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Statistical modelling for urban roads traffic noise levels

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A B S T R A C T

Traffic noise is one of the most significant types of vehicular emissions that result in physical and psychological health effects on humans and is caused by an increase in vehicular ownership and urbanisation. The central business district (CBD) of Ondo has been exposed to persistent road traffic and commercial activities due to development and expansion of the economy, and this has led to an increase in traffic noise levels. Due to the increase in traffic volume, urbanisation, and population deterioration of road pavements in the CBD, it was hypothesised that noise related to traffic has increased and is above the permissible limit of the World Health Organisation in the study area. Monitoring noise levels by administrative agencies will help mitigate traffic noise intensity and aid in urban planning. This study examined the traffic noise levels and developed models for the CBD of Ondo, Nigeria. Adopting the empirical methods of the Calculation of Road Traffic noise (CoRTN) model and statistical Multiple Linear Regression (MLR) modelling approach, traffic noise models for the assessment of equivalent noise levels (Leq) at the CBD of Ondo were developed. Over 90% of the roadsides surveyed were above the world health organization's 70 dB(A) threshold. Correlation between CoRTN and MLR models demonstrated reliable efficiency relative to observed noise levels with an acceptable coefficient of determination (R^2) values of 0.943 and 0.963, respectively. The deviation between the noise levels measured with the expected noise levels (MLR and CoRTN) varied, between 0.44 dB(A) and 2.09 dB(A) with an average mean difference of 0.37 dB(A) to 1.9 dB(A). These values are adjudged satisfactory since it is within the +/- 3.0 (dB)A allowed by the Federal Highway Administration (FHWA). The models are therefore robust and accurate in estimating the level of noise from road traffic for the study area.

Introduction

Noise pollution is one of the most significant forms of emissions observed as a result of the consequences of the development of various transport systems over the past decade [1]. Economic growth, population growth, and vehicle ownership

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may contribute to roadway noise, thereby causing health deterioration to humans living/working in proximity to roads. The transition from rural to built-up areas, demographic change, and development in infrastructure are some of the determinants, leading to a growing number of urban noise emissions [2]. However, Oyedepo [3] reported that because of the development of roads, the noise being emanated affects the ecosystem and inhabitants, the vibration of structures, and even disrupts wildlife.

Furthermore, Govindaraj and Pachiappan [4] divided the noise impact of traffic, reliant on the noise intensity exposure and its length of time, into four categories: physical aspect (hearing defects), depression (irritability, sleeplessness, and stress), biological responses (high blood pressure, cardiovascular rate, and ulcers), and influence on the execution of tasks (decline in efficiency and misunderstanding over what is communicated). Recent studies have focused on the connection between urban roadway noise and human health effects and have shown that traffic noise can lead to irritation, communication interference [5], and noise-induced hearing loss (NHIL) [6]. Awareness of the effects of traffic noise pollution on the environment and public health consequences has urged some countries to adopt noise pollution limits and implement policies to minimise traffic noise levels. Monitoring of noise levels by administrative agencies will help mitigate traffic noise intensity and aid in urban planning based on the applicability of traffic noise prediction models.

The World Health Organization (WHO) states that at least one million healthy life years are lost every year from traffic-related noise in the western part of Europe [7]. Similarly, "The WHO in 1999 suggested a standard guideline value for average outdoor noise levels of 55 dB(A), applied during normal daytime (16 hours) to prevent significant interference with the normal activities of local communities and is considered as a serious annoyance, while a value of 50 dB(A) as a moderate annoyance," [8,9]. Table SM1 shows the WHO permissible limits for community noise levels for industrial, commercial, and traffic areas.

Noise pollution is a severe problem in Nigeria, and despite the dangers it poses to the environment, little attention is paid to it [10]. Consequently, road traffic noise is a serious threat to the environment in various geopolitical zones in Nigeria, with its levels exceeding the allowable threshold. Based on research, it was found that all workers, including minor dealers, who were exposed to noise for fourteen years had hearing loss [11–13]. According to the research by Onuu [11] noise exposure has steadily increased in South-East Nigeria as a result of growing industrial, commercial and urbanisation. This is exacerbated by the widespread use of (used) outdated automobiles, branded *Tokunbo* or *Belgium* [11] in Nigeria. Furthermore, a study in Agbor, Nigeria, indicated that big trucks, luxurious buses, and commercial activity were the main sources of increase in noise [14]. Consequently, justifying the fact that traffic related noise is an addendum to noise pollution; which needs to be curbed, in relation to its menace to the environment.

The level and frequency of traffic noise may continue to rise due to population expansion, urban sprawl, and a related increase in car usage. Recognition of roadway factors is, however, crucial to identifying the dynamics of traffic noise and then aiding in the development of noise models; modelling of traffic noise typically depends on the source of noise generation and the distance to the destination, considering certain contributing factors, mostly the traffic conditions (i.e., the stream of traffic, the proportion of traffic flow, pavement type, width and gradient of the roadway and vehicular speed) and non-roadway factors such as barriers (buildings, shrubs, trees) and weather. Therefore, the availability of such data makes it possible to compute, evaluate, and predict traffic noise levels in relation to noise descriptors [15].

Several countries have developed their own traffic noise models, and these models have been adjudged to be satisfactory. Similarly, in some cities with similar prevailing traffic conditions to these existing and standard models, test the applicability of these models to determine if they are fit for noise prediction. Examples of some of these standard models include the Federal Highway Administration (FHWA) in the United States, RLS 90 (Germany), Harmonoise (Europe), and CoRTN. The CoRTN model was formulated in the United Kingdom in 1988 [16]. It considers a length of 10 metres from the side of the roadway to the receptor point. Thereafter, specific modifications are required for the flow of vehicles, the percentage of heavy vehicles, angle, road surface, road width, barrier, and so on to get the final hourly L_{10} value. The FHWA model estimates traffic noise levels at a distance of 15m from the source of noise emission to the receptor to account for the average noise emission level (L_0). Calculations are obtained for the flow of vehicles and obstructions, and summed up to get the equivalent sound level (L_{eq}) in Eq. (1) [17,18].

$$L_{eq} = L_0 + \sum L_i \tag{1}$$

Where L_0 = Noise emission level and L_i = modifications for traffic parameters (pavement type, the composition of flow, speed, obstruction, etc.).

The CoRTN model has been used worldwide and has been adjudged accurate for traffic noise prediction [19,20]. In particular, it is one of the major tools for environmental assessment by local authorities in the United Kingdom and Hong Kong [21]. Several authors have examined the strength of the CoRTN model for the prediction of traffic noise. In Asia, the CoRTN model's accuracy in predicting traffic noise was tested, with over half of the automobiles comprising motorcycles; the results showed the effectiveness of the model was satisfactory in the forecasting of traffic noise, having a coefficient of determination value of 0.832 and a mean difference of 0.52 dB(A) between the observed values and those predicted [19].

Some scholars have studied the application of regression analysis to examine the efficiency of traffic noise prediction and found it to be satisfactory. Govindaraj and Pachiappan [4] studied the parameters of traffic noise in Tamil Nadu and the Kerala States, and a model for MLR was developed to predict traffic noise. The model proved to be satisfactory with an R^2 value of 0.809. Likewise, in Tirupati City, Sukeerth et al. [22] measured the volume of traffic and sound intensity at rush periods in certain areas of the city. Models using regression analysis and artificial neural networks were formulated and validated. The mathematical equations developed gave accurate predictive noise levels between the two models (i.e., linear regression and artificial neural networks) with (R^2) values of 0.982 and 0.970, respectively.

In this study, a set of traffic noise data and other traffic parameters were collected along 3 major transport corridors in the central business districts of Ondo town, Nigeria, to examine the applicability of the CoRTN model. Also, the data were analysed to derive an L_{10} MLR traffic noise model. The robustness of these models was compared with the observed data. These models were validated with another set of noise data for the prediction of traffic-related noise.

Materials and methods

Study area

The research covers the central business district (CBD) areas in Ondo town in the western part of Ondo State. The town is relatively large; it has an area of 970 km² and a population of 432,000 [23]. It is located at around latitude 7.02568 North and longitude 4.769159 East of the Greenwich Meridian. There has been significant development in the town in terms of population and economic growth. The traffic composition of the town comprises different vehicles such as taxis, minibuses, motorcycles, lorries, and trailers, and as a result, the study location is characterised by high emissions from road noise. Its major road network systems are Akure-Ondo road, Ondo-Ife road, Ore-Ondo road, and Ondo-Ilegbira road, which serve as the major arterial routes in the town and a link to other towns as indicated in Figure SM1.

The CBD of Ondo town is easily identified by features such as its most accessible location, costly value of properties, high road networks and buildings, cultural and historical monuments, business sector, transport centres, and high traffic at peak hours. In addition, some road pavements in the town are deteriorating due to persistent road traffic and lack of proper maintenance. However, all these are contributing factors that lead to an increase in traffic noise in the CBD of the study area and can cause health disorders in individuals.

Data collection

Data were recorded during the morning period (7-8 am), afternoon period (11- 12 pm) and evening period (3-4 pm) for seven (7) days at three locations. As the behaviour of vehicles, drivers, and traffic conditions might vary depending on the time and day of travel, the measurements were made at different dates and times to account for variability in the measured data. The four-hour intervals considered are expected to reflect the city's traffic fluctuations between the rush hours (morning and evening) and the afternoon period (off-peak) when there is less traffic. The traffic volume data were extracted from digital video camera recordings. Vehicles were classified into two categories: light vehicles (LV), which include private cars, taxis, and motorcycles, and minibuses, and heavy goods vehicles (HGV), which are buses, trucks, and trailers. Simultaneously, vehicular speed data were measured and recorded by observing the length of time a vehicle spends to travel 100 m distance. An IEC Type II wireless sound level metre was used for noise measurement. The instrument was affixed to a tripod stand at a location without the presence of barriers like elevated structures, trees, etc., with the microphone height of 1.5 metres above ground level pointing to the road and 5 metres from the middle of the roadway. The measured hourly noise levels were recorded manually every 30 s for 1 hour at each location.

Model calibration

Data collected from the field survey were fitted into the CoRTN model to obtain a predicted data set. The CoRTN traffic noise prediction model is:

$$L_{10} = L_0 + \Delta f + \Delta p + \Delta g + \Delta d + \Delta s + \Delta a + \Delta r \tag{2}$$

Where L_0 is the standard hourly noise level, Δf is an adjustment for speed of traffic and proportion of heavy vehicles in percent. Subsequently, calculations are made for (Δp, Δg, Δd, Δs, Δa, and Δr) pavement surface, gradient, distance, obstacles, angle view and reflections, respectively. Each of the CoRTN model parameters is defined mathematically below;

$$L_0 = 42.2 + 10\ \log\ q\, dB(A) \tag{3}$$

Where q denotes the time flow of traffic and v is the speed

$$\Delta f = 33\log(v + 40 + (500/v)\ \ + 10\ log(1 + 5p/v) - 68.8 \tag{4}$$

$$p = 100f/q \tag{5}$$

Where p is the percentage of heavy vehicles and f is the volume of heavy vehicles by the hour

$$\Delta g = 0.3G \tag{6}$$

Where G denotes the slope, only assigned for extremely steep roadway pavement

$$\Delta p = -1dB(A) \tag{7}$$

Table 1
Measured traffic noise levels dB(A).

	Ife Garage			Akure Garage			Oka Roundabout		
	7-8 AM	11-12 PM	3-4 PM	7-8 AM	11-12 PM	3-4 PM	7-8 AM	11-12 PM	3-4 PM
No.	*Leq* (dB)A as Measured								
Day 1	75.9	75.4	73.7	74.2	72.3	74.0	73.6	71.3	70.7
Day 2	73.7	73.1	71.9	73.7	70.5	72.1	73.5	71.0	70.9
Day 3	75.5	72.9	73.6	72.0	71.2	72.4	72.4	71.8	71.5
Day 4	75.5	72.7	76.1	73.1	70.5	71.9	73.0	73.3	72.0
Day 5	76.0	74.1	74.9	74.0	72.1	73.9	74.6	73.1	72.8
Day 6	71.1	68.8	71.0	72.0	71.3	72.5	71.4	72.0	72.6
Day 7	68.8	69.0	69.1	69.9	68.7	69.5	71.0	69.5	70.0

$$\Delta d = -10\, log\left(d'/13.5\right)\, dB(A) \tag{8}$$

Where *d'* represents the minimum distance from a reference point to receiving end; *h* is the ground level height of SLM

$$d' = \left\{(d+3.5)^2 + h_2)\ 0.5\right\} \tag{9}$$

$$\Delta a = 10\left\{{}^{\theta}/_{180}\right\} dB(A) \tag{10}$$

Where Θ and Θ_s are the roadway elevation and total of inclination points from the buildings opposite the roadway, respectively;

$$\Delta r\ =\ \left\{1.5\left(\frac{\theta_s}{\theta}\right)180^\circ\right\} dB(A) \tag{11}$$

Lastly, an adjustment to the Equivalent noise level (Leq) is required because the CoRTN model is factored on L_{10} values. The *Leq* is estimated using the algebraic expression in Eq. (12).

$$L_{eq} = 0.94\, L_{10} + 0.77\ dB(A) \tag{12}$$

The MLR model was evaluated using the coefficient of determination (R^2). The model's reliability was also compared with the standard CoRTN model. The MLR equation is of this form:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_k X_k \tag{13}$$

Where Y represents the traffic noise levels, βo is the model constant representing that portion of the value of the dependent variable not explained by the independent variables and β_1-β_k are regression coefficients associated with traffic composition, traffic volume (TV), and speed X_1-X_k. Significance tests and correlation analysis were examined in the derived regression model to determine its reliability.

Considering previous studies in road traffic noise modelling, passenger cars, HGV, bus, and speed were basic parameters of input in model development. Other variables, such as the proximity of roads to buildings or barriers, the pavement surface, and the gradient of the road, were factored into the equation as per the inputs described by the noise prediction model CoRTN.

Results and discussion

Results of traffic volume recorded from the various study locations during the peak and off-peak periods are presented in Figure SM2. The highest TV of 12,760 vehicles per hour was recorded at Ife Garage during the morning peak period. There was a slight decrease during the off-peak period and a gradual increase at between 3-4 pm. Oka Roundabout had the least traffic volume of 4478 vehicles per hour and the highest percentage of heavy vehicles exceeding 20 % of the TV.

The speed of vehicles was observed at the three study locations; the speed at these locations were considered as an average speed of all vehicles ranging between 57.86 km/h and 67.7 km/h. The highest speed of 73.87 km/h was recorded during the off-peak period, at which traffic volume was low and vehicles were travelling at free speed. The results of measured traffic noise in Table 1 shows that approximately 90% of traffic noise levels measured at the study area exceed 70 dB(A) threshold established by WHO Guideline for Community Noise for industrial, commercial, and traffic areas.

Measured traffic noise data collected were fitted into the CoRTN model in Eq. (2) and calibrated for the study area. It should, however, be noted that modification for Δg, is only assigned for extremely steep roadway pavement does not apply to any of the study locations because all road sections had flat gradient, therefore, it was not considered in the model equation. Likewise, Δs which is the adjustment for any obstacle during the measurement is not considered in the model equation.

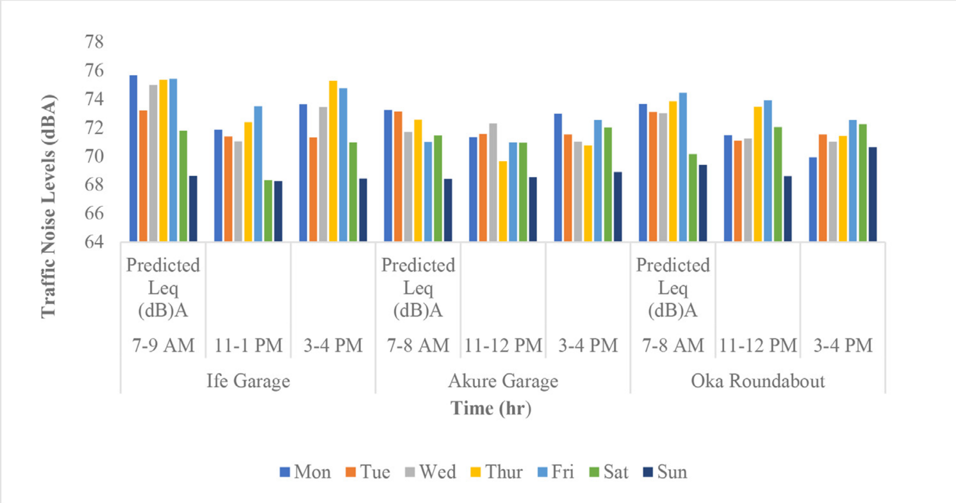

Fig. 1. CoRTN predicted traffic noise levels.

The CoRTN model, as applicable to the study locations is represented in Eq. (14)

$$L_{10} = L_0 + \Delta f + \Delta p + \Delta d + \Delta a + \Delta r \tag{14}$$

Eq. (14) was further expanded as Eq. (15).

$$L_{10} = (42.82 + 10\,logq) + 33\log\left(v + 40 + \left(\frac{500}{v}\right) + 10\log\left(1 + \frac{5p}{v}\right) - 68.8\right) + (-\Delta p) + (-\Delta a) \;+ (\Delta r) + \left(-10\log\left(\frac{d' = \left\{\left((d+3.5)^2 + h^2\right)^{0.5}\right\}}{13.5}\right)\right) \tag{15}$$

The CoRTN model in Eq. (15) was used to achieve the predicted traffic noise levels for the study locations. While Eq. (12) was used for the conversion of L_{10} to *Leq* to enhance the comparison between predicted and measured noise levels as presented in Fig. 1. The highest predicted equivalent noise level of 75.67 dB(A) was obtained during the evening period at Ife Garage which is a value that is higher than the permissible limit in the WHO standard evening period at Ife Garage which is a value that is higher than the permissible limit in the WHO standard.

Traffic noise multiple linear regression model analysis

Eq. (16) represents the Multiple Linear Regression Model generated from field studies
Regression Analysis: Leq versus HGV, traffic volume, traffic speed
Null Hypothesis: H_0=Model adequately fits the data
Alternative Hypothesis: H_A= Model does not adequately fit the data
Regression Equation

$$Leq = 44.83 + 8.152(Q) + 0.031(v) + 0.085(HGV) \tag{16}$$

Where the dependent variable: *Leq* = the traffic noise levels
Independent variables: *Q*= traffic volume, *v*= traffic speed, and *HGV*= heavy goods vehicle

The relationship between explanatory variables was evaluated using a correlation assessment provided in Table SM2. The Pearson correlation values ranged between 0.073 to 0.228 indicating a weak relationship between the independent parameters, with *p*-values below 0.05, therefore, the parameters revealed statistical significance.

Model summary

The model developed for the traffic noise prediction in the Ondo Central Business District shows that at 95 percent level of confidence, there is a significant relationship amongst the independent and the predictor variables based on the model with (*P*-Value <0.005) hence, the null hypothesis cannot be rejected. The model summary results are presented in Table 2. The Variance of Inflation Factor (VIF) values to test for multicollinearity range from 1.31 to 1.65 in Table 2 which is less than 10, obtained for each independent variable, which explains also that the independent variables are not correlated. Also, the *p*-values are less than 0.005, which explains that the variables are statistically significant.

Furthermore, the adjusted R^2 value of 0.857 shown in Table 2 implies that about 86.0% of the model variation in the traffic noise prediction is explained by the associated predictor variables which are statistically significant (traffic volume, speed, and HGV) in the overall model. Therefore, the study fails to reject the null hypothesis.

Table 2
Summary of the model.

S	R-square	R-square(adj)	R-square(pred)		
0.715728	86.40%	85.70%	85.07%		
Term	Coefficients SE	Coefficients	T-Value	Value of P	Variance of Inflation Factor (VIF)
Constant	44.83	1.78	25.14	0.000	
HGV	0.0848	0.0189	4.48	0.000	1.31
Traffic volume	8.152	0.453	18.02	0.000	1.65
Traffic speed	0.031	0.00830	3.79	0.000	1.32

Table 3
Analysis of variance.

Source	DF	Adj SS	Adj MS	*F*-Value	*P*-Value
Factor	2	6.669	3.335	0.99	0.373
Error	186	626.097	3.366		
Total	188	632.766			
Factor	Mean	StDev	95% CI		
REGRESSION (Leq)	72.325	1.759	(71.869, 72.781)		
CoRTN (Leq)	71.927	1.849	(71.470, 72.383)		
MEASURED (Leq)	72.325	1.893	71.869, 72.781)		

One-way ANOVA

While the value of the coefficient of determination provides an encouraging measurement of the relationship between the measured noise levels and the predicted noise levels, the Analysis of Variance (ANOVA) method was used to further clarify whether the mean of the observed traffic noise values and the estimated traffic noise values are substantially different. The result of the ANOVA is shown in Table 3.

Null assumption: means of all variables are equal

Alternative hypothesis: one of the variable means is different

Level of Significance: $\alpha = 0.05$

In these results from Table 3, the null hypothesis states that the mean of the traffic noise levels is equal at a 95% simultaneous confidence interval. Since the value of p is 0.373 which is higher than the significant point of 0.05, the null assumption is not rejected and therefore confirms that all traffic noise levels (measured and predicted) have equal means.

Validation of CoRTN model for the study locations

The performance of the CoRTN model in predicting traffic noise levels was tested by comparing the CoRTN noise prediction values and the newly measured traffic noise values. The differences between the measured and predicted traffic noise levels were between -0.51 dB(A) to 2.09 dB(A); the mean difference is 1.19. The model correlated well with the measured values with an R^2 of 0.94 as indicated in Fig. 2.

Validation of predicted traffic noise regression model

The differences between the measured traffic noise values and the corresponding generated traffic noise regression prediction values were in the range of -0.44 dB(A) to 1.48 dB(A); the mean difference is 0.37 dB(A). The predicted traffic noise regression model correlated well with the measured traffic noise values with an R^2 value of 0.963 as shown in Fig. 3.

The noise survey results shown in Table 1 for the various locations are different due to the demographic statistics and activities in the area. Ife garage had one of the highest traffic noise levels, at 76.1dB(A), because of the presence of various institutions (government, education, and health centers), which drew people to that direction of travel. On the contrary, Oka and Akure produced lower values from the result. However, Oka roundabout recorded 74.6 dB(A), which is slightly higher than Akure garage at 74.2 dB(A), despite Akure having a higher traffic volume of 7226 vehicles per hour during the morning peak hour in Figure SM2. This location serves as a major arterial linking to other cities and commercial regions or markets. Hence, the maximum number of HGV exceeding 20% of the TV passes during the morning and evening hours, accumulating to a greater portion of the flow and increasing noise levels. In all locations, light vehicles contributed significantly to traffic composition.

The study showed that some outdoor living areas, including hospitals, residential, academic sectors, etc. in the CBD of the town are at risk of traffic noise pollution. Some of these places are within the study area. Most of these supposed areas are above 50 dB(A) permissible limit recommended by WHO. Eq. (16) represents the multiple regression model for the study location. Holding the other factors (traffic volume and speed) constant, an increase of 10 HGV increases the *Leq*

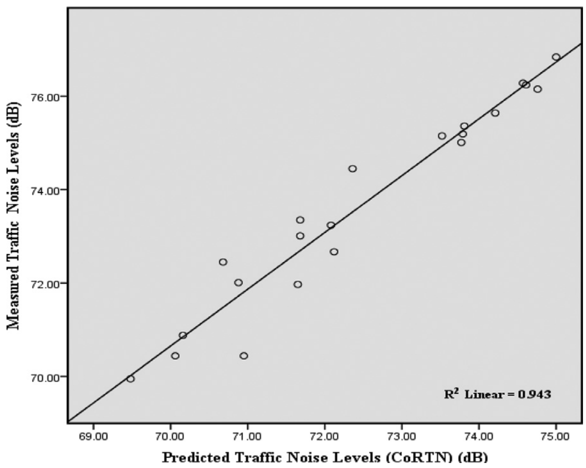

Fig. 2. Comparison of measured and predicted CoRTN *Leq*.

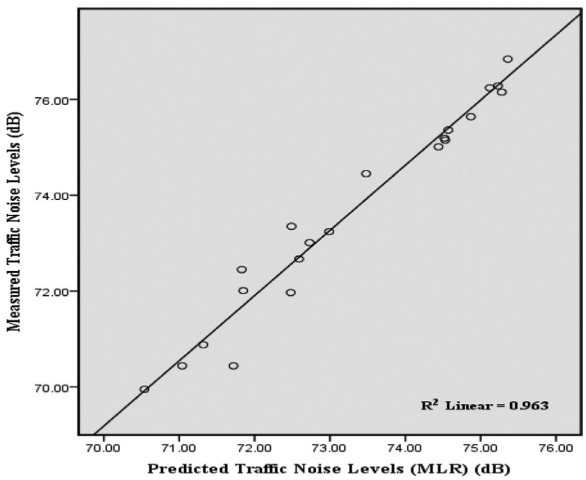

Fig. 3. Measured and predicted regression *Leq* compared.

by about 0. 8dB(A). It is important to note that the traffic noise prediction model developed using MLR had a constant value of 44.83. This constant value is the expected mean value of *Leq* (traffic noise levels) when Q, v, and HGV (volume of traffic, speed, and proportion of heavy vehicles in percent) remain zero. The constant value in the model equation results from the concentration of various noise sources such as commercial activities, schools, pedestrians, and religious activities concentrated at the study locations that contributed to an increase in the levels of traffic noise measured.

Conclusion

The level of traffic noise measured in *Leq* for the study locations was relatively high, varying between 68 dB(A) and 76 dB(A). In reference to the WHO Guideline for Community Noise, about 90% of traffic noise levels at the study locations examined exceeded the threshold of 70 dB(A) by 6 dB(A) which confirms that the study area is at risk of traffic noise pollution and may pose a great threat to the health of inhabitants of the city in the long term. This is because a high level of noise may not cause immediate serious effects, but if such a noisy environment prevails, it may affect the population.

Both models exhibited strong accuracy in predicting traffic noise levels relative to the measured values, with acceptable (R^2) values of 0.943 (CoRTN) and 0.963 (MLR). The dissimilarity between the observed traffic noise values and the MLR values varied from -0.44 dB(A) to 1.48 dB(A), and the mean difference was 0.37 dB(A). Also, the differences between the measured traffic noise levels and predicted CoRTN values were in the range of -0.51 dB(A) to 2.09 dB(A) and the mean difference was 1.19 dB(A). The variation between the field traffic noise recorded and the predicted values were deduced to be satisfactory since it is within the +/- 3.0 (dB)A allowed by the Federal Highway Administration (FHWA). Therefore, the developed models from this study are robust and perform reasonably well in predicting traffic noise and to investigate the reduction measures in the study area.

In this research, the speed of vehicles was measured only in the considered direction of travel. The results may be improved if the speed of vehicles plying the opposite direction was also considered. Furthermore, noise effects on rigid pavements may be distinct as this study was conducted on flexible pavements. However, further research can be measured on rigid pavements.

Authors' contribution

- Conceptualization and design: Ibili Fidelma and Owolabi Oladipo Adebayo.
- Material preparation and data analysis were performed by Ibili Fidelma and Amara Ballack Massaquoi.
- Original draft preparation: Ibili Fidelma.
- Review and editing for the final manuscript: Ibili Fidelma, Williams Ackaah, Owolabi Oladipo Adebayo and Amara Ballack Massaquoi.
- Resources: Ibili Fidelma.
- Supervision: Owolabi Oladipo Adebayo and Williams Ackaah.

Intellectual property

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property.

Authorship

We attest that all authors contributed significantly to the creation of this manuscript. We confirm that the manuscript has been read and approved by all named authors and the order of authors listed in the manuscript has been approved by all named authors.

Declaration of Competing Interest

The authors declare that they have no conflict of interest.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.sciaf.2022.e01131.

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