ASSESSMENT OF TRAFFIC NOISE LEVEL AND TRAFFIC COMPOSITION IN KULIM, KEDAH

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SCHOOL OF CIVIL ENGINEERING
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By

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ABSTRAK

Kajian ini memberi tumpuan kepada pengukuran bunyi bising di kawasan Kulim, Kedah. Sebanyak 20 kawasan di sekitar Kulim telah dipilih termasuk Jalan Raya Kulim, Jalan Tunku Asaad, Jalan Tunku Putra dan Jalan Lunas. Kajian ini dijalankan untuk menganalisis kaitan antara paras bunyi bising trafik, L_{Aeq} dan kepadatan trafik di Kulim, Kedah. Aplikasi Decibel-X Pro telah menjadi pengganti kepada meter pengukur tahap bunyi yang digunakan untuk merakam paras bunyi selama 15 minit untuk setiap kawasan kajian dan diulangi sebanyak tiga kali untuk waktu pagi, tengahari dan petang. Paras bunyi dirakamkan pada waktu pagi (0800-0930), tengahari (1200-1400) dan petang (1700-1900) untuk setiap hari pengukuran bunyi. 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 65 dB(A). Rata-rata data bunyi L_{Aeq} yang direkodkan adalah melebihi nilai maksimum yang dibenarkan mengikut Garis Panduan Penggunaan Tanah untuk Perancangan dan Pembangunan Baru Bagi Had dan Kawalan Bunyi Alam Sekitar oleh Jabatan Alam Sekitar Malaysia. 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 measuring the noise levels at the study area in Kulim, Kedah. There are 20 points selected around the area including Jalan Raya Kulim, Jalan Tunku Asaad, Jalan Tunku Putra dan Jalan Lunas. This study was carried out to identify the relationship between traffic noise levels and traffic composition in Kulim, Kedah. Decibel-X Pro application was used to record the noise levels for 15 minutes for the morning, afternoon and evening period. The noise level measurements were monitored in the morning (0800-0930), afternoon (1200-1400) and evening (1400-1530). The traffic density was manually counted simultaneously with noise level measurement according to Arahan Teknik Jalan (8/86), A Guide on Geometric Design of Roads (cars, light vans, motorcycle, small lorries and heavy lorries). The average sound level (L_{Aeq}) obtained at the areas ranging from 55 dB(A) until 65 dB(A). All the sound level (L_{Aeq}) recorded 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 is any sound, regardless of volume, that can have a negative physiological or psychological effect on a single person or a group of people. The level of sound that exceeds the appropriate threshold and causes agitation is referred to as noise *(Madu et al.*, 2018). According to the World Health Organization (WHO), noise pollution is the third most dangerous form of pollution after air and water pollution. Increased environmental noise has a negative impact on people's wellbeing all over the world. According to recent research, a 5 dB increase in roadside noise will increase the risk of hypertension by 3.4 percent (Basu *et al.*, 2020). Industrial noise, community noise, and road noise are the three main types of noise. The consequences of traffic or vehicular noise are more inconvenient than the other two groups. Vehicle noise comes from a variety of sources, including car engines, exhaust systems, tire interaction with road horns, aerodynamic friction and vehicle interaction, and also cooling fan noise (Madu *et al.*, 2018).

Noise pollution has a negative effect on one's quality of life. It reduces comfort, impairs communication, disturbs serenity, and can even lead to psychological issues and cardio-cerebrovascular illnesses (Lu *et al.*, 2019). Noise also poses a serious threat to a child’s physical and physiological health and may negatively interfere with a child’s learning and behavior. Noise is a growing health threat, and if left unchecked, could result to hazardous conditions (Aderinola and Owolabi, 2020).

1.2 Problem Statement

In Malaysia, the DOE Guideline on Noise was introduced in 2004. It is the first set of guidelines for minimizing environmental noise. Previously, the UK standard was used, which is the $L_{10\ 18h}$ maximum of 68 dBA where the amount approaches 10% of the time measured hourly between 0600 and 2400 hours. Noise levels established by the World Health Organization were also listed (Haron *et al.*, 2019). Noise pollution has a negative effect on one's quality of life. It reduces comfort, impairs communication, disturbs peacefulness, and can even lead to psychological issues and cardio-cerebrovascular illnesses (Lu *et al.*, 2019). Moreover, noise is also a severe threat to a child's physical and physiological health, as well as having a detrimental impact on their learning and behaviour. Noise is becoming a bigger problem for people's health, and if it's not controlled, it may lead to dangerous consequences (Aderinola and Owolabi, 2020).

As a result of rapid urbanization and motorization of transportation in recent decades, a variety of environmental problems have arisen in cities, affecting urban quality of life and sustainable development, especially in city centres where human activities and mobility are typically concentrated. Traffic noise has been identified as a significant contributor to the degradation in citizens' quality of life and general well-being, with the worst impacts happening in densely populated and congested urban centres (Nourmohammadi et al., 2021). Malaysia's economy relies heavily on transportation to achieve its target of becoming a developed nation by 2020. The value of transportation is shown by the 11 percent rise in registered vehicles from 22,616,106 in 2012 to 25,101,192 in 2014 at a 45 percent annual pace. The demand for transportation is expected to rise in the future, as the population is expected to expand at a rate of 0.8 percent per year from 28.6 million in 2010 to 41.5 million in 2040 (Haron et al., 2019).

Increased urban traffic has long been a point of concern for the environment. If modal change measures such as transferring traffic from highways to railways, as well as pedestrian and cycling traffic, are helpful in minimizing road traffic, the problem can be solved in the future. Road traffic, on the other hand, is also will and is likely to do so for some time (Ögren et al., 2018). Road traffic has contributed the largest proportion of noise pollution reports worldwide since the twentieth century, owing to industrialization and urbanisation. Many components influence to traffic noise, including noise created by a vehicle's engine, emissions, contact between tyres and ground surface, and interaction between moving vehicles and the air that passes through, traffic volume, traffic composition, road quality, and traffic management (Halim et al., 2017). Noise also can cause anxiety, disturb sleep, disrupt routines, impair work, and make it difficult to learn. As a consequence, noise pollution has always been a serious environmental problem for people. It is described as an obtrusive sound that disrupts people's everyday activities (Sulaiman *et al.*, 2018).

On the main road of the commercial city, which runs between Jalan Tunku Assad and Jalan Tunku Putra, there is traffic congestion and confrontation between pedestrians and vehicles. The key routes connecting Bukit Mertajam to the Kulim zone, commercial area and Kulim Hi-Tech. These are the main highways, and there are still vehicle-pedestrian conflicts. This is due to the straight line of the road layout and wide lanes, which result in high vehicle speeds and make crossing difficult for pedestrians. Due to the road's position as a primary road access to the Kulim area, there are also issues with traffic congestion at certain times, especially during the weekday rush hour (Misni and Aziz, 2015). It is observed that there is still no traffic noise data collection to support the on-going noise pollution that occurs within that areas and this requires further research to be done. Therefore, this study is carried out to examine the levels of traffic noise that occur at the selected locations including Jalan Tunku Asaad, Jalan Raya, Jalan Bukit Awi, Jalan Tunku Putra and Jalan Lunas.

1.3 Objectives

The aim of this research is to determine the level of traffic noise in Kulim Town. This research is being conducted in order to meet the following objectives:

i) To measure the traffic noise level and traffic composition in Kulim Town.

ii) To analyse the relationship between traffic noise level and traffic composition in the selected areas by using SPSS software.

iii) To produce the noise mapping that visualize the noise level distribution and the sound waves propagation at Kulim by using ArcGIS software.

1.4 Scopes of Study

This research is conducted to monitor the traffic noise level at Kulim Town. This research is conducted at the town areas and also covers Jalan Tunku Asaad, Jalan Raya, Jalan Bukit Awi, Jalan Tunku Putra and Jalan Lunas. The scope of works focuses on collecting data of traffic noise and the traffic density of the vehicles on the road network at the residential areas. The scope of works includes the site visit to the study area to determine a suitable location for the research and identify the traffic condition at the area. In this project, Decibel-X Pro was used instead of Sound Level Meter (SLM) as there are some restriction occur during the Movement Restricted Order (MCO) which prevent the student from coming back to the campus and thus prevent the student to use the equipment from the university.

1.5 Dissertation Outline

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

Chapter 1 provides an overview on traffic noise pollution, maximum permissible limit for a certain place and noise pollution issue. The introduction describes follow by problem statements, objectives and scopes of the study.

Chapter 2 reflects the literature review of the previous research that related to the project study which explain 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 will provide information on the study area, data monitoring and method to analyse data.

Chapter 4 explains the results and discussion of this research. The data obtained at the study area was discussed and analysed.

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 long been a major environmental concern for humans. It is described as any unwanted sound that interferes with people's everyday activities. In both urban and rural areas, traffic is a major source of noise (Sulaiman *et al.*, 2018). Of the various types of environmental pollution that can impact cities, noise pollution is often overlooked. It is instantly recognisable that, noise had a direct effect on public wellbeing about six decades before (Abdullah *et al.*, 2019). Noise is a phenomenon where, as compared to other pollutants in the atmosphere, disperses at a faster pace with time and distance as soon as it is produced. (Surashmie and Vinayak, 2019). In general, the acoustic environment consists of both natural sounds, such as animal noises and sounds originating from the geophysical atmosphere likes wind, thunder and others and also the ambient sounds produced by humans, which are caused by various human activities (Han *et al.*, 2018). The volume of sound or noise is measured in logarithmic decibel (dB) units. The decibel is defined as the logarithm of the ratio between a given wave's acoustic intensity, expressed in Pascals (Pa), and the sensitivity limit of 20 µP, which is the lowest sound pressure level accepted by the human ear (Śliwińska-Kowalska and Zaborowski, 2017).

Road traffic noise is commonly characterised as noise incidents induced by a single car passing through with the temporal configuration of sound pressure intensity (SPL) range from local one-lane city streets with extremely unpredictable noise to massive multi-lane highways with nearly constant noise with a very minimal fluctuation.

(Brambilla *et al.*, 2020). The growth of cities or countries leads to an increase in the number of vehicles, including those used for ground transportation. This is due to the growth in population, and many people use cars to get to work or to their destinations. When the number of cars on the road increases, traffic noise levels rise, and urban pollution rises (Segaran *et al.*, 2019).

Railways, airports, factories, and traffic are among the most common sources of noise in cities. The latter is thought to be the source that has the greatest effect on people, especially in densely populated areas. The frictional effect between the road surface and the tires produces the majority of traffic noise, which has a significant negative impact on urban areas and the surrounding environment. The dominance of traffic noise in the local area has an effect on population sleeping, resting, learning, and contact, and together with traffic noise irritation, they constitute threatening impacts (Segaran *et al.*, 2020).

Similarly, due to the exponentially rising air traffic, the local population has become very noise-conscious in recent years (de Luque-Villa *et al.*, 2020). Traffic noise, second only to particulate air pollution as an environmental risk factor in Europe, has been related to a rise in the incidence of cardiometabolic diseases, sleep disruptions, depression and anxiety, poor birth outcomes, and quality of life impairments due to noise irritation and interference with activities (Dzhambov *et al.*, 2021). The increasing in noise pollution is unsustainable because it has both immediate and cumulative negative health implications. It also has negative socio-cultural, aesthetic, and economic consequences for future generations. One of the most effective methods for identifying vulnerable locations in residential, commercial, and industrial areas is noise monitoring under various road and environmental conditions (Alam *et al.*, 2020).

2.2 Worldwide Traffic Noise Pollution

Urban noise is commonly recognised as an environmental stressor, and the World Health Organisation (WHO) has listed noise as a pollutant, reporting that more than 80 million residents in Europian Union (EU) countries are subject to outdoor noise levels above 65 dB(A) (Zambon *et al.*, 2020). Traffic noise is the most pervasive and dangerous of the noise sources associated with transportation. Statement from the European Environment Agency (EEA) said that urban noise was classified as a significant public health problem in Europe in 2014. From the survey that have been made, road traffic is a major source of environmental pollution, with an estimated 125 million residents impacted by noise levels higher than 55 decibels dBA, accounting for roughly 40% of Europe's population (Segaran *et al.*, 2020). From a statement made by World Health Organization (WHO), "at least one million healthy life years are wasted per year in Western Europe due to traffic-related noise." According to the literature, "sleep disturbance and distress, often related to road traffic noise, constitute the primary burden of environmental noise." (Brambilla *et al.*, 2020). Despite international and national noise reduction laws and rules, road traffic noise is the most diffuse noise source in urban areas, ranging widely in space and time. As a result, people's perception of the negative health effects of road traffic noise is growing (Brambilla *et al.*, 2020).

To calculate these Sound Pressure Level (SPL) fluctuations and differences, typical methods use thresholds to track events that exceed certain thresholds and count the number and length of these events such as percentile values L_{A1}, L_{A5}, and L_{A10}, and known as the A-weighted SPL reaching for 1%, 5%, and 10% of the measurement time, respectively (Brambilla *et al.*, 2020). Researchers discovered that when exposed to night noise at levels ranging from 40 to 55 dBA, health-harming effects will rise, a noise level of more than 55 dBA raises the risk of cardiovascular disease, and a noise level of more than 80 dBA causes cerebral cortex retardation and auditory organ damage. (Klepikov *et al.*, 2021).

From Table 2.1, the standard level of noise for various countries was represented according to guidelines produced by WHO for both daytime and night-time noise levels. In Malaysia, the noise levels for daytime are set at 55 dBA and noise levels for night-time are at 45 dBA for low residential areas.

Table 2.1 : Noise standard level for several countries according to WHO (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

According to a recent World Health Organization (WHO) research, 466 million people worldwide suffer from damaging hearing loss, and by 2050, it is predicted that 900 million people, or one of every ten people, will be affected. In European countries, the maximum disability-adjusted life years lost due to ambient noise are projected to be 1.6 million years (Manojkumar et al., 2019). In the United Kingdom, the cumulative number of cases due to noise-induced dementia, stroke, and acute myocardial infarction is 1169, 788, and 542, respectively. Furthermore, the monetary cost in both of these cases is calculated to be 1.09 billion UK pounds (Manojkumar et al., 2019). While the research in India discovered that comparable noise levels within homes near the highway ranged between 61–87 dBA, while noise levels in houses away from main traffic in the region ranged between 48–63 dBA (Śliwińska-Kowalska and Zaborowski, 2017).

2.3 Traffic Noise in Malaysia

Malaysia is one of the developing countries affected by this noise pollution issue as a result of the rapid speed of growth and the growing number of road transportation networks enabling the development process. Noise pollution perception is not a recent concept; it was first called to the attention of Malaysian authorities in 1979 (Segaran *et al.*, 2020).

In Malaysia, noise pollution is the most widely neglected form of pollution while water and air pollution are considered necessary to life because noise pollution is just an inconvenience to certain people (Halim *et al.*, 2019). And according to Star Online (2016), 132 noise emission concerns were registered to Malaysia's Department of Environment in 2015. The rest of the concerns were about noise from commercial and building projects. Other noise pollution concerns have been registered, including noise from manufacturing and transportation systems (Segaran *et al.*, 2020).

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) pollution protection limits for suburban and residential areas, the maximum allowable noise level outside of low-density residential areas does not surpass 55 decibels (dBA) to protect the population from urban noise. According to recent Malaysian research by Halim et al., (2019) noise levels in rural areas near Sungai Besi Expressway are higher than traffic flow on Duke Highway and KESAS Highway. In comparison to the other two highways, the Sungai Besi Expressway has a higher traffic volume. The highest noise level was 75.7 (dBA). The lowest average constant noise levels (L_{Aeq}) in Sungai Besi Expressway is 73.4 dB (A) during off-peak hours, and 73.8 dB (A) and 72.6 dB (A) during peak hours (Mohamad Nor *et al.*, 2019). From another research of traffic noise levels in Malaysia by (Haron *et al.*, 2019), the average daily noise level in Kuala Lumpur, Johor Bahru, and Seremban during typical traffic conditions on workdays, excluding peak periods of 0800-0900 hrs, 1200-1400 hrs, and 1600-1800 hrs. The greatest mean noise level was recorded in Kuala Lumpur (67.4-73.6 dBA), followed by Johor Bahru (61.8-65.7 dBA) and Seremban (61.8-65.7 dBA) (61.9-65.5 dBA).

In Malaysia, traffic noise level is projected to be higher since the Road Transport Department Malaysia 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).

In Figure 2.1, the L_{Aeq} recorded in Malaysia is compared to its nearby countries. Although the data was collected throughout a different time periods, it still indicates the degree of traffic noise in Malaysia in comparison to other nations. The data collected from Ho Chi Minh and Hanoi City have a similar intensity as Malaysia which caused by the honking of the motorbikes. Philippines also produced a high noise levels due to the high volume of tricycles, while Singapore and Thailand have a lower noise levels than Malaysia (Haron *et al.*, 2019).

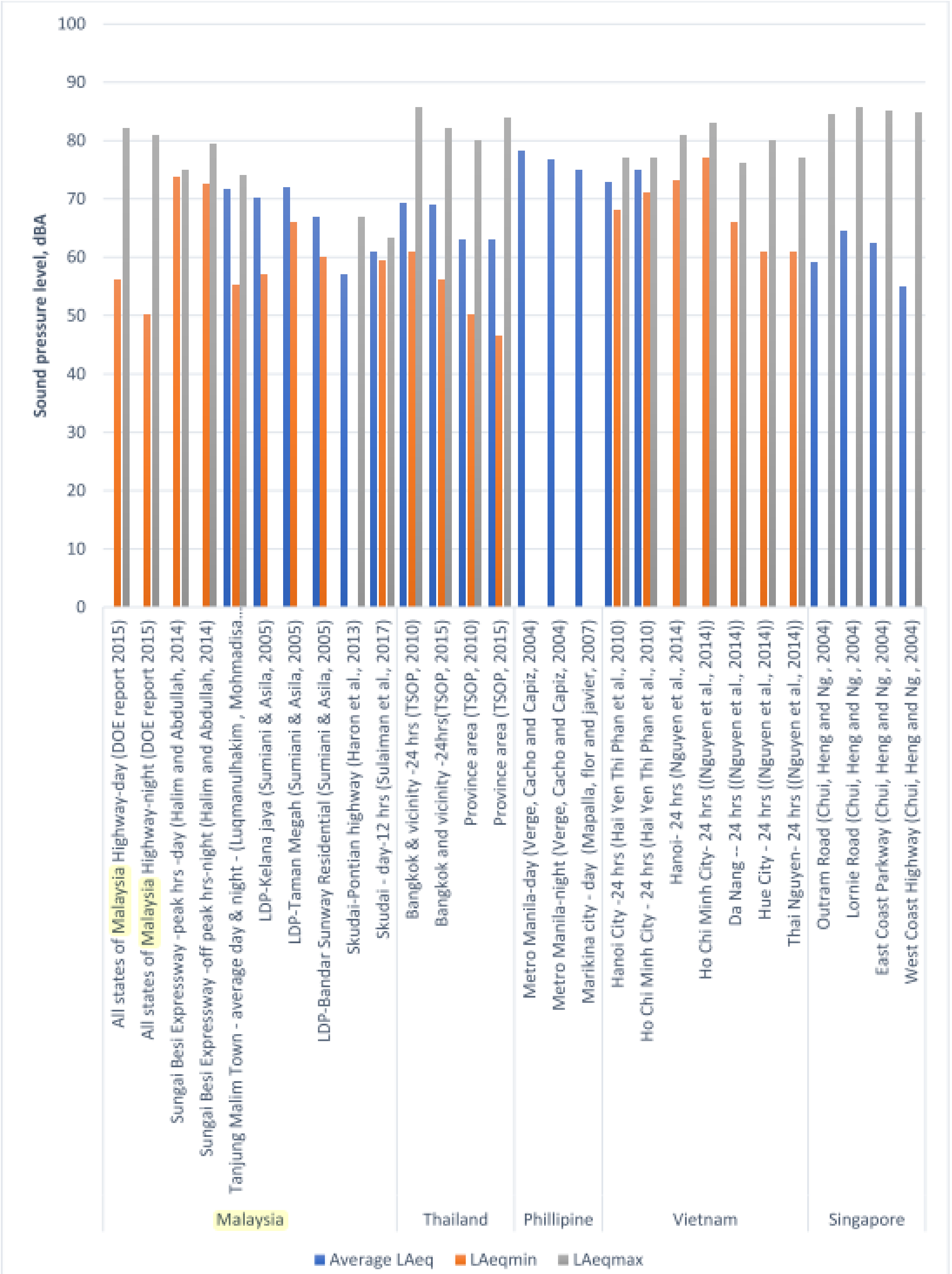

Figure 2.1: Comparison of L_{Aeq} in Malaysia and other countries (Haron *et al.*, 2019)

From the study made by (Halim *et al.*, 2019), all noise levels in the study area exceeded the noise limitations set by the Malaysian Department of Environment (DOE) for low, medium, and high density populated residential zones. The maximum noise levels were generally recorded in the evening, with noise levels ranging from 56.3 dBA to 67.8 dBA. The data shows higher noise levels occur when the traffic volumes and the percentage of heavy vehicles were increased especially during peak hours at night.

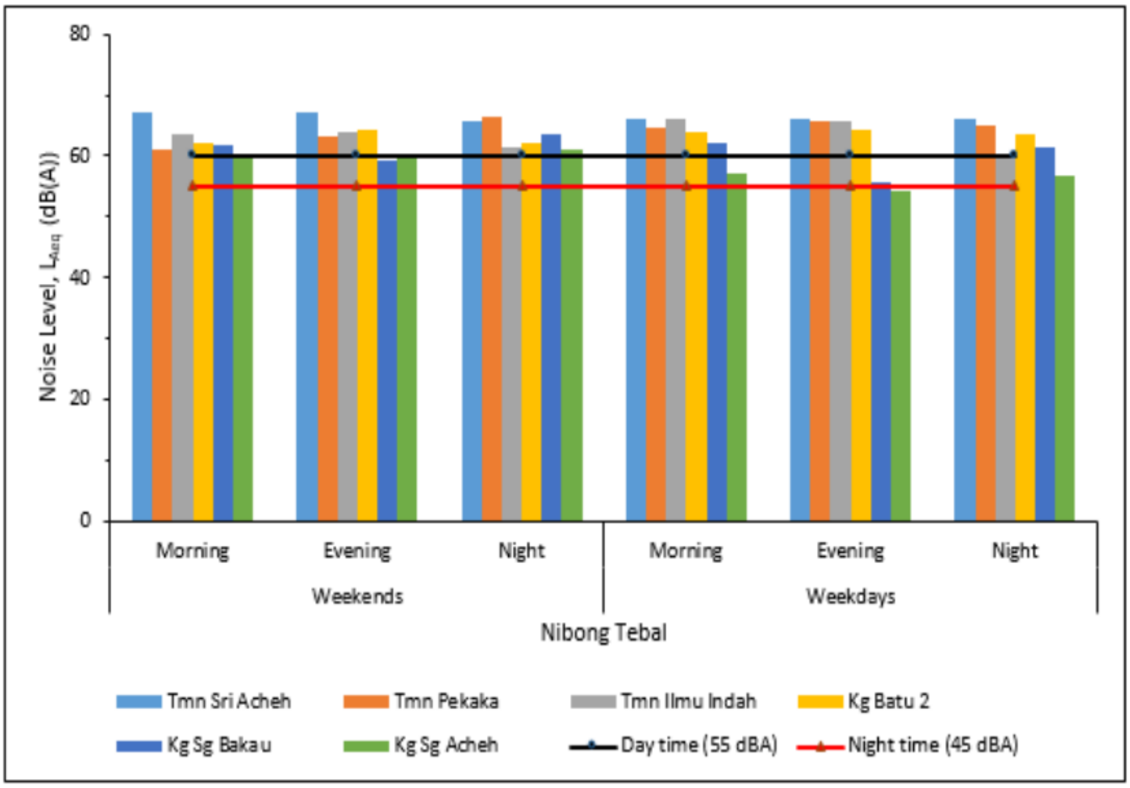

Figure 2.2: Noise levels in Nibong Tebal, Source: (Halim *et al.*, 2019)

By referring to DOE 2019, the recommended permissible sound level, LAeq for new development areas in medium density residential are 60 dBA and 55 dBA for daytime and night-time respectively. Table 2.2 shows the permissible sound levels for all types of land use categories in Malaysia.

Table 2.2: The recommended permissible sound level LAeq for new development area, 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

The L_{Aeq} or known as equivalent sound pressure level over time is used by the DOE as a measure of the noise emissions. During the day, people are vulnerable to noisy sounds in locations such as low-density suburban neighborhoods, schools, religious places, and hospitals, therefore, these places have a noise exposure level of 50 dBA for a 15-hour duration from 7:00 to 22:00 and 45 dBA for 9 hours between 22:00 and 7:00. These thresholds rise by 5 decibels in the residential areas. This limitation is consistent with WHO guidelines, which say that during the day, noises over 50 dBA L_{Aeq} start to irritate people moderately, and noises above 55 dBA L_{Aeq} start to irritate people severely (Haron *et al.*, 2019).

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 (Mohamad Nor *et al.*, 2019).

From Table 2.3, the vehicle classes were distributed into 4 classes which are Class 1 for cars, Class 2 for motorcycles, Class 3 for medium lorries and Class 4 for heavy lorries include buses and trailers. Each class has its own Equivalent Value (PCU) as stated in

Table 2.4 according to Arahan Teknik Jalan (8/86).

Table 2.3 : Classification of the vehicle classes (Mohamad Nor *et al.*, 2019), Source: Arahan Teknik Jalan (8/86)

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 (Mohamad Nor *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 descriptors

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}. L_{Aeq} is used to reflect noise amplitude since it has a better association with subjective sound perception. Noise amplitude, which is due to noise fluctuation, is represented by the L_{10}–L_{90} scale (Lu *et al.*, 2019). 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 L_{A10} 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). The L_{eq} (equivalent continuous sound level) is described as the constant sound pressure level which has the same energy produced as the actual fluctuating noise over a given time span (Surashmie and Vinayak, 2019).

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).

The annual composite day-evening-night level L_{den} is adopted as a required noise descriptor, for noise mapping, in the EU (Committee of the Regions, 2012). The annual night frequency L_{night} is also carefully monitored in order to determine the noise effect during the night. The annual composite day-evening-night level L_{den} is adopted as a required noise descriptor for noise mapping in the EU. The annual night frequency L_{night} is also carefully monitored in order to determine the noise effect during the night (Jagniatinskis et al., 2016).

The differences of all the noise descriptors can be simplified as in Table 2.5. The description for each type of descriptor was explained together with its affect towards the surroundings. The categorization of indicators was created because it may be beneficial for the future study and can help to explain outdoor sound in the context of the unique event we are witnessing from many perspectives, such as soundscape ecology (Asensio *et al.*, 2020).

Table 2.5: The description of each type of indicators, Source: (Asensio *et al.*, 2020)

	Indicators and Description	**Physical Descriptive Power**	**Descriptive Factor**
Energetic Indicators	Leq defined as continuous equivalent sound pressure level during period, T	Cumulative energetic indicators including A, C or Z frequency weighting	Correlated to long term health effects
Statistical Indicators	L90 (90% percentile level)	Describes background noise	Does not emerge from studies
	L50 (50% percentile level)	Useful for distinguishing between different sound environments.	Correlate with perceived sound intensity and pleasantness
	L10 (10% percentile level)	Describes the contribution of the loudest occurrences	Describes the perception of high noise levels

2.5 Effect of Traffic Noise Towards Surrounding

Noise can cause anxiety, interrupt sleep, disrupt schedules, interrupt work, and make learning difficult. As a result, noise pollution has long been a major environmental problem for residents. It is defined as an obtrusive sound that interferes with people's daily activities (Sulaiman *et al.*, 2018). Constant exposure to excessive noise levels can result in environmental problems that affect residents' quality of life, such as depression, sleep disruption, frustration, poor working performance, and negative health effects. (Suthanaya, 2015). High noise levels can have a negative impact on the cardiovascular system and raise the risk of coronary heart disease in humans. Noise can raise the risk of fatality in animals by changing predator or prey detection and avoidance, interfering with reproduction and navigation, and contributing to severe loss of hearing (Harcourt, 2019).

Figure 2.3 shows the decibel scale in dBA for various types of noise sources. The value of sound pressure level above 60 dBA can be considered as unhealthy to human’s health including the noise from passenger car, truck, jackhammer and also the noise from concert of a rock band which can reach until 110 dBA.

Figure 2.3 : The sources of noise and sound pressure levels, Source: (Münzel et al., 2018)

2.5.1 Effect on Human’s Health

Noise exposure can trigger auditory effects such as hearing disturbance and voice disturbance in people’s live. It can also causes psychological effects, such as sleep problems and a reduction in productivity (Isa *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). Moreover, epidemiological studies have demonstrated that noise exposure not only causes hearing loss, especially at work, but it is also associated with diseases of the cardiovascular system, the digestive and endocrine systems, as well as neurological and behavioural disorders (Zambon *et al.*, 2020). According to the World Health Organization (WHO), almost 5% of the world's population, or 360 million people, suffer from a severe hearing loss. One of the leading causes of hearing loss is excessive noise (Śliwińska-Kowalska and Zaborowski, 2017). According to recent research, a 5 dB increase in roadside noise will increase the risk of hypertension by 3.4 %. According to further research, excessive noise sensitivity may trigger hormone disruption as well as an increase in blood pressure, all of which may have serious consequences for the body's cardiovascular system (Basu *et al.*, 2021).

People should also stress that a negative noise effect measurement must take into consideration the time of day and the subject's occupation. An 80 dBA noise could be less harmful on a person doing daily physical labour during the day than a 65 dBA noise on a person performing mental labour or a 50 dBA noise on a sleeping person (Lozhkina *et al.*, 2020). Noise disturbance may also have significant physiological, psychological, and social effects, with sleeping disturbances being one of them. Many of these negative outcomes lead to a decline in fitness and quality of life (Zambon *et al.*, 2020). WHO reports that sleep disorders and annoyance alone cost Western Europe more than 1,550,000 years of healthy life and noise has a direct effect on the economy and housing market, previously observed that noise levels have a negative impact on housing rental prices in Machala, Ecuador (Čurović *et al.*, 2021).

The long-term average effect of noise levels above 55 decibels is a rise in blood pressure, weakening of the central nervous system, changes in breathing and pulse rates, disruptions of digestion, respiratory conditions, stomach ulcers, asthma, diabetes, and psychiatric illnesses (Mavrin et al., 2018). The implementation of a methodology for assessing health risks from noise exposure enabled researchers to discover that when exposed to night noise at levels ranging from 40 to 55 dBA, the risk of cardiovascular disease increases, and at levels greater than 55 dBA, the risk of cardiovascular disease increases, and at levels greater than 80 dBA, cerebral cortex retardation and hearing organ abnormalities develop (Klepikov *et al.*, 2021). According to a new report undertaken in Madrid, a 1 dB(A) drop in noise level would have prevented 184 premature respiratory deaths and 284 premature cardiovascular deaths (Manojkumar *et al.*, 2019). According to the European Environment Agency (EAA), noise is a significant public health issue, with road traffic causing the majority of the noise. EAA also stated that noise pollution causes 10,000 cases of premature death in Europe every year, 20 million adults are annoyed, and 8 million suffer from sleep distress; and environmental noise causes over 900,000 cases of hypertension annually (EEA, 2014).

The study of the relationship between noise and cardiovascular disease was explained in Figure 2.4 which stated that noise causes annoyance and stress responses characterized by the activation of the hypothalamic-pituitary-adrenal axis, inflammation, thrombosis, and altered gene expression. Hypertension is the most well researched risk factor for cardiovascular disease in a noise setting. A meta-analysis of 24 studies published in 2012 found that a 5-dBA increase in road traffic noise was linked with a significant odds ratio of 1.034 for prevalent hypertension (Münzel *et al.*, 2018).

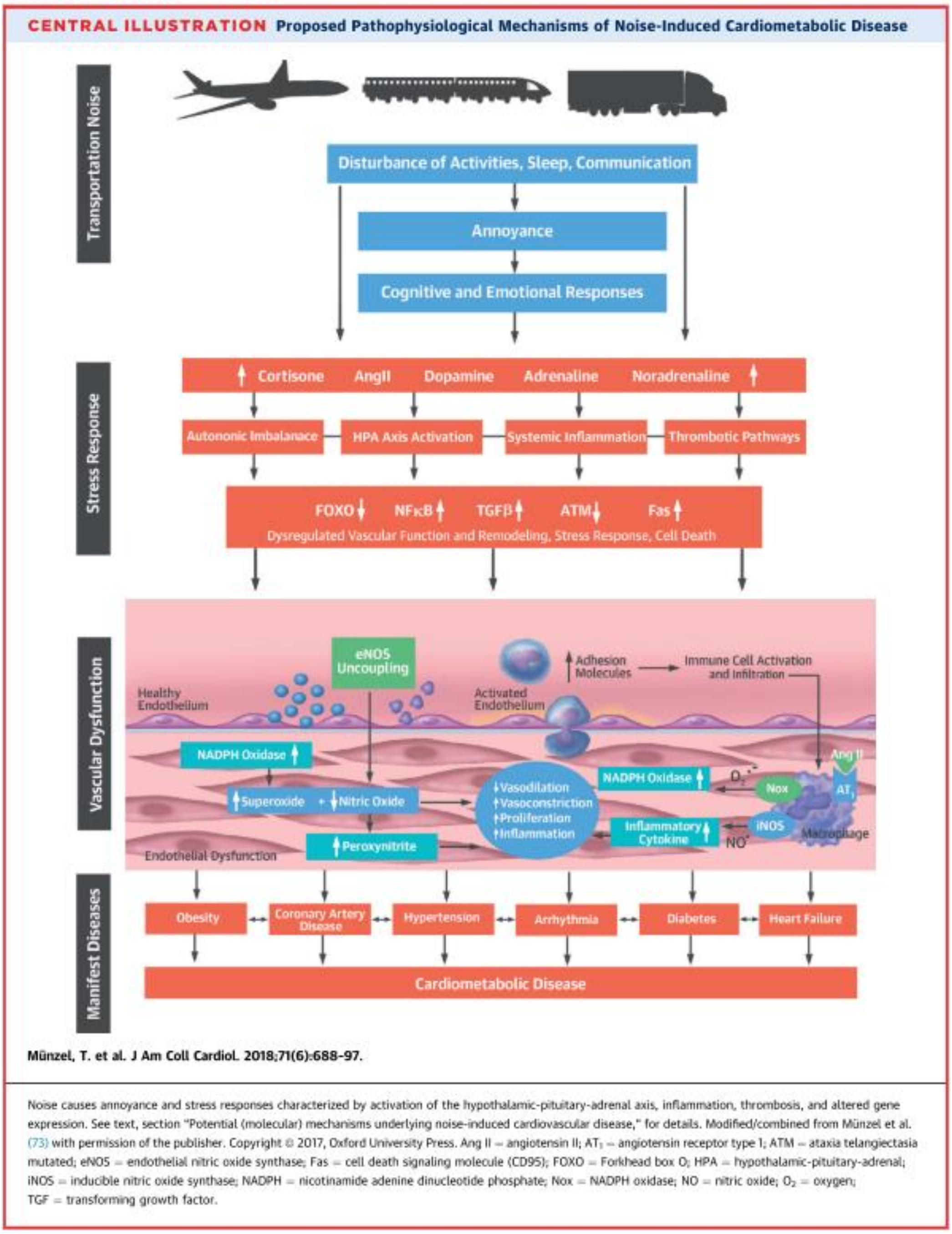

Figure 2.4: The effect of traffic noise to human's health (Münzel *et al.*, 2018)

2.5.2 Economic Effects

Since road noise is one of the most noticeable causes of annoyance associated with city life, it has the potential to have a significant effect on housing values. The relationship between noise levels and house prices has been widely discussed topic in recent years. According to studies conducted in Munich, when the noise level grows by

1 dBA, the cost of renting regular living quarters rises by approximately 0.4 percent. 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).

The impact of noise on the housing sector has been thoroughly researched in recent years. The hedonic price regression model was used to assess the association between rental rates and noise levels in Munich, Germany. On average, rental rates fell by 0.4 percent per dB (A) (Szczepańska et al., 2020).

2.5.3 Covid-19 Impacts

Because of the increased demand for road transport, more people are subjected to noise, and noise exposure is increasingly being recognised as a critical environmental and public health problem (Jamalizadeh *et al.*, 2018). In 2021, noise levels and vibrations are expected to have decreased as a result of improvements in human and industrial operations and the decline of public and private transportation during the COVID-19 measures, which measured a 6 dB reduction in sound pressure levels resulting in lower road traffic in Barcelona (Čurović *et al.*, 2021).

From the investigation on the effect of the COVID-19 lockdown on sound level in Dublin, Ireland conclude that the significant decrease in sound is due to the reduction in road and air traffic during the lockdown. It shows the substantial ($p < 0.05$) reduction caused by the reduction of active traffic which result in an average and minimum sound levels in a large urban environment as shown in Table 2.6 below (Basu *et al.*, 2021).

Table 2.6 : Number and percentage of time the L_{eq}(1hr) exceeded the threshold 55 dB

Station ID	Total number		Percentage	
	Pre lockdown	During lockdown	Pre lockdown	During lockdown
1	1393	247	69.13	**21.42**
2	1987	963	98.61	**83.52**
3	1244	420	61.74	**46.00**
4	1962	947	97.37	**82.13**
5	1467	203	72.80	**17.29**
6	1637	700	81.24	**62.00**
7	432	8	21.44	**0.69**
8	1466	616	72.75	**53.43**
9	1491	121	74.00	**10.49**
10	1387	340	69.11	**29.49**
11	1207	220	59.90	**19.08**
12	265	29	13.15	**2.47**

Source: Investigating changes in noise pollution due to the COVID-19 lockdown in Dublin, Ireland by (Basu *et al.*, 2021)

The number of vehicles on the road has increased dramatically, resulting in a rise for vehicular traffic noise levels (Choudhary and Gokhale, 2018). High noise levels have been found to have an effect on the health and prosperity of a large segment of the population, including those who live along highways and urban roads (Patil and Nagarale, 2019).

2.6 Approaches to Reduce Noise pollution

Exposure to such high noise levels can result in a variety of health effects, including: sleep disturbances with arousals, learning disability, hypertension, cardiovascular disease, and irritation. The avoidance of such consequences has been relegated to obligatory action plans for large infrastructures or urban agglomerations, and in order to optimize mitigations noise generation systems are of critical importance (Del Pizzo *et al.*, 2020).

2.6.1 Noise Barriers

Globally, noise sources are often similar to receivers in most populated areas, with no noise barriers. As a result, the urban living environment is subjected to a high degree of noise pollution. Persistently elevated levels of noise sensitivity have been linked to physiological and other health consequences (Manojkumar et al., 2019). Traffic noise has long been a problem in urban areas, thus certain abatement solutions were proposed for existing roads or roads being redeveloped include forming buffer zones, adding barriers, planting trees, and implementing noise insulation on buildings (Ow and Ghosh, 2017). Noise barriers are civil engineering elements installed along roadways to shield residents from noise emissions. These components, which are often located between high-traffic roads and homes, often have a positive effect on air quality (Reiminger *et al.*, 2020). Some noise control steps are recommended in order to reduce the effect of road noise on receivers. Noise control on existing roads could include erecting noise walls and handling traffic. Noise barriers are strong barriers that are constructed between the highway and suburban areas (Halim *et al.*, 2018).

According to reports, the noise screening impact of vegetation is generally assumed to be poor unless the plantation is dense and the plantation belt is wide, but where effective, noise barriers have been reported to minimize noise levels by 10–15 dB (Ow and Ghosh, 2017). Other than vegetation such as in Figure 2.5, establishing buffer zones along major road areas which is commonly used due to its convenience also can be implemented as the noise and air quality levels are normally higher in these regions (Potvin et al., 2019). Figure 2.6 shows the other barriers that can be used to controlled the noise levels with the construction of wall along the road.