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A Comprehensive Evaluation and Mitigation Approaches for Traffic-Related Noise in the Sungai Long Region, Malaysia

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ABSTRACT: The fast development of technology and transportation systems has resulted in a disturbing level of noise pollution over time that requires research and regulatory. Most existing research is deemed ineffective as it primarily focuses on conducting assessments of traffic noise without providing a structured framework for noise mitigation. This study focused on three main stages to monitor road traffic noise in Sungai Long area: (1) examination of traffic features, (2) derivation of noise indices, and (3) evaluation of the influence of traffic noise. Total of four roads were selected with four stations on each road in Bandar Sungai Long to assess the traffic noise impact. The sound level metre (SLM) was used to calculate the noise indices for each road. Besides, peak-hour sessions and off-peak sessions of traffic flow were measured in field measurement to compare the differences in noise conditions. Additionally, based on the measured noise indices, traffic noise index (TNI), noise pollution level (LNP), and expected community response were calculated to reveal the impact of traffic noise. Overall, this study's findings demonstrated that residential areas experiencing traffic noise disturbance, particularly on roads, namely Jalan Bp Satu and Jalan Persiaran SL 7, had exceeded the Malaysian environmental standard. In addition, two optimized methods are proposed which are prohibiting heavy vehicles and a simple noise barrier was designed on Jalan Bp Satu and Jalan Persiaran SL 7. The expected noise level between these two methods had been compared in the discussion part. In summary, prohibiting heavy vehicles on the road is more suitable if the aim is to save cost. However, if reducing traffic noise is a priority and a long-term solution is needed, constructing noise barrier may be a more effective solution.

KEYWORDS: Traffic noise; Noise pollution; Annoyance; Environmental noise

1. INTRODUCTION

Noise pollution impacts millions of people daily and the most common health problem from over noise exposure is Noise Induced Hearing Loss (NIHL) (Mohamed et al., 2021). One of the major risks that has an impact on people's quality of life all over the world is noise pollution. According to studies by Zhao et al. (2015) and Fink et al. (2021), exposure to loud noise can also lead to stress, high blood pressure, heart disease, and sleep disturbances. Since technology and transportation systems have developed quite rapidly, transport sector is a critical enabler of Malaysia's economic development where it continued to be the country's largest consumer of energy with 38.5% share (24,039 ktoe) in 2019 (Sofwan & Latif, 2021). The number of registered vehicles in Malaysia increased steadily with average 6.9 million units from about 1.7 million in December 1986 to 17.7 million until in December 2021 (CEICdata.com,2020). Private vehicles including cars and motorcycles dominated about 93% of the vehicles in the country. Different countries utilize different approaches, including restrictions on vehicle noise in Singapore with undertake periodic mandatory inspections at authorized centres for road tax renewal, physical inspections of heavy trucks in Australia, additional operating hours for trucks and other noisy traffic in the evenings and at night in Germany, and fines for loud cars that impact the environment in Canada (SPATS, 2019). Noise is a level of sound that exceeds tolerable and causes aggravation. Frequent exposure to loud noise strains the auditory and neurological systems. Excessive noise has been shown to cause physical and psychological harm when exposed for an extended period (Irene et al., 2017). Because of its discomfort and disruption consequences, noise contributes to mental stress and impacts the overall well-being of persons exposed to it (Thompson et al., 2022). Individuals are frequently irritated by noise (Dutilleux et al., 2010). Industrial noise, traffic noise, and community noise are the leading causes of noise. The source that has the most significant impact on the above three characteristics is traffic noise (Cole et al., 2017). Vehicular noise is the result of the vibrating body of the vehicle plus its engine operating sound (Nakashima et al., 2018). The engine and exhaust system of the vehicle, aerodynamic friction, the interaction of the car with the road system, and the interaction of the cars themselves all contribute to vehicle noise (Rahim, 2021). People are affected by noise so badly that in some areas, such as New Delhi, India (Chauhan et al., 2023), and Guangzhou district, China, politicians were forced to advocate for restrictions on loud cars to reduce noise pollution (Cai et al., 2015). Compared to villages, noise is more of a problem in cities because of mechanisation and increased traffic (Klein et al., 2015). Traffic density in Malaysia had an increment of population leads with 508,911 registered vehicles in 2021 (Malaysian Automotive Association, 2022). There are several studies had pointed out noise pollution issues have become more serious due to the increased number of vehicles in Malaysia (Balasbaneh, 2020; Nor, 2019; Ahmed, 2019). The rapid population growth in Bandar Sungai Long and the increase in the number of vehicles have caused an increase in daily trips (Yazid, 2020). Few studies reported that the residents of Bandar Sungai Long are facing health issues that caused by road traffic noise pollution (Nor, 2019; Bachok, 2017).

The majority of current research lacks effectiveness as it solely conducts traffic noise assessments without offering

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a framework for noise mitigation. This paper aims to fill this gap by presenting a comprehensive process, starting from the initial stages of traffic noise assessment and concluding with the proposal of effective solutions to mitigate road traffic noise. Researchers can utilize this guide as a reference and incorporate it into their studies when conducting traffic noise assessments in the future. For instance, a study by Segaran et al. (2020) exclusively centered on road traffic noise assessment within the residential environment of Batu Pahat, Johor, lacking any corresponding noise mitigation strategies. Similarly, the research conducted by Rosli and Lamsa (2013) solely explored the impacts of road humps on traffic volume and noise levels in a residential area in Kuala Lumpur, with a notable absence of noise mitigation planning. The commonality among these studies lies in their exclusive emphasis on traffic noise assessment without the incorporation of noise mitigation planning. Therefore, the primary objective of this paper is to outline key aspects related to road traffic noise assessment and propose effective solutions for mitigating road traffic noise in the Bandar Sungai Long. Bandar Sungai Long was selected for this study due to its status as an underdeveloped area with numerous institutions, including universities, primary schools, and secondary schools. Consequently, the traffic volume is exceptionally high, encompassing various types of vehicles. In Bandar Sungai Long, the primary vehicle types are light vehicles, with some motorcycles. During off-peak hours, heavy vehicles such as dump trucks and tractor-trailers are also present (Mutalib, et al., 2018; Abdulrazzaq, et al., 2020). Besides, the traffic noise index (TNI), noise pollution level (LNP) and anticipated community response were performed to analyze the road traffic noise in the selected locations. Two proposed solutions in this paper for mitigating noise in the Bandar Sungai Long Area include the restriction of heavy vehicle access during specific time intervals and the design and proposal of a noise barrier to reduce the noise along the road. Subsequently, this paper will delve into the methodology for monitoring road traffic noise, comprising three key phases: examination of traffic characteristics, derivation of noise indices, and evaluation of the impact of traffic noise. The findings presented in this paper will propose the A-weighted equivalent continuous noise level (L_{Aeq}) for all selected roads in the Bandar Sungai Long Area during both peak and off-peak hours. Additionally, the traffic noise index (TNI), noise pollution level (LNP), and anticipated community response will be tabulated and discussed across the selected roads in the results section. In response to roads surpassing the noise limit set by the Department of Environment Guideline (Department of Environment Malaysia, 2007), two solutions will be presented in the results section for noise mitigation. Finally, the conclusion will provide insights into future research directions and recommendations for a more comprehensive study in the future.

2. ROAD TRAFFIC NOISE MONITORING

This study consisted of three major phases: (1) examination of traffic features, (2) derivation of noise indices, and (3) evaluation of the influence of traffic noise. The subsequent sections cover the specifics of each phase.

2.1 Examination of Traffic Features

Due to the establishment of numerous colleges, universities, and other educational institutions, Bandar Sungai Long has grown tremendously. The residential areas that were chosen to evaluate the effects of traffic noise on the local population were the focus of the study's noise assessment. Four significant residential districts were picked for this study in order to evaluate the effects of traffic noise on the local population. Jalan Bp Satu, Jalan Persiaran SL 1, Jalan Persiaran SL 7, and Jalan Mahkota are the four main roadways. As shown in Figures 1 and 2, four relevant stations were chosen for each location to precisely determine the traffic noise conditions. These four roadways go along the residential area and are linked with two major townships. All of the monitored stations were selected using the same criteria as outlined by the Malaysian environmental guidelines under the Department of the Environment (DOE), hence a minimum distance of 75 m from intersections, traffic signals, and other noise sources such as schools, stadiums, mosques, and playgrounds (Department of Environment Malaysia, 2007).

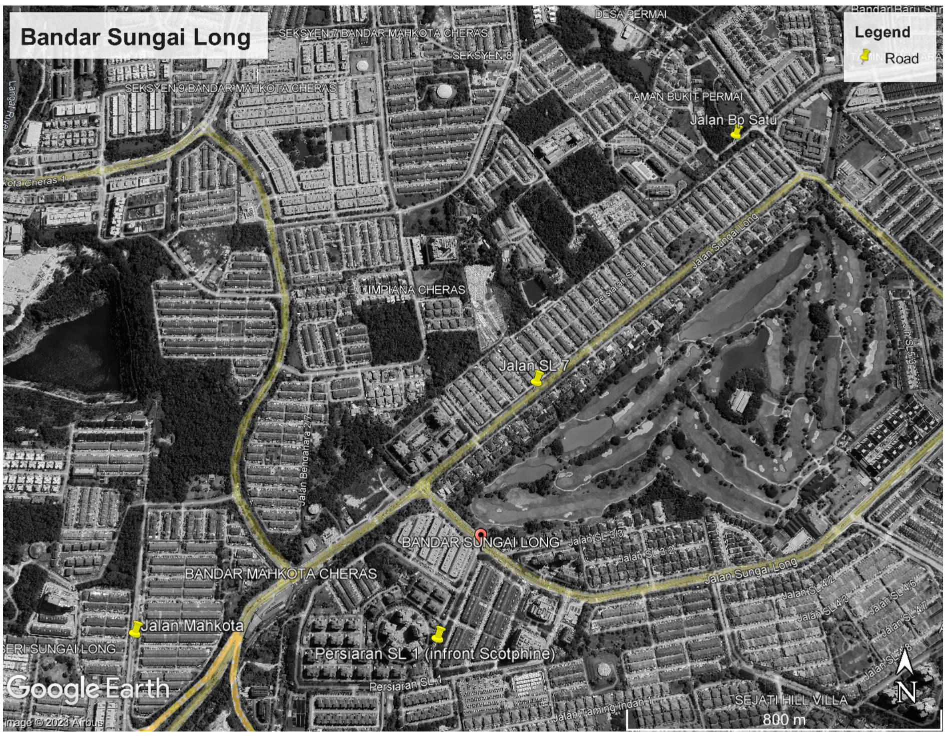
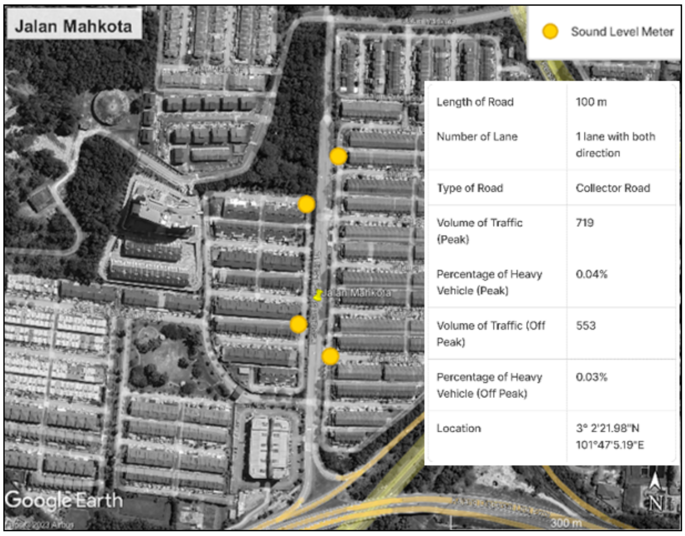
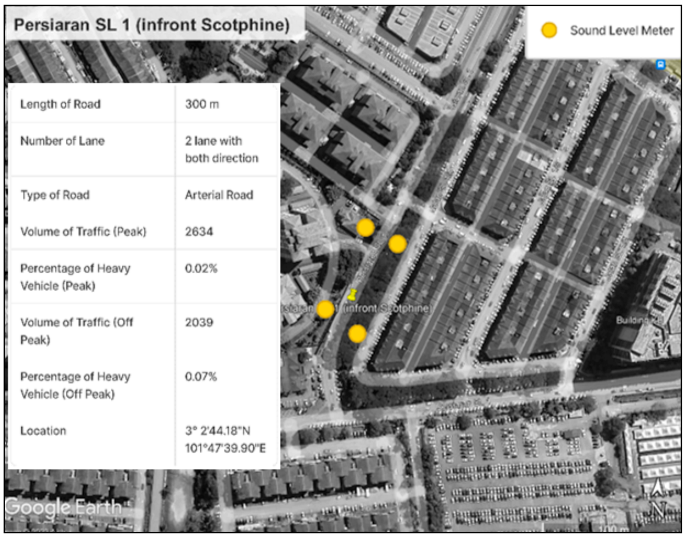


Figure 1: Study Area in Bandar Sungai Long.



(a)



(b)

(c)

(d)

Figure 2: (a) Location of Jalan Mahkota; (b) Location of Jalan Persiaran SL 1; (c) Location of Jalan Persiaran SL 7; (d) Location of Jalan Bp Satu.

2.2 Determination of Noise Indices

This research used a Norsonic 140 sound level meter to analyse the noise indices on the ground in accordance with the Malaysian Department of Environment's recommendations (Department of Environment Malaysia, 2007). In the present investigation, a sound level meter (SLM) with a 1/3 octave band and A-weighted units was used to measure sound levels. The A-weighted equivalent continuous noise level (L_{Aeq}) was measured and used in noise assessment to represent the equivalent continuous energy level of a fluctuating noise over a specified period. It is a single value that summarizes the overall loudness or energy content of a noise signal, taking into account the sensitivity of the human ear to different frequencies.

The SLM was set on a tripod at an approximate height of 1.5 m and an angle of 70 degrees to the noise source on a level surface. The SLM microphone was shielded by a windscreen cover, and stations were located by avoiding any adjacent reflected sources. The SLM was set away from the source with a distance of 7.5 m. Figure 3 illustrates a sample site setup with a distance of 7.5 m between SLM and sources. The assessment of traffic noise was undertaken on weekdays (Tuesday, Wednesday, and Thursday) for one week. The first and last days of the week were omitted to prevent varying traffic patterns at sample locations. Two noise assessments were conducted, during peak hours (7.00 am to 9.00 am) and off-peak hours (9.00 am – 11.00 am).

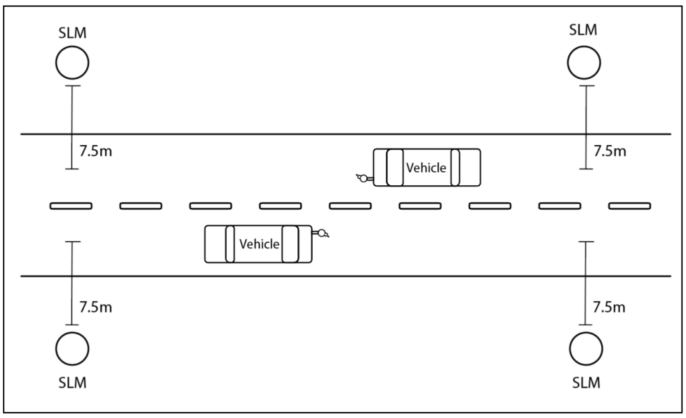


Figure 3: Illustration of Distance for SLM.

2.3 Assessment of Traffic Noise Impact

Based on the measured noise indices such as L_{Aeq}, L_{10}, L_{50} and L_{90}, the traffic noise index (TNI) and noise pollution level (LNP) were determined. TNI was calculated by combining the values of L_{10} and L_{90}. In addition, TNI provides justification for noise variation in relation to the L_{10} (Marathe, 2012). The Traffic Noise Index (TNI) is a measure used to quantify the impact of traffic noise on the acoustic environment. It is a composite index that takes into account various factors related to road traffic noise, providing a comprehensive assessment of the noise generated by vehicles on a particular road or in a specific area. The TNI considers factors such as the volume of traffic, the types of vehicles (e.g., cars, trucks, motorcycles), their speed, and the time of day.

The calculation of the Traffic Noise Index typically involves assigning specific weighting factors to different types of vehicles and adjusting for their noise contributions. The goal is to capture the overall noise impact that traffic is likely to have on the surrounding environment. The resulting TNI value is expressed as a single numerical indicator, making it easier to compare and communicate the potential noise effects of traffic in different locations.

Researchers and urban planners often use the Traffic Noise Index as part of noise impact assessments to evaluate the potential impact of road traffic on residents, wildlife, and the overall quality of the environment. It helps in understanding the cumulative effect of traffic noise and aids in making informed decisions regarding noise mitigation measures, urban planning, and traffic management strategies. Moreover, TNI values should not exceed 74 dBA to prevent discontent among surrounding people. Equation 1 shows the equation of TNI by using L_{10} and L_{90} (Li et al., 2002). Where TNI is Traffic Noise Index; L_{10} is the level of sound exceeding for 10% of total time of measurement or Peak Noise Level; L_{90} is the level of sound exceeding for 90% of total time of measurement or Background Noise.

(1) $TNI = 4(L_{10} - L_{90}) + L_{90} - 30$

Meanwhile, LNP considers variances in sound signals as a more accurate measure of environmental contamination (Swain & Goawani, 2013). Equations 2 were used to calculate LNP, respectively (Li et al., 2002). In addition, L_{Aeq} and LNP values were compared with the standard guidelines from WHO and the Department of Environment, Malaysia (World Health Organization, 2001; Department of Environment Malaysia, 2007). Both standards indicated that the daytime traffic noise tolerance level in urban residential areas should not exceed 65 dBA. Where LNP is the Noise Pollution Level; L_{eq} is Equivalent Continuous Noise Level.

(2) $LNP = L_{eq} + (L_{10} - L_{90})$

CoRTN is a model used for road design and the determination of sound insulation entitlements in the UK (Delany et al., 1976). It assumes a line source and constant speed traffic, and is the sole instrument for assessing road traffic environmental impacts. CoRTN was replaced by a more convenient model, Predicting Road Traffic Noise (Anon, 1976). The accuracy of CoRTN varies depending on the prevailing conditions, and it is less suitable for situations where the distance is not great in relation to the inter-vehicular spacing, or when the spacing is very even or uneven. The model calculates the basic noise level at a reference distance of 10 m away from the nearside carriageway edge by using traffic flow, speed, composition, gradient, and road surface which is equation 3. The noise emission level equation for L10 is given. By using L_{10} calculated, L_{eq} can be calculated by using equation 4. Where L_0 is the basic hourly noise level; Δf is the correction for the speed of actual mean traffic and the proportion of heavy vehicles; Δp is the portion of heavy vehicles; Δg is the adjustment or correction of the basic noise level for the road gradient; Δd is the correction for the distance; Δs is the ground cover correction; Δa is the correction for the adjustment for the angle of view; Δr is the reflection correction.

(3) $L_{10} = L_0 + \Delta f + \Delta p + \Delta g + \Delta d + \Delta s + \Delta a + \Delta r$

(4) $L_{eq} = 0.94\ L_{10} + 0.77$ dB(A)

A barrier is a solid structure that is built to deflect sound energy back to its source (Laxmi, 2021). In addition, it effectively reduces the noise created between the noise source and the receiver. Furthermore, noise barriers will be utilised to reduce the level of traffic-generated ambient noise (Redondo, 2021). The material selected for the design of a noise barrier is mostly determined by the needs of various scenarios. The optimal noise barrier must be made of solid, impermeable material with a minimum density of 20 kg/m² (Paige & Eng, 2015). In addition, noise barriers can be constructed from materials such as concrete, metals, wood, transparent materials, plastics, recyclable materials, and sound-absorbing materials (Laxmi, 2021).

For example, concrete is employed in the building of noise barriers due to its minimal maintenance requirements and its ability to endure vehicle impact damage, whereas steel panels are excellent for mechanical equipment noise barriers due to their suitability for pipe and duct penetrations. In addition, sound-absorbing material will be applied on the side of a sound source to avoid sound reflection from the barrier surface. On the other side, sound absorption can enhance the barrier system's overall acoustic performance. When sound waves pass through a barrier, the light waves diffract, creating a brilliant and dark zone (Crocker, 2007). The diffracted wave from the barrier's top height disrupts only a tiny region adjacent to the shadow zone.

Additionally, path length difference may be computed based on geometry. The route length difference is affected by several variables, including barrier height, barrier position, and source and receiver heights. For instance, the difference in path length may be determined using equation 5. The principle of diffraction leads to the barrier design geometry seen in Figure 4 (Department of Environment Malaysia, 2007). A greater path length difference will result in a greater attenuation, with a theoretical maximum of 24 dB for barrier attenuation (Department of Environment Malaysia, 2007).

(5) Path length difference = A + B - C

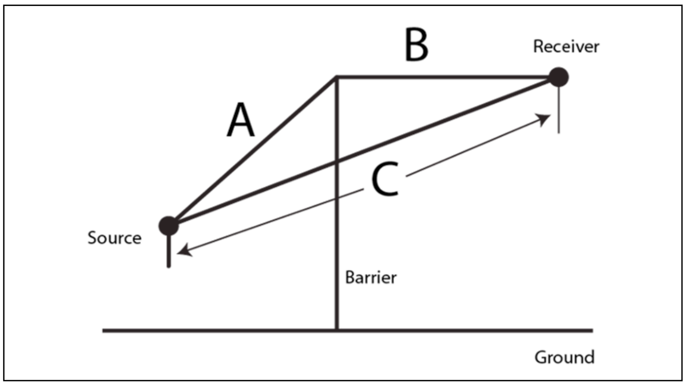


Figure 4: Theory of Diffraction (Department of Environment Malaysia, 2007).

The insertion loss estimates for an ideal solid barrier may be derived from the path length difference as given in Table 1. A greater path length difference will result in a greater attenuation, with a theoretical maximum of 24 dB for barrier attenuation. (Paige & Eng, 2015).

Path-Length Difference, mm	Insertion Loss, dB							
	Octave Band Center Frequency. Hz							
	31	63	125	250	500	1000	2000	4000
3.048	5	5	5	5	5	6	7	8
6.096	5	5	5	5	5	6	8	9
15.24	5	5	5	5	6	7	9	10
30.48	5	5	5	6	7	9	11	13
60.96	5	5	6	8	9	11	13	16
152.4	6	7	9	10	12	15	18	20
304.8	7	8	10	12	14	17	20	22
609.6	8	10	12	14	17	20	22	23
1524	10	12	14	17	20	22	23	24
3048	12	15	17	20	22	23	24	24
6096	15	18	20	22	23	24	24	24
15240	18	20	23	24	24	24	24	24

Table 1: Insertion Loss for an Ideal Solid Barrier (Paige & Eng, 2015).

Location	Parameter / Station	L_{Aeq}	L_{max}	L_{min}	L_{peak}	L_{10}	L_{50}	L_{90}
Jalan Bp Satu	A1	67.7	89.4	40.6	106.5	71.6	64.5	53.5
	A2	67.1	89.4	40.6	110.0	70.3	64.1	56.4
	A3	67.6	89.9	48.3	110.1	71.4	63.9	54.9
	A4	67.4	93.9	48.3	110.8	70.1	66.4	54.9
Jalan Persiaran SL 1	B1	64.2	90.5	48.0	109.1	65.7	58.6	54.0
	B2	64.4	91.1	48.5	105.4	66.3	59.9	55.0
	B3	62.8	87.8	49.4	101.3	64.9	58.9	54.6
	B4	65.2	91.5	49.5	101.7	67.2	59.9	55.2
Jalan Persiaran SL 7	C1	68.6	99.5	44.4	126.2	70.1	60.4	53.4
	C2	69.3	99.6	42.8	114.8	70.3	60.9	52.4
	C3	69.1	103.8	43.4	118.8	69.7	60.8	52.8
	C4	68.7	96.4	42.5	110.2	70.7	61.8	52.9
Jalan Mahkota	D1	62.3	83.5	42.2	100.0	64.5	56.2	46.9
	D2	60.9	85.4	38.8	99.5	63.9	54.8	45.0
	D3	62.9	92.3	41.4	116.6	65.9	56.0	47.7
	D4	65.3	89.9	41.2	111.3	69.4	55.9	48.0

Table 2: Summary of Traffic Noise Assessment for Peak Hour (7.00 am – 9.00 am).

Location	Parameter / Station	L_{Aeq}	L_{max}	L_{min}	L_{peak}	L_{10}	L_{50}	L_{90}
Jalan Bp Satu	A1	66.7	94.3	40.6	106.5	70.9	61.2	52.1
	A2	67.2	91.6	40.6	110.0	70.5	63.8	55.2
	A3	66.1	88.5	46.0	103.7	70.1	60.1	50.4
	A4	65.8	89.8	46.0	104.7	69.1	60.5	50.7
Jalan Persiaran SL 1	B1	64.3	89.8	52.3	109.1	66.7	60.4	55.8
	B2	64.7	84.0	52.1	102.0	68.4	61.5	56.8
	B3	62.8	93.1	50.7	108.3	64.1	58.6	55.1
	B4	64.3	89.5	51.0	109.9	65.8	59.6	55.7
Jalan Persiaran SL 7	C1	66.2	97.4	39.0	109.1	68.8	58.4	50.4
	C2	66.5	95.6	38.7	107.9	68.6	58.1	49.0
	C3	64.8	91.7	38.0	108.2	67.7	57.5	48.5
	C4	66.4	93.5	36.5	113.4	68.8	59.5	50.0
Jalan Mahkota	D1	60.8	77.4	41.4	91.2	64.1	56.1	48.2
	D2	60.9	89.0	39.1	100.9	63.3	54.8	47.1
	D3	65.2	89.7	39.1	102.4	67.9	58.1	46.6
	D4	65.0	86.3	38.8	101.0	68.7	54.7	46.0

Table 3: Summary of Traffic Noise Assessment for Off-peak Hour (9.00 am – 11.00 am).

3. RESULT AND DISCUSSIONS

To evaluate the intensity of traffic noise pollution in the Bandar Sungai Long area, field measurements at various time intervals were obtained. The measured equivalent continuous noise level (L_{Aeq}) for each road, as well as noise parameters like noise levels above 10%, 50%, and 90%, maximum noise level (L_{max}), minimum noise level (L_{min}), and peak pressure level(L_{peak}), were summarised in Tables 2 and 3. Table 2 shows the summary of traffic noise assessment for the morning peak hour which is from 7.00 am to 9.00 am, while Table 3 shows the summary of traffic noise assessment for the off-peak hour which is from 9.00 am to 11.00 am. The overall comparison of peak and off-peak sessions has been illustrated in Figure 5.

In light of the elevated noise levels on Jalan Bp Satu and Jalan Persiaran SL 7, it becomes imperative to delve deeper into the factors contributing to this exceedance of permissible sound limits. The geographical positioning of these roads, connecting the bustling townships of Bandar Sungai Long and Bandar Mahkota Cheras, emerges as a pivotal element influencing the heightened noise levels. Particularly noteworthy is the adjacency of primary and secondary schools along these roads within Bandar Sungai Long, thereby exposing the educational institutions and their occupants to an environment exceeding the recommended sound threshold.

Moreover, the impact of traffic flow on noise levels cannot be overstated. The recorded traffic data for Jalan Bp Satu and Jalan Persiaran SL 7 surpassing that of Jalan Persiaran SL 1 and Jalan Mahkota underscores the role of vehicular movement as a significant contributor to heightened noise pollution. Notably, the configuration of Jalan Persiaran SL 7 as a dual motorway, separated by a central median with two traffic lanes in each carriageway, accentuates the intensity of noise emissions from the constant stream of vehicles.

Moving beyond mere decibel measurements, an exploration into the maximum noise level (L_{max}) and peak pressure level (L_{peak}) further elucidates the nuanced characteristics of noise within these residential areas. The recorded range of Lmax values, spanning from 77.4 dBA to 103.8 dBA, portrays a spectrum of noise intensity that, despite falling within WHO guidelines, still poses potential discomfort to residents. It is noteworthy that noise levels exceeding 60 dBA, deemed discomforting, warrant attention due to their potential impact on the well-being of the community.

The transient nature of the maximum noise level is juxtaposed against its psychological and physiological ramifications. As evidenced by existing literature (Yuen, 2014), higher noise levels, even if momentary, can induce a range of effects on human well-being, from discomfort to severe consequences. Understanding the unique noise profiles at each residential station becomes paramount, considering factors such as the presence of playgrounds, open spaces, public utility areas, and commercial establishments. This comprehensive analysis reveals a complex interplay of human activities and natural elements, contributing to the dynamic acoustic environment of these residential areas.

In essence, the multifaceted nature of noise generation, encompassing vehicular activities, residential behaviors, and natural disturbances, necessitates a holistic approach to address and mitigate the escalating noise pollution levels along Jalan Bp Satu and Jalan Persiaran SL 7. Implementing targeted interventions, informed by a thorough understanding of the specific noise dynamics in each residential area, becomes imperative to foster a quieter and more harmonious living environment for the residents.

The comprehensive analysis presented in Tables 4 and 5 sheds light on the various noise indices employed to gauge the potential impact on the residential community in Bandar Sungai Long. The inclusion of the traffic noise index (TNI) and the noise pollution level (LNP) provides a nuanced understanding of both the physiological and psychological effects stemming from the prevalent road noise.

Examining the data in Tables 4 and 5, it becomes evident that Jalan Persiaran SL 1 stands as the sole exception, adhering to the DOE-mandated level of 74 decibels. This underscores the pervasive nature of road noise, as all other assessed areas grapple with noise levels surpassing the stipulated guidelines. The noise pollution levels (LNP) in the four residential zones, although below 88 dBA, signal potential concerns, especially when considered in conjunction with the surpassing of maximum noise levels and continuous noise levels as per DOE guidelines.

The anticipated community response, delineated in accordance with DOE guidelines, unravels the varying degrees of impact from the measured noise levels on the surrounding neighbourhoods. Notably, the moderate effect on the environment due to a 10 to 15 dBA rise in noise along Jalan Bp Satu indicates a discernible but not severe impact. Similarly, the increase in sound intensity from 8 to 10 dBA along Jalan Persiaran SL 1 reflects a mild to moderate effect on the immediate surroundings.

In contrast, the noteworthy environmental impact emerges along Jalan Persiaran SL 7 and Jalan Mahkota, where a substantial rise of 15 to 20 dBA in sound level is observed. This significant escalation is attributed to the pivotal role these roads play in connecting Bandar Sungai Long and Bandar Mahkota

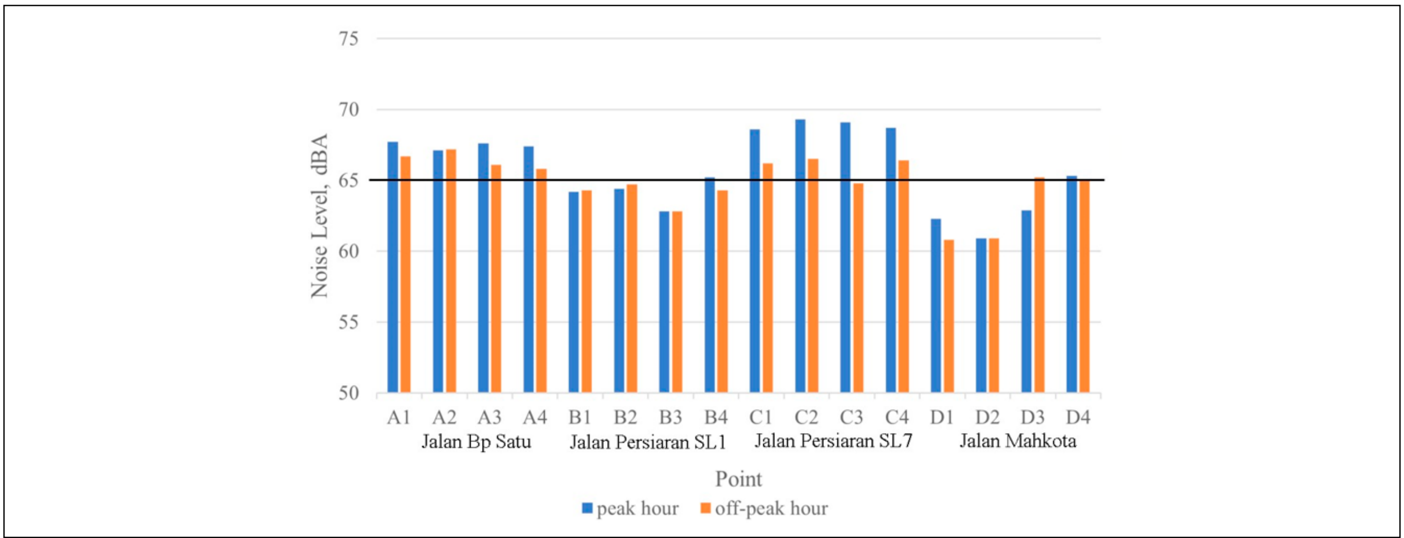


Figure 5: A-weighted equivalent continuous noise level (L_{Aeq}) for peak and off-peak hours.

Location	Parameter / Station	L_{Aeq}	L_{90}	TNI	LNP	K	L_r	$L_r - L_{90}$	Anticipated community response
Jalan Bp Satu	A1	67.7	53.5	95.9	85.8	0	67.7	14.2	Medium
	A2	67.1	56.4	82.0	81.0	0	67.1	10.7	Medium
	A3	67.6	54.9	90.9	84.1	0	67.6	12.7	Medium
	A4	67.4	54.9	85.7	82.6	0	67.4	12.5	Medium
Jalan Persiaran SL 1	B1	64.2	54.0	70.8	75.9	0	64.2	10.2	Medium
	B2	64.4	55.0	70.2	75.7	0	64.4	9.4	Little
	B3	62.8	54.6	65.8	73.1	0	62.8	8.2	Little
	B4	65.2	55.2	73.2	77.2	0	65.2	10.0	Medium
Jalan Persiaran SL 7	C1	68.6	53.4	90.2	85.3	0	68.6	15.2	Strong
	C2	69.3	52.4	94.0	87.2	0	69.3	16.9	Strong
	C3	69.1	52.8	90.4	86.0	0	69.1	16.3	Strong
	C4	68.7	52.9	94.1	86.5	0	68.7	15.8	Strong
Jalan Mahkota	D1	62.3	46.9	87.3	79.9	0	62.3	15.4	Strong
	D2	60.9	45.0	90.6	79.8	0	60.9	15.9	Strong
	D3	62.9	47.7	90.5	81.1	0	62.9	15.2	Strong
	D4	65.3	48.0	103.6	86.7	0	65.3	17.3	Strong

Table 4: Noise Indices and Anticipated Community Response to Noise for Peak Hour Session.

Location	Parameter / Station	L_{Aeq}	L_{90}	TNI	LNP	K	L_r	$L_r - L_{90}$	Anticipated community response
Jalan Bp Satu	A1	66.7	52.1	97.3	85.5	0	66.7	14.6	Medium
	A2	67.2	55.2	86.4	82.5	0	67.2	12.0	Medium
	A3	66.1	50.4	99.2	85.8	0	66.1	15.7	Strong
	A4	65.8	50.7	94.3	84.2	0	65.8	15.1	Strong
Jalan Persiaran SL 1	B1	64.3	55.8	69.4	75.2	0	64.3	8.5	Little
	B2	64.7	56.8	73.2	76.3	0	64.7	7.9	Little
	B3	62.8	55.1	61.1	71.8	0	62.8	7.7	Little
	B4	64.3	55.7	66.1	74.4	0	64.3	8.6	Little
Jalan Persiaran SL 7	C1	66.2	50.4	94.0	84.6	0	66.2	15.8	Strong
	C2	66.5	49.0	97.4	86.1	0	66.5	17.5	Strong
	C3	64.8	48.5	95.3	84.0	0	64.8	16.3	Strong
	C4	66.4	50.0	95.2	85.2	0	66.4	16.4	Strong
Jalan Mahkota	D1	60.8	48.2	81.8	76.7	0	60.8	12.6	Medium
	D2	60.9	47.1	81.9	77.1	0	60.9	13.8	Medium
	D3	65.2	46.6	101.8	86.5	0	65.2	18.6	Strong
	D4	65.0	46.0	106.8	87.7	0	65.0	19.0	Strong

Note: K = Correction to Initial Sound Level; L_r = Rating Sound Level

Table 5: Noise Indices and Anticipated Community Response to Noise for Off-Peak Hour Session.

Cheras, resulting in an upsurge in traffic volume. Compounding the issue is the fact that Jalan Persiaran SL 7 serves as a primary route connecting elementary and secondary schools in Bandar Sungai Long, leading to heightened traffic and, often, a tendency for drivers to accelerate, particularly on the broad and straight expanse of Jalan Persiaran SL 7.

The confluence of these factors paints a complex picture of the acoustic environment in Bandar Sungai Long, necessitating a strategic and tailored approach to mitigate the adverse effects on the residential community. Addressing the root causes, such as traffic management and road design considerations, becomes imperative to foster a quieter and more sustainable living environment for the inhabitants.

Given that the equivalent continuous noise level and various noise indices have exceeded permissible limits on Jalan Bp Satu and Jalan Persiaran SL 7, the imperative to implement effective mitigation strategies becomes evident. Two optimization methods are proposed to alleviate the impact of environmental noise: restricting heavy vehicle access during specific times and constructing noise barriers.

Prohibiting heavy vehicles during designated hours emerges as a viable and impactful strategy for curtailing traffic noise levels. Heavy vehicles, including trucks and buses, are notorious for generating elevated noise levels due to their substantial size, weight, and powerful engines. The rationale behind this method lies in reducing the overall number of vehicles on the road, subsequently leading to a decrease in the overall noise level. The Calculation of Road Traffic Noise Model (CoRTN) proves instrumental in predicting anticipated noise levels in scenarios devoid of heavy vehicles. This predictive model considers alterations in traffic flow and speed limits, providing a comprehensive estimation of noise levels.

The reliability of the CoRTN model is validated by previous research, as highlighted by studies conducted by Melo et al. (2015) and Abdur-Rouf et al. (2022), which have demonstrated its accuracy through field measurements. During field measurements on Jalan Bp Satu and Jalan Persiaran SL 7, heavy vehicles were categorized into peak and off-peak sessions. The calculations indicated that during peak sessions on Jalan Bp Satu, there were 41 heavy vehicles, while during off-peak sessions, there were 31. Similarly, on Jalan Persiaran SL 7, 34 heavy vehicles were observed during peak sessions and 64 during off-peak sessions. The CoRTN model was then employed to predict expected noise levels in scenarios where heavy vehicles were prohibited, taking into account factors such as traffic volume, vehicle speed, and road surface type.

The summarized results in Figure 6(a) demonstrate the expected reduction in noise levels achieved by prohibiting heavy vehicles using the CoRTN model. With this strategy in place, the expected noise levels fall just within the bounds of the DOE noise limit, showcasing the efficacy of the proposed method. This reduction in heavy vehicle traffic is anticipated to have a positive impact on overall traffic noise levels, aligning with the goal of creating a quieter and more sustainable living environment for the residents of Bandar Sungai Long. This proactive approach, grounded in predictive modeling and field measurements, underscores the potential success of targeted interventions in managing and mitigating environmental noise.

The noise barrier, meticulously designed to address the heightened noise levels along Jalan Bp Satu and Jalan Persiaran SL 7, encompasses various key parameters outlined in detail in Table 6. In the strategic planning of the noise barrier, monitoring points A1 on Jalan Bp Satu and C2 on Jalan Persiaran SL 7 were pivotal, identified as locations where the L_{Aeq} was highest and the environmental impact most pronounced among all stations. This targeted approach ensures that the noise barrier is optimized to address the specific areas experiencing the greatest noise-related challenges.

The design specifications include a barrier height of 1.5 m, with the path length difference meticulously calculated to maximize effectiveness. The insertion loss, determined through interpolation based on the path length difference, informed the selection of a 6.35 mm thickness of aluminum sheet for the noise barrier. Figure 6 (b) provides a visual representation of the proposed noise barrier's location, emphasizing its strategic placement to intercept and mitigate traffic-generated noise effectively.

A crucial aspect of the noise barrier's design is its anticipated impact on noise reduction. With a transmission loss of 23.2 dBA, the noise barrier is projected to substantially alleviate the impact of traffic noise on the adjacent community. Upon implementation, the overall barrier design is estimated to reduce noise levels by up to 14 dBA, a significant improvement that promises a quieter living environment for residents.

Upon completion, the projected noise levels after installing the noise barrier are expected to be 53.7 dBA for Jalan Bp Satu and 55.3 dBA for Jalan Persiaran SL 7. These post-barrier noise levels fall comfortably below the permissible noise level recommended by the DOE guideline, which stands at 65 dBA for suburban and urban residential areas. This achievement underscores the effectiveness of the proposed noise barrier in achieving the dual objectives of noise reduction and regulatory compliance.

To visually capture the comparative impact of various scenarios, Figure 7 serves as a valuable tool, illustrating the contrast in noise reduction among normal conditions, scenarios where heavy vehicles are prohibited, and the pro-

	Monitoring Point	**Jalan Bp Satu (A1)**	**Jalan Persiaran SL 7 (C2)**
	Height of source, H_s (m)	0.5	0.5
	Height of receiver, H_r (m)	1.2	1.2
	Height of barrier, Hb (m)	1.5	1.5
	Receiver noise level (without barrier)(dBA)	67.7	69.3
	Insertion Loss, IL (with barrier) (dBA)	14.0	14.0
	Transmission Loss, TL (with barrier)(dBA)	23.2	23.2
Proposed Barrier Noise	**Barrier material**	Aluminium Sheet	Aluminium Sheet
	Barrier height (m)	1.5	1.5
	Barrier thickness (mm)	6.35	6.35
	Final receiver noise level L_{eq} (dBA)	53.7	55.3

Table 6: Noise Barrier Design for Monitoring Jalan Bp Satu and Jalan Persiaran SL 7.

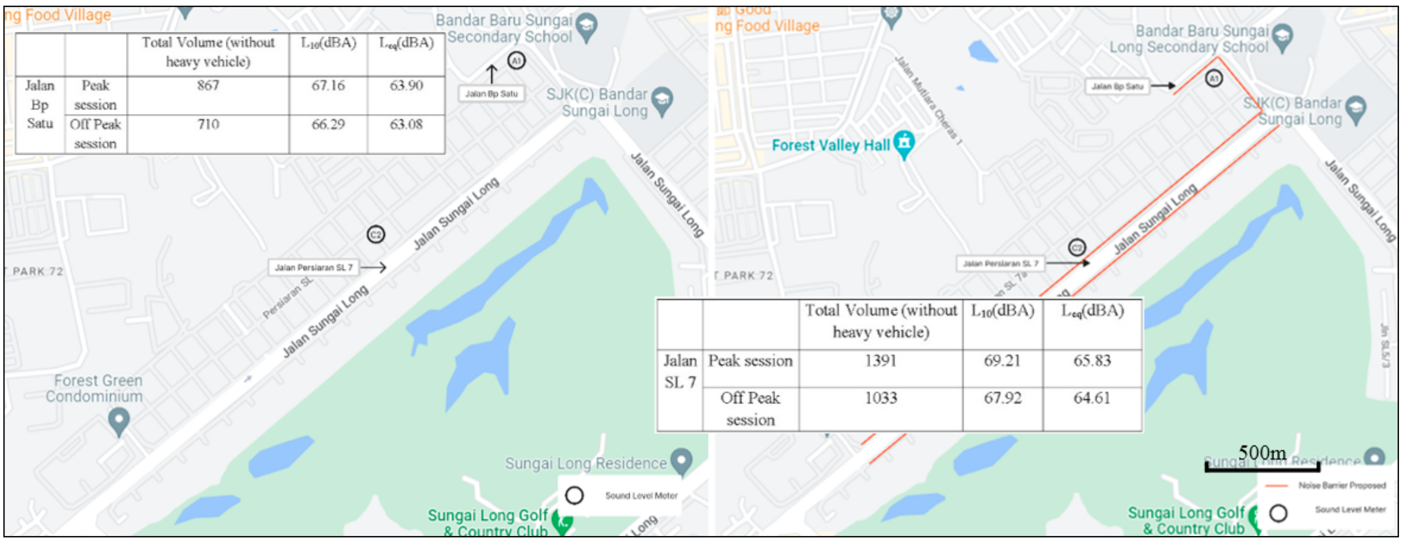


Figure 6 a): Location of Prohibiting Heavy Vehicles along Jalan Persiaran SL 7 and Bp Satu; b) Aluminium Sheet Noise Barrier Installing along Jalan Persiaran SL 7 and Bp Satu.

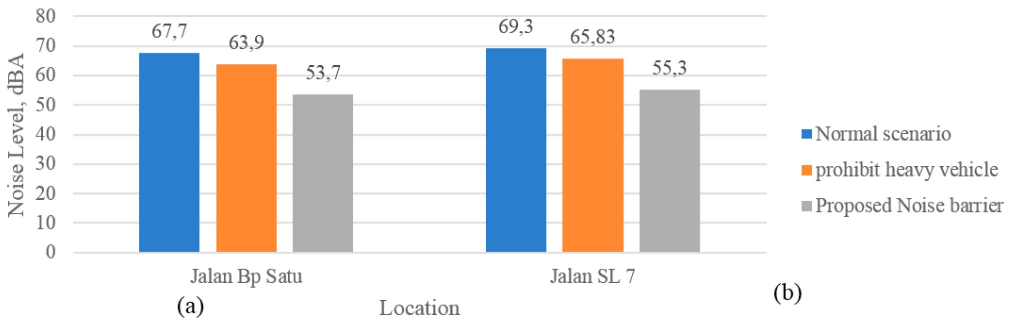


Figure 7: Comparison Of Noise Level Between Three Scenarios.

	Prohibit Heavy Vehicles	Construct a Noise Barrier
Advantage	This approach can significantly reduce noise levels, especially during peak hours, as heavy vehicles tend to emit higher levels of noise. It is a relatively simple and cost-effective solution that does not require any significant construction or maintenance efforts.	This approach can provide an effective and long-term solution to reduce noise levels, as it physically blocks the transmission of sound waves. It can also improve the aesthetics of the surrounding area and provide additional benefits such as increased privacy and security.
Disadvantage	This approach can have negative impacts on transportation and logistics industries, as heavy vehicles play a crucial role in the movement of goods and products. It can also lead to increased congestion and longer travel times, which can have indirect economic and environmental impacts.	This approach can be expensive and time-consuming to implement, especially in densely populated areas or where space is limited. It may also require ongoing maintenance and cleaning efforts to ensure its effectiveness, which can add to its overall cost. Additionally, it may not completely eliminate noise, as sound waves can diffract over the top of the barrier or reflect off nearby surfaces.

Table 7: Summarized Advantage And Disadvantage Between Two Methods.

posed noise barrier. The noise reduced by constructed noise barrier is more effective compared to This graphical representation succinctly communicates the efficacy of the noise barrier in outperforming alternative measures, consolidating the case for its implementation as a strategic solution to alleviate environmental noise and enhance the quality of life for the community. Prohibiting heavy vehicle is also a saving budget way to reducing the noise for the community. Prohibiting heavy vehicles also presents a cost-effective approach to reducing noise for the community, bringing it below DOE standards.

Prohibiting heavy vehicles and constructing noise barriers are two methods proposed in this research to reduce road traffic noise on the Bandar Sungai Long. Prohibiting heavy vehicles involves restricting or banning large, noisy vehicles from using specific roads or areas. On the other hand, constructing noise barriers involves building physical barriers that block or absorb sound waves. Both methods have their advantages and disadvantages, and the choice between them depends on various factors such as cost, feasibility, and effectiveness. Table 7 summarises the advantages and disadvantages of these two methods.

In selecting a noise reduction method for a busy township, it is important to consider the specific location, traffic volume, and noise levels. Prohibiting heavy vehicles could be a potential solution for peak hours, but may not be suitable as a long-term option as it could negatively affect transportation and logistics industries. In contrast, constructing noise barriers could provide a permanent solution to reduce traffic noise, but it can be expensive to build and maintain. However, noise barriers can provide a more consistent and effective reduction of traffic noise for the surrounding community. Ultimately, the selection of a noise reduction method should be based on a comprehensive analysis of the specific situation and the needs of the community.

4. CONCLUSION

In this study, field measurements were conducted in Bandar Sungai Long at four different locations to assess the impact of traffic noise. According to the findings, Jalan Bp Satu and Jalan Persiaran SL 7 exceeded the Department of Environment Malaysia (DOE) limit, with the highest L_{Aeq} measuring approximately 69.3 dBA. The most significant L_{max} value recorded was 97.4 dBA, impacting the residents near Jalan Persiaran SL 7. Stations that exceeded the DOE standard during field measurements provided researchers with insights into sound properties and real-world scenarios. The highest levels of the Traffic Noise Index (TNI) and Noise Pollution Level (LNP) reached 103.6 dBA and 87.2 dBA, respectively, which are still within the advised limits of the DOE guidelines. Furthermore, residences near Jalan Persiaran SL 7 often experience elevated levels of traffic noise disturbance, while those located deeper within residential areas typically encounter higher background noise levels from natural factors. The results of the traffic noise assessment highlight the importance of considering background noise in residential areas when delineating the field associated with traffic noise studies for future researchers. Various methods can be employed to mitigate noise levels, including prohibiting heavy vehicles on the road and constructing noise barriers. A 1.5-meter-high noise barrier has been proposed and recommended along Jalan Bp Satu and Jalan Persiaran SL 7 based on references in the DOE guidelines. To address the disturbance caused by uncontrolled variables in the study region, further research focusing on the impact of traffic noise related to targeted traffic annoyances can be conducted.

Constructing a noise barrier can be more expensive compared to prohibiting heavy vehicles on the road. Prohibiting heavy vehicles on the road is relatively easier and cost-effective as it does not require any construction work. Instead, it involves enforcing traffic regulations, imposing speed limits, and incentivizing heavy vehicle operators to use quieter technologies. However, the effectiveness of prohibiting heavy vehicles on the road may vary depending on the local conditions and the number of heavy vehicles on the road. If there are only a few heavy vehicles passing through the area, prohibiting them may not significantly reduce the traffic noise. Additionally, this method may not be suitable in cases where heavy vehicles are necessary for essential services, such as emergency vehicles or public transportation. On the other hand, constructing a noise barrier can be a more effective long-term solution to reduce traffic noise, especially in areas where the traffic volume is high. Noise barriers can provide a significant reduction in traffic noise, even for residents or businesses that are located relatively close to the road.

In summary, prohibiting heavy vehicles on the road is more suitable if the aim is to save cost. However, if reducing traffic noise is a priority and a long-term solution is needed, constructing a noise barrier may be a more effective solution. The most suitable method will depend on various factors such as the local conditions, traffic volume, and the desired level of noise reduction. In the future, further in-depth research will be required to determine the extent to which variables affect the amount of traffic noise along this busy road as well as data on traffic characteristics such vehicle acceleration and deceleration. Additionally, the review can take into account additional variables that may have an impact on communication, sleep disturbance, instruction, and other relevant areas. Moreover, the strategic application of these noise mitigation methods can serve as a model for other urban areas facing similar challenges. By documenting the process and outcomes of these initiatives, the study could provide valuable insights and best practices for urban planners and policymakers in other regions. This knowledge transfer is critical in the broader context of urban development and environmental sustainability.

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