TRAFFIC NOISE PREDICTION IN BANDAR MAHKOTA CHERAS USING CALCULATION OF ROAD TRAFFIC NOISE (CoRTN)

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UNIVERSITI TUNKU ABDUL RAHMAN

TRAFFIC NOISE PREDICTION IN BANDAR MAHKOTA CHERAS USING CALCULATION OF ROAD TRAFFIC NOISE (CoRTN)

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A project report submitted in partial fulfilment of the requirements for the award of Bachelor of Civil Engineering with Honours

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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

I certify that this project report entitled **"TRAFFIC NOISE PREDICTION IN BANDAR MAHKOTA CHERAS USING CALCULATION OF ROAD TRAFFIC NOISE (CoRTN)"** was prepared by **GAN YUYUN** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Civil Engineering with Honours at Universiti Tunku Abdul Rahman.

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ABSTRACT

Noise pollution is a worldwide issue that grows tremendously, especially in the cities areas due to urbanization. Nowadays, the major source of environmental noise is transportation noise, or known as traffic noise. The increasing population lead to an increase in the number of transportation and subsequently contributes to a higher level of road traffic noise. Research on traffic noise is needed to ensure the noise levels are within the acceptable range by referring to the road traffic noise regulations. Studies proved that the CoRTN model was able to provide accurate estimation in Macau, Nigeria and Malaysia. Hence, this study has been conducted, which aimed to investigate the performance of the CoRTN noise prediction model in estimating the road traffic noise level of a road in Bandar Mahkota Cheras. This study has been carried out with the objectives to measure the traffic noise level in Bandar Mahkota Cheras, as well as to develop a noise prediction model, referring to the CoRTN model, using MATLAB. The reliability and accuracy of the CoRTN model were then validated by comparing the measured and predicted noise levels. Field measurements with four control points for peak hour and off-peak hour at Jalan Permaisuri in Bandar Mahkota Cheras were conducted in this study. A noise prediction model has been developed using MATLAB and proven to be workable since the predicted noise level obtained was similar to the value provided in CoRTN for a type of road condition. Besides, by comparing the predicted noise level with the data collected, the results obtained for R^2 correlation for L_{10} and L_{eq} were 0.0285 and 0.0215 respectively which indicated the CoRTN model has low reliability. Next, the mean absolute difference between the predicted L_{10} and measured L_{10} was 3.125 dB(A), while between the predicted L_{eq} and measured L_{eq} was 2.453 dB(A). These values showed that the CoRTN model has high accuracy. Hence, the outcome of this study was the noise prediction model developed based on the CoRTN model was accurate but may not be reliable to be implemented in Malaysia especially for urban areas due to the results obtained were not consistent. The model developed still can be utilised for predicting noise levels in future as a reference, however, improvements were needed to increase the reliability of results and field measurements were required for the comparison of data.

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LIST OF SYMBOLS / ABBREVIATIONS

R^2	Coefficient of Determination
X_i	Predicted ith value
Y_i	Actual ith value
$\bar{X}$	Mean Average Value of the Data Set
N	Size of the Population
q	Hourly Traffic Volume, veh/hr
Q	Traffic Flow, veh/18-hour day
V	Average Speed of the Traffic, m/s
F	Hourly Flow Rate of the Heavy Vehicles, m^3/hr
G	Road Gradient, %
d	Shortest Horizontal Distance Measured from the Edge of the Nearside Carriageway to the Point of the Reception, m
h	Vertical Distance Measured from the Line Source to the Point of Reception, m
H	Mean Height, m
p	Percentage of Heavy Vehicles, %
I	Section of the Absorbing Ground Measured from the Nearside Carriageway Edge to the Boundaries of the Segment to the Reception Point
θ	Angle of View, °
θ'	Total Value of the Subtended Angles of All the Reflecting Façade that Located on the Other Direction of the Road Facing to the Receiver Point, °
δ	Barrier Path Difference, m

ASJ	Acoustical Society of Japan
CNOSSOS-EU	Common Noise Assessment Methods
CoRTN	Calculation of Road Traffic Noise
CVD	Cardiovascular Diseases
DALY	Disability Adjusted Life Years
DMRB	Design Manual for Roads and Bridges
DOE	Department of Environment

EEA	European Environment Agency
FHWA	Federal Highway Administration
HGV	Heavy Goods Vehicles
LLM	Lembaga Lebuhraya Malaysia
MESTECC	Ministry of Energy, Science, Technology, Environment and Climate Change
MLR	Multiple Linear Regression
NCHRP	National Cooperative Highway Research
Nord 2000	JOINT Nordic
TNM 3.0	Federal Highway Administration Traffic Noise Model
TSC	Program Transportation Systems Centre
UIC	Internal Union of Railways
WHO	World Health Organisation

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CHAPTER 1

INTRODUCTION

1.1 General Introduction

Noise can be defined as a sound that is unwanted or undesirable. It can be classified as occupational or environmental depending on the noise source. Occupational noise is the noise generated from the workplace where the most crucial noise is the construction noise from the construction site or the manufacturing industry. While environmental noise is the noise generated from the non-workplaces such as from the roadway, railways, or airports. Recently, the most critical and major source of environmental noise is the transportation noise or also known as traffic noise which will be investigated and studied in this project (Kim, et al., 2012). According to Grubesa and Suhanek (2020), the distribution of human noise annoyance based on various kinds of noise sources clearly shows that the noise produced by the road traffic is considered the most usual type of traffic noise with 79 % which poses an issue, mainly in the urban areas. Other types of noise sources including railways noise, construction sites noise, aircrafts noise, industrial noise, and other types of activities contribute to 21 % which are lower compared to road traffic noise.

Over the last few decades, Malaysia has developed in many aspects in order to enhance the economic status of the country, especially in transportation. Nowadays, development of the cities and the increasing population of the daily demands have caused the number of ground transportation increased by leaps and bounds. The rising number of transportations has directly contributed to the traffic noise levels. According to the statistics published by the Malaysian Automotive Association, there were 159 752 vehicles including passenger cars and commercial vehicles registered from Year – to – date March 2022 (Malaysian Automotive Association, 2022). The number of vehicles being registered is considered to be high within three months period. The traffic noise is primarily contributed by the effect of friction effect between the surface of the road and the tires of the vehicles, the noise produced by the vehicles’ engines, exhaust system, and aerodynamic noise.

Since road traffic noise has been labelled as a critical environmental issue across the world, there are many developments of noise level prediction models from various countries that aim to assess the traffic noise level and mitigation can be provided to crop the noise problem. Firstly, the prediction model developed by Britain known as the Calculation of Road Traffic Noise (CoRTN) in 1975 and is being implemented in this study. Next, the other prediction model is the Highway Traffic Noise Prediction Model published by the Federal Highway Administration (FHWA) of the United State in 1978. Moreover, the Acoustical Society of Japan (ASJ) created a noise prediction model for the road traffic noise in 1975 which is known as the ASJ Model 1975. This model is then known as ASJ RTN-Model 2008 when the latest version was published in 2009 (Suthanaya, 2015).

Besides, there are traffic noise regulations that exist in Malaysia. In Malaysia, the majority of the new urban cities pose high demands of transportation which might lead to roads congestion and road traffic noise pollution. Hence, the issues related to the road traffic noise are critical in the future. Malaysia's government promulgated the Department of Environment (DOE) Guideline for noise in 2004 to improve the environmental noise in Malaysia. This guideline outlines the permissible noise level based on the different types of land use to monitor the noise level pollution in Malaysia (Haron, et al., 2019).

In this study, the CoRTN model is utilised to estimate the road traffic noise level in Bandar Mahkota Cheras, Kajang, Malaysia. CoRTN is the first official road traffic noise prediction model established by Britain in 1975. CoRTN was able to predict the L_{A10} at the study location. This standard calculates the level of traffic noise depending on the flow of the traffic, the speed of traffic, the percentage of heavy goods vehicles (HGV's) and the propagation distance from the noise source to the receiver. This standard accounts for the correction of the road gradient, road surface type, ground cover correction, obstruction caused by objects and lastly the site layout correction.

Besides, this study utilized MATLAB to create the model for traffic noise prediction. MATLAB is also known as a programming platform that utilised the MATLAB language or the matrix-based language which permits for analyzing and designing of a system with computational mathematics.

MATLAB consists of a variety of applications in all aspects including in the industry world or the academic world for engineering and science. This platform is able to analyze the input data, process and develop algorithms and even create models for applications. This study will be inserting a mathematical equation from the traffic noise prediction model which is the CoRTN into the MATLAB program and generate the analyzed result to forecast the traffic noise level of the study area. In order words, a program has been developed to automate a complete task to forecast the traffic noise level.

1.2 Importance of the Study

This study is related to the prediction of traffic noise in Bandar Mahkota Cheras, Kajang by referring to the noise prediction model CoRTN. The significance of this study is to ratify the accuracy and validity of CoRTN in forecasting the road traffic noise level for Bandar Mahkota Cheras. However, not all traffic noise models able to be simply generalized for the usage of certain areas. This is because the factors like local circumstances and environments will influence the noise generated to vary from one another for different areas and countries. The circumstances include the type, specification, and classification of the vehicles, the meteorological conditions or the weather of the area (Halim, et al., 2017). CoRTN was first developed in the United Kingdom in 1976 with the goal to assess the capability of properties to have extra noise insulation in line with the UK Noise Insulation Regulation at the time. The method was then revised in 1988 and some advice on the procedure was developed by UK Highways Agency Design Manual for Roads and Bridges (DMRB) in 2008 and 2011. Hence, slight modifications would be required since the method was published and already existed for a long period and the area assessed was dependent on the United Kingdom (Mclver, Lester and Jackett, 2020). Thus, this study is important to verify the accuracy of this approach in predicting the noise level in the area of Bandar Mahkota Cheras located in Selangor, Malaysia.

Next, the significance of the study is to develop a tool for noise prediction using MATLAB. This programming platform can effectively extend the functionality and capability of the noise prediction model by working with the CoRTN. Since this method is designed for users from all around the world where the charts and correction formulae are simple that allowed users to use it manually. This method is available for the third-party software platform such as MATLAB to implement it. However, own modelling rules are required to be developed where this method did not comprise procedures to thoroughly solve and handle the complexity in conditions such as topography and screening in the software (Mclver, Lester and Jackett, 2020). With the aid of MATLAB, the process of predicting the noise level in the future is being easier and more convenient compared to the traditional calculation method which this tool can provide time and cost efficiency to the user. Hence, this study is censorious to develop a noise prediction model with the aid of advanced software MATLAB and expand the application of the model in the future.

1.3 Problem Statement

Transportation noise is a major source of noise pollution. Observing the quantity of transport vehicles travelling on the roadway are in the increasing trend over the past few years, hence it is crucial to research on traffic noise and ensure the noise level is still within the acceptable range by referring to the standard. According to the Environmental Noise Guidelines published by the World Health Organisation (WHO), noise level generated by road traffic is recommended below 53 dB for the average exposure of noise since noise above the limit will cause adverse health effects. Moreover, during night noise exposure, the noise level is recommended to be below 45 dB to avoid causing a significant impact on the sleep behaviour of the residents (World Health Organization Regional Office for Europe, 2018). Referring to Segaran, et al. (2020), there are different noise level limits published by WHO and other countries including Malaysia, Germany, Australia, Japan, Korea, Philippines, and Iran during daytime and night-time. In Malaysia, the noise level limit set by the DOE is 55 dB(A) during daytime while during the night-time, the noise level limit is 50 dB(A) in low-density areas.

A high level of traffic noise would bring significant impacts to the community and hence this problem needed to be monitored frequently. According to WHO, traffic noise contributed to health issues including headaches, stress, high blood pressure, sleep problems and other health problems. The noise pollution which disturbs sleep will bring an impact on carcinogenesis which is related to cancer development. Additionally, the children have high risk of facing difficulty in the learning process if continuously exposed to environmental noise for a long period. Babisch (2005) has developed a noise effect reaction scheme that established that noise able to move through either a direct or an indirect pathway. For the noise level exceeded 85 dB(A), the direct pathway cause hearing loss issues. For the low level of noise, it act as an indirect pathway that indicates the perceptible and physiological reaction of the sound. This might activate the cortical and lead to disturbance of human activities, sleep, and communication. This disturbance contribute to emotional stress responses like noise annoyance. Besides, the indirect pathway increase the sympathetic retaliation and also the release of corticoids, which results in rising in the viscosity of the blood, coagulation of blood and an increase in blood pressure. Hence, if humans are subjected to noise stress continuously for a prolonged period, the body might develop cardiovascular diseases (CVD) such as stroke, heart failure, coronary artery problems and arterial hypertension (Munzel, et al., 2020).

Another problem would be Bandar Mahkota Cheras is lack of systematic city planning to cope with the tremendous increase in population in this city. Residents around Bandar Mahkota Cheras are required to face daily traffic congestion especially during peak hours and will be stuck in the traffic when travelling to work or back home. Obviously, the traffic gridlock indicated that a very huge amount of ground vehicles are travelling on the roadways and this will contribute to a crucial level of road traffic noise during the daytime and night-time. The city planning is not able to cater for the population in the area which is approximately 200 000 people (Star Property, 2022). The traffic noise problem turns more significant due to the ease of accessibility to this city where Bandar Mahkota Cheras is linked to the Cheras – Kajang Highway and SILK Highway (Sistem Lingkaran Kajang). These conditions allowed more and more vehicles to travel to this city and relatively contribute to the road traffic noise.

Besides, the problem is the driver’s behaviour and low percentages of compliance with the traffic regulations outlined by the government agencies. Malaysia has introduced various kinds of public transport including LRT, monorail, MRT, commuters and buses. However, most of the residents still favour depending on their own vehicles and this increased the amount of vehicles travelling on the road and lead to rises in traffic noise. Nowadays, teenagers are likely to modify their motor vehicle engines to have ear-splitting noises when travelling on the roadways to attract attention. This contribute to traffic noise as the sound produced by such types of modified engine are over the sound limit outlined in the regulations published by the local government agencies.

The other problem is there are commercial areas and residential areas located along the road that be investigated. Traffic noise generated from the roadways is significant since the community or the residents who live nearby the road in Bandar Mahkota Cheras will be impacted and faced with health issues if continuously exposed to the high level of road traffic noise generated by the vehicle travelled on the roadway. In-depth research is needed to be conducted regarding traffic noise in order to enhance the method of measuring and predicting the noise level. This is important to assist the transportation agency in solving the traffic noise problem.

1.4 Aim and Objectives

This study aimed to investigate the performance of CoRTN in predicting the road traffic noise level in Bandar Mahkota Cheras. There are several objectives of this study which are:

(i) To measure the level of traffic noise at Bandar Mahkota Cheras in a specific period.

(ii) To program the model for road traffic noise level prediction utilising the CoRTN model with the aid of MATLAB.

(iii) To validate the accuracy and the reliability of the prediction model by having a comparison of the predicted noise level with the results of the measured noise level from the study area.

1.5 Scope and Limitation of the Study

There are several scopes and limitations in this study in predicting the road traffic noise level in Bandar Mahkota Cheras which is located in the Cheras-Kajang area. For the scope of this study, there are several noise prediction models being developed in this world to predict the noise level including the CoRTN, FHWA, ASJ RTN-Model, Common Noise Assessment Methods in Europe (CNOSSOS-EU), Federal Highway Administration Traffic Noise

Model (TNM 3.0), JOINT Nordic noise prediction method (Nord 2000) and others. However, the standard or noise prediction model implemented in this study is CoRTN. This method is chosen for the study since it is quite common to be implemented in other countries such as the United Kingdom, Australia, New Zealand and Hong Kong. Additionally, this model is the only model used by the local authorities of Hong Kong and the United Kingdom to evaluate the impacts of road traffic on the environment. In Malaysia, there are many researchers who conducted a study of road traffic noise prediction using the CoRTN model. Hence, this model is the scope of this study despite other models to validate the performance of this model in estimating the road traffic noise levels for the city in Malaysia.

Next, MATLAB is used to formulate the noise prediction model in this study. This is because MATLAB is able to handle various kinds of complex tasks and ease the work for users. The data and information collected can be input into the model and MATLAB is able to analyze it and produce the output effectively. Moreover, the study is focused only on the road in Bandar Mahkota Cheras. Several stations are being set up along the road for the noise level measurement within a specific period in order to get the measured results for traffic noise levels generated by the vehicles. Lastly, this study focused on the accuracy and reliability test of the CoRTN model. For the accuracy test, a comparison between the predicted results generated from MATLAB with the measured noise levels from the study area are carried out to identify the absolute difference between both the predicted and measured results. For the reliability test, the coefficient of determination for the multiple regression or known as R^2 are being investigated to validate the reliability of the CoRTN model.

For the limitation of this study, the noise prediction model implemented is limited to the CoRTN model only. The results of noise level obtained from the field measurement are used to compare with the CoRTN model only and not able to compare to other models and measure their performance due to time constraints for this study. Next, the study of road traffic noise level is limited to one road which is Jalan Permaisuri in Bandar Mahkota Cheras. The results are collected from only one road in the urban area and are not able to compare with other roads from the same study area or roads located in the rural area. This is due to time constraints and limited resources in terms of personnel and measuring equipment.

1.6 Contribution of the Study

This study conducted a field measurement at Jalan Permaisuri located in Bandar Mahkota Cheras. Four control points are provided along the road to measure the road traffic noise level during the peak and off-peak hours. Hence, the values or parameters for noise levels such as L_{10}, L_{50}, L_{90}, L_{eq}, L_{peak}, L_{max} and L_{min} can be measured. The trend of the traffic noise along this road can be utilized for further study and mitigation can be provided to ensure the noise level was within the acceptable range for the road.

Moreover, this study developed a noise prediction model using MATLAB by referring to the CoRTN model. The noise prediction model was assessed to ensure it is workable by comparing the value of the predicted basic noise level with the value of the basic noise level provided in the CoRTN model. Besides, the reliability and accuracy of the CoRTN model also have been measured by calculating the R^2 correlation and mean absolute differences. Hence, this model can be implemented to estimate the traffic noise level of a road as a reference to compare with the results obtained from the field measurement in future research. This model is able to save time and costs where the required data can be inputted into the model and the value of the predicted traffic noise level can be automatically forecasted within a short period, eliminating the need for graph analysis and lengthy calculation steps stated in the CoRTN noise prediction model.

1.7 Outline of the Report

Chapter 1 of this study was the introduction including the general introduction, the importance of the study, problem statement, aim and objectives, scope and limitation of the study and the contribution of the study.

Chapter 2 of this study was regarding the literature review. This chapter discussed the topic related to noise pollution, traffic noise, standards and regulations for traffic noise, traffic noise prediction models, CoRTN model, noise mitigation and research gap.

Chapter 3 was the methodology and work plan. This chapter discussed the overview of the research methodology, study area, measurement of traffic noise, road traffic noise prediction model referring to the CoRTN model, noise prediction model development using MATLAB and lastly the Gantt chart.

Chapter 4 was the results and discussion on the results obtained from the field measurement. Next, this chapter discussed the development of the noise prediction model by comparing the predicted noise level between the CoRTN model and MATLAB. Lastly, the reliability and accuracy of the CoRTN model have also been evaluated.

Chapter 5 was the conclusions and recommendations for future works that can be studied for other researches.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Noise pollution is a worldwide problem that growth rapidly especially in the cities area due to urbanization. The word noise came from the Latin word ‘Nausea’ with the meaning of sickness and feeling the need to vomit. Noise pollution is generally any unwanted and unpleasant sound that interferes with human health and wildlife or may cause harmful effects on the environmental quality (Jain, Cui and Domen, 2016). Sound pressure is a fundamental way to measure the air vibration. The decibel (dB) is a logarithmic scale utilised to measure the range of sound pressure that is able to be detected by human ears (Sulaiman, et al., 2018). Besides, the different characteristics of noise make it to be various from other pollutants such as air and water pollutants. Noise is invisible, it will disappear and can’t be traced in the environment when the noise source is turned off. Hence, noise pollution is generally not emphasized and attracts lesser attention than other pollution issues including water and air pollution (Gonzalez, 2014). However, the ambient noise has raised to an unbearable level in many cities around the world. Noise pollution brings tremendous negative impacts and the occurrence of noise pollution is being more critical as the development of the countries keeps continued over the past decade (Feng, Noh and Mansob, 2020).

There are various kinds of noise pollution. Figure 2.1 is the distribution of human noise annoyance based on various kinds of noise sources. It clearly shows that the noise caused by road traffic has the highest percentage which is 79 %, this might be due to the tremendous increase in transportation or the number of vehicles travelled on the road, especially in the urban areas. The other noise sources including noise generated from aircraft, railways, industry and construction sites account for 4 % respectively and are relatively lower percentages compared to road traffic noise. This is because these types of noise sources are generated from a location far from the local community and hence contribute to lower noise annoyance. Moreover, the other noise sources including other business activities, shooting ranges and motor sports have lower percentages of noise annoyance which the value are 2 %, 2 % and 1 % respectively (Grubesa and Suhanek, 2020).

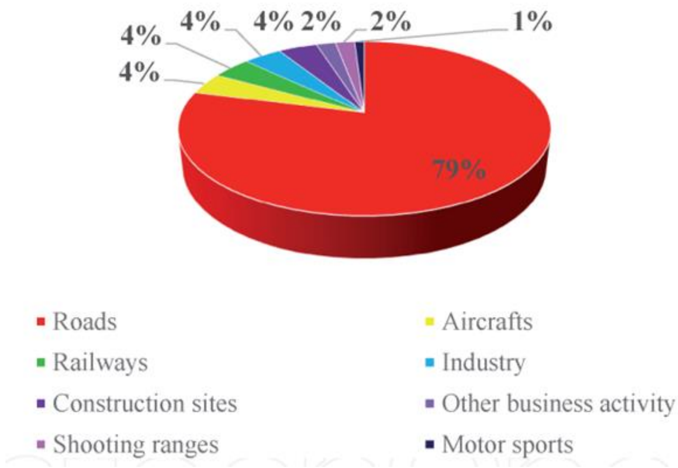


Figure 2.1: Distribution of Human Noise Annoyance Based on Various Kinds of Noise Sources (Grubesa and Suhanek, 2020).

Construction noise is a noticeable and critical issue at the construction site. It can be generated from the demolition and excavation works, piling works and continuous noise when the construction works progressed. The level of construction noise might be different throughout the day and possibly keep generating throughout the night. The effects of the construction noise on local residents or community will be affected by some factors including the site location, operating times, the ambient levels present in the area and the specific features of the noise. Moreover, there are several sources of noise that can be generated from the construction site including the motions of the vehicles especially the heavy vehicles, welding, drilling, cutting the steel, breaking up concrete, pumping and others. BS 5228-1 (2009) is used in the United Kingdom to control the noise and vibration in construction sites. Table 2.1 is the ordinary noise levels for different construction activities (BS 5228-1, 2009). The data indicates the petrol hand-held circular saw gives the highest typical noise level at 10 m which is 91 dB, followed by the precast concrete pilling with a hydraulic hammer with a typical noise level of 89 dB and breaking windows with a lump hammer with a value of 81 dB. Furthermore, industrial noise does not have such predictive techniques to predict the noise level, hence the method to determine the source emission is through measurement (Murphy and King, 2014).

Table 2.1: Typical Noise Levels for Different Construction Activities (BS 5228-1, 2009).

Equipment	L_{Aeq} **at 10 m**
Breaking up concrete with pulverizer mounted on excavator	76
Breaking stud partition with lump hammer	69
Breaking windows with lump hammer	81
Clearing site with a dozer	75
Loading lorries with tracked excavator	79
Water pump (size 6 in.)	65
Precast concrete piling – hydraulic hammer	89
Small cement mixer	61
Diesel scissor lift (idling)	70
Petrol hand – held circular saw	91
Angle grinder (grinding steel)	80
Hand – held cordless nail gun	73

Industrial noise is the noise generated from the industrial area including steel manufacturing plants, power stations for coal-fired, furniture manufacturing workshops, vehicle assembly plants, train depots, mineral extraction sites and others. It is associated with the industrial process which requires exposure to high decibel levels of noise. The impacts of industrial noise has been an issue or topic of debate among researchers for many years ago and there are regulations that limit the noise exposure of industrial workers where industrial employers are required to limit their employees' noise exposure to 90 dB(A) during an eight-hour period according to Occupational Noise Exposure Regulation in United State (Atmaca, Peker and Altin, 2005). Atmaca, Peker and Altin (2005) have conducted research on industrial noise exposure in several industries including the textile industries, iron and steel industries, cement industries and concrete traverse industries in Sivas, Turkey. Table 2.2 is the results of industrial noise measurement which indicates that all the industries are not meeting the standard stated in Noise Control Regulations and the concrete traverse industries have the highest noise level with 107 dB(A). The research has shown that 73.83 % of the industrial employees were affected by the noise disturbance during their working period and the industrial noise caused nervousness problems among the workers at a rate of 60.69 %. Moreover, 30.86 % of the employees suffered from ailments such as hearing loss and ringing in the ear.

Table 2.2: Results of Noise Level Measurement for Different Types of Industries (Atmaca, Peker and Altin, 2005).

Industries	**Max (dBA)**	**Min (dBA)**
Textile	99	75
Iron and Steel	100	77
Cement	106	70
Concrete Traverse	107	80

2.2 Traffic Noise

Noise pollution that is induced by transportation is generated from several sources including the road traffic noise, railway noise, aircraft noise, marine noise and others. Nowadays, road traffic noise is considered one of the main environmental problems worldwide. Traffic noise is the unwanted or undesired sound produced by vehicles when travelling on the roadways. Among various aspects of transportation noise, traffic noise is the most significant and widespread source of noise (Segaran, et al., 2020). Many research has been conducted on traffic noise and this section is related to the sources of the noise and the negative impacts of traffic noise.

2.2.1 Noise Sources

In the year 2014, European Environment Agency (EEA) categorized urban noise as the primary environmental threat to health in Europe. It reported that road traffic is the major contributor to environmental noise and forecasted approximately 125 million people which is around 49 % of the overall population living in Europe were influenced by the noise level higher than 55 dB(A). Figure 2.2 is the presentation of several most common noise sources with the frequency content and the arrangement on a sound level scale. Based on Figure 2.2, the traffic noise generated by the vehicle including the normal vehicle and the heavy truck is between 80 dB to 110 dB (Ouis, 2001).

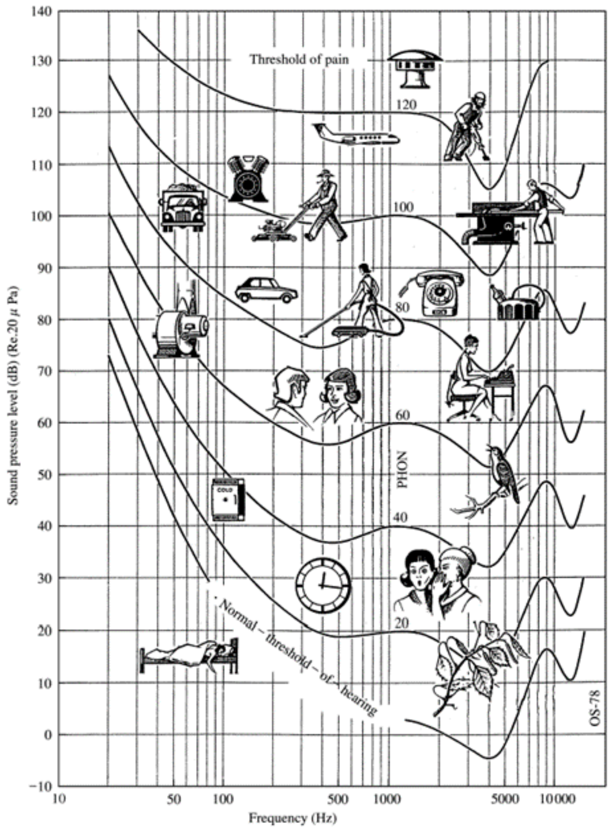


Figure 2.2: Typical Sound Pressure Level and Frequency of Common Noise Sources (Ouis, 2001).

Moreover, the Internal Union of Railways (UIC) has reported the average noise level produced by various kinds of vehicles as shown in Table 2.3. Based on the results, it can be observed that the turbojet airplane generated the highest average noise level with a value of 150 dB(A) and the cargo train has the lowest average noise level which is 60 dB(A). This study is more focused on road traffic noise and hence the average noise level for road vehicles including cars, motorcycles and heavy cargo trucks are 82 dB(A), 90 dB(A), and 103 dB(A) respectively. The heavy cargo trucks generated higher noise pollution than other vehicles due to the huge engine noise generated when moving in order to transport the high loading. The results also show that all types of trains generally produced lower noise levels than road vehicles which is a more favourable type of public transport in terms of noise that affects human health and environmental pollution (Grubesa and Suhanek, 2020).

Table 2.3: Average Noise Level of Different Types of Vehicles (Grubesa and Suhanek, 2020).

Type of vehicle	**Average noise level, dB(A)**
Car (700 – 1300 cm^3)	82
Motorcycle	90
Heavy cargo truck	103
Turbojet airplane	150
Fast passenger train	65
Cargo train (speed up to 120 km/h)	60
Local train	70

According to Grubesa and Suhanek (2020), road traffic noise is depending on several factors including the type of the vehicles, the friction between the tyres of the vehicles and the roadway surfaces and the driving style of the driver. Engine vibrates and emits noise when it undergoes compression and expansion. The engine noise is influenced by the volume, speed and capacity of the engine. Additionally, the rapid discharge of gases into the exhaust system for opening the exhaust valve will contribute to exhaust system noise. The type of surface of the road, speed, and driving technique will impact the tyre noise when the tyres come into contact with the road surfaces.

Moreover, Haron, et al. (2019) had done a study on the traffic noise problem. They discovered that traffic noise can be generated by individual vehicles, traffic volume, speed and composition which is the quantity of commercial vehicles, the slope of the road and pavement surface type. The noise generated by a vehicle's engine, gearbox, exhaust, tyre friction with the road surface, and air turbulence combined to create the noise that is generated by each vehicle. The tyre noise will increase significantly with the speed of the vehicles where studies established that the speeds from 30 to 50 km/hr for normal vehicles and speeds from 40 to 80 km/hr for trucks, the noise generated by the tyre of vehicles will increased until it dominated the overall noise of the vehicle. In addition, decreasing the traffic volume by 50 % will decrease 3 dB(A) of noise. For traffic speed, reducing 50 % of speed can reduce 3 dB(A) of noise and reducing 75 % of speed can reduce 6 dB(A) of noise (Boer and Schroten, 2007). In terms of the pavement type, the porous pavement generates noise from 3 to 5 dB(A) less noise than the road built by hot mix asphalt. For the slope of the road, the noise level generated by the engine and exhaust of the vehicles increases gradually when it travels up a sloping pavement (Haron, et al., 2019).

2.2.2 Impacts of Traffic Noise

According to an environmental noise expert from EEA (2021), exposure to noise in long term can lead to various health issues like annoyance, sleep disturbance and adverse impacts on the metabolic and cardiovascular systems. With the data collected, EEA (2021) estimates that environmental noise particularly road traffic noise cause 48 000 of new cases of ischaemic heart disease and also 12 000 cases of premature death annually. The agency also forecasts the number of people who suffered serious high annoyance and high sleep disturbance were 22 million and 6.5 million respectively. Hence, noise pollution will bring a negative impact on the quality of life and mental health. Moreover, in Western European countries, the environmental noise that contributed to the burden of disease related to traffic annoyance in the range of 1.0 to 1.6 million DALYs1 (disability adjusted life years), 587 000, years (Soares, et al., 2017). Besides, traffic noise is the dominant or major noise source in living and working environments which seriously impacts the roadside residents by decreasing their quality of life significantly (Ranpise and Tandel, 2022). In addition, traffic noise will interfere with communication, leading to cardiovascular effects, causing annoyance and sleep disturbances, reducing performance and altering social behaviour (Kalansuriya, Pannila and Sonnadara, 2015).

Pachiappan and Govindaraj (2014) study the impacts of traffic noise by relying on the length of time and the noise intensity exposure. According to the research, they divided the impacts of traffic noise into four categories which were the physical aspect, depression, biological responses and influence on the execution of the tasks. For the physical aspect, traffic noise might cause hearing defects, while for depression, traffic noise will cause some effects on humans including irritability, stress and sleeplessness. In terms of biological responses, overexposure to traffic noise will lead to high blood pressure, ulcers and affect the cardiovascular rate. Next, traffic noise will affect the execution of work since noise caused a decrease in efficiency and misunderstanding during communication.

According to WHO (2018), road traffic noise pollution can have seven distinct impacts on human health including hearing impairment, interference in communication, sleep disruptions, cardiovascular diseases, mental health issues, poor working performance and negative social behaviour and irritation reactions. Firstly, noise pollution will cause hearing impairment where hearing is critical for overall well-being. Hearing disability or impairment means a rise in the threshold of hearing which clinically determined by audiometry. Exposure to sound levels over of 85 dB for more than eight hours will cause hazards and sound levels exceeds 85 dB will cause damage corresponding to the sound pressure and time of exposure. Hearing loss will eventually lead to loneliness, depression, impaired performance, limited job opportunity and others (Ihemeje and Onyelowe, 2021). Next, the impact of traffic noise pollution is causing interference in spoken communication. Noise pollution will interfere with the ability to understand the common conversation and contribute to disabilities and behavioural changes. This might lead to issues related to concentration, fatigue, misunderstanding and reduced working capacity.

Furthermore, the impact of traffic noise is sleeping disturbances since the environmental noise is considered the major factor that disturbed human sleep (Stansfeld and Matheson, 2003). Continuous road traffic noise exceeded 30 dB will disturb the quality of sleep. The primary sleep disturbance is hard falling asleep, secondary effects might include fatigue and reduced performance where decreased alertness will lead to accidents, injuries or even death due to lack of sleep. Moreover, the impact of traffic noise pollution is it will cause cardiovascular disturbance. Noise can cause responses in the endocrine and autonomic nervous systems, which might affect the cardiovascular system and increasing the risk of developing cardiovascular disease (Babisch, et al., 2005). Acute exposure to traffic noise triggers hormonal and neurological system reactions, raising blood pressure, heart rate, and causing vasoconstriction. Reflex reactions will also be triggered by quick and unexpected noise exposure. In addition, traffic noise pollution cause disturbances in mental health. Traffic noise will accelerate the development of latent mental disorders and contribute to several adverse effects including anxiety, emotional instability, nausea, headache and others (Ihemeje and Onyelowe, 2021). Next, traffic noise pollution will impair task performance. Research has shown that noise pollution will strongly influence reading attention, problem-solving and memory. Noise pollution also brings a significant effect on memory deficits and leads to errors. There are two types of memory deficits including the recall of the contents of the subject and the recall of incidental details (Berglund and Lindvall, 1995). Lastly, the impacts of traffic noise pollution led to negative social behaviour and annoyance reactions. Noise pollution causes several negative behaviours such as disappointment, dissatisfaction, depression, anxiety and others. Berglund and Lindvall (1995) stated that noise exposure will contribute to change in everyday behaviour, change in social behaviour, change in social indicators and also change in moods.

2.3 Traffic Noise Regulations

Traffic noise regulations are the guideline that outlines the noise limits and aimed to minimize the noise disturbance in the environment. The guidelines provide the procedures for the measurement, assessment and mitigation of environmental noise. This section will include the traffic noise regulations in other countries and the traffic noise regulations in Malaysia.

2.3.1 Regulations in Other Countries

According to Moroe and Mabaso (2022), the majority of the countries including Australia, United States, India and Japan have the permissible noise level since the tremendously rise in environmental noise pollution. The United States Federal Highways Administration and the World Health Organization have established noise standards for various types of land use such as residential, commercial, industrial and others. Moreover, the United State Environmental Protection Agency has designated noise-sensitive areas or zones. For noise levels within 55 to 60 dB(A), the sensitivity index is risky. For noise levels within 60 to 65 dB(A), the sensitivity index is moderately risky. Next, noise levels within 65 to 70 dB(A) have a sensitivity index of high risk. The noise level from 70 to 75 dB(A) has a sensitivity index of dangerous. Moreover, the sensitivity index considers highly dangerous for noise levels from 75 to 80 dB(A). Lastly, the sensitivity index is extremely dangerous when the noise level exceeded 80 dB(A).

The noise limits set by each of the countries are various depending on the sensitivity of the area, the type of location and various regulations in respective countries. In United State, the noise level standard is designed according to the noise regulation known as "Procedures for Abatement of Highway Traffic Noise and Construction Noise" (23 CFR 772) developed by the Federal Highway Administration (FHWA). According to the World Health Organisation (WHO), the noise level limit is 55 dB(A) during daytime while during night-time, the noise limit is 45 dB(A). Table 2.4 below shows the noise level standard of respective countries during daytime and night-time. The noise level limits in Germany, Australia and Japan during daytime and night-time are 45 dB(A) and 35 dB(A) respectively which are lower compared to the limit set by WHO. Besides, Korea and the Philippines have the same noise level limit of 50 dB(A) during daytime but during night-time, the noise level limit for Korea is 45 dB(A) and the noise level limit for the Philippines is as low as 40 dB(A). For Iran, the noise limits are various for residential areas, commercial areas and industrial areas. The noise level limits range from 55 dB(A) to 75 dB(A) during the daytime and range from 45 dB(A) to 65 dB(A) during the night-time (Segeran, et al., 2020).

Table 2.4: Noise Level Standard by WHO and Various Countries (Segeran, et al., 2020).

Noise Level Limit	**Noise level L_{eq}, dB(A)**	
	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) (Commercial area) (Industrial area)	 55 65 75	 45 55 65

2.3.2 Regulations in Malaysia

In Malaysia, traffic noise regulation is referred to the Guidelines for Environmental Noise Limits and Control Third Edition published by the Department of Environment of the Ministry of Energy, Science, Technology, Environment and Climate Change (MESTECC) in the year 2019. The guidelines provide guidance and recommendations for the ambient noise standards to minimize the environmental disturbance. It also highlights the noise limits in the environment for the new development and projects to protect the public from excessive noise. It presents the procedures or guidelines for measuring, assessing and mitigating the environmental noise. Generally, these guidelines cover all ordinary types of environmental noise sources and noise pollution. Table 2.5 below is the suggested permissible noise level from the road traffic noise for the proposed construction of new roads or proposed rehabilitation of existing roads.

According to Table 2.5, the noise level limit for the residential areas including the low density, medium density and high-density areas is within the range of 55 dB(A) to 65 dB(A) for daytime and 50 dB(A) to 60 dB(A) during night-time. For commercial or business areas, the noise level limit is 70 dB(A) for daytime while for night-time, the noise limit is 60 dB(A). For the industrial area, the noise level limit is the highest compared to the residential area and commercial area, where the noise limits for daytime and night-time are 75 dB(A) and 65 dB(A) respectively (DOE, 2007). Hence, the assessment of road traffic noise levels accurately reflected the degree of noise pollution in the residential area. The results allowed for identification of the preservative measures to reduce the annoyance caused by traffic noise in the residential areas (Segeran, et al., 2020).

Table 2.5: Limiting Sound Level (L_{Aeq}) from Road Traffic (DOE, 2007).

Receiving Land Use Category	Day Time 7.00 a.m. – 10.00 p.m.	Night-Time 10.00 p.m. – 7.00 a.m.
Noise Sensitives Areas Low Density Residential Areas	55 dB(A)	50 dB(A)
Suburban Residential (Medium Density)	60 dB(A)	55 dB(A)
Urban Residential (High Density)	65 dB(A)	60 dB(A)
Commercial, Business	70 dB(A)	60 dB(A)
Industrial	75 dB(A)	65 dB(A)

2.4 Traffic Noise Prediction Model

Difference kinds of noise prediction models were developed after World War II has indicated the concerns of the nation about noise pollution. Road traffic noise is a critical environmental problem worldwide and hence the establishment of traffic noise models is required to assess the traffic noise level and look into reduction measures (Suthanaya, 2015). There are several road traffic noise prediction models including the FHWA model, ASJ model, GIS model of China and CoRTN model. This section will we discussing on the first three methods and the CoRTN method will be discussed in the next section.

2.4.1 FHWA Model

Barry and Reagan developed a model in response to the flaws in the pre-existing methods for predicting highway noise, the report FHWA-RD-77-108 was produced in 1979. This model considered the area that was not covered by the National Cooperative Highway Research Program (NCHRP) and the Transportation Systems Centre (TSC) models of the USA. This model used a sound level as a reference and determines the noise level through a series of modifications. The field measurement of each individual vehicle determined the reference sound level, which also served as the energy mean emission level. This level is then adjusted to take into consideration several factors including traffic flow, receiver distance from the roads, roads with finite length, ground cover and the effects of shielding. Moreover, this model considered a point source moving continuously with similar speed. The authors made the comparison between the predicted A-weighted sound pressure levels and the

Four State Noise Inventory which is the data abstracted from a program. The receiver's distance from the source and the vehicle compositions affects the accuracy of the method. There are three assumptions in this model where the vehicles are illustrated as the acoustic point sources. The second assumption is the distribution of the emissions levels between groups such as cars, medium trucks and heavy trucks is normal. The last assumption is the effects of the distance serve as a proxy for the propagation losses (Rajakumara and Gaowda, 2008).

2.4.2 ASJ Model

The Acoustical Society of Japan published a method known as the ASJ model in 1975 for the prediction of pseudo-L_{50} resulting from the road traffic which is freely flowing. This model is first mentioned by Koyasu in 1978 and updated in 1993 by Takagi and Yamamoto. In the updated version of this model, the L_{eq} can be calculated directly and is known as A-method. This model also provided the B-method, which is an empirical method that was only applicable far from the line sources (Rajakumara and Gaowda, 2008). According to Suthanaya (2015), this model is frequently applied in the evaluation of road traffic noise on the nearby roads. Furthermore, a new version of this model known as ASJ RTN-Model 2008 is published in April 2009. This model is anticipated to be used to assess the environmental impacts and monitored the regular noise of the existing roadways.

2.4.3 GIS Model of China

China has developed the GIS Road traffic noise prediction model in 2002 where the model is created according to the local environment factors, types of vehicles and traffic patterns in China. The general function of the noise modelling and extra tool for the noise barrier design is provided by this integrated noise – GIS system. A new communication or interaction mode in the manner of 'WHAT IF Question/Explanation' was implemented in this system. By using this system, the traffic noise measurement and the design of noise barriers have improved to be more precise and more effective. The vehicles have been classified into three categories in this study including light cars (LC), medium trucks (MT) and heavy trucks (HT). Based on the element of acoustic equivalence between various classes of the vehicle, a composite relationship was established. The final version of the noise prediction model considered the adjustment for the speed, distance, gradient, traffic flow, ground absorption, finite length of the road segment and the effect of shielding. According to Rajakumara and Gaowda (2008), the results obtained from the model at locations nearer to the road carriageway have higher accuracy since the environment of sound propagation was low complexity. This model gives accuracy for traffic noise prediction to 0.8 dB(A) and 2.1 dB(A) for locations nearer to the road and locations within the housing estate respectively. Furthermore, the prediction results do not have an error in any conditions and this model provides predictive accuracy of 2.0 dB(A) when compared to the FHWA model.

2.5 Calculation of Road Traffic Noise

CoRTN is a noise prediction model that is used by many researchers in the investigation of the road traffic noise level around the world. This section discussed the history of CoRTN and the implementation of the CoRTN model in other countries and in Malaysia.

2.5.1 History of CoRTN

This model is published in 1975 by the Department of the Environment and the Welsh Office in the UK. This model aids with road design and establishes the British Land Compensation Act's entitlements to soundproofing private residences on public property. This affected the selection of L_{10} as the index of noise. This method is revised in 1988 and the UK Highways Agency Design Manual for Roads and Bridges (DMRB) published additional advice on the CoRTN procedure in 2008 and 2011 (Mclver, Lester and Jackett, 2020). The CoRTN model frequently uses curve fitting when compared to the empirical data, even though this does not conform to the theory. The road authorities in Britain use this model as their only tool to evaluate the effects of traffic on the environment.

According to Mclver, Lester and Jackett (2020), this model provides charts and simple correction formulae that can be implemented manually since it was designed to be accessible to a wide range of users. Moreover, it is possible to use the CoRTN technique with third-party software platforms. When applying the CoRTN method to topography and screening conditions made possible by the software platforms, it may be necessary for the software developers to develop their own modelling rules if the method does not provide the steps that are able to fully handle the complexity.

For the application of this method, a reference noise level taken 0.5 m above a surface made by densely graded asphaltic concrete and positioned 3.5 m inside measured from the edge line of the nearside road is implemented by the CoRTN source emission model to represent the uninterrupted stream of the traffic. The noise level is then modified to consider other factors related to traffic such as the composition and speed of the vehicles. The gradient of the road and surface types of the road is also being considered for the modified noise level. In addition, the CoRTN method divides the roads being modelled into several discrete line sources and identifies the contribution from each segment to the noise level at the receiver location in order to calculate the level traffic noise at the receiver location. CoRTN modified the source emission level by adjusting the distance or length between the nearside edge of the carriageway to the location of the receiver, the amount of the “absorptive” ground cover, the angle at which the roadways are visible from the location of the receiver, diffraction attenuation and the effects of reflection. Compared to other methods or approaches that are calculated from the source and implement the propagation models in computing the spread of the noise from the sources to receivers, the CoRTN approach bases the calculation on the receiver (Mclver, Lester and Jackett, 2020).

2.5.2 Implementation of CoRTN Model in Other Countries and in Malaysia

Lam and Tam (1998) have examined and analyzed the traffic noise level in Hong Kong based on the Calculation of Road Traffic Noise model. They investigated several variables to assess and evaluate the applicability and reliability of the CoRTN model in Hong Kong where the variables included traffic flow, speed of vehicles, composition of traffic, road gradient and surface of the road. They do a simple modification to the prediction procedure where they only reanalyzed the equation’s coefficients and constant parameters by referring to the survey data. They carried out the regression analysis for four observed noise descriptors which included the L_{10}, L_{eq}, L_{50} and L_{90}. Based on the results, they discovered that the CoRTN model overestimates the road traffic noise compared to the measured road traffic noise level obtained from on-site measurements in Hong Kong. This is because the model was developed specifically for the urban pattern, road systems and the local condition in the United Kingdom while the local conditions in Hong Kong haven been investigated.

Peng, Parnell and Kessissoglou (2017) conducted a study to evaluate the performance of the CoRTN model in Australia using statistical and sensitivity analysis and the study was carried out at 323 locations within the state of New South Wales. The analysis shows that the CoRTN is no longer suitable in Australia where heavy vehicles or large trucks are the primary influence on the performance of the CoRTN model. They found that this model will lead to underestimation of noise levels during both daytime and night-time, especially in the presence of heavy vehicles. They also discovered that temperature influence was effective in minimizing the difference in the prediction error in urban areas during daytime and night-time. Besides, the effects of the combination of detailed heavy vehicle input are also able to minimize the difference between the prediction error. Hence, considering the variation of heavy vehicles and temperature for the noise prediction model allows Australia's road authorities to be more efficient in managing the risks regarding the environmental impacts caused by road traffic noise.

Sheng, Xu and Li (2015) have conducted a study to investigate the accuracy of the CoRTN model in estimating the road traffic noise level in a city in Asia in which the majority of the motor vehicles are motorcycles. The study area selected for their research is Macao Peninsula. The variance between the noise level measured and predicted using the CoRTN model at 31 roadsides ranged from -1.47 dB(A) to 2.96 dB(A) with a average difference of +0.52 dB(A). The CoRTN model gives values of R^2 equal to 0.832. Besides, they also evaluated the performance the of CoRTN model in forecasting the vertical distribution of road traffic noise level of a selected building. The differences between the measured and estimated noise level ranged from -1.77 dB(A) to 2.12 dB(A) with a mean difference of +0.28 dB(A). The value of R^2 is 0.836. Hence, they concluded that the CoRTN model is reliable in predicting the traffic noise level for both the roadside and the vertical distribution of the road traffic noise levels for an area consisting of a high percentage of motorcycles usage.

Ibili, et al. (2022) have studied on the noise level of the Ondo central business district located in Nigeria since this area has been exposed to continuous road traffic and various kind of business or commercial activities. They developed the traffic noise prediction model to assess the equivalent noise level (L_{eq}) at the study area by adopting two approaches which are the empirical method CoRTN model and the statistical Multiple Linear Regression (MLR) modelling methods. They obtained the measured L_{eq} for the study area within the range of 68 dB(A) and 76 dB(A) which was relatively high. The measured noise levels give a coefficient of determination (R^2) with the values of 0.943 and 0.963 for CoRTN and MLR respectively which this value is acceptable and these models demonstrated high accuracy in estimating the noise level. Besides, the differences in noise level between the estimated noise level of the CoRTN model and the measured noise level were ranging from -0.51 dB(A) to 2.09 dB(A) with a mean difference of 1.19 dB(A). The values obtained from the on-site measurement and prediction model were satisfactory since the variation is approximately 3 dB (A) acceptable by FHWA. As a result, the models are solid, trustworthy, and precise in measuring the level of road traffic noise in the research region.

Halim, et al. (2017) carry out a study to compare the measured traffic noise level and the predicted noise level by the noise prediction model in Klang Valley located in Malaysia where approximately 30 % of motor vehicles are motorcycles. They carried out the analysis on the L_{10} CoRTN model and the Ontario Ministry of Transportation traffic noise model by implementing the regression analysis. The results show the traffic noise levels indicate a satisfactory correlation with the measured value R^2 of 0.7109. This study proved that the CoRTN model is valid in forecasting traffic noise levels for Klang Valley City in Malaysia although this city has high percentages of motorcycles travelling on the road.

2.6 Noise Mitigation

Noise mitigation is significant to ensure that traffic noise pollutions are able to be monitored and reduced. The purpose of noise control is to modify the generation and propagation of the noise to the receptor to be maintained within a specific limit of the noise level. This might involve engineering methods to manage the generation, containment and reduction of noise reaching the receptors. A systematic approach is needed for noise control, which consists of three basic elements including the noise sources, the transmission path and the receiver or receptor as shown in Figure 2.3. Generally, noise control involves the reduction of noise emissions from the noise sources. Next, for the transmission path, an increase in transmission or insertion loss and attenuation of sound propagation would be recommended for noise mitigation. Lastly, the reduction of transmission of noise and the exposure of noise will be included in the approach for noise control (DOE, 2019).

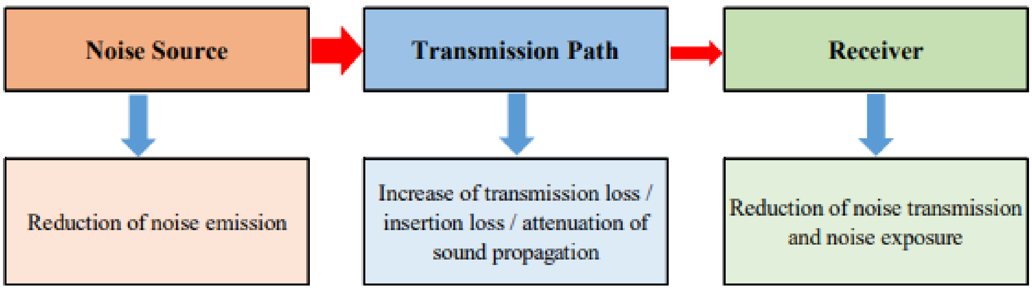


Figure 2.3: Basic Elements in Noise Control (DOE, 2019).

Furthermore, DOE (2019) outline several methods that can be employed for reduction at the noise source stage including the road alignment, the speed limit of the vehicles, traffic restrictions on heavy vehicles and the operating hours, implementation of the buffer zone, vehicles noise emissions control, construction workmanship and lastly is the road maintenance. While noise reduction at the noise transmission path stage, noise barriers can be constructed, tree planting and enclosures can be implemented. Lastly, for noise reduction at the receiver stage, building orientation will be considered and the sound insulation on the buildings is required to be improved. In short, noise control approaches can be applied at any stage of the sound transfer chain from the noise source to the receiver to achieve the desired noise reduction (DOE, 2019). This section will be focused on the noise barrier and tree planting approach for noise mitigation.

2.6.1 Noise Barrier

According to DOE (2019), noise barriers are the most popular noise reduction method for various environmental noise sources including traffic noise. Barriers or screens that are installed in the route of the source-free field sound propagation will produce an area which is considerably quieter or also referred to as an acoustic shadow behind the noise barrier, contributing to the sound wave shielding. However, there are frequency-dependent waves propagated beyond the barrier through diffraction as shown in Figure 2.4.

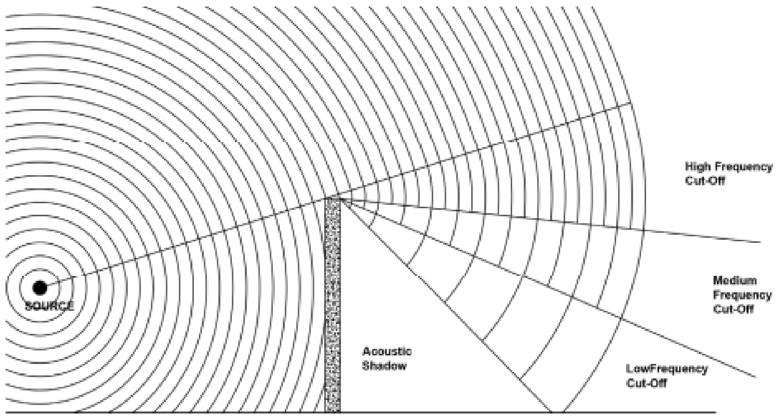


Figure 2.4: Acoustic Screening of Source in the Airborne Transmission Path (DOE, 2019).

It is significant to ensure the noise barriers are an impervious structure such as panels without gaps to be installed in the transmission path of the airborne sound between the noise source and the area that required to be shielded from it to effectively reduce noise pollution. Generally, a typical barrier with a surface weight of at least 10 kg/m^2 to 20 kg/m^2 should have a minimum sound insulation of 25 dB to 30 dB. In order to ensure the barriers function effectively, the receptor should be no direct line of sight to the noise source. To achieve this condition, the height of the barrier needed to be sufficient to block the view from all parts of the noise source from the point of the receptor. Moreover, for level ground, the noise barriers should be installed as close as possible to the receptor or the noise source without any gaps or openings existed at the joints in the noise barrier to ensure the maximum effectiveness of the noise barriers (DOE, 2019).

Moreover, the typical noise barriers installation are the aluminium or steel sheet metal panels, masonry panels, composite panels, and transparent panels such as laminated glass or polycarbonate glass, which this noise barrier will be constructed with acoustic infill for acoustic absorption purposes. Noise barriers can be categorized into two forms which are permanent barriers and temporary barriers. Permanent barriers also known as fixed structures will be always in place, while the temporary barriers will only be erected when required. Temporary barriers include the moveable barriers that may be relocated to different areas depending on the noise source or activities to be carried out. In addition, the road, railway and industry will utilize permanent barriers for noise mitigation. The construction sites will commonly install temporary barriers for noise reduction where it will be positioned around the perimeter of the construction site, adjacent to the noise sensitive area such as the residential areas or hospitals. Figure 2.5 shows the masonry noise barriers employed in highway noise reduction (DOE, 2007).

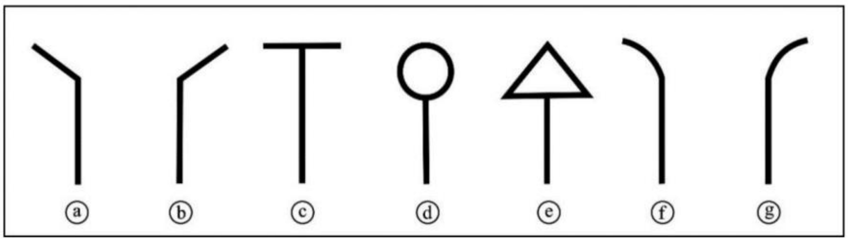
Figure 2.5: Masonry Noise Barriers Employed in Highway Noise Reduction (DOE, 2019).

According to Haron and other researchers (2019), the traffic noise mitigation measure that is implemented in Malaysia is the installation of noise barrier. The design of the noise barrier and the construction technique was referred to guidelines stated by Lembaga Lebuhraya Malaysia (LLM). This method is able to provide comfort to the residents who live near the highways, especially for the highways that produced road traffic noise levels that exceeded the allowable limits stated by the guidelines in DOE 2004. For instance, a hollow block concrete masonry noise barrier with 4 m width has been constructed at Bukit Setiawangsa. This measure is able to protect the residents from traffic noise generated by the Duta Ulu Kelang Expressway (DUKE) highway.

Moreover, another study was conducted to measure the effectiveness and efficiency of several types of noise barriers such as the concrete hollow block and concrete panel in protecting residents in the residential areas from traffic noise originating from DUKE Highway, KESAS Highway and Sungai Besi Highway. The barriers' insertion losses are results from both diffraction and reflection of noise waves by the surfaces of even and solid concrete hollow blocks that faced the highways. This might be due to the cavities that existed in the noise barriers that aided in noise absorption from the traffic noise generated by the highways. Besides, the presence of numerous joints in the concrete hollow blocks type of noise barrier results in sound leakage, where this ultimately decreases the insertion loss of this type of noise barrier. Hence, the concrete panel noise barriers exhibited a more consistent and sufficient insertion loss which were ranging from 5.8 dB(A) to 8.2 dB(A). On the other hand, the concrete hollow blocks noise barriers were fairly effective where it was ranging from 4.5 dB(A) to 9.4 dB(A) (Halim, et al., 2017).

Furthermore, another study was conducted by Lee and other researchers (2022) on the geometries of noise barriers. Figure 2.6 shows the geometries of different types of noise barriers where ⓐ is an L-shape towards the left, ⓑ is an L-shape towards the right, ⓒ is a T-shape, ⓓ is the cylindrical, ⓔ is the roof edge; ⓕ is curved cantilever towards the left and lastly ⓖ is the curved cantilever towards the right. The study stated that the L-shaped design of noise barriers has been most commonly used in recent years for noise barriers, as well as the curved cantilever and straight-edge noise barriers. In the study conducted by Lee and other researchers (2022), five different types of noise barriers have been erected along the roads within an area of 0.785 km^2 at Guangzhou University in order to validate the effectiveness of different geometry of noise barriers. The stimulation of noise maps proved that the L-shaped noise barrier was the most effective geometry in noise reduction since it significantly reduced the noise level in the area during daytime and night-time.

Figure 2.6: Geometries of Different Noise Barriers (Lee, et al., 2022).



2.6.2 Tree Planting

According to Rahim, Hashim and Nayan (2011), tree planting was another mitigation measure for traffic noise reduction. When the sound passes through the green vegetation or the green barrier, it will be reflected and diffused by the plant structure, where this will cause the sound energy to dissipate. However, the types of tree would influence the ability of noise absorption. In addition, Yaakob (1998) stated that there were several species of trees that are suitable for planting to serve as an absorber or noise barrier along the highways. The selection of the type of trees for planting depends on the linear relationship of the capacity of noise attenuation including the canopy openness of trees, overlapping of the leaves, density and size of the leaves and the distance between the trees. With a more open and denser canopy, as well as smaller distances between the trees, the capacity of noise absorption will increase. A study conducted by Yaakob (1998) recommended several species of trees that can be planted along the road which able to reduce the traffic noise including the Pukul Lima tree (Samanea saman), the Betik Dedap tree (Ethrina Variegata), Kasia Biflora (Cassia biflora) and Jambu Laut (Eugenis Grandis). The tree species known as Samanea saman consists of dense and horizontally branched foliage which is able to have traffic noise reduction up to 8.8 dB(A). Besides, the Ethrina Variegata species is able to attenuate traffic noise up to 3.1 dB(A) when planted densely. Hence, tree planting can contribute to traffic noise absorption and improve the aesthetics of an area.

2.7 Research Gap

A research gap is an unexplored subject that is revealed during the research or a key problem that has not yet been solved by the existing research that allows for further research. A review of existing literature on the research topic is required to be broad and specific in order to identify the gap. Firstly, the research gap is lacking method or model for continuous monitoring of road traffic noise. Continuous monitoring of road traffic noise is applicable to specific authorities but is limited for the public to obtain data from it for research purposes. Noise monitoring requires sound monitoring for a long-term period without the need for human interaction. Environmental noise monitoring is often carried out using a monitoring system (Svantek, 2022). Generally, data collected from road traffic noise aim to improve the environmental conditions by minimizing the impacts and preventing potential litigation. The data on road traffic noise can monitor daily noise levels and can be used to define solutions to protect the environment from critical noise pollution (Acoem, 2022). Noise can be considered a powerful environmental agent with a high dynamic range. It has an extreme locality and will undergo rapid change in the sound level if the traffic conditions or urbanization pattern alters. Hence, continuous road traffic noise monitoring is significant to ensure the noise levels remain within acceptable limits (Quintero, Balastegui and Romue, 2021).

In this study, the road traffic noise data and parameters are being collected in a specific period since there are various procedures for measuring the noise level along the selected road and it is impossible to manually collect the road traffic noise data on-site continuously for a long-term period. On-site measurement of the road traffic noise requires many resources in terms of measurement equipment and personnel since there are several sampling points needed to record the noise level for a long period. Hence, the study can be done on developing other methods or models in order to provide continuous monitoring of road traffic noise levels by allowing a wide range of users for the developed model. This is because noise pollution brings significant impacts to the community and will contribute to health issues such as stress, annoyance, sleep problems and even promote the development of cancer. Another important reason for the development of noise monitoring tools is that the study area is Bandar Mahkota Cheras which this city is lacking systematic city planning to cope with the tremendous increase in population in this city. The increase in population leads to an increase in vehicles and subsequently generates a high level of noise pollution.

Moreover, the next research gap is regarding the CoRTN noise prediction model implemented in this study where this model is a manual prediction model. All of the related procedures, formulas and equations are listed in the model. The researcher needed to extract the formula and apply it to the software for further calculation and estimation of the road traffic noise level by referring to the method. All the steps required to input manually and any changes in the road traffic conditions also required manual changing of the input data in order to obtain an accurate result when developing the noise prediction model. It can be tedious and deemed to spend much time manually changing or inputting the data. However, existing studies can be considered to be less focused on any advanced software like MATLAB in developing the model. For instance, software like Microsoft Excel is being implemented to compute the noise level analysis, it will require researchers to analyse and develop the graph manually or it is not as effective as other advanced software to perform numerical analysis, numerical computation of matrix, data analysis and visualization. The function is limited compared to other advanced software which can carry out various kinds of analysis for a wide range of applications.

Hence, modern software like MATLAB can be explored in order to create the noise prediction model and various kinds of data can be analysed automatically by the software itself. The model that is developed using MATLAB able to be implemented for a variety of application and provide convenience to other researchers where the model can be used as a reference for others to study this topic. The model developed using MATLAB is able to analyse the collected input data automatically and generated complicated and details results or output automatically in a short period of time.

2.8 Summary

In this chapter, the study regarding the noise pollution where noise pollution is a worldwide problem that growth rapidly. There are various kinds of noise pollution including noise generated by road traffic, aircraft, railways, industry and construction sites. Nowadays, road traffic noise is considered to be one of the main environmental problems. The noise sources that lead to road traffic noise are depending on several factors including the number of individual vehicles, the volume, speed, and composition of traffic, as well as the types of pavements and road grade. The various cars' engines, transmissions, exhaust systems, tire-to-road friction, and air turbulence all contribute to the overall noise level. There are numerous detrimental effects of road traffic noise including hearing loss, disruption of spoken communication, disturbed sleep, cardiovascular disturbance, disturbance of mental health, poor task performance, and unfavourable social behaviour and displeasure reactions.

Moreover, there are several traffic noise regulations all around the world that outlines the noise limits and aimed to minimize the noise disturbance in the environment. In United State, the noise regulation is "Procedures for Abatement of Highway Traffic Noise and Construction Noise" (23 CFR 772) developed by FHWA. The regulations in Malaysia refer to the Guidelines for Environmental Noise Limits and Control Third Edition published by the Department of Environment of MESTECC. Moreover, there are a variety of traffic noise prediction models including the FHWA model, ASJ model, GIS Model of China and CoRTN model. The CoRTN model was used in this study and hence the history and implementation of this model in other countries and in Malaysia have been studied. Next, noise mitigation is crucial to ensure that traffic noise pollutions are able to be monitored and reduced. The noise control approaches can be applied for all stages of the sound transfer chain from the noise source to the receiver to obtain the desired noise reduction where this study focused on the erected of noise barriers and tree planting. Furthermore, the discussion was focused on the research gap. The first research gap is lacking a method or model for continuous monitoring of road traffic noise. Besides, the next research gap is regarding the CoRTN model implemented in this study is a manual prediction model.

CHAPTER 3

METHODOLOGY AND WORK PLAN

3.1 Overview of Research Methodology

Figure 3.1 was the flowchart for the overview of the research methodology for this study. This study consisted of four stages which were the first stage, second stage, third stage and final stage. The first stage was conducted the literature review on the traffic noise, road traffic noise prediction model and MATLAB. The literature review has been done to study the effects of road traffic noise on the community, to determine the traffic noise prediction model used by other researchers for the noise assessment and lastly to familiarise with MATLAB. The second stage of the study was the measurement work. This stage was planned for the field measurement in which a single carriageway was chosen to conduct the noise measurement for this study. The road to be measured was known as Jalan Permaisuri located in the Mahkota Cheras area. This stage also included the procedures of measuring the road traffic noise level and determining the data that needed to be collected from the field measurement where the parameters including the L_{10}, L_{50}, L_{90}, L_{eq}, L_{peak}, L_{max} and L_{min}. Moreover, the third stage was the noise prediction stage in which MATLAB will be utilised to predict the traffic noise level by referring to the CoRTN. The noise prediction model has been developed to calculate the basic noise level depending on different types of road conditions. Lastly, the final stage was the results predicted have been compared with the data collected from the field measurement to validate the reliability by investigating the R^2 correlation and measure the accuracy of the CoRTN model by calculating the mean absolute difference.

Besides, in order to validate the reliability of the CoRTN model, the coefficient of determination (R^2) was investigated. R^2 can be defined as a measure to evaluate the ability of a model to estimate or explain a result with a linear regression setting. R^2 represented the percentage of the variance in Y which is the dependent variable which is estimated or explained by X which is the independent variable and the linear regression (Zhang, 2016). The value of

R^2 was within 0 to 1 and the larger the value R^2, the more reliable the results. In other words, if the value of R^2 is closer to 1, it provides better performance. According to Chicco, Warrens and Jurman (2021), the formula to calculate R^2 can be expressed by:

$$R^2 = 1 - \frac{Sum\ Squared\ Regression\ (SSR)}{Total\ Sum\ of\ Square\ (SST)}$$

$$= 1 - \frac{\sum_{i=1}^{m}(X_i - Y_i)^2}{\sum_{i=1}^{m}(\bar{Y} - Y_i)^2} \quad (3.1)$$

$$\bar{Y} = \frac{1}{m}\sum_{i=1}^{m} Y_i \quad (3.2)$$

where

X_i= Predicted ith value

Y_i= Actual ith value

Moreover, accuracy is the degree to which the measured or calculated value resembles to the actual value. For the measurement of the accuracy of the CoRTN model, the absolute difference and the mean absolute difference have been evaluated. Absolute difference was calculated by using the measured value to subtract the actual value. In this study, the noise level measured from the site required to subtract the noise level predicted from the model and the absolute difference needed to be approximately 3 dB (A) allowed by the FHWA to obtain satisfactory results.

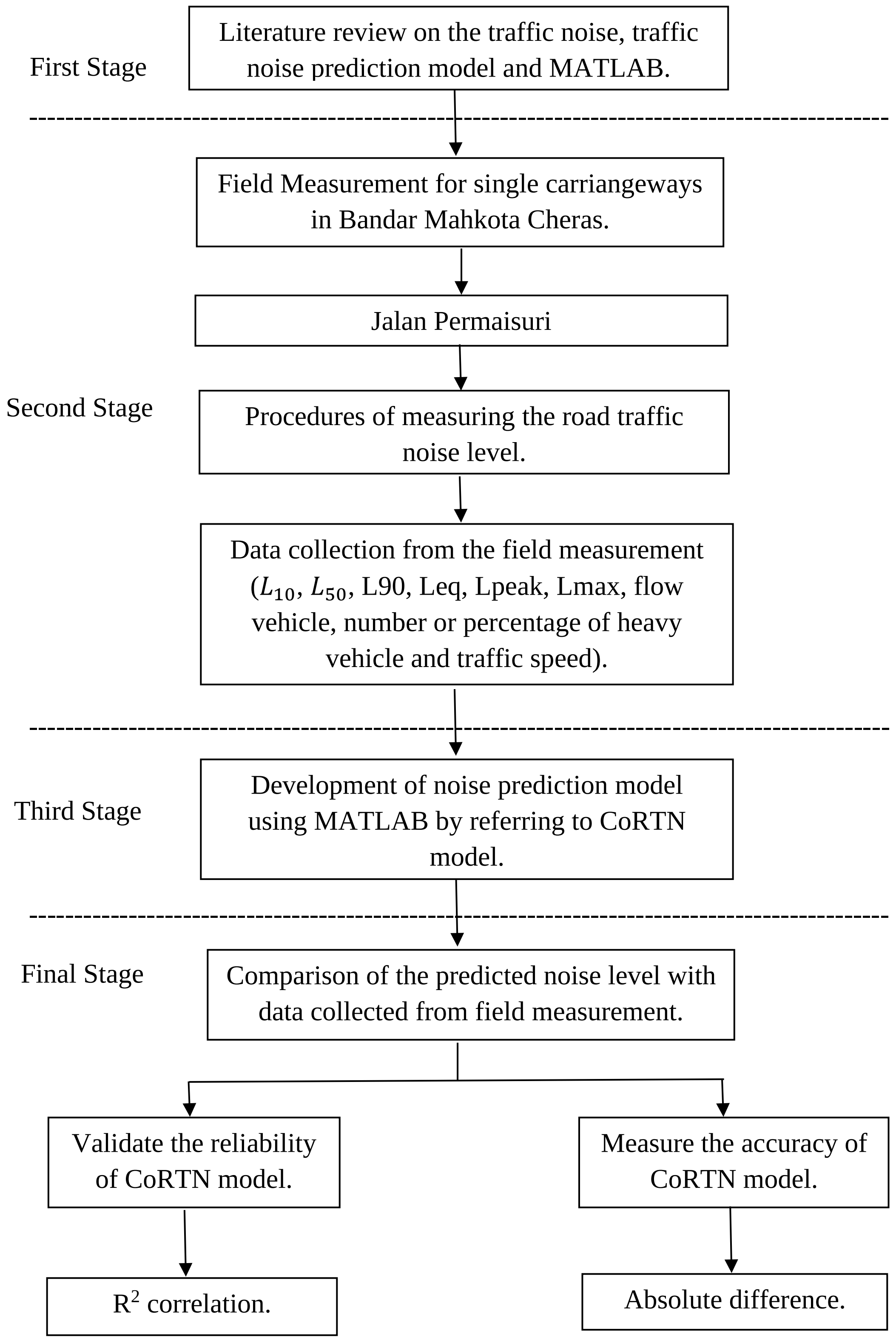


Figure 3.1: Flowchart for the Overview of Research Methodology.

3.2 Study Area

On-site measurement of the road traffic noise was carried out to record the road traffic noise level in the Bandar Mahkota Cheras. One road in Bandar Mahkota Cheras was selected for the field measurement known as Jalan Permaisuri which it was a straight single carriageway. Bandar Mahkota Cheras was a township located in Cheras within the Selangor State and this area was a freehold plot with an area of approximately 365 hectares. It was developed by Narajaya Sdn Bhd and the majority type of development were double-storey terraced houses. The population of this township was forecasted to be in excess of 50,000 households. This township can be accessed from the Cheras-Kajang Highway through the Cheras Perdana Interchange and can be assessed from the SILK Highway exit (Sistem Lingkaran Kajang) via Bandar Sungai Long.

Bandar Mahkota Cheras was selected to carry out the noise assessment due to its population, location and accessibility to this area. According to Star Property (2022), the population in this area was approximately 200,000 people and the current population kept increasing tremendously. An increase in population will lead to an increase in the number of motor vehicles which subsequently contribute to the road traffic noise level. Besides, the location of the selected roads in Bandar Mahkota Cheras was located nearby the residential and commercial areas. Hence, it was crucial to evaluate the road traffic noise levels around the area to ensure the noise levels are within the acceptable limit to avoid causing any adverse impacts to the public. Moreover, the ease of accessibility to this area allowed more vehicles to assess this area since it was linked to the Cheras – Kajang Highway and SILK Highway. Road traffic noise will generally increased due to more vehicles travelling in this area and hence it was needed to assess the noise levels. Figure 3.2 showed the location of Jalan Permaisuri in Bandar Mahkota Cheras.

Figure 3.2: Location of Jalan Permaisuri in Bandar Mahkota Cheras.

3.3 Measurement of Traffic Noise

This section was regarding the measurement of the road traffic noise level by referring to the DOE guidelines. The measurement equipment required for the field measurement, monitoring locations in order to collect the data, the measurement procedures and the data and parameters that needed to be collected were further discussed in this section.

3.3.1 Measurement Equipment

The noise level data have been recorded at four control points along the selected roads. According to the DOE guidelines, the data collection of the noise levels utilised the handheld sound level meters with the tripod to support the sound level meter. This type of sound level meter was operated manually and was designed for short-term measurements generally up to a day. The meter was mounted onto a tripod with the whole structure of the instrument exposed to the atmosphere or with a pre-amplifier and microphone which were detachable and exposed to the atmosphere. A microphone for a general purpose sound level meter was not suitable for long-term outdoor noise measurement since it was not waterproofing, in contrast, a dedicated microphone was recommended.

3.3.2 Monitoring Locations

According to the guidelines for Environmental Noise Limits and Control, the noise sampling stations or control points were selected based on the basic criteria stated in the guidelines. The sampling stations were located at a minimum reasonable distance of 75 m away from the intersections, stop signs, traffic signals along the roadways or other noise sources including the schools, stadiums and mosques in order to exclude the effects of acceleration and deceleration of the motor vehicles for the measurement (Segeran, et al., 2020). The monitoring locations were located at the boundary of the receptors and at the nearest vicinity to the noise sources in order to ensure the qualification of the traffic noise that propagated to the receptors. Besides, the sampling stations were avoided to locate in the distance with a range of 3.5 m measured from any of the surfaces that might reflect the sound to prevent any unwanted sound affect the noise source.

3.3.3 Measurement Procedures

The on-site or field measurement was conducted in this study to collect the noise level data and to evaluate the noise indices with the sound level meter to comply with the guidelines published by the Malaysia Department of Environment (Segeran, et al., 2020). The road traffic noise assessment was conducted in two time slots, the first time slot was from 7.00 a.m. to 9.00 a.m. which is representing the noise level during peak hours, while the second time slot was from 9.00 a.m. to 11.00 a.m. which was representing the traffic noise level during off-peak hours. There might be some variation on weekends, public and school holidays. These conditions require the noise measurement to be carried out on a weekday and weekends. Besides, noise measurements were needed to avoid being carried out during public holidays and school holidays. The setting up of equipment for noise measurement was shown in Figure 3.3 and the procedures to carry out the measurement were as follows:

(i) The road traffic noise levels have been measured by utilising the sound level meter.

(ii) The exact points or the monitoring locations to place the sound level meter prior to setting up for data collection were determined by referring to the guideline from the DOE. The sampling stations were located away from the wall, buildings and structures that might reflect the sound for a distance of at least 3.5 m.

(iii) The sound level meters have been mounted on a tripod and the microphone was set above the ground with a minimum height of 1.2 m to 1.5 m. The microphones have been installed in a correct direction corresponding to the direction of the noise sources.

(iv) The handheld sound level meters have been ensured not to be located in an enclosure for any period of time.

(v) The measurement of the traffic noise was conducted by setting the scale of the sound level meter to "A-weighting" with the time response set to "Fast".

(vi) The field data sheet which consisted of data such as measurements for the distances of the road and a site sketch of the measurement area was completely recorded.

(vii) Video recordings of the roadways for measurement were conducted.

(viii) The sound levels were measured with the required duration for intermittent sources including the vehicle backfire, loud motorcycle or passing by of a heavy truck through the roads.

(ix) Noise measurement for the equivalent sound levels which was the L_{Aeq} and the statistical centile levels including L_{10} were measured with continuous sampling for the period of interest.

(x) The traffic count and speed data were collected simultaneously with the sound level data.

(xi) The results for the parameters required were recorded on the field data sheet after the measurement was completed.

Figure 3.3: Setting Up of Sound Level Meter for Traffic Noise Measurement.

3.3.4 Data and Parameters Collection

There were several parameters that collected from the sound level meter and the site during the field measurement. The variables that recorded from the sound level meter included the L_{10}, L_{50}, L_{90}, L_{eq}, L_{peak} and L_{max} while the variables collected from the site including the flow vehicle (q), the number or percentage of heavy vehicles and the traffic speed (v). In the CoRTN model, the heavy vehicles generally were vehicles that are larger than 1525 kg unladen weight (Sheng, Xu and Li, 2015). Table 3.1 was the parameters recorded from the sound level meter and Table 3.2 was the parameters recorded from the site during the measurement.

Table 3.1: Parameters Recorded from the Sound Level Meter.

$\boldsymbol{L_{10}}$	Basic noise level hourly L_{10} at a reference distance of 10 m from the edge of the nearside carriageway expressed in terms of the total hourly flow rate (q).
$\boldsymbol{L_{50}}$	Refer to the sound level that exceeded for 50 % of the duration of the measurement period.
$\boldsymbol{L_{90}}$	Expressed as background or ambient noise.
$\boldsymbol{L_{eq}}$	Time – equivalent sound level.
$\boldsymbol{L_{peak}}$	Representing the actual peak point of the sound pressure wave.
$\boldsymbol{L_{max}}$	Refer to the highest sound level recorded during a single noise event.

Table 3.2: Parameters Recorded from the Site.

Flow vehicle (q)	Number of vehicles passing by
Number / Percentage of heavy vehicle	Number of heavy vehicles passing by
Traffic speed (v)	Speed of vehicle travel along

3.4 Traffic Noise Model

For the road traffic noise prediction model, the CoRTN model was referred to develop a noise prediction model using MATLAB. This section will be discussed the procedure for field measurement referring to the CoRTN model and the calculation of the CoRTN model with several formulae.

3.4.1 CoRTN Procedures

CoRTN was implemented and developed for the prediction of road traffic noise levels in the United Kingdom where this method was published by the Department of the Environment. This model considered a line source and the speed of the traffic remain constant. There were several adjustments that applied to the model including the proportion of heavy vehicles, the speed of the traffic, the roadways gradient, the road surface and propagation. Besides, this model does not consider acceleration. Figure 3.4 below was the flowchart for the CoRTN model.

Based on the flowchart, the procedure for CoRTN has been categorized into five steps. Firstly, the road scheme has been divided into several segments where the difference in noise level between the segment was lower than 2 dB(A). The second step was the basic noise level for a place located 10 m away from the edge of the adjacent carriageway for each of the segments was calculated. The hourly L_{10} or L_{10} (18 – Hour) was selected. The basic noise level depended on the flow of traffic, the speed of traffic, the percentage of heavy vehicles, the road gradients and the types of road surfaces. The traffic was assumed as a linear source located height of 0.5 m above when measured from the road surface and 3.5 m away from the carriage edge. The third stage was the noise level for each segment was evaluated by considering the attenuation caused by the distance of the linear source line. If the view was unobstructed, the ground cover correction would be considered, else the screening correction will be applied during this stage. Next, the fourth stage was the adjustment of the noise level by considering the reflection caused by the building and façade on another part of the roadway, as well as the size of the selected segments or known as the correction for the angle of view. Lastly, the fifth stage combined and added the noise level from all the segments to provide the estimated traffic noise level at the receiver for the entire road scheme (Ihemeje and Onyelowe, 2021).

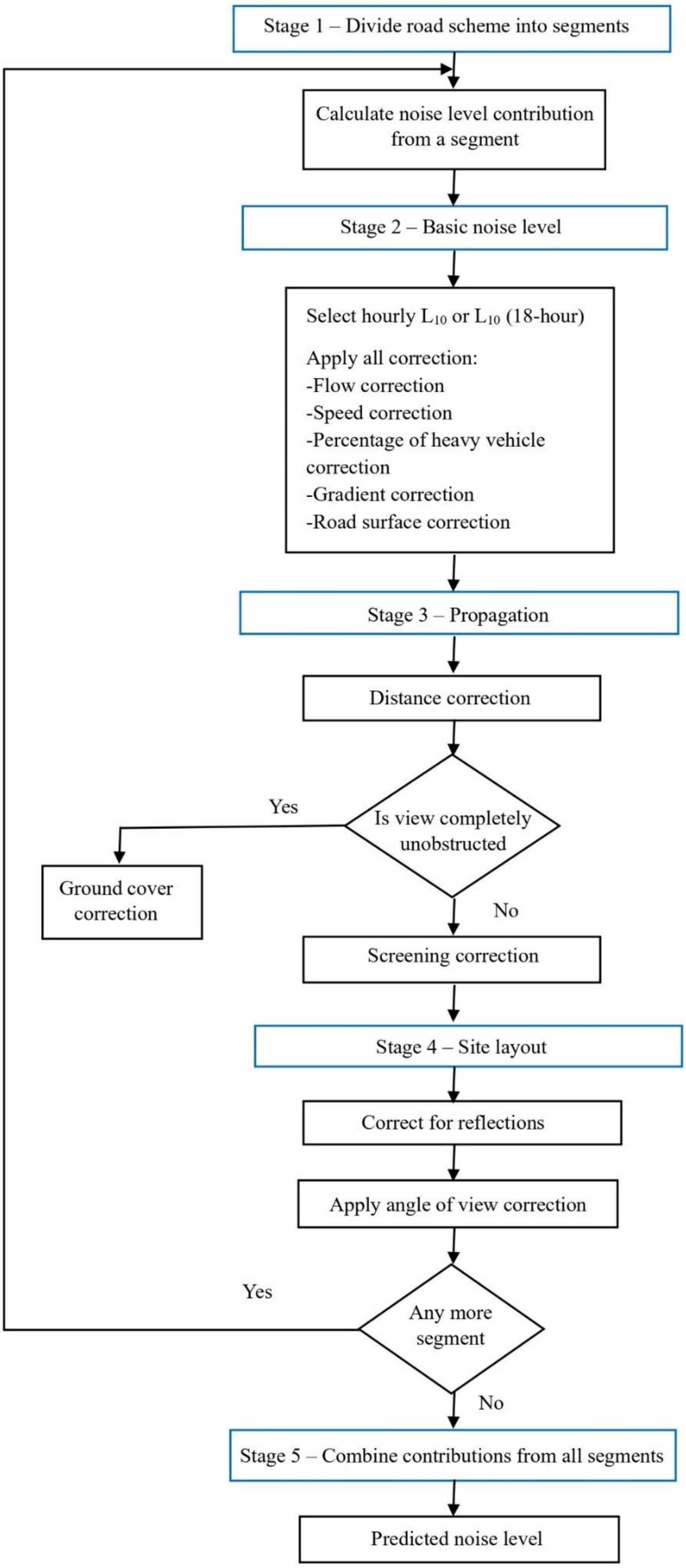


Figure 3.4: Flowchart for CoRTN Noise Prediction Model (CoRTN, 1988).

3.4.2 Calculation of CoRTN Model

The calculation of the CoRTN model in this study provided the assumption that there were consistent traffic and noise propagation with the velocity and direction of the wind being moderately detrimental during a specific period of time. The algorithm was shown below:

$$L_{A10,1h} = L_0 + \Delta f + \Delta g + \Delta p + \Delta d + \Delta a + \Delta r \qquad (3.3)$$

At a reception point located away from the nearside carriageway with a reference distance with length of 10 m, the basic hourly noise level was calculated using the equation below:

$$L_0 = 42.2 + 10log_{10}q \qquad (3.4)$$

Where L_0 was the hourly traffic noise level and q was hourly traffic volume for all the vehicles including heavy or light vehicles. It was assumed that the line of the source was above the carriageway with a height of 0.5 m and located 3.5 m away from the edge of the nearside carriageway as shown in Figure 3.5 (Sheng, Xu and Li, 2015).

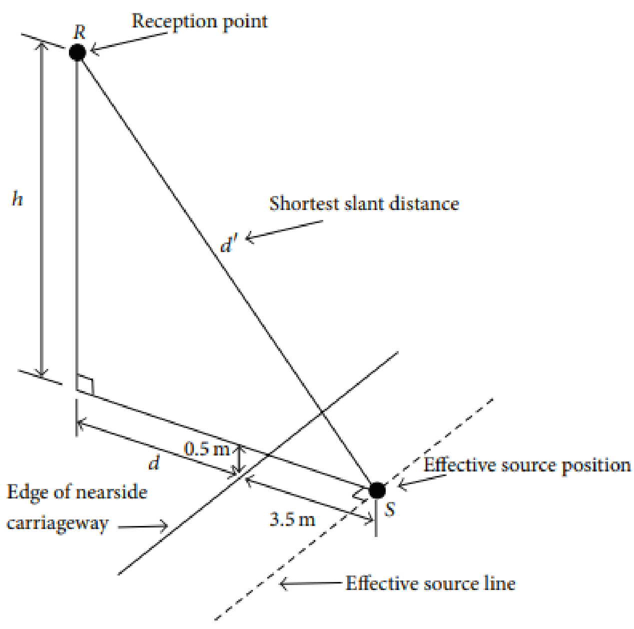


Figure 3.5: Positions of Source and Reception Point (Sheng, Xu and Li, 2015).

The calculation of the basic hourly noise level using Equation 3.4 considered the basic speed of traffic on the road to be equal to 75 km/hr, and the portion of heavy vehicles and the slope of the road were both equal to 0 %. Hence, the correction for the speed of actual mean traffic and the proportion of heavy vehicles, Δf can be computed by the following equation:

$$\Delta f = 33log_{10}\left(V + 40 + \frac{500}{V}\right) + 10log_{10}\left(1 + \frac{5P}{V}\right) - 68.8 \qquad (3.5)$$

Where V was the average speed of the traffic depending on the road classification stated by the CoRTN model and P was the portion of heavy vehicles which P can be calculated by the equation below:

$$P = \frac{100f}{q} \qquad (3.6)$$

Where f known as the hourly flow rate of heavy vehicles. The speed of the traffic (V) in Equation 3.5 was influenced by the road gradient. For road gradient not equal to zero, the speed of the traffic will be adjusted to the equation below:

$$\Delta V = \left[0.73 + \left(2.3 - \frac{1.15P}{100}\right)\frac{P}{100}\right]G \qquad (3.7)$$

Where G was the road gradient and hence, the Δf in Equation 3.5 can be expressed by following equation:

$$\Delta f = 33log_{10}\left(V + \Delta V + 40 + \frac{500}{(V+\Delta V)}\right) + 10log_{10}\left(1 + \frac{5P}{(V+\Delta V)}\right) - 68.8 \qquad (3.8)$$

The adjustment or correction of the basic noise level for the road gradient**,** Δg can be calculated by the equation below:

$$\Delta g = 0.3G \qquad (3.9)$$

The adjustment of the pavement type or known as road surface correction, Δp was equal to -1 dB(A) when the speed of traffic (V) was lower than 75 km/hr for impervious bituminous and concrete surface pavements. Subsequently, the corrections being applied to the fundamental noise level considered several impacts including the impacts of distance from the line of the source, the features of the ground surface, screening against any obstructing objects, as well as the reflections from the building and facades. Besides, the correction for the distance was expressed by the equation below:

$$\Delta d = -10log_{10}(\frac{d'}{13.5}) \qquad (3.10)$$

Where *d'* was the shortest slope distance from the noise source and *d'* can be calculated as $d' = \sqrt{(d+3.5)^2 + h^2}$ with d was the shortest distance horizontally measured from the edge of the adjacent carriageway to the point of the reception, *h* was the vertical distance measured from the line source to the point of reception as shown in Figure 3.5. The d or the shortest horizontal system considered to be larger than 4 m. Besides, the ground cover correction was expressed as:

$$\Delta gc = \begin{cases} 5.2Ilog_{10}(\frac{3}{(d+3.5)}) & for\ H < 0.75 \\ 5.2Ilog_{10}(\frac{(6H-1.5)}{(d+3.5)}) & for \leq H < \frac{(d+5)}{6} \\ 0 & for\ H \geq \frac{(d+5)}{6} \end{cases} \qquad (3.11)$$

Where *H* was the mean height and *I* was the section of the absorbing ground measured from the nearside carriageway edge to the boundaries of the segment to the reception point. Furthermore, the correction for the adjustment for the angle of view was calculated by the formula:

$$\Delta a = 10log_{10}(\frac{\theta}{180})dB(A) \qquad (3.12)$$

Where θ was the angle of view with unit in degree. In addition, the formula for the reflection correction was calculated by:

$$\Delta r = 2.5 + 1.5(\frac{\theta\prime}{\theta}) \tag{3.13}$$

Where the value of 2.5 considered the noise reflection from the façade near to the receiver point, $1.5\left(\frac{\theta'}{\theta}\right)\ dB(A)$ was the reflection correction of the façade facing to the reception point which located at the opposite side, θ' was the total value of the subtended angles of overall reflecting façade that located on the other direction of the road facing to the receiver point and θ was the sum of the angle of view at the receiver point.

3.5 Model Development Using MATLAB

In this study, MATLAB will be implemented to develop the model to predict the road traffic noise level by referring to the CoRTN model. This section discussed the general procedures for the development of the noise prediction model. In-depth explanations and programming algorithms have been provided in Chapter 4 Results and Discussion and Appendix B. The first step was the formulas provided by the CoRTN model was extracted from the model where the formulas can be found from the previous section from Equation 3.3 to Equation 3.13. The next step was developed the programming algorithms by referring to the equations extracted where these equations were representing different road conditions. Moving to the next step, there were required to input data including the hourly traffic volume (q), the average speed of the traffic (V), the hourly flow rate of the heavy vehicles (f), the gradient of the road (G), the shortest horizontal distance from nearside carriageway to the point of the reception (d), the vertical distance measured from the line source to the point of reception (h), the mean height (H), the section of the absorbing ground measured from the nearside carriageway edge to the boundaries of the segment to the reception point (I), the angle of view (θ) and lastly the total value of the subtended angles of all the reflecting façade that located on the other direction of the road facing the receiver point (θ').

3.6 Gantt Chart

Figure 3.6 and Figure 3.7 were the Gantt chart for FYP 1 and Gantt chart for FYP 2 respectively. During FYP 1, after the title registration in Week 1, four weeks were spent for the Chapter 1 Introduction. For Chapter 2, five weeks were required which started from Week 5 to Week 9 are spent on searching journals in order to complete the literature review. Next, six weeks were allocated for Chapter 3 to complete the Methodology and Work Plan of this study. All the chapters in this study were completed on time. For FYP 2, the time allocated for Chapter 4 Results and Discussion was ten weeks and three weeks was given for Conclusions and Recommendations. The time was well-planned and the tasks were able to complete on time for FYP 2 to ensure the objectives of this study can be achieved successfully.

	Task Name	Start Date	End Date	Duration (Days)	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
	Title Registration	13/06/2022	17/06/2022	5														
1.0	**Introduction**	20/6/2022	17/7/2022	28														
	Study Background of Project	20/06/2022	26/06/2022	7														
	General Introduction	27/06/2022	1/7/2022	5														
	Importance of the Study	1/7/2022	10/7/2022	10														
	Problem Statement, Aim and Objectives	1/7/2022	10/7/2022	10														
	Scope and Limitations of the Study	1/7/2022	10/7/2022	10														
	Contibution of the Study	11/7/2022	17/07/2022	7														
2.0	**Literature Review**	11/7/2022	14/8/2022	34														
	Noise Pollution	11/7/2022	17/7/2022	7														
	Traffic Noise	18/7/2022	7/8/2022	21														
	Traffic Noise Regulations	18/7/2022	7/8/2022	21														
	Traffic Noise Prediction Model	18/7/2022	7/8/2022	21														
	Calculation of Road Traffic Noise	25/7/2022	14/8/2022	21														
	Noise Mitigation	25/7/2022	14/8/2022	21														
	Research Gap	25/7/2022	14/8/2022	21														
3.0	**Methodology and Work Plan**	1/8/2022	26/8/2022	26														
	Overview of Research Methodology	1/8/2022	21/8/2022	21														
	Study Area	1/8/2022	21/8/2022	21														
	Measurement of Traffic Noise	8/8/2022	14/8/2022	7														
	Traffic Noise Model	8/8/2022	14/8/2022	7														
	Model Development using MATLAB	8/8/2022	2/9/2022	26														
4.0	**Report Writing and Presentation**	22/8/2022	16/9/2022	26														
	Report Writing	22/8/2022	12/9/2022	22														
	Presentation	14/9/2022	16/9/2022	3														

Figure 3.6: Gantt Chart for FYP 1.

	Task Name	Start Week	End Week	Duration (Days)	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16	Week 17
1.0	**Results and Discussion**	31/1/2023	9/4/2023	69																	
	Field Measurement Reulsts	31/1/2023	12/2/2023	13																	
	Development of Noise Prediction Model	13/2/2023	19/3/2023	35																	
	Reliability and Accuracy of CoRTN Model	13/3/3023	9/4/2023	28																	
2.0	**Conclusions and Recommendations**	3/4/3023	9/4/2023	7																	
	Conclusions	3/4/3023	9/4/2023	7																	
	Recommendations for Future Works	3/4/3023	9/4/2023	7																	
3.0	**Report Writing and Presentation**	3/4/2023	7/5/2023	28																	
	Final Report	3/4/2023	7/5/2023	28																	
	Poster	3/4/2023	12/4/2023	10																	
	Presentation	1/5/2023	7/5/2023	7																	
4.0	**Submission of Final Report**	8/5/2023	22/5/2023	15																	
	Revise and Submit the Report	8/5/2023	22/5/2023	15																	

Figure 3.7: Gantt Chart for FYP 2.

3.7 Summary

This chapter included the overview of the research methodology in estimating the road traffic noise level to achieve the objectives of this study. This study conducted a literature review, field measurement, model development to validate the reliability and measure the accuracy of the CoRTN model. The reliability of the model was depended on the R^2 correlation while three components were used to measure the accuracy of the model included the mean absolute difference. This chapter elaborated on the study area which was Bandar Mahkota Cheras. Besides, the measurement of road traffic noise was referring to the DOE guidelines and the discussion was related to the measurement equipment, monitoring locations, measurement procedures and the data and parameters collection. Next, the discussion was the traffic noise prediction model which consisted of the CoRTN procedures and calculation of the CoRTN model with a variety of formulae. Moreover, the general procedures on model development using MATLAB have been explained. The last section was the Gantt chart for FYP 1 and FYP 2 in order to have time to complete the task to ensure the objectives of this study can be achieved.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

The results of noise level obtained from the road measurement for Jalan Permaisuri located in Bandar Mahkota Cheras will be demonstrated in this chapter. Besides, a noise prediction model was established by referring to the CoRTN by utilising MATLAB. Lastly, the reliability and accuracy of CoRTN to be implemented in Malaysia were analysed by calculating the R^2 correlation and mean absolute difference between the predicted traffic noise level and measured traffic noise level.

4.2 Field Measurement Results

This section discussed the road properties of Jalan Permaisuri. This road was a straight road with zero gradients. It was a single carriageway subjected to a speed limit which less than 50 mph but higher than 30 mph. The area surrounding the road consists of a majority of double-storey residential houses and there was no sensitive area such as schools or hospitals located near the road. Although there were no sensitive areas near the road, the traffic noise level was still required to be assessed in order to monitor and mitigate the significant impacts of excessive traffic noise.

4.2.1 Traffic Volume

The traffic volume was an important parameter to be evaluated. This was because the traffic volume will give a direct impact on the amount of traffic noise generated by the vehicles. In the CoRTN model, traffic volume was required to determine the total amount of traffic noise produced by the vehicles over a period. Traffic volume affected the traffic composition which was the types of vehicles. The CoRTN model also considered the percentage of heavy vehicles that travel on the road because heavy vehicles like buses, vans or trucks tended to generate higher traffic noise levels due to their huge engine, heavier weight and utilization of the air brakes system. Li, et al. (2002) stated that a heavy vehicle with a weight higher than 3500 kg could generate a traffic noise level which is equivalent to the noise level generated by 9.12 cars. Tables 4.1 and 4.2 showed the traffic volume classified by the type of vehicles for two days during peak hour and off-peak hour.

Table 4.1: Traffic Volume for Day 1 During Peak Hour and Off-Peak Hour.

	Day 1					
	Peak			**Off Peak**		
Time	7.00 a.m. – 8.00 a.m.	8.00 a.m. – 9.00 a.m.	Total Volume	9.00 a.m. – 10.00 a.m.	10.00 a.m. – 11.00 a.m.	Total Volume
Number of Heavy Truck	20	44	64	45	42	87
Number of Light vehicles	454	674	1128	646	502	1148
Number of Motorcycles	97	103	200	90	74	164
Equivalent hourly traffic Volume	571	821	1392	781	618	1399
Total Volume			1392			1399

From Table 4.1, the results showed the total traffic volume for day one which was 2791 vehicles with 1392 during peak hour and 1399 during the off-peak hour. The values indicated that the volume of vehicles during off-peak was higher than that during peak hours. For the percentage of heavy vehicles, the values for peak hour and off-peak hour for day one were 4.60 % and 6.22 % respectively. The percentage of heavy vehicles during off-peak hours was also higher compared to peak hours. Besides, Table 4.2 illustrated the total volume of traffic for day two was 2723 vehicles whereas for peak hour and off-peak hour were 1359 and 1364 respectively. The percentage of heavy vehicles during day two for peak hour and off-peak hour were 4.78 % and 5.43 % respectively. The values on day two showed a similar trend to day one.

Table 4.2: Traffic Volume for Day 2 During Peak Hour and Off-Peak Hour.

	Day 2					
	Peak			**Off Peak**		
Time	7.00 a.m. – 8.00 a.m.	8.00 a.m. – 9.00 a.m.	Total Volume	9.00 a.m. – 10.00 a.m.	10.00 a.m. – 11.00 a.m.	Total Volume
Number of Heavy Truck	26	39	65	41	33	74
Number of Light vehicles	425	665	1090	608	489	1097
Number of Motorcycles	83	121	204	90	103	193
Equivalent hourly traffic Volume	534	825	1359	739	625	1364
Total Volume			1359			1364

By observing the traffic volume of peak hour and off-peak hour, the difference between the two values was very small which were seven and five vehicles for day one and day two respectively. This indicated that many vehicles still travelled on the road although they had already exceeded the off-peak hour.

Both the traffic volume and percentage of heavy vehicles indicated higher value during off-peak hour compared to peak hour, which might be due to people being more likely to travel during the off-peak hour since this period is lesser traffic and more flexible compared to the peak hour. The next reason was during peak hours, people will start going to work or go to school for a period which causes congestion and concentrated traffic for the specific period. While for an off-peak hour, the traffic is spread out over the entire off-peak hour and hence contributes to higher traffic volume on the road. Moreover, the delivery service starts to deliver their products to houses or shops during the off-peak hour to avoid congestion and this had increased the traffic volume, especially the heavy vehicles travelling on the road.

4.2.2 Noise Level

Next, the traffic noise level will be discussed in this section. The traffic noise level can be assessed through different kinds of parameters including L_{10}, L_{50}, L_{90}, L_{eq}, L_{peak}, L_{max} and L_{min}. Appendix A was the results of measured traffic noise during peak hour and off-peak hour for the four control points that be set up along the Jalan Permaisuri. Each control point was used to measure the traffic noise during peak hours and off-peak hours. According to DOE (2007), L_{90} is the background noise level and is the noise level that exceeded 90 % of the time. In order words, 90 % of the time, the traffic noise level would be above this level. This L_{90} are representing the background noise or the ambient level of the noise in the environment for the assessment of road traffic noise. Moreover, L_{max} or known as the maximum instantaneous sound level is refer to the highest noise level measured within a time period. It indicates the peak amplitude of a noise event recorded by the measurement (DOE, 2007). In Appendix A, the highlighted result for every parameter were the L_{10} and L_{eq} at the period of 120 minutes, average values of L_{50} and L_{90}, highest values for L_{peak} and L_{max} , and lastly the lowest value for the L_{min}.

The most important parameters that were needed for the CoRTN model were the L_{10} and L_{eq}. L_{10} represented the noise level that exceeded 10 % of the time. This implied that for 10 % of the time, the noise will have a sound pressure level higher than L_{10}, while for the remaining 90 % of the time, the noise will have a sound pressure level equal to or below L_{10}. It refers to the peak noise of a high noise events (DOE, 2007). The L_{eq} or known as equivalent continuous sound level is the steady level of sound pressure that has a similar total energy as the actual fluctuating noise over a specific period. Table 4.3 shown the measured and predicted values of L_{10} for the four control points during peak hour and off-peak hour. Table 4.4 represented the measured and predicted values of L_{eq} for four control points during peak hour and off-peak hour. It can be observed that the majority of the predicted values using CoRTN for L_{10} and L_{eq} were higher than the measured values. The L_{10} values were ranging from 68.8 dB(A) to 74.0 dB(A). For L_{eq}, all the noise levels were ranging from 66.5 dB(A) to 70.9 dB(A). These noise levels exceeded the guidelines published by the Malaysian Department of Environment (DOE) where for urban residential of high density, the L_{eq} should not exceed 65 dB(A) during daytime and 60 dB(A) during night-time (DOE, 2007). Figure 4.1 represented the measured values of L_{10} and L_{eq} for the four control points at Jalan Permaisuri.

Table 4.3: Measured and Predicted Values of L_{10}.

Control Point	Condition	Time	Measured, dB(A)	Predicted, dB(A)
Control Point 1 (Day 1)	Peak	7.00 a.m.- 9.00 a.m.	69.3	73.9
	Off-peak	9.00 a.m.- 11.00 a.m.	69.3	74.5
Control Point 2 (Day 1)	Peak	7.00 a.m.- 9.00 a.m.	72.3	73.9
	Off-peak	9.00 a.m.- 11.00 a.m.	71.3	74.5
Control Point 3 (Day 2)	Peak	7.00 a.m.- 9.00 a.m.	68.8	73.9
	Off-peak	9.00 a.m.- 11.00 a.m.	69.5	74.1
Control Point 4 (Day 2)	Peak	7.00 a.m.- 9.00 a.m.	74.0	73.9
	Off-peak	9.00 a.m.- 11.00 a.m.	73.5	74.1

Table 4.4: Measured and Predicted Values of L_{eq}.

Control Point	Condition	Time	Measured, dB(A)	Predicted, dB(A)
Control Point 1 (Day 1)	Peak	7.00 a.m.- 9.00 a.m.	66.5	70.2
	Off-peak	9.00 a.m.- 11.00 a.m.	66.9	70.8
Control Point 2 (Day 1)	Peak	7.00 a.m.- 9.00 a.m.	68.9	70.2
	Off-peak	9.00 a.m.- 11.00 a.m.	68.3	70.8
Control Point 3 (Day 2)	Peak	7.00 a.m.- 9.00 a.m.	66.5	70.2
	Off-peak	9.00 a.m.- 11.00 a.m.	66.7	70.4
Control Point 4 (Day 2)	Peak	7.00 a.m.- 9.00 a.m.	70.9	70.2
	Off-peak	9.00 a.m.- 11.00 a.m.	70.4	70.4

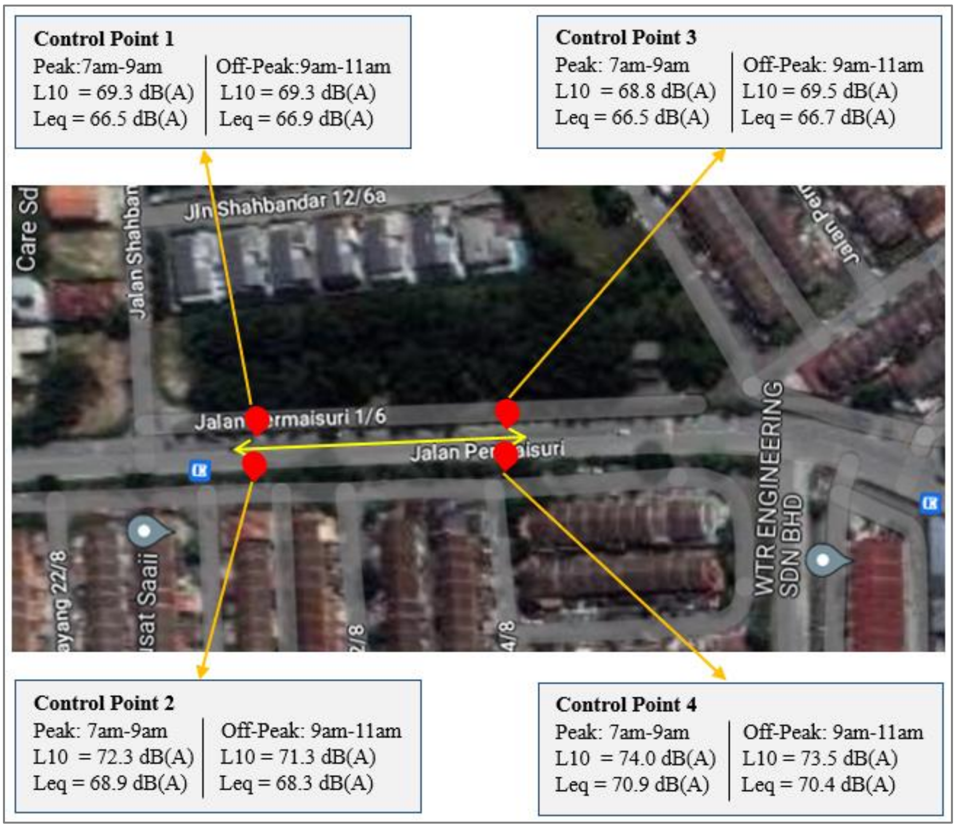


Figure 4.1: Measured Values L_{10} and L_{eq} for the Four Control Points.

4.3 Development of Noise Prediction Model

This section explained the development of the noise prediction model by referring to the CoRTN model by utilizing MATLAB. The flowchart for the coding part shown the steps to program the model. Besides, the output displayed by the developed model has been compared to the values stated in the CoRTN model in order to assess the validity of the developed noise prediction model.

4.3.1 Flowchart

Figure 4.2 shown the steps in developing the program for the noise prediction model. Figure 4.3 shown the programming algorithms for the coding of the prediction model. The first step was the program asked choice from the user to determine the quantity required for the repetition of the for loop by asking the user to input the number of road segments. Next, the program asked choice from the user to select L_{10} or L_{10} (18-hour) since these two parameters were included in CoRTN. Now reached the section to calculate the basic noise level and the program required the user to input the data needed to calculate the basic noise level including the traffic volume (Q), flow of heavy vehicles (F) for the calculation of the percentage of heavy vehicles (p), road traffic speed (V), the gradient of the road (G) and the types of the road surface. The program utilized these data and proceeded to calculate the basic noise level and store the value in the program.

For the next section, calculation required for all the corrections which were the propagation correction and site layout correction. For the propagation correction, the program asked the user to key in the data for the shortest horizontal distance between the reception point and nearside edge of the carriageway (d), the relative height from the reception point to the effective source position (h), and whether the source line is unobstructed or obstructed. The user was also required to determine whether the ground cover is absorbent or non-absorbent, and if is absorbent, what is the percentage of absorbent ground to obtain the value of absorbent ground cover (I) for the correction calculation. Under the propagation correction, the user also needed to identify where there is any barrier to calculate the barrier path difference (δ). After the program collected all the data, it proceeded to the calculation of propagation correction and stored it in the program. Moreover, the program now proceeded to the section for site layout correction where the user was required to determine if is there any façade near the receiver point, whether was there any reflection from the opposite façade or uniform rows of houses fronting onto the opposite side of the road and lastly the angle of view (θ). After all these data were obtained, the program continued to calculate the site layout correction and stored it in the program.

In addition, the program applied the calculated propagation correction and site layout correction to the basic noise level obtained in the first section and calculated the final noise contribution for each segment. The program repeated the for loop if the number of road segment key in by the user is more than one. The program next continued to combine all the noise contributions for each segment and calculating the final predicted value of L_{10} or L_{10} (18-hour). Finally, the program displayed the output on the command window by listing out all the input data keyed in by users, the value for the correction for each of the segments and the final predicted value of L_{10} or L_{10} (18-hour).

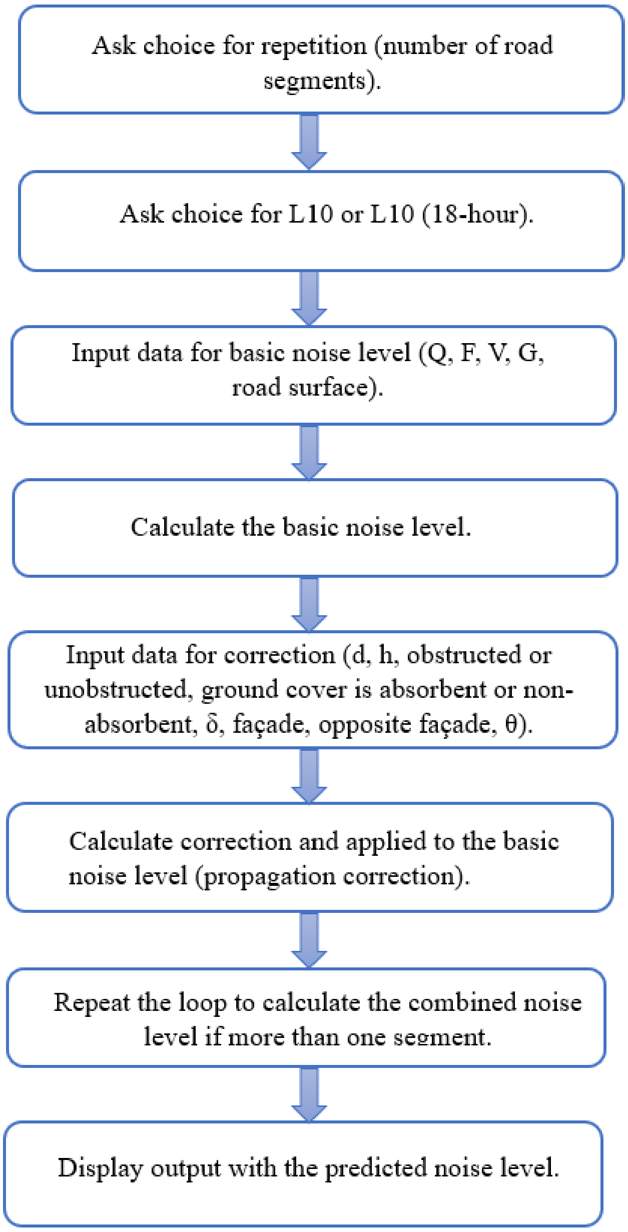


Figure 4.2: Flowchart for the Development of Noise Prediction Model.

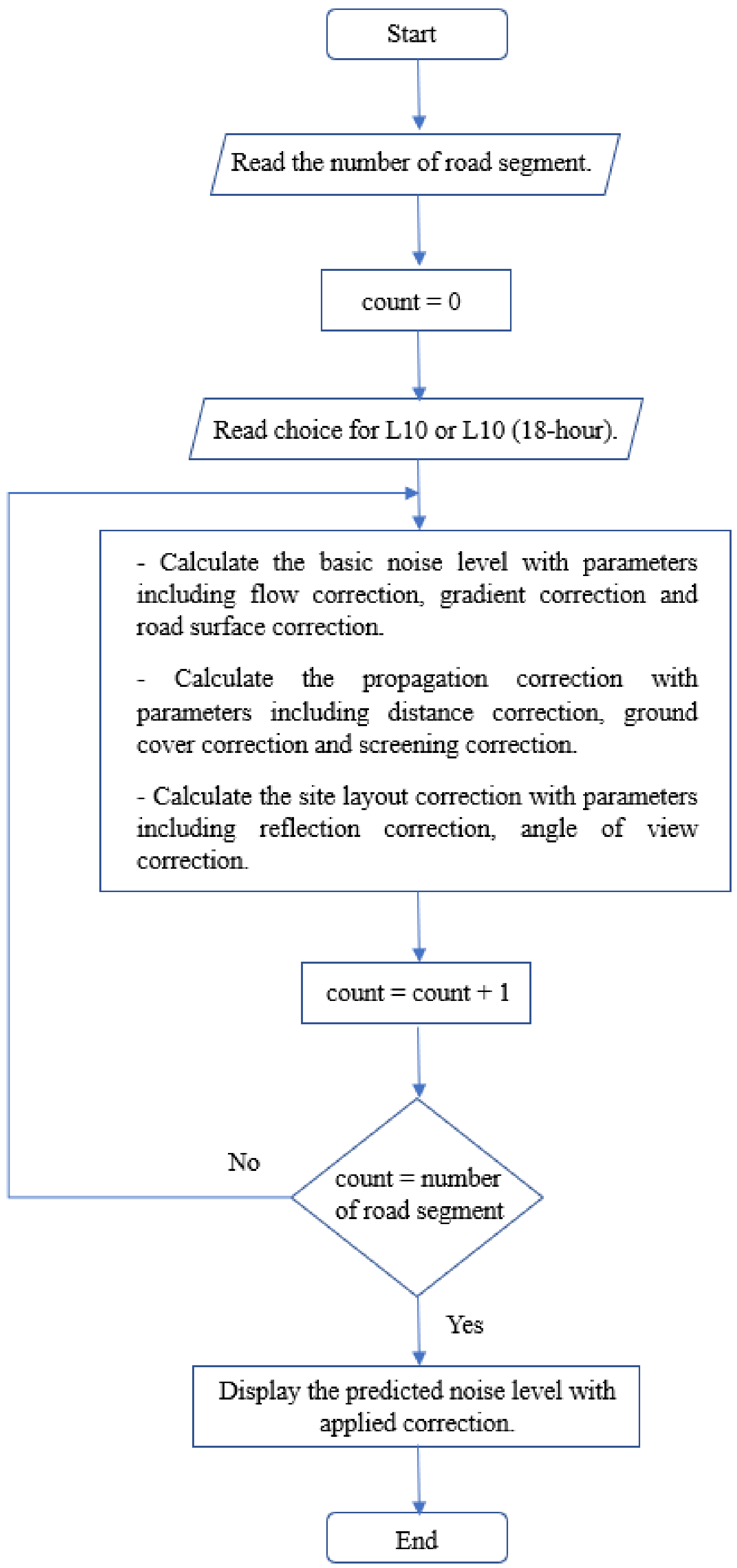


Figure 4.3: Programming Algorithms.

4.3.2 Comparison of Predicted Noise Level Between CoRTN and MATLAB

This section discussed the result of the predicted L_{10} (18-hour) by comparing the results obtained from the CoRTN model with the results calculated by the noise prediction model developed by MATLAB. A road condition in CoRTN was selected for this comparison to assess the validity of the developed model to perform its task.

Prediction of Noise Level from CoRTN

First and foremost, the predicted L_{10} (18-hour) for the road condition from the CoRTN model will be assessed. Figure 4.4 shown the propagation over mixed ground cover which was one of the road conditions stated in CoRTN.

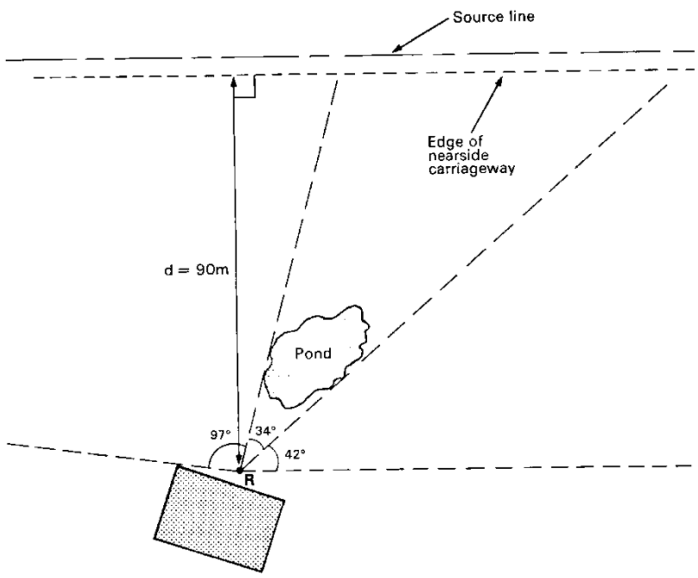


Figure 4.4: Propagation Over Mixed Ground Cover (CoRTN, 1988).

By referring to CoRTN Annex 6, below was the predicted value of L_{10} (18-hour) for a situation where a reception of 1 m away from a façade and was located 4m above the ground. In this condition, the road has been divided into two segments and the intervening ground was covered by grassland and was considered absorbent while the pond was considered non-absorbent. The type of road was a single carriageway and hence the speed limit was 50 mph. Furthermore, the surface of the road was impervious. Table 4.5 indicated various types of correction for the basic noise level for road segment 1 and Table 4.6 showed various types of correction for the basic noise level for road segment 2. Next, Table 4.7 was the combined noise level from road segment 1 and 2 or also represented the predicted value of L_{10} (18-hour).

Table 4.5: Various Types of Correction for the Basic Noise Level for Road Segment 1 (CoRTN, 1988).

Segment 1	**Value**	**Correction dB(A)**
Basic Noise Level		
Traffic flow, Q (veh/18-hour day)	20000	72.1
Traffic speed, V (km/h)	70	+2.6
Heavy vehicles, p (%)	15	
Gradient, G (%)	0	0
Road surface	Impervious	-1.0
		73.7
Propagation		
Shortest horizontal distance, d (m)	90	-8.4
Height relative to the source, h (m)	3.5	
Average height of propagation, H (m)	2.25	-4.6
Absorbent ground cover, I	1	
Barrier path difference, δ (m)	0	0
		-13.0
Site Layout		
Façade	Yes	+2.5
Opposite façade angle, θ' (°)	0	0
Angle of view segment, θ (°)	139	-1.1
		+1.4
	Total	**62.1**

Table 4.6: Various Types of Correction for the Basic Noise Level for Road Segment 2 (CoRTN, 1988).

Segment 2	**Value**	**Correction dB(A)**
Basic Noise Level		
Traffic flow, Q (veh/18-hour day)	20000	72.1
Traffic speed, V (km/h)	70	+2.6
Heavy vehicles, p (%)	15	
Gradient, G (%)	0	0
Road surface	Impervious	-1.0
		73.7
Propagation		
Shortest horizontal distance, d (m)	90	-8.4
Height relative to the source, h (m)	3.5	
Average height of propagation, H (m)	2.25	-3.5
Absorbent ground cover, I	0.75	
Barrier path difference, δ (m)	0	0
		-11.9
Site Layout		
Façade	Yes	+2.5
Opposite façade angle, θ' (°)	0	0
Angle of view segment, θ (°)	34	-7.2
		-4.7
	Total	**57.1**

Table 4.7: Combined Noise Level and the Predicted Value of L_{10} (18-hour) (CoRTN, 1988).

Segment	**1**	**2**
Noise contribution, dB(A)	62.1	57.1
Combined noise level, dB(A)	63.3	
Predicted value of L_{10} (18-hour), dB(A)	63.3	

From Table 4.5, segment 1 consisted of traffic flow (*Q*) of 20000 veh/ 18-hour day. The traffic speed, *V* was 70 km/h, the percentage of heavy vehicles, *p* was 15 %, the gradient, *G* was 0 % and the road surface was impervious type. Now, the basic noise level obtained was 73.7 dB(A) which the first L_{10} (18-hour) was 72.1 dB(A) with correction for traffic speed of +2.6 dB(A), and -1.0 dB(A) was the correction for the impervious road surface.

Next, the propagation correction will be applied to the basic noise level of 73.7 dB(A). In the condition given, the propagation was unobstructed, and the intervening ground cover was considered flat. The shortest horizontal distance, d was 90 m with the height relative to the source, h was 3.5 m. Next, the average height of propagation, H was 2.25 m and the absorbent ground cover, I was 1 for grassland. The barrier path difference, δ was zero. Hence, the total propagation correction in this condition was -13.0 dB(A) with a distance correction of -8.4 dB(A) and ground cover correction of -4.6 dB(A).

In addition, the site layout correction also will be applied to the basic noise level of 73.7 dB(A). The road that consists of a façade needed to include the correction of +2.5 dB(A). Next, there was no opposite façade on the road and hence no reflection correction. The angle of view for this segment, θ was 139° and the correction was -1.1 dB(A). Thus, the total site layout correction was +1.4 dB(A). By calculating all the noise levels and corrections as stated above, the basic noise level was 73.7 dB(A), and corrections for propagation and site layout were -13.0 dB(A) and +1.4 dB(A) respectively. Hence, the total noise contribution for this segment 1 was 62.1 dB(A).

For segment 2, by referring to Table 4.6, the condition of the road was mostly similar to segment 1 where the basic noise level was 73.7 dB(A) since both segments consist of similar traffic flow, traffic speed, percentage of heavy vehicles, road gradient and road surface. For the propagation section, the shortest horizontal distance and height relative to the noise source remain at 90 m and 3.5 m respectively. The average height of propagation, H was 2.25 m. However, for segment 2, the percentage of the absorbent ground cover was estimated to be in the range of 60 % to 89 % and hence the value for absorbent ground cover, I was equal to 0.75. Hence, the propagation correction for segment 2 was -11.9 dB(A). Besides, for the site layout section, segment 2 was similar to segment 1 which consisted of a façade near to receiver point but does not have any façade on the opposite of the road. The angle of view of the segment was 34° where by referring to Figure 4.4, the angle of view traversed by the pond at the reception point was designated as the boundary for segment 2 of the road. The total site layout correction for segment 2 was -4.7 dB(A).

Moreover, to calculate the noise level and correction for segment 2, the basic noise level was 73.7 dB(A), and the correction for propagation and site layout were -11.9 dB(A) and -4.7 dB(A) respectively. Hence, the total noise contribution for this segment 2 was 57.1 dB(A). Combining the noise contribution from segment 1 and segment 2 of the road, the total combined noise level or also known as the predicted results of L_{10} (18-hour) was 63.3 dB(A) as shown in Table 4.7.

Prediction of Noise Level by Utilizing MATLAB

After obtaining the predicted L_{10} (18-hour) from CoRTN, now the developed program will be utilised to calculate the L_{10} (18-hour) with similar road condition and compare it with the predicted results of 63.3 dB(A) to ensure the workability of the program. The coding of the noise prediction model has been displayed in the section of Appendix B of this report. There were comments on the left side of the coding for further explanation of the function of the coding in MATLAB. The general flow of the coding was explained in the previous section which was the flowchart for the development of the noise prediction model and the programming algorithms. Besides, the data input into the program was the same as the road conditions as stated in CoRTN in order to assess the functionality of the coding. The command window first displayed how many road segments for the road that needed to be calculated, next was the data required for calculating the basic noise level, propagation correction and site layout correction. Lastly, the coding run and displayed the output result with L_{10} (18-hour) value.

Tables 4.8 and 4.10 displayed the required input data for road segment 1 and road segment 2 respectively. Moreover, Table 4.9 was the output value for the basic noise level and correction values for road segment 1. Lastly, Table 4.11 was the output value for the basic noise level and correction values for road segment 2 and included the output of the final predicted results of L_{10} (18-hour) after combining the noise contribution from all the segments with the value of 63.3 dB(A). This value was the same as the predicted value in the CoRTN model and hence proved that this developed noise prediction model was valid and workable.

Table 4.8: Display of Required Input Data for Road Segment 1.

Required Input Data	**Values**
How many road segment to be calculated:	2
L_{10} (1) or L_{10} (18-hour) (2):	2
What is the total 18 – hour traffic flow (Q):	20 000
What is the 18 – hour flows of heavy vehicles (F):	3 000
What is the road traffic speed (V):	70
Is the road level (1) or gradient (2):	1
Road surface type (Impervious – 1, Pervious Macadams – 2):	1
What is the shortest horizontal distance between the reception point and the edge of nearside carriageway (d):	90
What is the relative height between the reception point and the effective source position (h):	3.5
Is the source line of the road segment completely unobstructed (1) or obstructed (2):	1
Is the ground cover non-absorbent (1) or absorbent (2):	2
What is the percentage of absorbent ground:	95
Is the road level (1) or uneven (2):	1
Is there any façade near to receiver point (Yes – 1, No – 2):	1
Is there any dual barriers and retained cuts (Yes – 1, No – 2):	2
Is there any reflection from opposite façade (Yes – 1, No – 2):	2
Is there uniform rows of houses along opposite side of road (Yes – 1, No – 2):	2
What is the angle of view:	139

Table 4.9: Output Value for Basic Noise Level and Correction Values for Road Segment 1.

Output Data	**Values**
Road segment:	1
The basic noise level using Chart 3:	72.1 dB(A)
Traffic flow correction:	2.6 dB(A)
Gradient correction:	0.0 dB(A)
Road surface correction:	-1.0 dB(A)
Distance correction:	-8.4 dB(A)
Ground correction:	-4.6 dB(A)
Screen correction:	0.0 dB(A)
Reflection correction:	2.5 dB(A)
Angle of view correction:	-1.1 dB(A)
Final noise contribution:	62.1 dB(A)

Table 4.10: Display of Required Input Data for Road Segment 2.

Required Input Data	**Values**
L_{10} (1) or L_{10} (18-hour) (2):	2
What is the total 18 – hour traffic flow (*Q*):	20 000
What is the 18 – hour flows of heavy vehicles (*F*):	3 000
What is the road traffic speed (*V*):	70
Is the road level (1) or gradient (2):	1
Road surface type (Impervious – 1, Pervious Macadams – 2):	1
What is the shortest horizontal distance between the reception point and the edge of nearside carriageway (*d*):	90
What is the relative height between the reception point and the effective source position (*h*):	3.5
Is the source line of the road segment completely unobstructed (1) or obstructed (2):	1
Is the ground cover non-absorbent (1) or absorbent (2):	2
What is the percentage of absorbent ground:	85
Is the road level (1) or uneven (2):	1
Is there any façade near to receiver point (Yes – 1, No – 2):	1
Is there any dual barriers and retained cuts (Yes – 1, No – 2):	2
Is there any reflection from opposite façade (Yes – 1, No – 2):	2
Is there uniform rows of houses along opposite side of road (Yes – 1, No – 2):	2
What is the angle of view:	34

Table 4.11: Output Value for Basic Noise Level and Correction Values for Road Segment 1 and the Output of Final Predicted Results of L_{10} (18-hour).

Output Data	Values
Road segment:	2
The basic noise level using Chart 3:	72.1 dB(A)
Traffic flow correction:	2.6 dB(A)
Gradient correction:	0.0 dB(A)
Road surface correction:	-1.0 dB(A)
Distance correction:	-8.4 dB(A)
Ground correction:	-3.5 dB(A)
Screen correction:	0.0 dB(A)
Reflection correction:	2.5 dB(A)
Angle of view correction:	-7.2 dB(A)
Final noise contribution:	57.1 dB(A)
After combining the correction from all segments and all correction, Predicted value of L_{10} (18-hour):	63.3 dB(A)

4.4 Reliability and Accuracy of CoRTN Model

This section showed the analyzed results of the reliability and accuracy of the CoRTN model. The graphs of the predicted noise level against the measured noise level have been plotted to calculate the R^2 correlation for the reliability of the results. While for the accuracy of the results, the mean absolute differences have been computed and discussed in this section.

4.4.1 Reliability of CoRTN

Reliability in measurement is refer to the consistency with which a method is able to measure something. A method considers as high reliability if it is able to consistently generate similar results under different conditions. By referring to Lim, et al., (2015), a graph was plotted to identify the goodness of the predicted results compared to the measured results for a noise mapping stimulation and determination of the accuracy of the random walk approach in predicting noise level. Hence, in order to assess the reliability of the CoRTN model in predicting the traffic noise level in Malaysia for this study, a similar method was implemented which a graph of predicted or calculated traffic noise level against the measured traffic noise level was plotted. Two parameters including the L_{10} and L_{eq} were determined for the reliability test. Figure 4.5 showed the R^2 for the graph of predicted L_{10} against the measured L_{10} for the four control points for peak hour and non-peak hour. While Figure 4.6 showed the graph of predicted L_{eq} against the measured L_{eq} for the four control points for peak hour and non-peak hour.

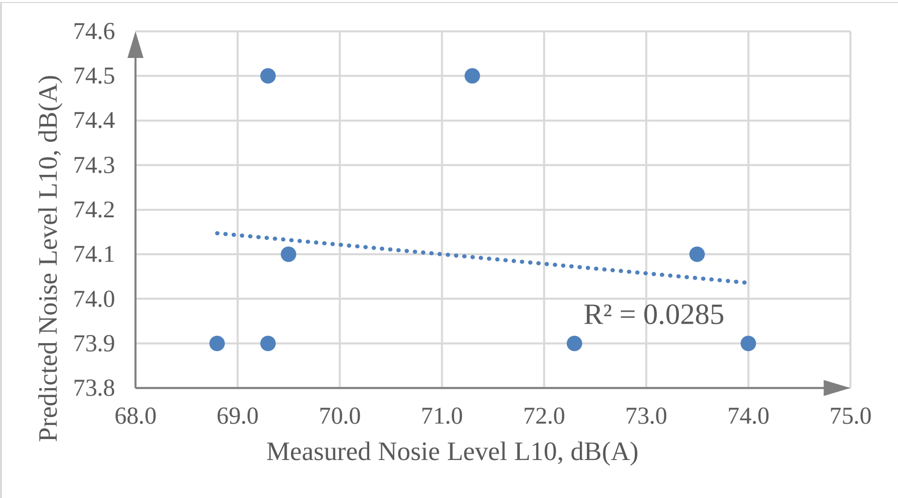


Figure 4.5: Graph of Predicted L_{10} against Measured L_{10}.

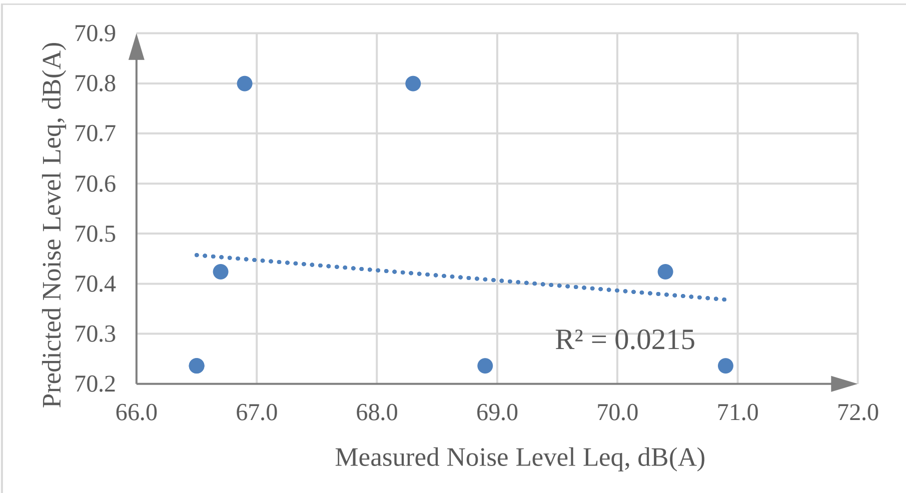


Figure 4.6: Graph of Predicted L_{eq} against Measured L_{eq}.

From the graphs provided, the coefficient of determination, R^2 obtained for the graph of L_{10} was 0.0285 while for the graph of L_{eq} was 0.0215. These results indicated that this model has very low reliability and low performance in predicting the traffic noise level since the results were not close to one. This might be due to the relationship between the independent variable and the dependent variable being non-linear or non-consistent and the trendline not able to fit all the points and reduced the R^2. Besides, it can be observed that there were at least two outliers existed in both the graph for L_{10} and L_{eq} which affected the fitness of the model and reduced the R^2 significantly. Another reason can be due to inadequate input data in the development of the CoRTN model which the model does not considered all relevant variables or parameters that affected the noise level and hence the model unable to represent the actual conditions of the road measured. This indicated that the CoRTN model might have limitations and can be considered not reliable in noise prediction for Jalan Permaisuri since this model has been published approximately 48 years ago. According to Alimohammadi, et. al. (2005), the study indicated that the CoRTN model overestimated the L_{10} value for a highway in Tehran. They explained that the CoRTN model overestimated the noise level by +1.46 dB(A) due to the model being non-calibrated. Besides, Halim, et al., (2017) also stated that the average overestimation of the traffic noise level in Klang Valley when implementing the CoRTN model is +3.6dB(A).

Moreover, another study conducted by Lisle (2016) showed that the CoRTN model seems to be improbable in noise predictions as it indicated the noise levels on the soft ground were the same as the hard ground in certain areas which was abnormal. This was because CoRTN computed the attenuation for the ground absorption and shielding separately where the noise reduction due to ground absorption was not factored in for the shielded receivers. According to CoRTN, the effect of both the ground absorption and barrier should be assessed and the one with higher propagation loss should be selected. Hence, CoRTN was unable to calculate the combined impact from both ground absorption and barrier loss. The study proved that the CoRTN model highly overpredicted the noise level in the rural and urban freeways, especially for the rural freeway, it overestimated the noise level by up to 10 dB.

4.4.2 Accuracy of CoRTN

Accuracy can be defined as the degree of proximity between the outcome obtained from a measurement and the actual value of the thing to be measured. In other words, accuracy indicates how close a measured result is to the actual results of the entity being measured. Moreover, for the accuracy of the results, the absolute mean difference between the predicted or calculated traffic noise level and the measured traffic noise level will be calculated to obtain the average results. Table 4.12 showed the absolute difference between the measured L_{10} and the calculated L_{10} for the four control points during peak hour and off-peak hour. Table 4.13 showed the absolute difference between the measured L_{eq} and the calculated L_{eq} for the four control points during peak hour and off-peak hour.

Table 4.12: Absolute Difference of Measured L_{10} and the Calculated L_{10} for the Four Control Points.

Control Point	**Condition**	**Time**	**Measured, dB(A)**	**Predicted, dB(A)**	**Absolute Difference, dB(A)**
Control Point 1 (Day 1)	Peak	7.00 a.m.- 9.00 a.m.	69.3	73.9	4.6
	Off-peak	9.00 a.m.- 11.00 a.m.	69.3	74.5	5.2
Control Point 2 (Day 1)	Peak	7.00 a.m.- 9.00 a.m.	72.3	73.9	1.6
	Off-peak	9.00 a.m.- 11.00 a.m.	71.3	74.5	3.2
Control Point 3 (Day 2)	Peak	7.00 a.m.- 9.00 a.m.	68.8	73.9	5.1
	Off-peak	9.00 a.m.- 11.00 a.m.	69.5	74.1	4.6
Control Point 4 (Day 2)	Peak	7.00 a.m.- 9.00 a.m.	74.0	73.9	0.1
	Off-peak	9.00 a.m.- 11.00 a.m.	73.5	74.1	0.6
				Average	3.125

From Table 4.12, the absolute difference of L_{10} were ranging from 0.1 dB(A) to 5.1 dB(A) with the mean difference between the predicted L_{10} and measured L_{10} being 3.125 dB(A). This indicated that the values of predicted values were closed to the measured values of L_{10} and were considered high accuracy.

Table 4.13: Absolute Difference of Measured L_{eq} and the Calculated L_{eq} for the Four Control Points.

Control Point	**Condition**	**Time**	**Measured, dB(A)**	**Predicted, dB(A)**	**Absolute Difference, dB(A)**
Control Point 1 (Day 1)	Peak	7.00 a.m.- 9.00 a.m.	66.5	70.2	3.7
	Off-peak	9.00 a.m.- 11.00 a.m.	66.9	70.8	3.9
Control Point 2 (Day 1)	Peak	7.00 a.m.- 9.00 a.m.	68.9	70.2	1.3
	Off-peak	9.00 a.m.- 11.00 a.m.	68.3	70.8	2.5
Control Point 3 (Day 2)	Peak	7.00 a.m.- 9.00 a.m.	66.5	70.2	3.7
	Off-peak	9.00 a.m.- 11.00 a.m.	66.7	70.4	3.7
Control Point 4 (Day 2)	Peak	7.00 a.m.- 9.00 a.m.	70.9	70.2	0.7
	Off-peak	9.00 a.m.- 11.00 a.m.	70.4	70.4	0.0
				Average	**2.453**

Next, from Table 4.13, another parameter, L_{eq} showed the absolute difference ranging from 0 dB(A) to 3.9 dB(A) with the mean difference between the predicted L_{eq} and measured L_{eq} being 2. 453 dB(A). The values of L_{eq} were lower than the values of L_{10} which was more accurate. Additionally, the majority of the predicted value for L_{10} and L_{eq} was greater than the measured results which indicated the CoRTN slightly overestimated the traffic noise level. However, since the mean absolute difference was small, it can be said that the CoRTN model was able to estimate the traffic noise level accurately and can be implemented for the assessment of road traffic noise levels in urban areas such as Mahkota Cheras. The study conducted by Alimohammadi, et al. (2005) reported that the CoRTN model had an acceptable accuracy in estimating the noise level in a heavy traffic stream.

4.5 Summary

This chapter first discussed the field measurement results. The total traffic volume for day one and day two including the peak and off-peak hours were 2791 and 2723 respectively. Next, the measured noise level which were the L_{10} and L_{eq} variables for the four control points was recorded to compare with the predicted value. The next section was the development of a noise prediction model by using MATLAB and referring to the CoRTN model. A road condition in CoRTN was selected and the value of the predicted L_{10} (18-hour) was calculated. The value was then compared with the output value of the developed program to evaluate the efficiency of the program. The value obtained was similar for both sides and hence the program was workable. The last section was to assess the reliability and accuracy of the CoRTN model. The results indicated that the CoRTN method might have high accuracy in traffic noise level prediction, however, its reliability to be implemented in Malaysia might be low since it will be influenced by various kinds of factors which will affect the stability and consistency of the noise level over a period of time when applied to different conditions.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In a nutshell, urban and transportation development had brought significant impacts on the human living environment since traffic noise has grown to be an issue, especially in the urban area as the major factor of noise pollution (Wang, Cai and Cui, 2019). Exposure to traffic noise continuously contributed to health problems physically and mentally. Hence, this study focused on measuring the road traffic noise in high density area which was Bandar Mahkota Cheras and predicting the road traffic noise using MATLAB by referring to CoRTN. This study assessed the reliability and accuracy of CoRTN in predicting noise level and to ensure the traffic noise level was within the acceptable range so that mitigation can be provided to reduce the traffic noise level.

The first objective of this study was to measure the traffic noise level for Jalan Permaisuri over a specific period. In this study, the sound level meter has been utilized to record the parameters for the noise level along the roads during peak hours and off-peak hours. The parameters including the L_{10}, L_{50}, L_{90}, L_{eq}, L_{peak}, L_{max} and L_{min} were recorded. Besides, the total traffic volume which was classified by various types of vehicles, especially for the percentage of heavy vehicles also be recorded. These data were then used to compare with the calculated noise level for assessment of the CoRTN model.

Besides, the next objective of this study was to develop a noise prediction model using a programming tool known as MATLAB by referring to the CoRTN model. The program has been developed with various sections where the first section was calculating the basic noise level based on the road condition. Then, the program continued to calculate the propagation correction and site layout correction to be applied to the value of the basic noise level. The program proceeded to combine the noise contribution if there was more than one road segment and generated the final predicted noise level. This developed program has been proven effective and workable since it produced similar output when evaluated with the road condition provided in the CoRTN model.

The last objective of this study was to evaluate the reliability and accuracy of the CoRTN noise prediction model by having a comparison between the predicted noise level and the measured noise level from the road of the study area. The graph of the predicted noise level against the measured noise level was plotted to calculate the R^2 correlation for the reliability of the results. While the mean absolute difference was determined to assess the accuracy of the results. The result shown that the model has low reliability since the R^2 values of L_{10} and L_{eq} were found with 0.0285 and 0.0215 respectively. However, the model has high accuracy since the mean difference between the predicted L_{10} and measured L_{10} was 3.125 dB(A), while the mean difference between the predicted L_{eq} and measured L_{eq} was 2.453 dB(A). This situation might happen in certain circumstances since the results obtained for reliability were not consistent. Hence, the CoRTN model may need some improvements for the reliability in the noise level prediction so that able to be implemented in Malaysia.

5.2 Recommendations for Future Work

In this report, the study emphasized the reliability and accuracy of the CoRTN model to be implemented in Malaysia. However, the results obtained were not satisfactory and might have some limitations that can be investigated. Hence, in-depth studies regarding the noise prediction method can be carried out to determine the limitations and to obtain the desired results. Here are some recommendations for future work:

(i) Study other types of roads like highways or roads at different location with various conditions such as roads with a curve, roads with gradients or roads with junctions. This study focused on evaluating one rural single carriageway which was a straight road. Research on different kinds of road conditions might determine other variables that did not include in this study and be able to assess the traffic noise level of the roads more accurately.

(ii) Conduct additional analysis such as traffic noise multiple linear regression model analysis, gradient boosting model (GBM) and sensitivity analysis. This analysis provides the ability to analyse deeper and more complex data on the traffic noise level to have a more accurate result. Besides, statistical methods also could be used to forecast the traffic noise level between the control or monitoring points based on the available results.

(iii) Provide long-term monitoring for the measurement of road traffic noise. This study only monitored the results for two hours for peak hours and off-peak hours respectively which the time period was short. Long-term monitoring can be conducted to determine the trend and the variations in the traffic noise level for the period of time. A full day measurement of the road traffic noise can be conducted to obtain the noise level for daytime and night-time. More sets of data might provide results with better quality and accuracy.

(iv) Provide more control points or monitoring points to measure the road traffic noise along the road to be assessed. There were only four control points be conducted for this study due to the limited resources. Hence, more sets of results be measured able to obtain more accurate results. In other words, a more comprehensive understanding of the traffic noise level along the road can be studied by increasing the number of the control points. This can certainly improve the accuracy of the results obtained.

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APPENDICES

Appendix A: Measured Noise Level from the Sound Level Meter.

Noise Level Recorded from Sound Level Meter at Jalan Permaisuri

SLM1
Date: 14/12/2022
Time: 7.00a.m. - 9.00a.m.
Condition: Peak

Noise	10min	20min	30min	40min	50min	60min	70min	80min	90min	100min	110min	120min	Avg
L10	67.4	67.3	67.5	67.9	68.3	68.7	68.8	68.9	69	69.1	69.2	69.3	68.45
L50	58.6	58.3	58.6	59.6	60.1	60.7	61.6	61.8	62	62.2	62.4	62.5	60.70
L90	48.4	49	49.7	50.5	50.8	51.3	51.8	52.1	52.4	52.8	53	53.2	51.25
Leq	64	63.8	63.9	64.2	64.8	65.6	65.8	66.1	66.1	66.4	66.4	66.5	65.30
Lpeak	99	99	99	99	102.1	105.8	105.8	115.4	115.4	115.4	115.4	115.4	107.23
Lmax	82.2	82.2	82.2	82.2	87.8	87.8	87.8	95.4	95.4	95.4	95.4	95.4	89.10
Lmin	43.6	43.1	43.1	43.1	43.1	43.1	43.1	43.1	43.1	43.1	43.1	43.1	43.14

SLM1
Date: 14/12/2022
Time: 9.00a.m. - 11.00a.m.
Condition: Off Peak

Noise	10min	20min	30min	40min	50min	60min	70min	80min	90min	100min	110min	120min	Avg
L10	70.4	69.3	69.2	69.2	69.3	69.4	69.4	69.2	69.3	69.3	69.2	69.3	69.38
L50	64.7	63.2	62.9	62.9	62.9	62.8	62.8	62.6	62.7	62.6	62.5	62.5	62.93
L90	55.5	54.4	54.2	54.1	54.4	54.1	54.2	54	54	53.9	53.8	53.7	54.19
Leq	67.7	66.3	66.4	66.2	66.5	66.5	66.5	66.3	66.3	66.4	66.4	66.9	66.53
Lpeak	96.4	96.4	98.1	98.1	98.6	98.6	98.6	98.6	98.6	98.6	102.5	104.5	98.97
Lmax	83.1	83.9	85.8	85.8	85.8	85.8	85.8	85.8	85.8	85.8	86.7	93.4	86.13
Lmin	42.5	42.5	42.5	42.5	42.5	42.5	42.5	42.5	42.5	42.5	42.5	42.5	42.50

SLM2
Date: 14/12/2022
Time: 7.00a.m. - 9.00a.m.
Condition: Peak

Noise	10min	20min	30min	40min	50min	60min	70min	80min	90min	100min	110min	120min	Avg
L10	69.7	70.1	70.6	70.9	71.1	71.6	71.7	71.7	71.9	72	72.1	72.3	71.31
L50	61	61.8	62.3	62.9	63.2	63.8	64.1	64.3	64.5	64.7	64.9	65.1	63.55
L90	52.1	52.7	53.5	54	54.2	54.5	54.9	55.1	55.4	55.6	55.8	56	54.48
Leq	66.1	66.5	66.9	67.1	67.6	68.1	68.2	68.2	68.5	68.7	68.8	68.9	67.80
Lpeak	96.2	97.2	97.2	97.2	98.6	108.3	108.3	108.3	108.3	109.6	109.6	109.6	104.03
Lmax	83.3	86.8	86.8	86.8	89.9	89.9	89.9	89.9	94.1	94.3	94.3	94.3	90.03
Lmin	45.4	44.9	44.9	44.9	44.9	44.9	44.9	44.9	44.9	44.9	44.9	44.9	44.94

SLM2
Date: 14/12/2022
Time: 9.00a.m. - 11.00a.m.
Condition: Off Peak

Noise	10min	20min	30min	40min	50min	60min	70min	80min	90min	100min	110min	120min	Avg
L10	75.2	73.6	73	72.6	72.3	72	71.8	71.6	71.5	71.5	71.3	71.3	72.31
L50	67.5	66.2	65.4	65	64.7	64.4	64.3	64.1	64	64	63.8	63.7	64.76
L90	57.6	57	55.8	55.5	55.5	55.3	55.3	55.2	55.1	55.1	55	54.8	55.60
Leq	71.9	70.3	69.8	69.3	69.2	69	68.8	68.6	68.4	68.4	68.2	68.3	69.18
Lpeak	103.5	105.3	105.3	105.3	105.3	105.3	105.3	105.3	105.3	105.3	105.3	105.3	105.15
Lmax	90.5	90.5	90.5	90.5	90.5	90.5	90.5	90.5	90.5	90.5	90.5	90.5	90.50
Lmin	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.20

SLM3
Date: 15/12/2022
Time: 7.00a.m. - 9.00a.m.
Condition: Peak

Noise	10min	20min	30min	40min	50min	60min	70min	80min	90min	100min	110min	120min	Avg
L10	66.6	66.1	66.4	66.6	67.3	67.7	68	68	68.4	68.6	68.6	68.8	67.59
L50	56.2	56.6	57.4	58.2	59	59.6	60.2	60.4	60.8	61.2	61.2	61.3	59.34
L90	48.3	48.5	48.9	49.6	50.1	50.6	51	51.3	51.7	52	52.1	52.2	50.53

Leq	64.1	63.5	63.4	63.5	64.3	64.9	65.7	65.6	66.3	66.4	66.3	66.5	65.04
Lpeak	97.6	97.6	97.6	97.6	97.6	98.4	109.6	109.6	109.6	109.6	109.6	109.6	103.67
Lmax	84.6	84.6	84.6	84.6	84.6	86.2	92.6	92.6	92.6	92.6	92.6	92.6	88.73
Lmin	42.5	41.4	41.4	41.4	41.4	41.4	41.4	41.4	41.4	41.4	41.4	41.4	41.49

SLM3
Date: 15/12/2022
Time: 9.00a.m. - 11.00a.m.
Condition: Off Peak

Noise	10min	20min	30min	40min	50min	60min	70min	80min	90min	100min	110min	120min	Avg
L10	69.6	70.1	69.7	69.6	69.7	69.5	69.4	69.5	69.5	69.5	69.6	69.5	69.60
L50	62.8	63.4	62.8	62.9	62.7	62.5	62.3	62.4	62.4	62.3	62.3	62.3	62.59
L90	56.4	56.1	55.5	55.5	54.9	54.2	53.9	54.1	54	54	54	54	54.72
Leq	66.3	66.8	66.4	66.4	66.5	66.5	66.4	66.4	66.5	66.4	66.5	66.7	66.48
Lpeak	95	101.8	101.8	101.8	101.8	101.8	101.8	101.8	101.8	101.8	101.8	110.8	101.98
Lmax	81.8	85	85	85	85	85	85	65	85	85	85.7	92.5	83.75
Lmin	50.8	47.8	46.7	46.7	44.6	41	41	41	41	41	41	41	43.63

SLM4
Date: 15/12/2022
Time: 7.00a.m. - 9.00a.m.
Condition: Peak

Noise	10min	20min	30min	40min	50min	60min	70min	80min	90min	100min	110min	120min	Avg
L10	68.2	70.8	71.7	71.9	72.4	73.2	73.3	73.3	73.6	73.8	73.8	74	72.50
L50	57	60.6	62.4	63.2	63.9	64.7	65.1	65.1	65.4	65.8	65.9	66	63.76
L90	49.7	50.9	51.9	52.5	53.1	53.8	54.5	55	55.4	55.9	56.2	56.3	53.77
Leq	65.1	67	67.9	68.2	68.8	69.6	69.9	69.9	70.5	70.7	70.6	70.9	69.09
Lpeak	98.9	98.9	99.4	99.4	101	106.3	114.3	114.3	114.3	114.3	114.3	114.3	107.48
Lmax	88.1	88.1	88.1	88.1	88.1	92.2	95.4	95.4	95.4	95.4	95.4	95.4	92.09
Lmin	45.9	45.2	45.2	45.2	45.2	45.2	45.2	45.2	45.2	45.2	45.2	45.2	45.26

SLM4
Date: 15/12/2022
Time: 9.00a.m. - 11.00a.m.
Condition: Off Peak

Noise	10min	20min	30min	40min	50min	60min	70min	80min	90min	100min	110min	120min	Avg
L10	70.9	72.7	72.5	72.5	72.9	73.3	73	73.3	73.3	73.4	73.4	73.5	72.89
L50	64.8	66	65.6	65.6	65.8	65.9	65.7	65.7	65.9	66	66	66.1	65.76
L90	57.9	58.5	57.8	57.8	57.9	57.8	57.6	57.6	57.8	58.1	58.1	58.1	57.92
Leq	67.9	69.3	69.1	69.1	69.8	70.3	70.1	70.1	70.3	70.3	70.3	70.4	69.75
Lpeak	104.3	104.3	104.3	104.3	104.4	107.6	107.6	107.6	107.6	108	108	110.4	106.53
Lmax	84	84	84	86.7	90.3	95.9	95.9	95.9	95.9	95.9	95.9	95.9	91.69
Lmin	51.1	50.3	50.3	49.7	49.7	49.3	49.3	49.3	49.3	49.3	49.3	49.3	49.68

Appendix B: Coding for the Noise Prediction Model.

```
clear      % To clear all variables from the current workspace
clc        % To clear all the text from command window

    % Read the number of loops for the noise level calculation
    prompt = "How many road segment to be calculated: ";
    choice = input(prompt);

for n = 1:choice  % Use for loop to repeat specified number of times

    prompt = "L10 (1) or L10_18hr (2): "; % Calculate L10 or L10(18hr)
    choice1 = input(prompt);

if choice1 == 1 % Calculate the noise level using L10

    % Basic noise level hourly L10 (Assume 75km/hr, p and G is 0%)
    prompt = "What is the total hourly traffic flow (q): "; % veh/hr
    q = input(prompt);
    L10 = 42.2 + 10*log10(q); % Calc basic noise level hourly L10 in dB(A)
    L10 = round(L10,1,"decimals");

    % Corretion for the percentage heavy vehicles (p)
    prompt = "What is the hourly flows of heavy vehicles (f): "; % veh/hr
    f = input(prompt);
    p = 100*f / q; % Calc the correction for percentage heavy vehicles (%)

    prompt = "What is the road traffic speed (V): "; % km/h
    V = input(prompt);

    % Correction for traffic on a gradient (G)
    % This correction is for carriageways treated separately or one-way
    % traffic schemes and applied only for upward flow
    prompt = "Is the road level (1) or gradient (2): ";
    choice2 = input(prompt);

    if choice2 == 1 % Level road condition
        c_gradient = 0;

    elseif choice2 == 2 % Gradient road condition
        prompt = "Is it upward(1) or downward(2) flow: "; % Flow direction
        choice9 = input(prompt);

        prompt = "What is the road gradient (G): "; % Percentage (%)
        G = input(prompt);
            if choice9 == 2 % Downward flow condition
                G = -G;
            end

            if G <= 0
                c_gradient = 0;
            else
                c_gradient = 0.3*G;
            end
```

```
end
    c_gradient = round(c_gradient,1,"decimals");

% Correction for traffic speed (V) and percentage heavy vehicles (p)
if choice2 == 1 % Level road condition
   c_flow = 33*log10(V+40+500/V) + 10*log10(1+5*p/V) - 68.8;

elseif choice2 == 2 % Gradient road condition
 disp("1. Carriageways treated separately");
 disp("2. One-way traffic schemes");
 disp("3. Measured traffic speed given");
 prompt = "Is the carriageway fulfill condition above (Yes-1, No-2): ";
 choice8 = input(prompt);

        if choice8 == 1 % Fulfill the conditions
        V_new = V; % No change in V required

        elseif choice8 == 2 % Not fulfill the conditions
        Vv = (0.73 + (2.3 - 1.15*p/100)*(p/100))*G; % Calc change in V
        V_new = V-Vv; % Find new V

        end

  c_flow = 33*log10(V_new+40+500/V_new) + 10*log10(1+5*p/V_new) - 68.8;
end
  c_flow = round(c_flow,1,"decimals");

% Correction for road surface
prompt = "Road surface type (Impervious-1, Pervious Macadams-2): ";
roadtype = input(prompt);

if (V<75) && (roadtype == 1)
    c_roadsurface = -1;
elseif roadtype == 3
    c_roadsurface = -3.5;
elseif (V>=75) && (roadtype == 1)
    prompt = "Road with concrete (1) or bituminous surface (2): ";
    surface = input(prompt);
    prompt = "What is the texture depth (TD): "; % m
    TD = input(prompt);

    if surface == 1
        c_roadsurface = 10*log10(90*TD+30)-20;
    elseif surface == 2
        c_roadsurface = 10*log10(20*TD+60)-20;
    end

end
    c_roadsurface = round(c_roadsurface,1,"decimals");

% Correction for distance disregarding the presence of ground
% or intervening obstacles
```

```
   prompt = "What is the shortest horizontal distance between the reception
point and the edge of nearside carriageway (d): "; % m
   d = input(prompt);
   if d<4
      d=4;
   end

   prompt = "What is the relative height between the reception point and the
effective source position (h): "; % m
   h = input(prompt);

   slant_d = sqrt(((d+3.5)^2)+h^2); % Calculate d' using d and h
   c_distance = -10*log10(slant_d/13.5); % Calculate distance correction
   c_distance = round(c_distance,1,"decimals");


   prompt = "Is the source line of the road segment completely
unobstructed(1) or obstructed(2): ";
   choice3 = input(prompt);

   if choice3 == 1 % Unobstructed propagation
       % Correction for ground cover absorption
       c_screen = 0; % No screening correction

       prompt = "Is the ground cover non-absorbent (1) or absorbent (2): ";
       choice4 = input(prompt);

       if choice4 == 1 % Non-absorbent ground cover
           c_ground = 0;

       elseif choice4 == 2 % Absorbent ground cover
           % Read the percentage of absorbent ground to know I
           prompt = "What is the percentage of absorbent ground: ";
           abs_ground = input(prompt);

               % Read I based on percentage of absorbent ground
               if abs_ground <10
                   I=0;
               elseif abs_ground<=39
                   I=0.25;
               elseif abs_ground<=59
                   I=0.5;
               elseif abs_ground<=89
                   I=0.75;
               else
                   I=1;
               end

           prompt = "Is the road level(1) or uneven(2): ";
           choice10 = input(prompt);

               if choice10 == 1 % Level road condition
                  H = 0.5*(h+1);
```

```
                elseif choice10 == 2 % Uneven road condition
                   prompt = "What is the average height of propagation(H): ";
                   H = input(prompt);

                end

                % Calculate ground cover correction
                if H <0.75
                    H=0.75;
                    c_ground = 5.2*I*log10(3/(d+3.5));

                elseif H<(d+5)/6
                    c_ground = 5.2*I*log10((6*H-1.5)/(d+3.5));

                elseif H>=(d+5)/6
                    c_ground = 0;

                end

        end
            c_ground = round(c_ground,1,"decimals");


    elseif choice3 == 2 % Obstructed propagation (Use chart 9a)

        prompt = "How many barriers interposed between the source line and the
reception point: ";
        choice12 = input(prompt);

            if choice12 == 1 % One barrier condition
                c_ground = 0; % No ground cover correction

                prompt = "What is the path difference (SB+BR-d'): ";
                path_dif = input(prompt);

                x_9 = log10(path_dif);

                % Region divided into illuminated zone and shadow zone
                % For shadow zone (Screening Correction)
                if (-3<=x_9) && (x_9<=1.2)
                    a1 = -15.4-8.26*x_9-2.787*(x_9^2)-0.831*(x_9^3);
                    a2 = -0.198*(x_9^4)+0.1539*(x_9^5)+0.12248*(x_9^6);
                    A_s = a1+a2+0.02175*(x_9^7);
                elseif x_9<-3
                    A_s=-5;
                elseif x_9>1.2
                    A_s=-30;
                end

                % For illuminated zone (Screening Correction)
                if (-4<=x_9)&&(x_9<=0)
                    a3 = 0.109*x_9-0.815*(x_9^2);
                    A_i = a3 +0.479*(x_9^3)+0.3284*(x_9^4)+0.04385*(x_9^5);
                elseif x_9<-4
```

```
            A_i=-5;
        elseif x_9>0
            A_i=0;
        end

        A_i = round(A_i,1,"decimals");
        A_s = round(A_s,1,"decimals");

    % Read the region of reception point
    prompt = "Reception point in shadow(1) or illuminated zone(2): ";
    choice11 = input(prompt);

        if choice11 == 1 % Shadow zone
            c_screen = A_s;

        elseif choice11 == 2 % Illuminated zone
            c_screen = A_i;

        end

elseif choice12 == 2 % More than one barrier condition
        c_ground = 0; % No ground cover correction

        for n = 1:choice12
            prompt = "What is the path difference (SB+BR-d'): ";
            path_dif = input(prompt);

            x_9 = log10(path_dif);
        % Region divided into illuminated zone and shadow zone
        % For shadow zone (Screening Correction)
        if (-3<=x_9) && (x_9<=1.2)
            a1 = -15.4-8.26*x_9-2.787*(x_9^2)-0.831*(x_9^3);
            a2 = -0.198*(x_9^4)+0.1539*(x_9^5)+0.12248*(x_9^6);
            A_s = a1+a2+0.02175*(x_9^7);
        elseif x_9<-3
            A_s=-5;
        elseif x_9>1.2
            A_s=-30;
        end

        % For illuminated zone (Screening Correction)
        if (-4<=x_9)&&(x_9<=0)
            a3 = 0.109*x_9-0.815*(x_9^2);
            A_i = a3 +0.479*(x_9^3)+0.3284*(x_9^4)+0.04385*(x_9^5);
        elseif x_9<-4
            A_i=-5;
        elseif x_9>0
            A_i=0;
        end

        A_i = round(A_i,1,"decimals");
        A_s = round(A_s,1,"decimals");

     prompt = "Reception point in shadow(1) or illuminated zone(2): ";
```

```
            choice11 = input(prompt);

               if choice11 == 1 % Shadow zone
                   c_screen = A_s;
               elseif choice11 == 2 % Illuminated zone
                   c_screen = A_i;
               end

               z(n)=c_screen;

               end

               if z(1)>z(2)
                   Aa = z(2);
                   Ab = z(1);
               else
                   Aa = z(1);
                   Ab = z(2);
               end

               prompt = "What is the horizontal distance between the top edge
of barriers(M): "; % m
               M = input(prompt);
               J = (M/(d+3.5))^(1/4);
               J = round(J,1,"decimals");

               Ac = -10*log10(10^(-Aa/10)+10^(-Ab*J/10)-1);
               Ac = round(Ac,1,"decimals");
               c_screen = Ac;

           end
   end

   % Corretion for facade effect
   prompt = "Is there any facade near to receiver point (Yes-1, No-2): ";
   choice5 = input(prompt);

       if choice5 == 1 % Facade exist
           y = 2.5;
       elseif choice5 == 2 % Facade not exist
           y = 0;
       end

   % Correction for multiple screened road segments
   prompt = "Is there any dual barriers and retained cuts (Yes-1, No-2): ";
   choice13 = input(prompt);

       if choice13 == 1 % Condition exist for dual barriers and retained cuts
           prompt = "What is the relative height of the screening barrier
above the road surface(W): "; % Read W (m)
           W = input(prompt);

           prompt = "What is the height of the reflecting barrier above the
road surface(Y): "; % Read Y (m)
```

```
            Y = input(prompt);

            prompt = "What is the height of the reception point R above the
road surface(a): "; % Read a (m)
            a = input(prompt);

            prompt = "What is the horizontal distance from the reception point
to the top edge of the scrmethod barrier(B): "; % Read B (m)
            B = input(prompt);

            prompt = "What is the horizontal distance between the top edge of
the screening barrier and the base of the reflecting barrier(E): "; % Read E
(m)
            E = input(prompt);

            prompt = "What is the angle of the reflecting barrier to the
vertical(phi): "; % Read angle
            phi = input(prompt);

                % For del_1
                if (Y>=W) && (a>=W)
                    del_1 = W;
                elseif (Y>=W) && (a<W)
                    if a<1
                        del_1 = a;
                    else
                        del_1=1;
                    end
                elseif (Y<W)&&(a>=Y)
                    del_1 = Y;
                elseif (Y<W)&&(a<Y)
                     if a<1
                        del_1 = a;
                     else
                        del_1=1;
                     end
                end

                % For del_2
                del_2 = (8.2-3*log10(a+10))*log10(a+10)-5;
                if a < del_2
                    del_2 = 0.2;
                elseif a > 30
                    del_2 = 0.44;
                end

                % For del_3
                del_3 = (1-0.6*log10(35+B/2))*log10(35+B/2);
                if B < 10
                    del_3 = 0.06;
                elseif B > 80
                    del_3 = -0.23;
                end
```

```
                % For del_4
                    del_4 = log10(1+(270/E));
                    if E < 30
                        del_4 = 1;
                    elseif E > 70
                        del_4 = 0.69;
                    end

                % For del_5
                del_5 = exp(-0.019*(phi^2));

            % Correction for reflection
            c_retained = (1.5+ (del_2 - del_3)*(1+del_5*(del_1-1)))*del_4;
            c_retained = round(c_retained,1,"decimals");

        elseif choice13 == 2 % No dual barriers and retained cuts
            % Reflection from opposite facades
            prompt = "Is there any reflection from opposite facade (Yes-1,
No-2): ";
            choice6 = input(prompt);

                if choice6 == 1 % Opposite facade exist
                 prompt = "What is the total value of the subtended angles: ";
                 ang1 = input(prompt);

                 prompt = "What is the sum of the angle of view at the
receiver point: ";
                 ang2 = input(prompt);

                   c_reflection = y +1.5*(ang1/ang2);

                elseif choice6 == 2 % Opposite facade not exist
                   c_reflection = y;

                end
        end

    % Correction for the houses fronting onto a main road
    prompt = "Is there uniform rows of houses along opposite side of road
(Yes-1, No-2): ";
    choice7 = input(prompt);

        if choice7 == 1
           prompt = "What is the mean opening between buildings: "; % m
           a = input(prompt);
           prompt = "What is the mean length of building evaluated along the
main road in the vicinity of the reception point: "; % m
           b = input(prompt);
           c_reflection = c_reflection + 1.5*(b/(a+b));
        end

        c_reflection = round(c_reflection,1,"decimals");

    % Correction for angle of view
```

```
    prompt = "What is the angle of view: ";
    ang_view = input(prompt);
    c_angle = 10*log10(ang_view/180);
    c_angle = round(c_angle,1,"decimals");

    % For low traffic flows
    if (slant_d <=30) && (50<= q) && (q <= 200)
    D = 30/slant_d;
    C = q/200;
    K = -16.6*log10(D)*(log10(C)^2); % Calculate the correction factor K
    LL = L10 + K; % Calculate the corrected predicted noise level
    L10 = LL;
    end

    % Display the output for each road segment
    fprintf('\nFor road segment %.0f\n', n);
    fprintf('The basic noise level using Chart 2 is %.1f dB(A)\n',L10);
    fprintf('Traffic flow correction: %.1f dB(A)\n',c_flow);
    fprintf('Gradient correction: %.1f dB(A)\n',c_gradient);
    fprintf('Road surface correction: %.1f dB(A)\n',c_roadsurface);
    fprintf('Distance correction: %.1f dB(A)\n',c_distance);
    fprintf('Ground correction: %.1f dB(A)\n',c_ground);
    fprintf('Screen correction: %.1f dB(A)\n',c_screen);
    fprintf('Reflection correction: %.1f dB(A)\n',c_reflection);
    fprintf('Angle of view correction: %.1f dB(A)\n',c_angle);
    L10 = L10+c_flow+c_gradient+c_roadsurface+c_distance+c_ground+c_reflection
+c_angle+c_screen;
    fprintf('Final noise contribution is %.1f dB(A)\n\n', L10);
    x(n)=L10; % Store value of L10 in matrix x if there is more than one loop


elseif choice1 == 2 % Calculate the noise level using L10(18hrs)

    % Basic noise level hourly L10(18hrs) (Assume 75km/hr, P and G is 0%)
    prompt = "What is the total 18-hour traffic flow (Q): "; % veh/hr
    Q = input(prompt);
    L10_18hrs = 29.1 + 10*log10(Q); % Calc basic noise level L10(18hr) in dBA
    L10_18hrs = round(L10_18hrs,1,"decimals");

    % Corretion for the percentage heavy vehicles (P)
    prompt = "What is the 18-hour flows of heavy vehicles (F): "; % veh/hr
    F = input(prompt);
    P = 100*F / Q; % Calc the correction for percentage heavy vehicles

    prompt = "What is the road traffic speed (V): "; % km/h
    V = input(prompt);

    % Correction for traffic on a gradient (G)
    % This correction is for carriageways treated separately or one-way
    % traffic schemes and applied only for upward flow
    prompt = "Is the road level (1) or gradient (2): ";
    choice2 = input(prompt);

    if choice2 == 1 % Level road condition
```

```
    c_gradient = 0;

elseif choice2 == 2 % Gradient road condition
    prompt = "Is it upward(1) or downward(2) flow: "; % Flow direction
    choice9 = input(prompt);

    prompt = "What is the road gradient (G): "; % Percentage (%)
    G = input(prompt);
        if choice9 == 2 % Downward flow condition
            G = -G;
        end

        if G <= 0
            c_gradient = 0;
        else
            c_gradient = 0.3*G;
        end

end
    c_gradient = round(c_gradient,1,"decimals");

% Correction for traffic speed (V) and percentage heavy vehicles (p)
if choice2 == 1 % Level road condition
    c_flow = 33*log10(V+40+500/V) + 10*log10(1+5*P/V) - 68.8;

elseif choice2 == 2 % Gradient road condition
 disp("1. Carriageways treated separately");
 disp("2. One-way traffic schemes");
 disp("3. Measured traffic speed given");
 prompt = "Is the carriageway fulfill condition above (Yes-1, No-2): ";
 choice8 = input(prompt);

        if choice8 == 1 % Fulfill the conditions
        V_new = V; % No change in V required

        elseif choice8 == 2 % Not fulfill the conditions
        Vv = (0.73 + (2.3 - 1.15*P/100)*(P/100))*G; % Calc change in V
        V_new = V-Vv; % Find new V

        end

  c_flow = 33*log10(V_new+40+500/V_new) + 10*log10(1+5*P/V_new) - 68.8;
end
  c_flow = round(c_flow,1,"decimals");

% Correction for road surface
prompt = "Road surface type (Impervious-1, Pervious Macadams-2): ";
roadtype = input(prompt);

if (V<75) && (roadtype == 1)
    c_roadsurface = -1;
elseif roadtype == 3
    c_roadsurface = -3.5;
elseif (V>=75) && (roadtype == 1)
```

```
        prompt = "Road with concrete (1) or bituminous surface (2): ";
        surface = input(prompt);
        prompt = "What is the texture depth (TD): "; % m
        TD = input(prompt);

        if surface == 1
            c_roadsurface = 10*log10(90*TD+30)-20;
        elseif surface == 2
            c_roadsurface = 10*log10(20*TD+60)-20;
        end
    end
        c_roadsurface = round(c_roadsurface,1,"decimals");

    % Correction for distance disregarding the presence of ground
    % or intervening obstacles
    prompt = "What is the shortest horizontal distance between the reception
point and the edge of nearside carriageway (d): "; % m
    d = input(prompt);
    if d<4
       d=4;
    end

    prompt = "What is the relative height between the reception point and the
effective source position (h): "; % m
    h = input(prompt);

    slant_d = sqrt(((d+3.5)^2)+h^2); % Calculate d' using d and h
    c_distance = -10*log10(slant_d/13.5); % Calculate distance correction
    c_distance = round(c_distance,1,"decimals");


    prompt = "Is the source line of the road segment completely
unobstructed(1) or obstructed(2): ";
    choice3 = input(prompt);

    if choice3 == 1 % Unobstructed propagation
        % Correction for ground cover absorption
        c_screen = 0; % No screening correction

        prompt = "Is the ground cover non-absorbent (1) or absorbent (2): ";
        choice4 = input(prompt);

        if choice4 == 1 % Non-absorbent ground cover
            c_ground = 0;

        elseif choice4 == 2 % Absorbent ground cover
            % Read the percentage of absorbent ground to know I
            prompt = "What is the percentage of absorbent ground: ";
            abs_ground = input(prompt);

                % Read I based on percentage of absorbent ground
                if abs_ground <10
                    I=0;
                elseif abs_ground<=39
```

```
                I=0.25;
            elseif abs_ground<=59
                I=0.5;
            elseif abs_ground<=89
                I=0.75;
            else
                I=1;
            end

        prompt = "Is the road level(1) or uneven(2): ";
        choice10 = input(prompt);

            if choice10 == 1 % Level road condition
                H = 0.5*(h+1);

            elseif choice10 == 2 % Uneven road condition
               prompt = "What is the average height of propagation(H): ";
               H = input(prompt);

            end

            % Calculate ground cover correction
            if H <0.75
                H=0.75;
                c_ground = 5.2*I*log10(3/(d+3.5));

            elseif H<(d+5)/6
                c_ground = 5.2*I*log10((6*H-1.5)/(d+3.5));

            elseif H>=(d+5)/6
                c_ground = 0;

            end

    end
        c_ground = round(c_ground,1,"decimals");


   elseif choice3 == 2 % Obstructed propagation (Use chart 9a)

       prompt = "How many barriers interposed between the source line and the
reception point: ";
       choice12 = input(prompt);

           if choice12 == 1 % One barrier condition
               c_ground = 0; % No ground cover correction

               prompt = "What is the path difference (SB+BR-d'): ";
               path_dif = input(prompt);

               x_9 = log10(path_dif);

               % Region divided into illuminated zone and shadow zone
               % For shadow zone (Screening Correction)
```

```
        if (-3<=x_9) && (x_9<=1.2)
            a1 = -15.4-8.26*x_9-2.787*(x_9^2)-0.831*(x_9^3);
            a2 = -0.198*(x_9^4)+0.1539*(x_9^5)+0.12248*(x_9^6);
            A_s = a1+a2+0.02175*(x_9^7);
        elseif x_9<-3
            A_s=-5;
        elseif x_9>1.2
            A_s=-30;
        end

        % For illuminated zone (Screening Correction)
        if (-4<=x_9)&&(x_9<=0)
            a3 = 0.109*x_9-0.815*(x_9^2);
            A_i = a3 +0.479*(x_9^3)+0.3284*(x_9^4)+0.04385*(x_9^5);
        elseif x_9<-4
            A_i=-5;
        elseif x_9>0
            A_i=0;
        end

        A_i = round(A_i,1,"decimals");
        A_s = round(A_s,1,"decimals");

    prompt = "Reception point in shadow(1) or illuminated zone(2): ";
    choice11 = input(prompt);

        if choice11 == 1 % Shadow zone
            c_screen = A_s;

        elseif choice11 == 2 % Illuminated zone
            c_screen = A_i;

        end

elseif choice12 == 2 % More than one barrier condition
        c_ground = 0; % No ground cover correction

        for n = 1:choice12
            prompt = "What is the path difference (SB+BR-d'): ";
            path_dif = input(prompt);

            x_9 = log10(path_dif);
        % Region divided into illuminated zone and shadow zone
        % For shadow zone (Screening Correction)
        if (-3<=x_9) && (x_9<=1.2)
            a1 = -15.4-8.26*x_9-2.787*(x_9^2)-0.831*(x_9^3);
            a2 = -0.198*(x_9^4)+0.1539*(x_9^5)+0.12248*(x_9^6);
            A_s = a1+a2+0.02175*(x_9^7);
        elseif x_9<-3
            A_s=-5;
        elseif x_9>1.2
            A_s=-30;
        end
```

```
                % For illuminated zone (Screening Correction)
                if (-4<=x_9)&&(x_9<=0)
                    a3 = 0.109*x_9-0.815*(x_9^2);
                    A_i = a3 +0.479*(x_9^3)+0.3284*(x_9^4)+0.04385*(x_9^5);
                elseif x_9<-4
                    A_i=-5;
                elseif x_9>0
                    A_i=0;
                end

                A_i = round(A_i,1,"decimals");
                A_s = round(A_s,1,"decimals");

             prompt = "Reception point in shadow(1) or illuminated zone(2): ";
             choice11 = input(prompt);

                if choice11 == 1 % Shadow zone
                    c_screen = A_s;
                elseif choice11 == 2 % Illuminated zone
                    c_screen = A_i;
                end

                z(n)=c_screen;

                end

                if z(1)>z(2)
                    Aa = z(2);
                    Ab = z(1);
                else
                    Aa = z(1);
                    Ab = z(2);
                end

                prompt = "What is the horizontal distance between the top edge
of barriers(M): "; % m
                M = input(prompt);
                J = (M/(d+3.5))^(1/4);
                J = round(J,1,"decimals");

                Ac = -10*log10(10^(-Aa/10)+10^(-Ab*J/10)-1);
                Ac = round(Ac,1,"decimals");
                c_screen = Ac;

            end
    end

    % Corretion for facade effect
    prompt = "Is there any facade near to receiver point (Yes-1, No-2): ";
    choice5 = input(prompt);

        if choice5 == 1 % Facade exist
            y = 2.5;
        elseif choice5 == 2 % Facade not exist
```

```
            y = 0;
        end

    % Correction for multiple screened road segments
    prompt = "Is there any dual barriers and retained cuts (Yes-1, No-2): ";
    choice13 = input(prompt);

        if choice13 == 1 % Condition exist for dual barriers and retained cuts
            prompt = "What is the relative height of the screening barrier
above the road surface(W): "; % Read W (m)
            W = input(prompt);

            prompt = "What is the height of the reflecting barrier above the
road surface(Y): "; % Read Y (m)
            Y = input(prompt);

            prompt = "What is the height of the reception point R above the
road surface(a): "; % Read a (m)
            a = input(prompt);

            prompt = "What is the horizontal distance from the reception point
to the top edge of the scrennning barrier(B): "; % Read B (m)
            B = input(prompt);

            prompt = "What is the horizontal distance between the top edge of
the screening barrier and the base of the reflecting barrier(E): "; % Read E
(m)
            E = input(prompt);

            prompt = "What is the angle of the reflecting barrier to the
vertical(phi): "; % Read angle
            phi = input(prompt);

                % For del_1
                if (Y>=W) && (a>=W)
                    del_1 = W;
                elseif (Y>=W) && (a<W)
                    if a<1
                        del_1 = a;
                    else
                        del_1=1;
                    end
                elseif (Y<W)&&(a>=Y)
                    del_1 = Y;
                elseif (Y<W)&&(a<Y)
                     if a<1
                        del_1 = a;
                     else
                        del_1=1;
                     end
                end

                % For del_2
                del_2 = (8.2-3*log10(a+10))*log10(a+10)-5;
```

```
                if a < del_2
                    del_2 = 0.2;
                elseif a > 30
                    del_2 = 0.44;
                end

                % For del_3
                del_3 = (1-0.6*log10(35+B/2))*log10(35+B/2);
                if B < 10
                    del_3 = 0.06;
                elseif B > 80
                    del_3 = -0.23;
                end

                % For del_4
                    del_4 = log10(1+(270/E));
                    if E < 30
                        del_4 = 1;
                    elseif E > 70
                        del_4 = 0.69;
                    end

                % For del_5
                del_5 = exp(-0.019*(phi^2));

            % Correction for reflection
            c_retained = (1.5+ (del_2 - del_3)*(1+del_5*(del_1-1)))*del_4;
            c_retained = round(c_retained,1,"decimals");

        elseif choice13 == 2 % No dual barriers and retained cuts
            % Reflection from opposite facades
            prompt = "Is there any reflection from opposite facade (Yes-1,
No-2): ";
            choice6 = input(prompt);

                if choice6 == 1 % Opposite facade exist
                    prompt = "What is the total value of the subtended angles:
";

                    ang1 = input(prompt);

                    prompt = "What is the sum of the angle of view at the
receiver point: ";
                    ang2 = input(prompt);

                    c_reflection = y +1.5*(ang1/ang2);

                elseif choice6 == 2 % Opposite facade not exist
                    c_reflection = y;

                end
        end

    % Correction for the houses fronting onto a main road
```

```
    prompt = "Is there uniform rows of houses along opposite side of road
 (Yes-1, No-2): ";
    choice7 = input(prompt);

        if choice7 == 1
           prompt = "What is the mean opening between buildings: "; % m
           a = input(prompt);
           prompt = "What is the mean length of building evaluated along the
 main road in the vicinity of the reception point: "; % m
           b = input(prompt);
           c_reflection = c_reflection + 1.5*(b/(a+b));
        end

        c_reflection = round(c_reflection,1,"decimals");

    % Correction for angle of view
    prompt = "What is the angle of view: ";
    ang_view = input(prompt);
    c_angle = 10*log10(ang_view/180);
    c_angle = round(c_angle,1,"decimals");

    % For low traffic flows
    if (slant_d <=30) && (50<= Q) && (Q <= 200)
    D = 30/slant_d;
    C = Q/200;
    K = -16.6*log10(D)*(log10(C)^2); % Calculate the correction factor K
    LL = L10_18hrs + K; % Calculate the corrected predicted noise level
    L10_18hrs = LL;
    end

    % Display the output for each road segment
    fprintf('\nFor road segment %.0f\n', n);
    fprintf('The basic noise level using Chart 3 is %.1f dB(A)\n',L10_18hrs);
    fprintf('Traffic flow correction: %.1f dB(A)\n',c_flow);
    fprintf('Gradient correction: %.1f dB(A)\n',c_gradient);
    fprintf('Road surface correction: %.1f dB(A)\n',c_roadsurface);
    fprintf('Distance correction: %.1f dB(A)\n',c_distance);
    fprintf('Ground correction: %.1f dB(A)\n',c_ground);
    fprintf('Screen correction: %.1f dB(A)\n',c_screen);
    fprintf('Reflection correction: %.1f dB(A)\n',c_reflection);
    fprintf('Angle of view correction: %.1f dB(A)\n',c_angle);
    L10_18hrs = L10_18hrs+c_flow+c_gradient+c_roadsurface+c_distance+c_ground
+c_reflection+c_angle+c_screen;
    fprintf('Final noise contribution is %.1f dB(A)\n\n', L10_18hrs);
    x(n)=L10_18hrs; % Store value of L10(18hrs) in matrix x if there is more
 than one loop

else
    disp("Run again  !!!"); % For choice other than L10 or L10(18hrs)

end

end
```

```
% Calculate combining noise level for multiple road segments
if choice == 2
    L_com = x(1) + 10*log10(1 + 10^(-(x(1)-x(2))/10));
else
    y_total = 0;
        for n = 1:choice
        y(n) = 10^(x(n)/10);
        y_total = y_total+y(n);
        end
    L_com = 10*log10(y_total);
end

L_com = round(L_com,1,"decimals");

% Display the final noise level consider all road segments
fprintf('\nAfter combining the contribution from all segments and all
corrections,\n');
if choice1 == 1
    fprintf('\nPredicted value of L10 value: %.1f dB(A)\n', L_com);
elseif choice1 == 2
    fprintf('Predicted value of L10(18hr) value: %.1f dB(A)\n', L_com);
end
```