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NOISE INDUCED BY RAILWAY TRAFFIC AT RESIDENTIAL AREA CONTRIBUTE TO HUMAN ANNOYANCE

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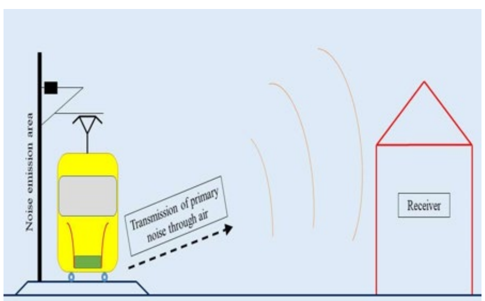
Graphical abstract



Abstract

The expansion of the railway industry in Malaysia has brought about numerous benefits, including improved transportation and reduced traffic congestion. However, the increased presence of railway systems has also resulted in the issue of noise pollution caused by moving trains, negatively impacting the well-being of nearby residents. This study aims to explore the correlation between permitted noise limits and actual noise levels produced by trains near residential areas in Malaysia. The findings indicate that the measured noise levels exceeded the allowable limits set by the Department of Environment (DOE) guidelines. Additionally, the study revealed significant correlations between various variables and the magnitude of noise emissions generated by moving trains. These findings highlight the need for effective noise mitigation strategies and further research to address the concerns of residents living near railway tracks. The results contribute to a better understanding of the impact of railway noise on communities and provide valuable insights for future noise management initiatives in the Malaysian railway industry.

Keywords: Railway noise, noise pollution, human annoyance, residential area, allowable limit

Abstrak

Perkembangan industri kereta api di Malaysia telah membawa banyak manfaat, termasuk peningkatan sistem pengangkutan dan pengurangan kesesakan lalu lintas. Namun, peningkatan kehadiran sistem kereta api juga menyebabkan isu pencemaran bunyi yang dihasilkan oleh pergerakan kereta api, yang memberi kesan negatif kepada kesejahteraan penduduk berhampiran. Kajian ini bertujuan untuk meneroka hubungan antara had bunyi yang dibenarkan dengan tahap bunyi sebenar yang dihasilkan oleh kereta api berhampiran kawasan perumahan di Malaysia. Penemuan kajian menunjukkan bahawa tahap bunyi yang diukur melebihi had yang dibenarkan oleh garis panduan Jabatan Alam Sekitar (DOE). Selain itu, kajian ini turut mendedahkan terdapat hubungan yang signifikan antara pelbagai pembolehubah dengan magnitud bunyi yang dihasilkan oleh pergerakan kereta api. Penemuan ini menekankan keperluan untuk strategi mitigasi bunyi yang berkesan dan kajian lanjut untuk menangani kebimbangan penduduk yang tinggal berhampiran landasan kereta api. Hasil kajian ini menyumbang kepada pemahaman yang lebih baik mengenai kesan bunyi kereta api terhadap komuniti dan memberikan pandangan yang berguna untuk inisiatif pengurusan bunyi pada masa hadapan dalam industri kereta api di Malaysia.

Kata kunci: Bunyi kereta api, pencemaran bunyi, gangguan manusia, kawasan perumahan, had yang dibenarkan

1.0 INTRODUCTION

The railway industry in Malaysia is experiencing significant growth, particularly in major cities like Kuala Lumpur, with extensive construction work underway. The development of the railway system aims to promote public transportation as an alternative to road transport, thereby reducing traffic congestion. Research by Aziz *et al*. [1] supports the idea that railways can help alleviate city traffic congestion. Malaysia has various types of rail transportation, including heavy rail, light rapid transit, monorail, airport rail link, and a funicular railway line. Light Rapid Transits serves urban public transport needs, while heavy rail is used for intercity passenger and freight transit. However, the railway system also poses challenges, such as noise pollution caused by moving trains, affecting the well-being of the community [2]. Concerns about the negative impact of railway noise on residents have prompted studies on the correlation between permitted noise limits and actual noise levels produced by trains near residential areas. Rail infrastructure has been expanding globally, including Malaysia, leading to increased public awareness of noise and stricter standards for allowable noise exposure. The main source of railroad noise is the wheel-rail interface, which can cause disturbance and negatively impact the quality of life for those living near railways. Arbaan *et al*. [3] highlight the disruptive nature of train noise for residents living near railway tracks in Malaysia. Complaints from residents often revolve around noise pollution, particularly from train horns at urban crossings [4]. Trains are ranked as the second most significant source of environmental noise, with millions of individuals exposed to noise levels exceeding the recommended thresholds[5]. Lack of sleep due to railway noise has linked to psychological disturbances and potential health issues among Malaysian residents [6]. Vincens & Persson Waye [7] emphasize the health risks associated with rail traffic noise, including cognitive impairment, daytime drowsiness, and sleep disruption. Communication disruption is a frequently reported annoyance reaction, along with other noise sources such as brake noise, horn whistles, and curve squeals [8]. These factors contribute to the overall annoyance experienced by the local population living near railway tracks. This research aims to correlate the empirical noise produced on operating railways with the Department of Environment (DOE), Malaysia guideline regarding human response and annoyance. In addition, this study aims to identify the noise levels in accordance to the variables subjected to the moving train.

1.1 Source of Noise

The issue of railway noise involves various sources and mechanisms addressing it, which is essential for the well-being of residents living near rail lines. Rolling noise is generated by the interaction between train wheels and the track surface, with higher speeds amplifying the noise levels. Another significant source of train noise is aerodynamic noise, which arises from pressure differences during train movement and becomes increasingly prominent at higher speeds. Research investigated the effects of train speed, distance from housing, train type, and marshaling length on aerodynamic pressure in high-speed railways [9]. They found that higher speeds and shorter distances increase wind loads, with sensitivity to speed rising as distance decreases [10]. Train motion also creates unstable pressure fields [11]. The noise generated influenced by train speed and the distance between the tracks and nearby communities [12]. Trains traveling at higher speeds produce elevated noise levels due to intensified wheel-rail interactions and mechanical vibrations. The distance between railway tracks and residential areas also critical role in noise propagation. Residents living near tracks where trains operate at maximum speeds may experience noise levels exceeding 70 dB(A), surpassing the recommended standards of 70 dB or lower for predominantly residential areas and 75 dB or lower for other zones [13]. These thresholds are to prevent sleep disturbances and reduce annoyance[14].

1.2 Propagation of Sound Wave

The propagation of railway noise influenced by the typical arrangement of noise sources on a moving train. The primary contributor to railway noise is often the train wheels, which exhibit complex, frequency-dependent directivity patterns and do not distribute sound evenly in all directions [15]. Atmospheric conditions, including air temperature, relative humidity, wind speed, and direction, can also influence noise propagation and result in variations in noise levels [16].

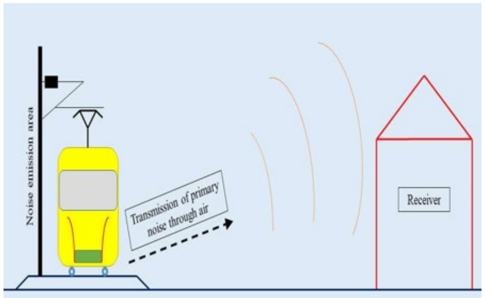


Figure 1 Rail noise propagation

1.2 Receiver of Noise from Railway Traffic

Homeowners living near railways are also affected by noise pollution, which disrupts their relaxation and sleep, leading to a decline in their quality of life [4]. According to study by researcher, workers who commute by train are among the recipients of noise pollution caused by the railway system [17]. In Vienna, more than 80% of the residents, including those working day and night, are exposed to noise levels exceeding the allowable limit. Another study by Arbaan *et al*. supports these findings, stating that residents living near railway tracks may experience interference with their rest due to the noise generated by trains [3].

Table 1 Survey on how noise induced by railway affects nearby neighbourhood in Curitiba, Brazil [4]

Effects of health and life quality	YES (%)	NO (%)
Bothersome towards daily life	84	15
Contribute to health issues	98	2
Irritation and Annoyance	92	8
Poor concentration	86	13
Headaches	59	39

1.3 Allowable Noise Limit

The DOE, Malaysia sets noise regulations for railways near urban and residential areas, with allowable equivalent sound levels (LAeq) of 65 dBA during the day and 60 dBA at night, and a maximum allowable level (Lmax) below 80 dBA. In Lithuania, the hygiene standard HN 33:2007 specifies maximum noise levels of 70 dBA during the day, 65 dBA in the evening, and 60 dBA at night, with allowable equivalent levels (LAeq) of 65 dBA, 60 dBA, and 55 dBA respectively. France permits LAeq levels of 63 dBA during the day and 58 dBA at night, with a maximum average noise level (Lden) of 73 dBA. Indonesia sets the maximum noise level for residential areas at 55 dBA, and Vietnam has limitations of 75 dBA, 70 dBA, and 50 dBA during the day, evening, and night respectively.

1.5 Type of Train

According to Shahidan *et al*. [2], intercity diesel and freight trains are known for producing high noise levels. At the same time, heavy rail train and intercity higher speed train have lower noise levels than to diesel trains. High-speed trains, such as the Shinkansen in Japan, generate substantial noise and be as irritating as airplane noise, or even worse than typical railway noise. Paozalyte *et al*. found that passing passenger trains measured an average equivalent noise level of 76 dBA at a distance of 7.5 meters from the tracks, while passing freight trains measured between 74-75 dBA [18]. At a distance of 20 meters, passing passenger trains measured 75 dBA, and passing freight trains measured 70-72 dBA, indicating that passenger trains produce slightly louder noise than freight trains. According to D. J. Thompson *et al*., as the speed of trains increases, the noise emissions also increase, with rolling noise and aerodynamic noise being the primary sources [19]. Rolling noise, caused by the interaction of wheels and rails, and aerodynamic noise, resulting from the flow of air over the train components, contribute to the overall noise emissions. Research has shown that the sound power generated by rolling noise increases with train speed. Similarly, Shao *et al*. [20] found that heavy-haul trains exhibit a gradual increase in radiated noise as their speed increases. This research establishes a direct relationship between train speed and the noise level produced.

2.0 METHODOLOGY

The study focuses on the Klang Valley region, as illustrated in Figure 2 that is Selangor Map, with specific attention to Serdang and Ampang. Field studies conducted at two distinct railway locations in the southern urban areas of Klang Valley, both situated near residential neighborhoods. These locations selected due to the rapid development of railway infrastructure and associated concerns about potential impacts on nearby residential communities. The first site, situated in Serdang neighborhood depicted in Figures 3 a) Desa Serdang and b) Jalan Telaga Hijau, features a high-speed train system. The second site, Ampang shown in Figure 3 c) Jalan Pinggiran Cempaka, serves as hub for light rapid transit operations. Here, the railway track is as close as 20 meters to residential properties, directly exposing local residents to potential noise from railway traffic. The high-speed train site featured two measurement points for each locations, while the light rapid transit site for one location included four points. This difference is due to the proximity of the light rapid transit tracks to multiple residential areas, requiring a more detailed noise analysis. These sites provide an ideal setting to investigate railway-induced noise's effects on urban communities.

Figure 2 Selangor Maps

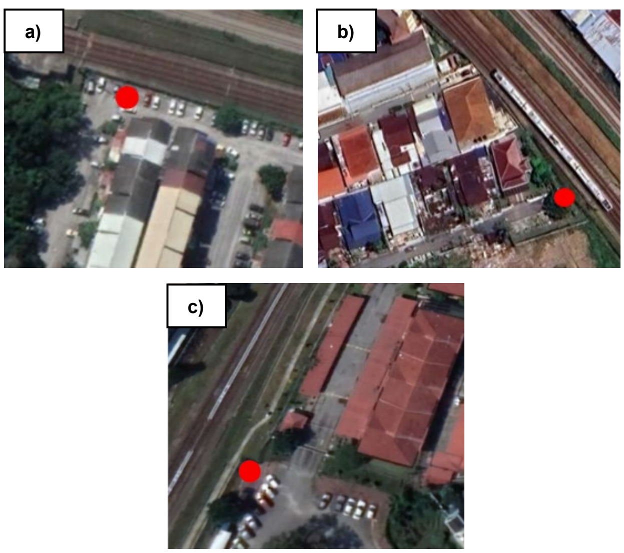


Figure 3 a) High Speed Train Location 1: Desa Serdang, Serdang b) High Speed Train Location 2 Jalan Telaga Hijau, Serdang b) Light Rapid Train Location 1 and 2: Jalan Pinggiran Cempaka, Ampang

The noise levels of moving trains recorded using a Sound Level Meter (SLM). The readings were adjusted to A-weighted values (dBA) to capture noise frequencies sensitive to human hearing and to ensure the validity of the data for the study's purposes. Figure 4 illustrates the data collection methodology, including the setup of noise level meters at two designated measurement points.

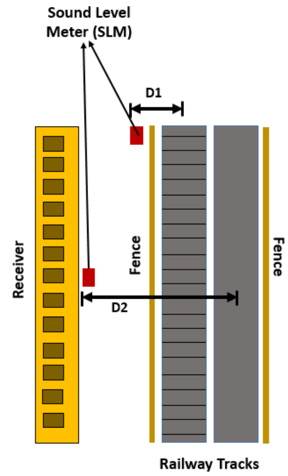


Figure 4 Data collection method

The SLM, represented by red squares, were strategically positioned at specific distances to accurately measure noise levels. The first measurement point, distance 1 (D1), represents the gap between the sound level meter and the railway fence on the right side of the railway track. The second measurement point, distance 2 (D2), measures the distance between the sound level meter near the receiver and the railway track on the left side. Here, the receiver symbolizes a nearby residential area or another noise-sensitive location. Each SLM was mounted on a tripod 1.5 meters above the ground and angled at 45° from the horizontal plane, as shown in Figure 5a. Data collected at each site during peak and non-peak hours of train operation. In the morning, two sessions peak hour for data collection were carried out, each lasting two hours. For high-speed trains, measurements taken at locations 1: D1 at 4.5 meters and 2: D1 at 7 meters. For light rapid transit (LRT) trains, measurements taken at location 1 and 2: D1 at 7.8 meters and D1 at 12 meters. The first session covered peak hours from 7:00 AM to 9:00 AM, while the second session captured non-peak hours from 10:00 AM to 12:00 PM, as shown in the setup depicted in Figure 5b. In the evening, the same procedures were repeated near the residential area (receiver), as illustrated in Figure 5c. For high-speed trains, measurements at location 1: D2 at 10 meters and location 2: D2 at 14 meters, while for LRT trains, measurements recorded at locations 1 and 2: D1 at 12.8 meters and D2 at 16.8 meters. The third session took place during non-peak hours from 2:00 PM to 4:00 PM, and the final session, representing peak hours, occurred from 5:00 PM to 7:00 PM. Figure 6 highlights additional measurement processes: (a) train speed measured using a laser radar gun, (b) distance measured using a laser meter, and (c) humidity and temperature recorded with a portable detector.

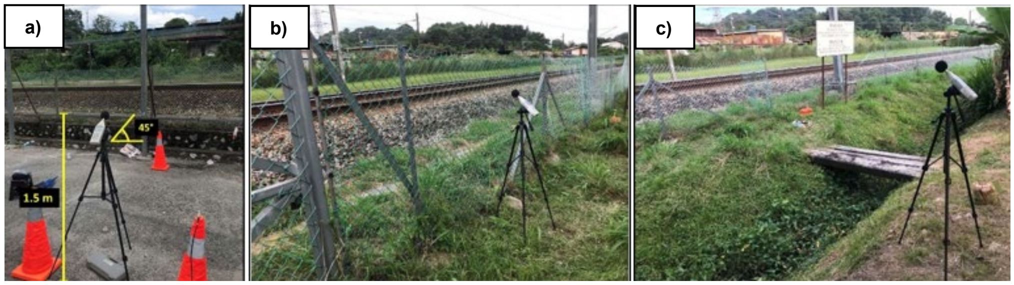


Figure 5 (a) SLM setup (b) SLM at D1 (c) SLM at D2 near residential area

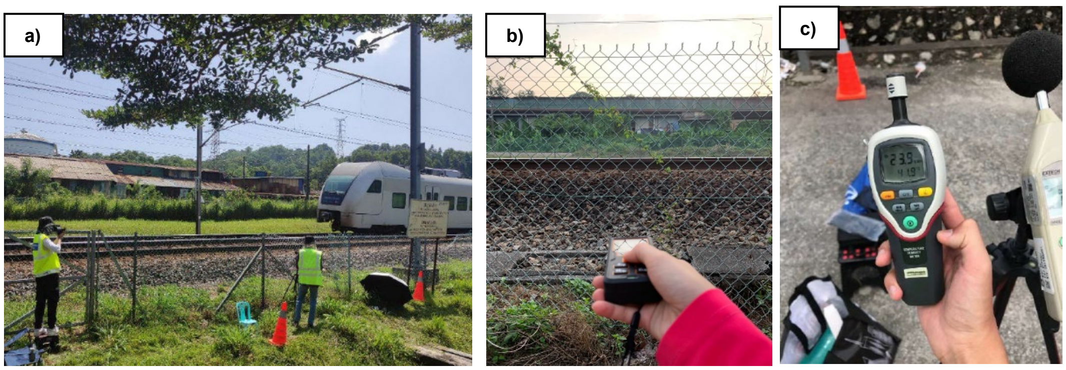


Figure 6 (a) Measured speed train using laser radar gun (b) Measured distance from residential to fence and railway track using laser meter c) Measured humidity and temperature

3.0 RESULTS AND DISCUSSION

The data collected through field measurements and recordings were meticulously analyzed using the statistical software, Statistical Package for the Social Sciences (IBM SPSS 27). The primary aim of this part was to provide a comprehensive understanding of the obtained data and identify significant patterns which may contribute to the noise levels. The statistical output or results were used to correlate empirical values obtain with the guideline from DOE, Malaysia in accordance to the noise level limit toward human annoyance. On top of that, from the analysis relationship between the variables tested and the noise level produced by moving train are obtained. Hence acquiring the most significance variables that contribute to higher noise emission.

3.1 Descriptive Analysis

The total sample is (N: 256), for high speed train (N: 128) and light rapid train (N: 128). Descriptive analysis entails calculating and summarizing numerous statistics to comprehensively describe the dataset's properties. Based on Table 2, it showed data properties comprising minimums, maximums means, standard deviations, skewness and kurtosis of the whole dataset. The main focus here is the value for skewness and kurtosis with regarding to the noise level produced by moving trains. These value are the indicators to ascertain that the data acquired normally distributed. According to Kim, a reference of substantial departure from normality as an absolute skew is value > 2 whereas a reference of substantial departure from normality as an absolute kurtosis is value > 7 [21]. Hence, the normality of noise levels data acquired from site is verified. Based on Table 3, it shows how significant the variables tested towards noise levels produced by moving train. For column with double "**" annotation, the p-value or "Sig.(2-tailed)" should be below 0.01 for it to indicate a significant correlation whereas for single "*" annotation, p-value or "Sig.(2-tailed)" below 0.05 refers to significant correlation. Based on the p-value depicted from the figure, speed, distance of SLM to railway track, type of train, humidity, wind and temperature shows a significant correlation towards noise levels. This results in these variables having major influence towards the emission of noise from the moving train

Table 2 Descriptive statistics of the empirical data

	Minimu m	Maximum	Mean		Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Std. Error	Statistic	Std. Error
Noise Level, dBA	76.60	94.00	84.020	.27945	4.47123	0.000	.152	-. 209	.303
Speed,. km/h	23	151	106.47	2.727	43.720	-.500	.152	-1.599	.303
Distance, m	4.8	16.7	10.423	.2234	3.5253	.057	.152	-.789	.307
Time Operation	1	2	1.44	.031	.497	.260	.152	-1.947	.303
Type of Train	1	2	1.40	.031	.490	.424	.152	-1.835	.303
Humidity, %RH	28.3	52.3	38.773	.5454	8.7436	.407	.152	-1.489	.303
Temperature,° C	28.3	43.0	35.503	.3458	5. 5432	-.414	.152	-1158	.303
Speed (km/h)	.12	3.90	1.411	0.0374	.8471	.941	.291	.569	.574

Table 3 Pearson's Correlations regarding variables and noise levels produced

		Noise Level, dBA	**Speed, km/h**	**Humidity,%** RH	**Temperature ,"C**	**Distance, m**	**Time Operation**	**Type of Train**	**Wind Speed (km/h)**
Noise Level, dBA	**Pearson Correlation**	**1**	**631****	-.181**	.160*	-.758*	-.180**	-.619**	.214
	Sig. (2-tailed)		.000	.004	.010	.000	.004	.000	.000
	N	**256**	**256**	**256**	**256**	**256**	**256**	**256**	**256**
Speed, kmfh	**Pearson Correlation**	**.631****	1	-.555**	**.538****	-.4 11**	- .101	-.984**	0.242*
	Sig.(2-tailed)	.000		.000	.000	.000	.105	.000	.047
	N	**256**	**256**	**256**	**256**	**256**	**256**	**256**	**256**
Humidity, %RH	**Pearson Correlation**	**-.181****	-.555**	1	-.976**	**-.129***	**-.310****	.554**	-.177
	Sig.(2-tailed)	.004	.000		.000	.041	.000	.000	.148
	N	**256**	**256**	**256**	**256**	**256**	**256**	**256**	**256**
Temperature, C	**Pearson Correlation**	**.160****	**.538****	-.976**	1	**.202****	.227**	**.538****	.183
	Sig. (2-tailed)	.010	.000	.000		.001	.000	.000	.134
	N	**256**	**256**	**256**	**256**	**256**	**256**	**256**	**256**
Distance,m	**Pearson Correlation**	-.758**	**-.411****	**-.129***	**.202****	1	**.027**	**.421****	-.192
	Sig.(2-tailed)	.000	.000	.041	.001		.667	.000	.138
	N	**256**	**256**	**256**	**256**	**256**	**256**	**256**	**256**
Time Operation	**Pearson Correlation**	-.180**	-.101	**- 310****	**.227****	**.027**	1	.089	0.129
	Sig. ((2-tailed)	.004	105	.000	.000	.667		.155	.000
	N	**256**	**256**	**256**	**256**	**256**	**256**	**256**	**256**
Type of Train	**Pearson Correlation**	-.619**	-.984**	.554**	-.538**	**.421****	0.089	1	0.027
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.155		.000
	N	**256**	**256**	**256**	**256**	**256**	**256**	**256**	**256**
Wind Speed	**Pearson Correlation**	-.214	.242	-.177*	.183	-.192	.227	0.089	1
	Sig. (2-tailed)	.080	.080	.148	.134	.138	.000	.000	
	N	**256**	**256**	**256**	**256**	**256**	**256**	**256**	**256**

** Correlation is significant at the 0. 01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

3.3 Determination of A-weighted Equivalent Continuous Level, LAeq

The study aimed to establish a correlation with the noise level limits outlined in the DOE, Malaysia guideline, expressed as the equivalent continuous sound level, LAeq. To achieve this, the following Equation (1) was adopted from Arbaan *et al.* [3],

$$LAeq = 10log_{10} = \frac{1}{n}\sum_{j=1}^{n} 10^{\frac{Li}{10}} \quad (1)$$

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

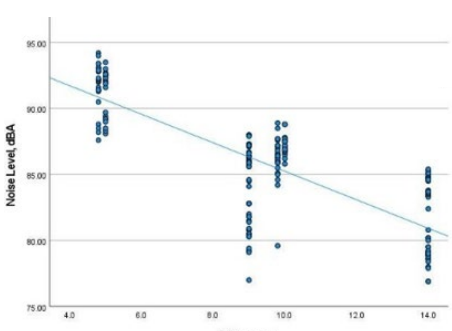
Table 4 provides the equivalent sound level (LAeq) obtained from the previous formula and the maximum values (Lmax) obtained from the data collection. It also includes the permissible noise limit specified by the DOE, Malaysia guideline. When the sound level meter (SLM) positioned at the fence to the railway tracks, it is evident that the LAeq readings for all locations exceeded the DOE, Malaysia guideline's threshold of 65 dBA by a substantial margin during peak and non-peak hours. Similarly, the Lmax values for each location exhibited a consistent pattern of surpassing the 80 dBA limit. When the SLM was relocated from the fence to the residential, the observations remained consistent. The LAeq readings for all locations continued to exceed the 65 dBA threshold, and the Lmax values displayed a similar pattern of surpassing the 80 dBA limit. This trend persisted for both peak and non-peak hours.

Table 4 LAeq and Lmax value for each site traffic flow and traffic violation

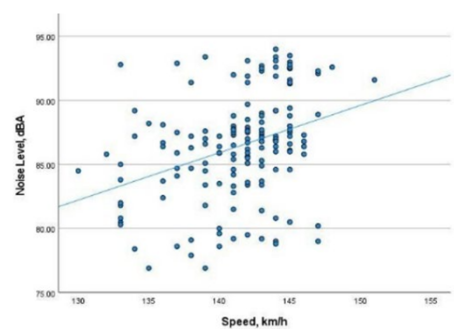
Location (Operating Hour)	D1		D2		DOE's LAeq Noise Limit (dBA)	DOE's Lmax Noise Limit (dBA)
	LAeq (dA)	Lmax (dBA)	LAeq (dBA)	Lmax (dBA)		
High Speed Train Telaga Hijau (Peak)	88.35	92.6	85.43	88.88	65	80
High Speed Train Telaga Hijau (Non-Peak)	85.21	89.2	84.15	88.88		
High Speed Train Desa Serdang (Peak)	87.53	93.4	81.95	87.7		
High Speed Train Desa Serdang (Non-Peak)	85.56	92.8	80.66	87.7		
Light Rapid Train Ampang (Peak)	80.46	87.10	77.52	83.30		
Light Rapid Train Ampang (Non-Peak)	79.16	83.30	77.40	81.35		

3.4 Scatter Plot of High Speed Train

The noise levels in the residential areas close to the railway lines rise in direct proportion to the increase in train speed. The increasing trend of the scatter plot indicates that stronger noise levels correlate with faster train speeds as shown in Figure 7 (a). This result is consistent with the hypothesis that faster trains make greater noise and consistent with the previous study [22]. Based on the Figure 7(b), the trend line clearly showing a decreasing line, suggesting that as the distance from the railway track increased the associated noise levels reduced. This data supports the claim that residents' experience towards noise levels influenced by their proximity to a railway track [23]. As individuals move further away from the track, the intensity of noise pollution decreases [24].



(a)

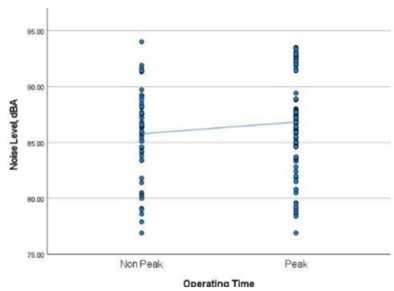


(b)

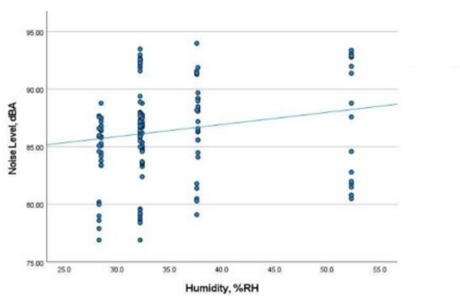
Figure 7 Relationship towards (a) speed (b) distance for High Speed Train

The trend line for high speed train displayed a slightly upward line, suggesting that peak operating hours are associated with higher noise levels than non-peak hours as depicted in Figure 8(a). This indicates that noise frequency is highest during peak hours, with elevated decibel levels. The noise level indicator remains active throughout the operating time [25]. From Figure 8(b), the analysis unveiled a different relationship between noise levels (dBA) and humidity. The trendline showed positive correlation. It showed an association that higher noise levels generated when higher humidity**.** The attenuation of sound in air is influenced by relative humidity. Both temperature and humidity significantly impact the noise levels at all selected points, as the velocity of sound increases with rising temperature [26].

Furthermore, it is consistent with the findings reported by Mahdi [27], who asserted that the relationship between the speed of sound and relative humidity follows a positive pattern [24]. Figure 8(c) displayed the analysis regarding the distinct association between noise levels (dBA) and temperature for the High Speed Train. The High Speed Train data displayed a downward trend as some research suggests that lower temperature values correlated to higher noise levels.



(a)



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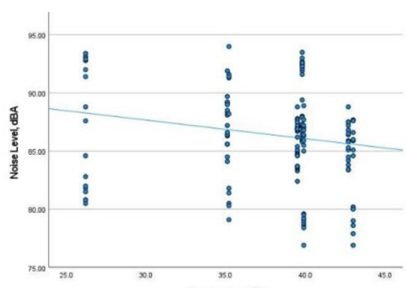


(c)

Figure 8 Relationship towards (a) operating time (b) humidity and (c) temperature

In Figure 9, the trendline slopes upward, indicating a positive correlation between wind speed and sound level (LAeq). This suggests that as wind speed increases, the sound level also tends to rise, driven primarily by wind-generated noise. This consistent relationship results in higher sound levels at higher wind speeds. Additionally, the LAeq ERL values exhibit a relatively narrow range, clustering between 86 and 94 dB. This observation aligns with the findings of Kumar *et al*. [28] which demonstrated strong positive correlations between variables like train speed and wind speed with Leq and Lmax. The study highlighted that when the line source was treated as moving rather than stationary, the influence of train and wind speed became more pronounced. Furthermore, the impact of wind was particularly significant at greater distances between the source and the receiver.

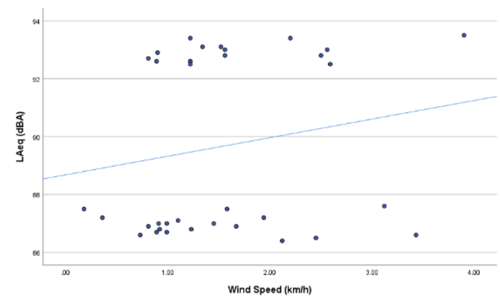
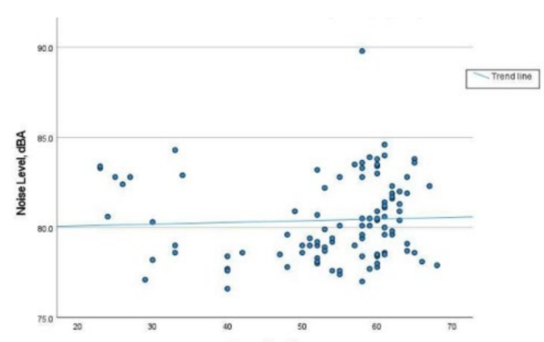


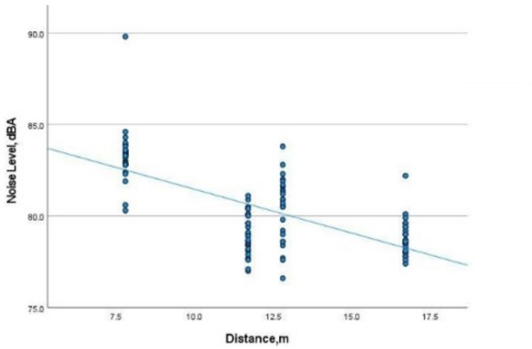
Figure 9 Relationship noise towards wind speed

3.5 Scatter Plot of Light Rapid Train

The Light Rapid Train dataset analysis in Figure 10(a), yielded similar findings as the High Speed Train analysis concerning the speed variable. As train speed increases, the noise levels in nearby residential areas also increase proportionally. The upward trend in the scatter plot indicates a relationship between higher train speeds and louder noise levels. This phenomenon is evident in the measured noise level diminishing when the SLM device is positioned at a greater distance from the railway track or the noise source, as outlined in the study conducted by Shahidan *et al*. [2]. As for Figure 10(b), the scatter plot analysis of the Light Rapid Train data exhibited a similar pattern to that observed in the High Speed Train. The trend line displayed a distinct downward trend, indicating that the corresponding noise levels decreased as the distance from the railway track increased. They are in accordance with the research by D. J. Thompson *et al*., [29] which supports the notion that heightened train speeds amplify rolling noise's sound power, thereby contributing to increased overall noise emissions from the trains.



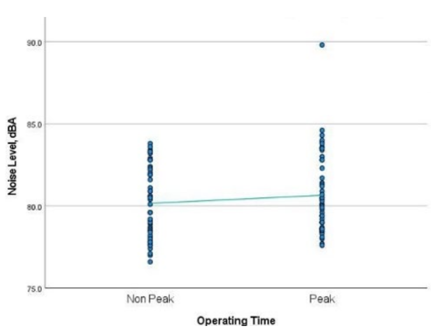
(a)



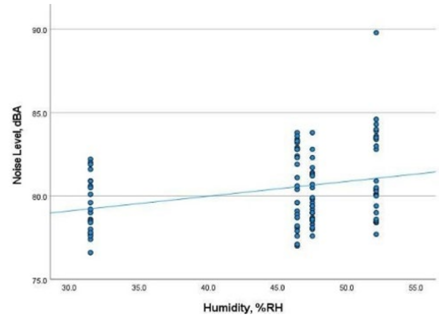
(b)

Figure 10 Relationship towards (a) speed (b) distance

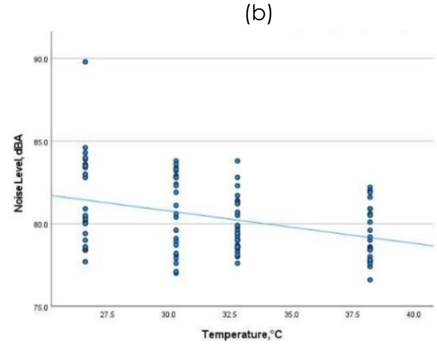
The Light Rapid Train trend line indicates a noticeable but slight upward trend as seen in Figure 11(a). This graph indicates that noise levels during peak operating hours are higher than non-peak hours. Figure 11(b) revealed a consistent pattern in the relationship between noise levels (dBA) and humidity for both the Light Rapid Train. However, this pattern trendline exhibited a moderate upward trend, indicating that higher humidity values were associated with increased noise levels. The specific findings derived from the Light Rapid Train data analysis can considered more reliable as it focuses exclusively on the noise levels generated by the Light Rapid Train. Figure 11(c) revealed a distinct relationship between noise levels (dBA) and temperature. The data for Light Rapid Train exhibited a downward trend. This research indicates that lower temperature values are associated with higher noise levels [30]. In contrast from other research, the increase in temperature causes sound waves to refract upward, away from the ground, leading to lower noise levels perceived at the listener's position [31].



(a)



(b)



(c)

Figure 11 Relationship towards (a) operating time (b) humidity and (c) temperature

The trendline in Figure 12, the slopes downward, revealing a negative correlation between LAeq and wind speed. This indicates that higher wind speeds are associated with lower sound levels in this dataset a result that may initially appear unexpected. The LAeq values in the scatterplot exhibit significant variability, ranging from approximately 76 to 84 dB, suggesting the influence of multiple confounding factors. High wind speed also disturbs the circulation of the sound over long spaces [32]. This finding aligns with Garrett *et al*., [33] who observed that sound waves tend to bend toward regions with lower wind velocity sound waves tend to bend towards regions of lower wind velocity. Such wind-related effects often outweigh temperature influences when both factors are present.

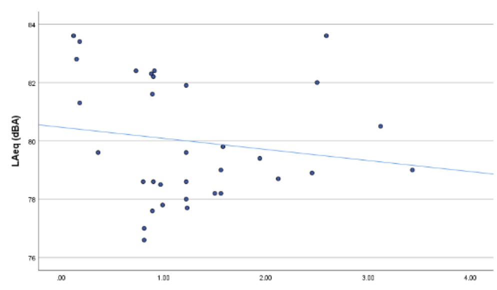


Figure 12 Relationship noise towards wind speed

4.0 CONCLUSION

This study presents findings on the human annoyance caused by railway noise in residential areas, based on empirical data collected from field measurements at designated railway tracks. The analysis revealed that SLM readings taken near fences and residential areas at Serdang and Ampang consistently exceeded the DOE, Malaysia guidelines for noise levels during both peak and non-peak hours. LAeq and Lmax values at these locations were significantly above the permissible limits, with faster train speeds contributing to higher noise levels and exacerbating noise pollution.

The findings indicate that noise levels decrease with increasing distance from the railway track and are higher during peak operating hours, underscoring the temporal and spatial variability of noise intensity. Despite these variations, the recorded values exceeded DOE, Malaysia guidelines across all conditions, highlighting the impact of excessive noise on residents' quality of life. The significant gap between observed noise levels and recommended thresholds emphasizes the urgent need for noise mitigation measures aligned with DOE, Malaysia standards.Key variables influencing noise levels were investigated, including train speed, distance from the track, operating hours, train type, humidity, temperature, and wind speed. Statistical analysis demonstrated significant correlations between these variables and noise levels, as all variables had p-values below the significance threshold. Higher humidity was associated with increased noise due to altered sound attenuation, while wind speed affected noise differently across train types, likely due to sound dispersion effects.

Noise emission induced by moving trains is a concerning topic to discuss since Malaysia has developed into a country that views railway as one of the important modes of transport as it offers convenience to users in various aspects, especially in urban areas. This study provides insights into the impact of noise generated by railway transportation on individuals, enabling the development of more effective strategies to mitigate noise pollution. This study improves residents' satisfaction and comfort in residential areas near railway tracks.

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Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

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