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Comprehensive Measurement and Analysis of Traffic Noise Along The Changlun-Kuala Perlis Highway

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Abstract

Road traffic noise, encountered by residents living close to major highway routes, has emerged as one of the most prevalent environmental concerns in recent years. Increasing noise levels result hugely from greater vehicles on the road, higher speeds, and heavier traffic volumes. However, the tire-pavement interaction often constitutes the most prominent noise source on highways. Some studies have discovered that prolonged exposure to highway noise is likely associated with hearing loss and other health problems. Notwithstanding its severity, data available on transport noise emission from highways in Malaysia is still lacking. Therefore, this study aims to analyze the traffic noise index (TNI) and noise pollution level (NPL) in dBA to assess the traffic noise impact along the Changlun-Kuala Perlis Highway, near the residential areas. Different noise indices, including equivalent continuous noise level (LAeq), maximum permissible 10% (L_{10}) and 90% (L_{90}) noise level, and maximum peak noise level (LAFmax) were all determined. The noise level status was also identified based on the measured noise indices to calculate the TNI and NPL. In this present study, the acoustic measurement was performed at various residential areas along the highway through the NoiSee application, which provides a readout of the noise level, using an external calibrated built-in microphone. Results revealed that all residential areas face a traffic noise disturbance with a DOE standard of more than 65 dBA, and 96% of them have TNI values higher than 74 dBA, with 70% of NPL that were below 88 dBA. As indicated by the analysis, it is clear that the residential areas along Jalan Changlun-Kuala Perlis were heavily affected by the traffic noise emitted from highways.

1. Introduction

Highway construction is one of the key elements for socioeconomic growth worldwide, which can relieve traffic congestion, boost the regional sector, and enhance accessibility in rural or metropolitan areas. The development of highways is essentially required to meet the need for efficient transport, thereby serving as the backbone of national traffic networks [1]. While highways contribute a significant asset to the regional economy, their expansion could sometimes pose an inadvertent adverse effect, particularly noise pollution. It is known that the most prevalent component of the contemporary acoustical environment is transportation noise. The largest source of highway noise is primarily triggered by the noise of tire rolling resistance. Moreover, pavement degradation [2], noise emission from the whirring of vehicular engines, interactions between running vehicles, and traffic composition [3] might also be contributing factors to highway noise. According to the Ministry of Transportation Malaysia, the number of registered automobiles was discovered to rise at an annual rate of up to 45% from 2012 to 2014. Inevitably, all of these have had an impact on road traffic noise, which is indirectly associated with various health illnesses [4]. The effects of noise on health are comprehensively presented in the World Health Organization (WHO) 2011 report on "Burden of Disease from Environmental Noise," and it is determined that the noise levels may be associated with irritability and sleep disturbance, thus affecting the quality of life [5].

Since the release of these WHO reports, there has been an abundance of pieces of literature that consistently report several negative outcomes, including respiratory [6] and cognitive impairment [7] when having extended exposure to transportation noise. After regulating for confounders, a recent study claimed that traffic noise over 70 dBA has been demonstrated to be associated with hearing loss [8]. This is in support of the environmental control standards issued by the Department of Environment (DOE) guidelines that state the maximum permissible noise limit for residential areas should not exceed 60 dBA [9], which is important to keep the community safe from highway noise. In the work of [10] mentioned, barely any studies have been reported from developing countries. Even if studies were conducted, the acoustic landscape of the surrounding area has not been adequately depicted by noise maps [11]. Furthermore, there is restricted data available on transportation noise emission from highways in Malaysia. Therefore, the objectives of this study are: 1) to analyze the parameters of traffic noise index (TNI) and noise pollution level (NPL), and 2) to assess the noise level measurement along Changlun-Kuala Perlis Highway.

2. Methodology

The present study focuses on objectives which are divided into two main stages: (1) measurement of noise indices; and (2) evaluation of traffic noise level.

2.1 Study Area

Changlun-Kuala Perlis Highway is a highway built under the Public Works Department (JKR) R5 road standard that connects Perlis state and the North-South Expressway. Hence, an increase in traffic volume could be expected daily, with many heavy vehicles speeding on the road. The assessment of noise level was typically conducted in residential areas that are situated along Jalan Changlun-Kuala Perlis. Four primary residential areas were specifically selected for assessing the effects of traffic noise on the local population. To effectively measure the traffic noise level, a sampling site was carefully assigned for each location, as displayed in Table 1 and Fig. 1. Every sampling site under observation was decided based on similar basic criteria as stipulated by DOE guidelines [12] which include, the sites must be located a minimum distance of 3.5 m from the traffic signals, intersections, and other noise sources for example, schools and factories.

Table 1 *Measurement locations*

Residential areas	Sampling sites	Coordinates
Kampung Langsat	L1	6.45180° N 100.38648° E
Kampung Bukit	L2	6.45486° N 100.34323° E
Taman Tengku Budriah	L3	6.42968° N 100.29912° E
Kampung Guar Sanji	L4	6.41971° N 100.27954° E

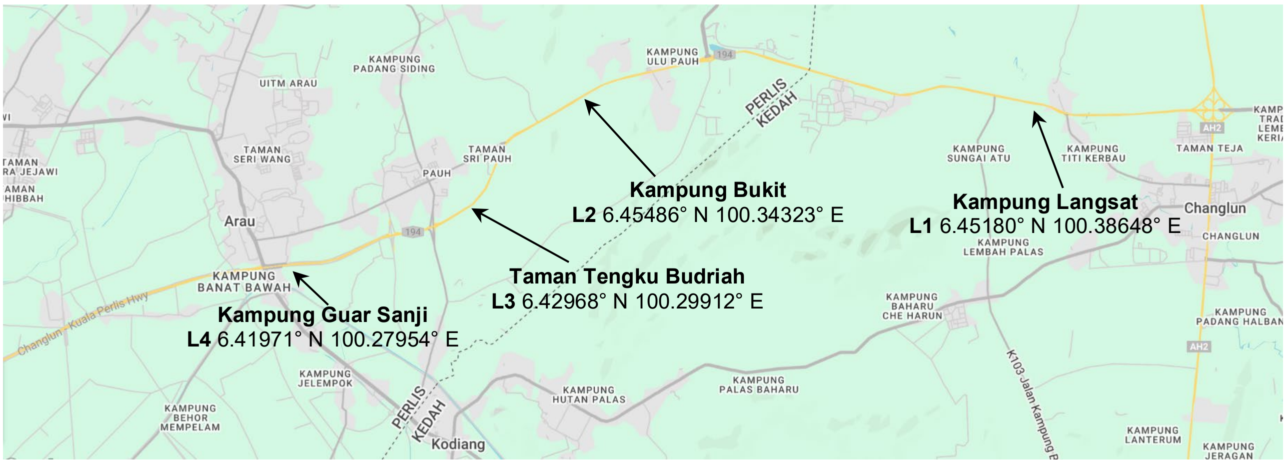

Fig. 1 *Map of study areas*

2.2 Determination of Noise Indices

The field measurement was performed to identify the noise indices using the NoiSee application with an external i436 microphone. This smartphone-based sound level meter (SLM) app is an intuitive professional-grade noise level meter and is per SLM standards of the International Electrotechnical Commission (IEC) [13]. During the setup, with the support of a tripod, the SLM was positioned approximately 1.2 m high from ground level and 3.5 m from the source of noise, as shown in Fig. 2. This setup is similarly implemented for all four residential locations.

Throughout the analysis, a windsock cover is used in conjunction with the SLM microphone, which acts as a protective shield from surrounding reflective sources, providing an ideal measurement condition. The study was generally carried out on weekdays and weekends in particular, during the peak hours of 7:00 a.m.-8:00 a.m. (MYT) and 5:00 p.m.-6:00 p.m. (MYT) largely because congestion on roads may occur most often.

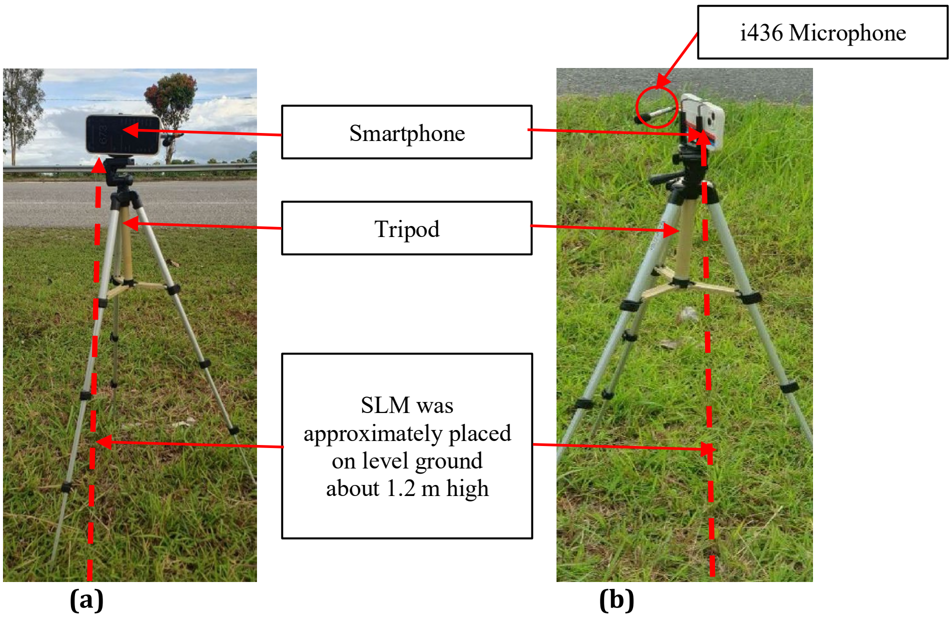

Fig. 2 *On-site traffic noise measurement setup: (a) Front view; and (b) Side view*

2.3 Assessment of Noise Level

The noise data were collected using SLM, which is necessary for further analysis such as generating the equivalent continuous noise pressure level (LAeq), maximum noise level (LAFmax), and percentile of noise exceedance. To determine the degree of noise pollution, the field-measured data were converted to NPL and TNI. The TNI is particularly crucial for estimating annoyance responses caused by traffic noise. On the other hand, NPL can be employed to express the varying levels of noise. Both the TNI and NPL values can commonly be derived from noise indices, namely LAeq, noise level exceeded 90% (L_{90}), and noise level exceeded 10% (L_{10}). The derivation of TNI was computed by integrating the non-linear noise variability of L_{90} and L_{10} as shown in Eq. 1 whereas NPL was calculated depending on the combination of LAeq, L_{90}, and L_{10} noise indices using Eq. 2. To achieve a healthy noise environment, the standardized NPL and TNI values should not exceed 88 dBA and 74 dBA respectively. For the entire analysis, the above-stated different noise descriptors were identified for the morning and evening periods to analyze various aspects of noise pollution. Fig. 3 illustrates an overview process of measuring and assessing the traffic noise impact.

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

$$NPL = LAeq + (L_{10} - L_{90}) \quad (2)$$

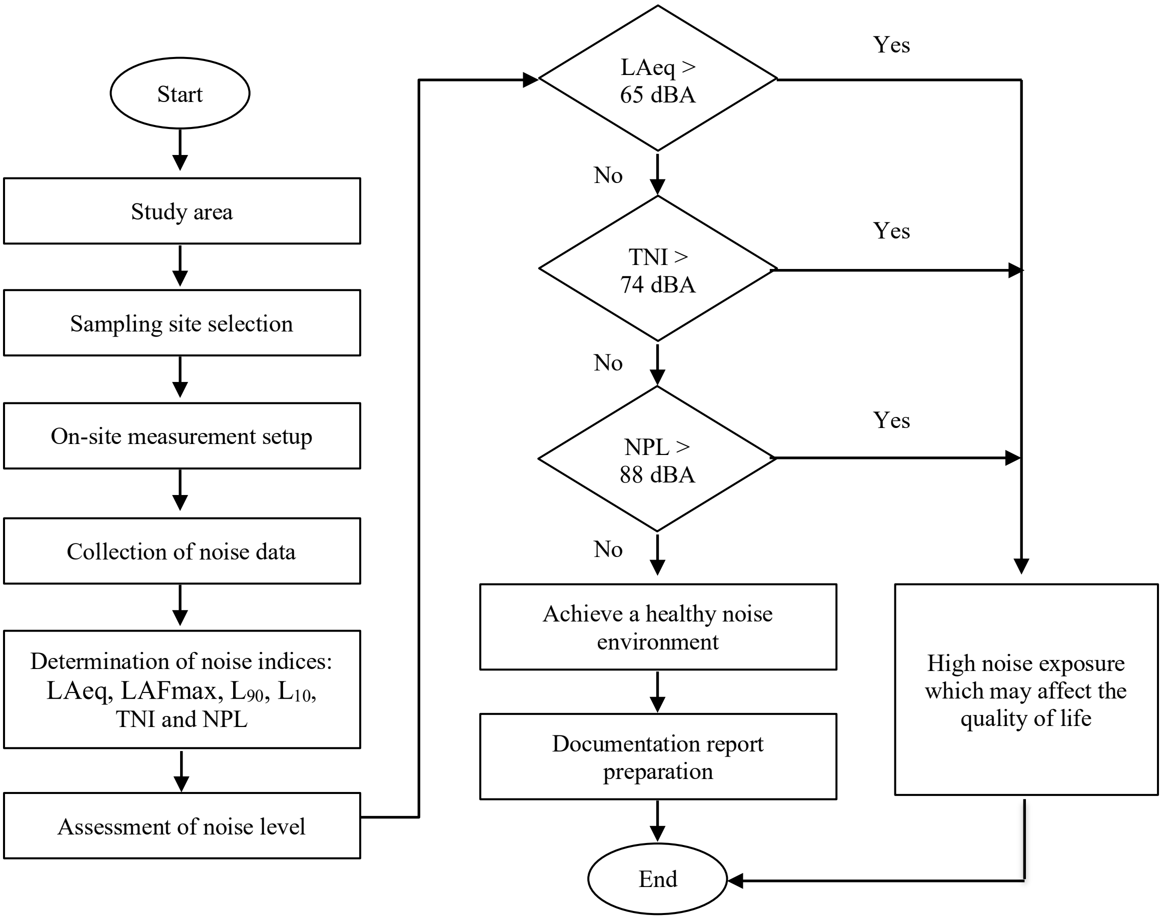

Fig. 3 *Flow chart model of traffic noise measurement level*

3. Results and Discussion

Traffic noise is a dominant source of noise pollution [14], garnering considerable interest due to the increase in social and economic activities [15]. In this present study, the results revealed a visual representation of noise levels with different noise parameters across various residential areas, including Kampung Langsat, Kampung Bukit, Taman Tengku Budriah, and Kampung Guar Sanji, as shown in Fig. 4-7. In this context, an analysis of the trends and variances in the noise indices such as LAeq, LAFmax, TNI, and NPL was conducted for interpretation. Given the many noise indices, LAeq is described as the average constant noise exposure, which over the specified measurement period, has the same overall energy content as the fluctuating noise; LAFmax is the highest time-weighted noise level that takes place during the observation period; TNI is a cumulative index, designates to measure annoyance responses to highway noise; and NPL is an indicator used to measure the level of perceived noise from external sources. Meanwhile, the maximum permissible L_{90} (90%) and L_{10} (10%) noise levels are specific percentile levels measured to assist the evaluation of the existing noise level at the pre-determined areas, as depicted in Table 2.

The impact level of traffic noise pollution at Changlun-Kuala Perlis Highway was assessed using field measurements at various time intervals. The finding demonstrates two hours from 7:00 a.m.-8:00 a.m. (MYT) and 5:00 p.m.-6:00 p.m. (MYT) was selected to measure the LAeq because these timeframes typically correlate with peak traffic hours when significant intensity of traffic on highways tends to reach its maximum traffic capacity. Hence, collecting noise data at these hours can provide a realistic representation of the cumulative noise exposure levels experienced by residents in the vicinity of the highway. Moreover, among the four studied residential locations, the noise pollution rate was determined by calculating the noise parameters, which include the LAFmax, TNI, NPL, L_{90} (90%), and L_{10} (10%) noise levels. For better graphical illustration, the analyzed noise indices are reported in the figures.

According to the DOE standards, safe noise levels should be below 65 dBA. However, the results showed that the residential areas of Kampung Langsat, Kampung Bukit, Taman Tengku Budriah, and Kampung Guar Sanji all exhibited LAeq levels surpassing 65 dBA, indicating substantial exposure to traffic noise on Monday and Wednesday (Fig. 4-7). Concerning this, prolonged exposure to traffic noise exceeding 56 dB could raise the risk of myocardial infarction [16]. There is also an increased tendency to suffer cardiovascular disease and hypertension when the continuous weighted noise levels are more than 50 dBA [17]. Throughout the study, a sampling site situated 3.5 meters away from the traffic signal was allocated for each residential location, essentially, for an effective measure of noise generated by road traffic along the Changlun-Kuala Perlis Highway. Among different sampling sites, L4 has the overall highest LAeq with its majority LAeq values that lie between 60-70 dBA (Fig. 7). This may suggest that residents living at Kampung Guar Sanji encounter the most consistent exposure to noise compared to other residential locations. The slight difference in the geographical layout and traffic vehicle service could also contribute to the standout elevated LAeq observed at L4.

To assess the characteristics of noise generated in the various residential areas, the LAFmax values were recorded. The lowest measured LAFmax value was found to be 82.1 dBA, and the highest was 93.6 dBA (Fig. 6). In this regard, a value of 82.1 dBA may indicate that the maximum instantaneous noise level was within a moderately loud range, whereas a LAFmax value of 93.6 dBA implies a very high instantaneous noise level, leading to potential concerns regarding noise disturbance and an urgent need for further noise mitigation initiatives in these areas. Although the LAFmax only lasts for a short while, the increased noise above 85 dBA intensity can lead to fatigue, irritability, and stress [18]. In any residential area, the LAFmax would represent the case-dependent variable factor. In response to the exposure and continual day-to-day activities such as vehicle speeding, honking, and intense noise from modifications of the vehicle, LAFmax could generally vary for each residential area. Table 2 presents the noise level exceeded value (L_{10}) for the 4 residential areas, wherein, for at least 10% of the total measurement duration, the recorded value is more than 65.0 dBA at least. Furthermore, for the majority of the time (90%), the noise level exceeded value (L_{90}) in these areas has a minimum value of 49.2 dBA, which an indicative that there is a sustained exposure to heightened noise levels.

The traffic noise pollution levels in the studied areas were assessed using TNI and NPL based on the measured noise indices. As shown in the figures, all residential locations recorded NPL values higher than 88 dBA, especially during weekdays. High noise levels (> 85 dBA) can directly lead to health issues, such as hearing loss or direct physiological alterations caused by sleep disturbances [19]. However, a decrease in NPL values (< 88 dBA) was observed during the weekends. Overall, 70% of NPLs were below 88 dBA. Weekdays are often observed with a substantial volume of traffic, especially at peak hours, because there are more commuting and work-related activities, therefore, a greater NPL value. In contrast, on weekends, residential areas would experience reduced ambient noise levels due to lower vehicular activity coupled with a reduction in industrial operations. When assessing the TNI measurements, it is identified that the respective 4 residential areas all have a value of more than 74 dBA except Kampung Guar Sanji during the weekend at morning peak hour with a TNI value of 72.1 dBA (Fig. 7). On average, 96% of the residential areas have TNI values exceeding 74 dBA. A TNI value above this level is considered to surpass the acceptable threshold. Since the Changlun-Kuala Perlis Highway is the main expressway connecting major towns in Perlis, such as Arau, Pauh, and Kangar, it likely contributes to intensified noise levels. Studies have demonstrated a link between road traffic noise and an increased risk of stroke [20], cardiovascular morbidity, and mortality [21].

Table 2 *Traffic noise measurement for L_{10} and L_{90}*

Residential areas	Day	Time (MYT)	Noise level exceeded value (L10) (dBA)	Noise level exceeded value (L90) (dBA)
L1	Monday	7:00-8:00 a.m.	78.9	60.2
6.45180° N		5:00-6:00 p.m.	80.1	62.0
100.38648° E	Wednesday	7:00-8:00 a.m.	78.3	63.4
		5:00-6:00 p.m.	79.3	61.8
	Saturday	7:00-8:00 a.m.	75.7	65.7
		5:00-6:00 p.m.	73.5	60.1
	Sunday	7:00-8:00 a.m.	72.6	53.5
		5:00-6:00 p.m.	78.2	65.8

L2	Monday	7:00-8:00 a.m.	72.3	53.3
6.45486° N		5:00-6:00 p.m.	74.9	54.9
100.34323° E	Wednesday	7:00-8:00 a.m.	70.9	53.8
		5:00-6:00 p.m.	75.4	57.9
	Saturday	7:00-8:00 a.m.	72.1	56.1
		5:00-6:00 p.m.	75.2	55.6
	Sunday	7:00-8:00 a.m.	67.4	49.2
		5:00-6:00 p.m.	73.6	56.3
L3	Monday	7:00-8:00 a.m.	73.2	53.6
6.42968° N		5:00-6:00 p.m.	77.5	57.4
100.29912° E	Wednesday	7:00-8:00 a.m.	74.8	55.1
		5:00-6:00 p.m.	76.7	59.6
	Saturday	7:00-8:00 a.m.	70.4	51.3
		5:00-6:00 p.m.	69.2	52.8
	Sunday	7:00-8:00 a.m.	70.1	50.7
		5:00-6:00 p.m.	71.3	51.5
L4	Monday	7:00-8:00 a.m.	75.8	53.4
6.41971° N		5:00-6:00 p.m.	74.5	56.2
100.27954° E	Wednesday	7:00-8:00 a.m.	73.8	52.7
		5:00-6:00 p.m.	74.6	55.4
	Saturday	7:00-8:00 a.m.	70.8	53.6
		5:00-6:00 p.m.	75.2	60.2
	Sunday	7:00-8:00 a.m.	72.4	62.5
		5:00-6:00 p.m.	74.4	59.7

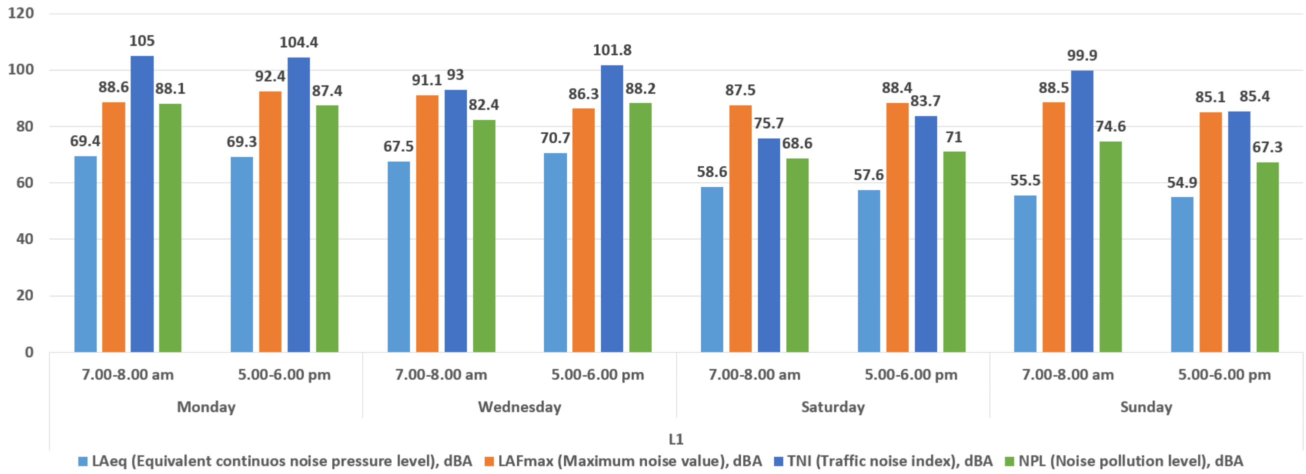

Fig. 4 *Noise parameters for morning peak hours (am) and evening peak hours (pm) at Kampung Langsat*

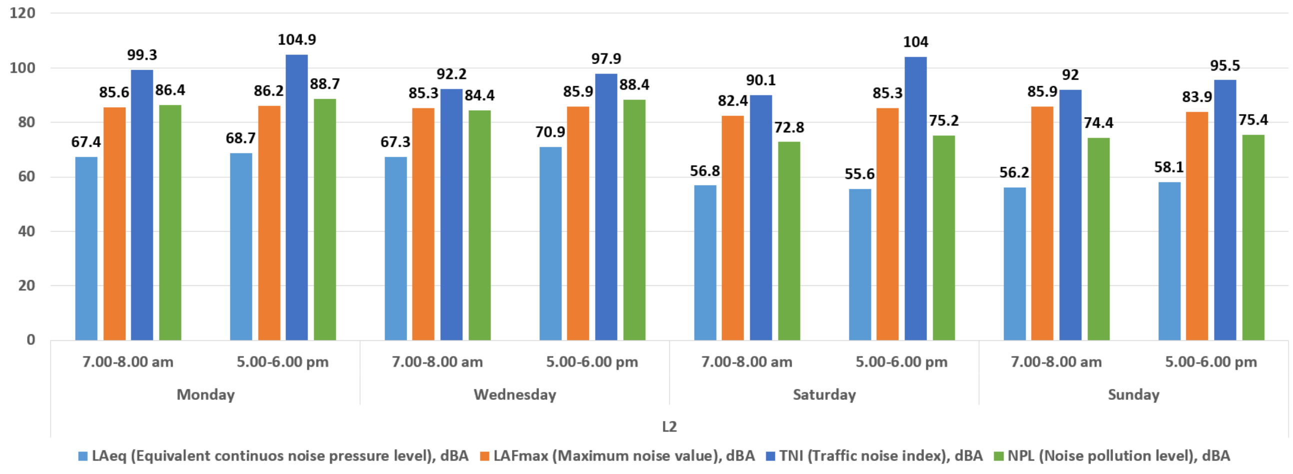

Fig. 5 *Noise parameters for morning peak hours (am) and evening peak hours (pm) at Kampung Bukit*

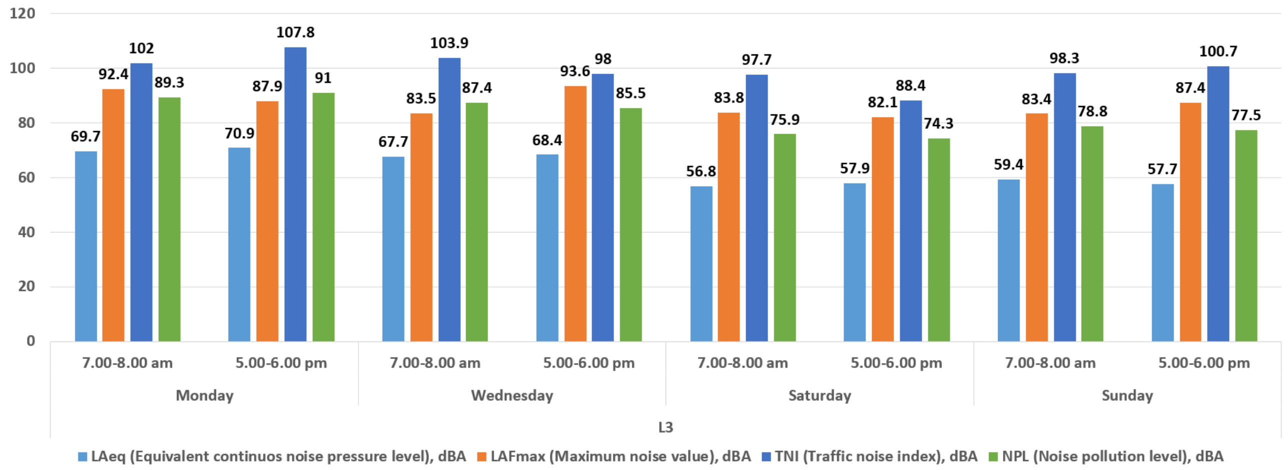

Fig. 6 *Noise parameters for morning peak hours (am) and evening peak hours (pm) at Taman Tengku Budriah*

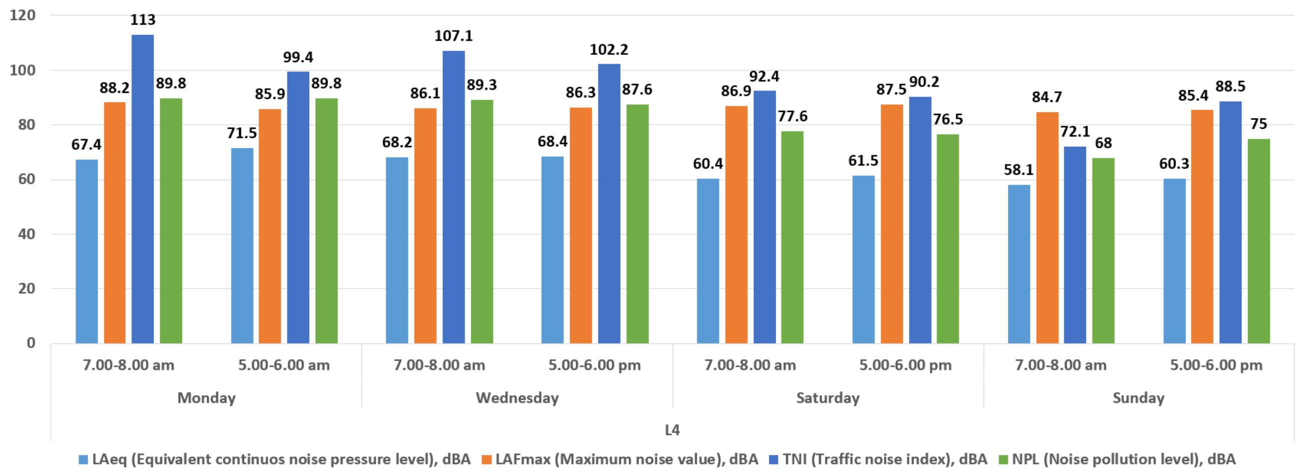

Fig. 7 *Noise parameters for morning peak hours (am) and evening peak hours (pm) at Kampung Guar Sanji*

4. Conclusion

Highway noise has become a risk source of environmental noise as the highway infrastructural development that can provide a stimulus for socio-economic growth has been expanding over the recent years. Through this study, it was concluded that the traffic noise level along the Changlun-Kuala Perlis Highway is greater than the acceptable limits due to the increasing number of vehicles and several other factors. Traffic noise measurements were typically performed at various residential areas to measure the noise indices along Jalan Changlun-Kuala Perlis. Findings found that the LAeq values obtained have exceeded the DOE standard of 65 dBA, suggesting the prevailing noise levels are high. Exposure to traffic noise with TNI values over 74 dBA was also observed in most residential areas, which is highly likely to lead to a probable risk of damage to the auditory system. In this regard, such increased levels of traffic noise should be abated by building sound barrier walls along the road, traffic measures such as speed reduction, and regular monitoring of noise pollution in the efforts to protect human health, which in turn could significantly improve the overall quality of life in the neighborhood.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm their contribution to the paper as follows: ***study conception and design:*** *Tan Wei Hong, Amares Singh, Teoh Choe Yung;* ***data collection:*** *Mohammad Salman Khan Bin Nazaruddin;* ***analysis and interpretation of results:*** *Tan Wei Hong, Stephanie Kew Yen Nee;* ***draft manuscript preparation:*** *Tan Wei Hong, Stephanie Kew Yen Nee, Mohammad Salman Khan Bin Nazaruddin;* ***final editing and checking:*** *Stephanie Kew Yen Nee, Amares Singh, Teoh Choe Yung. All authors reviewed the results and approved the final version of the manuscript.*

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