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# A study of heterogeneous traffic noise trigger parameters for urban areas

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Abstract. So far, the review of the parameters that trigger traffic noise in urban areas has been partially based on only one factor, namely traffic flow. Meanwhile, other factors have not been included as variables that trigger traffic noise and the analysis has not been conducted simultaneously. In this research, the noise level was measured using a Sound Level Meter (SLM) and analyzed using a mathematical equation. The method for determining the parameters that trigger noise was analyzed through a simultaneous equation system using SmartPLS. The results of the study show that in big cities with heterogeneous traffic, the traffic composition is more dominated by motorcycles at 64%, followed by light vehicles at 32%, and heavy vehicles at 4% with an average vehicle speed of 36 km/h. The low speed is not due to traffic congestion but is mainly caused by driver behavior of not accelerating their vehicles. The parameters that can be used as indicators of heterogeneous traffic noise triggers in urban areas are traffic aspects with indicators of motorcycle volume and traffic density, road physical aspects with superelevation indicator, as well as environmental aspects of the road with the air temperature indicator

Keywords. parameters, trigger, noise, traffic.

#### 1. Introduction

Traffic noise is one of the strategic issues that has become a transportation problem in urban areas due to the rapid increase in motorized vehicles. Based on preliminary observations at several points on the road, it was identified that the noise level had reached the level of 72 dB, which exceeded the noise threshold applicable in Indonesia [1]. When it reaches a certain level of intensity, traffic noise can have a negative impact on human health and comfort as well as to road users themselves. The impact is in the form of psychological disorders and hearing problems. Therefore, every activity in the field of traffic and road transportation must implement prevention measures and overcome environmental pollution to meet the provisions of environmental quality standards. In general, the highest noise intensity occurs in the trading area, followed by the office area. The lowest is in the school area due to the increased distance from the roadside. There is no significant difference in traffic noise intensity on Tuesday and Sunday [2].

One of the previous studies has identified factors that affect the level of traffic noise from the traffic aspect, namely vehicle volume, speed, and traffic density [3]. However, logically, the intensity of noise on the highway is not only determined by traffic factors but also other factors such as road physical



characteristics and road environmental conditions. This is due to the large use of motorized vehicles compared to other types of vehicles, both two-wheeled and four-wheeled, as well as those with more than four wheels. Heavy vehicles (trucks, buses) and passenger cars are the main sources of noise on the highway, even though the composition of motorcycles is more dominant, reaching 60% [4].

Although the volume of two-wheeled vehicles is higher, light vehicles are the primary source of noise in urban areas [5]. The composition of heavy vehicles at 4% has an important role in influencing noise. Meanwhile, compositions below 4% are not significant for the increase in noise. Noise is more dominantly influenced by motorcycles and light vehicles [6].

Tree density is the parameter that has the highest influence on the increase and decrease of traffic noise on the highway, which is 19%, followed by the volume of leaf cover with 9.7%, temperature with 9.1%, uilding density with 8.7%, and type of soil surface 5.8% [7]. Variations in tree and shrub vegetation can reduce traffic noise on the highways and lower temperatures. The composition of trees and shrubs vegetation is more effective in reducing noise up to 12.25% and lowering temperature up to 8.18% [8].

To predict traffic noise, it is not only based on vehicle volume and the percentage of heavy vehicles, but also on the average vehicle speed and road conditions such as road height, width, and gradient [9]. At average speeds below 40 km/h where traffic flow conditions are still stable, noise is more dominantly influenced by vehicle density than speed [10]. In addition, there is also a traffic noise prediction model that can be used effectively according to the conditions of cities in Iran. The variables used include vehicle volume, speed, percentage of truck, road width, gradient, and observation distance. The resulting prediction model has the smallest difference value with measurement results compared to using several other models [11]. The noise prediction value tends to be lower than the measurement results with an average difference of 2.2 dB. It is estimated that this low value is mainly related to urban morphology conditions [12]. The TNM method can provide predictions based on the distribution of traffic volume as it can rank areas with low or high noise levels [13].

Vehicle volume, speed, and road geometry do not have a significant relationship with noise due to heterogeneous traffic conditions. Therefore, a multiple linear regression approach should be developed for predicting traffic noise in India's heterogeneous traffic conditions [14]. The development of a traffic noise model using graph theory approach with variables such as vehicle speed, traffic volume, road width, number of heavy vehicles, and horn sound can be applied in the form of matrix as a function of permanent noise. Although the model's result is satisfactory, the size of the results is rather large [15]. Every addition of one lane of road will increase the noise level by 0.50 dB. Assuming other factors remain constant, an increase of 1 km/h in speed will increase traffic noise by 0.15 dB [16].

#### 2. Materials and methods

Noise is an undesirable sound generated by activities or operations within a certain level and time that can cause human health and environmental discomfort. The threshold limit value or standard noise level is the maximum noise level allowed to be discharged into the environment from activities or to prevent health problems for humans and discomfort to the environment.

The sound will become weaker as it gets farther from the noise source. The reduction of noise due to distance will differ between single and multiple noise sources. Equivalent noise level is a model used to express the average sound pressure over a specific time period, which is obtained from the results of measurements using SLM.

$$L_{eq} = L_{50} + 0.43 (L_1 - L_{50}) \tag{1}$$

where,  $L_{eq}$  is equivalent noise level (dB) and  $L_{50}$  is noise indicator rate 50% (dB)



## Table 1. Noise level quality standard

	Description	Noise Level dB(A)
a.	Appropriation of region	
	1. Housing and Settlements	55
	2. Trade and Services	70
	3. Office and Commerce	65
	4. Green open space	50
	5. Industry	70
	6. Government and Public Facilities	60
	7. Recreation	70
	8. Specifically:	
	- airport *	
	<ul> <li>Railway station *</li> </ul>	
	- harbor	70
	- Cultural heritage	60
b.	Surrounding Activity	
	1. Hospital or the like	55
	2. School or the like	55
	3. Worship place or the like	55

Source: Decree Number: 48/MENLH/11/1996



Figure 1. Study area

Traffic identification was carried out together with noise surveys, with observation time of 10 minutes during peak hours at each sample point. The placement of the sound level meter (SLM) was 1 meter from the edge of the road. Measurement of vehicle speed was carried out by taking speed samples of 30 units at each location; consisting of 10 motorcycle samples, 10 light vehicle samples,



and 10 heavy vehicle samples. In addition to vehicle composition, traffic density on the highway will also be obtained. Next, the physical condition of the road will be identified to determine the condition of road damage (good, fair, poor, very poor).

The surface distress index (SDI) method is used to determine the condition of the road pavement. Geometric measurements of the road include; slope, superelevation, and road width. Environmental aspects of the road include the identification of building density, tree density on the roadside, leaf lush in one segment, and the type of soil surface from roadside to land use. All noise-triggering variables are measured based on indicators selected from several references. Then, the variables are analyzed using a simultaneous equation system using the Partial Least Square.



Figure 2. Noise and traffic measurement scheme



Figure 3. Leaf canopy measurement

### 3. Results and discussion

The characteristics of traffic include traffic volume, vehicle composition, speed, and traffic density. The calculation of traffic volume is based on the number of vehicles passing through the road during the observation time in units of vehicles per hour. AS3 area has the highest traffic volume among all regions with an average of 3435 veh/h. This is because the road sections in the area are the main route of traffic movement in Kendari City. In addition, it was also influenced by the attraction of travel due to the presence of activity centers in the area. Meanwhile, the lowest traffic volume occurred in the AS1 area, with an average of 1966 veh/h. This is because the road section in the area only serves as a connection to outside the city and is not a city development area. In general, the average traffic volume on the highway is 2393 veh/h, consisting of 1531 veh/h, 766 light veh/h, and 96 heavy veh/h.





Figure 4. Behavior of traffic volume

In Figure 4, it can be seen that fluctuation of motorized vehicles on the highway in all areas only occur between motorcycles (MC) and light vehicles (LV). This means that when the composition of motorcycles increases, the composition of light vehicles also increases, and vice versa when the composition of motorcycles decreases, the composition of light vehicles also decreases. Meanwhile, heavy vehicles (HV) show constant behavior. Traffic composition in big city categories with heterogeneous traffic is dominated by motorcycles at 64%, followed by light vehicles at 32%, and heavy vehicles at 4%.

These results indicate that the composition of motorcycles is higher compared to light vehicles and heavy vehicles. Nevertheless, heavy vehicles have the largest contribution to traffic noise on the highway. This is supported by previous study stating that heavy vehicle compositions above 4% have a dominant influence on fluctuations in noise levels. Meanwhile, compositions below 4% are not significant to the increase in noise, where noise is more dominantly influenced by motorcycles and light vehicles. The same is also supported by the results of a research in India which states that heavy vehicles and light vehicles are the main source of traffic noise on the highway, even though the composition of motorcycles is more dominant 60%.



Figure 5. Behavior of vehicle speed

In Figure 5 shows the average speed of motorcycles is 43 km/h, light vehicles is 35 km/h, and heavy vehicles is 31 km/h. The highest traffic density occurs in service land use areas with 90 veh/km, followed by commercial land use 79 veh/km, schools with 70 veh/km, offices with 67 veh/km, and the lowest in residential areas with 51 veh/km. The low speed is more dominantly caused by driver's behavior who do not speed up their vehicle. Every increase in motorcycle speed is always followed by light vehicles and then heavy vehicles (HV) with the lowest speed.



Several previous studies have stated that in stable traffic conditions with an average vehicle speed below 40 km/h, noise is more dominantly influenced by vehicle density than speed. Vehicle speed has little effect on the noise level. Noise is more influenced by traffic volume alone. However, in medium city categories such as Kendari City, traffic noise is directly proportional to the number and speed of motorized vehicles on the highway.



Figure 6. Road pavement condition

The physical characteristics of road consist of road width, superelevation, slope, road type, and pavement condition. Based on the analysis results in Figure 6 it is known that the road width varies between 4.5 to 16 meters with superelevation of 1.3 to 4.4% and road gradients of 0.4% to 8%. The average road segment in the AS3 area is flat, while the AS2 area has a slightly sloping road. The pavement condition is assessed based on the SDI (Surface Distress Index) criteria. The types of road damage found are only functional damage such as cracks, aggregate loss, patching, and potholes. Overall, the condition of the road pavement is good at 49%, fair at 36%, slightly damaged at 12%, and heavily damaged at 3%.

The road environment consists of building density, tree density, leaf lush volume, type of road environment soil surface, and air temperature. The building density is between 20% to 100% with the type of permanent wall construction. However, there are some study segments where there are no buildings. This is intended as a comparison to see the effect of the absence of noise reflection from building walls. A building density of 100% is indicated by the absence of space/gaps between buildings.

Meanwhile, the variation in tree density ranges between 18% to 88% with a volume of leaf lush between 3m3 to 259m3. The height of the trunk ranges from 0.9m to 1.7m from the ground surface. However, there are also several segments where there are no trees. This is intended to as a comparison to see the effect of noise without the presence of trees.



Figure 7. Road environment surface type

In Figure 7, it can be seen that the composition of the type of soil surface on the road environment at the research location is soil (41%), concrete rebates (31%), grass (18%), and paving blocks (10%).





Meanwhile, the air temperature fluctuates between 30°C to 38°C. The results of the noise level analysis can be seen in Figure 8.

Figure 8. Traffic noise fluctuations

Based on Figure 8, it is evident that the noise level has exceeded the environmental threshold according to Ministerial Decree Number: 48/MENLH/11/1996 for residential areas, hospitals, schools, and places of worship (Tres1) as well as trade and services (Tres2). The average noise level on the roadside is 70.5 dB. Based on the noise zone criteria (KDB), the distance of land use from the roadside is identified as being in a noise risk area (DRB), 51% moderately noise area (DMB), and 14% noisy safe area (DAB).

The highest noise intensity occurred in the AS3 area and the lowest in the KS1 area. This is identical to the intensity of traffic volume in the area, where the highest noise occurs in service land use areas (hotels, advertising, car rentals, and restaurants). The noise level was also high in office buildings, trading areas, schools, residential areas, and lowest in public facilities areas. The high noise exposure in each land use was due to the attraction of the trip. Additionally, it is influenced by their strategic location on road sections connecting several activity centers in the surrounding area. The noise level decreases as the distance from the roadside increases. To obtain noise trigger parameters, the variables that have been identified previously are integrated into a simultaneous equation system.



Figure 9. Total effect of traffic, physical, and road environment on noise



	<b>Regression Weights</b>	Standardized Loading Factor ≥0.7	Validity
ExL <sub>10</sub>	← Noise	0.918	valid
ExL <sub>50</sub>	← Noise	0.964	valid
ExL <sub>90</sub>	← Noise	0.885	valid
Leq	← Noise	0.923	valid
Grad	← Physical of Road	-0.214	invalid
Kond	← Physical of Road	-0.121	invalid
Spel	← Physical of Road	0.729	valid
Lja	$\leftarrow$ Physical of Road	-0.663	invalid
Тур	← Physical of Road	0.176	invalid
Dbg	← Road Environment	0.022	invalid
Dph	← Road Environment	0.242	invalid
Vda	← Road Environment	-0.024	invalid
Pbu	← Road Environment	-0.513	invalid
Su	← Road Environment	0.732	valid
Dtr	← Traffic	0.884	valid
VHV	← Traffic	-0.407	invalid
VLV	$\leftarrow$ Traffic	-0.456	invalid
VMC	$\leftarrow$ Traffic	-0.487	invalid
qHV	← Traffic	0.429	invalid
qLV	← Traffic	0.622	invalid
qMC	← Traffic	0.856	valid
Vol	← Traffic	0.913	valid

**Table 2.** Result of measurement model evaluation

Source: own analysis

In Table 2, it can be seen that out of the five indicators included to measure the physical parameters of the road, only superelevation has a value above 0.7. The selected environmental parameter for the road is temperature. Meanwhile, the selected indicators for traffic parameter are motorcycle volume and traffic density. This indicates that all selected indicators have accuracy, consistency, and instrument precision in measuring their respective constructs.

Traffic noise issues are something that needs attention. Every activity in the field of traffic and road transportation must be accompanied by environmental pollution prevention measures in order to comply with the provisions of environmental quality standards. However, so far, these efforts have only been focused on addressing traffic aspects, such as road widening and traffic engineering. This appears to be less optimal as it is not comprehensively reviewed. Therefore, from the results of this analysis, indicators are obtained as parameters that can be used to represent the triggers of heterogeneous traffic noise in urban areas. However, these indicators need to be further investigated in other big cities. This research is an initial study for the next stage in determining priorities for reducing traffic noise in urban areas.

### 4. Conclusion

The traffic noise level on the roadside reached the level of 70.5 dB, which has exceeded the environmental noise threshold. Based on the noise zone criteria, the distance of land use from the roadside in Kendari City is classified as 35% in the high-risk noise area (DRB), 51% in the moderate noise area (DMB), and 14% in the low-noise area (DAB). In big city categories, the composition of traffic is dominated by motorcycles at 64%, followed by light vehicles at 32%, and heavy vehicles at 4%, with an average vehicle speed of 36 km/h and a traffic density of 71 veh/km. The parameters that can be used as indicators of heterogeneous traffic noise triggers for urban areas are traffic aspects with indicator, and environmental aspects of the road with air temperature indicator. The continuation of this study



aims to develop a blueprint for the distribution of traffic noise and its implications on various land uses through a prediction and overlay approach. In the final stage, the development of a traffic noise mitigation model will be carried out.

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