Journal of Civil Engineering, Science and Technology

Volume 14, Issue 2, September 2023, 129 – 137

INVESTIGATING THE ENVIRONMENTAL NOISE IMPACT OF MASS RAPID TRANSIT ON NEARBY COMMUNITIES AT BATU 11 CHERAS, MALAYSIA

Ming Han Lim[1], Yee Ling Lee[1*]

[1]Department of Civil Engineering, Lee Kong Chian Faculty of Engineering and Science, Universiti Tunku Abdul Rahman, Cheras, Kajang 43000, Malaysia

Date received: 24/04/2023 Date accepted: 16/05/2023
*Corresponding author's email: yllee@utar.edu.my
DOI: 10.33736/jcest.5654.2023

Abstract — Mass Rapid Transit (MRT) in Malaysia is designed to provide commuters with a comfortable journey that is highly functional and safe. Besides, it allows commuters to explore the city with ease and convenience. Due to the extension of the network throughout the years, the noise generated from MRT had increased and this environmental noise tends to annoy the adjacent community. This research aims to evaluate the environmental noise impact generated by MRT on the surrounding community at Batu 11 Cheras Station. A total of 4 monitoring points were selected for environmental noise impact assessment. After that, a sound level meter was set up at these monitoring points to measure the sound level and some parameters such as L_{Aeq}, L_{max}, L_{min}, L_{10}, L_{50}, and L_{90}. For each monitoring point, the noise level was measured for 6 hours continuously from 7:00 am to 1:00 pm. Based on the results, the noise levels at critical monitoring points exceeded 2.71% of the permissible sound level in Batu 11 Cheras Station. While for the maximum sound level, all four-monitoring points A, B, C and D had exceeded 2.75%, 10.13%, 4.38%, and 7.13%, respectively. For community annoyance impact, little levels of environmental impact and subjectively perceived noticeable differences were found at all the monitoring points.

Keywords**:** Mass Rapid Transit, Environmental Noise Impact, community, permissible limit, annoyance

1.0 INTRODUCTION

Noise pollution is recognized as one of the major disturbances that can affect the quality of life and daily human activities. Exposure to continuous environmental noise within the range of 85–90 decibels (dBA) can lead to hearing loss and changes in human threshold sensitivities [1]. Road transportation noise is the primary contributor to environmental noise pollution, such as the rolling noise of an engine [2]. Domestic noise is mainly contributed by the premises, ventilation systems and household appliances. Meanwhile, industrial noise is generated by machinery operations and mechanized tools in the workplace.

Environmental noise issues have been drastically increasing due to rapid population growth, industrialization, technological developments, and improvements to the living environment, resulting in adverse impacts on the environment around the world. Noise has a wide range of influences on human sensitivity. Hence, different people can perceive the sound or noise at varying levels of intensity. According to previous studies, surveys and monitoring, Malaysia is at a critical level of noise pollution [3]. Chronic environmental noise has been linked to multiple detrimental health effects in humans, like sleep disturbance, community annoyance, noise-induced hearing loss, cardiovascular disease, endocrine effects, and increased incidence of diabetes. In the United States, the primary sources of noise such as transit traffic, air transportation, and occupational and industrial activities have exposed around ten million Americans to adverse health outcomes, including heart disease and hearing loss [4]. The activation of the sympathetic nervous system in noisier environments generally results in a shift from deep to light sleep-in response to sound, which in turn increases blood pressure due to the reduction in the quantity and quality of sleep. Furthermore, noise exposure can lead to significant stress and annoyance to the communities. It has been demonstrated that even low-level noise can cause elevated physiological stress, enhanced annoyance, and reduced performance on cognitive tests [4]. Epidemiological studies found that environmental noise is associated with an increased incidence of arterial hypertension, heart failure, myocardial infarction, and stroke. According to the World Health Organisation (WHO), more than 1.6 million healthy life-years are lost annually from traffic-related noise in Western Europe [5, 6]. Moreover, this is especially relevant in Malaysia, where there appears to be little concern over such noise levels. Citizens are subject to nausea, headaches, and changes in mood and anxiety when constantly exposed to high environmental noise levels. Consequently, noise exposure can result in numerous physical and mental health issues.

Malaysia is a developing nation, and the development of public transport services, such as Keretapi Tanah Melayu (KTM), Light Rapid Transit (LRT), monorail, and Mass Rapid Transit (MRT), are essential to its growth. However, these public transports generate a considerable amount of noise and vibration, so it is essential to design rails that have low noise levels that can ensure the comfort of passengers. Some studies had been done on traffic noise to explore its adverse effects, such as the noise from the railway [7–9] aircraft [10–12] and road traffic [13–15]. According to Thompson et al. [16], approximately 1.7% of the global population is exposed to rail traffic noise levels above 65 dB, while 20% and 60% of the population in Western Europe were exposed to noise levels above 65 dB and 55 dB respectively. The primary cause of this noise is rolling noise, which occurs independent of train speed, and traction noise, which is only effective at lower speeds. Even when transit vehicles are stationary, noise is still generated due to the auxiliary equipment such as motors, radiator fans and air-conditioning pumps continuing to operate. Horns and bells are classified as noise sources and are used as warnings to trespassers within the right-of-way to avoid accidents. Rolling noise is the dominant source, caused by the contact between the wheel and rail. The roughness of the rail and wheel generates airborne and structure-borne noise, both of which propagate around and along a vehicle. The wavelength of this roughness is typically between 5 and 500 mm [16]. The vibration is transmitted to the wheel and track structures and causes sound radiation. Several factors such as wheel type, train speed, and stiffness may affect source strength.

In Malaysia, a rapidly developing country, the construction of railways brings considerable environmental noise pollution. The noise produced by Mass Rapid Transit (MRT) systems has a particularly acute impact on sensitive receptors, such as residential areas, schools, hospitals, and shop lots, which are forced to bear daily exposure to the MRT's loud noise. Moreover, the adjacent community near the MRT station will be exposed to significant levels of sound and vibration. Daily exposure to railway noise can have adverse effects on human health, so an environmental impact assessment is needed, comprising of noise and vibration assessment, to reduce the impacts on the neighbouring community. This study aims to analyze the environmental noise impacts of the Mass Rapid Transit station near the Batu 11, Cheras, Selangor Malaysia on the adjacent community.

2.0 MEASUREMENT METHODS

This section will be mainly focused on the procedures and methods used to assess the environmental noise impact generated by Mass Rapid Transit (MRT) to the adjacent community.

2.1. Site Selection

For environmental noise impact assessment, it is better to choose some noise-sensitive receptor sites such as residential areas and shop lots. Thus, the selected site is the Batu 11 Cheras MRT Station and there are more commercial shop lots surrounding the MRT Station. Four monitoring points were chosen surrounding the Batu 11 Cheras Station as shown in Figure 1. All four monitoring points A, B, C and D are shop lots. All of these monitoring points except D are considered near enough to the noise source and were chosen as the noise-sensitive areas in this study. For example, monitoring point A was set beside a furniture shop, monitoring point B was set at a shop at the edge in front of MRT, monitoring point C was set beside an instrument shop, and monitoring point D was set in front of an eyewear shop. To get a consistent result, the noise measurement for all these four monitoring points was measured every Wednesday to ensure the traffic flow condition is almost similar during each time of the sample collection.

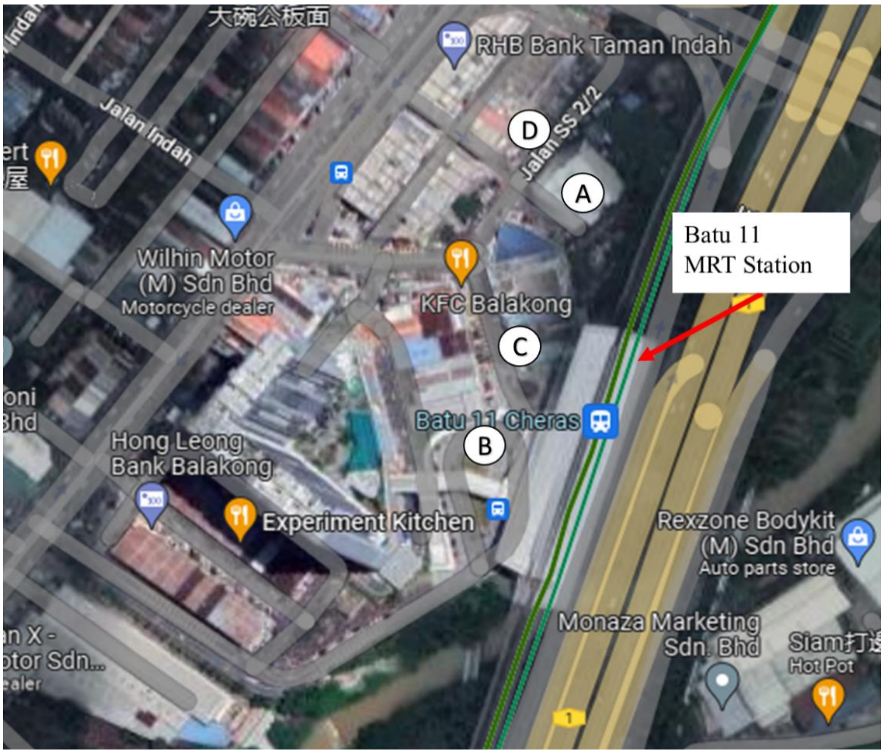

Figure 1 Monitoring Points at Batu 11 Cheras Station

2.2. Equipment

There are a few pieces of equipment needed to be used in the field measurement for the environmental noise impacts assessment such as a sound level meter, tripod, and distometer. According to the Department of Environmental (DOE) guidelines 2019 [17], the measurement equipment such as the precise sound level meter has to comply with the type of meters in Class 1. The sound level meter that will be used during the field measurement is the Class 1 Entry Level Sound Level Meter and it is named SoundTrack LxT. A tripod is needed to hold the sound level meter in place for the noise measurement. A distometer named Sndway Hand-Held Laser Distance Meter will be used during field measurement to measure the distance between two points. A battery-operated calibrator is used for the calibration of the sound level meter. Calibration must be carried out every time before a new noise level measurement to improve the accuracy of the measuring device and calibrated again after the measurement.

2.3. Data Collection

According to DOE guidelines [17], the tripod with the sound level meter has to be set at 1.2 m to 1.5 m above the ground level and at least 3.5 m from sound-reflecting structures for measurement [17]. Under some special conditions, the measurement location can be set at a greater height. During the noise measurement, additional care has to be taken to avoid unwanted sounds such as wind or noise from incidental sources. Apart from that, it is not recommended to carry out the noise measurement in intense climate conditions when the noise source is at a far distance. In this research, the data will be collected during day time which is within the range from time 0700 to 1300. Due to the different characteristics of noise and the noise varies over time, the equivalent continuous noise level over a time period will be used to measure the environmental noise level [17], as shown in Equation 1.

$$L_{Aeq} = 10\log_{10}\left(\frac{1}{m}\sum_{s=1}^{m}10^{\frac{L_{T(s)}}{10}}\right) \quad (1)$$

where L_{Aeq} is the equivalent continuous noise level, dBA

$L_{T(s)}$ is the s-th sound pressure level from the prediction, dBA m is the total number of the noise data

s = 1, 2, 3, . . . ,m

For the assessment of community annoyance, the sound emission of the source will be determined by using the equivalent "A" weighted sound level (L_{Aeq}). It is possible to assess the noise concerning community annoyance based on the human perception of sound level change and whether the sound is deemed intrusive. At each measuring location, at least three measurements have to be carried out. The measurement is only considered accurate if the range of three measurements cannot be higher than 2 decibels for a stagnant noise [17]. Apart from that, for the temporary or instinctive noise that occurred throughout the measurement, the Lmax value will be taken as the maximum instantaneous sound level.

2.4. Data Analysis

In this study, the measured environmental noise level will compare with the permissible limit stated in DOE guidelines as shown in Table 1. Table 1 shows the permissible sound level (L_{Aeq}) for railways including transits. The experimental L_{Aeq} values are collected during field measurement will be computed using software and then the final L_{Aeq} will be used to compare with the permissible noise limit level.

Table 1 L_{Aeq} for Railways Including Transits [17]

Receiving Land Use Category	Day Time 7.00 am – 10.00 pm	Night Time 10.00 pm – 7.00 am	L_{max} (Day & Night)
Noise Sensitive Areas, Low Density and Suburban Residential Areas	60 dBA	55 dBA	75 dBA
Urban Residential Areas	65 dBA	60 dBA	80 dBA
Commercial, Mixed Development	70 dBA	65 dBA	80 dBA
Industrial	75 dBA	75 dBA	NA

Apart from the comparison of permissible sound limits, there is an assessment of community annoyance response also included in this study. The equivalent of the fast response of "A" weighted sound level, L_{Aeq} will be adopted for evaluation. According to DOE 2019 [17], corrections have to be done to the measured sound level according to the sound with different types of characteristic features, such as audible tones like a whine or impulsive noise like from piling work need +5 dB correction shall be added to the rating level. After the value is corrected the perception of sound and the likely environmental impact of the noise can be interpreted based on Table 2. Lastly, the prevalence of high annoyance (PHA) assessment also will be analysed based on the DOE 2019 guideline [17].

Table 2 Human Perception of Sound and likely environmental impact [17]

Increase in sound level, dB	Subjective change in perceived loudness	Environmental Impact
3	Just perceptible	None
5	Noticeable difference	Little
10	Twice as loud	Medium
15	Large change	Strong
20	Four times as loud	Very strong

3.0 RESULTS AND DISCUSSION

The overall noise levels at 4 monitoring points indicated as A, B, C and D around Batu 11 Cheras MRT Station were summarized in Table 3. The measured equivalent sound level and maximum sound level were compared with the permissible sound limit stated by DOE guidelines (Table 1). For this case, the limiting sound level is 70 dBA for business land use at day time. The maximum sound level stated by the guidelines is 80 dBA. From Table 3, point B generated the highest equivalent sound level of 71.9 dBA and point C has an equivalent sound level of 70.2 dBA. Both monitoring points A and D showed a lower equivalent sound level which is 68.0 dBA and 65.0 dBA respectively. Furthermore, monitoring point B created a maximum sound level of 88.1 dBA is the highest among the 4 monitoring points.

Table 3 Summary of Noise Levels at Batu 11 Cheras MRT Station Daytime 7.00 am – 1.00 pm

Noise Parameters	Monitoring Points			
	A	**B**	**C**	**D**
L_{Aeq} (dBA)	68.0	71.9	70.2	65.0
L_{max} (dBA)	82.2	88.1	83.5	85.7
L_{min} (dBA)	60.6	62.9	62.6	64.5
L_{10} (dBA)	69.9	72.2	72.0	67.0
L_{50} (dBA)	67.1	69.4	69.2	63.8
L_{90} (dBA)	65.0	67.1	67.1	61.9

The percentage of exceedance of noise levels compared to the permissible sound level for 4 monitoring points were calculated and tabulated in Table 4. From Table 4, monitoring points A and D are within the permissible sound level limit whereas monitoring points B and C exceeded the sound level limit provided by DOE guidelines [17]. Monitoring point B showed the highest exceedance of the equivalent sound level among the 4 monitoring points which is 2.71 %. While for the maximum sound level, all four-monitoring points A, B, C and D had exceeded 2.75 %, 10.13 %, 4.38 %, and 7.13 % respectively.

Table 4 Percentage of Exceedance of Noise Levels

	Monitoring Points			
	A	**B**	**C**	**D**
L_{Aeq} (dBA)	68.0	71.9	70.2	65.0
Limiting sound level (dBA)	70.0	70.0	70.0	70.0
Percentage of exceedance (%)	Within limit	2.71	0.29	Within limit
L_{max} (dBA)	82.2	88.1	83.5	85.7
Maximum sound level (dBA)	80.0	80.0	80.0	80.0
Percentage of exceedance (%)	2.75	10.13	4.38	7.13
L_{Aeq} (dBA)	68.0	71.9	70.2	65.0

From the observations during sample collection, the noise generated by the railway will affect the adjacent community more symbolically. But for monitoring point B, it showed the highest percentage of exceedance of maximum sound level due to the ongoing construction work nearby it. Thus, the recorded noise level is higher compared to the other three monitoring points. Apart from that, monitoring point D showed the lowest equivalent sound level because the monitoring location is far from the MRT Station and it is the furthest monitoring point among A, B, C and D.

Noise levels for 4 monitoring points were collected in day time starting from morning 7.00 am until 1.00 pm, a total of 6 hours continuously by using the sound level meter. All the data collected for 4 monitoring points A, B, C and D were plotted in graphs of $L_{eq,10s}$ versus duration as shown in Figure 2 to 5 respectively. The points with black dot markers are significant points when the MRT is passing through the monitoring point.

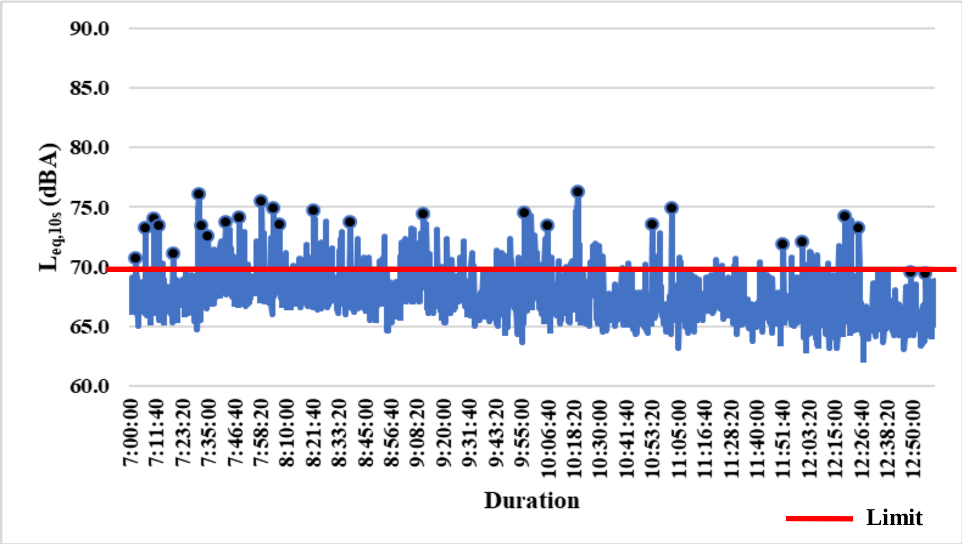

Figure 2 Noise Level Graph of Monitoring Point A

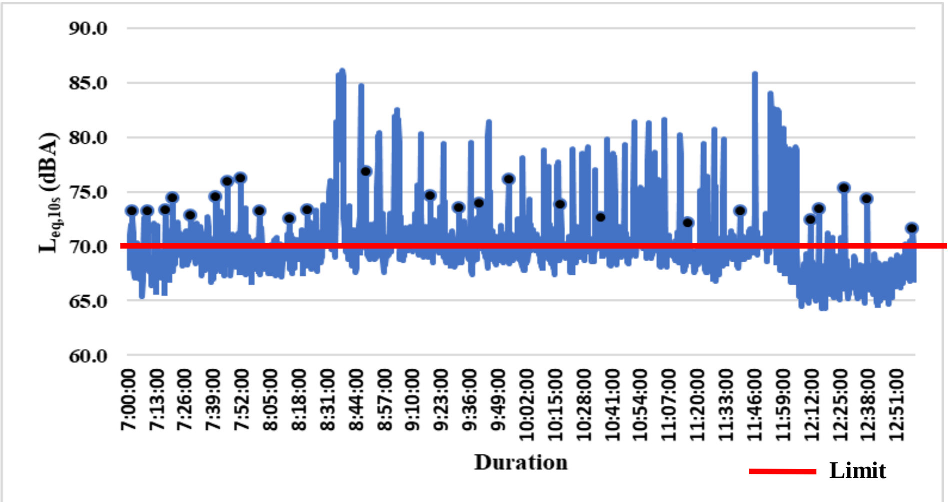

Figure 3 Noise Level Graph of Monitoring Point B

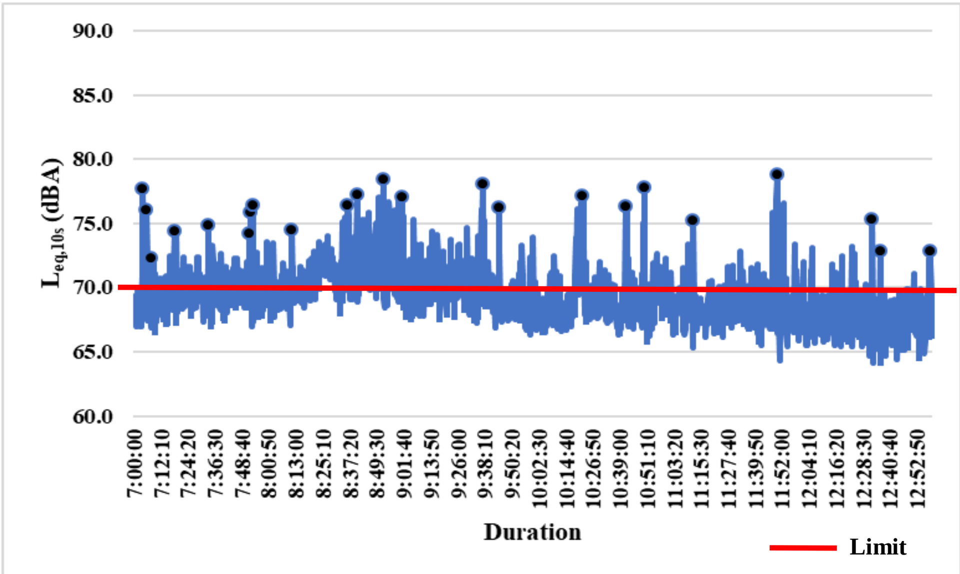

Figure 4 Noise Level Graph of Monitoring Point C

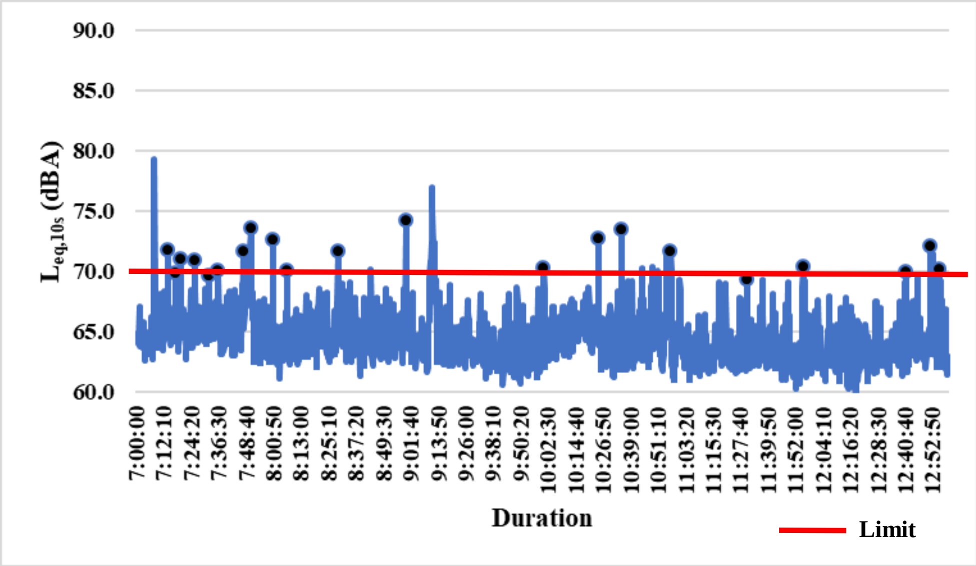

Figure 5 Noise Level Graph of Monitoring Point D

Figure 2 to 5 show the 6 hours of continuous noise level graph at the monitored locations. Due to the high train frequency on weekdays especially from 7:00 am to 9:00 am early in the morning, only some of the significant noise generated by MRT were indicated in black dot markers as shown in Figure 2 to 5. From 7:00 am to 9:00 am, the MRT will reach every 4 minutes whereas the MRT will only reach every 7 minutes from 9:00 am to 5:00 pm.

Based on Figure 2 to 5, the overall results showed that the area around shop lots exceeded the permissible noise limit at day time from 7:00 am to 1:00 pm. As the road traffic noise at these four monitoring points was less significant, the noise level recorded at these points can be considered as the noise generated by the MRT. For monitoring points A and C, most of the noise generated was in the range of 65 dBA to 75 dBA, which is slightly higher than the permissible noise limit, of 70 dBA provided by DOE guidelines (2019). While for monitoring point B, the sound level recorded fluctuated due to the construction noise and it can raise to 85 dBA. And for monitoring point D, the noise generated was in the range of 60 dBA to 70 dBA, which can be considered within the permissible noise limit.

Monitoring point A was set beside a furniture shop and this point is far from the road traffic. So, most of the noise recorded was generated by railway noise. The noise generated when the MRT passing by can be measured clearly by the sound level meter and is around 73 dBA to 74 dBA. The same goes for monitoring point C which was set around the MRT pick-up point, and this is the nearest distance from the monitoring point to the MRT Station, the rolling noise produced by the railway recorded by the sound level meter is around 75 dBA to 79 dBA and this increased the overall equivalent sound level.

Monitoring point B received not only railway noise, but also road traffic noise and construction noise. There is a bus stop beside this monitoring point, so there are noises generated by buses, cars, and motorcycles. Besides, the equivalent sound level from Figure 3 fluctuated in the range of 80 dBA to 85 dBA starting from 8:30 am till 12:00 pm. This is due to the construction of bore piling around the monitoring point. This construction noise is more annoying compared to railway noise. Hence, the railway noise is less critical for this monitoring point. For only the railway noise, this monitoring point recorded the noise level in the range of 70 dBA to 75 dBA.

Furthermore, monitoring point D was set across the road from the MRT and it received a lower range of equivalent sound level which is between 60 dBA to 70 dBA. At this point, the noise received from the MRT is the least critical because most of the noises were only generated by the motor vehicles that passed by. So, the noise level measured at this point when the MRT passed by was included with the road traffic noise such as motor vehicles and heavy trucks. This showed no proof that the noise received by the sound level meter was affected by the railway noise. The adjacent community who stayed around this monitoring point were more annoyed by the road traffic.

Based on the overall sample collection, other noises were affecting the population adjacent to Batu 11 Cheras MRT Station other than railway noise such as noises generated from cars, buses, motorcycles, trucks, ambulances, and noise produced from the construction site. For road traffic noises, the highest level of noise was produced by ambulance. Throughout the 6 hours of continuous measurement, it was observed that an ambulance passed through this road around 5 times every Wednesday. The noise detected when the ambulance with an emergency alarm passed by can be raised to the range between 75 dBA and 80 dBA, which is only around 5 dBA exceeding the noise permissible limit. By concerning the environmental impact of the noise on human perception, the Table 5 shows the community annoyance response around Batu 11 Cheras MRT Station. Regarding DOE guidelines [17], the impacts of environmental noise from this station on the adjacent community were determined.

Table 5 Human Perception of Sound and Likely Environmental Impact of the Noise

	Monitoring Points			
	A	**B**	**C**	**D**
L_{Aeq} (dBA)	68.0	71.9	70.2	65.0
Correction (dBA)	+5	+5	+5	+5
L_{90} (dBA)	65.0	67.1	67.1	61.9
Increase in sound level (dBA)	8.0	9.8	8.1	8.1
Environmental Impact	Little	Little	Little	Little
Subjective change in perceived loudness	Noticeable difference	Noticeable difference	Noticeable difference	Noticeable difference

From Table 5, it was observed that the increase in sound level at monitoring points A, B, C, and D is about from 8.0 to 9.8 dBA. This shows that there is little environmental impact and the noticeabale human perception of sound according to Table 2 as it is fall in between 5 dB and 10 dB. This means that while some individuals in the vicinity of the noise source may be aware of the noise, it is unlikely to cause significant annoyance or disruption. It is important to note, however, that the impact of noise can vary depending on a variety of factors, including the time of day, the duration of the noise, and the sensitivity of the individuals affected. Besides that, according to the methods for rating and assessing industrial and commercial from BS 4142: 2014, it is likely marginal significance. Apart from that, using the given chart provided in DOE guidelines [17] on the prevalence of high annoyance to road traffic and the corresponding 95% prediction interval, it was found that monitoring point B and C has more than 40% prevalence of high annoyance compared to 36% and 30% at the respective monitoring point A and D. The upper limits of high annoyance are 62% at point A, above 68% at point B and C respectively, and 55% at point D. The ongoing construction at Batu 11 Cheras MRT Station, causes community annoyance to the adjacent community, especially at monitoring point B. The noises generated by Batu 11 Cheras MRT were added to the existing background noises and this caused extra annoyance to the adjacent community.

4.0 CONCLUSION

This study was carried out to study the environmental noise impact generated by MRT on the adjacent community. One of the objectives was to measure the environmental noise level around the MRT. Noise measurements were carried out at Batu 11 Cheras MRT Station from 7:00 am to 1:00 pm, in a total of 6 hours. After that, the measured noise levels were compared with the permissible limit. At Batu 11 Cheras Station, monitoring points A and D were within the noise permissible limit, while points B and C exceeded 2.71 % and 0.29 % respectively. Small levels of environmental impact and subjectively perceived noticeable differences were found at all monitoring points. To diminish the environmental noise, a noise barrier design has to be proposed and designed to reduce the noise level in future studies.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgement

The authors want to acknowledge the financial support provided by the Ministry of Higher Education (MoHE) through the Fundamental Research Grant Scheme project FRGS/1/2021/TK02/UTAR/02/2. The authors would like to thank Ms. Hoo Pui Yi for her assistance in this research study.

References

[1] Ding, T., Yan, A., & Liu, K. (2019). What is noise-induced hearing loss? British Journal of Hospital Medicine, 80(9), 525–529. https://doi.org/10.12968/hmed.2019.80.9.525

[2] Faulkner, J.-P., & Murphy, E. (2022). Estimating the harmful effects of environmental transport noise: An EU study. Science of The Total Environment, 811, 152313. https://doi.org/10.1016/j.scitotenv.2021.152313

[3] Yuen, F. (2014). A vision of the environmental and occupational noise pollution in Malaysia. Noise and Health, 16(73), 427. https://doi.org/10.4103/1463-1741.144429

[4] Hammer, M. S., Swinburn, T. K., & Neitzel, R. L. (2014). Environmental Noise Pollution in the United States: Developing an Effective Public Health Response. Environmental Health Perspectives, 122(2), 115–119. https://doi.org/10.1289/ehp.1307272

[5] Münzel, T., Schmidt, F. P., Steven, S., Herzog, J., Daiber, A., & Sørensen, M. (2018). Environmental Noise and the Cardiovascular System. Journal of the American College of Cardiology, 71(6), 688–697. https://doi.org/10.1016/j.jacc.2017.12.015

[6] Münzel, T., Sørensen, M., & Daiber, A. (2021). Transportation noise pollution and cardiovascular disease. Nature Reviews Cardiology, 18(9), 619–636. https://doi.org/10.1038/s41569-021-00532-5

[7] Ögren, M., Gidlöf-Gunnarsson, A., Smith, M., Gustavsson, S., & Persson Waye, K. (2017). Comparison of Annoyance from Railway Noise and Railway Vibration. International Journal of Environmental Research and Public Health, 14(7), 805. https://doi.org/10.3390/ijerph14070805

[8] Smith, M. G., Ögren, M., Ageborg Morsing, J., & Persson Waye, K. (2019). Effects of ground-borne noise from railway tunnels on sleep: A polysomnographic study. Building and Environment, 149, 288–296. https://doi.org/10.1016/j.buildenv.2018.12.009

[9] Licitra, G., Fredianelli, L., Petri, D., & Vigotti, M. A. (2016). Annoyance evaluation due to overall railway noise and vibration in Pisa urban areas. Science of The Total Environment, 568, 1315–1325. https://doi.org/10.1016/j.scitotenv.2015.11.071

[10] Eriksson, C., Bluhm, G., Hilding, A., Östenson, C.-G., & Pershagen, G. (2010). Aircraft noise and incidence of hypertension—Gender specific effects. Environmental Research, 110(8), 764–772. https://doi.org/10.1016/j.envres.2010.09.001

[11] Fidell, S., Tabachnick, B., Mestre, V., & Fidell, L. (2013). Aircraft noise-induced awakenings are more reasonably predicted from relative than from absolute sound exposure levels. The Journal of the Acoustical Society of America, 134(5), 3645–3653. https://doi.org/10.1121/1.4823838

[12] Schreckenberg, D., Meis, M., Kahl, C., Peschel, C., & Eikmann, T. (2010). Aircraft Noise and Quality of Life around Frankfurt Airport. International Journal of Environmental Research and Public Health, 7(9), 3382–3405. https://doi.org/10.3390/ijerph7093382

[13] Lee, E. Y., Jerrett, M., Ross, Z., Coogan, P. F., & Seto, E. Y. W. (2014). Assessment of traffic-related noise in three cities in the United States. Environmental Research, 132, 182–189. https://doi.org/10.1016/j.envres.2014.03.005

[14] Oftedal, B., Krog, N. H., Pyko, A., Eriksson, C., Graff-Iversen, S., Haugen, M., Schwarze, P., Pershagen, G., & Aasvang, G. M. (2015). Road traffic noise and markers of obesity – A population-based study. Environmental Research, 138, 144–153. https://doi.org/10.1016/j.envres.2015.01.011

[15] Gjestland, T. (2020). On the Temporal Stability of People’s Annoyance with Road Traffic Noise. International Journal of Environmental Research and Public Health, 17(4), 1374. https://doi.org/10.3390/ijerph17041374

[16] Thompson, D. (2008). Railway noise and vibration: mechanisms, modelling and means of control. Elsevier.

[17] Department of Environment. (2019). Guidelines for Environmental Noise Limits and Control. 3rd Edition. .