

ORIGINAL ARTICLE

Road Traffic Noise Assessment at Residential, Institutional and Commercial Areas In Bachok, Kelantan

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ABSTRACT

Introduction: Road traffic noise is a growing environmental concern in rapidly developing rural and semi-urban areas. This study investigated noise levels from road traffic across residential, institutional, and commercial areas in Bachok, Kelantan and examined related factors (land use activities, traffic hours, and volume). **Materials and Methods:** Noise measurements were taken for one hour at 15 purposively selected locations, using a Class 1 sound level meter over different periods (morning until evening), during peak and non-peak hours between 7:30 am and 6:00 pm. Total number of vehicles pass-by the road was counted manually. **Results:** Most locations exceeded the Department of Environment's recommended noise limits. Bandar Baru Jelawat recorded the highest LAeq during both peak (77.4 dB(A)) and non-peak (77.3 dB(A)) periods. Noise levels varied significantly across land use activities ($p < 0.001$). There were strong significant correlations ($p < 0.015$, $r > 0.613$) between traffic volume (for most vehicles) and noise levels for both peak and non-peak hours. Cars, vans, and small lorries were identified as the primary sources of increased noise levels. **Conclusion:** This study provides novel insights by simultaneously assessing multiple land-use areas and linking traffic characteristics to noise exposure in a semi-urban Malaysian context. The findings underscore the need for targeted traffic management, continuous monitoring, and urban planning strategies to mitigate noise impacts which can contribute to adverse health outcomes such as sleep disturbance, cardiovascular problems, hearing impairment, and increased stress among residents.

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INTRODUCTION

Noise is an unwanted sound that can harm health when it is continuous and exceeds safe levels. In Malaysia, rapid urbanisation and industrial growth have led to increased road traffic, making traffic noise a major environmental concern. Prolonged exposure to traffic noise is linked to health issues such as hypertension, heart disease, and stress [1]. Despite its role in supporting economic and social activities, road transport contributes significantly to noise pollution. Bachok, Kelantan, is a coastal town renowned for its natural beauty and traditional culture. It is connected by major roads such as Jalan Kota Bharu - Bachok (D1), which sees heavy traffic from cars, motorcycles, and commercial vehicles. While these roads are important for connectivity, they can be noisy,

particularly in residential and central areas.

A study in Jeli, Kelantan, found noise levels as high as 85.9 dB(A), far exceeding the Malaysian limit of 60 dB(A) [2]. However, there is a lack of data on traffic noise exposure in semi-urban towns like Bachok, Kelantan, especially across multiple land-use types such as residential, institutional, and commercial areas. Existing studies often focus on urban centres or single site types, limiting understanding of the spatial and temporal variability of noise in smaller towns [1,3]. If left unaddressed, traffic noise pollution could have long-term health impacts, including sleep disturbances, hypertension, heart disease, hearing loss, and reduced learning performance in children [3,4]. High noise levels in hospitals can also disrupt patient recovery and care [5]. Residential areas may suffer from chronic stress and a decline in quality of life due to prolonged noise exposure.

Traffic noise levels tend to vary based on the time of day. During peak hours, congestion and stop-and-go driving result in louder, more irregular noise. In contrast, non-peak hours typically see smoother traffic flow and lower, more consistent noise levels [6]. Given the limited research in semi-urban Malaysian contexts, investigating these patterns is essential to inform local policy and public health interventions. Understanding these variations is important for protecting public health, planning urban infrastructure, and ensuring regulatory compliance. Therefore, this study aimed to investigate traffic noise pollution in sensitive areas by measuring noise levels at different times and locations, analysing traffic patterns, and estimating population exposure. The findings will support the development of targeted strategies such as traffic calming, noise barriers, and better urban design to reduce noise pollution. Ultimately, this research will offer practical insights for policymakers, urban planners, and public health authorities to create quieter, healthier, and more sustainable living environments.

MATERIALS AND METHODS

Study Design and Location

This study used a cross-sectional design to assess and compare road traffic noise levels during peak and non-peak hours across different land use categories in Bachok, Kelantan. The areas chosen included residential, institutional (schools and hospitals), government, and commercial zones. This design was chosen due to its simplicity, cost-effectiveness, and suitability for providing quick, snapshot-like data within a set timeframe. Although cross-sectional studies offer valuable insights, they are limited in their ability to capture variations across different days, seasons, or special events. To ensure a diverse sample, 15 traffic-prone locations representing key land-use categories were purposively chosen for assessment. To meet the required sample size, the minimum number of sites was determined using statistical power calculations based on previous studies [7,8], and additional sites were included to strengthen coverage.

The study was carried out at several sites in Bachok, Kelantan, including those near major roads and highways. These locations were chosen because they are close to high-traffic areas and pose a risk of chronic noise exposure for vulnerable populations such as schoolchildren, patients, and residents. While the district's road networks promote economic activity and local mobility, they also contribute significantly to environmental noise, particularly in areas where noise-reduction measures are limited or absent.

The site selection criteria were as follows: locations within the Bachok sub-districts, within 200 meters of a main road, and classified as residential, institutional, or commercial. Sorensen et al. [9] found that residents living within a 200-meter radius were more likely to

have hypertension. Exclusion criteria included areas near industrial zones or construction sites to avoid data interference from non-traffic noise sources. The sample size was calculated using the two-means formula, with the level of statistical significance is set as; $Z_{\alpha}=1.96$, and the power of study $Z_{\beta}=0.84$, and noise level data from Segaran et al. [7,8]. Calculations were performed for hospitals, schools, and residential areas, yielding an estimated minimum requirement of 12 sites (8 hospitals, 1 school, and 3 residential). A total of 15 sampling points were ultimately included to enhance spatial representation and improve data reliability.

Noise Measurements and Traffic Count

The primary instrument used to measure traffic noise levels was the Optimus Sound Level Meter (SLM) CR171B Class 1 (Cirrus, United Kingdom). To avoid interference, the SLM was calibrated according to manufacturer standards and placed 1.2 meters above ground on a tripod. It came with a weather-resistant microphone and a windscreen to ensure accurate outdoor measurements. Key noise parameters like LAeq (average noise level), Lmax (maximum), Lmin (minimum), L10, L90, and LCpeak were measured. Measurements were taken following the Malaysian DOE guidelines [10], during designated peak and non-peak hours for each land use category, and researchers exercised caution when operating near busy roads.

A pilot study was conducted at 25 potential sites to identify high-noise areas. Based on preliminary LAeq readings, 15 sites representing residential, institutional, and commercial zones were selected for the main study. This ensured that final sites captured the expected variability in traffic noise exposure. Actual field measurements were performed during designated peak and non-peak hours for residential, institutional, and commercial zones. Simultaneously, traffic density data were gathered manually with a tally counter. Vehicles were divided into three categories: motorcycles (2 wheels), passenger vehicles (4 wheels), and heavy vehicles (more than 4 wheels), with the count recorded during each noise monitoring session.

Statistical Analysis

The recorded noise metrics were subjected to statistical tests appropriate for the study objectives. A one-way ANOVA test was used to compare noise levels across land use categories. An independent samples t-test was used to compare noise levels during peak and non-peak periods. Furthermore, Pearson's correlation analysis was used to investigate the relationship between traffic volume and noise level. All statistical tests had a significance level of $\alpha = 0.05$. Measures were taken to address missing or inconsistent data, which could be caused by equipment failure or environmental interference (for example, rainfall). Instruments were calibrated before and after use, and faulty readings were replaced with new ones taken under similar conditions.

Every data inconsistency was documented to ensure transparency and dependability.

RESULTS

Average Traffic Noise Levels

Based on **Table I**, traffic noise levels in Bachok, Kelantan, showed significant variation across different land use types during both peak and non-peak hours. Among healthcare facilities, Klinik Kesihatan Beris Kubor Besar recorded the highest peak noise level at 74.0 ± 7.0 dB(A), indicating considerable exposure to road traffic noise. Although Hospital Bachok had a slightly lower peak value of 71.0 ± 4.4 dB(A), its smaller standard deviation suggests more consistent noise levels. Notably, during non-peak hours, both Klinik Kesihatan Beris Kubor Besar and Klinik Kesihatan Bachok maintained high noise levels at 72.9 ± 6.7 dB(A) and 72.1 ± 6.9 dB(A), respectively. While in the education sector, Sekolah Kebangsaan (SK) Jelawat recorded the highest average noise levels, with 75.6 ± 4.8 dB(A) during peak and 75.5 ± 5.3 dB(A) during non-peak hours. Other schools, such as Sekolah Menengah Kebangsaan (SMK) Bachok and SK Seri Kemudi, also exceeded the recommended limits, registering between 66.9 ± 6.8 dB(A) and 74.3 ± 7.8 dB(A).

Government offices in Bachok also experienced considerable noise exposure. Pejabat Tanah 1 showed the highest peak traffic noise level in this category at 76.0 ± 7.1 dB(A), while District Education Office (PPD) Bachok and Pejabat Tanah 2/ National Registration Department (JPN) followed closely with peak levels above 74.9 dB(A). Even during non-peak hours, these

sites maintained high noise levels, with PPD Bachok reaching 75.9 ± 7.5 dB(A). This suggests that government office areas are exposed to steady vehicular activity, which could affect employees' focus, comfort, and work performance.

Unexpectedly, residential areas also recorded high traffic noise levels. Kampung Jejawi had the highest peak noise level at 75.2 ± 6.2 dB(A) and also the highest non-peak reading at 75.8 ± 6.8 dB(A), surpassing even some school and hospital areas. Kampung Telok and Kampung Seneng reported lower levels but still exceeded the Department of Environment (DOE) residential limit. In commercial and recreational areas, Bandar Baru Jelawat recorded the highest overall traffic noise levels, with 77.4 ± 6.7 dB(A) during peak and 77.3 ± 7.4 dB(A) during non-peak hours. These values reflect constant vehicular movement and possibly commercial activity in the area. Bandar Lama Jelawat and Pantai Irama showed lower peak values at 72.9 ± 4.6 dB(A) and 69.2 ± 5.8 dB(A), respectively.

Comparison of Noise Levels Across Land Use Activities

Table II presents the comparison of average LAeq values across institutional, residential, and commercial locations during both peak and non-peak periods. During peak hours, the average LAeq ranged from 68.4 dB(A) at institutional sites to 69.2 dB(A) at commercial areas, with commercial zones recording the highest average. A one-way ANOVA test revealed a statistically significant difference in noise levels between location types ($F = 45.64$, $p < 0.001$). Similarly, during non-peak periods, institutional areas remained the quietest with an average LAeq of 67.2 dB(A), while residential areas recorded

Table I: Average traffic noise levels (LAeq) for peak and non-peak hours

Traffic Period	Mean $\pm$ SD LAeq (dB(A))									
	Hospital / Clinics		School		Government Office		Residential		Commercial	
Peak	Hospital Bachok	71.0 ± 4.4	SK Jelawat	75.6 ± 4.8	PPD Bachok	75.5 ± 6.8	Kg. Jejawi	75.2 ± 6.2	Bandar Jelawat (new)	77.4 ± 6.7
	K.K Bachok	69.4 ± 6.1	SMK Bachok	72.9 ± 7.2	Pejabat Tanah 1	76.0 ± 7.1	Kg. Telok	74.9 ± 8.0	Bandar Jelawat (old)	72.9 ± 4.6
	K.K Beris Kubor Besar	74.0 ± 7.0	SK Seri Kemudi	66.9 ± 6.8	Pejabat Tanah 2 / JPN	74.9 ± 6.0	Kg. Seneng	69.8 ± 6.6	Pantai Irama	69.2 ± 5.8
	Hospital Bachok	68.7 ± 5.7	SK Jelawat	75.5 ± 5.3	PPD Bachok	75.9 ± 7.5	Kg. Jejawi	75.8 ± 6.8	Bandar Jelawat (new)	77.3 ± 7.4
Non-Peak	K.K Bachok	72.1 ± 6.9	SMK Bachok	74.3 ± 7.8	Pejabat Tanah 1	74.7 ± 7.3	Kg. Telok	73.9 ± 6.9	Bandar Jelawat (old)	72.6 ± 4.6
	K.K Beris Kubor Besar	72.9 ± 6.7	SK Seri Kemudi	66.9 ± 6.9	Pejabat Tanah 2 / JPN	72.7 ± 7.2	Kg. Seneng	70.5 ± 7.0	Pantai Irama	69.0 ± 6.0
DOE Limit	60.0		60.0		65.0		60.0-65.0		70.0	

SD: standard deviation; Kg.: Kampung (village); K.K.: Klinik Kesihatan; PPD: Pejabat Pendidikan Daerah; SK: Sekolah Kebangsaan; SMK: Sekolah Menengah Kebangsaan; DOE: Department of Environment

the highest at 68.8 dBA. Again, the differences between location types were statistically significant ($F = 264.29$, $p < 0.001$), indicating that land use type significantly affects ambient noise levels during both periods.

Table II: Difference of noise level between locations

Traffic Period	Location	Mean $\pm$ SD LAeq (dBA)	F	p-value
Peak	Residential	68.4 $\pm$ 7.6	45.6	<0.001
	Institutional	68.4 $\pm$ 7.2		
	Commercial	69.2 $\pm$ 6.6		
Non-Peak	Residential	68.8 $\pm$ 7.5	264.3	<0.001
	Institutional	67.2 $\pm$ 7.6		
	Commercial	68.6 $\pm$ 6.9		

Significant at $p < 0.05$; Statistical test: One-Way ANOVA

Comparison of Noise Levels Between Peak and Non-Peak Hours

Table III shows that the average LAeq during peak hours was 68.6 dB(A) with a standard deviation of 7.2 dB(A), while during non-peak hours, the average LAeq dropped slightly to 67.8 dBA with a standard deviation of 7.5 dB(A). The mean difference of 0.8 dB(A) between these two periods was found to be statistically significant ($p < 0.001$), indicating a reliable increase in traffic noise levels during peak hours.

Table III: Difference of noise levels between peak and non-peak hours

Traffic hours	Mean $\pm$ SD LAeq (dBA)	Mean Difference (dBA)	p-value
Peak	68.6 $\pm$ 7.2	0.8	<0.001
Non-Peak	67.8 $\pm$ 7.5		

Significant at $p < 0.05$; Statistical test: Independent t-test; SD: standard deviation

Correlation Between Traffic Volume and Noise Levels by Vehicle Type

As shown in Table IV, the analysis revealed varying degrees of correlation between traffic volume and equivalent noise levels (LAeq) across different vehicle types during both peak and non-peak hours. During peak hours, a strong positive correlation was observed between LAeq and the number of two-wheeled vehicles ($r = 0.657$, $p = 0.008$), indicating that motorcycles significantly contribute to noise levels in high-traffic periods. An even stronger relationship was found with four-wheeled vehicles ($r = 0.912$, $p < 0.001$), suggesting that cars and light trucks are the most dominant source of road traffic noise during peak hours. In contrast, vehicles with more than four wheels (e.g., buses, lorries) demonstrated a statistically non-significant correlation ($r = 0.266$, $p = 0.338$).

In non-peak hours, the pattern shifted slightly. All vehicle categories showed a statistically significant positive correlation with LAeq, reflecting their combined contribution to baseline noise even in lighter traffic

Table IV: Correlation Between Noise and Traffic Volume for Each Vehicle

LAeq; Traffic Period	Type of Vehicle	Traffic Count	
		r	p-value
Peak	2-wheels	0.657	0.008
	4-wheels	0.912	<0.001
	>4-wheels	0.266	0.338
Non-Peak	2-wheels	0.795	<0.001
	4-wheels	0.876	<0.001
	>4-wheels	0.613	0.015

Significant at $p < 0.05$; Statistical test: Pearson Correlation test; r: correlation coefficient

conditions. Two-wheeled vehicles maintained a strong correlation ($r = 0.795$, $p < 0.001$), while four-wheeled vehicles again showed a very strong correlation ($r = 0.876$, $p < 0.001$), consistent with their prevalence on the road. Interestingly, vehicles with more than four wheels now exhibited a moderate and statistically significant correlation ($r = 0.613$, $p = 0.015$), suggesting that their impact on noise levels becomes more apparent when the background noise from smaller vehicles is reduced.

DISCUSSION

Traffic Noise Levels and Compliance

The peak noise levels at Klinik Kesihatan Beris Kubor Besar, at Hospital Bachok and their elevated non-peak levels significantly exceeded the DOE noise limits of 60.0 dB(A) for healthcare areas. Rather than reflecting isolated peak-hour effects, these elevated levels indicate sustained exposure to traffic noise throughout the day, suggesting that patients and healthcare workers may experience prolonged auditory stress. Similar exceedances were also reported in Selangor hospitals, where ambient noise often surpassed these thresholds even within designated quiet zones [11]. From a public health perspective, continuous exposure to elevated traffic noise may contribute to sleep disturbance, increased stress levels, and delayed recovery among patients, while also affecting staff concentration and performance [12].

The reported noise averages at school and government offices were found to exceed Malaysia's DOE daytime limits for institutional zones. These findings were consistent with recent Malaysian measurements near schools where LAeq values of around 76 dB(A) were recorded along federal roads [13]. Sustained road-traffic noise at schools has been linked to slower development of working memory and attention, as well as poorer reading and behavioural outcomes among pupils [4]. These findings reinforce the need for noise-sensitive planning around educational facilities, including traffic diversion, buffer zones, and enforcement of speed limits during school hours. Persistent exposure to such levels has been also reported to increase annoyance and reduced productivity in office environments [14]. The World Health Organisation (WHO) [15] recommends

guideline limits for road traffic noise exposure of below 53 dB Lden for average day–evening–night levels and below 45 dB Lnight for night-time noise to minimise adverse health effects. These guidelines are based on Lden and Lnight indicators that integrate day–evening–night and nocturnal noise exposure with penalty weightings. In contrast, the present study measured daytime traffic noise using the LAeq metric. Therefore, direct comparison with the WHO guidelines was not methodologically applicable. Nevertheless, the traffic noise levels recorded in Bachok were substantially higher than the WHO recommended thresholds, indicating that the study area experiences noise exposure levels of potential public health concern [16]. Accordingly, interpretation of the findings was based on the Malaysian Department of Environment (DOE) guideline limits, which are consistent with the study design.

The unexpected high traffic noise levels recorded in residential zones such as Kampung Jejawi exceeded the DOE's residential limits and were comparable to those reported in other Malaysian towns such as in Batu Pahat, Johor [8]. Prolonged exposure in residential areas is linked to adverse health outcomes such as sleep disturbances, mental stress, and increased risk of cardiovascular diseases [17]. This current study reported exceedance of Malaysian DOE daytime limits for mixed-use zones as recorded in Bandar Baru Jelawat were found similarly reported in commercial areas along Jalan Kluang, where all measured sites surpassed permissible limits [7]. The persistence of elevated noise levels in residential settings indicates that current land-use separation and road design measures may be insufficient to protect community health, particularly in semi-urban districts undergoing development.

Comparison of Noise Levels Between Land Use Activities

During peak hours, commercial zones had significantly higher noise levels, largely due to heavy vehicle activity and human presence. For example, Pasar Besar Siti Aisyah in Jelawat experiences intense congestion during its operating hours in the morning and noon, leading to a buildup of noise. High customer inflow during breakfast and lunch further contributes to elevated noise levels. Similarly, Bandar Baru Jelawat, home to commercial outlets such as Mr. DIY, local pharmacies, and Pantai Timur Shopping Centre, experiences frequent traffic congestion.

In Bandar Lama Jelawat, elevated noise levels can be attributed to old, modified vehicles, poorly maintained and narrow roads, and limited pedestrian infrastructure, all of which increase vehicular friction and noise. These conditions mirror those observed in Jagiroad Town, Assam, where poorly planned commercial development without adherence to land use guidelines contributed to excessive ambient noise. This aligns with findings by Halim et al. [18], who reported that areas with dense

commercial activity, continuous human movement, and high vehicle flow tend to experience significantly higher noise levels.

Noise distribution during non-peak hours displayed a different pattern. Institutional zones were the quietest due to reduced traffic and fewer activities around schools and public facilities. Traffic in these areas is usually transitory, with limited stopping or idling, which lowers overall noise. Residential areas, however, maintained moderate noise levels, partly due to their proximity to roadways and the presence of roadside vendors or small shops that attract short-term vehicle stops. These dynamics expose residents to persistent traffic noise, even outside rush hours.

Interestingly, the comparison between residential and commercial zones during non-peak periods revealed no statistically significant difference in LAeq values. This suggests that both environments sustain relatively similar noise levels. In commercial zones, noise persists due to background activity and business operations, while residential zones experience occasional spikes caused by specific activities such as deliveries, vendor operations, or community events. This pattern is consistent with findings from the Klang Valley, where Halim et al. [19] found that night-time LAeq values in some urban areas could remain as high as 70–75 dB(A), indicating that non-peak hours do not always equate to low-noise conditions.

Overall, these findings highlight how land use type influences noise exposure levels throughout the day. Effective noise mitigation therefore requires land-use-specific interventions rather than a uniform control strategy, particularly in commercial and residential environments.

Comparison of Traffic Noise Levels Between Peak and Non-Peak Hours

This finding is consistent with expectations, as peak periods typically involve increased vehicular traffic, frequent acceleration and braking, and congestion, all of which contribute to higher noise emissions. The higher noise levels during peak times may be linked to the concentration of school, work, and business commutes, especially in areas close to schools, markets, and commercial centers. Conversely, the slight reduction in noise during non-peak hours reflects reduced traffic flow and smoother vehicle movement. However, the relatively small difference in mean LAeq also suggests that noise pollution is a persistent issue even during off-peak times, likely due to continuous background traffic, deliveries, and community-level activities. This suggests that noise mitigation strategies should be applied continuously rather than being limited to peak traffic hours, especially in sensitive areas such as schools, hospitals and residential neighbourhoods.

These findings align with previous studies conducted in urban and suburban Malaysian settings, where noise levels remain elevated throughout the day, often exceeding safe thresholds even during periods of lower activity [20-24]. From a public health perspective, the data highlight the need for consistent noise management strategies, not only during high-traffic times but throughout the day, particularly in sensitive zones such as schools, hospitals, and residential neighbourhoods. Interventions such as traffic calming measures, zoning regulations, and improved urban planning may help reduce overall noise exposure and its associated health impacts.

Correlation Between Traffic Count and Traffic Noise Levels

Cars, vans, and small lorries were identified as the primary sources of traffic noise during both peak and non-peak periods. The influence of heavy vehicles, however, became more apparent in areas with lighter traffic conditions where their contribution to overall noise levels was more pronounced. The relatively weaker correlation between four-wheeled vehicles and noise levels in congested areas may be attributed to their lower engine frequency or the presence of more effective noise suppression systems. Nourani et al. [25] highlighted total traffic volume as the primary determinant of road traffic noise, while Ruškić et al. [26] found that heavier vehicles, particularly buses, contributed significantly to noise levels during periods of reduced traffic. This highlights the importance of considering vehicle type and traffic composition when developing targeted noise mitigation strategies, especially in sensitive areas such as residential zones, schools, and healthcare facilities.

Study Limitations

One of the primary limitations of this study is the influence of weather conditions, particularly heavy rain, during specific measurement periods. The measurement of road traffic noise is impeded by the background noise produced by the sound of falling rain, resulting in readings that may not exclusively reflect vehicle-related sources. To minimise this effect, noise measurements were conducted only during periods of light or no rainfall, and measurements were temporarily paused during heavy rain events. Wet road surfaces might influence the sound produced by moving vehicles, particularly tire-road interaction noise. Measurements were therefore standardised across sites by maintaining consistent measurement duration and microphone positioning.

Secondly, the typical noise profile is influenced by heavy rain, which can result in a decrease in the volume of traffic and a reduction in the speed of vehicles, especially two-wheeled vehicles. To account for this, traffic volume was recorded simultaneously with noise measurements, allowing observed noise levels to be interpreted in relation to actual traffic conditions at the

time of measurement. Moreover, this study was unable to capture the full scope of temporal variations in traffic noise over a 24-hour period. Traffic noise levels typically fluctuate between day and night in response to changes in traffic volume and activity patterns. Nevertheless, due to time constraints and logistical limitations, a short-term measurement approach was adopted. This approach is consistent with similar environmental noise studies and remains suitable for comparative assessment between peak and non-peak traffic periods.

CONCLUSION

This study highlighted that traffic noise in Bachok varies across land-use types, with commercial zones and government offices experiencing the highest exposures. Many measured LAeq values exceeded DOE guidelines and international standard, suggesting potential health risks for nearby populations. The association between traffic volume, particularly four-wheeled vehicles, and noise levels emphasises the need for targeted management strategies.

Several practical measures are recommended such as traffic calming and speed limits near sensitive zones, buffer zones between major roads and vulnerable areas, installation of noise barriers, use of low-noise road surfaces, and regular monitoring to ensure compliance with DOE and international standards. Implementing these strategies can support healthier, quieter, and more sustainable urban environments.

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REFERENCES

1. Magiera M, Solecka K. Influence of traffic noise on urban environment. *Sustainability*, 2021;13(5):2495.
2. Kedri FK, Ahamed FNN, Sukri NS, Christianus I. Assessment of traffic noise pollution at residential and school areas in Jeli, Kelantan. *BIO Web of Conferences*, 2023;73. <https://doi.org/10.1051/bioconf/20237305024>
3. Bello JP, Silva C, Nov O, Luke DR, Arora A Salamon J, Mydlarz C, Doraiswamy H, Sony C. A system for monitoring, analyzing, and mitigating urban noise pollution. *Communications of the ACM*, 2019;62(2).

<https://doi.org/10.1145/3224204>

4. Foraster M., et al. Exposure to road traffic noise and cognitive development in children. *Environmental Health Perspectives*, 2022;130(1):017004.
5. Moreira SJ, Fonseca-Zang WAD, Bolina C. de C, Rocha SA, Zannin PHT. Road traffic noise assessment in a hospital area in Umuarama - Brazil. *Revista Nacional de Gerenciamento de Cidades*, 2021;9(74). <https://doi.org/10.17271/2318847297420213027>
6. Lan Z, Yuan M, Shao S, Li F. Noise Emission Models of Electric Vehicles Considering Speed, Acceleration, and Motion State. *International Journal of Environmental Research and Public Health*, 2023;20(4). <https://doi.org/10.3390/ijerph20043531>
7. Segaran VC, Tong YG, Abas NH, Azni NI, Zairuddin MA. Assessment of traffic noise pollutions outside school, residential, hospital and commercial areas along Jalan Kluang, Batu Pahat, Johor. *The International Journal of Integrated Engineering*, 2019;11(9):123-31. <https://doi.org/10.30880/ijie.2019.11.09.014>
8. Segaran VC, Tong YG, Abas NH, David DB, Nagapan S, Kelundapyan R. Traffic noise assessment among residential environment in Batu Pahat, Johore, Malaysia. *IOP Conference Series: Materials Science and Engineering*, 2020;713(1). <https://doi.org/10.1088/1757-899X/713/1/012049>
9. Suursen M, Hvidberg M, Hoffmann B, Andersen ZJ, Nordsborg RB, Lillelund KG, Jakobsen J, Tjønneland A, Overvad K, Raaschou-Nielsen O. Exposure to road traffic and railway noise and associations with blood pressure and self-reported hypertension: A cohort study. *Environmental Health: A Global Access Science Source*, 2011;10(1). <https://doi.org/10.1186/1476-069X-10-92>
10. Department of Environment (DOE). *Guidelines For Environmental Noise Limits and Control*. 3rd Ed. Putrajaya: Department of Environment, Ministry of Energy, Science, Technology, Environment and Climate Change (MESTECC); 2019.
11. Yusma HMN, Wan Zuriea WI, Alamah M, Hasnizan A. Assessing environmental noise pollution around public hospitals in Selangor, Malaysia: Implications for urban planning. *Journal of the Malaysian Institute of Planners*. 2024;22(6):129-43.
12. Zhang J, Lim YH, Napolitano GM, Backalarz C, Mortensen LH, Cole-Hunter T, Tuffier S, Bergmann M, So R, Brandt J, Ketzel M, Loft S, Andersen ZJ. Long-term exposure to road traffic noise and acute lower respiratory infections in the Danish Nurse Cohort. *Environment International*, 2024;190. <https://doi.org/10.1016/j.envint.2024.108842>
13. Nayan N, Hashim M, Saleh Y, Mahat H, Luyan MH, Juanis J, Khotimah N. School traffic noise pollution levels along federal roads in muslim district, Perak, Malaysia. *IOP Conf. Series: Earth and Environmental Science*. 2022;975:012009. doi:10.1088/1755-1315/975/1/012009
14. Yu B, Chai Y, Wang C. Effect of the exterior traffic noise on the sound environment evaluation in office spaces with different interior noise conditions. *Appl. Sci.* 2024;14:3017. <https://doi.org/10.3390/app14073017>
15. World Health Organisation (WHO). *Environmental noise guidelines for the European Region*. Copenhagen: WHO; 2018.
16. Chen X, Mingliang L, Zuo L, Wu X, Chen M, Li X, et al. Environmental noise exposure and health outcomes: an umbrella review of systematic reviews and meta-analysis. *European Journal of Public Health*, 2023; 33(4): 725-31. <https://doi.org/10.1093/eurpub/ckad044>
17. Cerletti P, Eze IC, Schaffner E, Foraster M, Viennau D, Cajochen C, Wunderli JM, Ruusli M, Stolz D, Pons M, Imboden M, Probst-Hensch N. The independent association of source-specific transportation noise exposure, noise annoyance and noise sensitivity with health-related quality of life. *Environment International*, 2020; 143. <https://doi.org/10.1016/j.envint.2020.105960>
18. Halim H, Hamid NFN, Yusob MFM, Nor NAM, Hilmi NHFM, Sukor NSA, Rahman NA, Haron Z, Wahab F. Road traffic noise levels at different types of residential areas in Nibong Tebal, Penang. *International Journal of Integrated Engineering*, 2019;11(1):101–112. <https://doi.org/10.30880/ijie.2019.11.01.013>
19. Halim H, Abdullah R, Nor MJM, Aziz HA, Rahman NA. Assessment of road traffic noise indices in urban residential areas of Klang Valley, Malaysia. *AIP Conference Proceedings*, 2017;1892. <https://doi.org/10.1063/1.5005682>
20. Murally T, Daud Z. Analysis of traffic noise pollution at school area that located in Gemencheh town, Negeri Sembilan. *Journal of Advancement in Environmental Solution and Resource Recovery*, 2022; 2(2): 44-55. <https://doi.org/10.30880/jaesrr.2022.02.02.006>
21. Wen HR, Mat Tahir MF, Ariffin A, Mohd Rasani MR, Meor Ahmad MI, Nuawi MZ. Assessing the levels of traffic noise in selected schools in Bandar Baru Bangi. *Jurnal Kejuruteraan*, 2023; 35(5): 1239-47. *Jurnal Kejuruteraan*, 35(5); 2023: 1239-1247. [https://doi.org/10.17576/jkukm-2023-35\(5\)-23](https://doi.org/10.17576/jkukm-2023-35(5)-23)
22. Mohd Nasir YH, Wan Ismail WZ, Misni A, Aksah H. Assessing environmental noise pollution around public hospitals in Selangor, Malaysia: Implications for urban planning. *Journal of the Malaysian Institute of Planners*, 2024; 22(6): 129-43.
23. Ahmad A, Maharani RA, Muhammad M, Jauhari ML, Ismail ZS. Comparison of traffic noise attribute factors and noise level assessment between residential and industrial areas. *paperASIA*, 2025; 41(3b): 245-57. Doi: <https://doi.org/10.59953/paperasia.v41i3b.489>
24. Hong TW, Nee SKY, Singh A, Teoh CY, Nazaruddin

- MSK. Comprehensive measurement and analysis of traffic noise along the Changlun-Kuala Perlis Highway. *International Journal of Integrated Engineering*, 2025; 17(1): 72-80. DOI: <https://doi.org/10.30880/ijie.2025.17.01.006>
25. Nourani V, Gukækuş H, Umar IK, Najafi H. An emotional artificial neural network for prediction of vehicular traffic noise. *Science of the Total Environment*, 2020;707. <https://doi.org/10.1016/j.scitotenv.2019.136134>
26. Ruskić N, Mirović V, Marić M, Pezo L, Lončar B, Nićetin M, Ćurčić L. Model for Determining Noise Level Depending on Traffic Volume at Intersections. *Sustainability (Switzerland)*, 2022;14(19). <https://doi.org/10.3390/su141912443>