COMPARISON OF TRAFFIC NOISE LEVEL ASSESSMENT BETWEEN INDUSTRIAL AREAS, RESIDENTIAL AREA AND CONSTRUCTION AREAS IN IPOH, PERAK

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SCHOOL OF CIVIL ENGINEERING

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By

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declare that I have checked and revised the whole draft of the dissertation as required by my supervisor(s) and examiner.

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Date: 13th September 2021

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ABSTRAK

Kajian ini memberi tumpuan kepada pengukuran bunyi bising lalu lintas di kawasan Ipoh, Perak melibatkan kawasan guna tanah yang berlainan iaitu zon kediaman, zon perindustrian dan zon pembinaan. Antara kawasan yang terlibat dalam kajian ini adalah kawasan perumahan Meru Impian, kawasan perindustrian Menglembu dan kawasan pembinaan Meru Perdana. Sebanyak 10 titik persampelan ditetapkan untuk setiap kawasan kajian. Aplikasi Decibel-X Pro digunakan bagi menggantikan peranti meter tahap bunyi untuk merakam paras bunyi lalu lintas selama 15 minit untuk setiap titik persampelan. Bacaan ini dirakam untuk tiga waktu yang berbeza, iaitu pada waktu pagi, tengahari dan petang. Paras bunyi ini dirakamkan pada waktu puncak iaitu antara jam 7.30 am - 9.30 am (pagi), jam 12.00 pm - 2.00 pm (tengahari) dan jam 5.00 pm - 7.00 pm (petang). Kawasan titik persampelan yang berbeza mempunyai ciri-ciri yang berbeza, oleh itu, had pendedahan bunyi bising yang berbeza akan diperolehi. Pengiraan secara manual kepadatan trafik juga diukur serentak dengan pengukuran bunyi mengikut Arahan Teknik Jalan (8/86), Panduan Rekabentuk Geometri Jalan (kereta, motorsikal, lori kecil dan kenderaan berat). Paras bunyi L_{Aeq} yang direkodkan di kawasan-kawasan tersebut adalah antara julat 55 dB(A) sehingga 75 dB(A). Tahap bunyi rata-rata (L_{Aeq}) yang dirakam melebihi tahap suara maksimum yang dibenarkan (L_{Aeq}) menurut Garis Panduan Perancangan untuk Menerima Penggunaan Tanah untuk Perancangan dan Pembangunan Baru untuk Had dan Pengendalian Kebisingan Alam Sekitar oleh Jabatan Alam Sekitar. Kajian mendapati bahawa terdapat pelbagai jenis perkaitan antara paras bunyi bising dan kepadatan trafik yang menunjukkan bahawa bunyi yang dihasilkan tidak semestinya meningkat jika kepadatan trafik meningkat dan begitu juga sebaliknya. Keadaan ini dipengaruhi oleh kelajuan kenderaan yang tidak konsisten dan bunyi yang dihasilkan oleh setiap kenderaan adalah berbeza.

ABSTRACT

This study focuses on the measurement of traffic noise in the Ipoh, Perak area involving different land-use areas, namely residential zones, industrial zones and construction zones. Among the areas involved in this study are the Meru Impian housing area, the Menglembu industrial area and the Meru Perdana construction area. A total of 10 sampling points were set for each study area. The Decibel-X Pro application was used to replace the sound level meter device to record traffic noise levels for 15 minutes for each sampling point. These readings were recorded for three different times, namely in the morning, afternoon and evening. This noise level is recorded during peak hours between 7.30 am - 9.30 am (morning), 12.00 pm - 2.00 pm (noon) and 5.00 pm - 7.00 pm (evening). Different areas or sampling points would have different characteristics, therefore, different noise exposure limit would be obtained. Manual calculation of traffic density is also measured simultaneously with noise measurement according to the Road Technical Instructions (8/86), Road Geometry Design Guide (cars, motorcycles, small trucks and heavy vehicles). The L_{Aeq} noise levels recorded in these areas ranged from 55 dB (A) to 75 dB (A). The average sound level (L_{Aeq}) recorded were exceeded the maximum permissible sound level (L_{Aeq}) according to the Planning Guidelines for Receiving Land Use for Planning and New Development for Environmental Noise Limits and Control by the Department of Environment. This study proved that there are various relationship between traffic noise levels and traffic composition which show that the noise levels decreases when the traffic composition increases and also the other way round. This event influenced by the difference speed of the vehicles and the noise produced by each vehicle is different.

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Noise, which is generally described as an unwelcome sound, is an environmental issue to which humans are constantly exposed. Transportation facilities involved in road service, railroad traffic, and air traffic are major sources of noise and vibration. The noise and vibrations they produce are extremely harmful to both passengers and drivers, as well as the environment (Ozyavuz and Sisman, 2017).

Aside from rising levels of air and water pollution, road traffic noise pollution has been identified as a new hazard to city dwellers. The standard of the urban environment in developing countries' "cities" has deteriorated due to an unrestricted rise number of automobiles, infrastructure, and population. As result, the ongoing rise in traffic noise levels as a result of population growth has degraded urban quality of life. To overcome road traffic noise in cities, urban planners and environmental engineers face a major challenge (Chandio et al., 2010).

Noise pollution continues to grow as a result of manufacturing, social, and transportation growth, in comparison to many other environmental concerns. The scale of noise pollution varies depending on the mode of transportation. The intensity of noise is directly linked with the magnitude of traffic and travel speed. Transportation is mostly responsible for ambient noise in urban environments. Many studies have shown that traffic is the most frequent and widespread source of noise in cities. Traffic noise has been linked to a variety of negative health and well-being effects in humans. It also has negative socio-cultural, aesthetic, and economic implications for future generations (Ozyavuz and Sisman, 2017)

Continuously high levels of noise can cause severe stress to city dwellers' auditory and non-auditory systems, as well as their nervous systems. It is also a major source of great annoyance for the general public due to bad engines, exhaust, and other conditions (Chandio et al., 2010).

There is also evidence that traffic noise disrupts sleep patterns, affects cognitive functioning (particularly in children), and contributes to the development of some cardiovascular diseases and in some cases related to high blood pressure (Ozyavuz and Sisman, 2017).

1.2 Problem Statement

Noise, commonly defined as an unwanted sound, is an environmental problem to which humans are exposed throughout their life. It can be deduced that noise pollution disturbs the condition of human beings physically, physiologically and affects the environment by destroying its properties. Continuous and prolonged sensitivity to noise at a frequency above 85 dB(A) usually results in loss of hearing.

The rising number of ground transportation due to the development of cities and population daily demands has directly been associated with urban noise pollution in terms of elevated traffic noise levels (Abdullah et al., 2009). The traffic noise mainly occurs from the frictional effect between the road surface and tires which causes a high negative impact on the urban communities and the surrounding environment (Ibrahim et al., 2000). Noise pollution has become a serious problem for humans and has been officially announced as the second threatening pollution in the world by World Health Organization (WHO).

In Asia, developing countries such as China, India, and Vietnam are facing a serious problem of traffic noise pollution in their cities (Ma et al., 2006). Malaysia is one of the developing countries included in this problem due to the development pace that constantly occurs with the increasing number of road transportation networks in supporting the development process. Noise pollution awareness is not a new scenario as it has received the attention of the authorities in Malaysia as early as 1979 (Abdul Rahim et al., 2011). The Star Online (2016) stated that 132 noise pollution complaints have been reported to the Department of Environment, Malaysia in 2015. Most of the complaints were reported due to the noise from the commercial and construction sites. Other noise pollution complaints were reported regarding the noise that came from the industrial and transportation system. Although traffic noise annoyance is not the major source of nuisance, the expert has highlighted that road traffic noise is the most pervasive noise pollution over the world (Segaran et al., 2020; Pahat et al., 2020).

For this project, the study site selected is in the district of Kinta, Ipoh, Perak. This study is very important, given the increasing volume of vehicle use in the industrial area, construction, and residential areas that exposes to noise pollution to the public. From the observations made, it was found that there is still no collection of traffic noise data to support the ongoing noise pollution in the area which requires further study. Therefore, this study is conducted to find out the level of traffic noise occurring in the area and to study the methods that can be proposed to reduce the noise level.

1.3 Objectives

The purpose of this study is to assess the level of traffic noise in different categories of areas, namely in Menglembu Industrial Area, Taman Meru Perdana Construction Area and Taman Meru Impian Residential Area in Ipoh, Perak. This study is conducted to achieve the following three main objectives:

i) To measure traffic noise level at different types of land use in Ipoh; industrial area, residential area and construction area Perak.

ii) To compare the level of traffic noise and traffic volume between industrial, and construction areas.

iii) To produce noise map that visualizes the noise level distribution and the propagation of the sound waves at studied areas.

1.4 Scope of Study

This research was conducted to monitor the level of traffic noise in three different categories of areas namely industrial, construction and residential areas. The areas involved in this research are Menglembu Industrial area, Taman Meru Perdana Construction area and Taman Meru Impian Residential area in Ipoh, Perak. The scope of work focuses on the collection of noise and vehicle traffic density data on the road network in designated areas. The scope of work also includes visits to the study area to determine a suitable location for research purposes and to identify traffic conditions in the area.

We were less fortunate during the period of undergoing this study because we were in a state of Movement Control Order (MCO). Due to that, the equipment to do this research is very limited. Only smartphones were used replacing the noise level meter to take noise readings of traffic passing through the study area. We were also unable to take speed readings of each vehicle that crossed the study location because it did not have speed gun equipment. Using the Decibel X Pro application downloaded on a smartphone, data measurements were performed for 15 minutes for each sampling period. Data collection was done at three different times, namely in the morning, afternoon and evening so that variations in noise levels could be obtained. As for traffic density data, it was recorded using manual counts to measure the amount of traffic on the road by breaking it down into several vehicle categories namely motorcycles, passenger cars and vans, medium lorries and heavy lorries. The number of vehicles acquired is converted into equivalent passenger car units (PCUs) according to the Road Technical Instructions (8/86), Guide on Road Geometric Design. Based on the Planning Guidelines for Limitation and Control of Environmental Noise (Department of Environment Malaysia, 2019), Maximum Permissible Noise Level (L_{Aeq}) by Accepting Land Use for Suburban and Urban Residential, Mixed Development is 65 dB (A) during the day and 60 dB (A) at night.

1.5 The Importance and Benefits of Project

The purpose of this study is to compare the level of traffic noise in three different areas namely Menglembu Industrial area, Taman Meru Perdana Construction area, and Taman Meru Impian Residential area. These three areas fall under the city category. By identifying the differences in noise levels produced by vehicle habits in industrial, residential, and construction areas can provide more information related to the influence of vehicle type on noise. By creating a sound mapping, it can help to visualize the spread of sound in the study area so that we can compare which areas are most influential and the possible effects that can occur on the surrounding area. The data obtained will inform whether the study area meets the guidelines set by the Department or otherwise. Areas exposed to relatively loud noise can be identified and suggestions for improvement or control can be suggested for reference.

1.6 Dissertation Outline

This dissertation consists of five main chapters that explain in detail about the research project that have been conducted.

Chapter 1: Introduction - General overview of the research consisting of the problem statement, objectives to achieve and scope of work to be carried out.

Chapter 2 - Reflects the literature review of the previous research that related to the project study which explains the details on traffic noise pollution, worldwide traffic noise pollution, traffic noise in Malaysia, effect of traffic noise on human and noise descriptors.

Chapter 3 - Presents all the material and methods involved in this study. Furthermore, this chapter provides information on the study area, data monitoring and method to analyse data.

Chapter 4 - Explains the results and discussion of this research.

Chapter 5 - Concludes the research and recommendations to solve traffic noise pollution problems. Finally, reference and appendices are included at the last part of the dissertation.

CHAPTER 2

LITERATURE REVIEW

2.1 Traffic Noise Pollution

Noise pollution has become a major problem for humans, and World Health Organization (WHO) has designated it as the world's second most dangerous pollutant. Traffic noise is described as an obnoxious sound produced by vehicles when driving on public roads. In 2014, the European Environment Agency (EEA) classified urban noise as one of the most serious public health risks in Europe (Pahat et al., 2020). Air pollution is the pollution that ranks first in the world. According to the World Health Organization (WHO), each year air pollution is responsible for nearly seven million deaths around the globe. Nine out of ten human beings currently breathe air that exceeds the WHO’s guideline limits for pollutants, with those living in low and middle-income countries suffering the most.

Noise pollution caused by traffic is the most popular and most talked about. Because of insufficient city planning, traffic is a serious issue. Residential areas, schools, commercial zones, hospitals, and other buildings are constructed close to the main road without creating a perfect buffer zone and adequate or soundproofing. Increases in traffic volumes in recent years have intensified the issue. This alarming rise in traffic volume is actually inversely linked to environmental degradation (Manea et al., 2017).

Developing countries in Asia, such as China, India, and Vietnam, are struggling with severe traffic noise pollution concerns in their cities. Malaysia is one of the developing countries affected by this problem, owing to the rapid rate of growth and the rising number of road transportation networks that support the development process.

Noise pollution awareness is not a new scenario as it has received the attention of the authorities in Malaysia as early as 1979. According to The Star Online (2016), the Malaysian Department of Environment received 132 noise pollution complaints in 2015. The noise from commercial and construction sites was the source of the majority of the complaints. Other noise emission concerns come from the manufacturing and transportation networks. Although traffic noise annoyance is not the major source of nuisance, the expert has stated that road traffic noise is the most prevalent form of noise pollution worldwide (Pahat et al., 2020). Figure 2.1 shows the relationship between vehicle speed and dB(A) noise level from various sources of traffic noise pollution based on vehicle class.

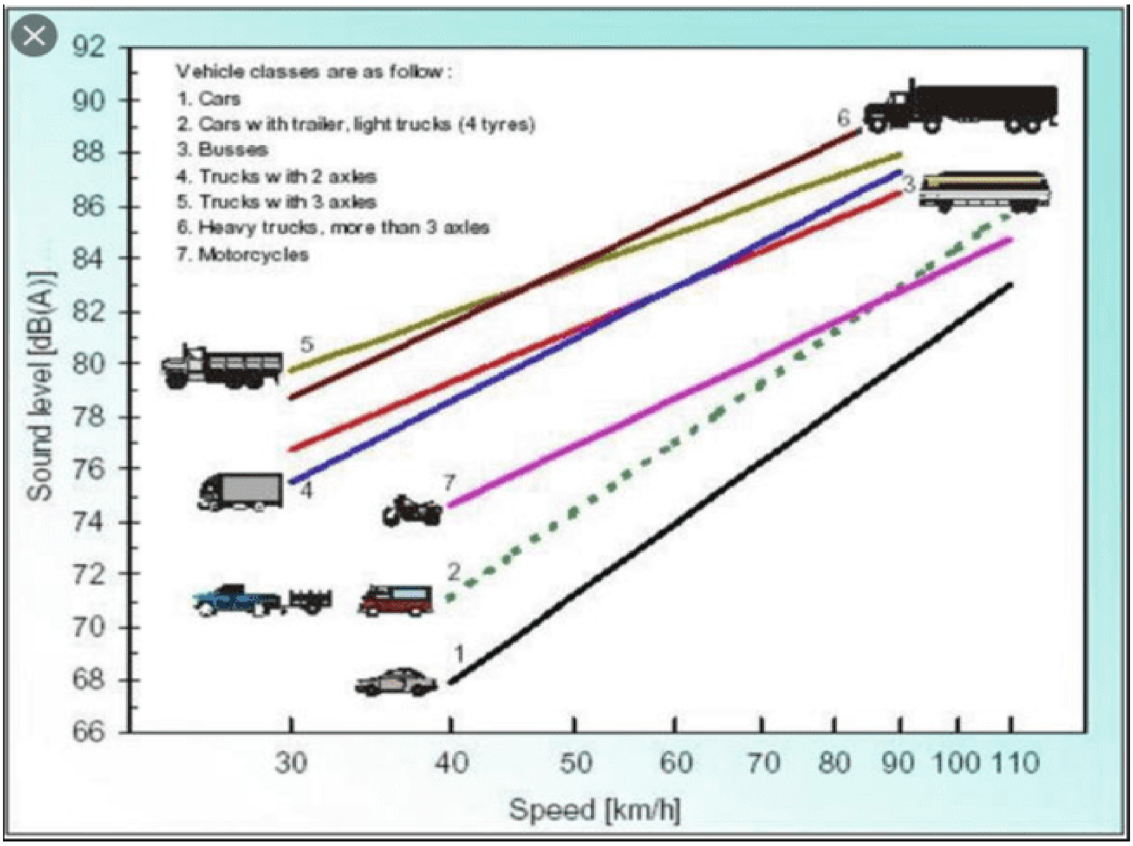

Figure 2.1 : Various sources of traffic noise pollution (Ivanova et al., 2016).

2.2 Worldwide Traffic Noise Pollution

Environmental noise, also known as community noise, is an obnoxious sound generated by a variety of sources, including traffic, industry, construction sites, and residential areas. It is classified as a toxic pollutant by the World Health Organization (WHO), that has ill impacts on public health. The European Union (EU) has introduced the Environmental Noise Directive (END), which focuses on evaluating the population exposed to community noise, reducing unhealthy noise levels, and mitigating the burden of adverse public health caused by noise. According to the most recent END revision, noise pollution remains a major environmental issue in Europe, with the following health consequences supported by ample evidence like an annoyance, sleep disruption with awakenings, asthma, ischemic heart disease, mental health, and even learning disability. In addition, some European countries such as Netherlands have created numerous windmill systems to produce energy for their national needs. This situation has caused noise that will disrupt the harmony of public life in the country (Park et al., 2018).

Transportation is a major source of community noise, particularly in modern urban environments in many countries with well-developed traffic systems. Road traffic is considered to contribute greatly to ambient noise and to impact a larger number of people than other modes of transportation. In Europe, for example, it is estimated that approximately 100 million people are exposed to harmful levels of road traffic noise (above 55 decibels (dB)). Road traffic noise has been linked to irritation and has been shown to cause direct awakening and changes in sleep stages, especially at night (Park et al., 2018).

The Republic of Korea (ROK), a developing Asian country, recently amended the Noise and Vibration Regulation Act of 1990 to create road traffic noise maps for densely populated urban areas and recognising that transportation noise as an environmental problem. According to some research based on the maps, ROK's road traffic noise levels were higher than those of EU member states, and many residents were subject to extremely high noise levels. However, the studies provide just little details on the number of people exposed to high levels of road traffic noise and the harmful effects of road traffic noise on health (Park et al., 2018).

Vietnam is one of the developing countries in Southeast Asia whose urban environments have changed dramatically as a result of industrialization, urbanization, and the steady rise in the number of motor vehicles over the last five years. Hanoi, Vietnam's capital, had a population of approximately 6.23 million people in 2007, while Ho Chi Minh City now has a population of over 7 million people. Apart from buses which provide the only public transportation in these large cities, the motorcycle is the most famous mode of transportation due to its low cost, flexibility, and adaptability to changing road conditions. According to World Bank figures, the number of motorcycles in Vietnam has exceeded 20 million, making it one of the highest per capita levels in the world. The use of motorcycles accounts for nearly 96 percent of all local transportation, resulting in clogged traffic and unnecessary noise all day. Table 2.1 shows noise level (L_{eq}) standard by WHO and selected countries for daytime and night-time.

Table 2.1: Noise level standard by WHO and selected countries (Segaran et al., 2020)

Noise Level Limit	Noise level, L_{eq} dBA	
	Daytime	**Night-time**
WHO	55	45
Malaysia (**DOE** Low Density)	55	50
Germany (Noise level guidelines)	45	35
Australia (Recommended outdoor background noise level)	45	35
Japan (Environmental quality standards)	45	35
Korea (Environmental quality goal)	50	45
Philippines (Environmental quality noise standards)	50	40
Iran		
(Residential area)	55	45
(Commercial area)	65	55
(Industrial area)	75	65

2.3 Traffic Noise Pollution in Malaysia

Transportation is a key factor to the growth of Malaysia's economy in fulfilling the nation's goal to achieve the 2030 shared vision of prosperity. The importance of transportation is shown by the rise in the number of vehicles registered, which grew by 11% from 22,616,106 in 2012 to 25,101,192 in 2014, reflecting a 45 percent annual growth rate. The population is expected to increase at a rate of 0.8% per year from 28.6 million in 2010 to 41.5 million in 2040, resulting in increased demand for transportation (Haron et al., 2019). The existence of new cities will result in transportation demand resulting in increased vehicles, road congestion, and traffic noise pollution. This will make the problems related to traffic noise become more pronounced in the future.

The DOE Guideline on Noise, introduced in 2004, was Malaysia's first set of guidelines for reducing environmental noise. The DOE's 2004 guideline identified a noise control mechanism. The mechanism's use in assessing the effect of noise during environmental impact assessments (EIA), which does affect people's tranquillity, is an obvious advantage. In an attempt to reduce the alarming increase in environmental noise pollution, the guideline has identified the allowable noise levels in various types of land areas, including road traffic, as specified in Schedule 1 under the Department of Environmental (Haron et al., 2019).

Individuals may experience health concerns, disruption, and discomfort as a result of noise exposure; in some situations, it may also affect work performance and quality of life. For example, low noise levels are usually associated with sleep disturbance, whereas noise levels greater than 70 dB(A) may cause hearing loss and ischemic heart disease. In several countries, traffic noise is the most extreme noise source because it is the most diffused in nature and has the largest effects. In Malaysia, motorcycles account for more than 40% of all vehicles and are a significant source of noise pollution (Aziz et al., 2012).

Noise levels are deemed exceedingly high if they meet the World Health Organization (WHO) recommendations of 55 dB(A) during the day and 45 dB(A) at night (Halim et al., 2019). According to the Malaysian Department of Environment's (2007) environmental protection limits for suburban and rural areas, the maximum allowable noise level outside of low-density residential areas should not exceed 55 decibels (dBA) to protect the population from urban noise. However, the noise limit varies according to the sensitivity of the area, type of location, and different regulations set by the countries (Pahat et al., 2020). In Malaysia, the traffic noise level is projected to be higher since the Road Transport Department Malaysia (JPJ) announced that the number of registered vehicles rose by 30.28 percent in 2015 relative to 2010. The number of registered vehicles increased by 4.78 percent in 2015 relative to 2014, and the trend is expected to continue in 2016 and future years (Isa et al., 2018). Highway sound levels in

Malaysia exceed the outdoor noise limit set by Malaysian standards, according to noise levels measured in residential areas near highways (Department of Environmental Malaysia, 2019) with constant sound intensity level (L_{Aeq}) for urban residential areas of 60 dB(A) during the day and 50 dB(A) at night (Halim et al., 2017). Table 2.2 shows limiting sound level (L_{Aeq}) from road traffic based on land use category for day and night-time.

Table 2.2: Limiting sound level (L_{Aeq}) from road traffic. Source (DOE, 2019.)

Receiving Land Use Category	**L_{Aeq} Day 7.00 am - 10.00 pm**	**L_{Aeq} Night 10.00 pm - 7.00 am**
Low Density Residential, Noise Sensitive Receptors, Institutional (School, Hospital, Worship).	55 dBA	50 dBA
Suburban Residential (Medium Density), Recreational	60 dBA	55 dBA
Urban Residential (High Density), Mixed Development	65 dBA	60 dBA
Commercial Business Zones.	65 dBA	60 dBA
Industrial Zones	70 dBA	65 dBA

In Malaysia, vehicles can be divided into multiple groups to make it easier to evaluate the vehicles that come through the lane. Arahan Teknik Jalan (8/86) was the grouping used for each class. The exposure level of noise levels would be affected by the various types of vehicles. All of the vehicles are divided into four categories which are car, motorcycle, light truck, and heavy vehicle (Halim et al., 2019). Table 2.3 shows the classification of vehicle classes while table 2.4 shows the classification of PCUs based on vehicle type.

Table 2.3: Classification of the vehicle classes (Halim et al., 2019)

Class	Type of Class
1	Car
2	Motorcycle
3	Medium lorries
4	Heavy Vehicle (Bus, Big Lorry, Trailer)

Table 2.4: Classification of the PCU (Halim et al., 2019) Source: Arahan Teknik Jalan (8/86)

Type of Vehicle	Equivalent Value (PCU)
Passenger cars	1.00
Motorcycles	0.33
Medium lorries	1.75
Heavy lorries	2.25
Buses	2.25

2.4 Noise Monitoring

One of the difficulties in ambient noise control is obtaining sufficiently comprehensive measurements in both the time and spatial domains. Changes in weather have a huge influence on monitored noise levels, and the noise must be monitored for long periods of time to catch the bulk of the variations. The most common reason for taking measurements is to keep track of noise from a noise source (such as an airport or a construction vehicle) in a residential area. Other noise sources still exist, and the captured noise level is typically the product of a mix of the target and intervening sound sources, such as wind-generated noise, vehicles, and birds (Maijala et al., 2018).

One of the most powerful methods for identifying sensitive locations in residential, commercial, and industrial areas is noise monitoring under various road and environmental conditions. It is important to know as many details as possible in order to create an acoustic model. Traffic noise prediction models are used to aid in the construction of highways and roads, as well as the estimation of current and expected improvements in traffic noise conditions. The noise levels in terms of L_{eq} are typically expected by most sound prediction models for the prediction of sound pressure levels. The noise prediction model's results can also be used to build 2D and 3D noise charts. Noise mapping is a graphical representation of the sound level distribution in a given area and environmental condition over a specific time span. The two types of noise mapping are 2D and 3D, respectively. In the existing world, 2D mapping has been widely and effectively used for environmental impact studies such as air pollution, soil pollution, and noise. The studies of noise monitoring, visualization, and modelling are all related. The results of noise monitoring can be used to predict the sound pressure level using various prediction models, and the forecast results can then be used to create noise maps (Alam et al., 2020).

2.5 Effect of Traffic Noise Towards Human

Noise pollution is a significant environmental problem that affects a large number of people, particularly in urban areas. The most severe and widespread form of noise pollution is possibly traffic noise. Because of insufficient urban planning in the past, traffic noise has become a major issue today. Typically, homes, schools, offices, hospitals, commercial business centers, and other community buildings are constructed in close proximity to major roads without adequate and perfect buffer zones or soundproofing (Pal and Bhattacharya, 2012).

According to the most recent END revision, noise pollution remains a major environmental issue in Europe, with the following health consequences supported by ample evidence: annoyance, sleep disruption with awakenings, asthma, ischemic heart disease, mental health, and even learning disability. The most significant psychological effects of community noise are considered to be annoyance and sleep disruption. Rage, dissatisfaction, anxiety, and depression are common manifestations of annoyance in humans. Night time noise causes interrupted sleep of residents in a community, and disturbed sleep could lead to fatigue, depression, and decreased performance, among others (Park et al., 2018). Excessive noise exposure can lead to damage to the sensory cells of the inner ear (cochlea), especially the outer hair cells. The main mechanisms in morphological pathologies are oxidative stress and synaptic excitotoxicity (Śliwińska-Kowalska and Zaborowski, 2017).

Over several decades, researchers have estimated exposure-response relationships for irritation caused by road traffic noise: There are many variations in the results of individual studies and various syntheses have been performed. According Miedema and Oudshoorn (2001) conducted the most recent meta-analysis, which looked at twenty-six studies from six European countries and Canada, involving a total of 19,172 people. They calculated the percentage of people who were Highly Annoyed (percent HA) over a 45- 75 dB Lden exposure range. Most of the data used in this meta-analysis has been around for decades. More recent exposure-annoyance studies for road traffic noise have been reported from Europe and Asia, but there have been no further syntheses conducted (Brown, 2015). According to the World Health Organization (WHO), nearly 5% or 360 million of the world's population has a hearing disability that is devastating. Excessive noise is one of the primary causes of hearing loss (Śliwińska-Kowalska and Zaborowski, 2017).

According to University of Texas School of Public Health, a systematic review of peer-reviewed scientific literature on the relationship between ambient noise and nonaural health effects found 35 studies conducted since 2001 that were significant. Overall, the data from these research supports the theory that ambient noise has certain negative health effects. The strongest evidence suggests that noise levels above 60 dB(A) during the day and 45 dB(A) at night are associated with an increased risk of arterial hypertension. Noise levels above 60 dB(A) are also linked to an increased risk of myocardial infarction at 70 dB(A) the risk is over 20% higher than in the unexposed population. Learning problems in schoolchildren have been related to daytime exposure above 55 dB(A). Sleep disruption and physiological stress responses are the main mediating factors for these effects (Health, n.d.). According to the European Environment Agency, noise is a major public health concern, with road traffic causing the bulk of the noise, environmental noise causes 10,000 cases of premature death in Europe each year, 20 million adults are irritated, and 8 million suffer from sleep disturbance and environmental noise causes over 900,000 cases of hypertension each year (EEA, 2014). Figure 2.2 shows the effects of environmental noise in Europe. One in five EU population lives in areas where noise levels are considered harmful to health.

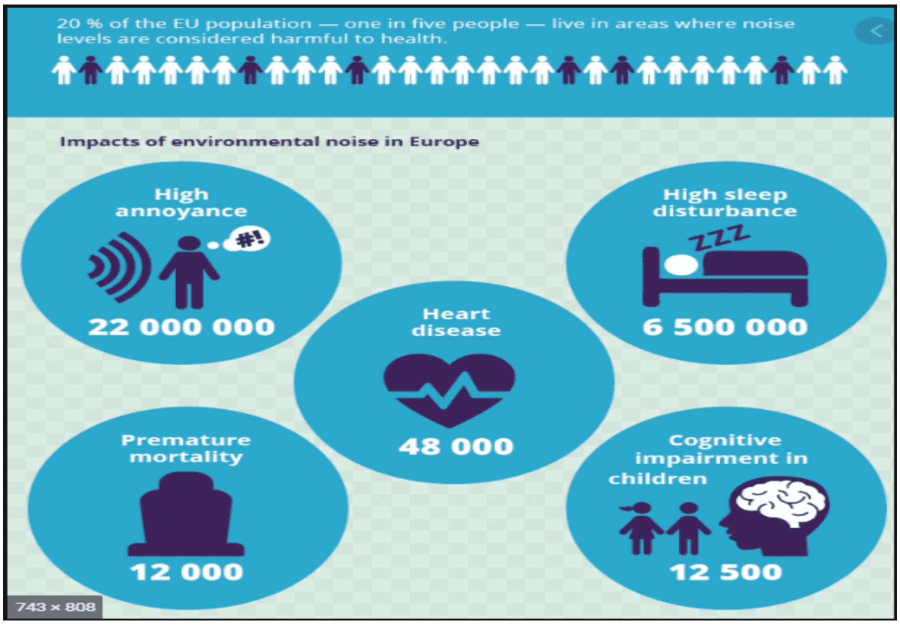

Figure 2.2 Source: EEA report - Noise in Europe 2020; EEA Infographic (Pahat et al., 2020).

In addition to affecting human health, traffic noise also affects the economic sector. In the city, traffic noise can affect house prices. It has a significant impact on the value of housing. In recent years, the relationship between noise levels and house prices has become a hot topic. According to studies conducted in Munich, every 1 dBA increase in noise causes a 0.4 percent increase in the cost of renting daily living quarters. According to studies undertaken in Sweden, the price of comparable housing will vary by up to 30% based on the degree of noise emissions (Lozhkina et al., 2020). In recent years, extensive research has been conducted on the effect of noise on the housing sector. In Munich, Germany, the hedonic price regression model was used to examine the relationship between rental rates and noise levels. Rental prices dropped by 0.4 percent per decibel on average (A) (Szczepańska et al., 2020).

2.6 Noise Descriptors

Noise pollution from traffic has been described as a major environmental issue around the world. Development of traffic noise models are needed in order to evaluate traffic noise level and to investigate the reduction measures. Traffic noise prediction models have been developed in many countries. The first official noise prediction model for L_{10} was developed in Britain and published in 1975 as "Calculation of Road Traffic Noise" (Suthanaya, 2015).

The key indicators for measuring traffic noise are the continuous equivalent A-weighted sound level, L_{Aeq}, and the statistical percentage sound level such as L_{10}, L_{50}, and L_{90}. Which is meant by the equivalent noise level and the statistical percentage noise level is :

i) $L_{EQ}(t)$, or Time-Equivalent Sound Level, descriptor accounts for noise fluctuations from moment to moment by averaging the louder and quieter moments and giving more weight to the louder moments. It represents the equivalent continuous sound pressure level over a given period of time. L_{EQ} should not be confused with L_{50}; L_{EQ} is a measure of sound energy, not a statistical measure or statistical average.

ii) The $L_{10}(t)$ is a statistical descriptor of the sound level exceeded for 10% of the time of the measurement period (t). It can be obtained using short-term measurements; however, it cannot be accurately added to or subtracted from other L_{10} measures or other descriptors. Typically, the L_{10} is about 3 dB(A) above the $L_{EQ}(t)$. This measurement is permitted for use by the Federal Highway Administration.

iii) The $L_{50}(t)$ is a statistical descriptor of the sound level exceeded for 50% of the time of the measurement period (t).

iv) The $L_{90}(t)$ is a statistical descriptor of the sound level exceeded 90% of the time of the measurement period (t). This is considered to represent the background noise without the source in question. Where the noise emissions from a source of interest are constant (such as noise from a fan, air conditioner or pool pump) and the ambient noise level has a degree of variability (for example, due to traffic noise), the L_{90} descriptor may adequately describe the noise source (Felipe, 2014).

The 'A' weighted standard, expressed as L dB(A) or LA dB, is the most commonly used metric of environmental acoustics. Noise measures combine noise level with time, such as LA10 dB, which is the level surpassed over a given proportion of time, or L_{Aeq} dB, which is an integration of volume with respect to time (Suthanaya, 2015). L_{eq} is a standard term used to assess noise, especially on highways, in residential and commercial areas. Furthermore, L_{eq} is more practical and applicable, as well as being globally recognized for traffic noise studies (Halim et al., 2019). Figure 2.3 shows the visual comparison of the sound levels represented by select descriptor.

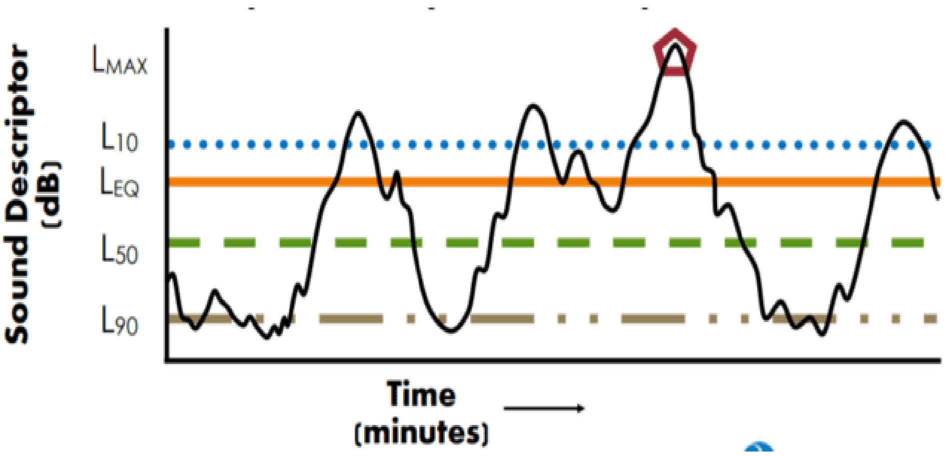

Figure 2.3 : Visual Comparison of the Sound Levels Represented by Select Descriptor (Felipe, 2014)

2.7 Noise Pollution Barriers as a Noise Control Measure

Besides the growing level of air and water pollution, road traffic noise pollution has been recognized rising as a new threat to the inhabitants of cities. The urban environmental quality of developing countries' “cities” has been deteriorated by an unlimited increase of vehicles, infrastructure, and population. Consequently, the continuous increased intensity of traffic noise level due to the population has degraded urban quality of life (Chandio et al., 2010).

The most effective way of reducing traffic noise is to reduce noise emissions at the source, for example, by greater use of electric vehicles, by introducing regulations demanding quieter engines, tires, or road surfaces, or by limiting traffic flow volumes and introducing stricter speed limits. However, such methods are often difficult to implement for economic, city planning, or political reasons. Noise reduction at source must be complemented with methods that act on the noise as it travels to the receiver. Noise barriers are a common method of reducing traffic noise between residences and roads or railways. A 3 m high noise barrier placed close to a road should give at least 10 dB reduction in noise levels over a wide area on the other side of the barrier. A reduction of 10 dB is substantial since it corresponds to a halving of loudness. But noise barriers may be visually intrusive and because of any gaps render them ineffective, they may divide communities (Noisy et al., 2016). Figure 2.4 shows the examples of wall noise barriers to reduce the traffic noise.

Figure 2.4 : Examples of wall noise barriers (Manea et al., 2017).

Apart from concrete walls, trees are also a medium to block noise from vehicles. Trees that grow along the road serve as a supplier of oxygen to life and absorb carbon dioxide gas as well as can reduce air pollution. The tree also acts as an efficient noise barrier to residential areas. In 2002, according Van Renterghem and Botteldooren (2002) investigated the wind effect of a tree belt behind a noise barrier. They took measurements along the highway and discovered that as wind speed increases, the performance of noise barriers with tree belts becomes increasingly stronger than noise barriers without tree belts. When there are a lot of trees between the sound source and the receiver, sound waves interfere with the foliage of the trees. Therefore, some part of it gets reflected and other is transmitted. So, trees act like noise filter (Gulia and Gupta, 2016). Figure 2.5 shows examples of traffic noise barriers using trees as a filter.

Figure 2.5 : Examples of noise barriers used trees (Manea et al., 2017).

2.7.1 Pavements low acoustical emission

Apart from the above methods, one of the most widely used methods for reducing noise levels is to use pavements with low acoustical emission profiles. Fabrication of sound absorbing materials is also an effective strategy for noise reduction. By dissipating energy and converting it to heat, sound absorption materials reduce noise. To minimise noise, porous materials such as absorption foams and fibres are widely used. The best options to choose are those that benefit a larger number of people, such as shifting flux, eliminating heavy vehicles, or changing pavements to environmentally friendly and recycled rubberized asphalts (Bottom, 2018). Increased porosity, texture optimization, and mechanical impedance reduction are three major pavement surface optimization techniques that have been well developed for reducing tyre/road noise. At higher frequencies, such as over 1000 Hz, increased porosity increases sound absorption and decreases tyre/road noise. Then, by optimising the surface texture, tyre rubber thread movements are reduced and noise levels are generated. For noise reduction, it is recommended to use cubic shape small overall aggregate size such as 4–6 mm for passenger cars and 8–10 mm for heavy duty vehicles (Vaitkus et al., 2016). Figure 2.6 shows the major influencing factors on tyre/road noise.

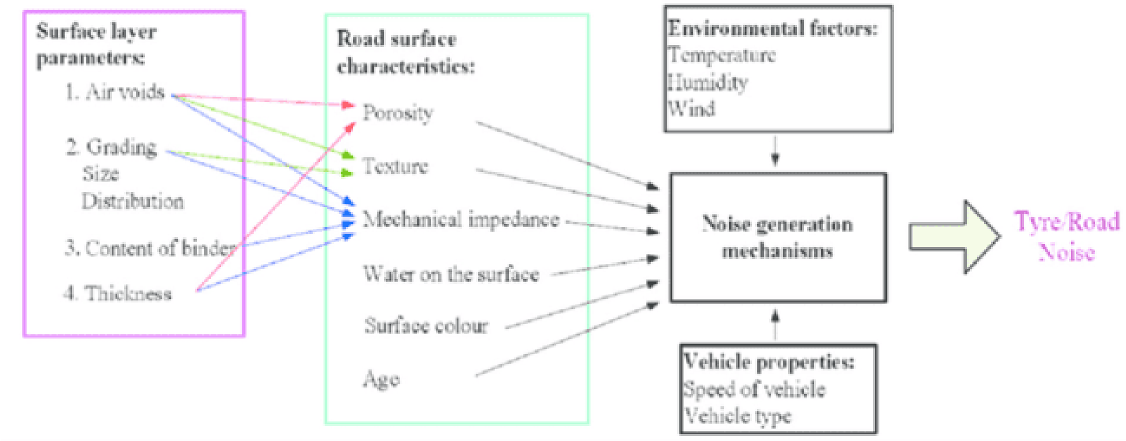

Figure 2.6 : Major influencing factors on tyre/road noise (Vaitkus et al., 2016).

2.8 Noise Mapping

Traffic noise is often regarded as one of the most serious environmental issues. Many studies have found a correlation between noise exposure and negative health effects. It is important to have knowledge of road noise levels in order to establish and plan remedial measures (Farcas, 2010).

For the past one decade, the Council in the EU has launched the idea of making EU-wide "noise maps" based on common methods and indicators. Noise mapping encompasses the entire mapping process, from the collection of raw data to its storage and retrieval for computation and modelling, as well as the presentation of information about outdoor sound levels, sound exposure, and noise effects, as well as the number of people affected. The public should be able to use these maps. They should serve as the foundation for developing noise pollution action plans and strategies at the local, national, and EU levels (Kliučininkas and Šaliunas, 2006).

Noise maps may be used to define noise levels within neighbourhoods, locate areas of higher exposure, determine possible conditions, aid in detecting the presence of this intangible contaminant, and act as a foundation for putting noise-reduction measures in place (Nourmohammadi et al., 2021). The noise map is a graphical representation of noise levels that is widely used as a reference in urban noise management. Noise mapping also aids in determining the level of ambient noise pollution in a given area (Manojkumar et al., 2019). The noise maps depict the propagation of road noise in a simple and intuitive way, which is useful for estimating traffic noise emissions. In some studies, the noise map of the sample area is generated by interpolating monitoring data from noise monitoring stations or manually gathered data, and road noise emission is measured using the equivalent sound pressure of day or night (Yang et al., 2020).

The two most popular types of noise mapping are 2D and 3D noise mapping. 2D mapping has been extensively and successfully used for environmental impact studies such as air emissions, soil pollution, and noise in the current world. Noise analysis, visualisation, and modelling research are all intertwined. Noise monitoring data can be used to forecast sound pressure levels using a variety of prediction models, and the forecasted results can then be used to generate noise map (Alam et al., 2020). Using a crucial feature such as a modelling model such as ArcGIS, noise emissions from industrial zones and other urban causes can be minimised. ArcGIS has strong noise propagation simulation tools which can help with the development of a spatial analysis system that can be used to make decisions (Aderinola and Owolabi, 2020). Figure 2.7 shows the example of noise mapping produced by ArcGIS software.

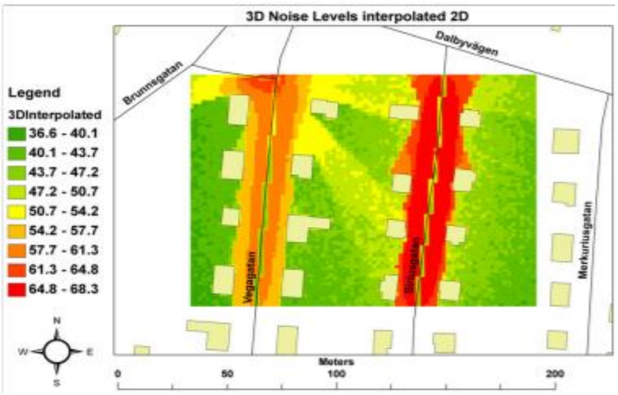

Figure 2.7 : Example of noise mapping produced by ArcGIS (Farcas, 2010)