

**NOISE LEVELS, TRAFFIC FLOW IN  
PORT HARCOURT METROPOLIS AND  
VALIDATION OF CALIXTO MATHEMATICAL  
NOISE PREDICTION MODEL**

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**BY**

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## CERTIFICATION

This is to certify that this work "NOISE LEVELS, TRAFFIC FLOW IN PORT HARCOURT MOTROPOLIS AND VALIDATION OF CALIXTO MATHEMATICAL NOISE PREDICTION MODEL was carried out by George, Daye Mandy Clement (Reg. No. 20124765118) in partial fulfillment for the Award of Masters Degree (M.Sc.) in the Department of Environmental Technology, Federal University of Technology, Owerri.



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## **DEDICATION**

This thesis is unequivocally dedicated to God Almighty for His unfailing love, guidance and protection all over me. It is also dedicated to my late father- Deacon George, Mandy and My beautiful and supportive wife –George, Duabo S. and our children for their understanding during my study in Owerri, Imo State.

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## ABSTRACT

Noise levels in selected locations in Port Harcourt metropolis, was assessed using field measurements and Calixto mathematical model. This was carried out in 10 different locations around the city using an Extech model 407780A integrated sound level meter, and Garmin eTrex HC GPS for geo-referencing. Measurements were carried out at various periods of the day (Morning, afternoon, evening and night). Calixto mathematical model was also applied to predict noise levels after counting the number of vehicular flow in a day at the located sites. Pearsons' product moment correlation ( $r$ ) was employed to compare the Leq measured with the Leq calculated, and single factor anova was used to ascertain any significant difference in noise levels in the monitored locations, while the results were validated using descriptive statistics. Results obtained showed that equivalent noise levels for the studied locations were all higher than the recommended standard by World Health Organization (WHO). Day-time and night-time noise levels were also obtained and used to ascertain the noise quality description of the city. The results also revealed that the day time mean equivalent noise level of the city were all of hazardous quality in the busy road junction/major intersections (95.99dB (A)), passenger loading bus stops (95.82dB (A)), and commercial areas (94.04dB (A)), while that of the residential areas were all of good quality, 56.27dB (A) and 58.80dB (A) for low and high density residential areas, respectively. Similarly, the night time noise levels were all of hazardous quality with values of 98.81dB (A), 92.17dB (A) and 85.36dB (A) for busy road junctions, passenger loading bus stop and commercial areas in that order. The residential areas also had satisfactory quality of 58.29 and 63.90dB (A) respectively for low and high density areas. Day-night time noise levels were very high. The night time which would have served as recovery time for people who were exposed to noise were lacking in these areas. The Pearsons' product moment correlation ( $r$ ) for all the periods of the day studied, showed that there was a strong relationship or association between them, as the values obtained were close to unity (1). The result of descriptive statistics showed that the mean  $\pm$  SD, coefficient of variance and standard errors were very close to each other and comparable, indicating the accuracy of the method. Validation was further confirmed by the low values of standard deviation, coefficient of variance and standard error. The result also revealed that there was statistically significant difference in the level of noise exposure at different locations studied ( $P < 0.05$ ). It is recommended that those whose daily activities confine them to areas with unhealthy noise levels should make sure they have at least 10 hours of recovery time in areas where the sound level is less than 65dB (A). The authority should improve the traffic situation in the city so as to prevent traffic build up in areas with high noise levels.

**Keywords:** Noise evaluation, mathematical model, Port Harcourt Metropolis

# CHAPTER ONE

## 1.0 INTRODUCTION

### 1.1 Background to the Study

The word noise is derived from the Latin word “nausea” implying “unwanted sound”. Environmental noise has been given various definitions by different authors. Defra (2003), and Anomoharan (2004), defined noise as an unwanted or harmful outdoor sound created by human activities. Ebeniro and Abumere (1999), viewed environmental noise as an unwanted acoustic signal or sound dumped into the environment without regard of its adverse effect on both man and the environment. In most cases the acoustic signal, sounds louder than normal acceptable levels. Acceptable levels of noise have been pegged by different agencies in different countries to suit themselves. These levels have been set for institutions, busy roads junctions/major intersections in cities, residential areas, commercial, social gathering etc. once the sound levels exceeds the allowable limit, the environment is said to be noise polluted.

The extent, to which a given noise is annoying, depends on many factors, such as pitch, irregularities, duration, rhythm, unexpectedness or whether the noise has meaning for the particular observer. However, by far the most important factor is

loudness. This loudness depends both on the physical sound pressure measured in decibels (db), and on the sensitivity of human ear which varies widely with frequency. The range of frequency the human ear responds to is from 20Hz to 20,000Hz, called the audio frequency range, below this range we have the infra-sound and above it we have ultra-sound.

Noise is generated from both indoors and outdoors. The sources of outdoor may be attributed to industrialization, noise generated from construction sites, aircrafts, trains, commercial activities and intrusive sounds especially from the use of public address system by churches, social gatherings, marriages and electric generator equipment (Oyedepo, 2012) Others include vehicular traffic or increased vehicle in circulation and population. Indoor noise may have sources like telephones, electrical and other appliances. Noise pollution is the third most hazardous type of pollution, right after air and water pollution in big cities (WHO, 2005). Noise is a common feature in Port Harcourt metropolis which is a result of the presence of several industrial activities going on in and around the city. Moreover, the discovery of oil and establishment of allied industries, have increased the migration of people from all walks of life to the city. This in turn has increased commercial activities, vehicular traffic and transportation problems, which are major sources of noise. It is now recognized worldwide as a major problem for the

quality of life in urban areas, yet noise pollution has been considered less important than other contaminants in the environment (Mansouri *et al.*, 2006).

## **1.2 Statement of the Problem**

In Nigeria, there are now so many innovations which increase the noise environment of the general public with the impression given that noise is not a problem. This is a very wrong impression; noise is indeed becoming a major problem.

For a long time many individuals have accepted noise as a part of the environment. However, over the years the general incidence of noise has been on the increase. The development of various engines, technological machinery in industries, jet planes etc., all contributed to an increasing noise environment. It has reached an alarming state and is now regarded by many people as a pollution component that contributes to the deteriorations of the environment. Some even regard noise as the sixth environmental pollutant apart from the commonly known ones.

In contrast to many other environmental problems, noise pollution continues to grow and accompanied by an increasing number of complaints from people exposed to the noise. The growth in noise has direct and cumulative adverse health effects and also affects the quality of life enjoyed by people in most industrialized

cities and urban areas all over the world (Serkan *et al.*, 2009). This is not different from Port Harcourt metropolis, especially along main road arteries.

### **1.3 Aim and Objectives of the study**

The aim of this study is to “assess noise levels in Port Harcourt metropolis using field measurements and Calixto mathematical model”, this will be achieved through the following objectives:

- (1) To determine the spatial and temporal noise levels in selected locations in Port Harcourt metropolis.
- (2) Use of the model to predict traffic noise levels in the selected locations for the different periods of the day.
- (3) To compare the measured noise levels with the predicted traffic noise data
- (4). To determine the noise quality description and risk zones of the various selected locations of the city

### **1.4 Justification of the Study**

Noise pollution has been stated as a serious health hazard, with noise related damage to human ranging from annoyance to difficulty in falling asleep and high blood pressure. Existing evidence indicate that noise pollution has negative impacts on human health including blood pressure. Despite these adverse effects

of noise pollution in Port Harcourt metropolis, most people have not recognized noise as an insidious pollutant or attributed any serious physiological impacts to it. There is a need therefore to carry out this research from where the findings and recommendations will provide valuable information to policy makers and general public on ways of solving the problem. Results from this research will also be a good reference material for future work on similar topic.

Furthermore, no studies on noise using mathematical modeling have been reported in Port Harcourt metropolis. Most studies were based on either measurement by sound level meters or questionnaires. Hence, there is need to investigate noise levels using simulation model, to assess road traffic noise at selected sites in Port Harcourt metropolis. Also, comparison of the past studies and the present study are necessary, since it can serve as tools to proffer practical actions to limit and control the exposure to environmental noise, and further planning and development of the city.

### **1.5 Scope of the Study**

This work is limited to determining the noise pollution levels in busy roads junctions/major intersections, passenger loading bus stops, commercial areas and residential areas(low and high density areas) in Port Harcourt metropolis, Rivers

State using global positioning system (GPS) and precision-grade Sound level meter (Extech 407780A) that is IEC or ISO compliant.

## CHAPTER TWO

### 2.0 LITERATURE REVIEW

In years past by, some valuable work has been done all over the world in this field of noise. Extensive noise survey of large cities was carried out in New York City, Turkey (Serkan *et al.*, 2009), and Brazil (Zannin *et al.*, 2002). Similar works have also been done in cities of developing countries like Nigeria, Ghana etc. The literatures to be reviewed for this work will be under the following sub-Headings: - Noise levels in different parts of the world and Nigeria; Sources of noise pollution and development of noise predicting models.

#### 2.1: Noise Levels in Different Parts of the World and Nigeria

On carrying out noise level measurements in Arrabba, a city in Palestine, to ascertain the noise levels of the city, it was found that noise level rose to 67 dB(A), from 20 measuring points (Zeid *et al.*, 2000). According to them, at 60% of these points, the level exceeded 65dB (A) indicating that noise level in the city exceeded the acceptable level of 65dB (A).

In addition, in Curitiba in Brazil, the results of noise survey, revealed that at 93% of the measurement points, the noise level was over the allowed value of 65dB (A)

and exceeded high noise level of 75dB (A) at 40.3% of these points studied (Zannin *et al.*, 2002). Similar results with the studies mentioned above were also obtained in Beijing (Li *et al.*, 2002) and Ca'ceres (Morillas *et al.*, 2002), Assiut city in Egypt (Ali, 2004) to mention but a few.

Mohammadi (2009), investigated community response to urban traffic noise, to determine day- time noise levels in commercial and residential areas in Kerman, located in South East of Iran. The equivalent noise level varied between 66 to 79dB (A). The results of the study established the fact that noise levels are more than the acceptable limit of 60dB (A), which is the day-time governmentally prescribed noise limit for the residential/commercial areas of the city.

Furthermore, a study to determine the noise level due to motorway in Tokat city centre, located at the Northern part of Turkey was carried out. Noise measurements were taken in the evening to determine noise pollution all over the city as motorway transportation noise. The equivalent sound levels ( $L_{eq}$ ) were measured at 65 points, between 17 and 19 p.m. in the city. High noise levels were observed throughout the monitored sites of the city, as noise levels exceeded 65 dB (A), limit value according to Turkish noise control regulation (Serkan *et al.*, 2009)

In Africa, similar trend has been observed in noise levels in busy roads junctions /major intersections, commercial areas and passenger loading bus stops/parks in urban areas that are highly industrialized or business inclined. Noise pollution associated with urbanization is an emerging environmental problem in many developing countries like Ghana, Nigeria etc. The determination of ambient noise levels in the main commercial area of Cape Coast, Ghana was studied. The focus was on five selected areas; commercial centers, busy road junctions/ major intersections, passengers loading stations, high density residential areas, and low-density residential areas. Paul *et al.*(2011), reported differences of the noise levels at high density residential areas and that of low-density residential area. However, they concluded that noise levels at the measurement points exceeded the Ghanaian EPA recommended upper limit by values of 1 to 15dB (A).

Again, Armah *et al.* (2010) carried out a similar noise evaluation studies, focusing on noise emanating from religious activities in Cape Coast metropolis. They found that religious activity related ambient noise levels in many areas in Cape coast were higher than the Ghana environmental protection agency (EPA) upper limits for day and night. Kotokuraba, the main commercial area of cape coast is not an exception to this environmental hazard.

In Nigeria, similar work on noise level evaluation in different states of the country, have been studied in urban areas. The study observed that Nigeria cities are environmentally noise polluted to a relatively high levels when compared to recommended levels by World Health Organization (WHO) or Housing and Urban Development (HUD), Committee on Environmental and Occupational Health (CEOH) or Federal Highway Administration (FHWA) (Oyedepo, 2012).

A comparative study of noise pollution levels in some selected area of Ilorin metropolis, Nigeria was carried out by Oyedopo and Saadu (2009). The study was conducted to compare the noise pollution levels at busy roads junctions/major intersections, passengers loading bus stop/parks, commercial, industrial and residential areas at Ilorin metropolis. A total of 47 locations were selected in the metropolis. The results of the study shows that industrial areas have the highest noise pollution level of 110.28dB (A), followed by the busy roads junctions major intersection (91.5dB (A),) passengers loading bus stop/parks (87.8dB (A)) and commercial areas (84.4dB (A)). According to the researchers, the noise pollution in Ilorin metropolis exceeded the recommended level by WHO at 34 of 47 measuring points. This was corroborated by Ugwuanyi *et al* (2005), who carried out a similar survey in Markudi, Nigeria and found that the noise pollution level in the city was about 3-10dB (A) above the recommended upper limit of 82dB (A).

Again, Onuu and Menkiti (1993), who had also done several works on noise level evaluations in Nigeria cities of Aba in Abia State and Uyo in Akwa Ibom states respectively, also found noise level to be higher than the recommended level of 60dB (A) for commercial and residential areas. According to them, the peak noise level ranges between 86-106dB (A) in Aba and Uyo, Nigeria.

Furthermore, day and night time noise pollution studies were carried out by Anomohanran and Iserhein (2006), in some major towns in Delta state, Nigeria. Their results revealed that the average day time noise level for Warri exceeded the WHO permissible limit. Similarly, Ighoroje *et al.* (2004), investigated the level of noise pollution in selected industrial location in Benin City, Nigeria. Their result revealed that the average ambient noise level in Sawmills, electro-acoustic market and food processing industrial areas was above 90dB (A), which is well above the healthy noise level of 60dB (A).

## **2.2: Sources of Noise Pollution**

The boom in Nigeria economy due to the huge revenue earnings from oil export during the seventies stimulated rapid growth of many urban centers in the country. As a result existing road networks could not cope with the increase number of vehicles plying city and inter-city roads. This contributed immensely towards

worsening environmental noise pollution in the cities (Saadu *et al.*, 1998 and Saadu,1998).

Noise pollution in urban areas is often generated by either man (anthropogenic) or by nature (naturally).Urbanization is one of the basic considerations for noise pollution by anthropogenic source. The urban environment has always been an area of high population concentration in Nigeria, mainly because people tend to believe that the only hope of improving their standard of living is to live in urban areas. The view of urbanization as a source of pollution was corroborated by Paul *et al.* (2011), who reported that noise pollution associated with urbanization is an emerging environmental problem for the quality of life in urban areas in many developing countries including Nigeria.

Again, road traffic noise can be considered as the main source of noise pollution in large cities as reported by Omidavari and Nouri (2009). Results of other Investigations, has shown clearly that road traffic noise is the most predominant and heavy generator of noise source in urban area (Ahamed *et al.*, 2006).The same idea was put forward by Serkan *et al* (2009), who studied the evaluation of noise pollution caused by vehicles in the city of Tokat, Turkey. In their investigation, noise measurements were taken in the evening to determine noise pollution all over

the city as motorway transportation noise. Their results revealed that the major source of noise pollution was heavy vehicular traffic due to concentrations of ring roads at the city centre.

Gh. Mohammadi (2009), corroborated the assertion that increase in population and in the number of circulatory vehicle have led to an increase in urban noise levels in Kerman, Iran. A similar report showing strong relationship between vehicular traffic volume and noise level has been reported as carried out by Ma *et al.*, (2006). This view was supported by Nataraja *et al.* (2010), who reported that as traffic volume increase, noise level also increases.

Furthermore, Yilmaz and Ozer (2005) ,studied the evaluation and analysis of environmental noise pollution in the city of Erzurum, Turkey. According to them, environmental noise was due to increase in urbanization and the number of cars in Turkey cities. In a similar study carried out by Mansouri *et al* (2006), on road traffic noise down town area of Tehran, found that the noise pollution level was higher than acceptable levels. The result obtained was attributed to increase in population and in the number of circulating vehicles in the city.

Bani and Paulo (2009), investigated the analysis and evaluation of sound scapes in public parks through interviews and measurement of noise. In the four parks

studied, the sound level at most of the points evaluated exceeded the 55 dB (A) limit established as acceptable for green areas. The result was attributed to the closeness of the park perimeter to the streets with intense vehicular traffic.

Aircraft /air traffic has been identified as another source of noise creation. Omubo-Peppele *et al* (2010), studied noise pollution in Port Harcourt metropolis: sources, effects and control. The survey was done in Port Harcourt international air port Omagwa .Their result revealed that the major source of noise pollution in the air port is air traffic or air craft noise. According to them, noise pollution level is such that can cause temporary deafness which can snow ball to permanent loss of hearing depending on the number of hours one is constantly exposed to .

Industrialization is another source that can generate noise. Oyedepo (2012), worked on noise pollution in urban areas: The neglected dimensions, and found that noise pollution levels were high and is on the increase. According to him, industrial machineries/plants and the use of captive generation equipment (generators of various sizes) are also good sources of noise pollution.

Onuu *et al* (1996), studied the sound levels and spectra of industrial layout in Calabar, Cross Rivers state of Nigeria. The obtained octave band pressure levels was found to be well above 85dB (A) and was as high as 115dB (A) to cause

deafness. They therefore concluded that industrial machineries or plants are also contributors to noise pollution in most Niger Delta communities hosting industries. Similarly, Alaminokuma *et al* (2008), studied the frequency-dependent noise characteristic in a gas-to-liquid plant in the swamp area of the Niger delta. The noise level within the gas plant is such that the high level of discomfort and annoyance were produced by discrete noise masked by broadband noise in the zones, where machines with rotating parts operate. They also concluded in support of Onuu *et al.* (1996), that industrial machines are major contributors of noise pollution in industrialized areas.

Furthermore, outside industrial areas, Singh and Daver (2004), reported that the most important factors raising noise pollution in urban areas included inter alia appliances, neighborhood electrical appliances, TV, and music systems, public address systems, rail way and generating sets. This view was corroborated by Armah *et al.* (2010), who studied religious activity –related ambient noise level in many areas in Cape Coast, Ghana. Their results revealed that noise levels from religious homes were higher than the Ghanaian EPA upper limit for day and night times. In conclusion, they corroborated the views of others that religious activity using loudspeakers/public address systems are major source of noise pollution.

## 2.4 Development of Noise Predicting Models.

The development of models to predict traffic noise started more than 50 years ago and the results have been very accurate. Usually, these kind of models are developed taking into account mainly traffic flow, both of light and heavy vehicles, features of the road surface, distance between carriage and receivers. Moreover, since several models have been developed all around the world, the peculiarities of different countries, in terms of roads, kind of vehicles and weather features have to be taken into account.

Many countries decided to regulate the use of these models, establishing which one can be adopted in traffic noise simulation. This is because it can be used in the designing of new road infrastructures in order to evaluate the acoustical impact and to avoid post construction mitigation actions that often present a greater cost. On the other side, it can be used on an existing road network, so that the measurement campaign can be minimized and can be used just for the tuning of the model.

One of the first models, developed in 1952, is the one reported in Handbook of Acoustic Noise control (Anon, 1952). This model states that the 50 percentile of traffic noise for speed of 35-45 mph (about 55-75 km/h) and distance greater than 20 feet (about 6 meters) is given by:  $L_{50} = 68 + 8.5 \text{Log}(Q) - 20 \text{Log}(d)$ . Where  $Q$  is

the traffic volume in vehicles per hour and  $d$  is the distance from observation point to the center of the traffic lane, in feet: no specification is included about vehicles and roads type.

In the following years, Nickson and Lamure (1965), presented a new model in which a new parameter is included to relate the model with the experimental data.

They proposed:

$L_{50} = C + 10\text{Log} (Q/d)$ . Where  $C$  is a constant value that can be evaluated making an analysis of experimental data and  $L_{50}$  is the sound level in dB (A).

Later, Johnson *et al.* (1968), presented a new traffic noise model taking also into account the mean speed of vehicles in mph,  $V$ . They proposed for  $L_{50}$  the following expression:

$L_{50} = 3.5 + 10\text{Log} (QV^3/d)$ . The model presents a good agreement with the experimental data for a percentage of heavy vehicles from 0% to 40%. It also includes some corrective factor for sound attenuation and gradient.

Some years later, Galloay *et al.*(1969), improved this model taking into account the percentage of heavy vehicles  $p$ . Their expression for the  $L_{50}$  level in dB (A) was :

$$L_{50} = 20 + 10\text{Log} (QV^2/d) + 0.4p.$$

The models developed in the next years introduced the equivalent level  $L_{eq}$  as sound level indicator. One of the most used is the Burgess model (1977), applied for the first time in Sydney in Australia. Using the same notation of the previous expression, the sound levels is giving by:  $L_{eq} = 55.5 + 10.2 \text{Log} (Q) + 0.3p - 19.3 \text{Log} (d)$ .

Another most used calculation formula is called “Griffiths and Langdon” method (1968). In particular, they propose the evaluation of equivalent level starting from the percentile levels as follows:  $L_{eq} = L_{50} + 0.018 (L_{10} - L_{90})$ . Where the statistical percentile indicator have the expression:

$$L_{10} = 61 + 8.4 \text{Log} (Q) + 0.15p - 11.5 \text{Log} (d).$$

$$L_{50} = 44.8 + 10.8 \text{Log} (Q) + 0.12p - 9.6 \text{Log} (d).$$

$$L_{eq} = 10 \text{Log} (Q_L + Q_m + 8Q_p + 88Q_{Bus}) + 33.5$$

Conclusively, it was from here that other models for calculating  $L_{eq}$  developed like the calixto *et al.*(2003), model used in this paper.

## **2.4 Noise Standards.**

In the measurement of noise, several methods and apparatus are used, which must comply with standards. Standards contains the necessary conditions for measuring

instruments, methods of measuring noise for different activities or types of equipment, assessing the harmful effects of noise. The most important standards are those published by ISO (International Standard Organization). ISO deals primarily in the measurement methods, experimental conditions, measurement parameters and method for evaluating the results (Demian *et al.*, 2008). Others include World Health Organization (WHO), Federal Environmental Protection Agency (FEPA), US Federal Highway Administration (FHWA), Department of Housing and Urban Development (HUD), and Environmental Noise Control by Federal-Provincial Advisory Committee on Environment and Occupational Health.

Most countries have come up with permissible noise standards to suite her peculiar environment. The US Federal Highway Administration (FHWA) in April, 1972 published interim noise standards for various uses. It recommends that for the exteriors of parks and open spaces, the noise levels  $L_{10}$  should not exceed 60 dB (A) and 70dB (A) for the exterior of residential areas, hotels, schools, libraries, hospitals etc. For developed areas, noise levels should not exceed 75dB (A), while the interiors of residential areas, hotels and libraries should not exceed 55dB (A) (Parbat & Nagamailk, 2007).

The US Department of Housing and Urban Development (HUD) recommends the following noise levels for residential areas, measured outdoor  $L_{Aeq} = 49\text{dB(A)}$  as clearly acceptable.  $49\text{dB (A)} - 62\text{dB (A)}$  or  $L_{DN} \leq 65\text{dB (A)}$  is normally acceptable.  $L_{Aeq} 62\text{dB (A)} \leq 76\text{dB (A)}$  or  $L_{DN} \leq 75\text{dB (A)}$  is normally acceptable and  $L_{Aeq} > 76\text{dB (A)}$  or  $L_{DN} > 75\text{dB (A)}$  is clearly not acceptable.

The environmental noise control guideline by Federal Provincial Advisory Committee on Environmental and Occupational Health, recommend a generally acceptable road traffic noise levels for both day time and night time. They recommended that the day time ( $L_D$ ) noise level should not exceed  $55\text{dB (A)}$  and the night time ( $L_N$ ) should not exceed  $50\text{dB (A)}$ . This implies that an area with environmental noise level  $< 55\text{dB (A)}$  is usually considered as a comfortable environment with little or no annoyance.

In Nigeria, Federal Environmental Protection Agency (FEPA) has been saddled with the responsibility of fixing permissible noise levels. Oyedepo and Saadu (2010) reported that the hazardous nature of industrial noise has laid credence to the formulation of permissible levels/standard by FEPA to which an employee may be subjected. According to them, for a duration of 8 hours the permissible limit

should not exceed 90dB (A) and for a duration of 6hours the permissible limit should not exceed 92DB (A).

## **2.5 Effects of Noise on Human Health.**

Depending on its duration and volume, the effects of noise on human health and comfort are divided into four categories: physical effects, such as hearing defects which may be temporal or permanent; physiological effects, ranging from increased blood pressure (Bronzaft, 2000), irregularity of heart rhythms ; psychological effects such as disorders, sleeplessness and going to sleep late (Stanfield & Matheson, 2003).Others include irritability, stress, anxiety; and finally interference with verbal communication and reduction in working efficiency (Ahmed *et al.*, 2006 and Ugwuanyi *et al.*, 2004).

## **2.6 Noise Control Measures.**

In Nigeria, the check (if there is any) against noise pollution is weak. Most of the people do not consider noise a pollutant, and take it as a part of routine life.

There are several methods that can be utilized for controlling the level of noise. First of all, the design and technology of machines/equipment could be altered, resulting in low noise emission. Secondly, noise barriers may help us control noise.

Thirdly, to protect receptors of sound by a shield, a building may be insulated against noise and also the body and window panes may be made sound proof. Apart from technology we may undertake various steps to modify or regulate the behaviors of users of machine and equipment. Educating the public may be a good option because it is a social problem. Sheer ignorance about the adverse effects of noise pollution appears to be a key factor in the laying inadequate stress on controlling or reducing its levels. Change in public attitude by government programs, non-governmental organizations and civil measures (fines) may reduce or prevent noise pollution. Many conflicts over noise pollution are handled by negotiation between emitter and receiver.

Noise due to traffic congestions are mostly controlled by traditional traffic management techniques such as one way, traffic light systems, construction of flyovers and new routes outside the city. In advanced countries like America, GIS structures have been developed, which are used in conjunction with the existing traffic control measures. The GIS provide traffic information that enables both commuters and motorist to take rational decision as regards routes to follow during peak hours. Sometimes traffic information systems (TIS) are provided in the city to monitor congestion. The TIS is linked to the state and federal radio, from where

traffic information is relayed to anybody that tunes to such channels, so that motorist and commuters can take an alternate route that is less congested.

In Nigeria where the power from the national grade is epileptic, Governments of the various states have put in place independent and efficient electricity that powers all the traffic lights stationed at road junctions rather than relying on power holding company of Nigeria.

## **CHAPTER THREE**

### **3.0 METHODOLOGY**

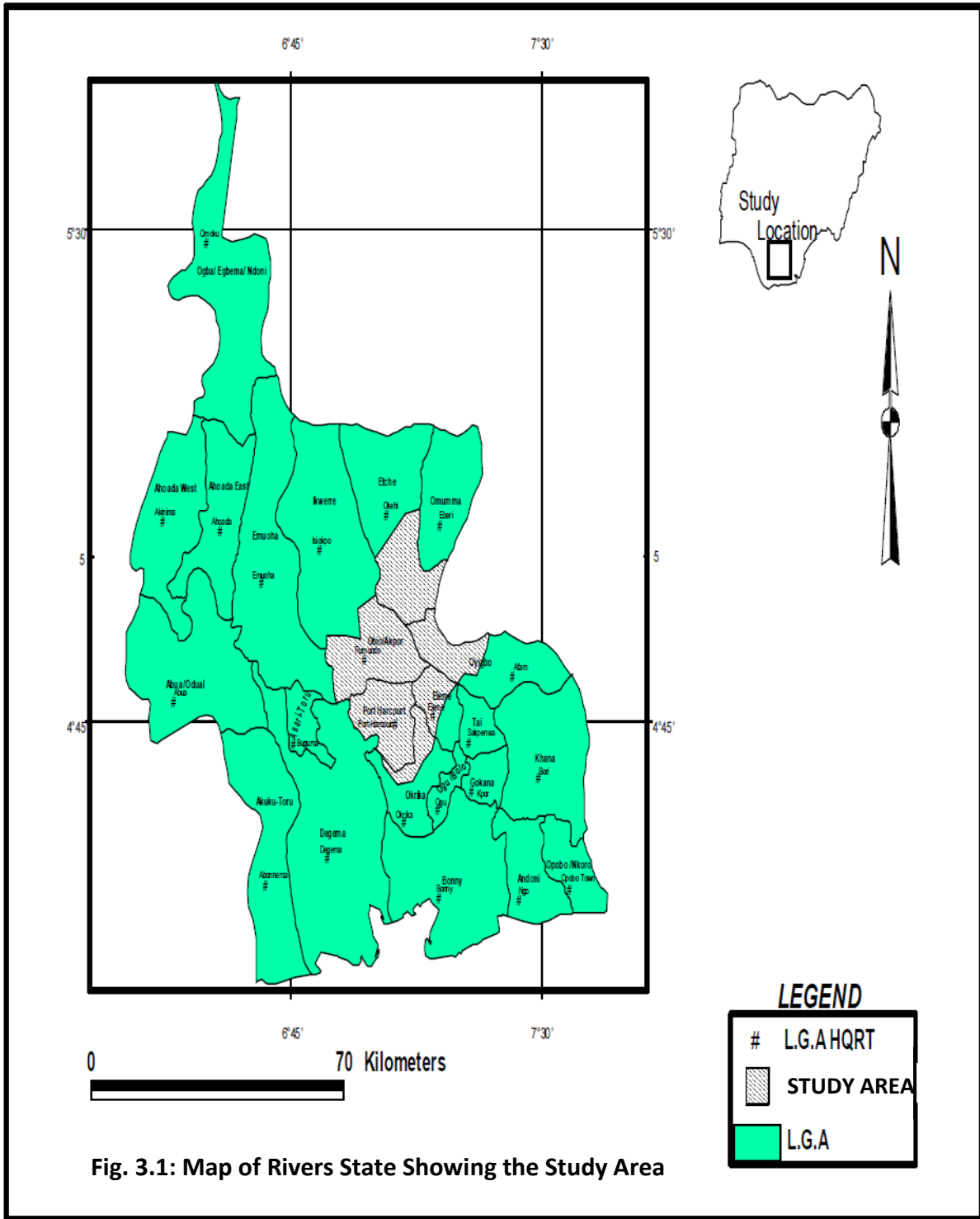
#### **3.1 Study Area**

##### **3.1.1 Location**

Port Harcourt metropolis comprising of Port Harcourt and Obio/Akpor local government areas is located in the Niger Delta, south-south geopolitical zone of Nigeria. It is bounded to the north by Ikwere, Etche and Omuma; East by Oyigbo, Tai, and Eleme, part of which are in the metropolis; West by Emuoha; and South by Okrika and Degema local government areas (figure 3.1) The city, lies between longitudes  $6^{\circ}55'E$  and  $7^{\circ}55'E$ , and latitude  $4^{\circ}35'N$  and  $5^{\circ}10'N$ . It has an elevation of 1.00 – 3.00m above sea level.

##### **3.1.2 Climate**

Port Harcourt features a tropical monsoon climate with lengthy and heavy rainy seasons and very short dry seasons. Only the months of December and January truly qualifies as dry season months in the city. The harmattan, which climatically influences many cities in West Africa, is less pronounced in Port Harcourt. Port Harcourt's heaviest precipitation occurs during September with an average of



367 mm of rain. December on average is the driest month of the year; with an average rainfall of 20 mm. Temperatures throughout the year in the city is relatively constant, showing little variation throughout the course of the year. Average temperatures are typically between 25 °C-28 °C in the city

### 3.1.3 **Population**

Like many cities in Nigeria, the population of Port Harcourt metropolis is ever growing from the day of its creation to date. Records have it that from an estimated population of 5,000 in 1915, it grew to 30,200 in 1944. By 1963, its population was 179,563 and by 1973 it has reached 231,532 persons. Port Harcourt population was given as 440,399 by the 1991 national census but results of the 2006 population census put the population at 1,255,387 and projected at 1,337,800 in 2009 (National Population Commission, 2006).

### 3.1.4 **Land Use**

In Port Harcourt metropolis, there are various land use patterns such as industrial, residential, commercial, road construction etc. There are a variety of road networks. These include highways of different categories, railways and waterways (seaport and jetties) and airports. For example, interstate highways serving Port Harcourt include:

(a).East-West Road: West-wards, this road leads to Yenagoa and Kaiama in Bayelsa State and Patani, Ughelli, Warri, Effurrum in Delta State. East-Wards, it leads to Eleme, Bori and Onne in Rivers State and Ikot Abasi in Akwa Ibom State. The road is one of the Trans – West African routes that run West-East through the country from Badagry, on the western boundary of Nigeria to Ikot Abasi on the eastern boundary.

(b) Port Harcourt – Aba expressway: Popularly called Aba road, links Aba and Umuahia in Abia state, and Enugu in Enugu state. It also accesses Uyo, Akwa Ibom state and Calabar in Cross River state. This is one part of the Trans –Sahara routes running south north. It is a very busy road both to commuters and motorists plying the road. Within the city, it has several bus stops/passenger loading parks, road junctions, commercial centers (Markets) and residential areas. The residential areas also host some big time ‘hang outs’ like clubs which are good sources of noise generation.

(c).Ikwerre road: Otherwise referred to as Port Harcourt – Owerri road is one of the four roads in Nigeria that run South-North and leads to Owerri in Imo state; Onitsha in Anambra state; and Enugu in Enugu state, from where the road accesses the northern part of the country. From Onitsha the road links Asaba and Agbor in

Delta and Benin in Edo state where it joins the Trans-west African routes running west. Ikwerre road also had similar features of loading parks, busy road junctions etc like Aba road.

The main industrial area of the city is Trans Amadi where there are clusters of industries that boost the economy of the State, while the residential areas include Port Harcourt Township known locally as “Town”, G.R.A phases 1-5, Abuloma, Amadi-ama, Amadi Flats, and Borokiri. The city consist of some major land marks which include: The Rivers State University of Science and technology, RSUST, the eighteen storey podium Block of Rivers State Secretariat, which is reputed to be the tallest building in the south/south and south/east geopolitical zones a region comprising 11 states. With many recreational and fun spots, Port Harcourt can boast of a number of 5 star hotels such as the Meridien Hotel, Presidential Hotel among others

### **3.2 Experimental Procedure**

Instrumentation for the field measurements consisted of integrating sound level meter which meets IEC 61672 – 1, 60651/60804 type 2 and ANSI SI.4 type 2 with frequency range and measuring level range of 31.5 Hz-8 KHz and 35 – 130 dB, respectively.

The measurements were made at street level (at busy road junctions/intersections, commercial, passenger loading bus stops/parks, and residential areas), using an Extech 407780A precision or integrated digital sound level meter. The instrument was automatically calibrated to the A-weighting network and the slow response was always used.

The instrument was held comfortably in hand with the microphone pointed at the suspected noise source at a distance of 1.2m above the ground level and 1.5m away from any reflecting object. However, the locations were chosen to allow for a good comparison. Measurements were taken from late December, 2014 through January, 2015 i.e for a period of two months under suitable meteorological conditions, i.e in the absence of wind and rain.

The readings were taken at the precise moment, after every 30 seconds interval there is no holding back in order to obtain, for example a higher reading as a lorry

passes by. The time for which measurements were taken lapsed from between 8:30am to 7:10pm. This time interval was further divided into four periods: morning (8:30am -8:40am), afternoon (1:00 pm -1:10 pm), evening (4:00 pm – 4:10pm) and night (7:00 pm – 7:10 pm).

The basic type of measurement procedure employed was the sampling procedure, where the data were recorded on a data sheet/form by noting the reading on the meter every 10 minutes (sampling time). These readings included the  $L_{Aeq}$  (A-weighted instantaneous sound pressure level), statistical indicators ( $L_{10}$ ,  $L_{50}$  and  $L_{90}$ ) and TNI. From these readings commonly used community noise assessment quantities like the day time average sound level,  $L_D$ ; night time average sound levels,  $L_N$ ; the day-night average sound level,  $L_{DN}$ ; and the noise pollution level,  $L_{NP}$  were computed using the appropriate formula as shown bellow:

$$L_{Aeq}=10\log_{10} \left[ \frac{1}{N} \sum_{i=1}^N \left( \text{anti log} \frac{L_{Ai}}{10} \right) n_i \right] \quad (1)$$

$$L_D=10\log_{10} \left[ \frac{1}{2} \left( \text{anti log} \frac{L_{AeqM}}{10} + \text{anti log} \frac{L_{AeqA}}{10} \right) \right] \quad (2)$$

$$L_{DN}=10\log_{10} \left[ \frac{1}{24} \left( 15 \text{anti log} \frac{L_D}{10} + \text{anti log} 9 \text{anti log} \frac{L_N + 10}{10} \right) \right] \quad (3)$$

$$L_N = 10 \log_{10} \left[ \frac{1}{2} \left( \text{anti log} \frac{L_{AeqE}}{10} + \text{anti log} \frac{L_{AeqN}}{10} \right) \right] \quad (4)$$

$$L_{NP} = L_{Aeq} + (L_{10} - L_{90}) \quad \text{or} \quad L_{Aeq} + 2.5\sigma \quad (5)$$

$$TNI = 4 (L_{10} - L_{90}) + (L_{90} - 30) \quad (6)$$

Where;

$L_{Aeq}$  = the A weighted equivalent sound pressure level,

$L_{AeqM}$  = the equivalent sound pressure level for the morning measurement,

$L_{AeqA}$  = the equivalent sound pressure level for the afternoon measurement,

$L_{AeqE}$  = the equivalent sound pressure level for the evening measurement,

$L_{AeqN}$  = the sound pressure level for the night time measurement,

$L_N$  = the night time noise level,

$L_D$  = the daytime noise level,

$L_{DN}$  = day-night noise level,

$L_{10}$  = the noise level exceeded 10% of the time,

$L_{90}$  = the noise level exceeded 90% of the time,

$L_{50}$ =the noise level exceeded 50% of the time

$L_{NP}$  = noise pollution level,

TNI= the traffic noise index.

Source: (Saadu *et al.*, 1998)

A mathematical model developed by Calixto *et al.* (2003), was applied for predicting noise levels based on the total no. of vehicular flow/hour for the different periods of the day, and the percentage of heavy vehicles. The predicted  $L_{eq}$  was obtained using the model as shown below:

$$L_{Aeq}=19.92224\text{Log} [Q (1+ 0.1 \times VP)] + 12.59764$$

Where: Q= Total no. of vehicles flowing per hour in the selected sites at different time intervals.

VP=Percentage of heavy vehicles per hour in the selected sites at different time intervals.

### **3.3 Statistical Analysis**

The estimated  $L_{Aeq}$  values were then compared with observed  $L_{Aeq}$  values to test for the fitness of the model in noise measurement using statistical method of

pearsons' product moment correlation( $r$ ) and scatter plot or graph of observed  $L_{Aeq}$  against calculated  $L_{Aeq}$  values.

In addition, descriptive statistics of mean  $\pm$  SD, coefficient of variance and standard error were employed to test for the validity of the method used in the evaluation.

Finally, inferential statistics using F-distribution (one way anova) was applied on the various noise descriptors to determine if there was statistically significant difference in the exposure levels of the various locations studied. All these were applied through 2007 excel and SPSS version 20 packages

## CHAPTER FOUR RESULTS AND DISSCUSION

### 4.0

#### 4.1 Results

In this chapter, the results obtained from the field survey are analyzed and presented in tabular forms below.

Table1. Average equivalent continuous noise level ( $L_{Aeq}$ ), day-time, night-time and day-night noise levels in the monitored locations in Port Harcourt metropolis.

S/N	Monitored Locations	GPS Location	Period	$L_{Aeq}$	Ave	$L_D$	$L_N$	$L_{DN}$
1	1 <sup>st</sup> Artillery (commercial)	N 04 <sup>0</sup> 84' 83.4'' E 007 <sup>0</sup> 03' 79.6''	Morning Afternoon Evening Night	85.30 102.00 101.00 79.20	91.88	99.08	89.18	99.12
2	Rumuola (Commercial)	N 04 <sup>0</sup> 49' 58.2'' E 007 <sup>0</sup> 00' 16.7''	Morning Afternoon Evening Night	93.00 100.00 82.00 81.00	89.75	89.00	81.53	95.71
3	Air force (Passenger loading bus stop)	N 04 <sup>0</sup> 50' 10.3'' E 007 <sup>0</sup> 00' 58.4''	Morning Afternoon Evening Night	93.00 99.20 89.00 91.00	93.05	97.12	90.11	98.49
4	2 <sup>nd</sup> Artillery (Passenger loading bus stop)	N 04 <sup>0</sup> 84' 5.10'' E 007 <sup>0</sup> 04' 18.8''	Morning Afternoon Evening Night	88.31 96.50 85.20 97.30	91.83	94.51	94.23	100.07
5	2 <sup>nd</sup> Artillery (Busy road junction/intersection)	N 04 <sup>0</sup> 84' 47.6'' E 007 <sup>0</sup> 04' 09.0''	Morning Afternoon Evening Night	94.00 98.00 92.10 101.20	96.32	96.45	98.51	100.47
6	Air force (Busy road junction/intersection)	N 04 <sup>0</sup> 50' 10.6'' E 007 <sup>0</sup> 01' 01.5''	Morning Afternoon Evening Night	85.00 98.00 99.00 100.10	95.53	95.53	99.11	100.51
7	GRA Iyaminima St (low residential)	N 04 <sup>0</sup> 49' 10.3'' E 006 <sup>0</sup> 59' 58.0''	Morning Afternoon Evening Night	52.10 56.60 56.00 55.60	55.08	54.91	55.81	62.19
8	Orogbum crescent St (low density residential)	N 04 <sup>0</sup> 49' 09.2'' E 006 <sup>0</sup> 59' 50.6''	Morning Afternoon Evening Night	57.20 58.10 60.50 61.00	59.20	57.67	60.76	66.84
9	Tere-ama (high density residential)	N 04 <sup>0</sup> 46' 58.4'' E 007 <sup>0</sup> 02' 23.3''	Morning Afternoon Evening Night	58.00 58.50 63.40 64.80	61.23	58.23	64.16	70.08
10	Dfri Road in femie (high density residential)	N 04 <sup>0</sup> 46' 58.6'' E 007 <sup>0</sup> 02' 23.3''	Morning Afternoon Evening Night	59.00 59.70 62.70 64.40	61.45	59.36	63.63	69.58

Source: Author's field survey, January, 2015.

The table shows that the A-weighted continuous equivalent noise level ( $L_{Aeq}$ ) computed for the 10 selected locations varied between 79.2–102dB (A) with an average of 90.82dBA (commercial areas); 85.2–99.2dBA with an average of 92.44dB (A) (passenger loading bus stop/parks); 85 – 101.2 dB (A), with an average of 95.92dB (A) (Busy road junction/major intersection); 52.1– 61 dB (A), with an average of 57.14dBA (Low density residential area), and 58-64.8dB (A), with an average of 61.34dB (A) (high density residential area). The highest and lowest  $L_{Aeq}$  for the commercial area were determined at 1<sup>st</sup> artillery junction in the afternoon (102dB (A)) and night (79.2dB (A)); while in passenger loading bus stops the highest and lowest  $L_{Aeq}$  were determined at Air force bus stop in the afternoon (99.2dB (A)) and 2<sup>nd</sup> Artillery bus stop (85.2 dB (A)) in the evening. Similarly, for busy road junctions/major intersections, the highest  $L_{Aeq}$  was determined at 2<sup>nd</sup> Artillery junction in the night (101.2dB (A)) and the lowest determined at Air force junction, in the morning (85dB (A)). For low density residential areas, highest  $L_{Aeq}$  was determined at Orogbum Crescesnt (61dB (A)) and the lowest at Iyaminima Street (52.1 dB (A)); While for high density residential areas, the highest  $L_{Aeq}$  was determined at Tere -Ama in the night (64.8dB (A)) and lowest at same place in the morning (58dB (A)).

It was also observed that the  $L_{Aeq}$  was highest during the afternoon in commercial and passenger loading bus stops. A similar trend was observed at night at busy road junctions/major intersections. Similarly,  $L_{Aeq}$  was highest during the afternoons in Iyaminima Street (56.6dB (A)) and during the night in Orogbum Crescent (61dB (A)) in low residential areas. In the high density residential area, the highest  $L_{Aeq}$  were observed during the night at tere-ama (64.8dB (A)) and Dffri Road in Femie (64.4dB (A)).

The average sound levels of the day-time, night-time and day-night times also showed variations. The day-time average sound level varied between 89 – 99.08dB (A) (Commercial), 94.51–97.12dB (A) (Passenger loading bus stops), 95.53–96.45dB (A) (Busy road junction/major intersections), 54.91–57.67dB (A) (low residential) and 58.23–59.36 dB (A) (high density residential areas.

For night time ,the sound levels varied between 81.53 – 89.18 dB (A) (Commercial ), 90.11–94.23dB (A) (passenger loading bus stop), 98.51–99.11dBA (Busy road junction/major intersections), 55.81–60.76dB (A) (low residential areas) and 63.63–64.16dB (A) (high density residential areas). Similarly, day-night noise levels varied between 95.71–99.12dB (A) (Commercial), 98.49–100.07dB (A) (Passenger loading bus stop), 100.47–100.51dB (A) (Busy road

junctions/intersections), 62.19– 66.84dB (A) (low residential) and 69.58–70.08dB (A) (high density residential areas).

These values were compared with noise quality description of WHO (1999), standard (table 2) to determine the noise quality of the city, and the result presented in table 3 below:

Table 2.WHO Standards of Noise quality Description for Day-Time and Night-Time Durations

DAY-TIME		NIGHT-TIME	
L <sub>eq</sub> (dBA)	Noise quality description	L <sub>eq</sub> (dBA)	Noise quality description
0 – 30	Excellent Quality	0 - 30	Excellent Quality
31 -40	Very good quality	31 - 40	Very good quality
41 -60	Good quality	41 - 50	Good quality
61 -75	Satisfactory quality	51 - 65	Satisfactory quality
76 -90	Unsatisfactory quality	66 - 75	Unsatisfactory quality
91 -110	Hazardous quality	76 - 90	Hazardous quality
>111	Not allowed	>90	Not allowed

Table 3.Noise quality description of monitored locations in the city

S/N	Location	Day time noise		Night time noise	
		L <sub>D</sub> dB(A)	Description quality	L <sub>N</sub> dB(A)	Description quality
1	1 <sup>st</sup> Artillery (commercial)	99.08	Hazardous	89.18	Hazardous
2	Rumuola (commercial)	89.00	unsatisfactory	81.53	Hazardous
3	Air force (passenger loading bus stop)	97.12	Hazardous	90.11	Hazardous
4	2 <sup>nd</sup> Artillery(passenger loading)	94.51	Hazardous	94.23	Not allowed

	bus stop				
5	2nd Artillery(busy road junction/major intersection)	96.45	Hazardous	98.51	Not allowed
6	Air force(busy road junction/major intersection)	95.53	Hazardous	99.11	Not allowed
7	Iyaminima st(GRA,low density residential area)	54.91	Good quality	55.81	Satisfactory
8	Orogbum crescent st (GRA,low residential area)	57.67	Good quality	60.76	Satisfactory
9	Tere-ama, Abuloma (high density residential area)	58.23	Good quality	64.16	Satisfactory
10	Dffri Road, femie(high density residential area)	59.36	Good quality	63.63	Satisfactory

Source: Author 'survey, January, 2015

Table 3 revealed that the day-time noise levels were hazardous in all the passenger loading bus stops, major intersections/road junctions and one commercial area (Rumuola) which had unsatisfactory quality. In high and low density residential areas, the day-time noise levels all had good quality. The night-time noise levels were hazardous in the commercial areas and one of the passenger loading bus stops (Air force), while 2<sup>nd</sup> Artillery passenger loading bus stop and the major intersections/ road junctions had not allowable quality. The residential areas all had satisfactory noise quality description. Despite the satisfactory and good qualities of the noise levels recorded, they were still above the approved day and night time noise levels by WHO (1999), and other comparable standards.

Table 4: Noise Descriptors (TNI, LNP, NC and L<sub>90</sub>, L<sub>50</sub>, L<sub>10</sub>) Variations at Different Monitored Locations at Different Time Intervals.

s/n	Site locations	Morning						Afternoon						Evening						Night					
		TNI	NPL	L <sub>90</sub>	L <sub>50</sub>	L <sub>10</sub>	NC	TNI	NPL	L <sub>90</sub>	L <sub>50</sub>	L <sub>10</sub>	NC	TNI	NPL	L <sub>90</sub>	L <sub>50</sub>	L <sub>10</sub>	NC	TNI	NPL	L <sub>90</sub>	L <sub>50</sub>	L <sub>10</sub>	NC
1	Rumuola (commercial)	118	106	83	90	96	13	121	118	79	94	97	18	113	100	71	76	89	18	105	96	75	77	90	15
2	1 <sup>st</sup> Artillery (commercial)	109	126	71	80	88	17	145	143	71	90	97	26	138	143	72	91	96	24	92	119	70	76	92	13
3	Air force Bus stop	102	105	84	90	96	12	124	119	74	92	94	20	96	103	82	87	93	14	109	106	79	87	94	15
4	2 <sup>nd</sup> artillery Bus stop	121	129	71	81	91	20	137	142	75	87	98	23	105	130	75	81	90	15	124	137	74	90	94	20
5	2 <sup>nd</sup> Artillery(road junction)	140	119	70	83	95	25	129	139	71	89	93	22	122	134	72	85	92	20	143	144	73	90	98	25
6	Air force(road junction)	95	97	79	82	89	12	114	113	84	94	99	15	125	118.5	79	93	98	19	114	115	84	96	99	15
7	Iyaminima St GRA (low density residential)	75	67.1	45	48	60	15	66	68.6	48	51	60	12	89	75	43	49.5	62	19	66	67.6	48	54	60	12
8	Orogbum Crescent st, GRA (low density residential)	89	74.2	51	52	68	17	88	85.1	50	52.9	69	17	93	78.5	51	54.7	69	18	97	80	51	54.5	70	19
9	Tere-Ama Trans-amadi. (High density residential)	79	72	53	54.5	67	14	88	72.5	52	55	66	14	82	78.7	56	59	70	14	81.5	74.3	53.5	61	68	14.5
10	Dffri Road (high density residential)	88	76	50	54.7	67	17	94	77.7	52	54.7	70	18	76	74.7	58	60.1	70	12	70	74.4	60	62.6	70	10

Source: Author's field survey, January, 2015

.Legend: TNI= Traffic Noise Index; NPL= Noise Pollution Level; L<sub>10</sub>, L<sub>50</sub> and L<sub>90</sub>= The Noise level exceeded 10% ,50% and 90% of the time respectively

Equivalent noise level is an insufficient descriptor of the annoyance caused by fluctuating noise, therefore, noise pollution level(NPL) expressed in dBA was also computed using the formula  $[NPL=L_{eq} + a(L_{10} -L_{90})]$ , where  $a=1.0$  (constant in the equation). NPL takes into account the variations in the sound signal and hence, serves as better indicator of the pollution in the environment for physiological and psychological disturbance of the human system. The noise pollution value varied between 96–143dB (A) (Commercial), 103–142dB (A) (Passenger loading bus stop/parks), 97–144dB (A)(Busy road junction/major intersection), 67.1 – 85.1dB (A) (low residential areas) and 72 – 78.7dB (A) (high residential areas).

Traffic noise index (TNI) which indicates the degree of variation in traffic flow was also calculated by using the relation  $[TNI=4(L_{10} -L_{90}) + (L_{90} - 30)]$ (Langdon & Schools,1968). This value varied between 92-145dBA (Commercial), 96–137dB (A) (Passenger loading bus stops/parks), 95–143dB (A) (Busy road junction/major intersections), 66-97dBA (GRA, low density residential areas), and 70-94dB (A) (high density residential areas).The result revealed that the traffic noise index differ from one location to another in the order: Commercial>junctions/intersections>passenger loading bus stop/parks>Low density residential area> High density residential area.

Noise climate (NC) which is the range over which the sound level are fluctuating in an interval of time was assessed using the formula  $(NC=L_{10} -L_{90})$ . This value varied between

13–26dB (A) (Commercial), 12–23 (Passenger loading bus stop), 12-25 (Busy road junctions/intersections), 12-19dB (A) (low residential areas) and 70-94dB (A) (high residential areas).

Table 5. Prediction of Noise Levels at Different Locations and Time.

S/N	Monitored sites	Morning		Afternoon		Evening		Night	
		Predicted noise Level	Actual L <sub>Ae</sub> measured	Predicted noise Level	Actual L <sub>Ae</sub> measured	Predicted noise Level	Actual L <sub>Ae</sub> measured	Predicted noise Level	Actual L <sub>Aeq</sub> measured
1	Rumuola (Commercial)	89.00	93.00	98.00	100.00	79.00	82.00	76.00	81.00`
2	1 <sup>st</sup> Artillery(Commercial)	80.00	85.30	99.00	102.00	97.40	101.00	79.00	79.20
3	Air force( bus stop)	91.00	93.00	98.00	99.20	88.00	89.00	90.00	91.00
4	2 <sup>nd</sup> Artillery( bus stop)	88.10	88.30	96.00	96.50	85.00	85.20	97.00	97.30
5	2 <sup>nd</sup> Artillery (junction)	94.00	94.20	97.00	98.00	92.00	92.10	100.00	101.20
6	Air force (junction)	84.80	85.00	96.00	98.00	94.20	99.00	95.00	100.10
7	Tere Ama (residential )	57.50	58.00	57.80	58.50	58.40	63.40	60.70	64.80
8	Dffri Road, femie (residential )	56.50	59.00	58.40	59.70	60.40	62.70	61.20	64.40
9	Iyaminima St GRA (residential )	52.00	52.10	56.20	56.60	58.40	56.00	55.40	55.60
10	Orogbum crescent GRA (residential)	56.00	57.20	58.00	58.10	60.40	60.50	60.70	61.00

Source: author’s field survey, January, 2015.

In table 5, the predicted L<sub>Aeq</sub> were observed to be very close or in strong association with the actual measured L<sub>Aeq</sub>. It also depicted that there are existence of variations of noise with variables such as the time of the day, road types (major intersections/ road junctions) and land use (public service sectors).

Table 6. No of Cars that Passed in a Day at Different Times in all the Locations Monitored.

Monitored sites	Morning			Afternoon			Evening			Night			Total no. of vehicles
	Total no. of vehicles/hour (Q)	No. of heavy vehicles (HV)	% of heavy vehicles (VP)	Total no. of vehicles /hour (Q)	No. of heavy vehicles (HV)	% of heavy vehicles (VP)	Total no. of vehicles /hour (Q)	No. of heavy vehicles (HV)	% of heavy vehicles (VP)	Total no. of vehicles/hour (Q)	No of heavy vehicle (HV)	% of heavy vehicle (VP)	
1 <sup>st</sup> Artillery (jCommercial)	3187	102	3.2005	5900	950	16.1017	6000	1200	20.00	1290	74	5.7364	16,377
Rumuola(Commercial)	3900	275	7.0912	4500	435	9.6667	1281	74	5.7767	1217	24	1.9721	10,898
Air force (passenger loading bus stop/parks)	4260	189	4.4366	6080	874	14.3911	3850	58	1.5065	6500	970	14.9231	20,690
2 <sup>nd</sup> Artillery(passenger loading bus stop/parks)	5800	142	4.2414	6055	775	12.7993	4487	149	3.3207	5545	235	4.2380	21,887
2 <sup>nd</sup> Artillery(busy road junction/intersection)	5900	650	11.0170	6700	990	14.7761	5550	375	6.7568	6500	1800	27.6923	24,650
Air force (busy road junction/intersections)	3200	103	3.21896	7900	346	4.3797	8520	400	4.6948	8900	460	5.1685	28,520
Iyaminima Street(low residential area)	85	1	1.1765	155	0	0	200	0	0	140	0	0	580
Orogbum crescent (low density residential area)	150	0	0	160	3	1.875	250	0	0	259	0	0	819
Tere-ama (high density residential area)	167	1		160	2	1.2048	170	3	1.7647	190	7	3.6842	687
Dffri Road in femie(high density residential area).	160	0	0	170	3	1.7647	250	0	0	275	0	0	855
<b>GROUND TOTAL OF VEHICLE FLOW</b>												<b>125,963</b>	

Table 6 revealed the number of vehicular flow per day at different locations and time. The flow varied between 1217 – 6000 cars (Commercial), 3850 – 6500 cars (Passenger loading bus stop), 3200 – 8900 cars (Busy road junction/intersections), 85 – 259 cars (low density residential) and 160 – 275 cars (high density residential). It was also observed that the total numbers of vehicles which passes through these locations from 8:30am through 7:10pm varied between 10,898 – 16,377 cars(Commercial areas), 20,690 – 21,887cars (Passenger loading bus stops/parks), 24,650 – 28,520cars (Busy road junctions/major intersections), 580 – 819cars (Low density residential areas) and 687 – 855cars (High density residential areas).

The maximum number of total vehicles passing in a day (from 8:30am – 7:10pm), was observed at commercial areas, passenger loading bus stops/parks, and busy road junctions/major intersections, whereas minimum number of total vehicles passing in unit time was observed at low and high density residential areas.

Table 7 shows the permissible limit of noise levels in the day for different countries and WHO. This was compared with the results obtained from the field survey in the selected locations in Port Harcourt metropolis to determine noise pollution levels. The table revealed that both the day time and night time noise levels in the studied locations exceeded the permissible levels of WHO and US, EPA standards (table 7).

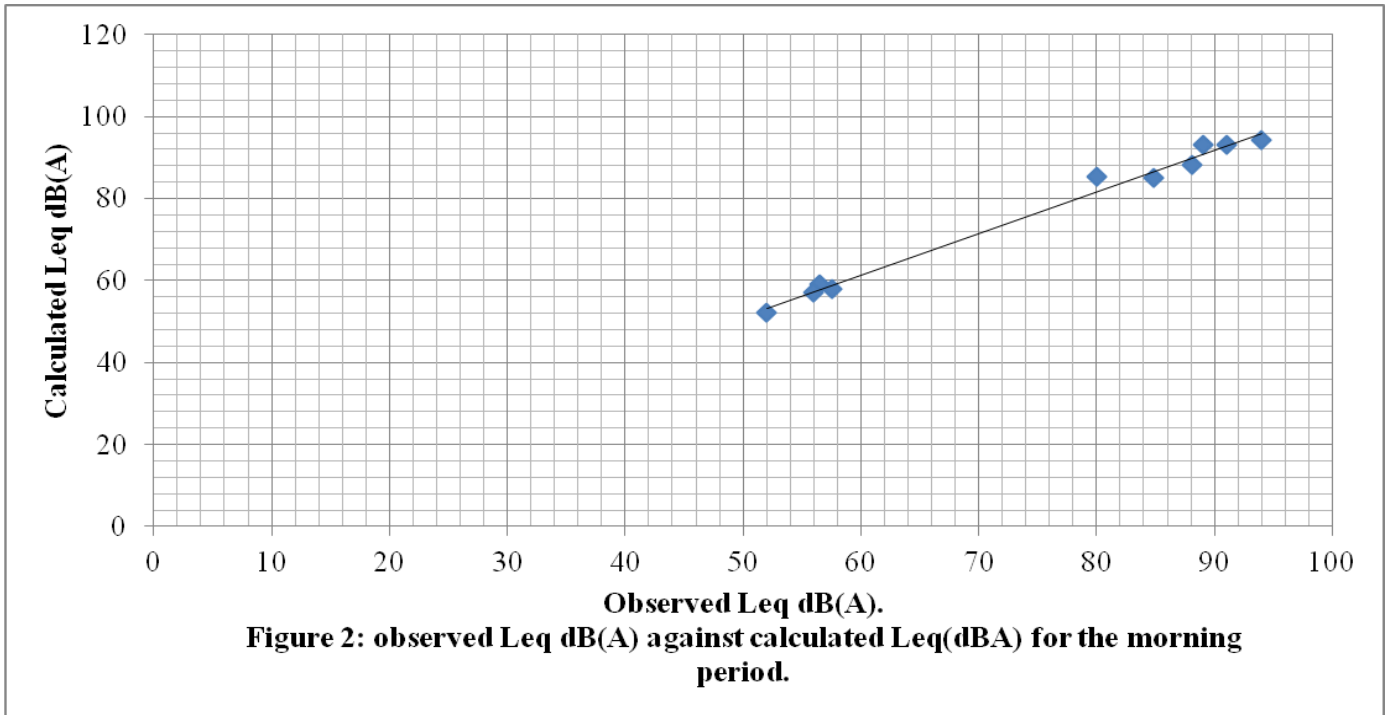
Table 7: Comparison of Observed Day-Time and Night-Time Noise Levels with WHO and US, EPA Standards .

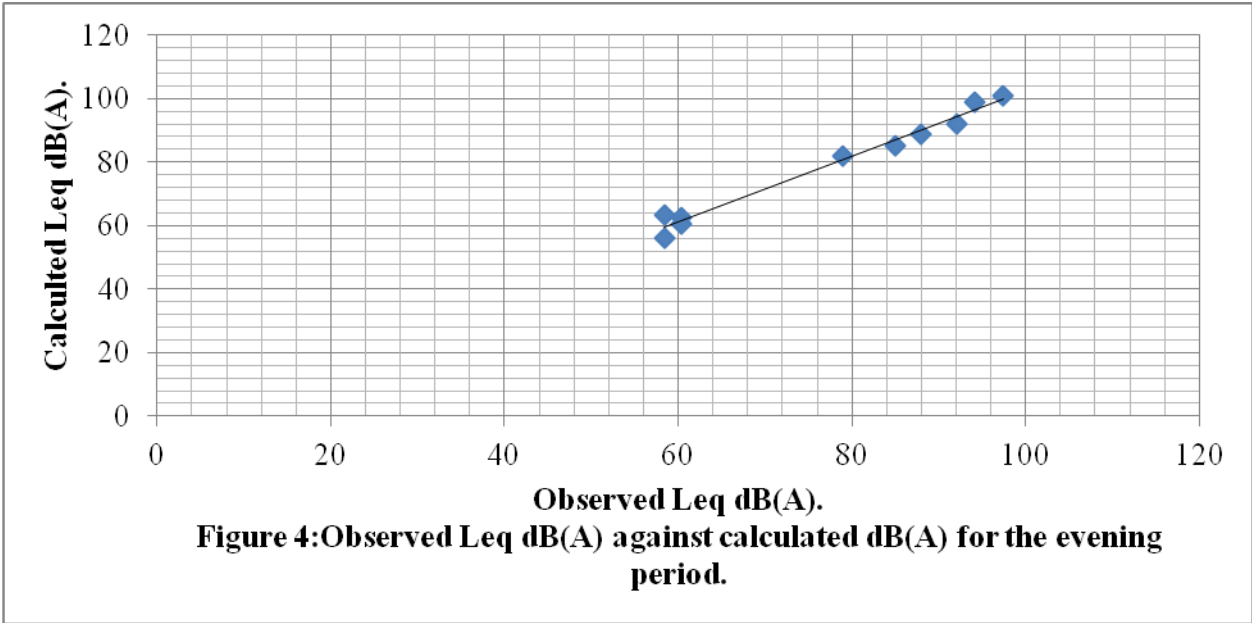
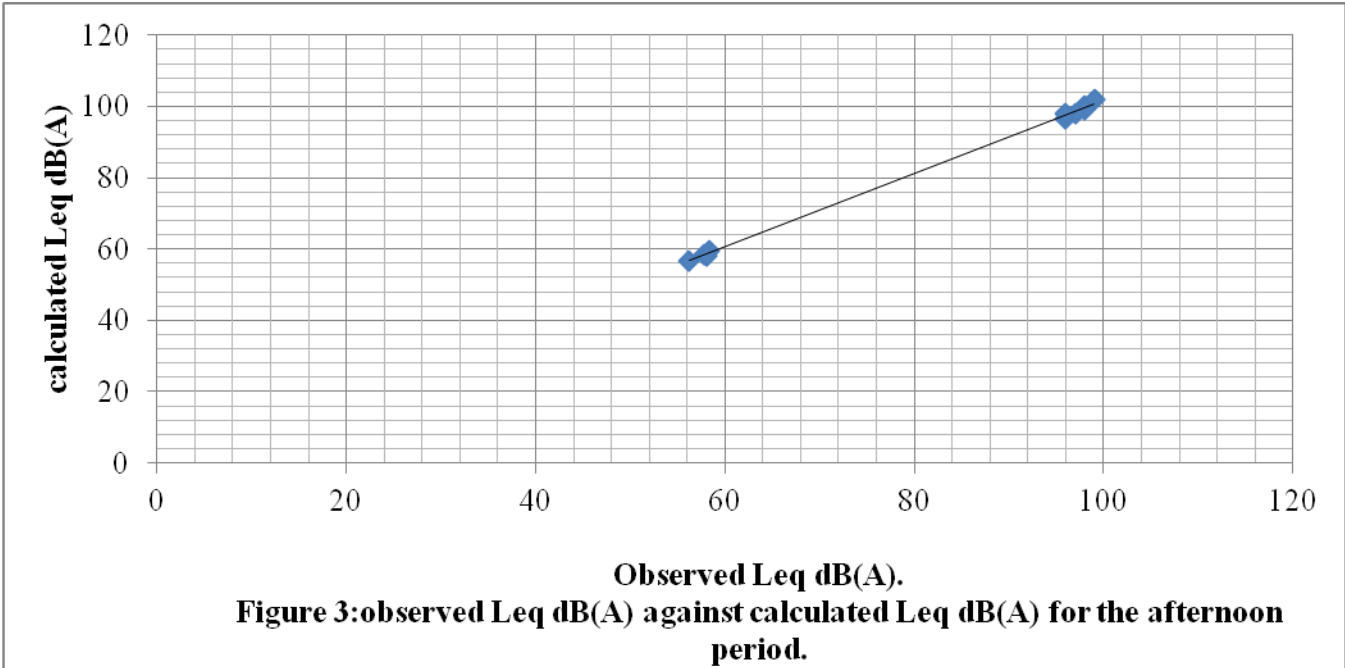
S/N	Monitored locations	L <sub>D</sub> Observed	L <sub>D</sub> (WHO)	L <sub>D</sub> (US,EPA)	L <sub>N</sub> Observed	L <sub>N</sub> (WHO)	L <sub>N</sub> (US,EPA)
1	Artillery(Commercial Area)	99.08	55	60	89.18	55	50
2	Rumuola(Commercial area)	89.00	55	60	81.53	55	50
3	Air Force(Passengers loading bus stop)	97.12	55	60	90.11	55	50
4	2 <sup>nd</sup> artillery (Passengers loading bus stop)	94.51	55	60	94.23	55	50
5	2 <sup>nd</sup> Artillery (Busy Road Junction)	96.45	55	60	98.51	55	50
6	Air Force (Busy Road Junction)	95.53	55	60	99.11	55	50
7	GRA Iyaminima St (Low density residential Area)	54.91	55	55	55.81	45	45
8	Orogbum crescent (Low density residential Area)	57.67	55	55	60.76	45	45
9	Tere-ama (High density Residential area)	58.23	55	55	64.15	45	45
10	DFPRI Road(High Density Residebtial area)	59.36	55	55	63.63	45	45

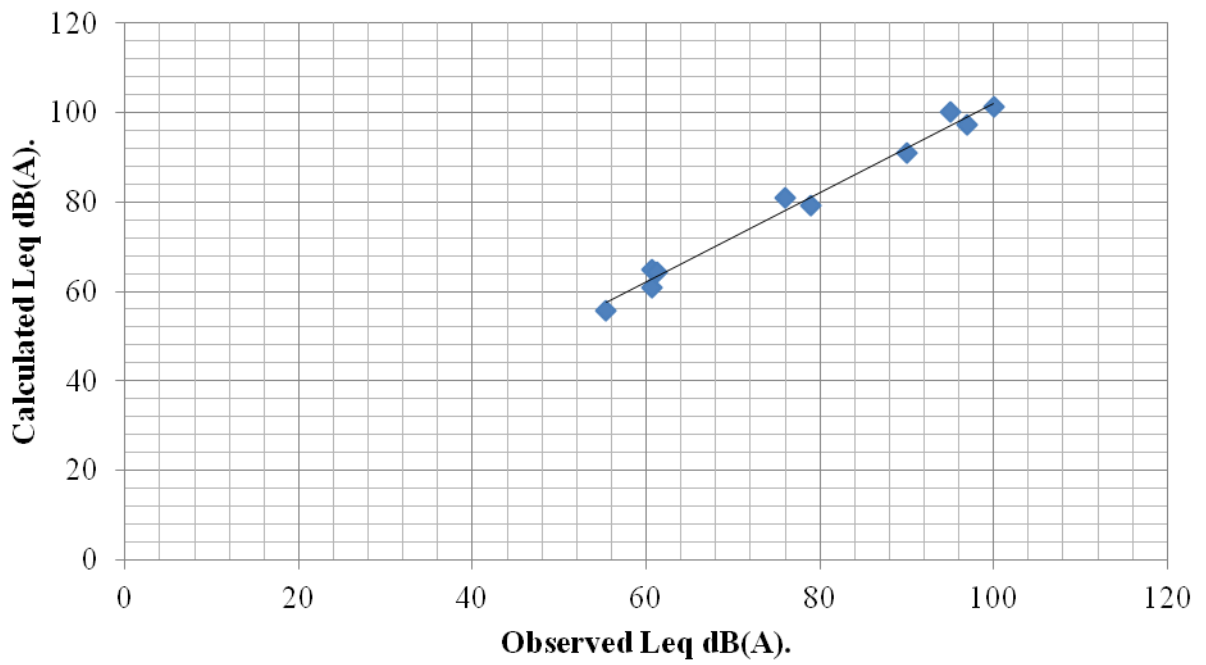
Chaunhan *et al.*, 2010.

In order to ascertain if there were significant differences in the noise exposure level in the selected locations, the data was subjected to analysis of variance for a single factor experiment, using F- distribution at 95% confidence level and the results presented in appendix I and II. For validation of the methods used to obtain the actual L<sub>Aeq</sub> and predicted L<sub>Aeqs</sub>, the data was subjected to descriptive statistics of mean  $\pm$  SD, coefficient of variance and standard error, and the result presented in

appendix (III) and (IV). Scatter plot of observed  $L_{Aeq}$  against calculated  $L_{Aeq}$  was also obtained and presented in figures 2, 3, 4 and 5 below:







**Figure 5: Observed Leq dB(A) against calculated Leq dB(A) for the night period.**

## 4.2

## Discussion

The equivalent continuous noise levels ( $L_{Aeq}$ ), average sound levels for day-time, night-time and day-night times were all found to be higher than the permissible limit of 65dBA as prescribed by EPA (1978), NCI (1986), ISO (1996), and WHO (1999) . Similar exceedence was observed when compared with US, EPA ambient noise standard, for both day and night time (table 7). These values were exceeded in the commercial, passengers loading bus stops and busy road junctions/major intersections which are in agreement with the works of Omubo-Pepple *et al.* (2010), who did a similar work in Port Harcourt metropolis. It further confirms the statement that noise pollution in Nigerian cities is found to be relatively high when compared with recommended levels by World Health organization , ambient noise standards of India, Housing and Urban Development (HUD), Committee on Environmental and Urban Development (CEOH), or Federal Highway Administration (FHWA) (Oyedepo, 2012). The result was also in agreement with previous studies on noise levels investigated in other cities of the world (Zeid *et al.*, 2000; Zannin *et al.*, 2002 and Li *et al.*, 2002).

The observed high noise levels in the commercial areas studied, is attributed to the presence of audio musical shop, advertising their products, and the activity of a vulcanizer in the vicinity. In addition, noise emanating from a loud speaker in a church located within the vicinity, constituted an intrusive noise at the time of

prayer. Again, it could be attributed largely to the closeness of the commercial centre to the main roads. In such places, there is usually traffic noise from vehicles horns, engine, speeding vehicles and traffic volume involving improper stoppages/packing of vehicles approaching the centre to buy their wares (Kumar *et al.*, 2011).

Similarly, there were also high noise levels in both passenger loading bus stops and busy road junctions/major intersections in the studied locations, which could be attributed to heavy road traffic volume. The intractable traffic could be slow moving (as in traffic hold-ups), or interrupted (by traffic lights or warden at a junction). Whichever is the case, the noise emanating from intractable traffic is usually high depending, of course, on the traffic volume and magnitude of commercial activity in the area. For example, at Air force passenger loading bus stop and junction/major intersection, in the afternoon and evening, the traffic is slow and congested. There is interruption by traffic warden, and in such areas, road traffic is the major source of the ambient noise, while vehicles horns, human voices (in conversation and bus conductors calling people), and radio from cars are the sources of intrusive noise (Paul & Fredericks, 2001). In addition, it could be attributed to the presence of public service sectors being close to the main roads. Unal (2004), reported that heavy presence of public sectors such as schools, hospitals, parks where majority of the active population works are most times

susceptible to high noise level. This is the scenario in air force junction, where most cars are parked wrongly along the road, causing other road users to improperly stop to alight and pick their children during the mornings and afternoons after school hours.

Furthermore, the total number of vehicular flow per day and the percentages of heavy vehicles also determine the noise levels as depicted in table 6. The vehicles are divided into heavy duty, buses, motor bikes, four wheelers and others. As the number of heavy duty trucks, buses in general and motor bikes in particular increases, so also the noise levels. In the Calixto *et al.*, (2003) model, it is only the heavy duty vehicles that were considered; the percentage of heavy vehicles to the total number of vehicles passing per day was calculated. The percentage of heavy vehicles (VP) was maximum i.e 27.6923 at artillery junction/major intersections and air force passenger loading bus stop/parks (14.9231) both at night due to the rush to get home quickly by both commuters and motorists. The data revealed that an increase in this ratio (i.e VP) increased the noise level (Bijay *et al.*, 2013, and Calixto *et al.*, 2003). Hence, noise is a function of the percentage of heavy duty vehicles i.e the higher the heavy duty vehicle percentage, the higher the noise level. Other sources of noise could be urbanization or settlement pattern along the roads, increased population, industrialization, and intrusive noise from audio music

shop, public address system/loud speaker from religious activity close to the junctions/bus stops.

In both low and high residential areas, the  $L_{Aeq}$ , day-time, night-time and day-night time noise levels were comparably lower than those of commercial, passenger loading bus stops and major road intersection/junctions. Average noise level was lowest in low residential areas than high density residential areas. The main sources of noise are transient, such as those of cars, motorcycles, coming on site and gradually disappearing and heavy duty generators. This suggests that there is a lower acoustic energy and annoyance ( $L_{10}$ ) and background noise ( $L_{90}$ ) in these areas in contrast to the aforementioned locations (Table 4). This could be due to the housing system, mostly in single apartment, lower traffic density and population, and absence of heavy public service sectors. However, when compared with international standards, this level is slightly above the acceptable level of 55 dB (A) (day) and 45 or 50 dB (A) (night) (Mohammed, 2009). The high noise levels measured even in areas considered to be primarily residential area are due to the fact that, there is no strict “zoning”, to define the residential, commercial, and industrial areas, thus one finds all three areas mixed up, especially the residential and the commercial.

#### **4.2.1: Comparison of Day Time and Night Time Noise Level with Standards**

The day-time and night-time average noise levels in the monitored locations were compared with WHO and US, EPA standards (Tables 7) of noise quality description for day-time and night-time duration. The results revealed that both day-time and night-time noise levels, exceeded the satisfactory index of WHO (61 – 75 dBA) and falls in the hazardous quality limit of 91 – 110dBA. It also exceeded the 65dBA (day time) and 55dBA (night) bench mark for commercial areas; 55dBA (day time) and 45dBA (night time) for residential areas. This shows that these are risk zones and that the noise levels can cause physiological and psychological problems both to human and animals around that vicinity especially traffic wardens, pedestrians, residents and those doing business there (Pirrera *et al.*, 2010 and Graham *et al.*, 2009). The high day-night noise level means that even after work, residents will still be exposed to high noise level which can lead to sleep episode disturbance and annoyance amongst other health problems. This implies no recovery time for the citizenry who live along the noise infested areas.

To ascertain the significant differences in the noise level exposure in the sites monitored throughout the day (from morning to night time), analysis of variance for a single-factor experiment, using F-distribution was carried out on the noise descriptors ( $L_{10}$  and  $L_{90}$ ). At 95% confidence level, or an alpha value of 0.05

(Appendix I), the mean square ratio (MSR) calculated for  $L_{10}$  is 159.3707 while the tabulated value of mean square ratio is 2.6415. Similarly, at the same confidence level, the mean square ratio calculated for  $L_{90}$  is 77.2539 and the tabulated value remained the same as 2.6415. Since in the two cases, the mean square ratio (MSR) calculated is greater than the mean square ratio tabulated, the noise levels exposure differ significantly from one location to another at different periods of the day.

A Turkey post hoc test was applied through SPSS version 20 to the various noise descriptors ( $L_{10}$ ,  $L_{90}$ , NPL and TNI) to determine the locations and periods where statistically significance difference occurred. For the level of annoyance ( $L_{10}$ ), statistical significant difference was observed in three periods of the day, at various locations studied. It was significant at only one residential area (Iyaminima Street GRA) in the morning, but significant at three residential locations (Tereama Trans-Amadi, Orogbum Crescent Street GRA and Dffri road) in the afternoon. Similarly, in the evening, there was significant difference in the commercial areas (Rumuola and First artillery), passengers loading bus stops (Second Artillery and Airforce), and busy road junctions (Second Artillery and Airforce) but wasn't significant in the night.

For background noise level ( $L_{90}$ ), Statistical significant difference was observed in the morning and afternoon in residential areas. For the morning it was significant at Iyaminima street GRA (Low density residential area), while in the afternoon a

similarly trend was observed at Tereama Trans-amadi and Dffri roads (High density residential area). In the evening it was significant at first artillery (Commercial area) and busy road junction (Second artillery).

To further ascertain significant differences in the noise level exposure in all the monitored locations throughout the day (from morning to night), analysis of variance for single factor experiment, using F-distribution was carried out on the noise descriptors (TNI and NPL). At 95% confidence level, the mean square ratio (MSR) calculated for TNI is 16.7712 while the tabulated is 2.6415. Similarly, at the same confidence level, the mean square ratio (MSR) calculated is 30.1810 and the tabulated remaining the same as 2.6415. Since in the two cases, the mean square ratios are greater than the mean square tabulated, the noise level exposure differ significantly ( $p < 0.05$ ) from one monitored location to another (Appendix II).

It can be observed that there are statistically significant differences in the noise level exposure from one location to another when the above noise descriptors are used. Noise pollution levels (NPL) was significant in the morning at residential areas (Tereama Trans-amadi, Dffri and Orogbum Crescent), while in the afternoon, it was significant in a commercial area (Rumuola), a passenger loading bus stop (Airforce) and a busy road junction (Airforce). In the evening, similar trend was

observed at one commercial area (First artillery), one busy road junction (Second Artillery) and a passenger loading bus stop (Second Artillery).

Similarly, the traffic noise index also showed significant difference in the residential area (Iyaminima Street GRA), while not being significant in the afternoon and evening but significant in the night at passenger loading bus stop (Second artillery) and a busy road junction (Second artillery).

The noise descriptors have revealed that people living in Port Harcourt metropolis are exposed to different degrees of environmental noise from road traffic (Table 3). Commercial areas and low density residential areas have the highest and lowest annoyance responses due to traffic noise respectively. It should be noted that a TNI of 74 dB (A) has been reported to be associated with less than 3% annoyance in social survey (Ahamad *et al.*, 2006). Similarly, commercial areas have the highest NPL (142dB (A)), while low density residential areas have the lowest NPL (67.1dB (A)).

#### **4.2.2 Model and Method Validation**

In order to validate the method used to obtain the noise levels in different periods of the day, the data were subjected to descriptive statistics (Appendix III and IV).

The mean  $\pm$  SD, Co-efficient of variance and Standard error for the monitored

periods were  $76.51 \pm 17.5216$  (morning),  $82.66 \pm 21.0915$  (Afternoon),  $79.09 \pm 16.9420$  (evening), and  $79.56 \pm 17.3340$  (night). The coefficient of variance were 0.22901, 0.25516, 0.21421 and 0.21787 for morning, afternoon, evening and night respectively; while the standard deviation of the morning, afternoon evening and night are 5.5408, 6.6697, 5.3575 and 5.4815 respectively for the measured values. The result revealed that the standard deviation, co-efficient of variance and standard error about the mean, were very small and close to each other and comparable, indicating the accuracy of the proposed method of assessment. Validation is further confirmed by the low values of standard deviation, coefficient of variance and standard error (George *et al.*, 2014), thus implying that the method used was correct, precise and simple. Similar trend was observed in the predicted noise levels.

The model used was also validated using inferential statistics of pearson' product moment correlation( $r$ ) to test how close the measured  $L_{eq}$  is to the simulated  $L_{eq}$  for the different periods of the day. The values obtained from morning through night were 0.9971(morning), 0.9994(afternoon), 0.9969(evening), and 0.9929(night). The result revealed that there is a strong relationship between the predicted and the measured  $L_{Aeq}$  values and that the relationship was near perfection, since they were close to 100% or 1.0

Further test to confirm the degree of closeness or discrepancy between the calculated  $L_{eq}$  and the observed  $L_{eq}$ , was also done. Scatter plot for the model or a graph of calculated  $L_{eq}$  against observed  $L_{eq}$  was obtained as shown in figures (2-5). The straight line graph is an indication that the values had very perfect closeness of linearity. This implies that the model could be used to evaluate noise at street levels without a dosimeter and can work perfectly in noise prediction in Nigerian road conditions apart from other parts of the world where it has been used previously, like Italy and India (Kumar *et al.*, 2011).

## CHAPTER FIVE

### 5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

In this chapter, a summary of the study is outlined, and concluding statements are made. Furthermore, recommendations are given on how to tackle the identified causes of noise pollution in the city.

#### 5.1 Summary

Environmental noise levels were assessed using field measurements and Calixto mathematical model at 10 different locations in Port Harcourt metropolis. It was observed that, the A-weighted sound levels ( $L_{Aeq}$ ) measured vary with the condition of the location and period of the day; with busy road junctions/major intersections having the highest, noise equivalent level,  $L_{Aeq}$ , and low residential area having the lowest; While the other six locations have values in between that of the former two. The busy road junction/major intersections have an average  $L_{Aeq}$  of 95.93dB (A) whereas low residential has an average  $L_{Aeq}$  of 57.14dB (A). Even though the low residential have the lowest noise level amongst all the monitored locations, these values were observed to be higher than acceptable noise limits when compared with international standards.

The high noise levels measured even in residential areas considered to be primarily residential are due to the fact that, there is no strict “zoning”, to define residential,

commercial, and industrial areas, thus one finds all three mixed up, especially the residential and the commercial. While in non residential areas, the noise levels are due to traffic characteristics, especially traffic volume, vehicle horns, vehicle mounted speakers, un-muffled vehicles, record player, high hawking, presence of numerous public service sectors and total number of vehicle that passes in a day, especially, the percentages of heavy duty vehicles.

The day-time and night-time noise levels were obtained and compared with stipulated standards, and found to be higher than the acceptable level of 65dBA. In the entire locations monitored, the night-time noise levels were very comparable to those reported for the day-time noise levels. Also, the noise levels were very much higher than the levels reported for living rooms, commercial, industrial and busy roads.

The noise quality description for the city was also determined by comparing the obtained data with the WHO standard, and was observed to vary between unsatisfactory to hazardous during the day and varied between hazardous to not allowable levels during the night in the commercial, busy road junctions/major intersections and passenger loading bus stops. The noise quality for both low and high density residential areas was found to be good during the day and of satisfactory quality during the night.

The result of analysis of variance for a single factor experiment, using F-distribution for the noise descriptors ( $L_{10}$  and  $L_{90}$ ; TNI and NPL), at 95% confidence level shows that noise exposure level differs significantly ( $p < 0.05$ ) from one location to another.

In the present paper a noise prediction model developed by calixto *et al* (2003), was applied using pearson's product moment correlation( $r$ ) analysis. Data collected has been analyzed and compared with the values predicted by calixto model. After comparison of results, it was observed that, calixto Model could be satisfactorily applied for Nigerian conditions as they give results with good ( $r$ ) value that is near perfect linearity.

## 5.2 Conclusion.

The data obtained clearly indicates that the citizens of Port Harcourt metropolis are exposed to a quite high unacceptable noise level for both day-time and night-time, which could be interfering with a number of vital activities and may even affect health. The continuous exposure of the citizenry to these levels of noise for a long period may impair their hearing or cause noises induced hear loss, which may be permanent or temporal. It implies that in the near future, people who do business or live in the noise infested areas may go deaf apart from other health problems like

insomnia. The noise exposure levels differ significantly from one location to the other and were also higher than the prescribed international standards.

The noise quality description of the city shows that the day-time noise levels were hazardous in the passenger loading bus stops, busy road junctions/major intersections, and commercial areas but differ slightly in one of the commercial areas, where it is unsatisfactory. Similarly, there was variation in quality description of the city in the night-time. The noise generated in the commercial areas was hazardous, followed by one of the passenger loading bus stop (Air force), while the other locations (passenger loading bus stops and busy road junctions) all had “not allowable” noise quality. In the residential areas, both for low and high density, the day time quality description is good and of satisfactory quality at night time. Despite these descriptions, the noise levels in all the monitored locations were higher than the recommended international limit.

The major causes of noise were identified as the volume of vehicular flow, especially the percentage of heavy duty vehicles, volume of traffic, nature of the road junctions/major intersections, and passenger loading bus stop, land use pattern and heavy presence of public service sectors. The model used was able to give good results and can therefore be used in the Nigeria condition to measure noise without a dosimeter with high degree of accuracy.

### **5.3 Recommendations**

In this survey, there is high noise levels observed which constitutes a threat to sleep activities (insomnia), noise induced deafness, and other health functions of the city dwellers. As a result, there is need for noise control measures in Port Harcourt metropolis. These include technical, planning behavioral and educational solutions. Noise due to traffic congestion in passenger loading bus stops, busy road junctions/major intersections and commercial areas can be reduced through the followings:

(1).Use of GIS structures in addition to existing traditional traffic management techniques such as one way, flyovers, construction of new routes outside the city, use of para-mass transit, park and ride system etc. The GIS will provide traffic information that will enable commuters and motorist to take rational decision as to which route to take during peak hour travel. It will also determine appropriate queries that can evoke graphical response, which can be used to manage traffic congestion.

(2).Promulgation and implementation of a noise bill and empowerment of regulatory agency.

(3).Education awareness on the hazards of noise pollution and problems of illegal parking to good flow of traffic and better use of traffic signs and information.

Governmental and nongovernmental organization (NGOs) also can play a significant role.

(4).Provision of more traffic lights / wardens at congested junctions for effective management of traffic.

(5).Government should put in place independent and efficient electricity that will power all the traffic lights stationed at road junctions rather than rely on the present epileptic power supply from power holding company of Nigeria (PHCN).

(6).Provision of noise meters at traffic points that systematically records noise levels on temporal bases. This could help in planning as well as monitoring noise levels in the city.

(7).Provision of Traffic Information System (TIS) in the city to monitor congestion.

(8).Linking “TIS” to the state and federal radio, this can relay to anybody that tunes to such channels the route that are congested, and provide alternate routes, which are less congested.

(9).Provision of plate number scanning equipment that can monitor and send information on traffic violators to a “TIS” monitoring base for immediate attention and dissemination.

(10).Changes in the land use pattern and the concentration of public service sectors along the main roads.

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## APPENDICES

### Appendix (I). Analysis of variance for Noise Descriptors ( $L_{10}$ and $L_{90}$ ).

ANOVA table

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>MSR(F)</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	7360.65	4	1840.163	159.3707	6.05E-22	2.641465
Within Groups	404.125	35	11.54643			
Total	7764.775	39				

ANOVA table

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>MSR(F)</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	5896.4	4	1474.1	77.25385	7.15E17	2.641465
Within Groups	667.8438	35	19.08125			
Total	6564.244	39				

### Appendix (II). Analysis of variance for Noise Descriptors (TNI and NPL).

Anova table

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>MSR(F)</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	12554.88	4	3138.719	16.77122	9.15E08	2.641465
Within Groups	6550.219	35	187.1491			
Total	19105.09	39				

Anova table

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>MSR(F)</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	20486.26	4	5121.565	30.18095	6.58E11	2.641465
Within Groups	5939.336	35	169.6953			
Total	26425.6	39				

Appendix (III): Statistical evaluation of  $L_{Aeq}$  measured at different periods of the day (n=10)

s/n	Periods of the Day	Mean $\pm$ SD	Coefficient of Variance (CV)	Standard Error (SE)
1	Morning	76.51 $\pm$ 17.5216	0.22901	5.5408
2	Afternoon	82.66 $\pm$ 21.0915	0.25516	6.6697
3	Evening	79.09 $\pm$ 16.9420	0.21421	5.3575
4	Night	79.56 $\pm$ 17.3340	0.21787	5.4815

Appendix (IV): Statistical evaluation of predicted  $L_{Aeq}$  at different periods of the day (n=10)

s/n	Periods of the Day	Mean $\pm$ SD	Coefficient of Variance(CV)	Standard Error (SE)
1	Morning	74.89 $\pm$ 17.1400	0.2180	5.4202
2	Afternoon	81.44 $\pm$ 20.5456	0.2420	6.4971
3	Evening	77.32 $\pm$ 16.2208	0.2010	5.1295
4	Night	77.50 $\pm$ 17.2307	0.2140	5.4488

**Appendix (V): Post Hoc Test for Exposure to Annoyance Noise levels (L<sub>10</sub>)**

**ANOVA**

PERIODS

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	7473.100	9	830.344	97.116	.000
Within Groups	256.500	30	8.550		
Total	7729.600	39			

**Homogeneous Subsets**

PERIODS

Tukey HSD

Locations	N	Subset for alpha = 0.05		
		1	2	3
IYAMINIMA STREET GRA	4	60.5000		
TEREAMA TRANS AMADI	4		67.7500	
OROGBUM CRESCENT GRA	4		69.0000	
DIFFERI (FEMIE)	4		69.2500	
RUMUOLA (Commercial area)	4			93.0000
FIRST ARTILLERY (COMMERCIAL AREA)	4			93.2500
SECOND ARTILLERY BUS STOP	4			93.2500
AIRFORCE BUS STOP	4			94.2500
SECOND ARTILLERY JUNCTION	4			94.5000
AIRFORCE JUNCTION	4			96.2500
Sig.		1.000	.999	.851

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 4.000.

## Appendix (VI): Post Hoc Test for Exposure to Background Noise levels (L<sub>90</sub>)

### ANOVA

PERIODS

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	6289.306	9	698.812	76.251	.000
Within Groups	274.938	30	9.165		
Total	6564.244	39			

### Homogeneous Subsets

PERIODS

Tukey HSD

LOCATIONS	N	Subset for alpha = 0.05				
		1	2	3	4	5
IYAMINIMA STREET GRA	4	46.0000				
OROGBUM CRESCENT GRA	4	50.7500	50.7500			
TEREAMA (LOW DENSITY RESIDENTIAL AREA)	4		53.6250			
DIFFERI ROAD (LOW DENSITY RESIDENTIAL AREA)	4		55.0000			
FIRST ARTILLERY (COMMERCIAL AREA)	4			71.0000		
SECOND ARTILLERY JUNCTION	4			71.5000		
SECOND ARTILLERY BUS STOP	4			73.7500	73.7500	
RUMUOLA (COMMERCIAL AREA)	4			77.0000	77.0000	77.0000
AIRFORCE BUS STOP	4				79.7500	79.7500
AIRFORCE JUNCTION	4					81.5000
Sig.		.466	.615	.181	.181	.540

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 4.000.

## Appendix (VII): Post Hoc Test for Exposure to Noise Pollution levels (NPL)

### ANOVA

PERIODS

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	24661.407	9	2740.156	46.963	.000
Within Groups	1750.433	30	58.348		
Total	26411.840	39			

### Homogeneous Subsets

PERIODS

Tukey HSD

LOCATIONS	N	Subset for alpha = 0.05		
		1	2	3
IYAMINIMA STREET GRA	4	69.5750		
TEREAMA (LOW DENSITY RESIDENTIAL AREA)	4	74.3750		
DIFFERI ROAD (LOW DENSITY RESIDENTIAL AREA)	4	75.7000		
OROGBUM CRESCENT GRA	4	79.4500		
RUMUOLA (COMMERCIAL AREA)	4		105.0000	
AIRFORCE BUS STOP	4		108.2500	
AIRFORCE JUNCTION	4		110.8750	
FIRST ARTILLERY (COMMERCIAL AREA)	4			132.7500
SECOND ARTILLERY JUNCTION	4			134.0000
SECOND ARTILLERY BUS STOP	4			134.5000
Sig.		.713	.982	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 4.000.

## Appendix (VIII): Post Hoc Test for Exposure to Traffic Noise Index levels (TNI)

### ANOVA

PERIODS

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	14593.406	9	1621.490	10.782	.000
Within Groups	4511.688	30	150.390		
Total	19105.094	39			

### Homogeneous Subsets

#### PERIODS

Tukey HSD

LOCATIONS	N	Subset for alpha = 0.05				
		1	2	3	4	5
IYAMINIMA STREET GRA	4	74.0000				
DFFRI ROAD (LOW DENSITY RESIDENTIAL AREA)	4	82.0000	82.0000			
TEREAMA (LOW DENSITY RESIDENTIAL AREA)	4	82.6250	82.6250	82.6250		
OROGBUM CRESCENT GRA	4	91.7500	91.7500	91.7500	91.7500	
AIRFORCE BUS STOP	4		107.7500	107.7500	107.7500	107.7500
AIRFORCE JUNCTION	4			112.0000	112.0000	112.0000
RUMUOLA (COMMERCIAL AREA)	4				114.2500	114.2500
FIRST ARTILLERY (COMMERCIAL AREA)	4				121.0000	121.0000
SECOND ARTILLERY BUS STOP	4					121.7500
SECOND ARTILLERY JUNCTION	4					133.5000
Sig.		.575	.130	.053	.055	.130

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 4.000.

Appendix (IX): Summary of Post Hoc Test Showcasing Significant Periods of the Day at Different Locations

LOCATIONS	L <sub>10</sub>	L <sub>90</sub>	NPL	TNI
IYAMINIMA STREET GRA (LOW DENSITY RESIDENTIAL AREA)	a <sup>*M</sup>	b <sup>*M</sup>	c <sup>*M</sup>	d <sup>*M</sup>
DFFRI ROAD (HIGH DENSITY RESIDENTIAL AREA)	a <sup>*A</sup>	b <sup>*A</sup>	c <sup>*M</sup>	ab
TEREAMA (HIGH DENSITY RESIDENTIAL AREA)	a <sup>*A</sup>	b <sup>*A</sup>	c <sup>*M</sup>	abc
OROGBUM CRESCENT GRA (LOW DENSITY RESIDENTIAL AREA)	a <sup>*A</sup>	ab	c <sup>*M</sup>	abcd
AIRFORCE BUS STOP	a <sup>*E</sup>	de	c <sup>*A</sup>	bcde
AIRFORCE JUNCTION	a <sup>*E</sup>	b <sup>*N</sup>	c <sup>*A</sup>	cde
RUMUOLA (COMMERCIAL AREA)	a <sup>*E</sup>	cde	c <sup>*A</sup>	de
FIRST ARTILLERY (COMMERCIAL AREA)	a <sup>*E</sup>	b <sup>*E</sup>	c <sup>*E</sup>	de
SECOND ARTILLERY BUS STOP	a <sup>*E</sup>	cd	c <sup>*E</sup>	d <sup>*N</sup>
SECOND ARTILLERY JUNCTION	a <sup>*E</sup>	b <sup>*E</sup>	c <sup>*E</sup>	d <sup>*N</sup>

Legend: \* means Significant, M-Morning, A-Afternoon, E-Evening and N-Night.