A STUDY OF USABILITY NOISE PREDICTION MODEL BY USING LINEAR REGRESSION ANALYSIS FOR KTMB COMMUTER BETWEEN SHAH ALAM TO BUKIT BADAK ROUTE

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A project proposal submitted in partial fulfillment of the requirement for the award of the Degree of Master of Science Railway Engineering

Centre for Graduate Studies
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MARCH 2016
DECLARATION

“I hereby declare that this thesis is written on my own effort except for the quotes and extracts in which they have been cited accordingly.”

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Alhamdulillah

Special to my beloved Abah and Mak,
Family members
Friends
Also to my supporting supervisor
Dr-Ing Joewono Prasetijo

Thank you to all of you
ACKNOWLEDGEMENT

First and foremost, I would like to thanks and gratefulness to my supervisor; Dr-ING Joewono Prasetijo, for his guidance, supervision and encouragement during of my study and for his assistance and advice.

I am also would like to thank En Osman, staff of Building Services Laboratory, Faculty of Civil Engineering, UTHM for his assistance in the experimental works, field measurement process and apparatus guidance.

I would like to express my sincere appreciation to my family and friends for the love, encouragement and support. I also like to thank contributors whose names have been missed out in the list of acknowledgement.

Finally, I would thanks to all CGR 2014/2015 members who were helping a lot for the whole journey in completing my master study.
ABSTRACT

Train operational process producing high level of noise especially from the rail, wheel and its body which affect the nearer residential. High level of noise emitted by the train might lead to annoyance and even cause severe damage to residents live near the train route. KTMB received several complaints from the resident about the noise pollution came from train operation. Currently, in-situ field measurement procedure is done in order to monitor and measure noise level of train. The procedure requires some cost, time, man power and precise equipment which sometime might become constrain in order to get a quick data. In most country, prediction model is used in assessment of existing or envisaged changes in traffic noise condition. The development of an efficient noise prediction model can be used for future railway development. A study is conducted to identify the emission of noise by KTMB commuter at distance of 15, 20 and 25m away from track centre. Sixty samples of actual noise level data were collected through field measurement and analysed to develop noise prediction model for KTMB commuter. Based on noise $L_{A,max}$, speed of train and distance between apparatus and centre of trackway measured and collected between Shah Alam to Bukit Badak station, the highest $L_{A,max}$ noise emitted by KTMB commuter was at level of 78.4dB. Data were analysed by using linear regression statistical Minitab software and prediction model was develop as $L_{A,max} = 52.92 - 0.2564 \text{distance} + 0.6406 \text{speed}$. The significant and usability of model were proved by the value of $R^2=0.9369$ (93.699%). The result of predicted noise level calculated by using prediction model then was compared to the actual and the different were lies between -0.5 to 1.8 dB from the actual reading on site.
ABSTRAK

Tahap bunyi bising yang terhasil sepanjang operasi sesebuah keretapi adalah sangat tinggi terutamanya bunyi bising yang dikeluarkan melalui interaksi roda, landasan dan badan keretapi terhadap keadaan sekeliling. Tahap bunyi bising yang tinggi boleh mengakibatkan rasa tidak senang dan juga boleh mengakibatkan masalah pendengaran terhadap penduduk yang tinggal berhampiran laluan keretapi. KTMB menerima beberapa aduan daripada penduduk mengenai pencemaran bunyi itu datang dari operasi kereta api. Pada masa ini, prosedur pengukuran lapangan dilakukan untuk memantau dan mengukur tahap bunyi kereta api. Prosedur ini memerlukan beberapa peralatan kos, masa, tenaga dan tepat yang kadang-kadang menjadi kekangan untuk mendapatkan data yang cepat. Di kebanyakan negara, model ramalan bunyi bising digunakan untuk menilai keadan bunyi bising atau hingar semasa. Model ramalan bunyi bising yang berkesan boleh digunakan untuk rancangan pembangunan sistem keretapi pada masa akan datang. Satu kajian dijalankan untuk mengenal pasti bunyi bising yang dihasilkan oleh KTMB komuter dengan jarak dari pusat landasan sejauh 15, 20 dan 25m. 60 sampel data diukur melalui kerjalapangan dan dianalisa untuk menghasilkan model ramalan bunyi untuk KTMB komuter berdasarkan data yang diperolehi. Berdasarkan ciri-ciri bunyi L_{max}, kelajuan tren dan jarak yang diukur dan dikumpul di laluan antara Stesen Shah Alam ke Stesen Bukit Badak, data bunyi paling tinggi dicatatkan pada bacaan 78.4 dB.

Data telah dianalisis dengan menggunakan linear regression analysis daripada perisian statistik Minitab dan model ramalan bunyi yang terhasil adalah L_{A,max} = 52.92 - 0.2564 jarak + 0.6406 kelajuan. Kebolehgunaan dan kesahihan model akan dikenal pasti melalui coefficient of determination, R^2=0.9369 (93.699%). Jangkaan bunyi bising dikira menggunakan model tersebut dan dibandingkan dengan nilai sebenar daripada pengukuran lapangan. Perbezaan bacaan berada dalam lingkungan -0.5 hingga 1.8 dB daripada bacaan sebenar.
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CHAPTER 1

INTRODUCTION

1.1 Background of study

Train transportation has been introduced as environmental friendly transportation mode which consumed less energy and less emission of pollution toward environment and residents health. However, operation of rail transportation has been identified to be the factor of traffic noise pollution. Railways cause undesirable noise due to the rolling contact between the vehicle and the track. As living standards rise, people are less likely to tolerate noise. W. Babisch (2005) conclude in his research by saying that the resident or public that have been exposed to high level of noise at more that 65 dB for a long periods of time will increase the risk of myocardial infarction (cardiovascular effect) and also increased the risk of having high blood pressure especially for male subjects.

Traffic noise models are useful aids in designing and developing railway system and infrastructure. Sometimes, prediction models is been used in assessment of existing or envisaged changes in traffic noise condition (Golmohammadi, 2009). In recent years, some developments have been made on traffic noise prediction model. Generally, noise prediction models will be predicted in terms of highest noise level $L_{A,max}$ which will be helpful to estimate the worst condition of noise pollution.
As the construction of train transportation being developed further, the first step to overcome the future noise issues should be discussed. The sources of the noise should be investigated thoroughly so that the noise produced by the train can be predicted and estimated quickly even during the construction phase. Various methods can be used to measure the noise level from different sources and in different noise environments. Usually, the noise level will be measured on the site by using suitable methods and personnel or workers according to the situation.

Train noise issues have been an increasingly important topic to discuss and debate as increasing development of the trains transportation system in Malaysia. When the noise becomes a concern, all the other matters related to noise will be investigated so that an action can be taken to overcome the complaints by the public including the use of noise barriers to decrease the noise level received by the residents nearer.

Nowadays, many technologies and theories can be used to predict the future situation so that any precaution and prevention step can be made early without waiting for the issues to appear. Noise prediction models have been used to estimate and calculate the noise level at specific locations based on the distance of equipment from the center of the train and also the speed of the train. To validate the theoretical formula used, the data calculated will be compared to the actual measured data on the field.

1.2 Problem statement

Train operational processes produce various types of noise whether from the inner part or outer part of the train. Some noise from the train can be categorised as unwanted and harmful towards the receiver. High levels of noise are harmful for people and will lead to hearing problems if exposed to the high frequency of noise for a long time. The route of the train that is located near residential areas and public buildings creates disturbances and discomfort to the residents and some complaints were filed to the authority.
According to Tea Min Kim (2011), based on his study held in Korea, increasing of rail speed causing serious noise damage to residential areas near the rail roads as increasing of its aero-acoustic noise and the population near that area suffering from noise damage has reached 1.7 million. The study shows that the noise problem caused by the train transportation was resulted on health problem and annoyance to the resident that live near the railway track.

Regular monitoring and measurement of noise level emitted by each train is very important factor that should be manage by all train operator. The noise level of train operation should not exceed the limited noise level state by the Department of Environment especially within the safe zone such as residential are which located near or along the trackway. So that, the operator has ordered their workers to construct a monthly observation and measurement of their train noise level to ensure that the noise were in allowed range. The measuring process requires the workers to visit various locations to collect the data. It can be seen that measuring process will involved lot of time and energy. According to KTMB staff, a measurement need to be taken when they recieved complaint from residents.

Besides that, future works of developing train transportation also need a suitable method to estimate future noise level emitted by the train. Field measurement can not be used on non-exist train operation to estimate the noise that will emit by the train and how it will impact the surrounding occupant or residents. In addition to cost, time and energy factors, $L_{A,max}$ statistical linear regression prediction model seems to be really helpful method that can be used in order to predict and estimate the noise emitted by the train whether for the existed train or for future train development with easier way.

Nowadays, Shah Alam city area has been one of the developed cities in Malaysia as it is the capital state of Selangor (Jabatan Penerangan Malaysia, 2000). Population in Shah Alam increased from 314,400 peoples on year 2000 to 558,308 peoples on year 2011 (Jabatan Perangkaan Malaysia, 2011). Increasing number of population will definitely bring a lot of development and changes in Shah Alam. The forest area along the KTMB comuter route has been developed by the developers and government in order to improved and fulfill community needs. The area was developed with many public building and public area. The population was increased
based on the economic opportunities that offered to them. So that, as the population increase, the other facilities also increased such as school, residential area and also universities.

All of these factors increased the importance of railway noise monitoring along that area to ensure that the community were living in comfort and not disturbed by the train noise pollution. As said by KTMB staff during the interview, Shah Alam is one of the critical areas that received many complaints regarding train noise in Selangor state (Nazihah, Safety Manager, Sept 14, 2015).

1.3 Objectives of study

There are several ways to measure the level of noise produce by all types of transportation mode. Basicly, the objectives of this study are listed as below:

a) To determine the current noise level produced by KTMB commuter on actual location by using sound level meter in terms $L_{A,max}$ noise level.

b) To develop noise level prediction model by using linear regression analysis in Minitab software based on the relationship of train speed and distance between receiver and centre of trackway.

c) To verify the usability of prediction model develops by statistical software according to the coefficient of determination, $R^2$ calculated and the comparison between the actual measurement on site and the predict value calculated.

1.4 Scope of study

These scopes of research should follow to achieve the objectives:

a) The information of noise produced by train will be investigates and measure on site based on KTMB commuter between Shah Alam to Bukit Badak route.
b) The main parameters involved were noise level $L_{A,max}$, speed($v$) of train and distance($d$) between the apparatus set-up and the centre of trackway.

c) Sound level meter was used to measure the actual noise on the field, while the linear regression statistical analysis Minitab software were be used to analised the measurement data and develop the prediction model.

1.5 Significant of study

This study is conducted in significant to determine the condition of noise level emitted by KTMB commuter. This study comes out regarding train noise issues complaint by the resident towards the authority and KTMB. Shah Alam to Bukit Badak station were chosen regarding it location that lies along many area of housing and community compared to other route of KTMB commuter.

Based on observation on site, discussion with people involved which are residents and the authorities, and the actual data collected during the measurement, an efficient noise prediction model were developed and discussed further based on its current noise level. An efficient prediction model will aids the process of noise assessment by KTMB and other organization such as Department of Environment and contractors that involved in railway construction and development whether for the existing or future development of railway transportation in Malaysia.

The prediction model will be very useful in order to reduce cost, time and man force for actual measurement. In addition, the model can be used by KTMB to monitor noise level emitted by their train in order to minimise community complaint regarding of noise disturbance. However, the model might be lack in some aspects due to other constrain that cannot be measure or hard to be include in the analysis or calculation.
1.6 Expected result

The expected results from this study are:

a) The relationship of the measured data and prediction analysis of the noise level for KTM commuter will be identified based on best line fit by the analysis by statistical software and based on the prediction model developed.

b) The measured noise level value will be almost the same with the results of prediction value calculated which means that the prediction linear regression model are significant.

c) The noise level generated by KTM commuter will be identified.
CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Literature review is a way to get a reference and information about the research. For this study, there is a wide range of relevant information that is focused more on the title on the train noise and the prediction model that will be used to calculate the predictive value of noise level. Some facts from the journal related research topics are grouped in this section to better understand and relate, and make comparison of the results generated.

Some of the information in this chapter is information focusing on the basic characteristic of train noise, research parameter, and the information on the model of prediction equation used. Related information is also discussed in this chapter include information on the location of the selected studies, the characteristics of each parameter, the resulting impact on the various factors that close and connected in a study that was carried out.

All information contained in this chapter is to explain in more detail the importance of the research for the future train transportation growth and for future research reference. Summary for this chapter was based on information obtained is summarized in more compact to facilitate understanding of the additional information related to this study conducted.
2.2 Rail transportation system in Kuala Lumpur

Malaysia’s largest transit hubs, is Kuala Lumpur integrated rail transportation centre. This transportation system connected and seamlessly linking all urban and suburban residential, commercial and industrial areas. It is also a direct link to Kuala Lumpur International Airport, Putrajaya (Federal Government Administrative Centre), Cyberjaya and key areas within the Multimedia Super Corridor. Kuala Lumpur rail transportation can be classified into several types which are ETS, KL Monorail, ERL and KTMB commuter. Generally, different types of rail are operated by different companies and having developed them separately at different times.

Saporna et al (2012) said the best way for tourist to travel around Kuala Lumpur is to take Malaysia’a rail transport which helps them to travel very fast and also can avoid congestion in the city. It is fast, inexpensive and mostly elevated metro system. With the increasing number of tourists, the government studying the feasibility of expanding its route by covering Damansara, Cheras, Kepong, Sri Petaling, Bukit Jalil and many more areas.

2.2.1 KTMB commuter

Today, KTMB provides 216 commuter services daily, serving 53 stations along to 217 route-kilometres from Tanjung Malim to Seremban, Batu Caves to Pelabuhan Klang with 15 minutes frequency at the peak time or 30 minutes frequency at off peak time.Rawang and to Tanjung Malim with 60 minutes frequency. Currently KTM Commuter has provide new 38 sets of six car set (SCS) trains and now 16 sets had been received while the remaining 22 sets would be acquired in stages until June 2012. KTMB runs 37 Freight Services daily of which about 70% are concentrated in the northern sector. In line with the strategy to focus more on containerized and long-haul cargoes, KTMB now carries maritime containers, cement and foods as main commodities.
Electric commuter train or commuter rail is passenger rail transport services that connecting city center and towns that draw large numbers of people who travel on a daily basis. Commuter trains are usually optimized for maximum passenger volume, in most cases without sacrificing too much comfort and luggage space, though they seldom have all the amenities of long-distance trains.

Commuter services were introduced in 1995 and provide suburban railway services connecting city centers and suburban areas. KTMB commuter 175 km (109 mi) network has 45 stations. It consists of two lines, namely the Sentul-Port Klang and Rawang-Seremban lines, as well as a shuttle service from Rawang to Rasa which was launched on 21 April 2007. Interchanges between the two lines can be done at KL Sentral, Kuala Lumpur and Putra stations. Stair-climbing or escalator-use may be required at KL Sentral and Putra, while cross-platform transfers can be conveniently done at Kuala Lumpur. Passengers continuing their journey on the Rawang-Rasa shuttle service have to interchange trains at Rawang station.

Figure 2.1 shows the route map for KTMB commuter for both Seremban-Rawang and Sentul-Pelabuhan Klang route. Seremban-Rawang commuter was marked with blue symbol. The route for Seremban-Rawang will travel along 25 stations. While Sentul-Pelabuhan Klang route will travel along 27 stations excluded Tanjung Malim to Rawang station. Both trains were interchange at four station which are Putra, Bank Negara, Kuala Lumpur and KL Sentral station.

Starting on 8 March 2012, KTMB commuter operated with new set of train built by CSR Zhuzhou of China known as Class 92 EMU commuter train. It contains 6 cars per train. Now, total of 36 sets of train were operate for both route and 2 sets remain in reserve. This commuter train were design to operate on maximum of speed 140km/h but KTMB were control the train to be operated at 120km/h. The Class 92 was procured under a Malaysian Government initiative, National Key Result Area (NKRA) to reduce congestion and improve public transport with a specific RM 2 billion allocation to KTMB to improve commuter rail efficiency. A sum of RM 1.894 billion was spent to procure these trains, with the remainder being spent on the improvement of signalling and a ticketing system upgrade.
Figure 2.1: KTMB commuter route map
(Source: KTMB website)
2.2.2 Importance of train transportation system

Train has been the earliest land mode of transportation that used in Malaysia. At the earlier stage, train were used in import and export Malaysia product during British government rule the country. Nowadays, the major used of KTMB still remain as the best way to transport the good from one to the place by using KTMB cargo train. KTMB intercity train were used by the customer to travel especially for a long journey. Train service has been better choice to be used based on its benefits and factors. The main factors that keep train as the best public transport in Malaysia were the fares. The fares are generally reasonable and cheapest compared to other mode of public transportation.

Malaysia government plans and improve the development of public transportation especially train in order to reduce the number of private car in crowded city. Hence, it can reduce traffic congestion in city during daily peak time and during holiday or festival break. Train transportation was improved with many good features and comfortness to attract and encourage community to use it. The route was design according to the shortest distance to reduce time travel. Other than that, the station was built at most strategic place which the distance between station and other nearest important buildings were at walking distance. Nowadays, train service still being the best choose for the netizen to go back to their hometown especially for those who travel to East Coast area.

Besides that, train transportation is important to attract the tourist to comes and travel in the country. Usually, tourist will choose the easiest and cheapest way to move or transit from one place to another. If the country can provide good service of public transportation, it will be and advantages for the tourist. The government provide million dollar budgets in order to improve railway transportation not only for the movement in the country but to connect our country with the neighbour country such as Singapore, Thailand and Indonesia. The development and connectivity will helps in increasing our economic, social and political connection between other countries.
2.3 Introduction of noise

Noise is conveniently and concisely describe as ‘unwanted sound’ which can lead to people annoyance (Bridgewater et al., 2011). Unwanted sound is the sound that disturbed the focus of ear to receive the wanted sound. For example, music from the radio maybe called unwanted noise for some people to focus on their conversation. Other examples of unwanted sound are traffic noise, industrial noise and loud musical or concert sound. Unwanted and annoyance sound is different in order of sound receiver effect.

Annoyance sound or misophoni, also known as hatred of sound. Annoyance is a purported disorder which may leads towards negative emotions, thoughs and physical reactions, caused by triggered of specific sounds. In other word, annoyance sound is the sound that usually soft but can be loud for some people. For example, conversation of other people might started with slow voice but when they become excited, the voice might becoming louder and louder. It might cause annoyance feeling towards other people surrounding. Reactions to the triggers can include aggression toward the origin sound, leaving, or remaining in its presence but suffering, try to block it, or trying to mimic the sound.

Discomfort phenomenon can be caused by various environment factors that happen on the surrounding. Noise that comes from all the sources resulted on annoyed feeling, although the degree of annoyance will be differ for each person. Typical environmental noise sources include road traffic, air traffic, rail traffic, industry, and noisy neighbors and sports facilities.

Nowadays, railway transportation growth in our country has been well known as the safe public transportation. However, noise emitted by the train operation has been reported to be problem and issues to the resident around the operation route. Sound is produced as result of mechanical disturbance creating pressure variations in an environment.
2.3.1 Train noise

The development of train services in several countries’s has lead to noise problem. According to Golmohammadi (2009), road traffic noise can be a nuisance, particularly in residential areas and most significantly main sources of environmental noise pollution in cities. Therefore, many countries have introduced noise emission limits for vehicles and issued other legislations to reduce traffic noise.

Noise legislation in Malaysia is control and monitor by Department of Environment, Ministry of Natural Resources and Environment Malaysia, DOE. There are three sets of legislation documents to provide guidance on acceptable noise limits for various types of land use and human activities in Malaysia. These documents provide useful guidance for planner and decision makers at the state and local level as well as other organization, bodies and agencies involved or having responsibilities in the design and/or approval of town planning, infrastructure development.

It was stated in the legislation document in Section 23 under The Environmental Quality Act 1974 stipulates that: “No person shall, unless licensed, emit or cause or permit to be emitted any noise greater in volume, intensity or quality in contravention of the acceptable conditions specified under section 21.”

Train noise is a type of the environment that interferes in complex task performance, modifies social behaviour and causes annoyance towards passenger and the resident nearer. Train noise might come from many sources whether from its own car body or from the interaction with other component such as rail or wind forces.

Tae Min Kim et al (2011) said that aerodynamic noise of train increased by the improvement of the speed. Based on his research, 1.7 million persons who stayed near the railway suffering from noise damaged in Korea. Train noise can be heard inside and outside of the train. Various parts on its own body produce noise especially when it is moving on the rail. Noise can be produce from the engine, air conditioner system or HVAC, locomotive body, air space between car, and also wheel-rail contact.
Table 2.1 shows maximum permission sound level allowed by Department on Environment Malaysia. Usually, some rail road is located near to the residential area. So, based on the table above, the maximum allowable noise received by the resident is 50 dBA during daytime and 40 dBA during night. However, ground borne vibrations and structure-borne noise mainly occur at low frequencies (<50 Hz). Frequencies above this are attenuated increasingly rapidly. Vibration disturbance is usually caused by the large vertical dynamic forces between wheels and rails. These forces fluctuate in response to wheel and rail roughness over a wide range of frequencies.

Table 2.1: Maximum permissible sound level
(Source: Department of Environment Malaysia)

<table>
<thead>
<tr>
<th>Receiving Land Use Category</th>
<th>Day Time 7.00 a.m –10.00 p.m</th>
<th>Night Time 7.00a.m–10.00 p.m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise sensitive areas, low density residential, institutional (school, hospital, worship area)</td>
<td>50 dBA</td>
<td>40 dBA</td>
</tr>
<tr>
<td>Suburban residential (medium density) areas, public spaces, parks, recreational areas</td>
<td>55 dBA</td>
<td>45 dBA</td>
</tr>
<tr>
<td>Urban residential (high density) areas, designated mixed development areas (residential-commercial)</td>
<td>60 dBA</td>
<td>50 dBA</td>
</tr>
<tr>
<td>Commercial business zones</td>
<td>65 dBA</td>
<td>55 dBA</td>
</tr>
<tr>
<td>Designated industrial zones</td>
<td>70 dBA</td>
<td>60 dBA</td>
</tr>
</tbody>
</table>

In addition, wheel squeal originates from frictional instability in curves between the wheel and rail. Stick-slip oscillations (more accurately referred to as roll-slip) excite a wheel resonance; the wheel vibration radiates noise efficiently. In the study conducted by D.T.Eadie et al (2010). The accepted model involves top of rail (TOR) frictional instability under lateral creep conditions leading to excitation of out of plane wheel bending oscillations. These are radiated and heard as squeal. The
starting point for squeal is lateral creep forces that occur as a bogie goes through a curve and the wheel/rail contact patch becomes saturated with slip (creep saturation).

A critical component in all the modeling work is the requirement that beyond the point of creep saturation, further increases in creep levels lead to lower coefficient of friction. This is known as negative friction, referring to the slope of the friction creep curve at saturated creep conditions. In more general tribological terms, this would be equated to changes in sliding velocity, rather than the railroad term creep. This leads to roll-slip oscillations between the wheel and the rail which excite a wheel resonance, and the wheel web radiates the noise.

Table 2.2 shows the frequency range for different types of railway noise produced by the train when moving. The higher frequency of noise is comes from flanging noise with frequency of 5000-10000 Hz, followed by top of rail squeal, flat spot, rolling and vibration noise. These show that every part of the car body is producing sound at different frequency level.

<table>
<thead>
<tr>
<th>Noise Type</th>
<th>Frequency Range (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rolling</td>
<td>30-5000</td>
</tr>
<tr>
<td>Flat spots</td>
<td>50-250 (speed dependant)</td>
</tr>
<tr>
<td>Ground borne vibrations</td>
<td>4-80</td>
</tr>
<tr>
<td>Structure – borne noise</td>
<td>30-200</td>
</tr>
<tr>
<td>Top of rail squeal</td>
<td>1000-5000</td>
</tr>
<tr>
<td>Flanging noise</td>
<td>5000-10000</td>
</tr>
</tbody>
</table>

2.3.2 Noise characteristic

Railway noise can described nearly same as all traffic noise. It can be describes in terms of daily average noise emission of the traffic flow, but also in more detail in terms of the noise characteristics of individual trains, vehicles and also the track
condition. Most current national legislation is limited to reception limit for daily noise levels, which for railways is based on calculations of noise emission from the traffic flow at that location. Basically, railway noise level depends on following factors:

- Average speed, $V$
- Distance between noise source to the recipient, $D$

i) Average speed, $V$

Train speed is a major influence parameter for noise emission. If the train is travelling within the limited range speeds, the noise produced is related to the engine. KTMB commuter is electrified system train which means the noise emitted is due to traction and auxiliary systems (diesel units, electrically driven powertrains, cooling equipment, compressors), if present, tends to be predominant at low speeds, up to around 60 km/h (European Commission, 2003). Therefore, term of ‘$V$’ is included in developing the prediction model.

Figure 2.2 shows the relationship of the train sound pressure level versus speed. Based on the graph, the highest sound pressure level is generated from the aerodynamic noise, followed by rolling noise and traction noise. From the graph, it can be clearly seen that the sound pressure level is proportional to the train speed which means that the noise of the train will be increase by the increasing of the speed.

Train speed is a major influence parameter for noise emission. The noise due to traction and auxiliary systems whether diesel units, electrically driven powertrains, cooling equipment, compressors, if present, tends to be predominant at low speeds, up to around 60 km/h. Wheel-rail rolling noise is dominant up to speeds around 200-300 km/h, after which aerodynamic noise takes over as dominant factor. The transition speeds from traction noise to rolling noise and from rolling noise to aerodynamics noise depend entirely on the relative strength of these sources. The rolling noise, for example, depends strongly on the surface condition of wheels and rails, whereas aerodynamic noise depends on the streamlining of the vehicle.
Figure 2.2: Railway exterior sound sources and typical dependence on train speed
(Source: European Commission, 2003)

ii) Distance between noise source to the recipient, D

Distance between the sources and receiver will be influence the sound level hear by them. As the distance increase, sound hear by the subject will be reduce because of some reflection, absorption and transmission of sound.

2.3.3 Railway noise sources

Railway noise is generated by various sources of sound that produced during its operation process. Noise is created when train body or rolling stock move and produces vibration, resulting in a minute variation in surrounding atmospheric pressure called sound pressure. Sonoma (2005) said, human response to sound depends on the magnitude of a sound or the sound loudness as a function of its frequency of the pitch. Railway noise can be categorised into four sub noise which are electric propulsion system, wheel-rail interaction, aerodynamic sound and rolling sound as shown in Figure 2.3.
The noise produced usually influence by types or train which also impact by the weight of the train, and its speed. Train speed is a major influence that might impact the noise emitted by the train. The transition speeds from traction noise to rolling noise, and from rolling noise to aerodynamics noise depend entirely on the relative strength of these sources.

![Sound Sources of Trains](image)

**Figure 2.3:** Sound sources of train
(Source: High speed train sound fact sheet)

According to article published by California High Speed Train Association, the train which moves at less than 160 miles per hour, the repulsion system and wheel-rail interaction noise will be the predominant sources of sound. While at speed above 160 miles per hour, aerodynamic sound will be the predominant source of sound. Stewart et. al. (2011) state that, aggressive use of acceleration has been shown to increase noise by as much as 6dB.
2.3.3.1 Rolling Stock Noise

The early types of KTM commuter rolling stock consists of three versions of three-car EMU’s added over the course of three years, beginning in 1994. All of the commuter operate in multiple unit formation, running from overhead catenary supply, with two driving cars and 1-3 trailer cars in between. Generally, rolling noise will be influenced by rail surface condition, steel-wheel profile condition and impact of the sound radiation.

According to the research done by David Thompson (2003), rolling noise radiate when an irregularities on the wheel and rail track surfaces excite vibration during the movement of the train. Depending on the wheel and rail surface condition, the receptances at high frequency, the roughness of surface can result in vibration which then will spreads out along the rail and around the wheel and at the end will generate noise.

The primary physical process responsible for the vibration that generates noise is the wheel-rail contact. The wheel tread rests on the rail head, and the mechanical contact is within a contact patch approximately 10 to 15mm long and about as wide. When the wheel is rolling on the rail, the small unevenness of both wheel and rail cause forces on both of them which at the end will results as vibration. These forces excite vibrations throughout the whole system which then radiates sound.

The dominant source in most cases of train noise pollution is influence by the rolling noise. Figure 2.4 shows the general mechanisms contributing to the generation of railway rolling noise. Irregular and roughness surface of the train wheel and rail track caused time-dependent contact forces at the wheel-rail contact. The contact forces lead to vibrations on both wheel and rail which then will generate air-borne noise.
Figure 2.4: Schematic representation of the mechanisms leading to the generation of rolling noise

The rail surface is not perfectly smooth but contains discontinuities, the most severe of which are rail joints. The geometry of rail joint can be characterized by the gap width and the height difference between the two sides of a gap. The gap width may be typically 5-20 mm and the height difference 0-2 mm. Figure 2.5 shows the gap in track joint that cause impact noise. Uneven rail track surface or joint will cause unstability of the car body. So that, when train passed through it, the body will vibrate and the movement of its component will produce sound.

Figure 2.5: Gap in track joint that cause impact noise
In addition the rail often dips near a joint by several millimeters. Even welded rail often has such dipped joints. These discontinuities on the rail can generate large impact forces between the wheel and rail when wheels roll over a dipped rail joint.

2.3.3.2 Aerodynamic Noise

Various studies around the world have been classified aerodynamic noise as the main sources of aero-acoustic noise of train. Aeroacoustic sources are closely related to airflow around the train and the optimisation for a low air resistance. There are few sources that might influence aerodynamic noise which are pantograph pan, pantograph frame, fan equipment and the truck or bogies of the train body. Besides that, the transition speeds from traction noise to rolling noise and from rolling noise to aerodynamics noise depend entirely on the relative strength of the noise sources.

Due to the fact that aerodynamic sources on the roof such as pantographs cannot be shielded by noise barriers along the track side, pantograph noise can be significant, at least subjectively. Pantograph noise generation is mainly due to vortex shedding around cylinders of the pantograph and the physical phenomena are now quite well understood said C. Talotte et al (2003). The theoretical analysis on aerodynamic noise by Curle (in Nagakura K.,2001) and results of wind tunnel experiments also show that the aerodynamic noise generated from trains increases in proportion to the 6th power of velocity in most cases. Optimization of pantographs has been mainly carried out in Germany and in Japan. Until now pantograph noise in Japan has been reduced by installing covers on the train roof around the pantograph region. However, since the pantograph covers themselves generate aerodynamic noise a ‘new low-noise pantograph’ without covers are under development.

In addition, a number of experiments were carried out in wind tunnels in Germany for the optimization of cylinder shapes as well as for testing the principle of ribs which allow coherent vortex shedding to be broken up and hence reduce noise generation. Adding the component sound levels associated with each region of the pantograph that is investigated, the total noise level due to the pantograph was
reduced by nearly 5 dB(A) in the wind tunnel. Unfortunately, in field tests, the overall reduction of generated sound was not as great as that achieved in the wind tunnel. As a conclusion, the noise reduction potential for conventional pantographs is limited and new pantograph concepts must be considered, including optimization of the pantograph in interaction with its equipment such as insulators.

2.3.2.3 Electric Propulsion Noise

Train noise also influenced by the electrical equipment that used on the train in order to give better service and riding comfort to the passenger. The sources of electric propulsion might come from air venting system, motor, propulsion and gearing, and also train braking system. The noise cause by ventilation system such as cooling fan and air conditioning system is the major equipment that emitted high level of noise.

The braking system also contributes to the noise generated in the normal train as well as in the monorail. However, based on the study conducted by C. Talotte et al. (2003), the widespread introduction of disc brakes replacing cast-iron tread brakes for passenger vehicles has given significant reductions, typically up to 10 dB. For freight vehicles in Europe cast-iron brake blocks are still widely used. Their replacement by disc brakes is considered both uneconomic and difficult due to the organization of the international traffic in Europe.

However, a recent initiative by the International Union of Railways (UIC) has set out to replace cast-iron blocks by a composite material. These do not roughen the wheels and therefore the rolling noise is reduced. If this can be done by retrofitting vehicles, there need be no additional costs. The Eurosabot project set out to develop such brake blocks but results were rather disappointing and suitable materials for retrofitting are not yet available.
2.3.4 Noise effect

Unwanted and annoyance sound or noise majorly affect on the public comfort feeling. Many research shows that the effects of noise towards the surrounding resident health and comfort can be divided into three main areas which are general annoyance, sleep disturbance and cardiovascular effects.

General annoyance usually refers to the disturbance experienced which makes them feel uncomfortable on hearing and also lead to bad mood or feeling. When they exposed for a long time, this disturbance might effect their sleeping process which their feel hard to sleep. This general disturbance and sleep disturbance then believed will lead to cardiovascular effects apart from the impact on the quality of life in general. Based on research done by W. Babisch et al (2005), it show that the subject that have been exposed to high level of noise at more that 65 dB for a long periods of time can increase the risk of myocardial infarction (cardiovascular effect) and also increased the risk of having high blood pressure especially for male subjects.

Noise disturbance generally will impact psychological of the recipient which will disturb their concentration that leads to the improper of human behavior. According to study done by Butt T. (2013), noise disrupts people’s sleep by direct and indirect way even at very low level of noise. It shows that disturbed sleep can be cause by the noise and this problem might leads to health problem.

Besides that, major complaint on traffic noise were reported by the community that live or work near the railway route which received high level of noise compared to the other community. Sometimes, the rail route also built near the institutional areas. The noise might disrupt the learning session and of course will disrupt student attention. Based on article of Noise, Health, and Place (2014), there were over 20 studies that proved noise as the negative impacts to childrens in terms of their ability on reading and memory.
2.4 Noise prediction model

Traffic noise models are useful aids in designing and developing railway system and infrastructure. Therefore, the linear regression analysis used to leverage statistics to predict the outcomes value based on the variables stated. Sometimes, prediction models is been used in assessment of existing or envisaged changes in traffic noise condition (Golmohammadi, 2009). In recent years, some developments have been made on traffic noise prediction model.

Generally, noise prediction models will be predicted in terms of \(L_{\text{Aeq}}\), \(L_{10}\) and \(L_{\text{max}}\). The model was made to help with noise measurement activities. The prediction models may be preferred in situations where:

- Train noise is difficult to measure through field investigations
- Train noise under dispute occurs infrequently and is difficult to capture through field studies
- Receptor locations are not accessible
- Background ambient noise levels may interfere with the measurement of the train noise.

2.4.1 Equivalent continuous (A-weighted) sound level, \(L_{\text{eq}}\)

In all cases, the levels of train noise, railway noise and other guided transport system noise used are expressed in terms of Equivalent continuous sound level (\(L_{\text{eq}}\)). Equivalent continuous (A-weighted) sound level is defined as the steady sound level that contains the same amount of acoustic energy as the fluctuating level over the prescribed period of time. \(L_{\text{eq}}\) which is an exposure based metric (time/number of events) to describe a receiver’s cumulative noise exposure from all events over a specified period of time for compliance assessment (Canada Transportation Act, 2008). Common prescribed periods are one hour \((L_{\text{eq, 1h}})\), 24 hours \((L_{\text{eq, 24}})\), and the day time hour \((L_d)\), and the night time hour \((L_n)\), (Basic Noise Calculation, 2007).
Equivalent continuous A-weighted sound pressure level is a common measurement used in industry to characterize noise levels in loud environments. The result is expressed in dB(A), a weighted decibel scale that filters.

2.4.2 Maximum sound level, $L_{\text{max}}$

Maximum sound level, $L_{\text{max}}$ represent a single event of sound. Basically, the value of $L_{\text{max}}$ is obtained directly from in-situ measurement. Maximum permissible noise level stated by Department of Environment is in between 50 tp 65 dB according to specific area as shown in Table 2.2. The maximum level is more difficult to predict using calculation methods, and has a complex dependence on the traffic volume since a noisy vehicle may be present even in low traffic conditions (Anderson H. 2009).

2.5 Prediction model

Noise prediction models play a vital role to assess the contemporary changes of traffic, railway, airport, factory or design schemes of town planning. These data are useful as a reference and guideline for future regulations on noise limit to be implemented for the urban areas in Malaysia. The analysis would benefit the researchers and policy makers, especially for those who involve directly with the noise pollution of environmental impact assessment (EIA) with the Department of Environment, Malaysia.

Noise models are established to assess the degree of noise annoyance for a given projected road, highway, railway, airport, factory or town planning. Since 1950’s, traffic noise prediction models were designed to estimate the single vehicle sound pressure, based on a constant speed experiments. The earliest road traffic noise model was given in the Handbook of Acoustic Noise Control. With the help of computer graphic programs, the predicted noise levels can be presented by a noise