The effect of distance of noise level in a residential area (case study: residential area that close to Jagorawi highway and Pandu Raya road in Bogor City)

D Widasari\(^1,3\), I S Fatimah\(^2\) and N Nasrullah\(^2\)

\(^1\) Graduate Student of Department of Landscape Architecture, Faculty of Agriculture, IPB University, Bogor, Indonesia
\(^2\) Lecturer of Department of Landscape Architecture, Faculty of Agriculture, IPB University, Bogor, Indonesia

E-mail: wida_2011@yahoo.co.id

Abstract. Bogor city is a city that continues to experience in population growth and physical city development, where the development creates various kinds of problems, which one is noise. This study aim to measure the noise level and analyse the influence of noise level and house distance from noise sources. Data retrieval was collected for three days a week. In one day, noise measurement was carried out for 16 hours (06.00 – 22.00) by measuring the sound pressure level for 10 minutes for each 27 measurement points. The results showed that the noise level in weekdays higher than weekend, with averaged 87.25 dB. In accordance with standard, the noise level of residential area is 55 dB, it means the noise level is above the noise threshold. Based on the regression analysis, the R square of housing is 0.76, the linear equation is \(Y = 77.656 - 6.292x\). The study concluded that the distance affects the value of noise, the closer to the noise source the greater the noise value.

Keywords: house distance, noise, residents.

1. Introduction

City development is often reflected more by the physical development of the city which is more determined by facilities and infrastructure, such as roads, highways, transportation, industrial estates, trade areas, settlements, and so on [1]. The strategic location of Bogor city is the potential for settlement development, economic growth and service, national industrial centre, trade areas, transportation, communication, and tourism. Based on the spatial planning and territory of Bogor city, most of the area of Bogor city is a settlement. The settlements consist of high-density settlements, medium-density settlements, and low-density settlements. The development of residential area and housing in urban areas has been increasing in line with the population growth [2]. To attract consumers interest to settlement and housing area offered sold, the developers are trying to equip the infrastructure including the road infrastructure. On one side of the road makes it easy for the public of need of transportation, however, on the other hand the existence of cars and motorcycles of course bring a variety of disorders and convenience for residents [3].
On form of interference caused by increasing development and human activities is noise. Noise has become a common problem in cities. The sound can be sourced from machine for infrastructure and transportation construction, but most of the noise comes from transportation, especially motorized vehicle. Based on the decision of the Environment Minister of Republic of Indonesia number 48/MENLH/11/1996, noise is an unwanted from a business or activity at a certain level and time that can cause disruption to human health and environmental comfort [4]. Hazardous noise affects the functioning of the inner ear, which may cause temporary hearing loss. After a period of time away from noise, hearing may be restored. With further exposure to hazardous noise, the ear will gradually lose its ability to recover and the hearing loss will become permanent [5].

Decree of Minister of Health of Republic of Indonesia Number 829/MENKES/SK/VII/1999, states that housing and residential environment health requirements in the recommended noise and vibration are 45 – 55 dB for maximum noise and vibration levels of 10 mm/sec [6]. Regarding noise issues in urban areas, residential noise quality standards have been stipulated in the Decree of Minister of Environment Number 48/MENLH/11/1996 concerning the noise level standard of 55 dB [4]. The aim of this study was to measure noise in housing of IPB I Baranangsiang and analyse the influence of noise level and house distance from noise sources. In meeting the ease of transportation facilities, the construction of highway infrastructure is also developing in the city of Bogor. However, the development of highway infrastructure sometimes has to go through old housing, which existed before the highway, so that it can have a negative impact on housing residents, which one is noise. In addition, the value of safe distance that is suitable for housing from noise originating from roads and highway can also be known in this study.

2. Methods

2.1. Study location
The research was conducted at the housing of IPB I Baranangsiang, located in Baranangsiang village, East Bogor district, Bogor city. The housing is located at coordinates 6°35’56” S and 106°49’1.7” E. In addition, the housing is close to the noise sources originating from the Jagorawi highway and Padi road in the north, as well as the Pandu Raya road and Kolonel Ahmad Syam road on the east.

2.2. Data collection
Data retrieval was collected for three days a week, one day on weekend (Sunday) and two working days (Monday and Wednesday). Noise measurement was measured using sound level meter (SLM) tool by measuring the dBA sound pressure level for 10 minutes and data reading is done every 5 seconds. The sound level meter’s microphone height was 1.2 m (chest height). The time for noise measurement was carried out for 16 hours (06.00 – 22.00). In one day, the measurement was carried out four times, i.e. in
period I (at 07.00, representing 06.00 – 09.00), in period II (at 10.00, representing 09.00 – 14.00), in period III (at 15.00, representing 14.00 – 17.00), and period IV (at 20.00, representing 17.00 – 22.00). Noise measurements were made in three replications consisting of one holiday and two working days. The measurement points at the study site were 27 points. SLM mounting points are 0 m, 10 m, 25 m, and 50 m from the noise source.

![Figure 2. Illustration of noise measurements.](image)

### 2.3. Analysis of noise level in housing

Data obtained during the measurement of 10 minutes, then the data is calculated to determine the noise value of the measurement results. Calculation of equivalent sound level (L\text{eq}) 1 minute data can be calculated using the formula [7]:

\[
L_{\text{eq}} \text{(1 minute)} = 10 \log_{10} \left[ \left(10^{0.1L_1} + 10^{0.1L_2} + \ldots + 10^{0.1L_{12}}\right)5 \right] \text{ dB(A)}
\]  

(1)

This formula is used every minute until the L\text{eq} 1 minute data is obtained. After each L\text{eq} 1 minute value is obtained, then proceed with the calculation of L\text{eq} 10 minutes with formula [7]:

\[
L_{\text{eq}} \text{(10 minutes)} = 10 \log_{10} \left[ \left(10^{0.1L_I} + 10^{0.1L_{II}} + \ldots + 10^{0.1L_X}\right)1 \right] \text{ dB(A)}
\]  

(2)

This study is only limited to measurements during 16 hours of activity (L\text{eq day}) with an interval of 06.00 – 22.00. Each measurement represents a certain time interval by setting 4 measurement times, including L1 (at 07.00, representing 06.00 – 09.00), L2 (at 10.00, representing 09.00 – 14.00), L3 (at 15.00, representing 14.00 – 17.00), and L4 (at 20.00, representing 17.00 – 22.00). The L\text{eq} 16 hours can be calculated using formula [7]:

\[
L_{\text{eq}} \text{(day)} = L_s(16 \text{ hours}) = 10 \log_{10} \left( Ta^{0.1L_a} + \ldots + Td^{0.1L_d} \right) \text{ dB(A)}
\]  

(3)

information:

- L\text{eq} : equivalent noise [dB(A)]
- L1, ..., L12 : noise every 5 seconds for 60 seconds [dB(A)]
- L1, ..., LX : noise every 1 minute for 10 minutes [dB(A)]
- L\text{eq} (day) : Leq in the daytime [dB(A)]
- Ta, ..., Td : interval of measurement during the day (hours)

### 2.4. Statistical analysis

Before carrying out statistical analysis, the first step was searched the average noise value for each day from each measurement point. Then, statistical data analysis was performed using a simple linear regression analysis to determine the effect of distance on noise, because it considers the inclusion of one explanatory variable for this study [8]. Data was processed using software SPSS IBM 21 and Microsoft Excel 2010. The dependent variable is the noise value and the independent variable is distance. The significance level used is 5%. The linear equation used is:

\[
Y = a + bX
\]  

(4)
information:
Y : dependent variable
X : independent variable
a : constant
b : coefficient of regression (slope), the amount of predictor response

3. Result and discussion

3.1. Types and sources of noise in housing of IPB I Baranangsiang
The dominant noise source at the study site came from motorized traffic activities. The combination of noise produced by motorized vehicles is the interaction between the engine, tires, and road surface. Several factors affect noise, including the type of vehicle, engine type, traffic speed, type of pavement, distance to noise sources, barriers, topography, and weather. Higher speed levels are produced by heavier vehicles, higher speeds, uphill slopes, overly high bridges, and relatively high humidity [9].

3.2. Noise level on weekdays and weekend
Based on the measurement of the noise level in housing of IPB I Baranangsiang, it is known that each point has a different noise level, and the measurement times four times a day produce different levels of noise. Factors that influence include measurement time and distance of measurement points from noisy source.

![Figure 3. Noise level in daytime (L_{eq} 16 hours).](image)

Figure 3 shows that the noise level measurement of L_{eq} 16 hours or L_{eq} in daytime exceeds the specified quality standard, which it has supposed to be 55 dB [7]. The L_{eq} 16 hours on Monday has a higher value than the other day, which is 89.2 dB. While the second highest Leq 16 hours value is 87.54 dB which occurs on Wednesday, then Sunday have a value of L_{eq} 16 hours 85.016 dB.

From the data, it can be seen that the noise level of the working day (Monday and Wednesday) is greater than the weekend (Sunday) (figure 4, 5 and 6). On weekdays, the peak of the increase in the number of vehicles occurs during rush hours, in the morning and during the afternoon. During weekend, vehicle activity in the housing area is reduced. The statement is in accordance with the literatures which suggest that the average volume of vehicles in residential areas on holiday is smaller [10]. Housing of IPB I Baranangsiang is close to Padi road and Kolonel Ahmad Syam road. Padi road and Kolonel Ahmad Syam road are the corridor with land use as residential and housing areas. The corridor is a secondary local road that connects the secondary area with housing, and it designed based on a vehicle speed at least 10 km/hour with a road width at least 7.5 m [11], so heavy transport vehicles are not allowed to pass through this road.
From the Figures 6, it can be seen that the highest noise intensity is at the time interval of morning, evening, and night measurement (06.00 – 09.00, 14.00 – 17.00, and 17.00 – 22.00). On weekend (Sunday) the highest noise levels occur at night. Some people do more leisure activities on weekends, such as visiting a nearby park [12], going to tourist attractions, going out of town visiting family, and so forth. When going to distant tourist attractions they usually go on Saturday morning and return on Sunday night, so they can stay overnight and have a longer time with family. Based on observations in the field, on Sunday nights, the atmosphere of Jagorawi highway road and Pandu Raya road is crowded by vehicles. On weekdays (Monday and Wednesday) the highest noise levels occur in the morning and
evening. The difference in measurement time will cause different vehicle intensity and will affect the noise level. In the morning and evening, human activities and the volume of vehicles that pass more than during the day.

3.3. Analysis of the effect of house distance on noise

Based on a simple regression analysis, Y variable is the noise level, while variable X is the distance from the noise source. Coefficient of determination ($R^2$) value of IPB Baranangsiang I resident is 0.76, it means that the distance variable affecting the noise by 76%, while 24% are other variables that affect the noise. Other variables that affect the noise level in the housing can be topographic conditions [9], barriers, and activities in the housing environment. The topography in the housing is indeed higher than the sound source, so that sound waves spread with high sound levels. In addition, if the road is steeper, then the vehicle will require more effort to be able to pass/climb the road, one of which will increase the speed of vehicle, so that the sound waves received will be even higher.

The p-value in IPB Baranangsiang I housing is 0.000, indicating that the distance relationship and noise level variables have a significant effect. The linear equation of the regression analysis is $Y = 77.65 - 6.3X$, indicating that if the noise variable has an increase of 1 dB it will reduce the variable distance from the noise source by 6.3. Lower the distance variable means getting closer to the noise source.

From the transects point assessment above (figure 7 – figure 10), noise source came from the east (Pandu Raya road and Kolonel Ahmad Syam road). It can be seen that distance affects the noise value. The farther away from the sound source, the noise level will decrease. figure 7 and figure 8 can be seen...
at a distance of 50 m (point 8 and point 12) having a higher noise value than distance of 25 m (point 7 and point 11). It is because of point 8 and 12 have close distances. Between these points there are only plant barriers that have spacing that is not tight/space, so that if there is a vehicle passing at point 8, the sound waves can still spread to point 12 or can’t be reflected/absorbed by plants between the two points that is. Natural vegetation, if high enough, wide enough, and dense enough, can decrease roadway traffic noise [13]. Vegetation plant noise barrier is environmentally friendly, having a natural appearance and often pleasant in visual inspection. The effectiveness in screening depends on the thicknesses of vegetation and density of leaves (type of vegetation). Effective noise barriers can reduce noise leaves by 10 – 15 decibels [14].

In the case Figure 9 and Figure 10, on transect 3 and transect 4 can be seen at a distance of 50 m has a noise value lower than the distance of 25 m. This is because at a distance of 50 m (point 16 and point 20) have blocked by several houses. So, if there is a vehicle that passes at point 16, the sound wave will be reflected by the house wall that blocks it. The house walls can be the noise barrier in resident or housing. Noise barriers (also referred in the literature as Noise Reducing Devices-NRDs, Sound Walls, Noise Walls, or Acoustical Barriers) form a major part of infrastructure system in mitigating undesirable road noise to impacted communities [15].

![Figure 11. Transect point 21 - 24 (house distance 0 – 50 m).](image1)

![Figure 12. Transect point 25 - 27 (house distance 0 – 25 m).](image2)

From the transects above (figure 11 and figure 12) the noise source came from the north (Jagorawi highway and Padi road). In Figure 12, the distance of the last house is only limited to 25 m. Next to the house is not part of housing of IPB I Baranangsiang. On transect 2 (figure 12), it can be seen that at a distance of 25 m it has a higher noise value than the distance of 10 m. This is because at point 27 (distance 25 m) adjacent to the residential village, which is already outside the housing boundary. So there are other noisy sources from that village.

In transect line V (figure 11) has a rather steep topography, but because the path is still long so the sound waves, which coming from the noise source, will be smaller when the distance is farther away. Unlike the transect line VI (figure 12) also has a rather steep topography, but the path on the housing is short, only up to a distance of 25 m. It also borders on residential villages, so the effect of distance is not too significant in decreasing sound waves at a distance of 25 m on transect line 2 (figure 12). If there is a path with a steep topography, the vehicle will need an attempt to cross the route. The effort needed by a vehicle to cross this route can be increasing speed, which can lead to louder engine sound, and use brakes that can cause sound interaction between the wheels and the road surface. Therefore, it is not surprising if the distance from the noise source is getting farther but the noise value is still not reduced, this may be due to the steep topography.

4. Conclusion

Noise in residential areas can interfere with comfort and have a negative impact on its residents. Research conducted at the IPB I Baranangsiang housing estate found that the noise level was highest during weekdays, this occurred in the morning and evening, when there was heavy vehicle activity. This
study also found that the noise value affects the distance of the house. The average noise value obtained at 0 m distance is 73.30 dB, at 10 m distance is 60.68 dB, at 25 m distance is 56.46 dB, and the average noise value at 50 m distance is 56.10 dB. The closer the distance of the house to the noise source, the noise value increases, but conversely the farther the house falls from the noise source, the noise value decreases. The efforts in controlling noise in housing can be done by several ways, such as closing doors and windows, using earplugs, and also use barrier walls or plant barriers. The combination of barrier walls and vegetation is effective in reducing noise by up to 5-15 dB [16]. Both types of barrier can be used if the land in a house is not too broad.

5. References
[1] Dahlan E N 2004 Hutan Kota Untuk Pengelolaan dan Peningkatan Kualitas Lingkungan Hidup (in Bahasa) (Bogor, Indonesia: Institut Pertanian Bogor) p 3
[2] Makarau V H 2011 Penduduk, perumahan pemukiman perkotaan dan pendekatan kebijakan (in Bahasa) Jurnal Sabua 3 53
[3] Dora C, Hosking J, Mudu P and Fletcher E R 2011 Sustainable Transport: A Sourcebook for Policy makers in Developing Cities (Bonn, German: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) Gmbh and World Health Organization)
[4] Minister of State for The Environment 1996 Standard Noise Level (Jakarta: Ministry of Environment Republic of Indonesia) p 36 & 38
[5] Australian Government 2015 Managing Noise and Preventing Hearing Loss at Work: Code of Practice (Australia: Safe Work Australia) p 6
[6] Minister of State for The Health 1999 Housing Health Requirements (Jakarta: Ministry of Health Republic of Indonesia) p 8
[7] Endi D R and Palupi M 2011 Review of minister living environment no. 48/1996 using results of environmental noise measurement in 2009 J. Purifikasi 12 41
[8] Fávero L P and Belfiore P 2018 Data Science for Business and Decision Making (Cambridge, Massachusetts: Academic Press) p 444
[9] Seong J C, Park T H, Ko J H, Chang S I, Kim M, Holt J B and Mehti M R 2011 Modelling of road traffic noise and estimated human exposure in Fulton County, Georgia, USA Environment International 37 1337
[10] Maharoesman I Y 2009 Dampak “killing time” angkutan kota pada waktu peak hour kasus beberapa ruas jalan di Kota Bandung Jurnal Perencanaan Wilayah dan Kota 20 208
[11] Republic of Indonesia 2006 Government Regulations Republic of Indonesia Number 34 Year 2006 about Road (Jakarta: Secretariat of Republic of Indonesia) p 6 & 9
[12] Bertram C, Meyerhoff J, Rehdanz K and Wüstemann H 2017 Differences in the recreational value of urban parks between weekdays and weekend: a discrete choice analysis Landscape and Urban Planning 159 13
[13] Tyagi V, Kumar K and Jain V K 2006 A study of the spectral characteristics of traffic noise attenuation by vegetation belts in Delhi Applied Acoustics 67 935
[14] Kalansuriya C M, Pannila A S and Sonnadara D U J 2009 Effect of roadside vegetation on the reduction of traffic noise levels Proceedings of the Technical Sessions 25 2
[15] Dumbrava C O and Miah A 2016 Assessment and relative sustainability of common types of roadside noise barriers J Cleaner Production 135 919.
[16] Lacasta A M, Peñaranda A and Cantalapiedra I R 2018 Green streets for noise reduction Nature Based Strategies for Urban and Building Sustainability eds.. Gabriel P and Katia P (Oxford: Butterworth – Heinemann) pp 181-190