NOISE $L_{A,\text{max}}$ STATISTICAL LINEAR PREDICTION MODEL FOR AMPANG LINE LIGHT RAIL TRANSIT (LRT) AT RESIDENTIAL AREA ALONG CEMPAKA STATION

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ABSTRACT

Ampang line Light Rail Transit Train (LRT) trains one of the public transport service provided for Kuala Lumpur and its neighbourhood area to fulfil the mobility demand from the users in Klang Valley. Nonetheless, the effect of this is that the public, especially those living near to the Ampang Line, are exposed to sound problem from the LRT train. This studies are to analyses the noise $L_{A,max}$ field measurement data with the distance 15 m, 25 m and 35 m from the center downtrack and 20 m, 30 m and 40 m from the center uptrack at residential areas, to develop a noise $L_{A,max}$ statistical linear regression prediction model for train LRT Ampang and to predict noise $L_{A,max}$ at residential areas by using statistics linear regression model. The methodology used in this research is primary data. Sixty data noise $L_{A,max}$ from LRT Ampang train were collected and measured based on the distance in this study by using the Sound Level Meter (SLM). The speed was calculated from the measured pass-by time of the head train to back train at point A and the length of the train. The length of trains in this study was constant at 85.536 m. In this study, Statistic SPSS (Version 22) Software was used to establish the statistical liner regression prediction model for LRT Ampang. The result noise $L_{A,max}$ from the field measurement and prediction model shows that the highest was 79.3 dB and 78.5 dB respectively. The lowest noise $L_{A,max}$ field measurement was 70.9 dB and prediction model was 71.0 dB. There no significant difference between the noise $L_{A,max}$ prediction model and field measurements. From the output analysis by the statistic SPSS (version 22) software, it was shown that ANOVA value of the significant are 0.000 which is <0.005. While, the value coefficient determination is 88.5 % ($R^2= 0.885$). The study concludes with some suggestion on future studies on other places with have barriers at residential area.
Tren Transit Aliran Ringan (LRT) bagi aliran Ampang merupakan salah satu pengakutan awam yang disediakan untuk memenuhi permintaan bergerak daripada pengguna, dari satu tempat kepada satu tempat yang lain untuk menghubungkan pengguna ke tempat bekerja, pusat perkhidmatan, sekolah dan institut pengajian. Namun, kesan pengakutan ini orang ramai terdedah dengan masalah bunyi yang dibebaskan oleh tren ini terutama penduduk kawasan perumahan yang tinggal berhampiran dengan aliran Ampang ini. Kajian ini dijalankan untuk menganalisis bunyi hingar \( L_{A,max} \) ukuran padang pada jarak 15 m, 25 m dan 35 m daripada pusat downtrack dan 20 m, 30 m dan 40 m daripada pusat uptrack. Kajian ini juga dijalankan adalah untuk membina model bunyi hingar \( L_{A,max} \) regresi linear statistik dan meramalkan bunyi hingar \( L_{A,max} \) tren LRT aliran Ampang menggunakan model regresi linear statistik. Keadaan data premier telah digunakan. Enam puluh data bunyi hingar \( L_{A,max} \) tren telah dikumpul dan diukur berdasarkan jarak kajian menggunakan Sound Level Meter (SLM). Kelajuan tren di dalam kajian ini telah diukur dengan menggunakan masa tren melalui point A bermula bahagian kepala tren sehingga belakang dengan panjang tren LRT aliran Ampang. Panjang tren LRT aliran Ampang didalam kajian adalah tetap iaitu 85.536 m. Perisian statistic SPSS (versi 22) telah digunakan untuk membentuk model ramalan statistik regresi linear tren LRT aliran Ampang. Hasil kajian menunjukkan, bunyi hingar \( L_{A,max} \) paling tinggi bagi ukuran padang adalah 79.3 dB dan daripada ramalan model pula 78.5 dB. Manakala, bagi bunyi hingar \( L_{A,max} \) paling rendah bagi ukuran padang adalah 70.9 dB dan bagi model ramalan pula adalah 71.0 dB. Oleh itu, hasil nilai paras bunyi hingar \( L_{A,max} \) daripada ukuran padang dan ramalan model menunjukkan tidak ketara. Berdasarkan analisis hasil keluaran daripada perisian statistic SPSS (versi 22) menunjukkan nilai bagi significant = 0.000<0.005 dan pekali penentuan menunjukkan 88.5 % (\( R^2 = 0.885 \)). Kesimpulannya, cadangan bagi kajian akan datang pada kawasan lain yang mempunyai hadangan di kawasan perumahan.
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\[ dB \quad = \quad \text{Decibel} \]
\[ downtrack \quad = \quad \text{The LRT train track that headed from Sentul Timur to Ampang and Sri Petaling} \]
\[ headway \quad = \quad \text{Time difference between any two successive vehicles when they cross a given point} \]
\[ km/h \quad = \quad \text{kilometre/hour} \]
\[ L_{Aeq} \quad = \quad \text{The equivalent A-weighted sound-level, energy averaged over the time} \]
\[ L_{A,max} \quad = \quad \text{The maximum instantaneous level over the monitoring time} \]
\[ L_{A10} \quad = \quad \text{The noise level exceeded for 10% of the time of the measurement} \]
\[ L_{A90} \quad = \quad \text{The ambient or background noise level} \]
\[ LRT \quad = \quad \text{Light Rail Transit} \]
\[ m \quad = \quad \text{meter} \]
\[ N \quad = \quad \text{Sound Level Meter device} \]
\[ R \quad = \quad \text{Coefficient of correlation} \]
\[ R^2 \quad = \quad \text{Coefficient of determination} \]
\[ SLM \quad = \quad \text{Sound Level Meter} \]
\[ uptrack \quad = \quad \text{The LRT train track that leads from Ampang and Sri Petaling to Sentul Timur} \]
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CHAPTER 1

INTRODUCTION

1.1 Introduction

Noise pollution has become a common issue in the City of Kuala Lumpur especially for the citizen living near the main roads or railway. Kuala Lumpur is the capital city of Malaysia and is greatly expanding throughout the years. Alongside the modernization of the city, a plethora of transportation mode has been provided for people to commute between places. This is to fulfill the increasing demand of the citizen that wish to travel safely and economically while also being user friendly (Nor and Nor, 2006).

One of the modes of land transportation is the train. It is highly effective for people who want to travel without the hassle of traffic congestion within Kuala Lumpur. This is because other modes of transportation like buses and cars are frequently stuck in traffic therefore becoming a big headache in the city (Shafii and Musa, n.d.). This study will focus on urban area, primarily the Light Rail Transit (LRT) Ampang line because the trains go through the metro area which is within the heart of Kuala Lumpur itself.

In Malaysia, there are many issues and challenges to be faced in order to reach a high quality of living in the city. This study raises the issue on the comfort level of households situated near railway tracks that are frequently exposed to noise pollutions. Exposure to this kind of pollution may affect the population’s health. Among the more prominent effects are children’s school performance, sleep disturbance, ischaemic heart disease and hypertension (Haines et al., 2004). In relation to that, responsible parties are always monitoring the noise level $L_{A,max}$ emitted by the trains in the city to ensure that it is of a safe level. Noise prediction
model for the $L_{A,max}$ has been tested and checked to curb this noise problem. With the existence of this model, train engineers can collect data easily to evade it.

1.2 Problem Statement

The noise measurement for $L_{A,max}$ is very important to ensure that the sounds emitted by the Ampang line trains are within the safe zone especially for the households situated near the tracks. Therefore, the Ampang line LRT workers are scheduled to a monthly observation of the $L_{A,max}$ check and ensure the safety of the noise level. They are then required to visit various locations to collect the $L_{A,max}$ noise data. It can be seen that the assigned workers will have to spend a lot of time and energy to record the noise level emission. In addition to that, the cost to travel to all of these places that require a checking is extremely high and the device used for monitoring the noise level is highly expensive. These are among the reasons why the noise $L_{A,max}$ Statistical linear regression prediction model was built. It helps reduce the cost of the process and at the same time reduces time consumed to collect the data. This is because they can calculate the noise level without having to visit individual sites. Not only that but the LRT Company can save expenses by not having to buy a sound level meter to measure the noise level. Thanks to the noise $L_{A,max}$ statistical linear regression prediction model, data collection and calculations can be done quickly and efficiently.

1.3 Objectives of the Study

The goal of this study is to create one such model of the noise $L_{A,max}$ statistical linear regression prediction model for residential areas along the way of LRT Ampang. Among the prominent objectives are:

i. To analyse the noise $L_{A,max}$ field measurement data with the distance 15 m, 25 m and 35 m from the center downtrack and 20 m, 30 m and 40 m from the center uptrack at residential areas.

ii. To develop a noise $L_{A,max}$ statistical linear regression prediction model for train LRT Ampang.

iii. To predict noise $L_{A,max}$ at residential areas by using statistics linear regression model.
1.4 Scope of the Study

This study is focus primarily on the Ampang line LRT as a transportation mode. In accordance to that, the noise level $L_{A,max}$ of residential areas are the main item of measurement and calculation. Residential area along the way of Cempaka Station (Cempaka Indah and Pinggir Cempaka) was chosen for this study. They have been chosen to be focused on because the two are the closest to the Ampang line LRT downtrack and uptracks. The method infused in collecting the data have used the sound level meter in ranges of 15 m, 25 m dan 35 m from the center of downtrack and 20 m, 30 m and 40 m from the center of uptrack. Data collections were occur within the peak hour and the off-peak hour which is limited to daytime only. This study also have three important parameters in creating and setting up the noise $L_{A,max}$ statistical linear regression prediction model. The three parameters are noise $L_{A,max}$ field measurement, speed and distance from center of the up/downtrack. Lastly, the Statistics software (version 22) have be used in this study to help with the creation of the statistics linear regression model for predicting the value noise $L_{A,max}$ for the Ampang line trains.

1.5 Significance of the Study

The study hopes to contribute towards the general betterment of train engineering. The purpose of this academic research is to create and grasp a better understanding of the prediction model based on the noise emition of the Ampang line trains. A study of the noise $L_{A,max}$ for the Ampang line trains is important because not only does it relate to the health of the public, it also reduces time and cost spent as it can incorporate the statistical linear regression prediction model which coincides with the ease of data collection for the noise $L_{A,max}$ level.
1.6 Contents of Report

The report will contain five chapters. Chapter 1 briefly describes about the introduction, the problem statement, the objectives, the scope of study and the significance of this study. Chapter 2 presents reviews from previously published studies carried out by local and international researchers. They provide further information that are useful and can be used as a guideline to produce better results. The methodology and concept applied in this study are discussed in Chapter 3. Chapter 4 contains the results and discussions of this research. Lastly, the conclusion of the study and recommendations of improvement towards the studies in the future are discussed in Chapter 5.
CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter explores past studies in this area of research. The chapter explains the guides for this current research and insightful suggestions from past researches to create a better understanding. This chapter will discuss the definitions of noise as well as the prediction model for trains as a transportation mode. Train noise sources will also be discussed in this chapter. Aside from that, the effects of noise pollution towards human health and wildlife will also be discussed in this chapter. Described in this chapter is also the method in building the noise prediction model for trains. Furthermore, this chapter will review past noise prediction models for trains used in past years from different countries and show the importance of these models. Noise measurement and limited noise level for Ampang line Light Rail Transit (LRT) train, specifically the Ampang line trains, will be explained theoretically.

2.2 Definitions of Noise and Linear Regression Prediction Model

Past researchers have defined sound in its simplest form as a succession of vibrating waves or oscillations of pressure waves, also called energy, transmitted in a fluid medium such as air. These pressure waves cause the ear drums to vibrate and create the sensation of sound. Noise, however, is defined as unwanted sound (Bridgewater et al., 2011).

Physically, there is no distinction between sound and noise: sound is a sensory perception evoked by physiological processes in the auditory brain. The complex pams of sound waves are perceptually classified as “Gestalts” and are labeled as noise, music, speech, etc. Consequently, it is not possible to define noise
exclusively on the basis of the physical parameters of sound. Instead, it is common practice to define noise simply as unwanted sound. However, in some situations noise may adversely affect health in the form of acoustical energy (Berglund et al., 1995).

In relation to that, Wardika et al., (n.d), defines noise in three classes; 1) Sounds that come in cut off waves instead of continuously called impulsive noise. An example would be a drum being hit. 2) A continuous sound that lasts for a long time called continuing noise. An example would be a motorized machine humming while it’s running. 3) Lastly is the semi continuous noise or intermittent noise. This type of noise comes in medium length waves that would occasionally appear in certain times, much like the sounds of vehicles such as trains, airplanes, cars, lorries and buses. Loud noises occurring due to the traffic is unavoidable in the modern world but is also one of the most unwanted noises.

The linear regression model is a regression model where the dependent variable is continuous, explained by several exogenous variables, and linear in the parameters. The linear regression model coefficients for previously added terms change depending on what was successively added. For example, the \( X_1 \) coefficient might change depending on \( X_2 \) term was included in the model (Francis & Michael, 2012). Therefore, the linear regression model used to leverage statistics to predict outcomes. The prediction model was made to help with noise measurement activities. The prediction models may be preferred in situations where the:

- 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.
2.3 Train Noise Source

Past researches have found that there are a few factors contributing to the noise sources from trains either from freight trains, high speed trains, intercity trains or urban trains.

According to Ogren (2006), there are three sources that contribute to the train noise. Firstly, noise comes from rolling objects which would be the wheel and rail interaction underneath the train car. This happens due to the primary physical contact between the train wheel and the rail which would be responsible for vibrations that radiate. Figure 2.1 shows a sketch of a wheel on a rail-way track. When the wheel is rolling on the rail the small unevenness of both wheel and rail causes force on both of them. These forces excrete vibrations throughout the whole system which in turn radiates sound. This noise generation mechanism is known as rolling noise.

![Figure 2.1: Sketch of wheel-rail interaction and the track including sleepers and pads (Ogren, 2006).](image)

Further explanation of the mechanical power flow through the system can be described by the simple flow chart in Figure 2.2. Energy is generated by the force on the contact patch and is emitted via vibrations or dissipates as heat.
The secondary noise source is from the curve squeal which is the intense tonal noise that can set in when a rail vehicle traverse through a curve or switch. The process starts with either lateral creeping in the contact patch between rail and wheel or rubbing of the flange of the wheel against the rail. When the stick-slip process at the patch or the flange becomes unstable, for example, when there is a feed-back that leads to instability, the wheel will radiate the tonal noise. Thirdly, aero acoustic sources are closely related to airflow where turbulence and sounds will be emitted. At high speed of more than 300km an hour, the contribution can be substantial. The pantograph is a typical problematic area, as well as other structures that are protruding from the exterior of the train. Recesses are as important as the turbulence boundary layer on the surface of the train. The sound energy emitted by the aero acoustic sources is strongly dependent on the train’s speed. Secondary sources of noise are the machinery on the train such as cooling fans and power transmitters. When poorly designed, it may contribute to the total noise emitted by the vehicle (Ogren, 2006).

Aside from that, European Communities (2003) has listed train speed as a major influence parameter in noise emission. The noise produced due to traction and auxiliary systems – commonly from diesel units, electrically driven power trains, cooling equipment, compressors - tend to be predominant at low speed of up to around 60 km/h. Wheel-rail rolling noise is dominant up to speed around 200-300 km/h, after which aerodynamic noise takes over as the 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.
For the Japanese ‘shinkansen’, noise sources are divided into four components that are the noise generated by the lower parts of cars, which consist of the rolling noise, aerodynamic noise, and gear noise, concrete bridge structure noise, aerodynamic noise generated by the upper parts of cars and pantograph noise, which consists of the aerodynamic noise and spark noise. The positions of the noise sources adopted in shinkansen trains are shown in Figure 2.4 where the coordinates of the noise sources are labeled respectively (Nagakura and Zenda, n.d).
2.4 Noise Effect

Based on past researches, it has been proven that noises do affect the livelihood of both human and wildlife.

2.4.1 Effects of noise towards human health

Basically, the effects of noise on human health could be viewed from three different aspects (Suhaimi Yusoff and Mohammad Rehan Karim, 1997):

- The effects of noise on sleep
- Physiological and psychological effects of noise
- The effects of noise on hearing
The primary impacts are annoyance and sleep disturbance with night-time noise as the major source of concern especially older. The effects on sleep disturbance tend to be a reduction in the sleep period, arousals, awakenings, sleep stage modifications and autonomic responses (e.g. change in heart rate) (Tassi et al., 2010). Moreover, the reduction in sleep quality has secondary impacts (generally felt the day after disturbance) including fatigue, low work capacity, reduced cognitive performance, changes in day time behaviour as well as mood changes and associated negative emotions. In fact, chronic exposure to environmental noise can lead to a permanent disruption in sleep (Murphy and King, 2013).

Furthermore, the research also implies that noise induced annoyance may have an adverse effect on health. People annoyed by noise may experience a variety of negative responses such as anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation or exhaustion. Stress-related psychosocial symptoms such as tiredness, stomach discomfort and stress have been found to be associated with noise exposure as well as noise annoyance (Elmenhorst et al., 2012).

According to the, World Health Organization (2011), the physiological and psychological effect of noise towards children is disturbance of learning and memory. The affected area of learning are those involving central processing and language, such as reading comprehension, memory and attention. Exposure during critical periods of learning at school could potentially impair development and have a lifelong effect on educational attainment. Other symptom of effects from noise to the human health is on hearing. There are a few effects based in the Table 2.1 below with different noise sources and sound levels.
Table 2.1: Correlates common sounds with effects on hearing (World Health Organization, 2011)

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<tr>
<td>Conversation at home</td>
<td>50</td>
<td>Quiet</td>
</tr>
<tr>
<td>Freeway traffic (15m), vacuum cleaner, noisy party</td>
<td>70</td>
<td>Annoying, intrusive, interferes with phone use</td>
</tr>
<tr>
<td>Average factory, train (at 15m)</td>
<td>80</td>
<td>Possible hearing damage</td>
</tr>
<tr>
<td>Jet take-off (at 305 m), motorcycle</td>
<td>100</td>
<td>Damage if over 1 minute</td>
</tr>
<tr>
<td>Thunderclap, textile loom, chainsaw, siren, rock concert</td>
<td>120</td>
<td>Human pain threshold</td>
</tr>
<tr>
<td>Toy cap pistol, jet take off (at 25m), firecracker</td>
<td>150</td>
<td>Eardrum rupture</td>
</tr>
</tbody>
</table>

2.4.2 Effects of noise towards the wildlife

A researcher found in March of 1997 a forty foot sperm whale trapped in the inshore waters of Firth of Forth near Edinburgh, Scotland. Scientists attributed this to traffic noise from the rail and road bridges that traverse the waterway. The clamorous noise made the sperm whale reluctant to return to open waters which eventually caused it to become stranded in the shallows between the bridges (Radle, 2007).

2.5 Noise Measurement

In forming the noise prediction model, the method to acquiring the field noise measurement is very important. The correct method of measurement will yield accurate and better results. The SLM used to determined noise level $L_{Aeq}$, $L_{A,max}$, $L_{A10}$ and $L_{A90}$. According Malaysian Department of Environment (Noise Labeling and Emmision Limits of Outdoor Sources) (2007), the noise level $L_{Aeq}$ is the equivalent A-weighted sound-level, energy averaged over the time. The maximum instantaneous level $L_{A,max}$ over the monitoring time. $L_{A10}$ is the noise level exceeded
for 10% of the time of the measurement duration and this is often used to give an indication of the upper limit of fluctuating noise and \( L_{A90} \) is taken to be the ambient or background noise level.

Sound Level Meter (SLM) was used to measure the noise emission from the Ampang line LRT trains. The correct way to acquire the noise \( L_{A,max} \) from passing trains is to make sure that the SLM is in the “A” weighting network and “fast” time weighting response states. These two will determine the sound pressure level measurements for maximum instantaneous level (\( L_{max} \)), equivalent (\( L_{eq} \)) and statistical centile readings (\( L_{10}, L_{90} \)). Then, the calibration of SLM should be checked and adjusted according to the standard sound source at the beginning and at the end of each series of measurements. If the errors of the sound level meter obtained from these calibrations deviate by more than 1dB during a series of measurements, the measured result shall be considered invalid. Measurements cannot normally be made if the wind speed exceeds 5 m/s at the microphone position. For continuous remote monitoring, the wind speed shall be monitored concurrently with the sound levels. Lastly, the receiver’s height should be 1.2 m to 1.5 m above ground and practically at least 3.5 m from any walls, buildings or other sound reflecting structures (DOE, Malaysia, 2007).

Past journals have dictated a few ways to gain noise values to base the prediction models on. According to Nassiri et al., (2008) and The British Standard ISO 3095:2005 (2006), the correct way in acquiring noise levels is in making sure the test is performed in an open environment which is a flat site, free of sound-reflecting object like barriers, hills, rocks, bridges or buildings and clear weather which should be without rain or snow. The field measurement should be free of sound absorbing covering and well maintained, ballasted, fault-free, dry and not on frozen track. There are no other important sources that could cause an increase in the noise level during the passing of trains. There are no obstacles around the microphone that can interfere in the sound recording. When the field measurement is taken, ensure that no other person is between the microphone and the sound source and the observer must be in a position that does not affect the meter reading. Distance between the train and the measuring microphone must be as free as possible from any sound absorbing rain. Stabilize the microphone position so the background noise level is at least 10
dB below the sound pressure level that is going to be measured. Effects of increasing wind background noise should be minimized. Position of the microphone can be fixed by using a tripod or a handheld device (that is not moving) and placed on the floor of the same ground position perpendicular to the railway vehicle.

Field measurement method used by European countries prepared by Miller and Hanson (1996), discussed below. The type of trains includes trains from French, Italy and Sweden. The guidance is provided with regards to the site’s geographical characteristics. It was based primarily on measurement logistics as follows:

- The sites in each country should be located in the same general region, within a one hour (or less) drive of each other.
- The sites should be in generally open level areas.
- The sites should allow access for placement of instrumentation within an area extending between 12.5 m and 75 m from the nearest track centreline along a 60-meter segment of the railroad line with no intervening obstacles or major roads.
- The sites should not be too close to sources of significant noises that could contaminate the measurements such as major roads, airports, industrial plants, construction sites or agricultural equipment.

2.6 The Prediction Model Method

Based from past researchers that have delved into the topic of study, noise prediction models have been created for easier data collection, more specifically to collect train noise data. Their method in creating the noise prediction model will be used as reference within Chapter 4.

Givargis and Karimi (2008), presented statistical linear regression models that are capable of predicting maximum A-weighed noise level (L_{A,max}) for the Tehran–Karaj express train by using the STATISTICA software (version 7.0). According to this research, the vehicle length for the Tehran–Karaj express train became the constant factor while the L_{A,max} will be a function of vehicle speed and
distance from the track centre line. Table 2.2 represents the results of the linear regression modeling in the model training step.

**Table 2.2: The results of the linear regression modeling in the model training step (Givargis and Karimi, 2008)**

<table>
<thead>
<tr>
<th>Predictor</th>
<th>B(^a)</th>
<th>t(^a)</th>
<th>t(_{0.99}(27))(^c)</th>
<th>t(_{0.01}(27))(^d)</th>
<th>F(^c)</th>
<th>F(_{0.99}(2,27))(^f)</th>
<th>R(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>80.429</td>
<td>55.69</td>
<td>(t\text{-value})</td>
<td>(t\text{-value})</td>
<td>99.44</td>
<td>5.49</td>
<td>0.8805</td>
</tr>
<tr>
<td>Speed</td>
<td>0.103</td>
<td>5.83</td>
<td>2.473</td>
<td>-2.473</td>
<td>99.44</td>
<td>5.49</td>
<td></td>
</tr>
<tr>
<td>Distance</td>
<td>-0.113</td>
<td>-13.24</td>
<td>(t\text{-value})</td>
<td>(t\text{-value})</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2.7 showed the constant and speed coefficients are significantly positive while the distance coefficient is significantly negative. In other words, the model conforms to the theory that the increasing speed level will cause an increase in noise level and the increasing distance will cause a decrease in noise level. Eventually, the results show that the emerged linear regression model is significantly linear with 88\% \((R^2 = 0.8805)\) located points on the regression line. Ultimately, from Table 2.7, the linear regression model for the Tehran–Karaj emerges as follows:

\[
L_{A,max} = 80.429 + 0.103X_1 - 0.113X_2
\]  \hspace{1cm} (2.1)

Where:

- 80.429 : Constant.
- \(X_1\) : Speed (Km/h).
- \(X_2\) : Distance (m).

Based on Figure 2.6, the results shown of the linear regression analysis also demonstrate a suitable correspondence between the linear regression equation relating to the model predictions and the field measurements \((y = 0.9988x)\) with 96.05\% \((R^2 = 0.9605)\). Figure 2.6 also shows that both the value noise \(L_{A,max}\) from field measurement and prediction model data points are fall to the fitted regression line.
According to the prediction model in Greece noise $L_{A,max}$, four types of trains were studied. The four types of trains were trains that are in current use in Greece which are intercity train, self-propelled car, diesel passenger (DI passenger) and diesel freight trains (DI freight). These trains were measured at a distance of 25m from the centerline of the track. The train noise prediction model for determined noise $L_{A,max}$ depends mainly on speed and the specific characteristics of vehicles and track. In relation to that, the prediction models’ designs are different in various countries because of the specific characteristics of train noise in every country due to different vehicle used as well as track types and condition. The regression analysis is used to create the prediction model for noise $L_{A,max}$. Figure 2.7 shows the measured value noise $L_{A,max}$ and the corresponding regression curves for intercity train. Figure 2.8 shows measured value noise $L_{A,max}$ and the corresponding regression curves for self-propelled cars. Figure 2.9 shows measured value noise $L_{A,max}$ and the corresponding regression curves for diesel passenger (DI passenger). Figure 2.10 shows measured value noise $L_{A,max}$ and the corresponding regression curves for diesel freight trains (DI freight). Based on the all figures below, the models are shown to conform to the theory that the increasing speed level will cause an increase in noise level (Bamnios and Trochides, 2000).
Figure 2.6: Measured $L_{A,\text{max}}$ and regression curve for intercity train
(Bamnios and Trochides, 2000)

Figure 2.7: Measured $L_{A,\text{max}}$ and regression curve for self-propelled cars
(Bamnios and Trochides, 2000)
The analytical results of expression of noise $L_{A,\text{max}}$ as function of speed $V$ were obtained for each type train:

**Intercity train:**

$$L_{A,\text{max}} = 85,4 + 18,6 \times \log(V/60)$$
\[ L_{A,max} = 83.5 + 14.5 \times \log\left(\frac{V}{60}\right) \]  \hspace{1cm} (2.2)

Self-propelled car:

\[ L_{A,max} = 82.3 + 11.1 \times \log\left(\frac{V}{60}\right) \]  \hspace{1cm} (2.3)

Diesel passenger:

\[ L_{A,max} = 85.4 + 18.6 \times \log(V/60) \]  \hspace{1cm} (2.4)

Diesel freight trains:

\[ L_{A,max} = 84.5 + 10.3 \times \log(V/60) \]  \hspace{1cm} (2.5)

Base on the regression curve prediction model noise \( L_{A,max} \) train at Greence country showed the parameter in this study are the noise \( L_{A,max} \) at the field and the speed of train. This research also showed there are four different noise \( L_{A,max} \) prediction model be build based on the type of train. The differen t occur because the speed influence the noise \( L_{A,max} \) prediction model.

### 2.7 Ampang Line LRT Train

The Ampang line LRT train was launched in 1996. The Bandaraya LRT Station is one of the more prominent public transports in the city of Kuala Lumpur, Malaysia. The Ampang line LRT train uses electrification third rail as the main energy source. The train system is called the light metro.
Figure 2.10: The specification of rolling stock Ampang line LRT train

The Ampang line LRT service was also upgraded from 27 km with an extension of the Ampang route, adding 17.7 km starting from the Sri Petaling station through Kinrara and Puchong while ending in Putra Heights. With the expansion project, it was estimated that the usage of trains would increase therefore decreasing the traffic on the roads of Klang Valley. Additional 35 sets of four car trains increase the capacity of the train from 258,156 in 2011 to 254,745 in 2010 (Raduan Tambi, 2013).

Therefore, the increasing capacity showed the train transportation is very important in the daily modern life to connect people from their homes to their offices, schools and markets. This mode of transportation is the better choice in avoiding traffic congestions. Transportation is also a commodity that can be used to help improve the country’s economy to higher levels parallel to the modernization and improvement of the country’s produce, service, generators and energy sectors as well as the improvement of the people as a whole (Haryati Shafii and Sharifah Meriyam Shareh Musa, n.d.).
2.7.1 Limiting Sound Level Emission for Ampang Line LRT Train.

According to the Malaysian Department of Environment (Environmental Noise Limits and Control) (2007), there are sound limit levels for $L_{A_{eq}}$ and $L_{A,max}$ for the Ampang line LRT that should be obeyed. Table 2.1 below shows the sound limit level of $L_{A_{eq}}$ and $L_{A,max}$ during night time and day time according to different receiving land use category.

<table>
<thead>
<tr>
<th>Receiving Land Use Category</th>
<th>$L_{A_{eq}}$ Day Time 7.00 am – 10.00 pm</th>
<th>$L_{A_{eq}}$ Night Time 10.00 pm - 7.00 pm</th>
<th>$L_{A,max}$ (Day &amp; Night)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise Sensitive Areas Low Density Residential Areas</td>
<td>60 dBA</td>
<td>50 dBA</td>
<td>75 dBA</td>
</tr>
<tr>
<td>Suburban and Urban Residential Areas</td>
<td>65 dBA</td>
<td>60 dBA</td>
<td>80 dBA</td>
</tr>
<tr>
<td>Commercial, Business</td>
<td>70 dBA</td>
<td>65 dBA</td>
<td>80 dBA</td>
</tr>
<tr>
<td>Industrial</td>
<td>75 dBA</td>
<td>65 dBA</td>
<td>NA</td>
</tr>
</tbody>
</table>

2.8 Summary of the Chapter

Above are the discussions pertaining towards the noise prediction models for train. Methods and models created by other countries are also discussed and broken down into explicit formulae to explain the noise source, noise measurement method as well as the method used to form the country’s noise prediction models for train. In a nutshell, noise prediction models are model equations created to make data collection easier. Noise prediction models will benefit the country’s industry in which they help ensure safe noise levels according to local and international guidelines.
CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter explains the process involved to complete this project. Before any action was taken into account for starting this project, a proper planning was needed to ensure the project could run smoothly and successfully. The project methodology will be explained further in details in the work flow. The SPSS Statistic (version 22) software was used in this research.

Noise $L_{A,max}$ from field measurement and prediction model from train were studied in this research. In the noise $L_{A,max}$ statistical linear regression prediction model for Ampang line Light Rail Transit (LRT) train, field measurement was conducted to retrieve the real data from recorded train’s sound. Noise $L_{A,max}$ from the field measurement data that were recorded using Sound Level Meter (SLM) were studied and analyzed to form noise $L_{A,max}$ statistical linear regression prediction model for Ampang line LRT train. The SLM was also used to record the sound level for $L_{Aeq}$, $L_{A90}$ and $L_{A10}$. The field measurement was carried out by recording every sample of noise data for 15 minutes (equivalent to 900 seconds).

In this study, February 2015 was chosen to be the time to record the sound level produced by the train. Data collection was only carried out during normal working days which were from Monday until Friday on both peak and off-peak hour. During peak hours, the headway (time difference between any two successive vehicles when they cross a given point, Mathew and Krishna, 2006) was only 6 minutes and during off-peak hours it was 14 minutes.
Residential area along the way of Cempaka Station (Cempaka Indah and Pinggir Cempaka) was chosen for this study. The first location, Pinggir Cempaka had been identified as the downtrack. Meanwhile, Cempaka Indah, the second location, was identified as the uptrack. The downtrack was the LRT train track that headed from Sentul Timur to Ampang and Sri Petaling. The uptrack in this study was the LRT train track that leads from Ampang and Sri Petaling to Sentul Timur.

SPSS Statistics (version 22) software was used for the analysis purpose. Three parameters were needed to form the noise $L_{A,max}$ statistical linear regression prediction model in the SPSS. There are noise $L_{A,max}$ field measurement, speed of train and distance from the center of the up/downtrack. Based on the parameter of sixty samples, sound level data for noise $L_{A,max}$ were recorded and collected in the field, thirty noise $L_{A,max}$ data from each location. According to the research location during the field measurement, six distances were chosen. There are 15 m, 25 m and 35 m each from the center of the downtrack of the receiver at Pinggir Cempaka and 20 m, 30 m and 40 m each from the center of the uptrack of the receiver at Cempaka Indah. The speed was calculated from the measured pass-by time of the head train to back train at point A and the length of the train. The length of trains in this study was constant at 85.536 m.
3.2 Flowchart

Field measurement data collection

Field measurement data analysis using SLM software

Parameters identified
- Noise $L_{A,max}$ field measurement
- Speed
- Distance from the center of the up/downtrack to the receiver.

Enter and process all the parameter values into Statistics SPSS (version 22) software

If the significant value < 0.05 and coefficient of determination $R^2 > 50\%$ ($R^2 > 0.5$)

Yes

Noise $L_{A,max}$ statistical linear regression prediction model is significant and goodness fit

No

The model validated and predict accurately

Figure 3.1: Flowchart
REFERENCE


Raduan Tambi (2003), “National Key Result Area (NKRA) Menambah Baik Pengakutan Awam,” Published by Penerangan Malaysia Department.


