INTERNATIONAL JOURNAL OF SUSTAINABLE CONSTRUCTION ENGINEERING AND TECHNOLOGY
VOL. 13 NO. 4 (2022) 21-29

IJSCET

http://publisher.uthm.edu.my/ojs/index.php/ijscet

ISSN : 2180-3242 e-ISSN : 2600-7959

International Journal of Sustainable Construction Engineering and Technology

Evaluation of Noise Generated by Train Movement at Rail Near to Residential Areas – Case Study at Kluang, Johor.

Adilah Arbaan[1], Tong Yean Ghing[1*], Mohd Hanifi Othman[1], David B. K. Yeung[2]

[1]Faculty of Civil Engineering and Built Environment,
Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, MALAYSIA

[2]Ramboll Hong Kong Limited,
21/F, BEA Harbour View Centre, 56 Gloucester Road, Wanchai, HONG KONG SAR

*Corresponding Author

DOI: https://doi.org/10.30880/ijscet.2022.13.04.003
Received 27 October 2022; Accepted 31 October 2022; Available online 13 November 2022

Abstract: Rail transportation is one of the largest transportations that is widely used in Malaysia. Therefore, many railways have been built in urban and rural areas to improve interstate connectivity in Malaysia. However, train noise generated from train movement can disturb the comfort of nearby residents that live near railways. This study was conducted nearby the residential area between the Kluang – Renggam rail line to investigate the noise level and compare the existing noise level with the guideline from the Department of Environment (DOE) and World Health Organization (WHO) limits. Besides, the impact of this urban pollution to the residents nearby were evaluated by the noise index of noise pollution level (LNP). The results showed that the A-weighted noise levels (L_{Aeq}) at all locations exceeded WHO limit while the L_{Aeq} at 2 locations (20m and 30m from the rail track) were exceeded the noise limit that set by DOE. Besides, the noise levels captured at the location which 55m away from sound source were nearly approximated to 60 dBA. The residents nearby were affected by this urban noise pollution where the LNP values obtained from this study were approximately to the LNP limits. Thus, alternative strategies should be carried out in this area in order to make sure that the community in this area free from the noise disturbance. Further study such as developed noise mapping and the questionnaire of annoyance level for the residential area can be implemented to improve the findings on the effect of train noise in the future.

Keywords: train noise, residential area, permissible noise

1. Introduction

Railway transportation has advanced rapidly in recent years as technology has advanced. Malaysia's railway network has expanded rapidly since its inception in the early 19th century when it was built to meet the need to transport natural resources such as timber and tin ore from the hinterland to coastal ports (Yusof *et.al*, 2019). Malaysia has a diverse railway network, including Keretapi Tanah Melayu (KTM), Light Rail Transit (LRT), KL Monorail, and Express Rail Link (ERL). Many people prefer to use rail transportation as a mode of transportation because of its advantages. The advantages of rail transportation are they are more organized and have fixed routes and schedules. It also can reduce traffic congestion which can save time and shorten travel time. Moreover, because of the lower transport cost (Tinghao & Ali, 2009). However, as more rail lines are built to increase environmentally friendly modes of transportation, the noise generated by trains can disturb the comfort of nearby residents who live near the train track. Rolling noise is considered the most significant source of railway noise and is defined as noise caused by friction between the wheels and the track.

**Corresponding author: ygtong@uthm.edu.my*

Forces cause vibrations to propagate throughout the system, causing the sound to be emitted (Ogren, 2006). In addition to that, other sources of rail noise include various types of trains, cooling fans, power transmissions, which are more related to rail machinery, and noise from horns, bells, and whistles. Noise above 55 dBA is already considered as noise pollution, if the noise level is extended for a long period, it can cause the efficiency and wellbeing of a person to be reduced, meanwhile noise level at the range of 65 to75 dBA can cause stress to the body (Clausen et al., 2012). Besides that, loud noise can also lead to high blood pressure, heart disease, sleep disruptions, and stress (WHO, 2018).

The aim of this research is to investigate the noise level in a residential area near the rail track and to compare the existing noise level with the recommended guidelines.

2. Train Noise Limits

Train noise pollution in residential area is due to the higher number of train trips that pass by in that area, especially during peak times. Trains are one of the main sources of noise with a particularly strong negative impact on the environment and on the health of children and adults (Grubliauskas, 2014). Therefore, it is important to know the noise level in residential areas, especially those that live nearby the train track, as noise can be harmful to human health such as disturbance of sleep, increased blood pressure, affect the cardiovascular system, and interrupting activities of daily living (Kim, 2015; Stansfeld & Matheson, 2013; Ising & Kruppa, 2004; Croy et al., 2013). Exposure to railway noise also associated with a higher breast cancer risk (Sørensen et.al, 2021).

Based on Environmental Noise Limits and Control guidelines that had been provided by the Department of Environment, there has schedule of permissible sound levels by various receiving land use for human activities such as for new development, existing built-up areas, road traffic, railway, and transit lines, and for construction, maintenance, and demolition work (DOE, 2019). Table 1 shows the limiting sound level of three different countries which are Malaysia, China and Japan from railway and transit trains for receiving land use category that has been set by DOE. From these three countries shows that Malaysia has the highest noise limits compared to the others and the limits recommended are practicable for its existing social and economic conditions. Meanwhile, WHO has set in their environmental noise guidelines, namely for average noise exposure for train was strongly recommends reducing the noise level produced by the railway traffic below 54 dBA during the day (WHO, 2018).

Table 1 - Limiting sound level (L_{Aeq}) from railway and transit trains

Receiving Land Use Category	L_{Aeq} Day (Malaysia) 7.00 am – 10.00 pm	L_{Aeq} Day (China) 7.00 am – 10.00 pm	L_{Aeq} Day (Japan) 7.00 am – 10.00 pm
Noise Sensitive Areas, Low Density and Suburban Residential Areas	60 dBA	50 dBA	50 dBA
Urban Residential Areas	65 dBA	55 dBA	55 dBA
Commercial, Mixed Development	70 dBA	60 dBA	55 dBA
Industrial	75 dBA	65 dBA	60 dBA

Sources from DOE, 2019; Tinghao & Ali, 2009; Depart. Of Trasnportation, 2021.

3. Case Study Location

The case study is located at KTM Intercity Kluang - Renggam rail line in Johor. The train journey time between Kluang and Renggam is estimated at approximately 27 to 40 minutes, depending on the type of train and covers an area of around 21 km. Fig. 1 shows the illustrated location of the case study between the Kluang - Renggam rail line and Table 2 shows the coordinates for each location. The Renggam train station located at 1°53’05.22” N and 103°24’11.22” E. Meanwhile, the Kluang train station is located at 2°02’01.13” N and 103°19’02.63” E. The new development program has been upgraded the traditional rail track to the upper deck train track. Thus, the impact to the residential nearby can be reduced because of the elevation angle from the noise which the sound most probably will be prorogated through diffraction. However, there are some parts of the rail track still using the conventional where the direct rail noise will be exposed to the nearby residents. In this study, 3 measurement points were selected in which rail noise can be directly propagated to the nearby community.

Fig. 1 - The map of case study location

Table 2 - The measurement locations

Location	Coordinates	Road nearby
P1 (20 m from rail track)	2.010944º N 103.322328º E	Jalan Indah 4, Kampung Yap Tau Sah
P2 (30 m from rail track)	1.9745889º N 103.334503º E	Jalan Kluang - Renggam
P3 (55 m from rail track)	1.8902806º N 103.400306º E	Jalan 2, Renggam

3.1 Field Measurement Set-Up

Data were collected at three locations with different distances from the rail track. The sound level meter is mounted on a tripod with a height of at least between 1.2 and 1.5 m above the ground. Besides that, the measurement data shall be made at all strategic locations, which are in proximity to the noise source and away from another object that can reflect the sound. Before the measurement, the sound level meter was calibrated using B&K Type 4231 calibrator before each set of measurement with the reference sound source to ensure accuracy of ± 1 dB. The value of the reference sound source during the calibration is 94 dBA. Additionally, the sound level meter microphone should have a selectable reference direction between 0 and 90 degrees for outdoor environmental noise measurements (DOE, 2019). Table 3 shows the distance for each measurement location. Meanwhile fig. 2, fig. 3 and fig. 3 show the view of the measurement points which were placed near to the train track and residential areas.

Table 3 - The distance from Sound Level Meter

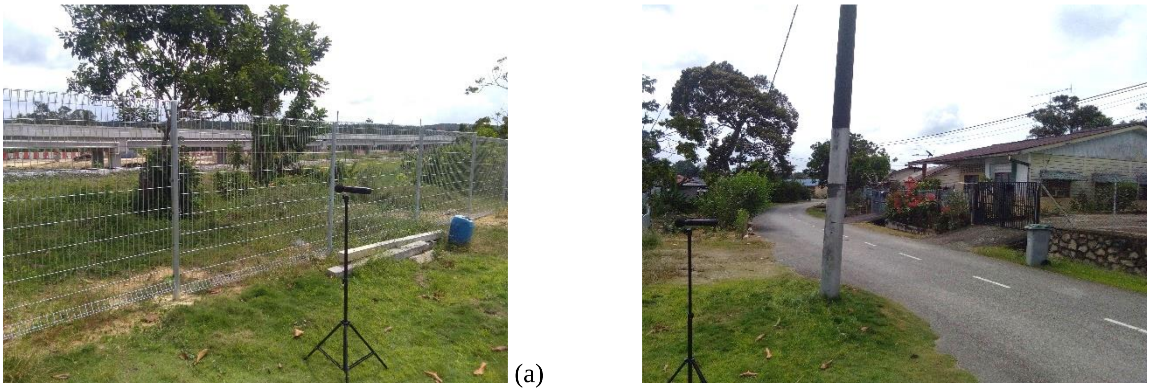
Location	Distance between Sound Level Meter and Rail Track	Distance between Sound Level Meter and Residential Area
P1	20 m	25 m
P2	30 m	6 m
P3	55 m	7 m

(a) (b)

Fig. 2 - Sound level meter setup for P1 (a) view facing to train track; (b) view of nearby residential area

(a) (b)

Fig. 3 - Sound level meter setup for P2 (a) view facing to train track; (b) view of nearby residential area



(a) (b)

Fig. 4 - Setup of sound level meters for P3 (a) view facing the train track; (b) view of the nearby residential area

The frequency of train trips during the day when Malaysian Movement Control Order (MCO) for KTM Intercity from Gemas – Johor Bahru is only three trains while there are six train trips after the MCO where this are based on the latest (until December 2021) KTM Intercity train schedule. In addition, there are no trains that operate at night. The schedule of the train must be known to facilitate the process of measurement because it takes some time to set up equipment. Table 4 shows the train time schedule at Kluang Station and Renggam Station for the Ekspres Selatan train (ES) and the Ekspres Rakyat Timuran sleeper train (ERT) and the arrival time of train at 3 different measurement points. Estimation is needed to know the arrival time of the train at different measurement locations because the time of train arriving is not fixed, it may change due to the delay of train at the station. Therefore, it needs to arrive early at the measurement location and standby to set up the sound level meter and measure the background noise.

Table 4 - KTM Malaysia train schedule for southbound intercity from Gemas to JB Sentral Station and measurement train arrival time at measurement points

	Train No.	ERT 27	ES 43	ES45
Train Schedule	Kluang	9.47 a.m.	11.17 a.m.	5.52 p.m.
	Renggam	-	11.57a.m.	6.19 p.m.
Measurement train arrival time	P1	9.54 a.m.	11.17 a.m.	5.58 p.m.
	P2	10.15 a.m.	11.42 a.m.	6.02 p.m.
	P3	10.27 a.m.	11.54 a.m.	6.12 p.m.

3.2 Noise Determinations

Since the rail noise is the fluctuation sound pressure level over the period of time. Thus, in this study, A-weighted equivalent continuous level, L_{Aeq} over a period of time as shown in Equation (1) was adopted. The noise data were analyzed using data record that was set with 1 second time interval. Measurements were carried out by capturing 120 seconds of noise level (train pass by).

$$L_{Aeq} = 10\, log_{10} \frac{1}{n} \sum_{j=1}^{n} 10^{L_i/10} \tag{1}$$

where *n* is the number of total noise data, L_i is the continuous A-weighted noise level.

Besides, several statistical noise levels were also adopted in this study for a better understanding of the impact of this environmental noise. The10-percentile, L_{10} as it used to show the annoying peak of the rail noise to the population, L_{50} is use to represent the median of the fluctuation train noise while 90-percentile, L_{90} is for representing the ambient noise of the surrounding measurement location. The train noise measurements were conducted during the day on weekdays based on the KTM Electric Train Southbound (in December 2021) timetable which trains passing the measurement locations. In order to investigate impact of this noise pollution to the community nearby, noise pollution level (LNP) was calculated using Equation (2) adopted (Swain & Goawami, 2013). This noise index is use to represent the physiological and psychological impact of fluctuation noise.

$$LNP = L_{Aeq} + (L_{10} - L_{90}) \tag{2}$$

4. Results and Discussions

Table 5 shows the overall results of the train noise indices that captured near the residential areas of Kluang. From the result, all A-weighted equivalent continuous noise levels (L_{Aeq}) for all measurement points exceeded the noise limit of the WHO (more than 54 dBA). The L_{Aeq} for 2 time periods at P1 and P2 were exceeded the noise limit that has been set by DOE, Malaysia. Although other measured noise levels were not exceeded the permission noise level, the recorded noise levels were considered serious since there were nearly to 60 dBA. The noise levels that above the noise limit above the noise limit were around 7 dBA at location P1 which may easily noticeable by the residents nearby. According to WHO (WHO, 2018), the community noise at outdoor living areas is considered annoyance if the equivalent continuous noise level exceeds 50 dBA. The background noise for all measurement points were recorded more than 40 dBA. From the table, it can be clearly seen that the noise pollution level (LNP) for 2 measurement events at P1 exceed the limit of 88 dBA which means this rail noise will give impacts to the surrounding community. However, precaution should be at residential area near to observation location of P2 because the LNP is closely to the LNP limits.

Table 5 - Rail noise indices near residential areas

Location	Time	Over DOE Noise Limit (dBA)	L_{Aeq} (dBA)	L_{Amax} (dBA)	L_{10} (dBA)	L_{50} (dBA)	L_{90} (dBA)	LNP (dBA)
P1	Morning	7.3	67.3	85.6	66.3	48.6	44.8	88.8
(20m)	Noon	6.6	66.6	84.7	54.5	44.8	42.6	78.5
	Evening	-	59.8	75.9	59.1	48.0	44.7	94.6
P2	Morning	-	59.5	76.1	54.5	47.0	41.4	72.6
(30m)	Noon	5.8	65.8	80.4	67.2	53.0	49.4	85.9
	Evening	3.4	63.4	79.7	66.4	53.8	48.4	81.4
P3	Morning	-	56.4	66.7	61.7	51.0	48.7	69.4
(55m)	Noon	-	57.4	71.1	62.1	49.3	45.2	74.3
	Evening	-	58.7	73.1	63.0	48.8	45.7	76.0

The Pearson correlations of studied noise indices was shown in Table.6. From the table, there is very strong correlation between L_{Aeq} and L_{Amax} (r = 0.96). The A-weighted equivalent continuous noise level, L_{Aeq} is influenced by the maximum instantaneous noise level, L_{Amax}. Besides, the ambient noise of the surrounding (L_{90}) is also significantly affects the median of noise level (L_{50}) where the r = 0.91. There is no relationship between L_{Aeq} and L_{50}. It was contradicted with the previous studies (Garoum et.al, 2015; Segaran et al, 2019), it may due to the facts that the peaks of noise signals were very short (few seconds) when the train was passed compare to the road traffic noise.

Table 6 - Statistical correlation between noise indices

	L_{Aeq}	L_{Amax}	L_{10}	L_{50}	L_{90}	LNP
L_{Aeq}	1.00					
L_{Amax}	0.96	1.00				
L_{10}	0.22	0.07	1.00			
L_{50}	-0.03	-0.20	0.82	1.00		
L_{90}	-0.03	-0.25	0.80	0.91	1.00	
LNP	0.54	0.58	0.31	0.06	0.06	1.00

Fig. 6 shows the A-weighted sound pressure level recorded at P1 (20 m away from train track) for 3 different train passed events. From the figure, it can be clearly seen the noise signals dramatically increased within to the peak impulse within 15 seconds when the train approaches to the measurement location. The maximum noise level, L_{Amax} recorded were between 75 dBA to 81 dBA. Based on study of Grubliauskas (2014), the maximum noise level was recorded at 81 dBA for the locomotive train at the distance of 20 m from the railway which similar to the present study. The total fluctuation of train noise signal from train approaching and leaving the measurement location took around 30 seconds. At this measurement location, more fluctuation of the noise signals recorded during morning event with several impulse signals can be observed when the train approaching and leaving the measurement point. These multiple peak impulse responses most probably due to the facts that the train (Train No: ERT27) was ringing the train bell during the measurement. One can also notice from the figure is that the noise levels when train is leaving the measurement points were different in amplitudes even, they have similar magnitude of noise signal when train is approaching to the measurement point.

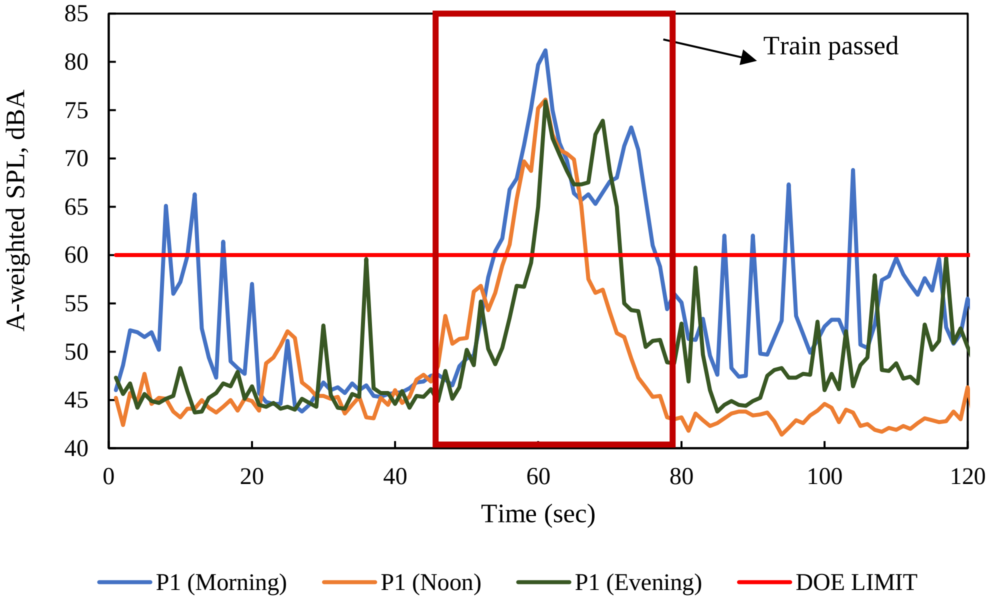


Fig. 5 - A-weighted Sound Pressure Level (dBA) at P1 for 3 measurement periods

The noise level measured at P2 (30m from the rail track) was shown in fig. 6. All three measurement events (morning, noon and evening) were similar the trends throughout the measurement period. Although the distance from the rail track were increased from 20m to 30m, the maximum impulse noise signals captured at this position were same magnitude. The similar multiple peaks can be observed at the similar time for 3 different trains may due to the noise friction created between the wheel and ballast of the track. Lower noise level of the train during the morning measurement event may due to the speed of the train. The noise level variation between the train at the morning and evening were around 5 dBA to 12 dBA except at the period when the train is moving heading to the 15 seconds period of time between the noise level reached to maximum level.

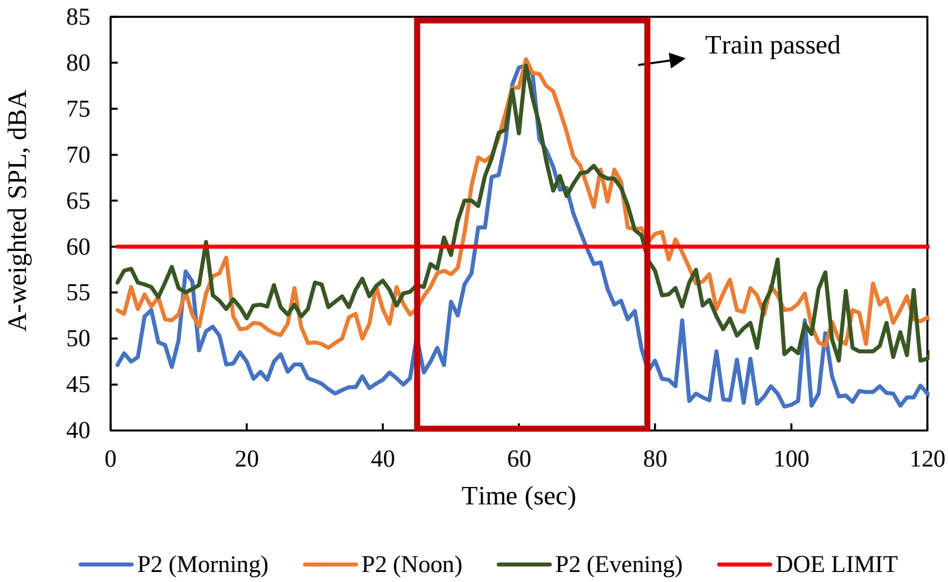


Fig. 6 - A-weighted Sound Pressure Level (dBA) at P2 for 3 measurement periods

Fig. 7 shows the A-weighted sound pressure level measured at P3 which located 50 m away from the rail track. At this location, microphone was placed near to the residential area and next to the traffic road. From the figure, the noise level trends for all three measurement times were different when the trains were approaching to the measurement point. However, there were similar trends of noise signal when the train is leaving from the measurement point. The different impulse responses at the beginning part of the figure may due to the noise from the vehicles passing by the road which located in front of the residential house as shown in Fig. 4(b). On can be noticed that the traffic noise from the road was as dominant as train noise. Although there were combination of the train and road traffic noise, the maximum of the noise level was still below 80 dBA if compare to previous 2 measurement locations. From the figure, one can discovered that the background noise (L_{90}) at this position (refer to Table-5) was higher than P1 even L_{Aeq} and L_{Amax} were lower because of high fluctuation of noise level at this point.

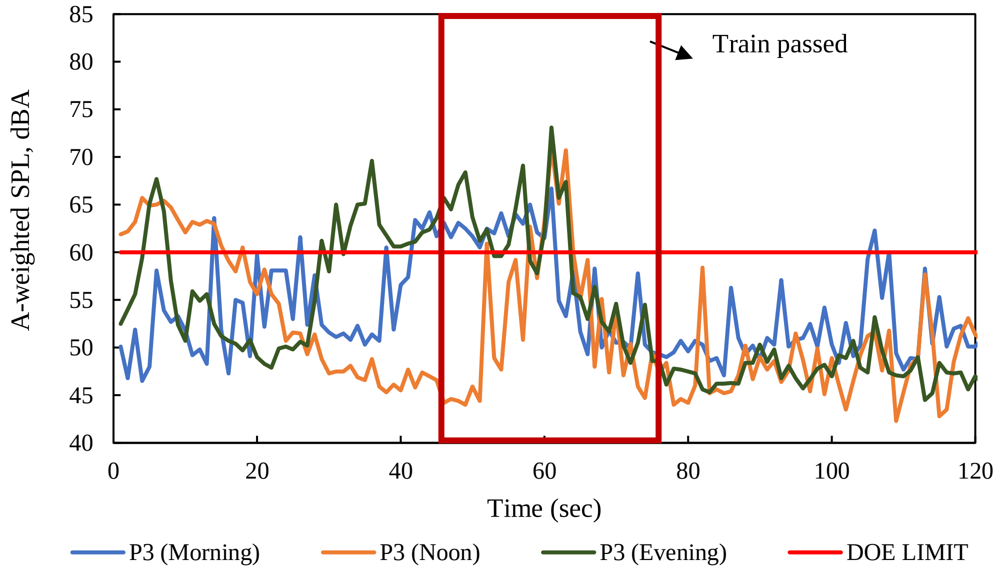


Fig. 7 - A-weighted Sound Pressure Level (dBA) at P3 for 3 measurement periods

5. Conclusion

Field measurement of rail noise to the residents nearby at Kluang was evaluated in the present study. A total of 3 measurement locations which located near to the train track and residential areas were chosen to capture this environmental noise. All L_{Aeq} noise levels at all measured locations were exceeded WHO noise limit of 54 dBA. The train noise was recorded at 3 different period of time during the day according to the train schedule using sound level meter. From the results, the A-weighted noise level at 2 locations (20m and 30m from the rail track) were exceeded the noise limit that set by DOE. Besides, the noise levels captured at the location which 55m away from sound source were nearly approximated to 60 dBA. Based on the data from noise pollution levels (LNP), some residents nearby were exposed to noise pollution and strategy should be carried out in this area in order to make sure that the community in this area free from the noise disturbance.

The statistical analysis of the noise determinations showed that L_{Aeq} in all 3 locations were not affected by the ambient noise (L_{90}) and average noise (L_{50}). However, the maximum noise level (L_{Amax}) was significantly influenced the equivalent continuous noise level (L_{Aeq}). From the trend of signal noise versus measurement period, it can notice that noise signals of train were increased to the peak impulse within 15 seconds when the train approaches to the measurement point. When the measurement location was further away from the rail track, surrounding noise will become as dominant as the train noise when the train is passing by.

In summary, the noise levels at all measurement locations are exceed or nearly approximate the limit that has been set by DOE. Thus, some efforts should be made to make sure this environmental noise will not affect the surrounding population. Further research on the train components that produce noise, noise mapping, and questionnaire survey can be carried in order to get more information that can be used for overcome this problem.

Acknowledgement

This research was supported by Universiti Tun Hussein Onn Malaysia (UTHM) through Tier 1 (Vot H753).

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