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RESEARCH ARTICLE

Comparative Study Of Vehicle Noise Levels at Different Times In An Urban Area: A Case Study

Indra Hasan[1,*], Albafery [2], Agus Mulyadi[3]

[1,3] *Universitas Muhammadiyah Riau, Jl. Tuanku Tambusai, Kota Pekanbaru, Indonesia.*
[2] *Purna Graha College of Economic Science, Jl. Nangka No.20 A, Kota Pekanbaru, Indonesia.*

* Corresponding author : indrahasan@umri.ac.id
Tel.:+62-811-7574-129;
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Abstract

Urban areas are increasingly facing the problem of noise pollution, which can significantly affect their residents' quality of life, health, and productivity. Noise caused by road traffic is one of the main contributors to this issue, particularly in cities with high traffic volumes. Despite its impact, the relationship between traffic patterns and noise levels at different times of the day remains underexplored. This study aims to investigate the variation in vehicle noise levels at different times of the day on Jalan Jenderal Sudirman in Pekanbaru City, Indonesia. The primary objective is to assess how vehicles' volume and speed contribute to noise pollution changes during peak and off-peak hours. The study was conducted by measuring the noise levels at three distinct time intervals: 07:00-09:00 GMT (morning), 11:00-13:00 GMT (daytime), and 15:00-18:00 GMT (afternoon/evening). These periods were selected to reflect the variation in traffic density and activity during the day. The data were analyzed using the ANOVA test to determine whether there were any significant differences in the noise levels across the different time intervals. The results showed that the average noise levels were similar during all three periods, with no statistically significant differences detected. The findings suggest that traffic volume and vehicle speed consistently impact noise pollution throughout the day. This study highlights the importance of managing traffic flow and vehicle speed to mitigate noise pollution in urban environments. The results also provide valuable insights for local authorities to develop policies to reduce noise pollution and improve the overall quality of life for residents in Pekanbaru.

Keywords: Noise Pollution, Traffic, Vehicle Noise Levels, ANOVA, Urban City.

1. Introduction

Sound pollution resulting from road traffic noise is a significant environmental issue, as it directly threatens the health and sustainability of urban populations. It is widely recognized that noise pollution harms human health, increasing cardiovascular disease risk, stress, and impaired cognitive function (Pal and Bhattacharya, 2012). Noise is an unwanted sound that disturbs the environment and can lead to discomfort and health issues for individuals living in high-traffic areas. Road traffic is one of the most significant sources of noise pollution, with the sound produced by motorized vehicles fluctuating throughout the day depending on traffic density and vehicle speed (Handayani and Sawitri, 2002). Studies have shown that vehicle noise levels are directly proportional to the number and speed of vehicles on the road. Consequently, as vehicle numbers and speed increase, so does the noise level.

Numerous studies have examined the effects of road traffic noise in urban and industrial areas. For example, Steele (2001) surveyed highway noise prediction, providing insights into the impact of traffic noise in developed countries. Similarly, Fiedler and Zannin (2015) studied pollution in Latin American cities, measuring noise levels at 232 highway points across different urban environments. Song et al., (2016) focused on the annoyance level caused by noise in Singapore, employing large-scale evaluations to assess the effects of highway noise on residents. These studies illustrate the importance of understanding traffic noise dynamics and its varying impact across locations and times of day. Moreover, Babisch (2006) conducted a comprehensive review of traffic noise and its health effects, concluding that long-term exposure to traffic noise is associated with an increased risk of cardiovascular diseases and adverse sleep patterns. Miedema and Oudshoorn (2001) presented a model for assessing the health effects of environmental noise, suggesting that noise exposure leads to both direct and indirect health impacts, including hearing impairment, annoyance, and stress. Similarly, (Andersen et al., 2018) highlighted how environmental noise from road traffic is linked to reduced quality of life and increased annoyance levels in densely populated urban areas. The consistent finding across these studies is that traffic noise remains a significant environmental and public health concern, emphasizing the need for effective urban policies to mitigate its adverse effects.

In the case of Pekanbaru, the city has experienced rapid population growth, leading to increased transportation demand (PemKo Pekanbaru, 2019). Between 2017 and 2018, Pekanbaru's population grew by 33.22%, reaching 1,117,539 people (BPS, 2019). This demographic shift and an annual growth rate of 2.73% directly influence the demand for motorized vehicles. By 2018, there were 1,097,026 motorized vehicles in Pekanbaru, representing an 86.1% increase in vehicle volume from the previous year. The rapid growth of vehicle numbers and the limited expansion of road infrastructure are expected to contribute to higher noise levels on the city's primary roads. Given this context, it is crucial to examine the noise levels at different times of day and their impact on the residents of Pekanbaru, particularly as urbanization continues at a fast pace.

Noise pollution, particularly from road traffic, has been extensively studied in large urban areas worldwide, focusing on its health and environmental impacts (Marve et al., 2016; Montes-González et al., 2018). However, studies in smaller or rapidly growing cities such as Pekanbaru are limited. Existing research, such as studies by Steele (2001) on highway noise and Song et al., (2016) on the annoyance caused by urban noise, predominantly focuses on developed countries or cities with stable urban infrastructures. Studies on the dynamic variation of noise levels across different times of the day, as influenced by fluctuating traffic volumes, are also sparse. Research in Latin American cities by Fiedler and Zannin (2015) and noise studies in industrial areas, such as Pal and Bhattacharya (2012), provide valuable insights but often overlook the influence of time-of-day traffic flow on noise levels.

This study fills a gap by focusing on Pekanbaru, a developing city in Indonesia, and analyzing the variation in traffic noise levels during three critical periods of the day—morning, midday, and evening. The novelty of this research lies in its focus on the time-dependent variation in traffic noise, which can provide more precise insights into traffic-related noise management and urban planning. Previous studies, such as those by Ravinder and Belachew (2014) and Goshu (2017), have highlighted the significance of time-dependent noise levels in metropolitan areas. Furthermore, studies like those by Calixto et al., (2008), Gonzaga et al., (2022) and Vaverková et al., (2021) demonstrate how variations in traffic flow and vehicle type can significantly affect urban noise conditions, adding further context to the findings of this study. Studies by Ibili et al., (2022), Mendonça et al., (2013), and Patel et al., (2024) also underline the importance of accurate modelling for traffic noise predictions in urban areas, highlighting the potential for improvement through the integration of real-time data. Other studies, such as those by Gidlöf-Gunnarsson and Öhrström (2007), Gorai and Pal (2006), Halperin (2014) have focused on the health effects of traffic noise, while Johnson and Saunders, (1968) and Panchal et al., (2014) provided essential theoretical foundations for noise level prediction models.

2. Methods

The research was conducted on Jalan Jenderal Sudirman in Pekanbaru, Indonesia, a key urban area known for its dense traffic. The location of the study is shown in Fig. 1, which provides a visual reference to the geographical area of interest. This study follows a comparative research design, which allows for the systematic comparison of noise levels across different times of the day. This research aimed to assess how traffic-related noise levels vary throughout the day, focusing on identifying any significant differences between peak and off-peak traffic periods.

The noise levels were recorded according to the ISO R-2006 Standard, which outlines the methodology for environmental noise measurement (ISO, 2016). This standard is widely accepted in ecological noise studies and provides a structured approach to ensuring that measurements are reliable and comparable across different research settings. The standard specifies the time intervals, measurement instruments, and procedures for noise recording to guarantee that the data reflects actual environmental conditions. The study measured noise at three distinct time intervals during the day to capture the variation in traffic density and the corresponding changes in noise levels:

1. Morning Peak (07:00 - 09:00 GMT): This time frame represents the morning rush hour, typically when traffic activity is at its highest due to commuters travelling to work and school. This period is expected to show the highest traffic volume and noise levels.
2. Midday (11:00 - 13:00 GMT): The midday interval was selected to reflect the quieter part of the day when traffic flow stabilizes and the roads experience moderate congestion. This period serves as a baseline for comparing noise levels with peak traffic times in the morning and evening.
3. Afternoon/Evening (15:00 - 18:00 GMT): This interval captures the evening rush hour as people begin to leave work or school. This period often experiences heavy traffic as commuters head home, which could lead to increased noise levels, similar to the morning peak.

The study used the ANOVA (Analysis of Variance) test for the data analysis. ANOVA is a powerful statistical method that allows for comparing the means of three or more independent groups to determine whether there are significant differences between them (Hess and Hess, 2018; Kaufmann and Schering, 2014). In this context, ANOVA was used to test whether the average noise levels at the three different time intervals (morning, midday, and evening) were significantly different from each other. The ANOVA test is particularly suitable for this research because it can handle multiple groups and examine the overall variance in the data. The study can determine whether variations in traffic density (and therefore noise levels) at different times of day are statistically significant or whether any observed differences are due to random fluctuations in the data. This approach allows a more robust understanding of how traffic-related noise levels fluctuate.

The statistical analysis was carried out using SPSS software, a widely used tool in environmental research for conducting advanced statistical analyses (Rahman and Muktadir, 2021). SPSS provides a user-friendly interface and powerful functions for running ANOVA tests and interpreting their results. It is well-suited for this type of analysis, where large datasets and complex statistical models are involved. SPSS also offers comprehensive options for post-hoc tests, which can be used to explore any significant differences between specific groups if the ANOVA test indicates significant variations in the noise levels (Emerson, 2017; Nowakowski, 2019).

3. Results

The data from the noise level measurements along Jalan Jenderal Sudirman are shown in **table 1.** The initial average noise level for Monday at 07.00-08.00 GMT was 75.4 dB. Furthermore, there was a decrease in noise levels from 08.00 – 09.00 GMT so that the noise level was 75.1 dB. This decrease is implied by the slope of the noise level data graph for Monday in the time range 08.00 – 09.00 GMT. This decrease in noise level occurs because the peak hour of people leaving for work in the morning has been completed so that traffic activities do not become congested and followed by a decrease in noise levels. Furthermore, in the time range of 08.00 – 11.00 GMT, the noise level decreased from its initial condition of 75.1 dB to 73.6 dB. In this time range, the slope of the chart is very significant, which means that there is a significant change from the initial condition.

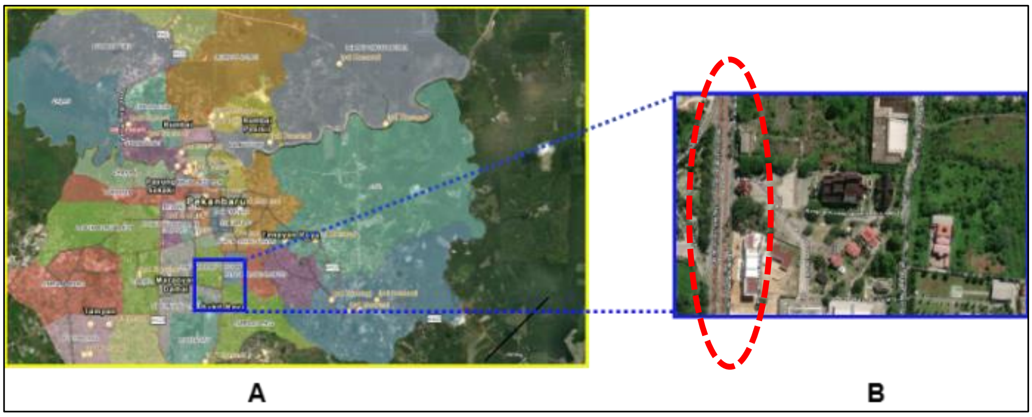

Fig 1. Research Location: Pekanbaru **(A)** and Jalan Jenderal Sudirman **(B)**

Table 1. Average noise level (dB) measurements on Jalan Jenderal Sudirman

Measurement Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
07.00-08.00	75.4	76.7	77.2	74.3	72.1	74.8	71.2
08.00-09.00	75.1	76.0	75.3	74.5	71.1	74.0	73.6
11.00-12.00	73.6	74.8	76.3	73.4	72.3	73.4	75.7
12.00-13.00	72.7	74.0	76.5	72.8	74.2	75.4	73.2
15.00-16.00	73.4	74.7	74.2	73.6	73.5	75.1	73.7
16.00-17.00	73.3	74.3	74.8	74.5	75.4	71.1	72.8
17.00-18.00	72.8	76.4	74.3	74.6	74.1	73.4	75.3
Average	73.7	75.3	75.5	74.0	73.2	73.9	73.6

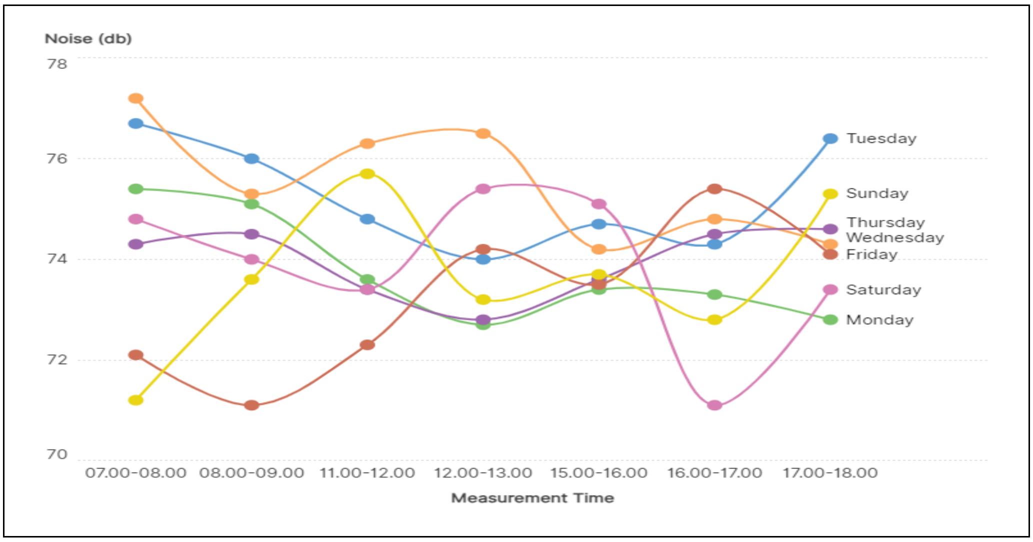

Fig 2. Graph of the average noise level on Jenderal Sudirman

This process was also followed for the time range of 11.00 – 17.00 GMT where at 11:00 GMT the noise level was 73.6 dB and at 17:00 GMT the noise level was 73.3 dB. This process is illustrated by an almost flat slope of the graph which means that no significant changes have occurred. The interpretation of the condition of the almost flat slope of the graph is that motorized vehicles that are the source of traffic noise do not pass through Jenderal Sudirman's road much for activities after work. Then the noise level from 17.00 GMT continued to show a decrease of 0.5 dB from the initial condition of 72.8 dB.

On Tuesday, the average noise level data started at 76.7 dB at 07:00-08:00 GMT. Then the noise level decreased as seen in Tuesday's chart slope from an initial condition of 76.7 dB to 76.0 dB. The process of reducing noise levels can be interpreted as motor vehicles that carry out traffic activities to go to work have begun to decrease. The process of reducing this noise level continued to occur until 13.00 GMT. The amount of reduction in noise levels is very significant when compared to Monday.

Initial data showed a noise level of 76.7 dB at 07.00 GMT and decreased by 74.0 dB at 13.00 GMT. This process of decreasing noise levels is evident on the slope of the chart for Tuesday. Furthermore, there was an increase in noise levels from 13.00 GMT to 18.00 GMT which in the initial condition was 74.0 dB to 76.4 dB. This increase is quite high at 2.4 dB where this increase is not seen in the data for Monday. It can be stated that vehicles that go to work in the morning again choose Jenderal Sudirman road to go home from work so that the noise level on Tuesday at 17:00 – 18:00 GMT increases significantly as a result of the noise of traffic activities.

Data from the results of the average noise level measurement on Jenderal Sudirman street that the highest noise level on Wednesday at 07.00 -08.00 GMT is because most people carry out activities to the workplace, then it can be seen that the low noise level is on Friday at 16.00 – 17.00 GMT because people do not go out at rush hour and also coincide with national holidays.

Then it can be seen that the average noise level at the time of measurement from 07.00 – 18.00 GMT on Monday is 73.7 dB, at 07.00 – 18.00 GMT on Tuesday is 75.3 dB, at 07.00 – 18.00 GMT on Wednesday is 75.5 dB, at 07.00 – 18.00 GMT on Thursday is 74.0 dB, at 07.00 – 18.00 GMT on Friday is 73.2 dB, at 07.00 – 18.00 GMT on Saturday it was 73.9 dB and at 07.00 – 18.00 GMT on Sunday it was 73.6 dB. The increase in noise levels that occurred on Monday to Sunday was almost the same except on Wednesday at 07.00 – 18.00 GMT there was a significant noise level of 75.5 dB because at the same time there was a surge in crowded traffic flow from the South of Pekanbaru city to the city center.

Table 2. Noise Level Descriptives

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
07.00-09.00 GMT	14	74.4357	1.86820	.49930	73.3570	75.5144	71.10	77.20
11.00-13.00 GMT	14	74.1643	1.36529	.36489	73.3760	74.9526	72.30	76.50
15.00-18.00 GMT	21	74.0619	1.12937	.24645	73.5478	74.5760	71.10	76.40
Total	49	74.1980	1.41649	.20236	73.7911	74.6048	71.10	77.20

Based on the Table 2. the average noise value is highest at 07.00-09.00 GMT while the lowest average noise value is at 11.00-13.00 GMT. The highest noise level occurred at 07.00-09.00 GMT at 77.20 dB with the minimum noise value (lowest) being 71.10 dB.

Table 3. Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
1.787	2	46	.179

Based on the output of SPSS, the statistical levene value is 1.787 with a significance or probability (sig) of 0.179. So that the noise values at 07.00 – 09.00 GMT, 11.00 – 13.00 GMT and 15.00 – 18.00 GMT have homogeneous noise level values or the same noise level values, this is because the value of sig. 0.179 > 0.05.

Table 4. ANOVA Test Results

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.196	2	.598	.289	.750
Within Groups	95.114	46	2.068		
Total	96.310	48			

The results of the different tests using can be seen a value (sig) of 0.750. Because the value of sig. 0.750 > 0.05 which means that the noise value of the range at that time has a significantly equal noise level value.

Table 5. Multiple Comparisons

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
07.00-09.00 GMT	11.00-13.00 GMT	.27143	.54349	.872	-1.0448	1.5877
	15.00-18.00 GMT	.37381	.49614	.733	-.8278	1.5754
11.00-13.00 GMT	07.00-09.00 GMT	-.27143	.54349	.872	-1.5877	1.0448
	15.00-18.00 GMT	.10238	.49614	.977	-1.0992	1.3039
15.00-18.00 GMT	07.00-09.00 GMT	-.37381	.49614	.733	-1.5754	.8278
	11.00-13.00 GMT	-.10238	.49614	.977	-1.3039	1.0992

Table 6. Tukey HSD Test on Noise

Time	N	Subset for alpha = 0.05
		1
15.00-18.00 GMT	21	74.0619
11.00-13.00 GMT	14	74.1643
07.00-09.00 GMT	14	74.4357
Sig.		.747

In the table 5. It shows that the results of the measurement at 07.00-09.00 GMT compared to 11.00-13.00 GMT have a different mean value of 0.27 at the confidence level of 95% with the difference in the lower limit of -1.04 and the difference in the upper limit of 1.59. The results of the study showed that the noise level at 07.00-09.00 GMT compared to 11.00-13.00 was no difference, this was evident from the .sig value of 0.872 > 0.05. The results of the measurement at 07.00-09.00 GMT compared to 15.00-18.00 GMT have a different average value of 0.37 with a difference in the lower limit of -0.83 and a difference in the upper limit of 1.58. The results of the study showed that the noise level at that time was no different. Furthermore, at 11.00-13.00 GMT compared to 15.00-18.00 GMT there was also no significant difference.

In Table 6, having one column means the average noise level at 07:00-09:00 GMT, 11:00-13:00 GMT, and 15:00-18:00 GMT had the same and significant noise level. This study's results revealed no statistically significant differences in noise levels across the three-time intervals (morning, midday, and evening). Although variations in noise levels were observed at different times of the day, the ANOVA test showed that the differences between the average noise levels for the periods (07:00-09:00 GMT, 11:00-13:00 GMT, and 15:00-18:00 GMT) were not large enough to be considered statistically significant. This indicates that the noise levels in the study area remained relatively consistent throughout the day despite the expected fluctuations in traffic volume. In other words, the traffic-related noise pollution did not show a notable increase or decrease at any particular time interval, suggesting that the impact of vehicle noise on the environment and public health in this location is stable across the observed times.

4. Conclusion

Based on the results of this study, the noise levels on Jenderal Sudirman in Pekanbaru remained consistent across the three time intervals studied: 07:00-09:00 GMT, 11:00-13:00 GMT, and 15:00-18:00 WI. The ANOVA analysis revealed no statistically significant differences in the average noise levels during these periods, indicating that traffic-related noise levels remain stable throughout the day, regardless of traffic volume variations. This suggests that the noise pollution in the area is more strongly influenced by the number and speed of vehicles rather than the time of day. The findings contribute to understanding traffic noise in a developing city like Pekanbaru, an area with limited studies on this subject. Unlike previous research on larger metropolitan areas, this study provides important insights into how noise levels fluctuate over time in smaller cities experiencing rapid urbanization. The study's results are valuable for urban planning and policy development. They provide a foundation for local authorities to design traffic management strategies to mitigate noise pollution. These strategies include regulating traffic volume, restricting heavy vehicles during certain hours, and implementing speed limits. Improving road infrastructure, such as reducing road slopes and selecting quieter pavement materials, can also help minimize noise. The installation of plant barriers along roads could also reduce sound propagation. This research is a significant reference for future environmental impact assessments and noise prediction models, offering guidance for other cities in Indonesia facing similar challenges related to traffic noise. It underscores the importance of integrating noise reduction strategies into urban development plans to enhance residents' quality of life and public health.

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