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Full Length Research Paper

Aircraft noise pollution assessment of Port Harcourt International Airport, Omagwa, Rivers State, Nigeria

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An expressive survey, measurement and analysis of aircraft noise pollution assessment at the Port Harcourt International Airport, Omagwa, Rivers State, Nigeria has been performed. The study collaborated both sound levels and environmental pollution of aircrafts noise impact on the communities. Physical/acoustic measurements of the airport were carried out through the use of a BK Precision digital sound level meter. Noise generating sources were identified and classified, with due regard to the health and safety hazards. In order to validate the field measurements, an optimization model was adopted using a symbolic computational software package (Maple). The unique derivable model was thereafter evolved from which graphical and quantitative results of noise were comparably found suitable, it was evident that the optimization model is in an excellent agreement with the field measurement/data such that the model explicitly interpolate, extrapolate empirical data. The pivot of this work is hinged on the derivation and placement of the optimization model that is used to accurately evaluate and validate airport field measurements.

Key words: Optimization model, aircraft noise pollution, noise assessment.

INTRODUCTION

The ability of human beings to perceive noise is a major important development to human wellbeing. The degree of annoyance to noise depends on the individual attitude and mood to noise and the quality and magnitude of the sound. Relatively, to some persons a quiet sound can be annoying to some individuals as loud sound. Sound and noise are often used interchangeably, but when talking of physical quantity, sound is preferred (Avwiri and Nte, 2003).

The primary aim of this research work is to develop a mathematical model that is suitable for aircraft noise assessment and evaluation. A lot of notable scientists have researched extensively on environmental noise (road, rail, airport, industrial complexes, domestic noise etc) Owate, Avwiri, Ogobiri (2005). Christophe et al. (2007) used the lighthill equation to compute the noise produced by subsonic flows. Nwaogazie and Owate (2002) investigated the transient and impact of noise pollution arising from the industrial machines.

Abumere and Ebeniro (2001) worked extensively on environmental noise assessment of industrial plants in Port Harcourt metropolis. Abumere et al. (1999) investigated the environmental noise in some selected areas of Port Harcourt metropolis using a quest 300 noise level meter as opposed to other types, Bodony and Lele (2004). Avwiri and Nte (2003) investigated the noise quality of some selected flow stations in the Niger Delta

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Figure 1. Satellite map of Ikwerre LGA with communities.

region in Nigeria. Also, a cross–sectional work has been reported on the adverse health effects of aircraft noise; these studies find a positive association with hypertension (Eriksson et al., 2007; Jarup et al., 2008), risk of heart attacks (Huss et al., 2010), sleeping problem and sleep medication intake (Franssen et al., 2004), stress (Black et al., 2007), and headaches (Franssen et al., 2004), and also on negative association with a child's cognitive development (Stansfield et al., 2005).

Study area

This research work was carried out at the Port Harcourt International Airport, Omagwa in the Ikwerre Local Government Area of Rivers State. The Airport is located at about 30 km away from the capital city in a town called Omagwa on Latitude 05°01'N and Longitude 06°57'E (Figure 1). It has a dimension of about 3000 m in length with an elevation of about 27 m, the airport handles both local and International flights.

MATERIALS AND METHODS

This research work comprises two basic ways of evaluating the effects of aircraft noise on an airport which are:

i) Noise monitoring.
ii) Mathematical modeling.

Noise monitoring

This involves the use of physical measurements using a BK precision digital sound level meter set on the A-weighting network. The A-weighting was used because of its recommendation for both industrial and environmental studies (Christophe and Juve (2000); Avwiri and Nte, 2003). The digital sound level meter is an instrument that has been designed to meet the sound level measurement for safety engineers, health, and quality control for various environments such as home use, measuring noise level in factories, schools, offices, airports, etc and also for checking acoustic levels of studios, auditoria, and home hifi installations. It has a frequency range of 30 Hz to 12 kHz and can hold noise readings with delay for 3 min. The digital sound level meter was held with its microphone at a distance of 1.2 m above the ground which is the approximate average ear–ground distance for a human being (Onuu and Inyang, 2004).

Measurements

The noise measurement was carried out at both Port-Harcourt International Airport, Omagwa and communities. A provisional letter of approval was gotten from the Airport security in order to have access to vital locations within the airport; we were kitted with safety wears, earmuff, and a security personnel attached to us to avoid been embarrassed by security men within the airport. Readings were obtained with the BK precision digital sound level meter at different strategic locations within the airport operational zones. The essence of this measurement is to determine the noise levels at the Port Harcourt International Airport, and also to access the levels of annoyance caused to these people as a result of the noise. A total number of 30 different locations within the airport operational zones were investigated, which include the Ram (tarmac), Runway 021, Runway 03, Taxiway, Departure Hall local, Departure Hall international, Arrival international, Arrival local, Administrative block, Ticket hall, Checking hall, Control tower, Carpark 1-6, NACA office, NAMA office, FANN office FANN staff residential quarters, 1-5 and the communities which include Omagwa, Igwuruta, Omuademae, Umuchem. Readings were obtained at a fixed distance of 20 m from the two run ways for safety purposes. Aircraft of various degrees of engine capacity were parked at the tarmac.

The digital meter was set to A-weighting network and in slow

Table 1. Noise distribution level in Port Harcourt International Airport (Omagwa) main airport operational zone.

S/No	Location	Noise level measurement in decibel dB(A)						
		t_1= 10 s	t_2= 20 s	t_3= 30 s	t_4= 40 s	T_N	L_N	Ambient noise dB(A)
1	Ram (Tarmac)	86.9	94.2	88.0	96.6	130.1	98.2	51.3
2	Runway 021	93.0	78.0	96.0	84.0	102.0	90.5	50.0
3	Runway 03	74.0	92.0	90.0	85.5	98.0	96.0	52.0
4	Taxi Way	70.0	82.1	73.0	69.9	88.4	97.0	54.0
5	Departure Hall Local	53.0	54.5	52.0	57.0	66.0	64.7	38.6
6	Departure Hall International	50.0	55.0	49.9	60.0	64.0	65.8	39.0
7	Arrival (International)	60.0	62.3	54.0	61.0	65.0	67.0	44.0
8	Arrival (Local)	64.0	58.0	52.0	60.0	70.0	73.0	51.0
9	Administrative block	63.0	64.1	60.0	58.7	68.0	72.0	52.0
10	Ticket Hall	67.0	70.0	66.0	73.0	77.0	75.0	54.0
11	Checking Hall	77.0	74.0	69.0	72.0	79.0	81.0	53.0
12	Control Tower	57.0	64.0	58.0	66.0	75.0	78.0	54.0
13	Car Park 1	57.0	57.2	59.0	63.0	74.0	78.0	56.0
14	Car Park 2	49.3	54.0	49.9	52.0	67.0	69.0	48.0
15	Car Park 3	53.1	55.0	60.0	57.0	68.0	70.0	52.0
16	Car Park 4	63.0	65.0	59.0	63.5	74.0	76.0	58.0
17	Car Park 5	66.0	64.1	59.9	64.0	75.0	78.0	57.0
18	Car Park 6	53.0	55.3	62.0	59.0	71.0	76.0	54.0
19	Internal Airport Road	71.0	67.0	65.0	73.0	75.0	80.0	57.0
20	NACA Office	57.0	62.0	60.0	58.0	73.0	78.0	50.0
21	NAMA Office	58.0	57.5	60.0	61.1	72.0	69.0	51.1
22	FANN Office	62.0	59.4	62.5	58.0	74.0	66.0	49.0
	Residential noise distribution at International Airport (Omuagwa)							
23	Catholic Church	66.5	68.5	59.4	58.3	74.0	68.0	55.4
24	Primary School	54.3	57.2	55.4	56.0	77.0	74.6	57.3
25	Police Station	66.0	65.2	67.3	68.4	82.0	79.9	54.5
26	FANN Staff Q	54.0	53.0	58.0	57.0	76.0	74.0	56.5
27	FANN Staff Quarters 2	56.0	59.0	58.0	63.0	75.0	76.0	57.8
28	FANN Staff Quarters 3	62.0	56.0	63.0	62.0	78.0	73.0	56.7
29	FANN Staff Quarters 4	58.0	57.0	56.0	62.0	69.9	78.0	58.2
30	FANN Staff Quarters 5	58.0	59.0	58.0	63.0	74.0	72.0	57.4

Where: t_1, t_2, t_3, t_4 are time for 10, 20, 30 and 40 s, respectively; T_N is Aircraft takeoff noise level measured in dB(A); L_N is Aircraft landing noise level measured in dB(A).

response position; readings were obtained at an interval of every 10 s each for the different locations within the airport operational zones and communities surrounding the airport. All readings were recorded in dB(A) where the A stands for the A-weighting. The aircraft take-off noise level (TN) were measured when the aircraft two engines is in full thrust capacity before take-off and also the aircraft landing noise level (LN) was also measured at every interval of 10 s each to ensure proper accuracy of readings. The ambient noise level which is the background noise level of the airport was earlier obtained when the airport was shut down for general maintenance.

Modeling

Mathematical model is the description of a system using a mathematical language. The process of developing a mathematical model is termed mathematical modeling. Aircraft noise models can also be used to validate and predict future noise levels. The use of this noise model can therefore reduce the need for large arrays of noise monitors at our airport.

RESULTS

The results of the various noise levels obtained in dB(A) from different strategic points within the Port Harcourt International Airport and the communities around the airport are displayed in (Tables 1 and 2).

The ambient noise level for the communities were left out because of the semi-urban nature of the communities due to mass movement of haulage vehicles, motorcycles,

Table 2. Noise distribution level in communities around the Port Harcourt International Airport (Omagwa).

S/No	Location	Noise level measurement in decibel dB(A)					
		t_1 = 10 s	t_2 = 20 s	t_3 = 30 s	t_4 = 40 s	T_N	L_N
		Omagwa community					
1	Interlock Road	60.0	62.0	58.1	63.0	74.0	74.0
2	Primary School	58.1	60.0	59.0	62.8	75.0	73.5
3	Omolu	57.0	63.0	58.0	61.1	71.1	69.8
4	Omagwa/Alu Road	54.5	56.0	53.0	58.0	67.0	65.8
		Airport Hotel Omagwa					
5	Swimming Pool	45.0	48.0	47.6	52.0	66.0	58.1
6	Mini Golf Court	53.0	52.0	50.0	55.0	65.1	63.0
7	Hotel Building	45.2	48.0	44.0	45.0	58.0	56.3
8	Security Post	58.0	59.1	63.0	57.0	73.2	70.0
		Igwuruta					
9	Igwurutali 1	58.0	61.0	59.0	60.5	70.0	68.0
10	Igwurutali 2	62.6	59.4	60.0	60.0	69.8	71.0
11	Ompadec Road	53.0	48.6	57.0	54.0	64.0	59.4
12	St. Anthony Primary School	62.0	66.0	58.0	67.0	74.0	76.0
13	Igwuruta Round About	65.0	70.0	73.0	67.0	76.0	73.0
14	Alua Ordu Market Junction	64.0	72.0	72.0	75.0	77.0	67.9
		Umuadaeme					
15	Omuadaeme 1	53.0	49.8	54.0	53.0	73.0	76.0
16	Omuadaeme 2	48.0	54.0	54.0	56.0	67.0	73.0
17	Omuadaeme 3	57.0	55.0	60.0	58.0	69.0	69.7
18	Omuadaeme 1	53.0	49.8	54.0	53.0	73.0	76.0
19	Omuadaeme 2	48.0	54.0	54.0	56.0	67.0	73.0
		Umuechem					
20	Umuogo Farm 1	41.0	40.0	42.0	40.0	63.0	68.0
21	Ikpopo Farm 1	38.2	37.0	42.0	42.5	65.0	70.1
22	Estate Farm	50.0	48.2	53.0	49.0	68.0	72.0
		Isiokpo					
23	Isiokpo Girls	54.0	56.0	52.3	50.1	70.4	68.0

buses, taxis within these communities.

Optimization model

In order to validate, interpolate and extrapolate noise levels by using the field measurements, optimization model is herein adopted. An optimization model is a set of mathematical programming used to find the best possible choice out of available alternatives where $NL = f(t)$ been a polynomial function in one variable, t (time), which in general can be written as

$$NL = f(t) = \sum_{n=1}^{k} A_n t^n,$$

NL denotes noise level, t (time), where n and k are dummy variables, and A_n are constants to be determined. The data points acquired from the field measurements are only four, which implies that $k = 4$ and the aspect of $n = 1$ is necessitated by choice. A Symbolic Computation Software Package (MAPLE) implements the optimization/predictive model.

DISCUSSION AND ANALYSIS

Excessive exposures to noise possess a health and safety risk. The adverse effects of noise on health, economy and work performances and on individual longevity were discussed.

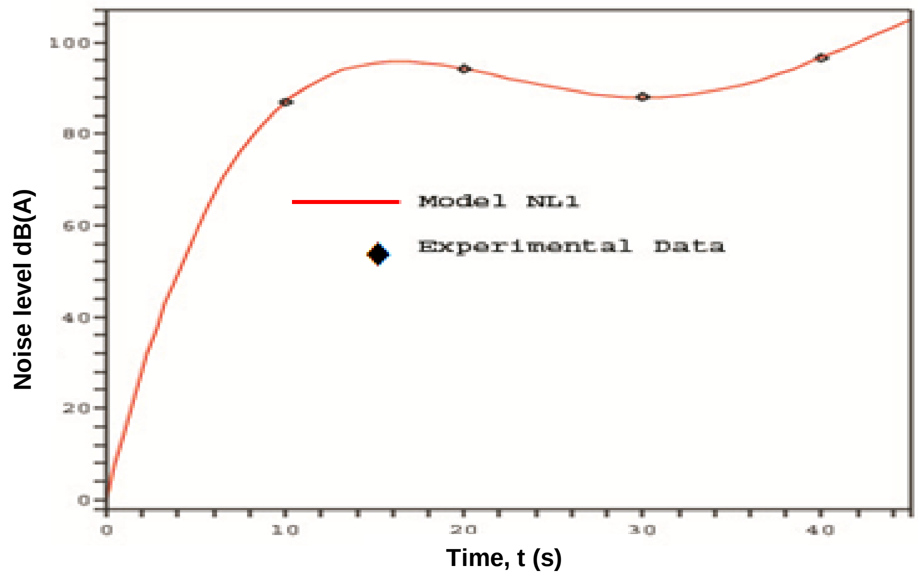

Figure 2. Comparison of Model *NL1* and experimental data graph at the Ram (Tarmac).

$$NL1 = 15.8183333333\ 334364\ t - 0.9017500000\ 00010710\ t^2$$
$$+ 0.0204666666\ 666670286\ t^3 - 0.0001575000\ 0000000382\ 9t^4$$

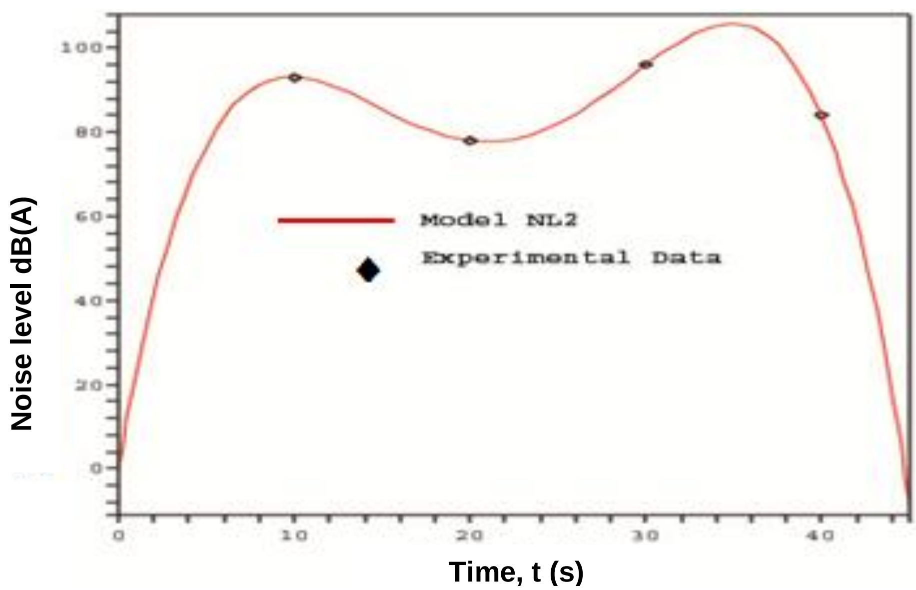

Figure 3. Comparison of Model *NL2* and experimental data showing noise level distribution pattern at the Runway 021.

$$NL2 = 24.5000000000005187t - 2.1800000000005566t^2$$
$$+ 0.0745000000000019535t^3 - 0.0008500000000000021746t^4$$

Tables 1 and 2 respectively shows the data obtained for noise distribution levels for both the airport operational zones and communities surrounding the airport. Figures 2 to 5 shows the graphical comparison between the optimization model and the experimental data at the airport operational zones. The graphical and the quantitative result shows that the optimization model is in excellent agreement with the field measurement/data. Tables 3 to 6 shows the extrapolated and interpolated noise levels of the experimental data using an optimization

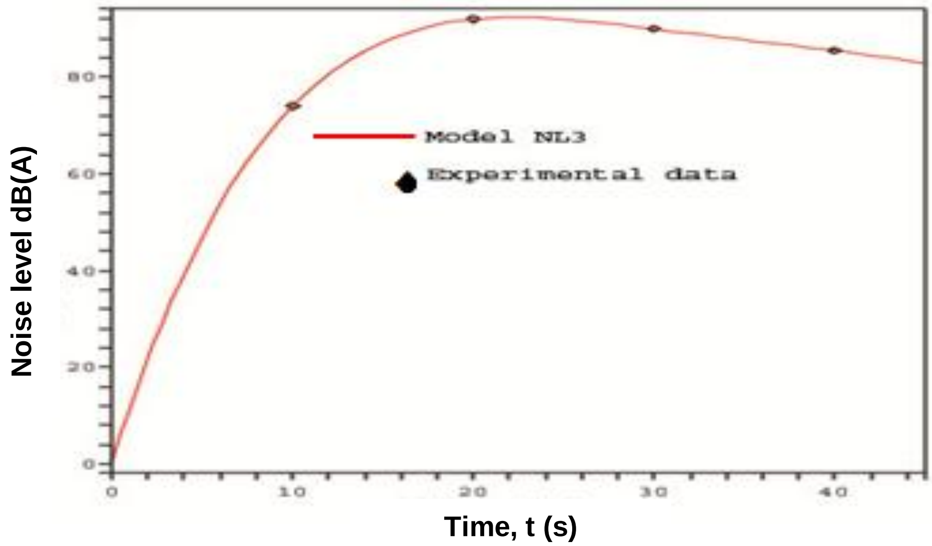

Figure 4. Comparison of Model *NL3* and experimental data showing noise level distribution pattern at the Runway 03.

$$\mathrm{NL3} = 11.8625000000000629t - 0.544791666666673113t^2$$
$$+ 0.0106250000000002246t^3 - 0.000077083333333358214t^4$$

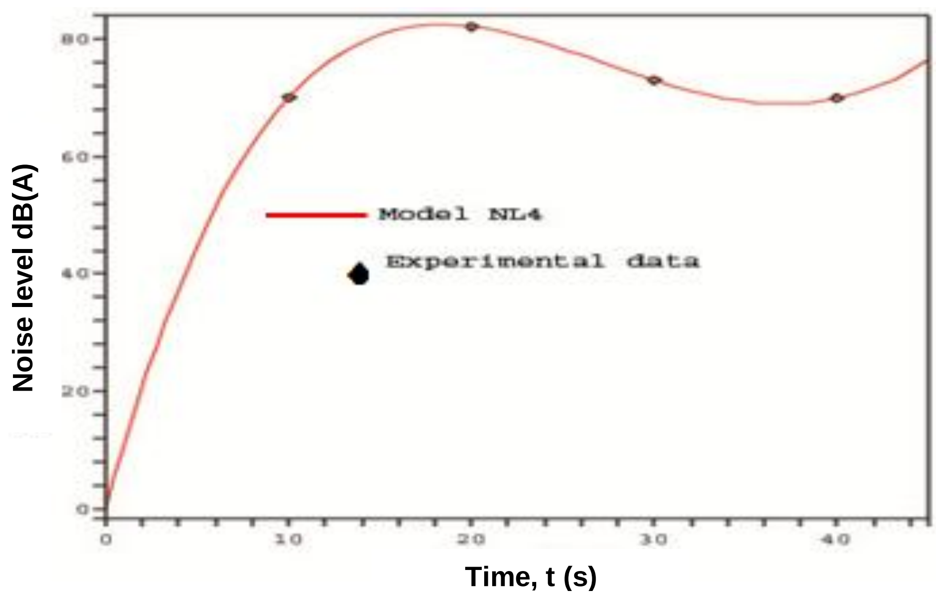

Figure 5. Comparison of Model *NL4* and experimental data showing noise level distribution pattern at the Taxi Way.

$$NL4 = 11.3558333333333774t - 0.516541666666671339t^2$$
$$0.0084916666666682086t^3 - 0.000039583333333349369t^4$$

model at the airport operational zones. The optimization model is predictive and can be used to validate the noise level for any environment, be it road, construction sites and airport. In order to sectionalize the noise level of the airport into high noise level, moderate noise level and low noise level using the Federal Environmental Protection

Table 3. Model noise level and field measurement data at the Ram (tarmac).

Time, t (s)	Model noise level dB(A)	Field measurement dB(A)	Relative % error
5	59.00781248	-	-
10	86.89999997	86.9	3.452×10^{-8}
15	95.48281250	-	-
20	94.20000000	94.0	0.00000000
25	90.13281240	-	-
30	88.00000000	88.0	0.00000000
35	90.15781260	-	-
40	96.60000020	96.6	0.00000000
45	104.9578125	-	-
50	110.5000000	-	-
55	106.1328120	-	-
60	82.40000100	-	-

Table 4. Model noise level and field measurement data at the Runway 021.

Time, t (s)	Model noise level dB(A)	Field measurement dB(A)	Relative % error
5	76.78125000	-	-
10	93.00000000	93.0	0.00000000
15	85.40625000	-	-
20	78.00000000	78.0	0.00000000
25	82.03125000	-	-
30	96.00000000	96.0	0.00000000
35	105.6562500	-	-
40	84.00000000	84.0	0.00000000
45	-	-	-
50	-	-	-
55	-	-	-
60	-	-	-

Table 5. Model noise level and field measurement data at the Runway 03.

Time, t (s)	Model noise level dB(A)	Field measurement dB(A)	Relative % error
5	46.97265625	-	-
10	74.00000000	74.0	0.00000000
15	87.31640625	-	-
20	91.99999997	92.0	3.260×10^{-8}
25	91.97265622	-	-
30	90.00000000	90.0	0.00000000
35	87.69140620	-	-
40	85.50000000	85.5	0.00000000
45	82.72265630	-	-
50	77.49999970	-	-
55	66.81640590	-	-
60	46.50000000	-	-

Agency (FEPA, 1991) standard which was adopted from the World Health Organization (WHO) for which for high noise level value range between 80 to 130 dB, moderate noise level 50 to 100 dB and low noise level range is 30

Table 6. Model noise level and field measurement data at the Taxi Way.

Time, t (s)	Model noise level dB(A)	Field measurement dB(A)	Relative % error
5	44.90234373	-	-
10	69.99999997	70.0	4.285×10-8
15	80.77109375	-	-
20	82.09999991	82.1	1.096×10-7
25	78.27734362	-	-
30	72.99999990	73.0	1.369×10-7
35	69.37109362	-	-
40	69.89999990	69.9	1.430×10-8
45	76.50234360	-	-
50	90.49999920	-	-
55	112.6210936	-	-
60	143.0000000	-	-

Table 7. High noise level.

Location	Take-off noise level dB(A)	Landing noise level dB(A)
Ram (Tarmac)	130.1	98.2
Runway 02	102.0	90.5
Runway 03	98.0	96.0
Taxiway	88.4	97.0
Checking Hall	79.0	81.0

Table 8. Moderate noise level.

Location	Take-off noise level dB(A)	Landing noise level dB(A)
Administrative Block	68.0	72.0
Ticket Hall	77.0	75.0
Control Tower	75.0	78.0
Car Park 4	74.0	76.0
Car Park 5	75.0	78.0
Internal Airport Road	75.0	80.0
FANN Office	74.0	66.0
Catholic Church	74.0	68.0
Police Station	82.0	79.9
FANN Staff Quarter 3	69.0	78.0

to 80 dB (Tables 7 to 9). The moderate noise levels are as a result of wind direction which may have been dispersed due to wind factors from the sources and other interfering factors too.

The low noise level at this point is expected due to the shielding nature of the building, air condition offices and apartment.

Conclusion

The proof of this work is hinged on the derivation and placement of the optimization model that can be used to accurately evaluate, estimate and validate any field measurements. The unique optimization model with the formula:

Table 9. Low noise level.

Location	Take-off noise level dB(A)	Landing noise level dB(A)
Departure Hall Local	66.0	64.7
Departure Hall Int'l	64.0	65.8
Arrival Int'l	65.0	67.0
Arrival Local	70.0	73.0
Car Park 1	74.0	78.0
Car Park 2	67.0	69.0
Car Park 3	68.0	70.0
Car Park 6	71.0	76.0
NACA Office	73.0	78.0
NAMA Office	72.0	69.0
Primary School	77.0	74.0
FANN Staff Quarter 1	53.0	57.0
FANN Staff Quarter 2	75.0	76.0
FANN Staff Quarter 3	74.0	72.0

$NL = f(t) = \sum_{n=1}^{k} A_n t^n$ has been established and equally recommended for most studies on environmental noise impact.

RECOMMENDATIONS

1. Buildings that are closes to an Airport must be well insulated to prevent noise disturbances.
2. Airports must be sited outside the city centre to prevent noise pollution.
3. An Environmental Impact Assessment (EIA) on noise should be carried out on the communities around an Airport to determine the noise impact on the people.
4. An optimization model must be adopted to determine the optimal noise level of such environment.

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