Journal of Energy Technology and Environment

Journal homepage: www.nipesjournals.org.ng

Modelling Vehicular Noise Pollution Data in Some Parts of Warri, Delta State Using Geospatial Analysis

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Article Info

Article history:
Received 13 July 2021
Revised 25 July 2021
Accepted 31 July 2021
Available online 31 August 2021

Keywords:
Noise pollution, Geospatial analysis, Kriging interpolation, Normality test, Homogeneity test.

https://doi.org/10.37933/nipes.e/3.3.2021.12
https://nipesjournals.org.ng

Abstract

The focus of the study is to apply geostatistical technique (kriging interpolation) for the analysis of vehicular noise pollution data in some parts of Warri, Delta State, Nigeria. In carrying out the noise level measurements, 10 locations comprising of commercial, industrial activities and busy roundabouts were selected. The measurement of sound level was carried out using a type 1 integrated sound level meter accompanied with a Garmin Oregon 650t hand-held GPS. The CR811C noise level meter was held at a height of 1.2m above ground level with the antenna pointing to the sound source. Noise level measurement was carried out twice daily for the 10 locations (7.00am – 9.00am and 5.00pm – 7.00pm) respectively. To conduct the measurement, the instrument was set at the A-weighting network and the equivalent noise level (Leq) which is the constant noise level that expands the same amount of energy over the same period, was measured for the various locations. Noise measurements was done for ten (10) weeks (70days) between march to May 2021 for each of the 10 locations and the weekly average noise level in (dBA) was recorded and employed for further analysis. Results of the preliminary analysis of the data revealed that; though the noise level data are significantly homogeneous and devoid of possible outliers, they are not normally distributed owing to their stochastic nature. The outcome of geospatial analysis revealed that; high concentration of noise pollution is experienced in areas such as; Enerhe, Opete, Efurun and Ekpan especially in the morning while Areas such as; Jelpa road, Aka junction, Enerhe, Efurun and Egbe layout normally experinced high level of noise pollution during evening.

1. Introduction

The Sensitivity of the human ear to sounds at different frequencies, measured by the A-weighted decibel scale with 0 dB(A), for normal conversation has been put at between 45 dB(A) and 60 dB(A) when people are within three to six feet apart. This translates roughly to the lowest threshold of human hearing [1]. Exposure to noise levels higher than 80 dB(A) for a prolonged period has been found to be deafening, while sound levels between 130 and 140 dB(A) are described as pain [2]. Over the years, these noise limits have been greatly exceeded in many urban settlements of developing countries. The traffic noise problem is not properly recognized despite the fact that it is steadily growing in developing countries [3, 4].

In Nigeria for example, the absence of noise to many urban dwellers, is perceived as a strange thing, only typical of the rural areas of the country. This may partly be attributed to the absence of enforced legislation aimed at correcting the negative effect of urbanization, in addition to the unavailability of sufficient theoretical and applied information-driven knowledge about noise pollution in the country [5, 6]. Although several studies have been conducted in respect to noise pollution in Nigeria, most of them have focused on the health and socio-economic effects of noise pollution [7, 8, 9]. Noise pollution has a tendency of exacerbating already degenerated urban settlements in the country. However, there is no legal framework upon which noise pollution can be abated [9]. Federal Environmental Protection Agency (FEPA) in Nigeria only provided daily noise exposure limits for workers in industry (i.e., 90 dB(A) for 8 h exposure). In short, the Nigerian Government and her citizens appear not to be conscious of the present and future impacts of noise induced health hazards in their environment. Unless and until measures are taken to control the level of noise, the ongoing urbanization and industrialization may complicate the problem so much that it becomes incurable [10].

2.0 Methodology

2.1 Description of study area

The study area is Warri, a popular city in Delta State, Nigeria located between latitude $5^{o}\ 31^{I}\ 0^{II}$ N and longitude $5^{o}\ 45^{I}\ 0^{II}$ E. It has a population of 611,970 according to the 2018 population census. It shares boundaries with Sapele, Okpe, Uvwie, Udu and Ughelli although most of these places have integrated to the larger cosmopolitan Warri.

Warri town is underlain by a sequence of sedimentary formations with a thickness of about 8000metres, which include from bottom to top, the Akata Formation, the Agbada Formation, the Benin Formation and the Somebreiro Warri Deltaic Plain Sands [11].

The Akata Formation rests unconformably on the migmatite-gneiss basement complex and forms the basal unit of the Niger Delta stratigraphic pile. This formation consists of an open marine facies unit dominated by high-pressured carbonaceous shales. The formation ranges in age from Paleocene to Eocene and its thickness could exceed 1000 meters. The Agbada Formation consists of a sequence of alternating deltaic sands and shales. It is Eocene to Oligocene in age and exceeds 3000 meters in thickness. This formation is the oil –reservoir in the Niger Delta basin. The Benin Formation which is Oligocene to Pleistocene in age consists essentially of massive and highly porous sands and gravels with a few thin clay intercalations. Its uppermost section is the quaternary deposit which is about 40-150m thick and comprises rapidly alternating sequences of sand and silt / clay with the later becoming increasingly more prominent seawards [8]. The Benin Formation houses the most productive and hence most tapped aquifer in the Niger Delta region, especially in areas North of Warri where it is shallow. The thickness of the formation is variable, but generally exceeds 2000m. The google earth map of the study area is presented in Figure 1

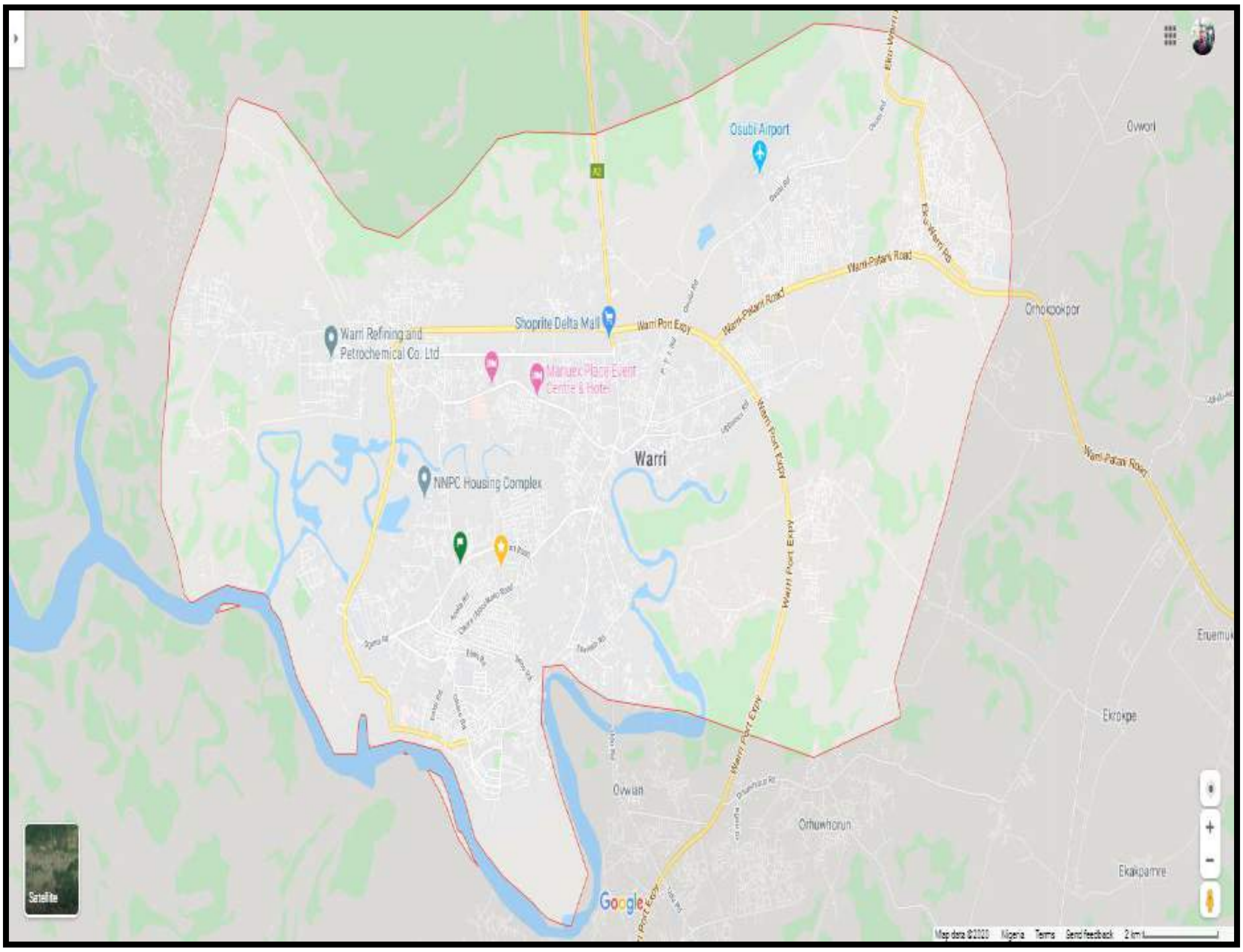

Figure 1: Google Earth map of the study area

2.2 Data Collection

Basic equipment employed for data collection are presented in Table 1

Table 1: Equipment used for data collection

S/N	Equipment Name	Model	Location	Purpose
1	Noise meter	CR811C	Warri	For measuring noise levels
2	Hand– Held GPS	Garmin Oregon 650t	Warri	For measuring elevations, longitudes and latitudes of point locations
3	Infrared thermometer	Flute 572-2	Warri	For measuring the temperature at a spot on a surface

In carrying out the noise level measurements, 10 locations comprising of commercial, industrial activities and busy roundabouts were selected for this study. The measurement of sound level was carried out using a type 1 integrated sound level meter accompanied with a Garmin Oregon 650t hand-held GPS. The CR811C noise level meter was held at a height of 1.2m above ground level with the antenna pointing to the sound source.

Noise level measurement was carried out twice daily for the 10 locations (7.00am – 9.00am and 5.00pm – 7.00pm) respectively. To conduct the measurement, the instrument was set at the A-weighting network and the equivalent noise level (Leq) which is the constant noise level that expands the same amount of energy over the same period, was measured for the various locations. Noise measurements was done for ten (10) weeks (70days) between march to May 2021 for each of the 10 locations and the weekly average noise level in (dBA) was calculated and recorded. The measured equivalent noise level gotten from these readings were use as input data in the calculation of commonly used community noise assessment quantities like the day time noise level and the night time noise level [4].

2.3 Data Analysis

Preliminary analysis methods employed include; test of normality aimed at assessing the trend and nature of data distribution, outlier detection aimed at investigating the presence of abnormallity in the form of outlier and homogeneity test aimed at confirming that the data collected are from same population distribution.

2.3.1 Test of normality

For normality;

i. The skewness and kurtosis significant values must be close to zero as possible
ii. The computed skewness and kurtosis Z-values must be between -1.96 and +1.98
iii. The histogram and Q-Q plot should visually indicate that the data are approximately normally distributed
iv. The computed Shapiro-Wilk and Kolmogorov- Smirnov significant values should be greater than 0.05 ($p < 0.05$)
v.

2.3.2 Outlier detection test result

For outlier detection analysis, the labelling rule method which utilizes the 25th percentile (lower bound) and the 75th percentile (upper bound). was employed. The underlying mathematics of the labelling rule method is presented as follows;

$$\textit{Lower Bound}\ Q_1 - (2.2 \times (Q_3 - Q_1) \tag{1}$$

$$\textit{Upper}\ \text{Bound}\ Q_3 + (2.2 \times (Q_3 - Q_1) \tag{2}$$

At 0.05 degree of freedom, any data lower than Q_1 or greater than Q_3 was considered an outlier and was removed before further analysis.

2.3.3 Homogeneity test

Homogeneity test was done to ascertain the fact that the dependent variables; noise level data are from the same population distribution. The underlying statistics of homogeneity was formulated as follows:

H0: Data are statistically homogeneous

H1: Data are not homogeneous

The null and alternate hypothesis were tested at 90%, 95% and 99% confidence interval that is 0.1, 0.05 and 0.01 degree of freedom.

2.3.4 Geospatial analysis of vehicular noise pollution data

For the spatial distribution of the pollutants, geospatial analysis using Kriging interpolation method was employed. The following steps are involved in the use of kriging interpolation method for the geospatial analysis of selected air pollutants.

i. Evaluation of normality test
ii. Selection of attribute data and model interpolation method
iii. Semivariogram fitting and testing
iv. Cross validation
v. Spatial Dependency determination

3.0 Results and Discussion

The computed statistics based on Shapiro-Wilk and Kolmogorov- Smirnov significant values is presented in Tables 2a and 2b representing morning and evening respectively

Table 2a: Normality test of noise pollution data (Morning)

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
MON	.224	10	.167	.897	10	.204
TUE	.156	10	.200*	.935	10	.499
WED	.236	10	.120	.906	10	.253
THUR	.219	10	.192	.891	10	.173
FRI	.289	10	.017	.823	10	.027
SAT	.195	10	.200*	.885	10	.148
SUN	.200	10	.200*	.901	10	.223

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

Table 2b: Normality test of noise pollution data (Evening)

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
MON	.275	10	.030	.884	10	.146
TUE	.205	10	.200*	.911	10	.286
WED	.323	10	.004	.828	10	.032
THUR	.264	10	.046	.833	10	.037
FRI	.215	10	.200*	.830	10	.034
SAT	.270	10	.037	.819	10	.025
SUN	.170	10	.200*	.942	10	.578

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

Since the calculated p-value based on Kolmogorov- Smirnov and Shapiro-Wilk test for noise level data collected during most time of the day had calculated p-value greater then 0.05, it was concluded that the noise level data did not follow the bell shape configuration reminiscence of the popular normal distribution curve. Hence, the data are not normally distributed. The stochastic nature of noise level data based on environmental influence means that they cannot obey normality. This assertion is rooted from the fact that measurement duration and wind direction as identified in the study by [7] can influence distribution of noise generated from a point source. For outlier detection analysis, the upper bound and lower bound statistics were calculated and result obtained is presented in Table 3.

Table 3: Calculated upper and lower bound statistics

Time	**Computed percentile**	**Lower and upper bound statistics**	**Computed lower and upper bound**	**Extreme value statistics**
Week 1	25th = 73.25 75th = 86.75	73.25 – (2.2 (86.75-73.25)) 86.75 + (2.2 (86.75-73.25))	Lower Bound = 43.55 Upper Bound = 112.05	Lowest value = 61 Highest value = 90
Week 2	25th = 70.25 75th = 80.75	70.25 – (2.2 (80.75-70.25)) 80.75 + (2.2 (80.75-70.25))	Lower Bound = 47.15 Upper Bound = 103.85	Lowest value = 51 Highest value = 89
Week 3	25th = 75.00 75th = 83.50	75.00 – (2.2 (83.50-75.00)) 83.50 + (2.2 (83.50-75.00))	Lower Bound = 56.30 Upper Bound = 102.20	Lowest value = 57 Highest value = 87
Week 4	25th = 71.50 75th = 82.50	71.50 – (2.2 (82.50-71.50)) 82.50 + (2.2 (82.50-71.50))	Lower Bound = 47.30 Upper Bound = 106.70	Lowest value = 50 Highest value = 86
Week 5	25th = 74.25 75th = 81.00	74.25 – (2.2 (81.00-74.25)) 81.00 + (2.2 (81.00-74.25))	Lower Bound = 59.40 Upper Bound = 95.85	Lowest value = 60 Highest value = 86
Week 6	25th = 70.00 75th = 84.75	70.00 – (2.2 (84.75-70.00)) 84.75 + (2.2 (84.75-70.00))	Lower Bound = 37.55 Upper Bound = 117.2	Lowest value = 57 Highest value = 90
Week 7	25th = 66.00 75th = 80.00	66.00 – (2.2 (80.00-66.00)) 80.00 + (2.2 (80.00-66.00))	Lower Bound = 29.20 Upper Bound = 110.80	Lowest value = 57 Highest value = 89

Using the extreme value statistics, the lowest noise level data were observed to be 62, 53, 58, 52, 62, 58, and 58 representing week 1, 2, 3, 4, 5, 6 and 7. While the highest noise level data are; 89, 88, 85, 85, 85, 88 and 87 also representing the maximum noise level for week 1, 2, 3, 4, 5, 6 and 7. Based on the results of Table 3, it was concluded that the data used are devoid of possible outliers since no value is lower than the calculated lower bound or higher than the calculated upper bound.

For homogeneity of the noise level data, the null and alternate hypothesis was tested at 90%, 95% and 99% confidence interval that is 0.1, 0.05 and 0.01 degree of freedom and result obtained is presented in Figures 2a and 2b representing measured noise level in the morning and evening respectively.

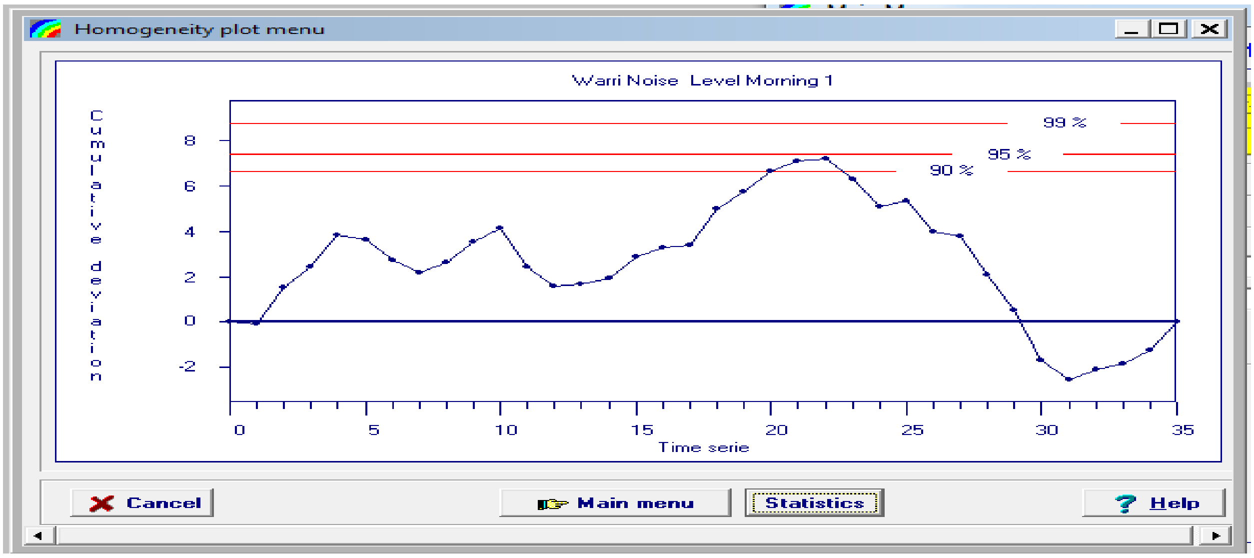

Figure 2a: Homogeneity test of noise level data (Morning)

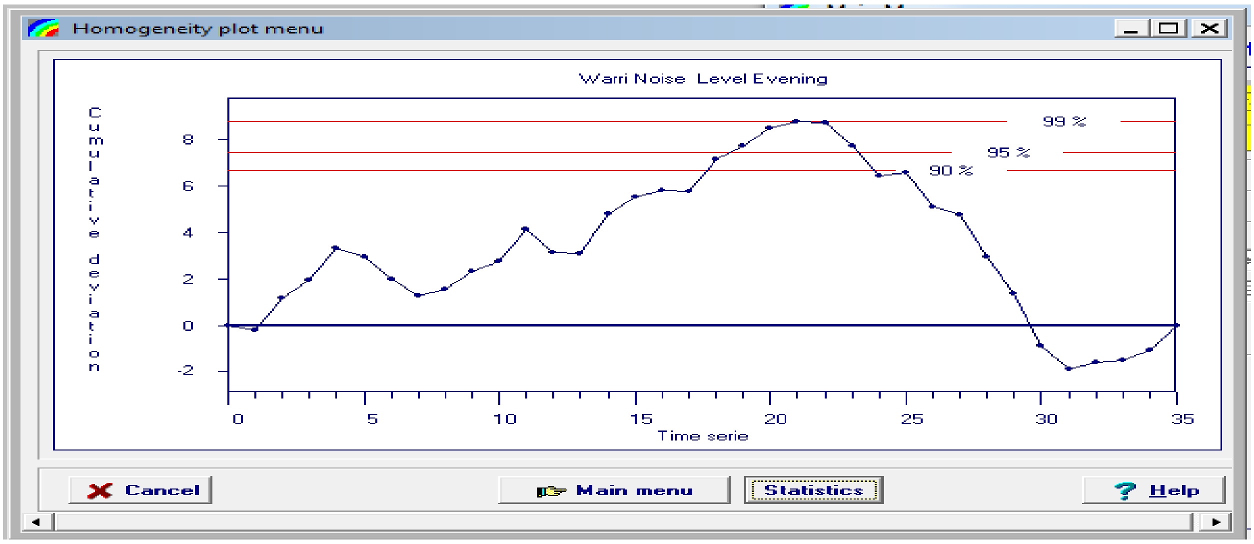

Figure 2b: Homogeneity test of noise level data (Evening)

From the result of Figures 2a and 2b, it was observed that the noise level data fluctuates around the zero-center line of the residual mass curve an indication that the data are statistically homogeneous. To study the spatial distribution of noise pollution around the study area, four semivariogram models, namely; stable, circular, spherical and exponential were fitted in order to select the best model for noise level. Using the different model, parameters of the semivariogram statistics for noise level data were generated and presented in Tables 4a and 4b representing morning and evening respectively.

Table 4a: Semivariogram parameters for noise level data (morning)

S/N	Model Type	Nugget	Major Range	Partial Sill
1.	Stable	0.00668	0.33070	0.00544
2.	Circular	3.03304	1.00929	8.09423

3.	Spherical	8.60108	2.33054	6.78019
4.	Exponential	4.22506	1.88011	7.89054

Table 4b: Semivariogram parameters for noise level data (evening)

S/N	Model Type	Nugget	Major Range	Partial Sill
1.	Stable	0.00367	0.10119	0.10987
2.	Circular	7.85094	1.29203	3.46338
3.	Spherical	6.95228	1.33777	3.00265
4.	Exponential	7.82009	1.44347	4.00201

Tables 4a and 4b show the result of the semivariogram statistics for the noise level data and their corresponding values of nugget (the variability in the field data that cannot be explained by distance between the observations), major range (the distance at which two observations are unrelated/independent) and sill (the semi-variance at which the levelling takes place). The difference between the sill and the nugget is called partial sill. The semivariogram statistics provides information about the range, nugget and partial sill which were used to measure the degree of spatial dependency. It also provides the input parameters that were utilized for the kriging interpolation.

To select the model that best described noise level data and which will be employed to generate the final prediction map, selected goodness of fit statistics, namely; Root mean square error (RMSE), Mean square error (MSE), Root mean square standardized error (RMSSE) and Average standard error (ASE) generated from the cross-validation step were employed. Estimated goodness of fit statistics corresponding to the different models are presented in Tables 5a, and 5b representing morning and evening respectively.

Table 5a: Calculated cross validation statistics for noise level (morning)

S/N	Model Type	RMSE	MSE	RMSSE	ASE
1.	Stable	0.00477	0.00405	0.10201	0.04002
2.	Circular	4.78033	0.66578	1.08819	3.04445
3.	Spherical	2.08044	0.10229	0.77077	2.11012
4.	Exponential	1.89087	0.33991	0.66033	1.04003

Table 5b: Calculated cross validation statistics for noise level (evening)

S/N	Model Type	RMSE	MSE	RMSSE	ASE
1.	Stable	0.00345	0.00881	0.01011	0.00893
2.	Circular	2.03119	0.08022	1.22033	4.58390
3.	Spherical	1.00663	0.11166	1.44022	1.44228
4.	Exponential	3.00992	0.44032	1.00443	2.40667

Following the application of different models, the errors were calculated using cross validation and the model that gives the best result was chosen. Based on the estimated errors, the stable model was selected as the best fit. To evaluate the degree of spatial structure (dependence), the ratio of Nugget (C_n) to Sill (C) was employed. If the ratio is less than 25%, the variable has strong partial dependence; between 25% and 75%, the variable has moderate spatial dependence, and greater than 75%, the variable shows only weak spatial dependence. Using the stable model, the spatial dependence was estimated and presented in Table 6.

Table 6: Estimated spatial dependence of noise level parameters

Group	Best Model	Nugget (Cn)	Partial Sill	Sill (C)	[Cn/C]	Degree of Spatial Dependency
Morning	Stable	0.00668	0.00544	0.01212	0.5512	Strong
Evening	Stable	0.00367	0.10987	0.11354	0.0323	Strong

Results of Table 6 revealed that the noise level data showed relatively strong degree of spatial dependency which made it possible to generate the spatial distribution map. Finally the prediction map which can be employed to predict the noise level around the study area was generated and presented in Figures 3a, 3b, 3c, 3d, 3e and 3f respectively.

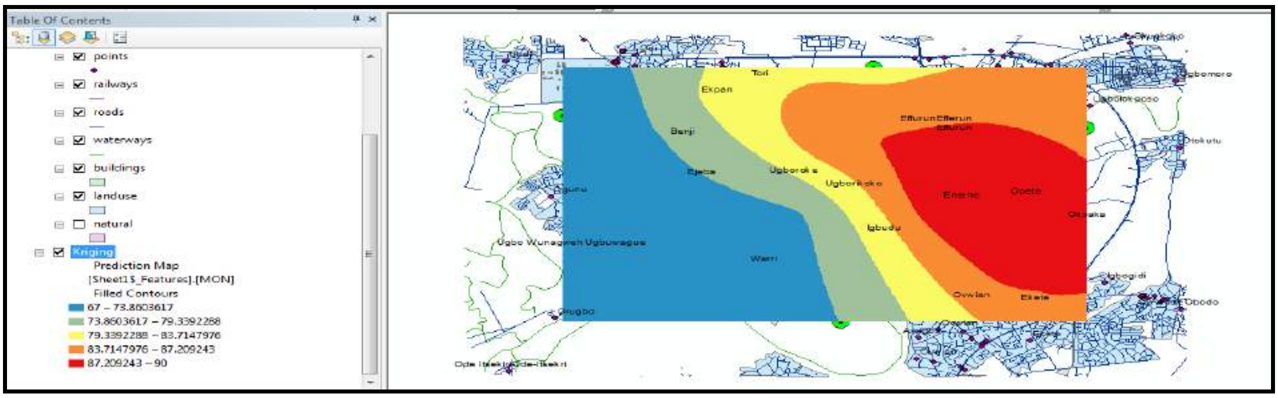

Figure 3a: Final prediction map for the spatial distribution of noise level (Monday Morning)

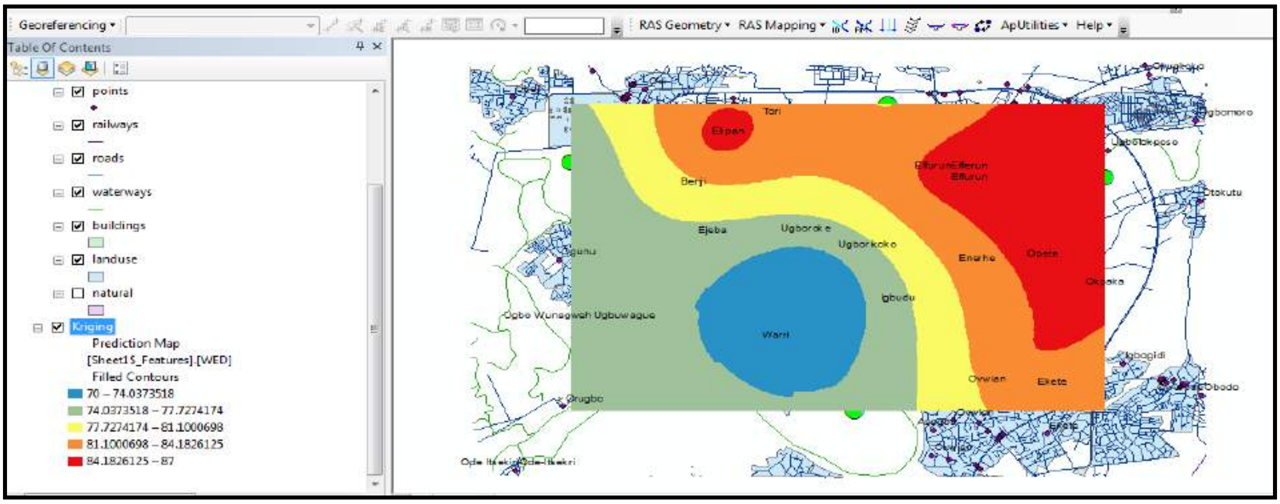

Figure 3b: Final prediction map for the spatial distribution of noise level (Wednesday Morning)

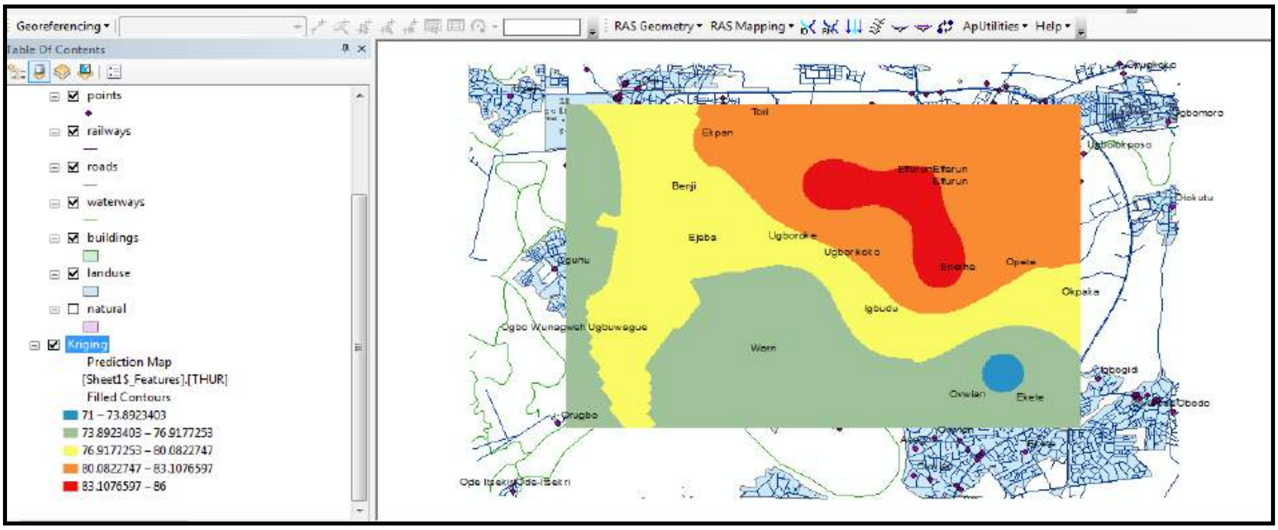

Figure 3c: Final prediction map for the spatial distribution of noise level (Thursday Morning)

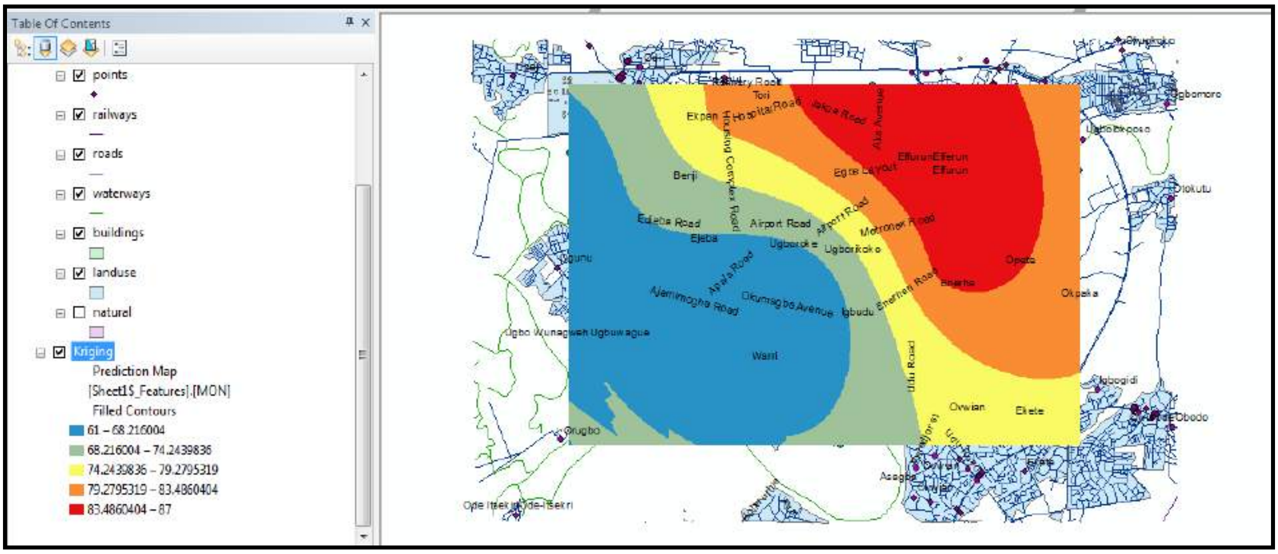

Figure 3d: Final prediction map for the spatial distribution of noise level (Monday Evening)

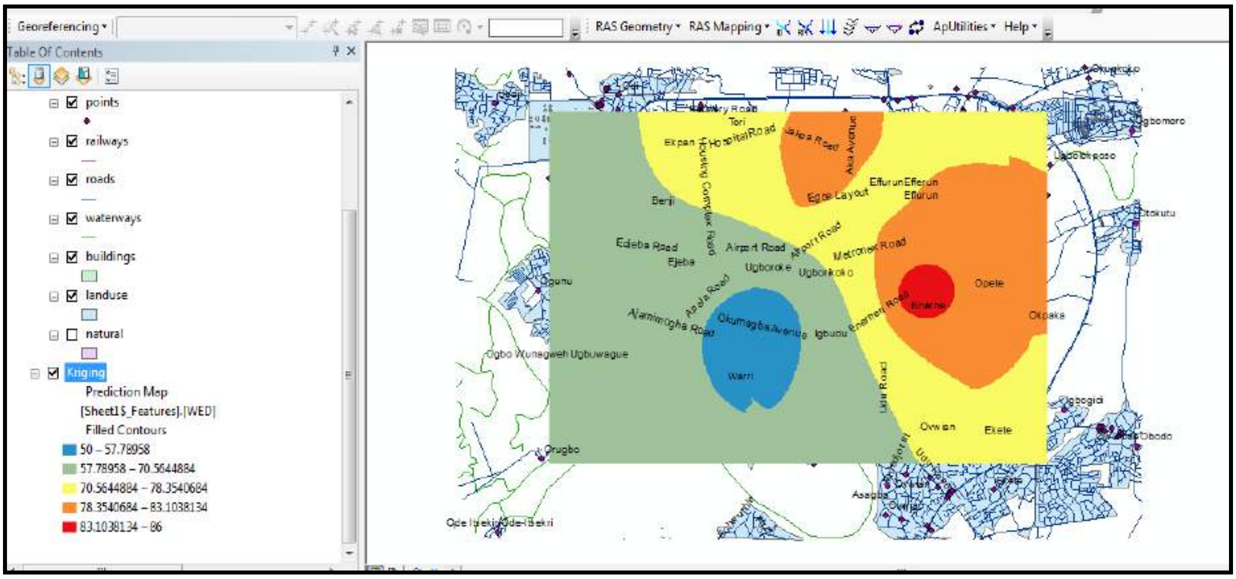

Figure 3e: Final prediction map for the spatial distribution of noise level (Wednesday Evening)

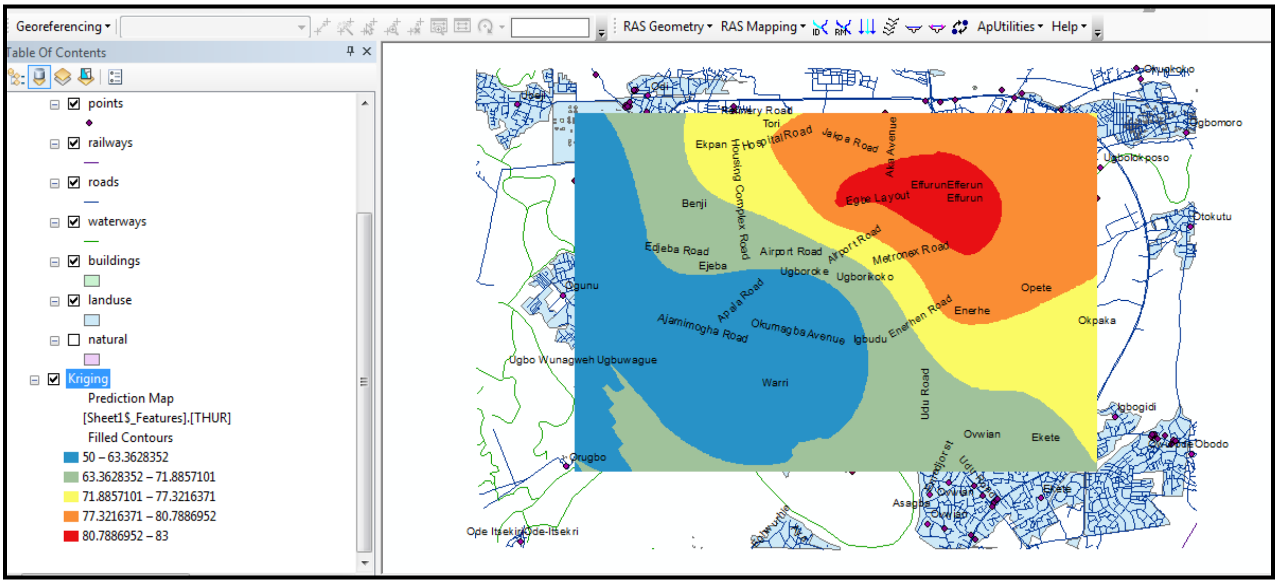

Figure 3f: Final prediction map for the spatial distribution of noise level (Thursday Evening)

From the results of Figures 3a, 3b, 3c, 3d, 3e and 3f, it was revealed that; High concentration of noise pollution is experienced in areas such as; Enerhe, Opete, Effurun and Ekpan especially in the morning while Areas such as; Jelpa road, Aka junction, Enerhe, Efurun and Egbe layout normally experienced high level of noise pollution during evening. Although the outcome of this study is in-line with the results of the study by [1, 2], the geospatial analysis was done to bridge one of the gaps observed with related studies on noise pollution modelling and evaluation.

4.0 Conclusion

In this study, modelling, analysis and prediction of noise level pollutants from vehicular emission in some selected locations around Warri in Delta State was done. To certify the adequacy of the field data, selected preliminary analysis, namely; descriptive statistics, test of normality, outlier detection autocorrelation and homogeneity test was done. In conclusion it was observed based on the overall analysis that; areas such as; Enerhe, Opete, Efurun and Ekpan experienced high level of noise pollution especially in the morning while areas such as; Jelpa road, Aka junction, Enerhe, Effurun and Egbe layout normally experienced high level of noise pollution during evening. It is concluded that geospatial technique can serve as veritable tool for noise pollution modelling especially in urban cities.

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