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Prediction of Noise Level in Ota Metropolis Using Artificial Neural Network

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Abstract. Capturing noise data is laborious, time-consuming, expensive and dangerous due to the exposure of the investigator to the menace. Also, appropriate software, computational skill and computational time are also required before the captured data could be of any use. In this work, an artificial neural network (ANN) was deployed to learn and train noise data in Ota Metropolis. Data were captured from forty-one (41) locations for the morning, afternoon and evening in Ota Metropolis. ANN with Levenberg Marquardt algorithm and architectural configuration of 2-21-9 (input-hidden neuron- output) was used to predict noise descriptors for Ota Metropolis with 73% accuracy. The two input variables were the latitude and longitude of the location measured in degrees while the nine output variables are the noise descriptors such traffic noise index (TNI), noise pollution level (LNP), and average equivalent noise levels (L_{Aeq}) computed for each selected location for morning, afternoon and evening periods. The results could be used in mobile applications, Google Earth and other platforms to guide residence dwellers, travellers, industrialists and technocrats in selecting travelling routes, choice of apartment location and use of appropriate personal protective equipment (PPE) in unavoidable noisy locations.

Keywords: Artificial Neural Network (ANN), Noise pollution, Traffic noise index, Levenberg Marquardt Algorithm, Regression, Latitude and Longitude

1. Introduction

Urbanization and industrialization brought water, land, soil, air, radioactive and noise pollution with them. This paper is on noise pollution. Sound is produced when vibration passes through air or other medium like water. It is termed ‘noise’ when it is undesired or rather prevented a wanted sound. Noise is a major factor that reduces the quality of life due to its harmful psychological and physiological effects on human beings [1]. Hence, adequate information on noise levels is a necessity for informed decisions in industrial, residential, commercial, recreational, construction, and transportation (airway, waterway, railway, highway) areas. However, harvesting such noise data in any area is usually cumbersome. Foremost, the investigator is exposed to the same pollution in the morning, afternoon and evening while taking the noise readings. This requires time, energy and money. Also, the raw data is of little use until hardware, appropriate software and manhours are deployed in the analysis. Oyedepo et al. [2], conducted extensive fieldwork and analysis of noise data for Ota Metropolis in Nigeria. The work specified latitude and longitude for forty-one different locations with their noise pollution data. The aim of this present work is to use an artificial neural network (ANN) to validate, model and forecast noise pollution data for Ota Metropolis.

Much work has been done using ANN. Mohsen et al. [3] used ANN to study composite produced from A356 matrix and B_4C powder. Mechanical properties of the composites were predicted and used in developing software code. Babalola et al. [4] applied ANN to predict the electrical and mechanical properties of aluminium and silicon carbide composite produced using the stir casting method. Ultimate tensile strength (MPa), tenacity at fracture (gf/tex), Modulus (N/mm^^{2}), yield strength (MPa), hardness (HV), time at fracture (s), electrical conductivity(MΩ/m), and tensile stress were predicted in the work. Ayoola et al. [5] used response surface methodology (RSM) and ANN to analyse the production of biodiesel from waste groundnut oil. Few researches have been carried out on the application of ANN in noise data analysis. Steinbach and Altinsoy [6] employed ANN to predict the annoyance level of electric vehicles from sound level, roughness, fluctuations in strength, tonality, sharpness and loudness. Bravo-Moncayo et al. [7] used ANN, multiple linear regressions (MLR) and support vector machines (SVM) to predict traffic-noise annoyance levels and found the ANN model to be the best. Hamad et al. [8] on his part modelled roadway traffic noise from the edge of the road, vehicle volume, average speed and roadway temperature using ANN. It was noted that investigators have not linked noise level to the latitude and longitude of the studied location. This is attempted in this work.

2. Noise level and health issues-WHO standards

Noise pollution is not without its adverse effects. Exposure of the ear to noise levels of 140 dB (A) and above may permanently damage the tympanum (eardrum) in the middle ear (Fig. 1). Noise levels below 140 dB may result in hearing impairment, hearing loss or temporal auditory fatigue. Non-auditory effects include: interference; stress and annoyance; physiological and behavioural effects; occupational hazards and accidents. The allowable noise level stipulated by the World Health Organisation (W.H.O.) for different localities and permissible dosages is shown in Tables 1 and 2 respectively.

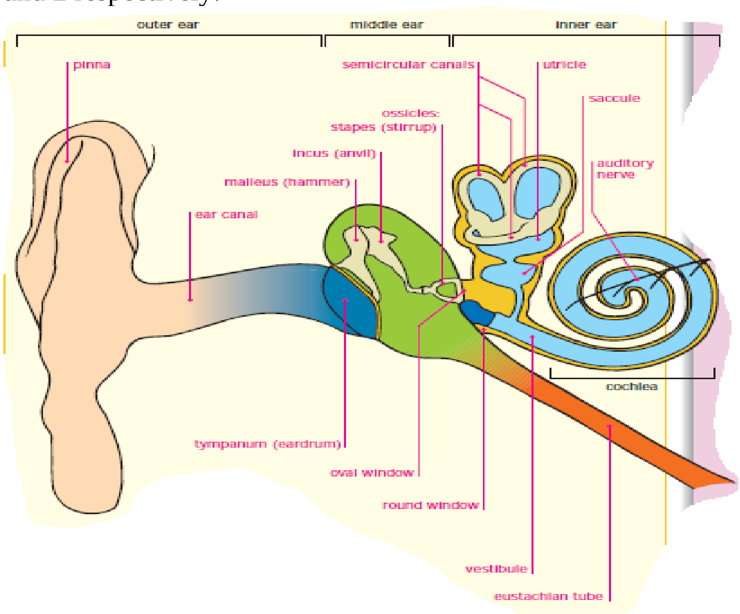

Figure 1: Internal structure of human ear [9]

Table 1: WHO Permissible Noise Levels in Different Types of Localities [10]

S/N	Locality	Permissible Noise Level dB		
		Day	Night	Mean
1	Industrial area	75	65	70
2	Commercial area	65	55	60
3	Residential area	55	45	50
4	Silent zones for educational institution	45	35	40

Table 2: Noise Dosage permissible limits by WHO [11]

Noise Level (dB(A))	Maximum Exposure Time per 24 Hours
85	8 hours
88	4 hours
91	2 hours
94	1 hour
97	30 minutes
100	15 minutes
103	7.5 minutes
106	3.7 minutes
109	112 seconds
112	56 seconds
115	28 seconds
118	14 seconds
121	7 seconds
124	3 seconds
127	1 second
130	less than 1 second
140	**NO EXPOSURE**

3. Methodology

3.1 Data Capturing

In this work, raw noise data including latitude, longitude, noise levels measurements for morning, afternoon and evening were recorded for forty-one locations within the Ota metropolis. These selected locations comprise of low- and high-density residential areas, commercial areas, road junctions, motor parks and industrial areas. The latitudes and longitudes of the forty-one locations were tracked using a global positioning system (Magellan eXplorist

310 model), while a sound level meter (model 8922) was used to capture noise data. Descriptions of these instruments and computation of environmental noise descriptors are highlighted by Oyedepo et al [1].

3.2 Use of ANN to validate, model and forecast

Artificial neural network is a novel mathematical tool motivated by the biological nervous system. It can be engaged to solve myriads of difficult engineering and scientific problems. It is comparable to the natural biological system such that it could acquire information from existing examples and use this information as a guide to obtain existing inherent patterns [12].In this paper, ANN was used to model, validate and forecast noise descriptors generated for Ota Metropolis. Modelling was done with the use of ANN feed-forward networks (nftool) deep learning toolbox 12.1 in MATLAB R2019a by MathWorks, Inc. Levenberg Marquardt backpropagation algorithm and the ANN architectural configuration of the input layer, hidden layer and target (output) layer was adopted for the analysis. Five ANN configurations of 2-10-9 (input-hidden neuron- output),2-15-9, 2-20-9,2-21-9, and 2-30-9 shown respectively in Figures 2-6 were used during the preliminary investigation. However, the ANN topology of 2-21-9 (input-hidden neuron-output) gave the best regression results and was adhered to henceforth. The input had two variables representing the latitude and longitude values of each location. The name with latitude and longitude for all the forty-one locations used in this work is shown in Table 3. There are twenty-one hidden neurons while the output (target) has nine variables (Table 4) representing traffic noise index (TNI-morning, TNI-afternoon, and TNI-evening), pollution noise level (LNP-morning, LNP-afternoon, and LNP-evening) and average noise levels (LAV-morning, LAV-afternoon, and LAV-evening) (Fig. 7). ANN was able to predict and generate noise levels for all the forty-one locations in Ota metropolis. The ANN-predicted data are shown in Table 5.

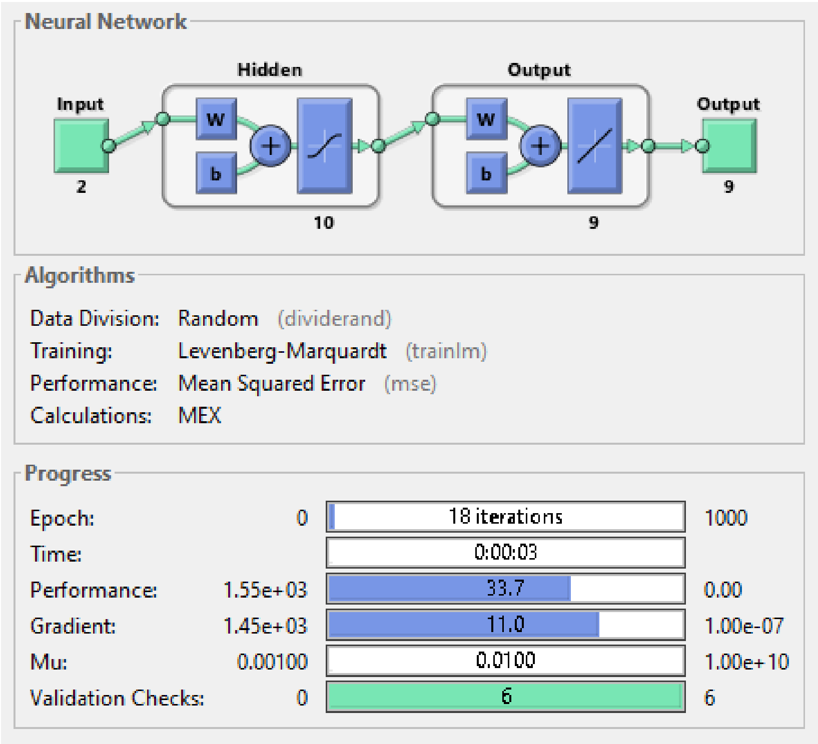

Figure 2a: ANN 2-10-9 Topology

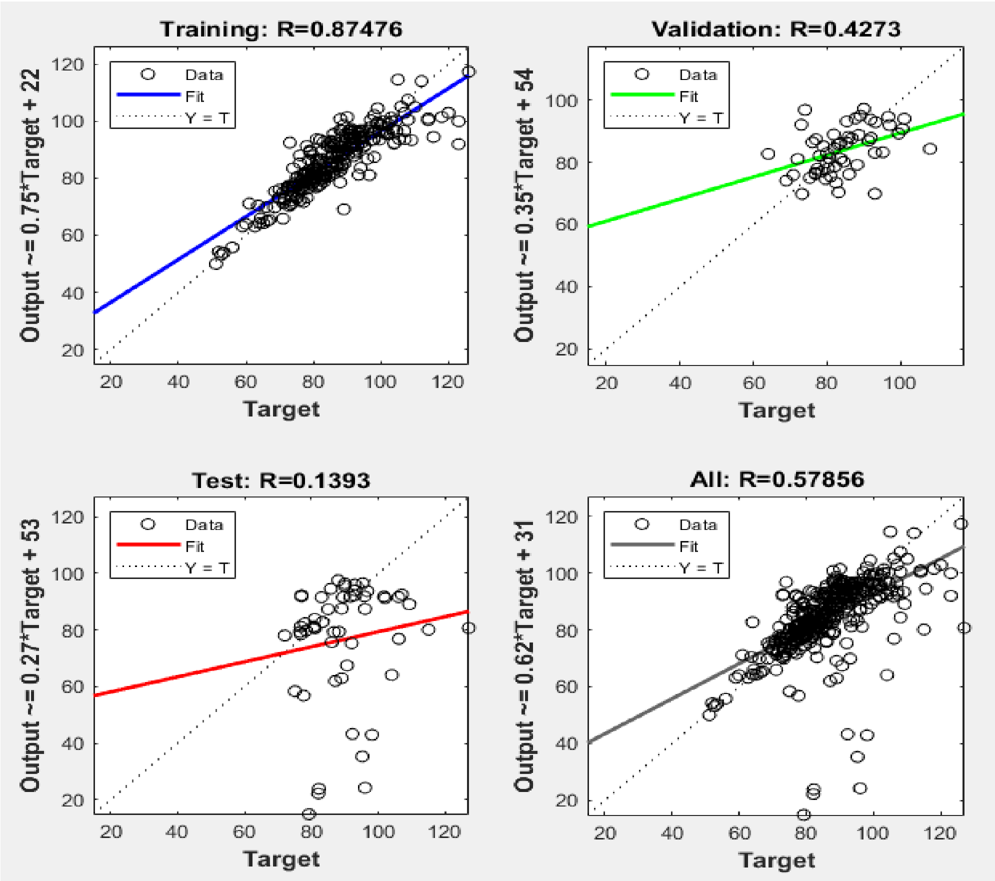

Figure 2b: Plots of regression for (i) training (ii) validation (iii) test for 2-10-9 Topology

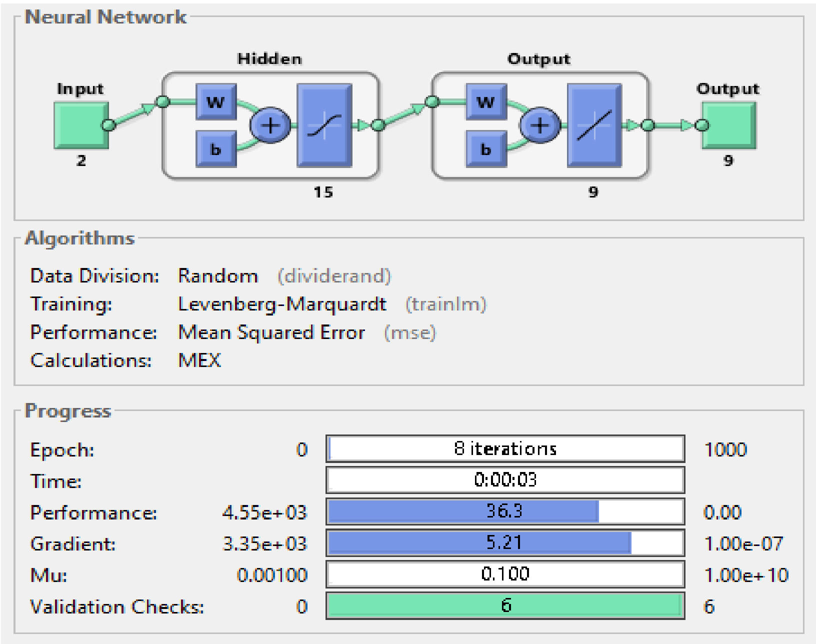

Figure 3a: ANN 2-15-9 Topology

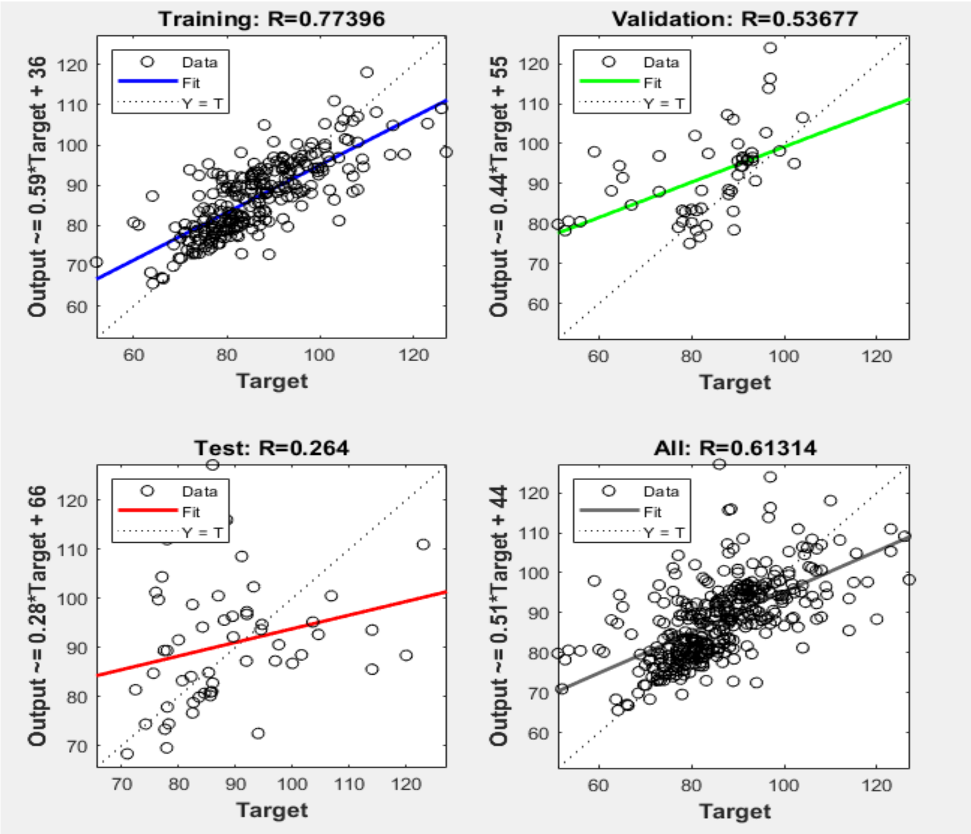

Figure 3b: Plots of regression for (i) training (ii) validation (iii) test for 2-15-9 Topology

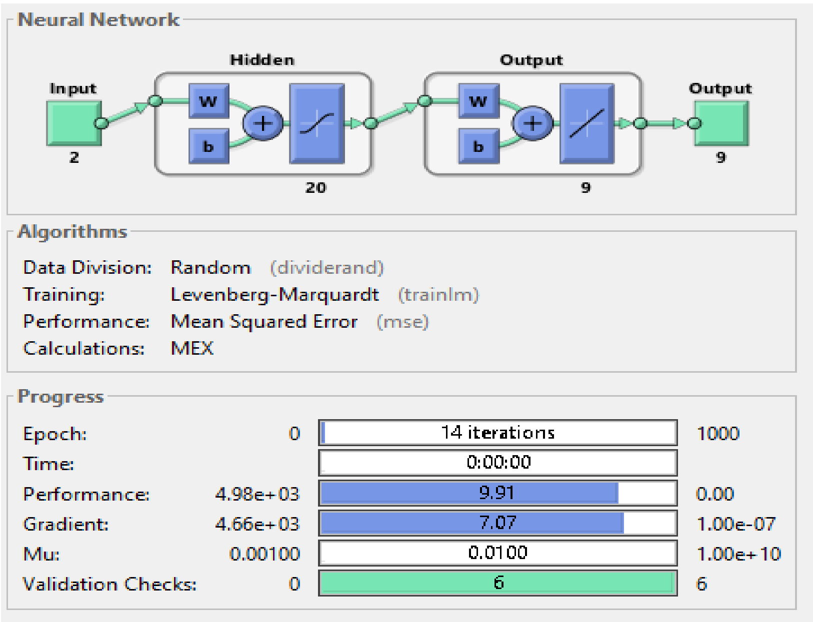

Figure 4a: ANN 2-20-9 Topology

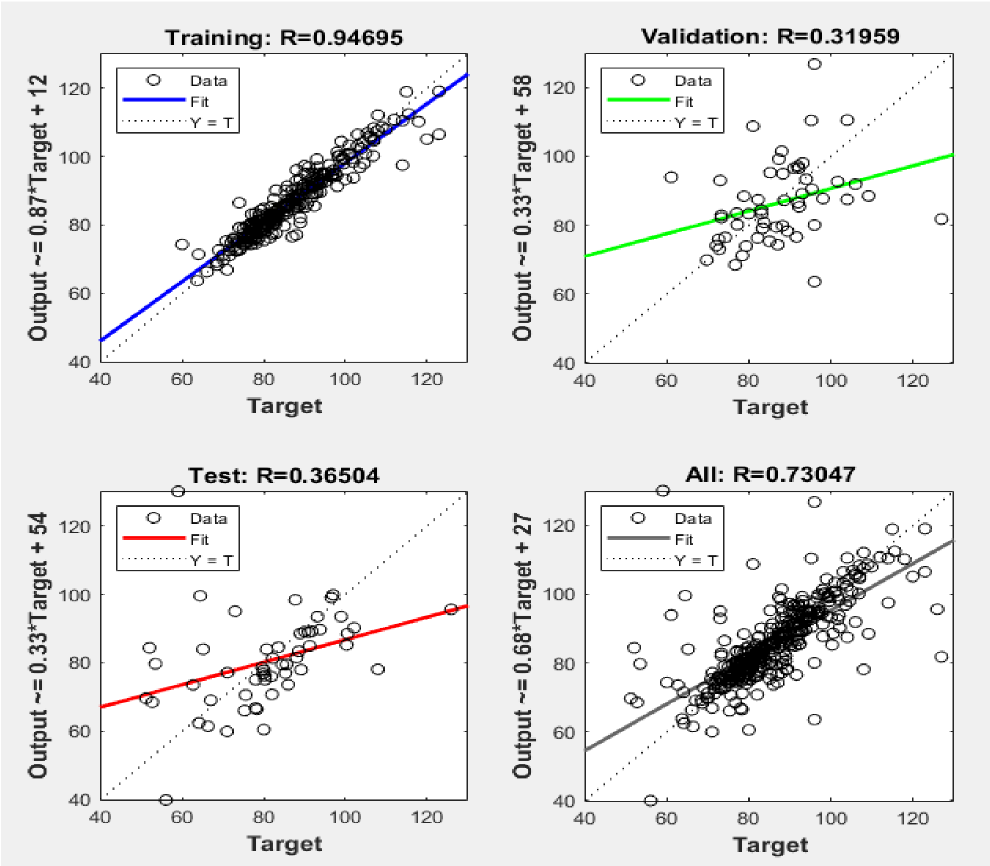

Figure 4b: Plots of regression for (i) training (ii) validation (iii) test for 2-20-9 Topology

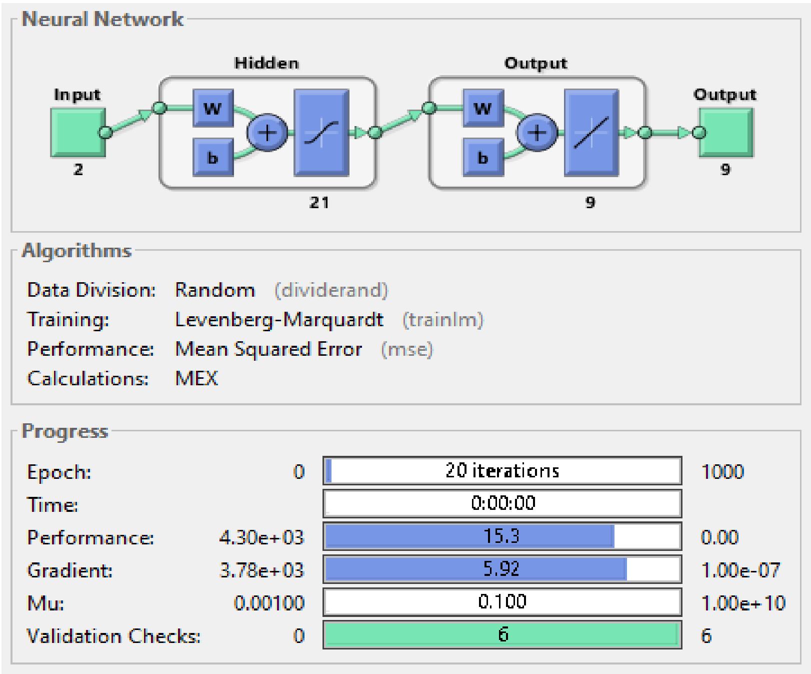

Figure 5a: ANN 2-21-9 Topology

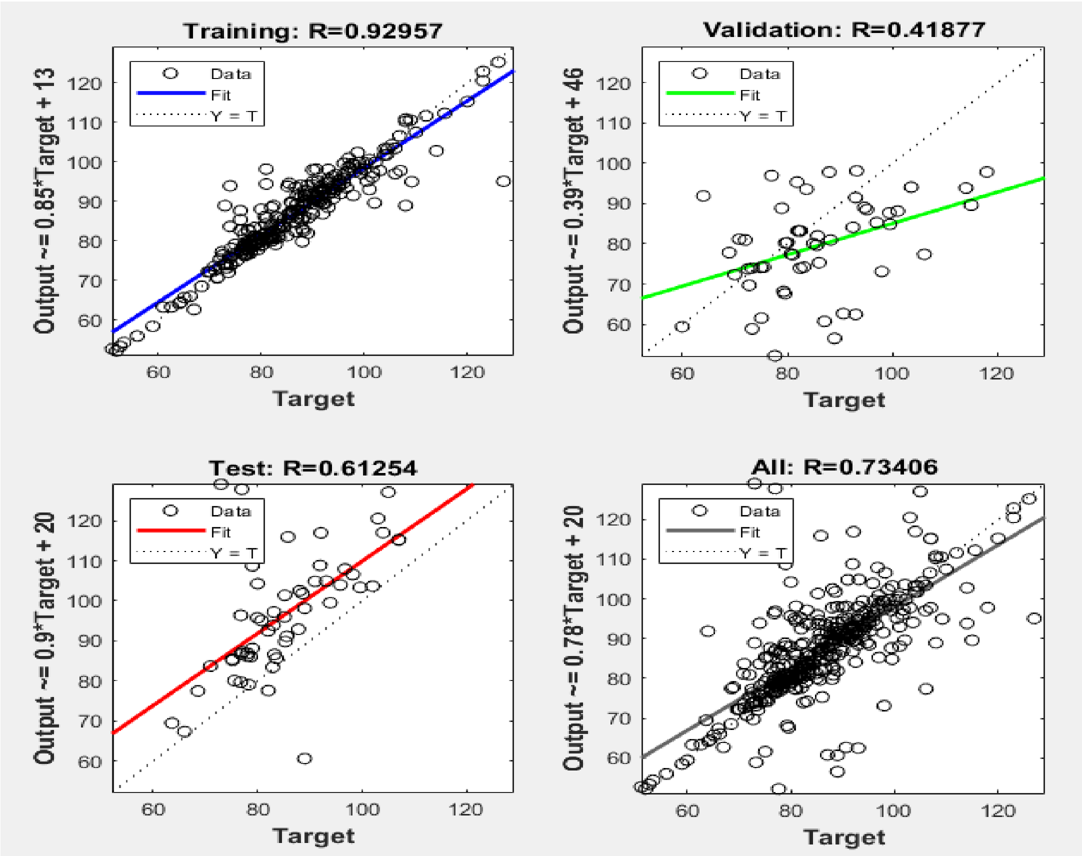

Figure 5b: Plots of regression for (i) training (ii) validation (iii) test for 2-21-9 Topology

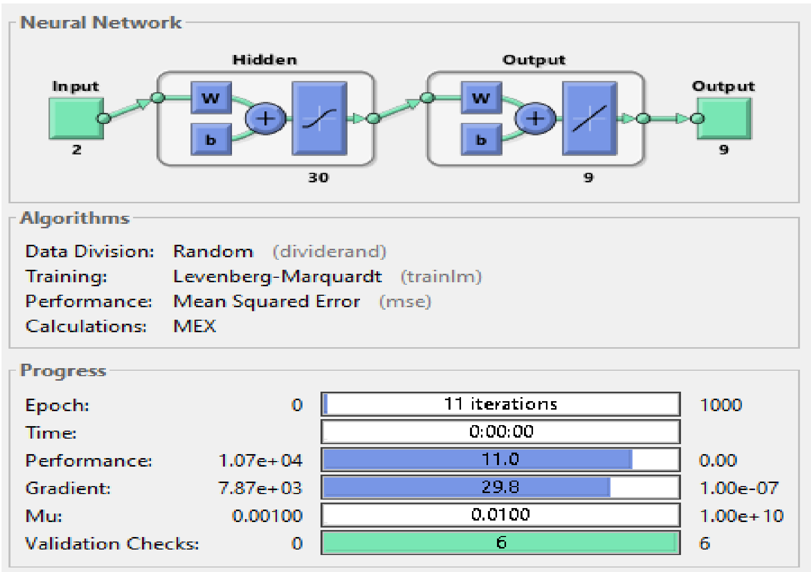

Figure 6a: ANN 2-30-9 Topology

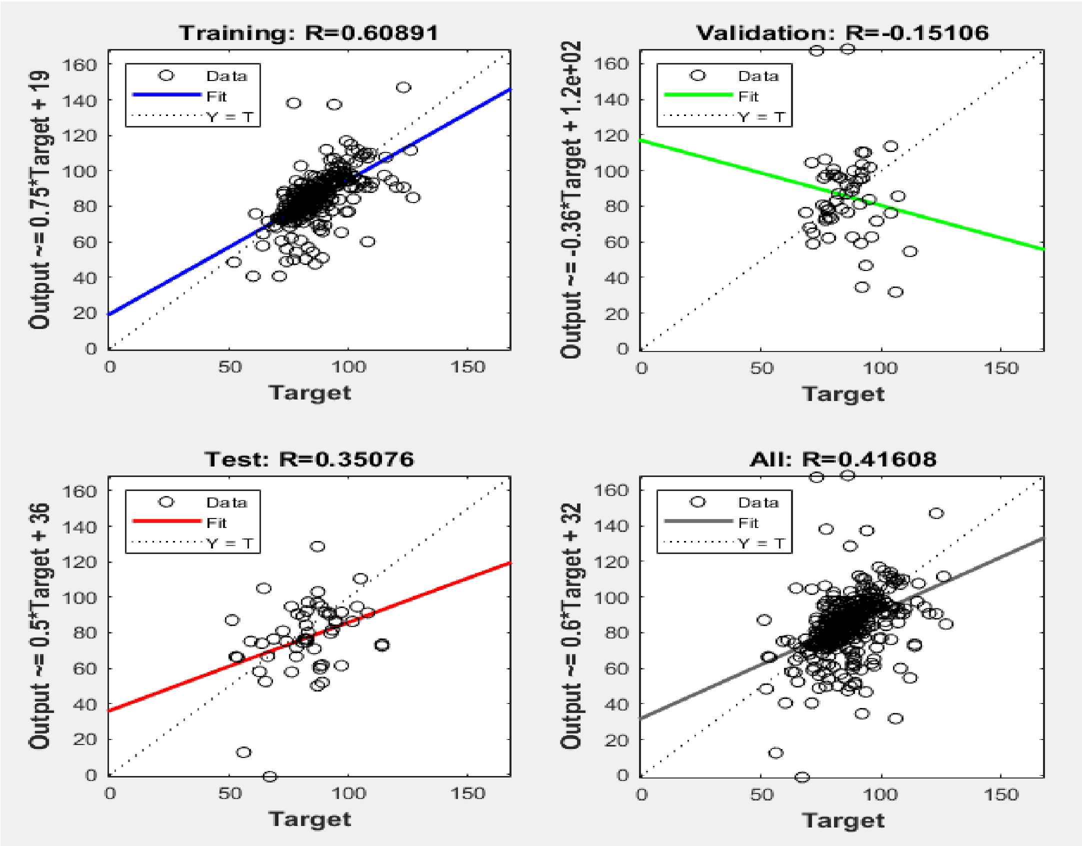

Figure 6b: Plots of regression for (i) training (ii) validation (iii) test for 2-20-9 topology

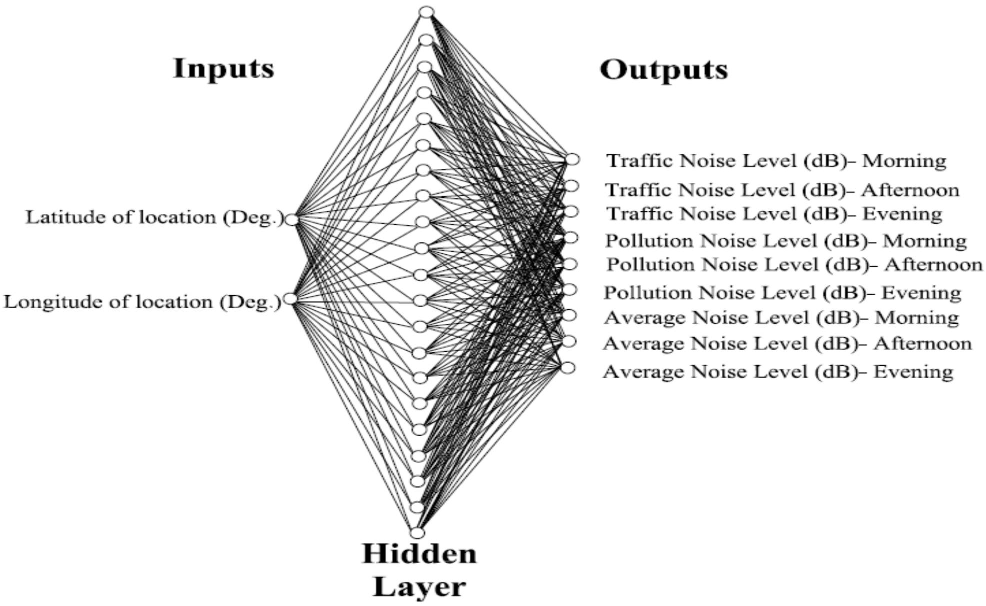

Figure 7: ANN architecture (2-21-9)

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Table 3: Input-Latitude and Longitude Coordinates for the Locations

S/N	Location	Latitude (DD)	Longitude (DD)
1	Sifor Area	6.682722	3.173417
2	Bells University Junction	6.683389	3.177278
3	Canaan Land	6.682139	3.167694
4	May And Baker Close	6.685333	3.167528
5	High Court Area	6.681306	3.184083
6	Nestle Area	6.681778	3.191444
7	Iyana-Iyesi Market	6.680000	3.183833
8	Iyana-Iyesi Junction	6.681639	3.184694
9	Oju-Ore	6.688389	3.225639
10	Joju Junction	6.698833	3.237972
11	Joju Express Road	6.709889	3.237917
12	Sango Under Bridge	6.707389	3.242694
13	Sango Car Park	6.704944	3.245889
14	Fowobi Junction	6.686472	3.220278
15	Toll Gate Express	6.705361	3.246444
16	Toll Gate Area	6.692389	3.257111
17	Obasanjo Junction	6.682833	3.209722
18	Ota-Market Area	6.684389	3.215472
19	Ogun State Internal Revenue Area	6.693222	3.236722
20	Ota Local Government Secretariat	6.691389	3.236694
21	Jack Ross Area (Road)	6.667944	3.181278
22	Chelsea (IDL)	6.667889	3.181444
23	Iganmode Sec School Area/Road	6.682306	3.181611
24	All-Over Polytechnic Road	6.697000	3.233278
25	Olota Palace Junction	6.687111	3.233306
26	Ijoko Road	6.682611	3.208528
27	Ijako Tipper Garrage	6.742861	3.266639
28	Ijoko Railway Station	6.749444	3.260667
29	Ilogbo Road	6.749278	3.214833
30	Ijoko Market	6.742833	3.266667
31	Ifo Road	6.750250	3.214722
32	Igbala	6.711861	3.237500
33	Dalemo Junction	6.700361	3.252250
34	Ilo-Awela Road	6.697417	3.239139
35	Indomie Area	6.685556	3.218306
36	Tower Aluminum Company	6.675889	3.201806
37	Kolokote Area	6.674583	3.201333
38	Owode Area	6.681500	3.202194
39	Idiroko Road(Chelsea Area)	6.681306	3.156583
40	Bells Drive	6.741667	3.215278
41	Estate	6.681500	3.202194

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Table 4: Output- Traffic Noise Index (TNI), Noise Pollution Level (LNP) and Average Noise Levels (L_{Aeq})

Location	TNI dB(A)			LNP dB(A)			L_{Aeq} dB(A)		
	M	A	E	M	A	E	M	A	E
Sifor Area	60	118	85	79.29	99.55	85.74	73.29	79.55	72.74
Bells University Junction	71	99	74	81.65	92.35	88.33	73.65	77.35	80.33
Canaan Land	89	115	81	90.65	106.09	86.06	77.65	87.09	75.06
May And Baker Close	56	59	67	62.68	64.42	65.14	52.68	53.42	51.14
High Court Area	82	76	80	88.52	85.82	86.71	78.52	76.82	76.71
Nestle Area	74	78	83	85.36	85.32	91.95	77.36	75.32	80.95
Iyana-Iyesi Market	77	72	64	81.83	78.93	83.63	70.83	68.93	79.63
Iyana-Iyesi Junction	87	89	88	92.44	90.18	91.89	81.44	78.18	80.89
Oju-Ore Junction	99	91	80	102.18	93.80	88.59	89.18	81.80	79.59
Joju Junction	82	79	79	87.79	85.20	85.13	76.79	75.20	75.13
Joju Express Road	89	97	73	93.16	96.62	87.73	82.16	83.62	80.73
Sango Under Bridge	109	123	93	103.92	115.57	105.36	87.92	96.57	93.36
Sango Car Park	107	77	102	95.82	85.80	96.73	76.82	76.80	80.73
Fowobi Junction	93	90	74	93.88	90.69	85.48	80.88	78.69	77.48
Toll Gate Express	104	73	91	93.14	92.11	91.95	77.14	83.11	79.95
Toll Gate Area	95	98	110	95.10	100.98	104.39	82.10	86.98	88.39
Obasanjo Junction	97	114	88	94.68	103.59	93.20	80.68	85.59	82.20
Ota-Market Area	88	90	89	90.01	93.03	92.98	78.01	81.03	80.98
Ogun State Internal Revenue Area	98	80	75	92.51	82.01	82.50	75.51	70.01	72.50
Ota Local Government Secretariat	80	75	77	87.10	83.30	84.04	76.10	73.30	74.04
Jack Ross Area (Road)	88	61	94	87.28	78.78	88.31	73.28	72.78	73.31
Chelsea (IDL)	101	93	93	99.43	88.22	95.15	82.43	73.22	83.15
Iganmode Sec School Area/Road	86	90	108	91.27	91.82	100.52	80.27	79.82	84.52
All-Over Polytechnic Road	103	108	102	94.53	98.73	99.43	77.53	80.73	85.43
Olota Palace Junction	80	78	71	88.04	85.59	85.30	78.04	75.59	78.30
Ijoko Road	88	90	97	90.64	91.03	96.06	78.64	78.03	82.06
Ijako Tipper Garrage	76	107	81	81.13	94.91	87.72	70.13	76.91	76.72
Ijoko Railway Station	108	83	87	97.05	87.12	86.89	78.05	76.12	73.89
Ilogbo Road	76	114	92	82.45	101.60	94.49	72.45	82.60	82.49
Ijoko Market	87	81	96	83.70	85.18	88.62	69.70	74.18	72.62
Ifo Road	101	86	92	97.85	91.01	92.40	82.85	80.01	79.40
Igbala	86	86	92	89.48	88.48	91.11	77.48	76.48	77.11
Dalemo Junction	78	94	87	84.22	91.93	89.62	74.22	77.93	77.62
Ilo-Awela Road	77	96	85	83.01	91.64	89.41	72.01	76.64	78.41
Indomie Area	93	106	127	95.34	101.67	109.22	83.34	86.67	88.22
Tower Aluminum Company	105	89	83	88.59	82.05	78.66	68.59	66.05	63.66
Kolokote Area	126	52	82	100.30	71.10	80.29	75.30	64.10	66.29
Owode Area	107	89	103	99.61	93.88	98.21	83.61	82.88	83.21
Idiroko Road(Chelsea Area)	104	96	92	98.07	95.21	92.26	82.07	82.21	79.26
Bells Drive	112	88	106	93.56	83.48	91.48	71.56	68.48	71.48
Estate	120	100	123	104.57	97.62	106.85	84.57	83.62	85.85

4. Results

In this study, noise levels of forty-one (41) selected locations in Ota Metropolis, Nigeria were predicted using ANN. ANN used twenty-nine data points representing 70% for training purposes, six data points representing 15% for validation and a further six sets representing 15% for testing purposes. There was convergence after twenty iterations. Regression R Values measured the correlation between outputs and targets. An R-value of 1 means a close relationship, and 0 a random relationship. An overall regression coefficient of 0.73406 (Figure 5b) was obtained in this analysis and ANN-predicted noise data are shown in Table 5.

The study also conducted an F-test on the two-tailed probability that the variances in measured and predicted data are not significantly different. The obtained low value of 0.262397511 shows that variances are generally low. Figure 8 shows the error histogram with significant zero (0) errors.

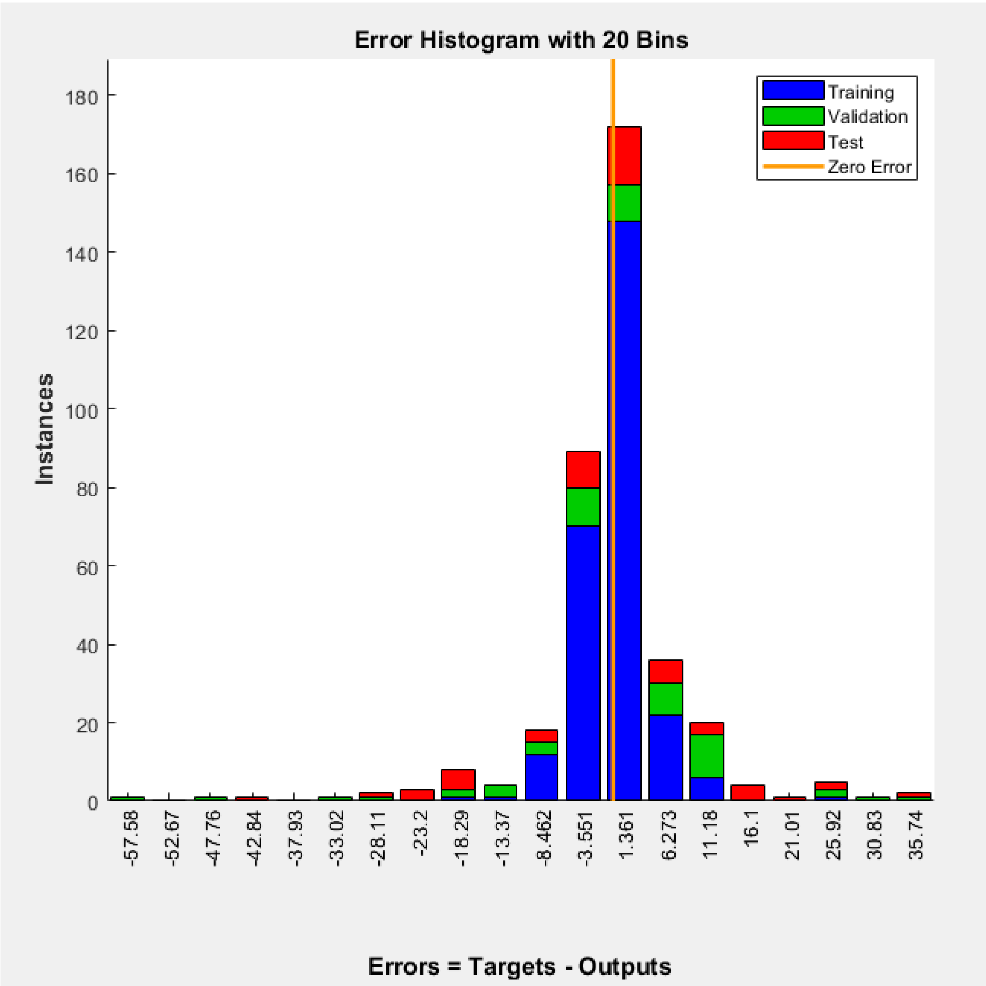

Figure 8: Error Histogram (2-21-9)

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Table 5: ANN Predicted Data-traffic noise index, pollution noise level and average noise levels.

Location	TNI dB(A)			LNP dB(A)			L_{Aeq} dB(A)		
	M	A	E	M	A	E	M	A	E
Sifor Area	59.42	97.82	80.06	68.17	84.83	81.96	58.90	67.59	69.69
Bells University Junction	73.62	98.38	83.68	81.60	92.46	90.15	72.07	76.70	79.07
Canaan Land	56.53	89.61	77.28	62.67	77.38	75.31	52.19	60.76	61.57
May And Baker Close	55.99	58.46	62.68	63.36	64.54	65.72	53.35	54.36	52.73
High Court Area	88.48	82.71	88.04	92.71	89.86	93.54	81.14	78.78	81.65
Nestle Area	75.69	79.07	84.20	86.72	86.89	92.17	77.85	76.88	80.80
Iyana-Iyesi Market	96.94	80.93	91.89	95.32	88.85	93.55	81.17	77.83	80.22
Iyana-Iyesi Junction	84.56	81.96	85.83	91.32	89.44	93.07	80.78	78.68	81.77
Oju-Ore Junction	99.87	91.12	83.43	99.90	93.02	89.55	85.89	80.49	79.64
Joju Junction	92.53	108.71	88.10	92.89	101.38	95.96	79.72	85.14	85.39
Joju Express Road	92.67	98.70	88.93	93.09	97.53	94.11	80.04	82.49	82.02
Sango Under Bridge	110.56	122.85	98.08	101.75	112.24	104.33	85.23	93.44	92.24
Sango Car Park	115.15	127.78	103.65	103.95	115.92	107.93	86.67	96.37	95.06
Fowobi Junction	95.62	97.98	93.93	96.34	98.17	94.59	84.33	83.45	82.85
Toll Gate Express	116.98	129.05	104.84	104.89	116.93	108.81	87.27	97.18	95.74
Toll Gate Area	95.28	99.36	107.47	94.06	100.58	101.80	81.06	85.87	86.15
Obasanjo Junction	85.28	93.85	97.80	89.02	94.09	98.12	77.48	79.64	83.22
Ota-Market Area	79.84	94.18	94.12	86.84	94.65	94.94	77.49	80.18	81.81
Ogun State Internal Revenue Area	73.15	80.29	74.17	84.12	83.21	83.20	74.24	72.32	73.75
Ota Local Government Secretariat	78.88	79.14	76.31	87.83	83.52	84.24	76.76	73.16	74.12
Jack Ross Area (Road)	88.46	63.30	92.28	87.77	81.25	88.79	73.95	74.07	74.36
Chelsea (IDL)	88.13	62.48	91.48	87.68	80.94	88.48	73.95	73.96	74.24
Iganmode Sec School Area/Road	87.29	91.15	88.95	92.35	93.96	95.13	81.43	80.91	83.66
All-Over Polytechnic Road	97.80	110.25	89.63	96.83	102.36	97.09	82.57	86.19	86.00
Olota Palace Junction	104.27	86.17	83.71	102.50	91.13	89.81	86.88	80.08	79.08
Ijoko Road	89.72	94.96	100.95	91.18	95.08	99.60	78.68	80.34	84.00
Ijako Tipper Garrage	87.68	97.79	94.43	85.83	93.67	91.21	72.22	78.04	76.34
Ijoko Railway Station	110.84	84.28	89.46	98.69	87.99	89.10	79.56	77.73	76.12
Ilogbo Road	85.39	102.78	93.16	88.93	96.14	93.05	77.28	80.63	80.80
Ijoko Market	87.67	98.17	94.58	85.81	93.83	91.32	72.22	78.14	76.45
Ifo Road	93.03	87.71	89.58	91.53	90.03	89.56	79.17	79.80	77.84
Igbala	89.61	86.73	86.88	91.75	91.67	90.71	79.22	78.58	77.89
Dalemo Junction	76.92	90.74	91.56	83.63	92.17	92.38	73.94	78.57	80.06
Ilo-Awela Road	79.72	95.73	81.31	86.15	92.79	89.69	75.35	78.73	79.86
Indomie Area	88.53	97.04	95.09	91.98	97.29	94.98	81.41	82.42	82.58
Tower Aluminum Company	127.07	60.64	93.89	101.78	77.61	86.03	77.50	67.38	69.49
Kolokote Area	125.21	52.20	83.91	99.74	72.66	80.74	75.02	64.22	66.03
Owode Area	115.25	98.10	120.50	103.32	99.49	106.57	85.63	83.40	86.61
Idiroko Road(Chelsea Area)	103.32	96.77	90.84	97.47	95.33	92.49	81.59	82.44	79.72

Bells Drive	111.64	83.15	103.46	93.40	80.88	89.94	70.79	68.54	70.67
Estate	115.25	98.10	120.50	103.32	99.49	106.57	85.63	83.40	86.61

4.1 **Charts comparing measured and ANN predicted value**

Figures 9-17 show experimental data and ANN-generated data for traffic noise index (TNI-morning, TNI-afternoon, and TNI-evening), pollution noise level (LNP-morning, LNP-afternoon, and LNP-evening) and average noise levels (L_{Aeq}-morning, L_{Aeq}-afternoon, and L_{Aeq}-evening). It was noted from the experimental data obtained in the field, that Ota metropolis is adjudged a noisy city and after the deployment of ANN to train, validate and test the experimental data, it was further corroborated without any exception in all the forty-one locations and all nine variables. This is another success story of the versatility of ANN in artificial intelligence (AI).

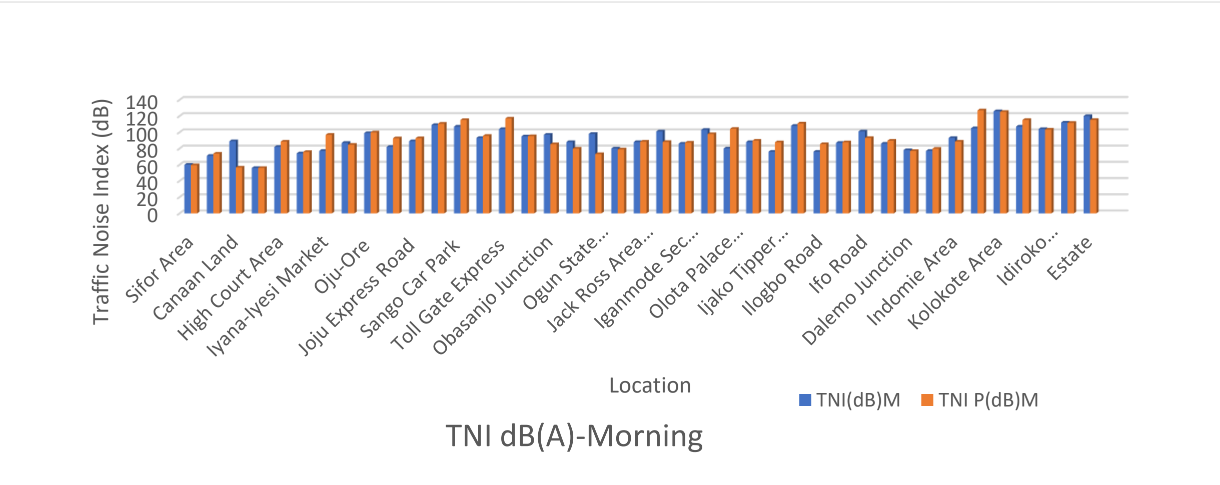

Figure 9: Measured and ANN Predicted TNI in the Morning for Ota Metropolis

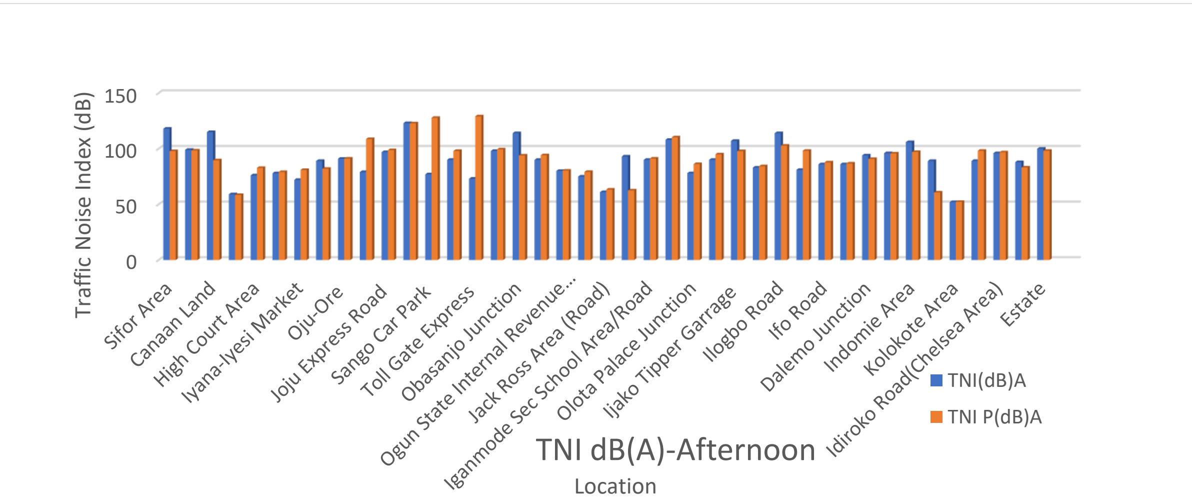

Figure 10: Measured and ANN Predicted TNI in the Afternoon for Ota Metropolis

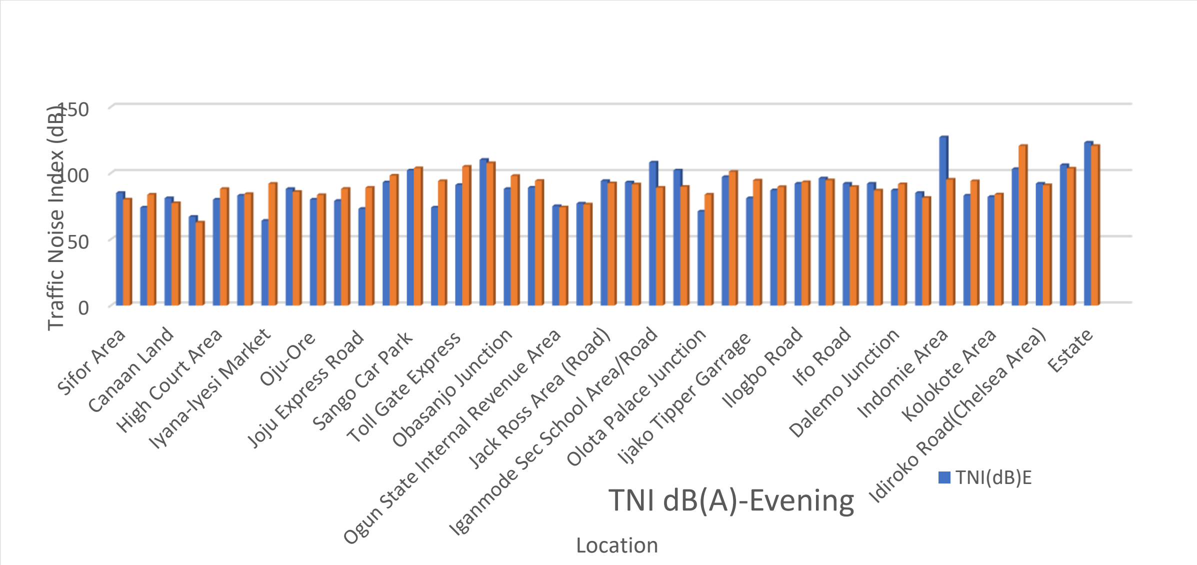

Figure 11: Measured and ANN Predicted TNI in the Evening for Ota Metropolis

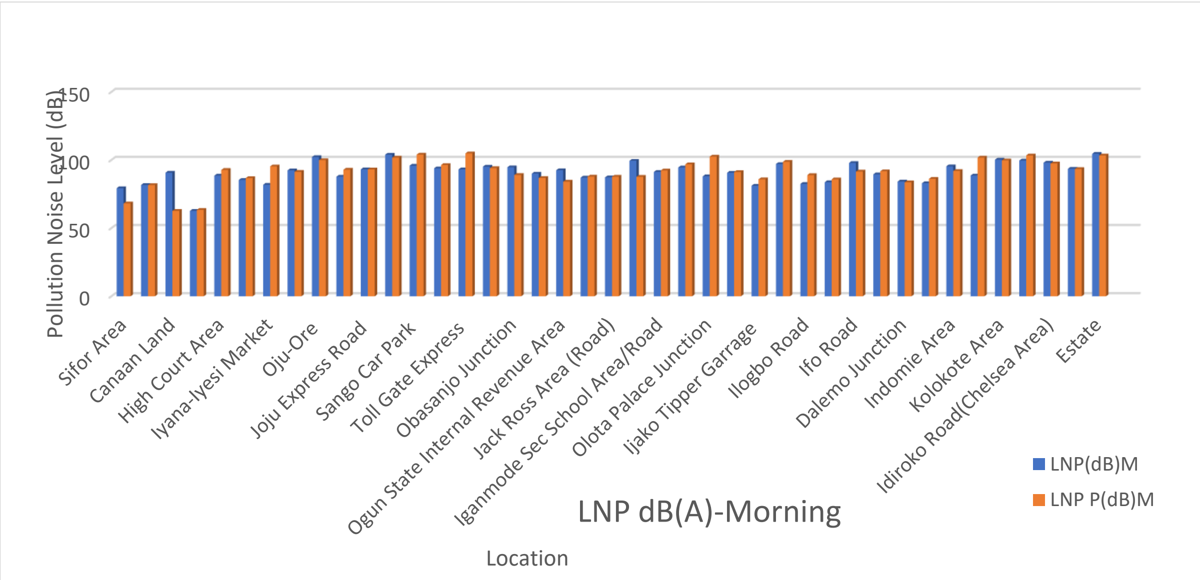

Figure 12: Measured and ANN Predicted LNP in the Morning for Ota Metropolis

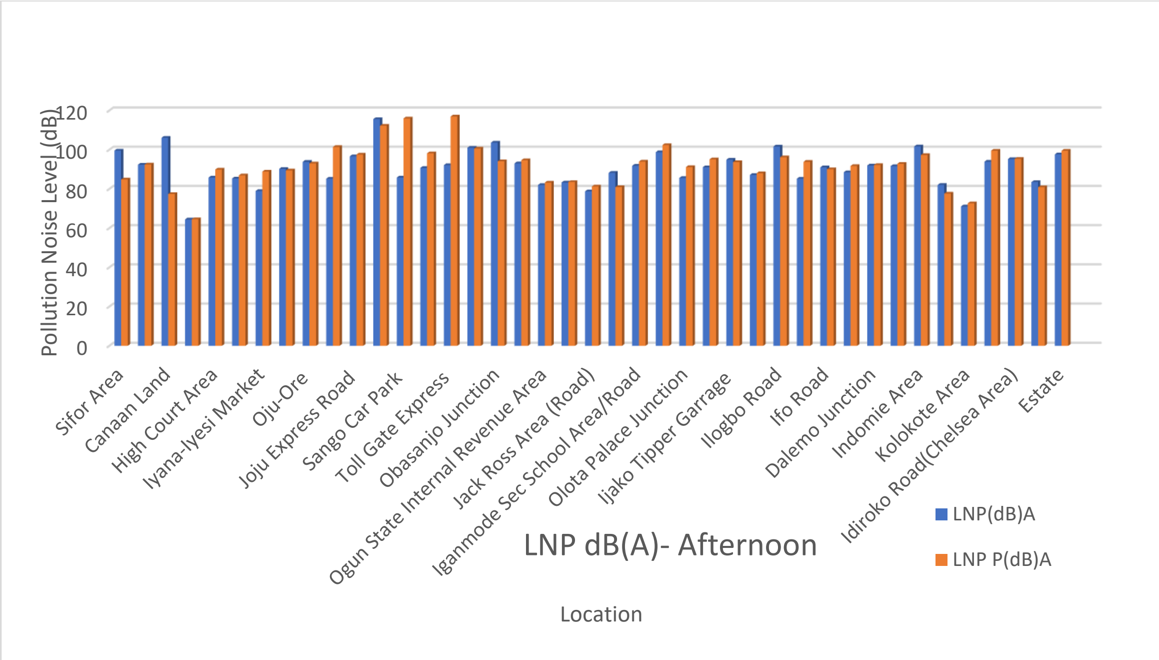

Figure 13: Measured and ANN Predicted LNP in the Afternoon for Ota Metropolis

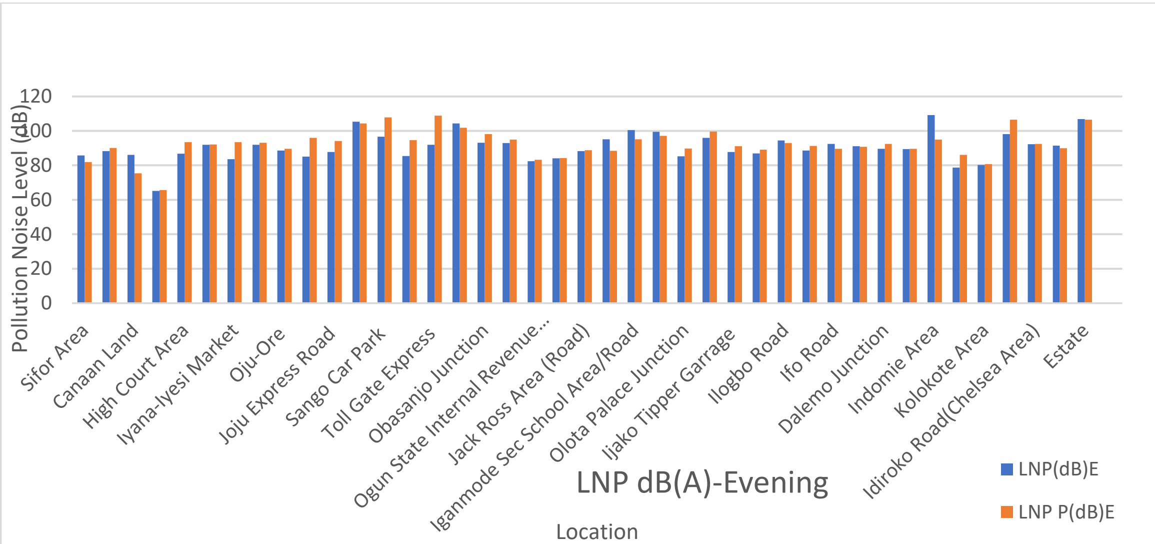

Figure 14: Measured and ANN Predicted LNP in the Evening for Ota Metropolis

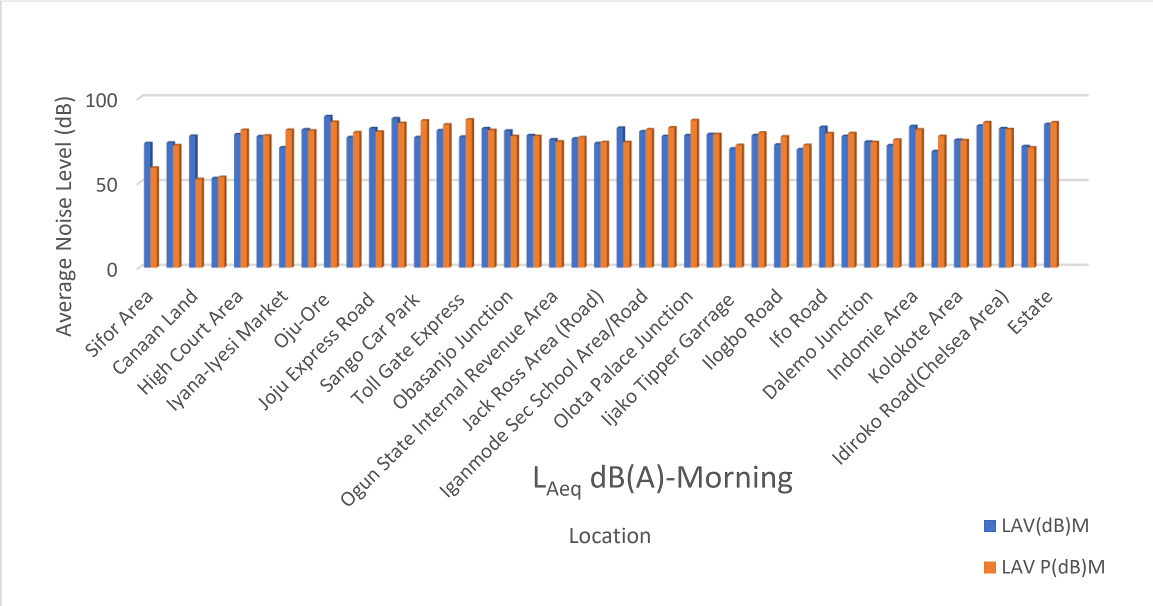

Figure 15: Measured and ANN Predicted L_{Aeq} in the Morning for Ota Metropolis

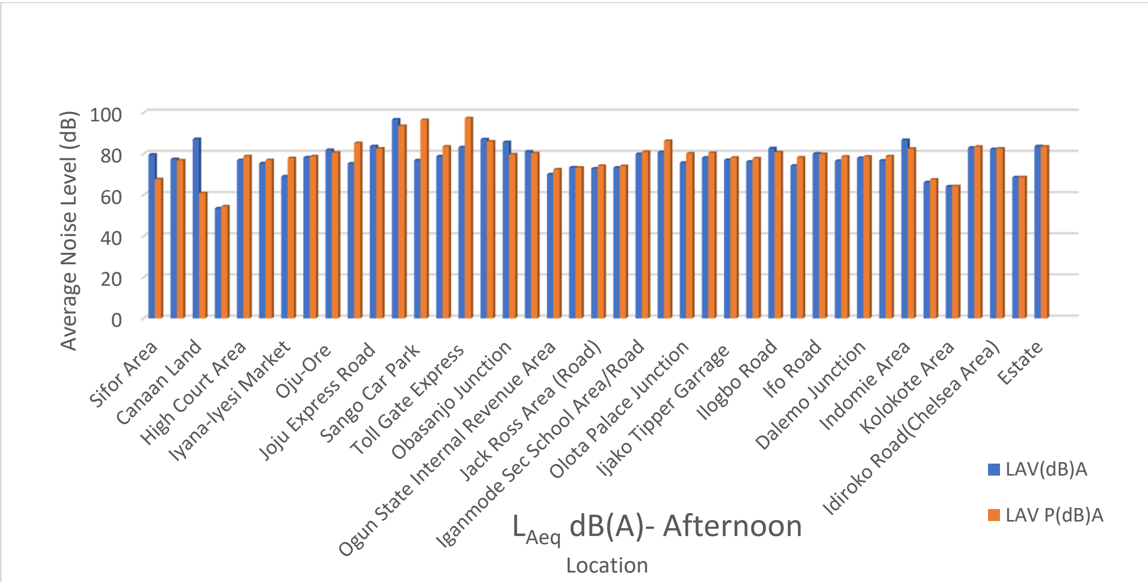

Figure 16: Measured and ANN Predicted L_{Aeq} in the Afternoon for Ota Metropolis

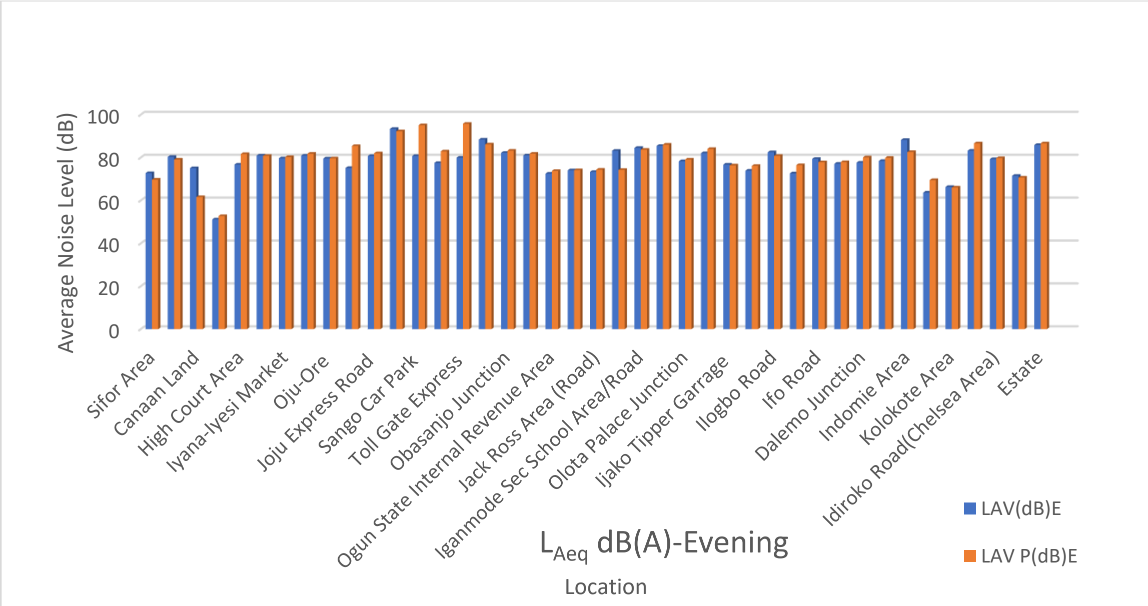

Figure 17: Measured and ANN Predicted L_{Aeq} in the Evening for Ota Metropolis

5. Conclusion

In conclusion, ANN has predicted accurately the measured noise descriptors at the selected locations in Ota Metropolis. Based on the results of this study, the authors recommended that ANN for noise descriptors in urban areas in developing countries like Nigeria be developed and inculcated in mobile apps, Google Earth and other platforms to guide residence dwellers, travellers, industrialists and technocrats in selecting travelling routes, choice of apartment location and use of appropriate personal protective equipment (PPE) in unavoidable noisy locations.

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