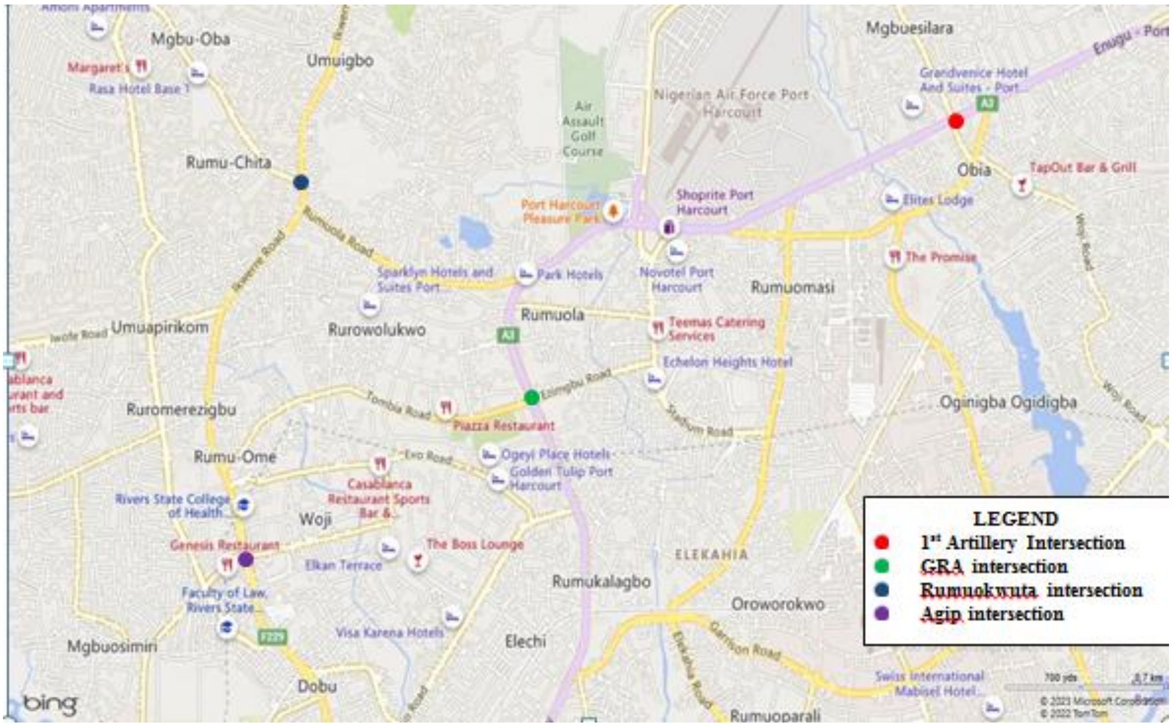


Fig. 1. Study area

$$TNI = 4 \times (L_{10} - L_{90}) + L_{90} - 30 \quad (3)$$

Where TNI is the traffic noise index in dB(A), L_{10} and L_{90} are sound levels equaled or exceeded 10 % and 90 % of the time respectively.

$$\text{Percentile} = \frac{2m-1}{2n} x\ 100 \quad (4)$$

Where m is rank number and n is the total number of samples

$$NPL = L_{50} + L_{10} - L_{90} + \frac{(L_{10} - L_{90})^2}{60} \quad (5)$$

Where NPL is the noise pollution level in dB(A), L_{10} , L_{50} and L_{90} are sound levels equaled or exceeded 10 % , 50 %and 90 % of the time respectively.

2.4 Model Concept

The mathematical models were created for all four sampled sites using the excel add-in tool Regressit, with the highest correlation resulting in the best noise level prediction model. Model idea Equation (6) served as the foundation for the models.

$$N = a_0 + a_1T + a_2 C + a_3 B + a_4Temp + a_5 RH + a_6WS \quad (6)$$

Where, N is the noise level to be predicted in dB(A), T is number of trucks, C is number of cars, B is the number of buses, Temp is the temperature in ^oC, RH is relative humidity in % and WS represents wind speed in m/s

3. RESULTS

To calculate the L_{eq}, L_n, TNI, NC, and NPL, the data was evaluated. To find out how the time of day affected the data obtained, a one-way analysis of variance was conducted. The following are the null and alternative hypotheses:

H_0 = 0; there is no significant difference between the data observed at the different time of day.

H_1 ≠ 0; there is significant difference between the data observed at the different time of day.

The noise levels on the left and right sides of the road were averaged at the chosen sites, and the energy average throughout the sample days was calculated. On all three sample days at the chosen sites, the data in Tables 1 to 4 include the noise energy hourly average L_{eq}, average traffic volume, temperature, relative humidity, and wind speed.

The hourly noise levels shown in Tables 1 through 4 illustrate the shifts in noise level over the course of 10 working hours at the different sites. Table 1 shows that the Rumuokwuta junction had a daily equivalent noise level maximum of 76.3dB(A) and a daily equivalent noise level minimum of 72.9dB(A). Data gathered at various times of the day do not significantly vary, according to a one-way analysis of variance result of $p>0.05$. This crossroads consistently shows to be active throughout the day. As stated in Table 2, Agip Intersection measured a maximum daily L_{eq} value of 74.8dB(A) and a lowest value of 72.5dB(A). Data gathered at various times of the day do not significantly vary, according to a one-way analysis of variance result of $p>0.05$. Another very busy junction where there is virtually constant traffic activity is this one. At the 1st Artillery Junction, Table 3 shows maximum and lowest daily L_{eq} values of 75.9 dB(A) and 73.4 dB(A), respectively. Data gathered at various times of the day do not significantly vary, according to a one-way analysis of variance result of $p>0.05$. The daily hourly L_{eq} readings for the GRA junction are shown in Table 4, with a high of 75.9 dB(A) and a low of 72.7 dB(A). Data gathered at various times of the day reveal a significant difference, as shown by the one way analysis of variance result of $p<0.05$. This shows that there are times of day with less traffic and hence lower noise levels, and also there are peak traffic events producing peak noise levels.

Equation (1) was used to compute the equivalent noise level L_{eq}, with the results shown in Table 5. Weilbull's approach is used to rank the noise data and compute the likelihood of excess to provide the statistical measures L_{10}, L_{50}, and L_{90} (Equation 4). As shown in Fig. 2, the likelihood of surpassing versus noise was plotted, and the relevant statistical measure was read off. Equations (2), (3), and (5) were used to derive NC, TNI, and NPL. The list of the determined indices is shown in Table 5.

Table 1. Data collected at the Rumuokwuta intersection

Hour	Average noise dB(A)	R. Humidity (%)	Wind speed (m/s)	Temp (^oC)	Cars (No/hr)	Trucks (No/hr)	Buses (No/hr)
7-8Am	72.9	85	0.2	27.7	1490	60	600
8-9Am	73.3	86	0.5	28.9	1050	40	625
9-10Am	73.8	87	0.8	30.6	1110	60	555
10-11Am	73.6	84	0.4	30.3	1220	40	570
11-12pm	76.3	83	0.4	31.0	1010	60	650
12-1Pm	73.9	81	0.5	30.8	1090	100	495
1-2pm	74.1	79	0.3	31.6	1065	100	495
2-3pm	74.6	77	0.6	30.3	985	60	540
3-4pm	73.7	75	0.5	29.3	1160	20	430
4-5pm	74.6	76	0.9	29.8	1050	40	430

Table 2. Data collected at the Agip Intersection

Hour	Average noise dB(A)	R. humidity (%)	Wind speed (m/s)	Temp(^oC)	Cars (No/hr)	Trucks (No/hr)	Buses (No/hr)
7-8Am	74.7	87	0.0	27.7	1300	20	620
8-9Am	73.9	82	0.3	28.6	1400	0	640
9-10Am	74.2	86	0.4	28.8	1260	40	800
10-11Am	74.8	86	0.5	30.8	1440	0	660
11-12pm	72.5	82	0.7	31.9	1400	40	640
12-1Pm	73.0	80	0.9	32.5	1500	60	640
1-2pm	74.7	73	1.0	32.3	1880	0	660
2-3pm	74.6	73	0.8	32.6	1520	40	700
3-4pm	74.7	70	0.9	31.5	1460	0	540
4-5pm	73.7	72	0.5	31.3	1500	0	540

Table 3. Data collected at the 1st artillery intersection

Hour	Average noise dB(A)	R. humidity (%)	Wind speed (m/s)	Temp (^oC)	Cars (No/hr)	Trucks (No/hr)	Buses (No/hr)
7-8Am	73.4	82	0.0	27.9	1740	70	450
8-9Am	75.3	88	0.2	27.0	2400	30	590
9-10Am	74.5	89	0.8	27.7	2370	30	500
10-11Am	74.8	91	0.8	28.7	2140	120	490
11-12pm	74.1	89	0.7	29.0	2250	90	380
12-1Pm	74.9	83	1.3	29.2	2810	60	450
1-2pm	75.6	83	1.0	29.5	2250	30	450
2-3pm	75.9	84	0.5	29.5	2210	30	320
3-4pm	75.4	85	0.9	28.9	2640	30	510
4-5pm	74.8	84	1.4	28.7	2810	50	520

Table 5's L_{10} value for the Rumuowkuta junction is 75.5 dB(A), with a background noise value of 73.1 dB(A). At this location, the computed noise pollution level and traffic noise index are 76.3 dB(A) and 49.7 dB(A), respectively. The peak noise level at the Agip intersection was determined to be 74.7 dB(A), and the background noise level to be 72.7 dB(A). A 76.4dB(A) noise pollution level and a 44.0dB(A) traffic noise index were also established for the site. At the First Artillery junction, an L_{10} value of 75.8 dB(A) and background noise of 73.8 dB(A) were calculated. The 1st Artillery junction also had a noise pollution level of 76.9 dB(A) and a traffic noise index of 47.5 dB(A), as indicated in Table 5. A peak level of 75.7dB(A) and a background noise level of 73.6dB(A) were determined at the GRA junction. At this location, a traffic noise index of 47.2dB(A) and a noise pollution level of 76.99dB(A) were determined.

Table 4. Data collected at the GRA intersection

Hour	Average noise dB(A)	R. humidity (%)	Wind speed (m/s)	Temp (^oC)	Cars (No/hr)	Trucks (No/hr)	Buses (No/hr)
7-8Am	74.4	89	0.4	27.5	3440	40	490
8-9Am	74.8	89	0.9	28.4	3780	40	480
9-10Am	74.8	91	0.7	29.8	3270	50	490
10-11Am	74.6	90	0.7	30.7	3000	60	310
11-12pm	74.8	87	0.7	32.9	2920	20	380
12-1Pm	75.9	78	0.8	33.2	3300	30	480
1-2pm	75.5	72	1.0	33.1	3150	40	360
2-3pm	74.9	72	0.8	32.1	2760	30	350
3-4pm	74.8	71	0.9	31.6	2820	30	360
4-5pm	72.7	71	1.2	30.4	2330	80	370

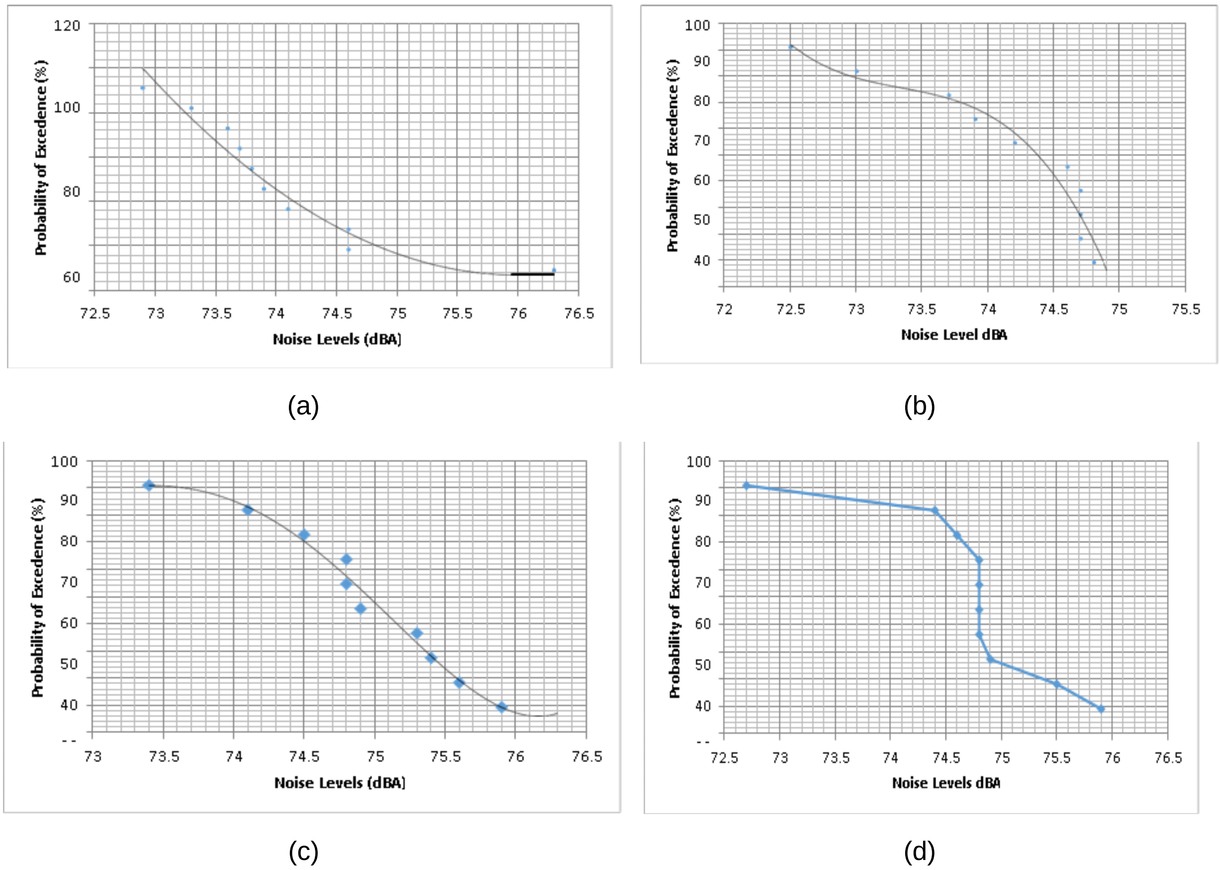


Fig. 2. Probability curves for (a) Rumuokwuta intersection (b) Agip intersection (c) First Artillery intersection (d) GRA intersection

Table 5. Calculated statistical measures for the Rumuokwuta intersection

Parameters	Rumuokwuta	Agip intersection	1^{st} Artillery	GRA intersection
L_{eq} dB(A)	74.2	74.1	74.9	74.8
L_{10} dB(A)	75.5	74.7	75.8	75.7
L_{50} dB(A)	73.8	74.4	74.8	74.8
L_{90} dB(A)	73.1	72.7	73.8	73.6
NC dB(A)	2.4	1.98	2.002	2.1
NPL dB(A)	76.3	76.5	76.9	76.99
TNI dB(A)	49.7	44.04	47.5	47.2

The L_{10} value for all places is found to be between 60 and 80 dB(A) which according to Langdon [17] is likely to be bothersome. The highest TNI value receptors at Rumuokwuta crossroads are more likely to be irritated by traffic noise. Agip has the lowest TNI value, while Artillery, which has the second-highest value, is closely followed by GRA. This is much lower than the threshold of irritation of 74 dB(A) proposed by Langdon and Scholes [18]. All of the L_{eq} are louder over 60 dB(A), which EPA [19] suggests makes them obtrusive and disrupts dialogue. A one-way analysis of variance reveals $p>0.05$, indicating no significant difference in the data, which may be used to assess if there is any significant difference in the results obtained in Table 5. This result implies that the receptors are likely to be disturbed by the noise levels seen at these sites.

3.1 Model Calibration and Dimension Reduction

The standardized coefficients for all of the independent variables were calculated using the statistical program Regressit, as shown in Fig. 3, from which the variables' sensitivity was evaluated. Trucks and small automobiles at the Rumuokwuta junction have the lowest values, as shown in Fig. 3(a), and as a result, have the least impact on the dependent variable noise. Fig. 3(b) demonstrates that at the Agip junction, wind speed and small autos have the lowest values and hence the least impact on noise levels. According to Fig. 3(c), relative humidity and small autos had the least impact on the dependent variable "Noise" at the 1st Artillery crossroads. The least values are seen in trucks and buses, as shown in Fig. 3(d). These factors may be eliminated from the model formulation without having a negative impact on the model's overall performance since they have the least impact on the dependent variable, noise.

Equations (7) through (10) for the intersections with the Rumuokwuta, Agip, 1st Artillery, and GRA, respectively, provide the model idea of Equation (6) that was calibrated with the other variables using multiple regression analysis in Regressit.

$$N = 70.46 - 0.22RH + 1.63WS + 0.4297Temp + 0.0143B \tag{7}$$

$$N = 78.55 - 0.049RH - 0.13Temp - 0.022T + 0.0057B \tag{8}$$

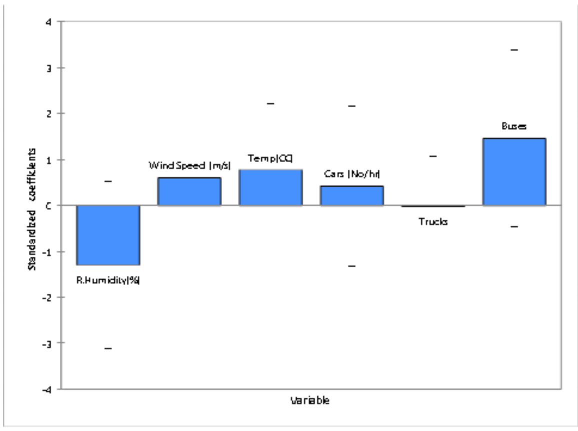
$$N = 45.68 - 0.56WS + 0.96Temp - 0.013T + 0.0063B \tag{9}$$

$$N = 62.02 - 0.03RH - 1.4WS + 0.33Temp + 0.0019C \tag{10}$$

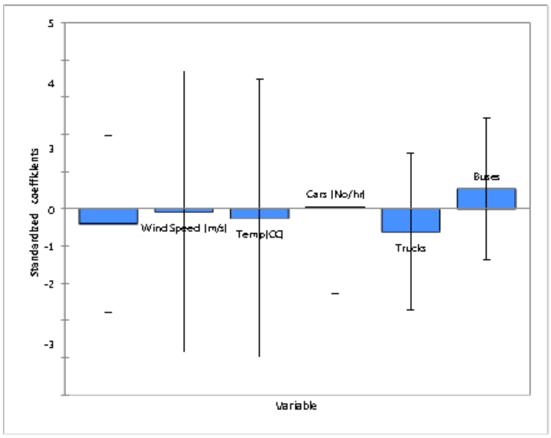
Where, N is Noise level to be predicted in dB(A), T is number of trucks, C is number of cars, B is number of buses, Temp is the temperature in ^oC, RH is Relative humidity in % and WS is the wind speed in m/s.

3.2 Model Validation

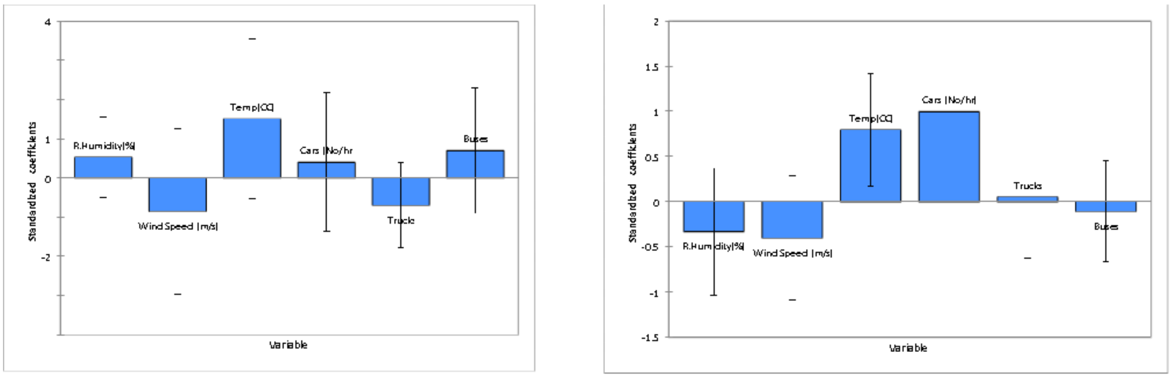
A plot of the actual and projected values versus the number of observations and the calculated R^2 value was created to verify the model. Fig. 4 displays the plot.



(a)

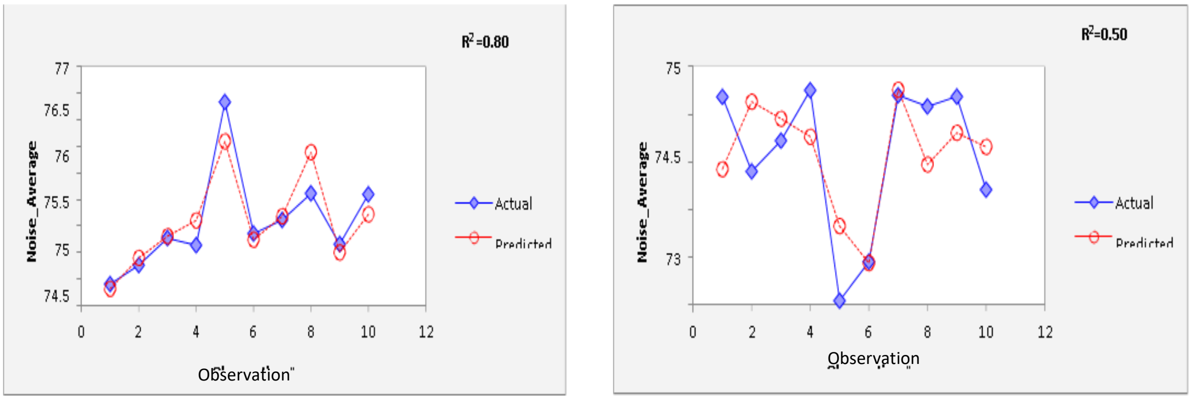


(b)

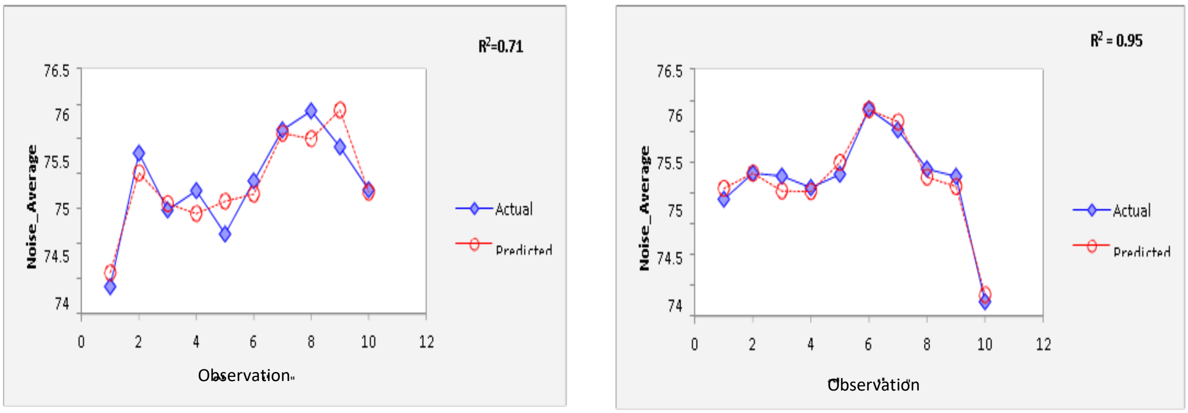


(c) (d)

Fig. 3. Standardized coefficients of variables from (a) Rumuokwuta (b) Agip (c) 1st artillery (d) GRA intersections



(a) (b)



(c) (d)

Fig. 4. Actual and Predicted values versus Observation at (a) Rumuokwuta (b) Agip (c) 1st artillery (d) GRA intersections

The plot of the actual and expected noise levels for each junction is shown in Fig. 4. According to Fig. 4(a), the Rumuokwuta model's coefficient of determination is 0.80. This demonstrates that the model may be used to make predictions with a 95% confidence level. The Agip model's obtained coefficient of determination is 0.50, as shown in Fig. 4(b). Because of the moderate correlation between the model and the actual data, forecasts of the noise level at a 95% confidence level should be taken with care. For the first artillery model, the coefficient of determination is 0.71, as illustrated in Fig. 4(c). This suggests that the model may be used as a tool for predicting noise levels. Fig. 4(d) shows a correlation of 0.95 in terms of coefficient of determination. This demonstrates a very high degree of predictability for the model when used as a tool to forecast noise levels at the GRA junction. The findings of Amah and Atuboyedia [20] who showed an R^2 range of 0.25 to 0.95 for linear models in forecasting traffic noise are in agreement with these results.

4. CONCLUSION

From this study, it was found that the noise level was lowest at the Agip intersection, measuring at 74.14 dB(A), even though it was higher than the recommended noise level of 60 dB(A), beyond which noise intrusions occur. The 1st Artillery Junction recorded the highest noise level, 74.9 dB(A), which is powerful enough to irritate receptors. The GRA and Rumuokwuta, for instance, reported noise levels of 74.8 dB(A) and 74.18 dB(A), respectively. These noise levels are too loud to allow for regular daily discussion. Rumuokwuta scored the highest value of 49.7 dB(A) on the TNI, increasing the likelihood that receptor discomfort may result from traffic noise at this site. Agip junctions had the lowest TNI of 44.04 dB(A), making them the least inclined to do so. The models created to forecast noise at various locations had excellent dependability, as shown in the model with an R^2 value ranging from 0.50 to 0.95 as its lowest and highest points.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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