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Research Paper

The Noise Level in Residential Areas Bordering Jagorawi Highway

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Abstract

Noise pollution has not become a priority in environmental issues, but the potential negative impact on society based on studies can be in the form of physical and psychological disturbances, the main cause of noise in the urban area is transportation. Identification of noise sources needs should be done to ensure that the sound produced accordance with environmental characteristics. The Jagorawi toll road is the 3^{rd} density toll road in the Jabodetabek area, compared to several other toll roads. Jagorawi toll road is bordered by residential areas. In the Cibubur-Cimanggis sector, this toll road is directly adjacent to residential areas with a distance of $<$ 20 meters and some points do not have barriers to reduce noise. The Cibubur-Cimanggis sector is currently developing with the addition of the LRT, which will operate in 2022 so that current noise measurements can be used as baseline data at the study site. This noise monitoring is intended to conclude whether or not there is an effect of noise felt by the surrounding community from activities on the Jagorawi toll road and to obtain a reduction in noise levels using a single barrier with a height of 0.5, 1, 1.5 and 2 m. Noise monitoring is carried out using SNI 8421:2017 for 24 hours at 2 measurement points in residential areas. Point one and point two each have a noise value (Lsm) of 68.87 and 61.29 dBA with a correlation value of 0.605 (medium). The noise value has exceeded the quality standard for residential designation based on the Minister of Environment Decree No. 48 of 1996 (55 dBA), so a barrier is needed to reduce the noise received by the community. The analysis of the use of the barrier studied is a single barrier with G = 1. As the result of adding a barrier at point 1 with high 2 m, the noise value can be reduced by 16.7 dBA with a p-value of 0.00, so the addition of a barrier has a significant impact on the noise value. This study found the effect of noise from the Jagorawi toll road up to a distance of 114 m at a point that does not use a barrier, so the role of the barrier along the toll road is very important. With the use of a barrier, the distance required to reduce single noise originating from the toll road to $<$ 55 dBA is 20 m.

Keywords

Noise Level, Jagorawi Highway, Residential Area, Barrier

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1. INTRODUCTION

Noise in the environment has become an old issue that has not received public attention and concern, even since 2009 a noise study has been compiled which shows that 96% of residential areas and settlements in big cities in Indonesia have exceeded the quality standard of 55 dBA. Noise problems also have an impact on physiological and psychological disorders, some of the impacts include disturbances, sleep disturbances, hearing problems, hypertension, etc. This effect is influenced by the length of time of exposure (Passchier-Vermeer and Passchier, 2000; Ba and Kang, 2019). Noise monitoring and handling activities in Indonesia have not yet experienced significant developments regarding the Minister of Environment Decree No. 48 of 1996.

Noise pollution in big cities is generally caused by traffic compared to other sources, urban development also increases urban noise levels with more activities resulting in more vehicle use (Kuldeep and Mathur, 2020). The characteristics of the location (activities around the location, especially the types of transportation available, the use of public transportation cars and motorbikes) will affect the noise measurement results (Syaiful and Wahid, 2020). Studies on noise complaints show that population density also affects the number of complaints, the denser an area is, the higher the complaints about noise (Tong and Kang, 2021). The noise level every year can continue to increase along with the growth in the number of vehicles. Noise disturbance in urban areas is dominated by transportation sources from roads, trains, and planes so in the predictive analysis of the combination of transportation types it is necessary to consider (Marquis-Favre et al., 2021). This also affects the noise level of residential and residential areas around toll roads, where there is an increase in the noise value of residential areas around the toll road by 12.5% from an increase in the number of vehicles by 10% (Çolakkadıoğlu and Yücel, 2017).

The City of Depok as a buffer for the DKI Jakarta area has a population growth of 15.5% from 2010-2020 (Statistik, 2021). Depok City has access to various modes of land transportation, this continues to be developed including public transportation modes and road network improvements so that it becomes an attraction for people to choose a location to live (Kadarisman et al., 2016). The rapid development of transportation facilities in buffer cities around DKI Jakarta provides comfort for the community, but without realizing it will affect the normal life of the community with the development around it, so noise prevention measures are needed (Liang et al., 2022). The Jabodetabek toll road is a toll road in the Jabodetabek area with traffic of 123,029,004 vehicles in 2020, this value is ranked third for toll roads in the Jabodetabek area (Statistik, 2021). Jagorawi has a road length of 46 km so in some sectors, it is directly adjacent to settlements. Previous research in residential areas in Bogor showed that at a distance of 50 m from the Jagorawi toll road the noise value was 56.10 dBA, above the quality standard of Minister of Environment Decree No. 46 of 1996. In addition, there are previous studies on the potential for noise from the Jagorawi toll road with the addition of a natural barrier (plants) with a thickness of 8 m to reduce noise by 10 dBA. Noise barrier can reduce 9.98 - 10.47 dBA from the highway depending on the distance and height of the barrier used so that in terms of noise mitigation, optimization of the barrier can be done (Sahraei and Ghaemi, 2013).

Residential areas have a higher sensitivity to noise, especially at night (Lm) because the housing area has a function to rest for its residents while other areas don't have. In addition, the effect caused by noise pollution is to cause sleep disturbances, interfere with speech, and can affect performance (Elfaig et al., 2014). The use of natural barriers (trees) and artificial barriers have a significantly reduced value from noise sources, so trees or artificial barriers in urban areas will become an important part of the considerations in urban planning (Zhao et al., 2021). The purpose of this study was to determine the noise level of the residential area around the Jagorawi highway and to determine the effect of noise reduction using a single barrier.

2. EXPERIMENTAL SECTION

2.1 Research Location

Harjamukti Village is located on the east side of the Cimanggis Sub-district, this village is directly adjacent to the Provin ce of DKI Jakarta, Bogor Regency, and Bekasi City. Harjamukti Village has a population of 23,269 people with a population density of 3,931 people/km^2 in 2019 (Statistik, 2021). Harjamukti Village is the only Sub-district in Cimanggis which borders the Jagorawi toll road. In addition, the Harjamukti Village has access to LRT transportation with the Harjamukti LRT station which will operate in 2022. In this study, the measurement locations were carried out at 2 points, point 1 at S06022'54.60" and E106053'43.80" with a distance of 20 meters from the Jagorawi toll road, while point 2 at S06022'47.50" and E106053'32.10" with a distance of 114 meters from the Jagorawi toll road. More detailed information about the location can be seen in Figure 1.

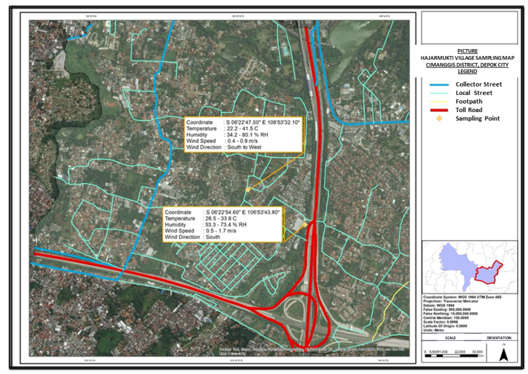

Figure 1. Research Location

2.2 Noise Measurement

Based on SNI 8427:2017, environmental noise level measurement is carried out using an integrating sound level meter that meets the requirements of applicable national and/or international standards. However, for steady noise, where the noise has a constant average characteristic over time (fluctuation limit of 5 dBA), measurements can be represented by a minimum of 7 data. The time of taking the 7 data are as follows:

1. Sample 1 was picked up at 07:00 representing 06:00 – 09:00
2. Sample 2 was picked up at 10:00 representing 09:00 – 14:00
3. Sample 3 was picked up at 15:00 representing 14:00 – 17:00
4. Sample 4 was picked up at 20:00 representing 17:00 – 22:00
5. Sample 5 was picked up at 23:00 representing 22:00 – 24:00
6. Sample 6 was picked up at 01:00 representing 24:00 – 03:00
7. Sample 7 was picked up at 04:00 representing 03:00 – 06:00

After the measurement data is obtained, calculations can be made to obtain pressure level in 10 minutes of measurement or regular noise in a certain period (LAeq) using Equation 1, the environmental noise level at day level (Ls) can be calculated using the Equation 2, night level (Lm), and night level (Lsm) can be calculated using Equation 3. Ls is the LAeq value during the day (16 hours) from 06:00 –

22:00, Lm is the LAeq value during the day (8 hours) from 22:00 – 06:00, while Lsm is the average noise level for 24 hours. Meanwhile, based on SNI 8427:2017, the formula for calculating the noise level is as follows:

$$\text{LAeq} = 10\ \log\frac{1}{n}\sum_{i=1}^{n} = 10^{0.1Li}\text{dBA} \quad (1)$$

$$\text{Ls} = 10\ \log\frac{1}{16}(T_1 10^{0.1L_1} + T_2 10^{0.1L_2} + T_3 10^{0.1L_3} + T_4 10^{0.1L_4})$$
$$\text{Ls} = 10\ \log\frac{1}{8}(T_5 10^{0.1L_5} + T_6 10^{0.1L_6} + T_7 10^{0.1L_7}) \quad (2)$$

Note: T_1 = 3; T_2 = 5; T_3 = 3; T4 = 5; T_5 = 2; T_6 = 3; dan T_7 = 3

$$\text{Lsm} = 10\ \log\frac{1}{24}(16\ \text{x}10^{0.1Ls} + 8\ \text{x}10^{0.1(Lm+5)}) \quad (3)$$

2.3 Noise Analysis of Distance and Noise Attenuation Variation

Noise has a different pattern with or without the use of barriers. To ensure the significance level of the use of the barrier, a simulation of the use of the barrier is carried out at point 1 and the resulting noise dilution pattern is carried out up to point 2. Sound moves through the propagation medium until it reaches the receiver, in its spatial movement the sound experiences a dilution which can generally be written in Equation 4 (Sutherland, 2000):

$$\text{Lp(R2)} = \text{Lp(R1)} - 20\ \log\ 10(\frac{R2}{R1}) \quad (4)$$

Where: Lp(R1) = Known sound pressure level at the first location; Lp(R2) = Unknown sound pressure level at the second location Location; R1 = Distance from the noise source to the location of known sound pressure level; R2 = Distance from the noise source to the second location.

The use of a barrier as an effort to mitigate noise is carried out by using a concrete wall barrier, this is done by considering the location adjacent to the Jagorawi toll bridge so that the use of natural barriers is not possible. The barrier is placed to block the acoustic propagation so that there is a change in the length of propagation (δ) besides the wavelength (λ).

$$\text{A} = \sqrt{C_1^2 + (h-S)^2} \quad (5)$$

$$\text{B} = \sqrt{C_2^2 + (h-R)^2} \quad (6)$$

$$\text{C} = \sqrt{(C_1 + C_2^2) + (R-S)^2} \quad (7)$$

$$\delta = \text{A + B - C} \quad (8)$$

Research on road attenuation was conducted by Kumar et al. (2014) using Fresnel numbers (N) and the Mekawa method using graphs. In addition to using graphs, noise reduction can be calculated according to Equation (7) according to the obtained Fresnel value. Fresnel value (N) is a dimensionless number to predict the noise attenuation perceived by the receiver.

$$N = \frac{2\delta}{\lambda} \quad (9)$$

$$\Delta\text{B} = 10\ \log\left[\left(\frac{1}{\varphi R - \varphi L}\right)\left(\frac{1}{\sqrt{10}}\right)\left(\int_{\varphi L}^{\varphi R}\frac{\tanh^2\sqrt{2\pi N cos\varphi}}{2\pi N cos\varphi}d\varphi\right)\right] \quad (10)$$

The research was conducted by measuring the noise level compared to the quality standard of the Minister of Environment Decree No. 46 of 1999 concerning noise. Furthermore, the noise barrier design is carried out with variations in height to get noise attenuation according to noise reduction needs. The results of the discussion will show the optimum barrier height required according to the noise level. The research flow chart can be seen more fully in Figure 2.

3. RESULTS AND DISCUSSION

3.1 Noise Measurement

The research location consists of 2 points, point 1 is 20 meters away and point 2 is 114 meters from the Jagorawi toll road. Identification of noise sources is carried out by observation and interviews, the results of the identification of the two methods the noise sources consist of the Jagorawi toll road and local roads. Based on direct observation, the noise source around the research location is transportation from Jagorawi toll road and local road, but based on community interviews at point 1 87.5% came from traffic noise and 12.5% came from horns and exhaust noise, while at point 2 there was the influence of community activities by 37.5%, traffic noise 50% and horns and exhaust noises 12.5%. Research in other residential areas shows similar results from finding sources of outdoor noise in residential areas which are generally caused by traffic, construction, environmental activities, and weather. In this study, the very noisy category is found at point 1, while point 2 is included in the noisy and slightly noisy category. This is also in line with the Lsm value aimed at point 1, which is 68.87 dBA while point 2 is 61.29 dBA. The distribution of noise data at both locations can be seen in Figure 3. Based on the Ministry of Environment Decree No. 48 of 1996, the measurement results show that location 1 (68.87 dBA) is included in the quality standard for trade and service and

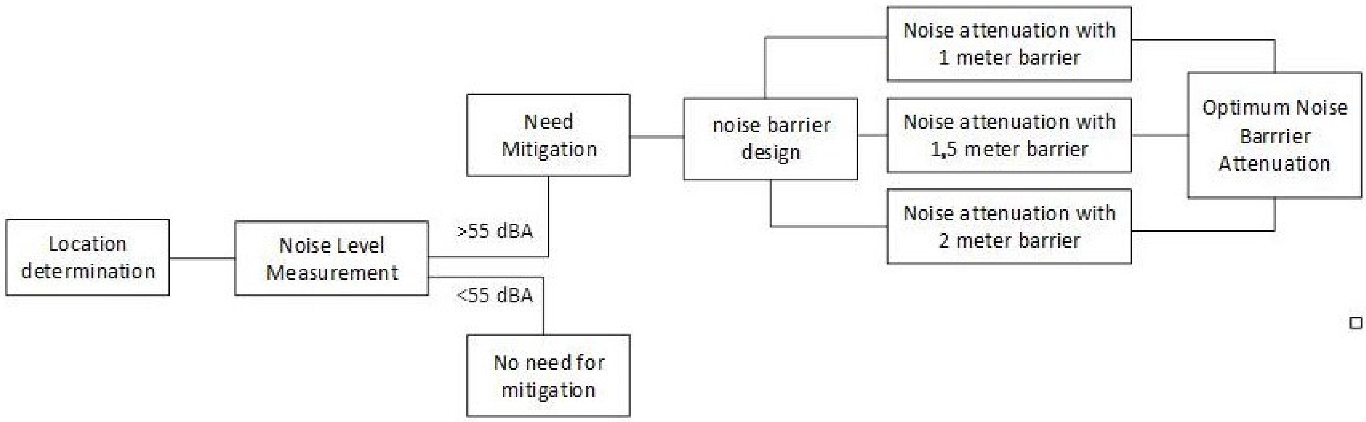

Figure 2. Research Flowchart

industrial areas of 70 dBA, while location 2 (62.77 dBA) is included in the quality standard for office areas of 65 dBA, so that the area under noise level research is not suitable for use as a residential area (55 dBA).

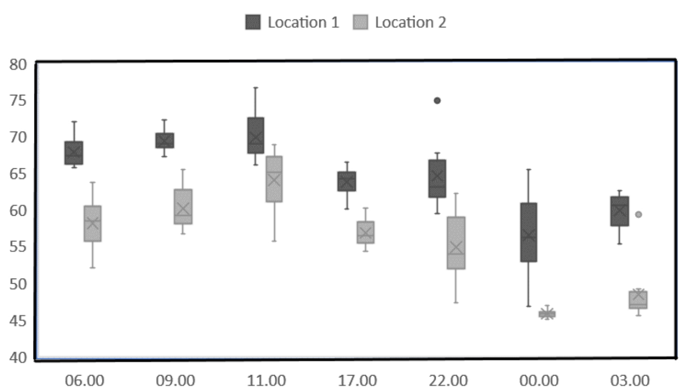

Figure 3. Noise Measurement Results for Each Location

It can be seen in Figure 3 that the noise level between 06.00 - 17.00 tends to be higher than the noise level at 22.00 - 03.00. This is influenced by human activities which are more active during the day, this is also in line with previous research that the noise level during the day tends to be higher than at night Ls > Lm (Çolakkadıoğlu and Yücel, 2017). The measurement results obtained that the Ls values at points 1 and 2 were 69.9 and 62.77 dBA. While the Lm values at points 1 and 2 are 60.52 and 49.05 dBA. Spatially a decrease in noise concerning the distance from the noise source occurs, this decrease can be seen from the comparison of the values of Lsm, Ls, and Lm at points 1 and 2. Spatial reduction of noise sources can occur due to reduced sound energy due to the distance of propagation, this also occurs in residential areas close to the urban expressway in the Shapingba District with a negative correlation value between distance and noise level with a p-value <0.01 (Li and Xie, 2021).

The statistical description of the data is displayed in the form of L10, L50, and L90. The L10 values at locations 1 and 2 were 71.6 and 64.7 dBA. The L50 values at locations 1 and 2 were 65.6 and 55.4 dBA. The L90 values at locations 1 and 2 were 57.2 and 45.8 dBA. At point 1 the Lsm value is between L50 and L10, this result illustrates that the noise value at that location tends to be consistent and can be associated with a noise source in the form of the Jagorawi toll road which operates for 24 hours. While point 2 has an Lsm value that is close to the L10 value, this contribution can be caused by sensitivity to peak activities or short-duration noise around the location. In spatially measuring noise, roads with high density have a characteristic Lsm value that is close to the L50 value, while on a low-density road it has an Lsm value close to L50 and L10 (Dirgawati et al., 2021).

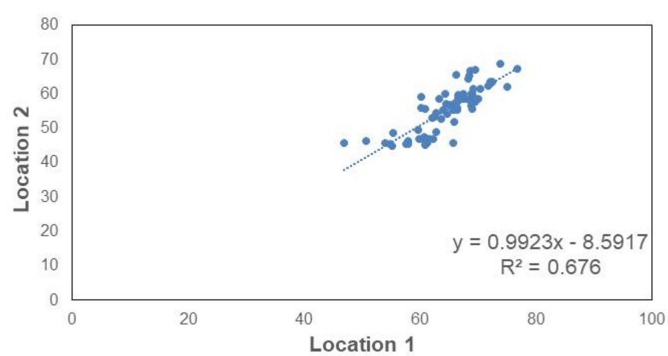

Figure 4. Correlation of Location Noise Values Location 1 and 2

Sample locations 1 and 2 had the same treatment during data collection and analysis so the interpretation used correlation R = 0.8 and the value of determination was 0.676. The value of determination can describe the relationship between

Table 1. Noise Attenuation

H (m)	N	ΔB (dBA)	Received Noise
1	0.279	11.699	57.170
1.5	1.443	12.992	55.877
2	4.803	16.726	52.143
2.5	9.306	21.729	47.140
3	14.366	27.351	41.518

the independent variables (point 1) and can explain 68% of the value of the dependent variable (point 2) with a positive correlation. While the results of the Kolmogorov-Smirnov normality test (n = 70) showed a sig value >0.05, meaning that both data were normally distributed. In addition, the analysis of mean differences t-test shows a value of sig <0.05, the test results show the influence of noise at location 2 from noise at location 1 (Jagorawi highway). The value of determination or correlation at several different points can be caused by the same noise source but still has other noise sources as the influence of each location (Dirgawati et al., 2021).

3.2 Noise Attenuation

The results of the noise measurement at point 1 with a radius of 20 m from the Jagorawi toll road have exceeded the quality standard. The position of the border which is a bridge requires a noise barrier in the form of a wall to reduce the noise received by the community (settlement). Noise mitigation design is planned in several variations of barrier height to get the noise reduction value to reach the required quality standard. While the distance variation is not carried out because the border area between the Jagorawi toll road and the settlement has been built. To find out the difference between the use of barriers and the use of barriers, a mathematical model is calculated according to Equation 8 and 9. The barrier usage function was analyzed in a mathematical model assuming the use of a barrier with reflected effect. The purpose of reflection is to think about the sound energy that will be received by the receiver (Gagliano et al., 2020). So that the noise reduction resulting from the variation of the barrier height can be seen in Table 1.

In Table 1 the height of the noise source used is 1 m and the height of the receiver is 2 m. While the Fresnel value is the value obtained from the calculation of the path traversed by the sound divided by the wavelength. Then this Fresnel value is associated with noise reduction which can be found using Equation 10 or the meikawa graph. The use of barriers in several previous studies has been shown to reduce noise statistically significantly (Ba and Kang, 2019). Noise reduction due to the use of barriers can be influenced by the height of the barrier and the distance between the noise source and the noise receiver (Iordache and Ionita, 2018).

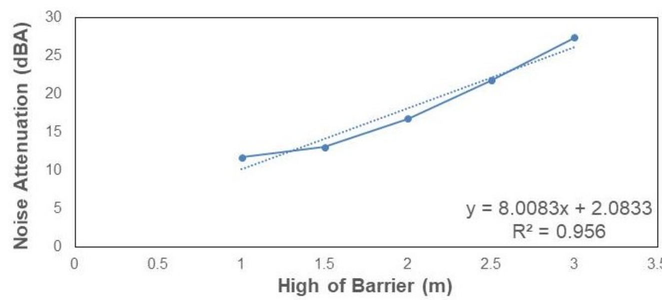

Figure 5. Effect of Barrier Height on Noise Reduction

Based on Figure 5, to achieve a noise level of 55 dBA (according to residential designation), a barrier with a height of 2 m is required, so that the noise level will be reduced to 52.143 dBA. In general, increasing the height of the barrier under the same conditions will reduce noise even more (positive correlation) (Kumar et al., 2014). This positive correlation is also found in the calculation of the use of a barrier with a high variation in Figure 5 with a determination value of 0.956. However, the use of a barrier that is too high can reduce the aesthetic value so that it is necessary to adjust the distance at a location that has a high noise level and is less than optimal in the use of the barrier.

4. CONCLUSIONS

In residential areas around Jagorawi highway has a value above the quality standard for residential areas (Lsm > 55 dBA). Residential areas have values that are influenced by transportation activities on the Jagorawi highway. The source of noise owned by residential areas is transportation, but in settlements with a distance of > 100 m, it is identified that there are sources of noise from human activities. Based on noise reduction analysis, with current conditions it is necessary to use a barrier as high as 2 m so that the noise level is < 55 dBA.

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