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Estimation of Noise Reduction by Different Vegetation Type as a Noise Barrier : A Survey in Highway along Waru – Sidoarjo in East Java, Indonesia

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Abstract - *Noise pollution has become a common problem in big cities. Most of the noise generated the sounds of transportation. All of these noises on the highways impact to the increasing intensity of noise pollution. The research objective was to estimate the noise reduction using vegetation as a noise barrier in the highway. The present study was conducted on the highway along Waru - Sidoarjo with existing vegetation at the side of the highway. A series of SLM (Sound Level Meter) was arranged at various distances from the highway, in the presence of vegetation, while another series was arranged in the absence of vegetation over the vegetation, the other series as control of those was placed without vegetation. Vegetation types used as samples were Samanea saman,Pterocarpus indicus,Tectona grandis and Pithecellobium dulce. The result was the estimation of noise reduction could be generated for specific distances. It showed that Pithecolelobium dulce have the highest noise reduction of 10.12% at 20 m distance, and the noise reduction equation for this vegetation was* $y=2.67 \ln(x) + 2.18$ *with coefficient determination* (R^2) = 0.92, *and the settlement should be built more than 20 m away from the highway.*

Keywords : *noise; noise barrier; vegetation diversity; highway; settlement*

I. INTRODUCTION

Noise is unwanted sound, allowing sound to interrupt the conversation, or cause pain, as well as the convenience of living activities impede the environment. Nowadays the noise has become a problem for many people. Noise sources can be produced by transportation, such as buses, trains, airplanes, cars, and motorcycles [14]. Noise above 55 dB is considered to get attention because disturbing the comfort of hearing. The noise between 65-80 dB can cause damage to the hearing function when the contact occurred in a long time [2]. In addition can cause deafness, noise can also affect a person's mental health, such as stress or tension. If the tension of the soul cannot be resolved then further impact is declining physical health.

The need for housing developments encourage developers to build housing, in areas that have high noise levels, such as in the area around the highway. The land around the highway are quite sought after because of relatively broad, relatively land price and not too far from center of the city. Trend of the increasing number of motor vehicles on highways have an impact of the rising intensity of noise pollution in the form of noise for environment around the road. According to previous research, the level of noise caused by traffic on Highway Waru Sidoarjo – in 2001 ranged from 65-80 dB. The settlement is located about 20 meters from the highway has also been subjected to noise nuisance caused by the sound of a vehicle through the streets [4]. Due to the large number of pass highway motorists who drove at high speed, it will increase the intensity of the noise pollution.Noise caused by traffic is not constant sound level [8] . The level of noise disturbance from traffic noise is influenced by the level of this voice, how often it occurs within a unit of time, and the frequency of the sound it produces. Traffic noise from the sound generated from motor vehicles, especially from vehicle engines, exhaust, and due to the interaction between the wheels to the road. Heavy vehicles (trucks, buses) and passenger cars are the main source of noise on the highway [12].

Noisy traffic also causes deafness [2]. Noisy because of the traffic caused by motor vehicles, not maintained machine and motor vehicle exhaust, as well as the frequent use of the horn. The intensity of the sound produced from the noisy traffic is about 80-88 dB, and this means the maximum a person can only be in this noise for 16-24 hours. People who are more at risk of traffic noise are the police and motorists.

The pattern is physically mute the sound when the wave damping phenomenon with a certain velocity through the medium of air and then blocked by an obstacle then there are three possibilities that occur in waves are transmitted, is reflected and absorbed. If a material has a good impedance of the incident wave then the wave can be well damped. Actually, a phenomenon that is happening around us is able to reduce the noise level without special treatment, for example by placing artificial elements.

The noise level can be controlled by vegetation depends on 1) the type of species, plant height, density, and distance grows. 2) the climate factors, namely wind speed, temperature, and moisture, and 3) the voice type, origin and the decibel level (level of intensity). Sound wave is absorbed by the leaves, branches, twigs of trees and shrubs. It has been reported that the most effective plants for sound absorption is the part that has thick leaves, fleshy with lots of petiole (leaf stalk). This combination provides a high degree of flexibility and vibration [6]. Sound was deflected and refracted by the branches, twigs and branches of larger trees. It is estimated that forests can reduce noise level 7dB every 30 m with distance and frequency at about 1.000cps [6]

The criteria of the types of green open space plants, particularly for the Green Line Road should be not sticky, not easily broken branches, roots do not interfere the foundation, the structure of the leaves is closed, various height plant. Annual plant type, and closed, half closed planting density [9].

From year to year the volume of vehicles has been increasing, especially on the days before the holidays, or weekends. In 2008 the number of vehicles passing through the highway will average 1.28% per month [7]. The increase is predicted to be greater for the next year. Thus, the noise will increasingly exceed the quality standards that have been set.

The purpose of this study was to estimate the noise reduction effect of each type of vegetation on the side of the highway along the Waru-Sidoarjo, and its dependence on distance from the center of the noise source. The results were vied to hold a model to estimate noise reduction of each type of vegetation as a function of distance from the noise source. Noise barrier reduce noise levels from traffic by blocking and deflecting sound waves [10].

This study was intended to help settlement developers and policy makers. In Indonesia, settlement was a primary need for the residents, but nowadays the land for it becomes narrow. Existing land used along sides of the highway to the settlement would be better if developer pays attention to comfort factor. One of these convenience factors was noise reduction. To reduce the noise which was coming from the highway, there were several ways that can be done, but the cheapest way was to utilize the planting of vegetation along the highway. Beneficial vegetation must be grown on the sides of the highway. In addition to cover crops it was also a beautiful sight to the highway users, as well as to reduce the noise coming from the highway.

II. METHOD

2.1 Study Area

The main highway Waru-Sidoarjo was located in East Java Province along over 49 km long (Figure 1). The noise level of this highway has been proven over the quality standard, the noise levels due to traffic on the highway Waru-Sidoarjo in 2001 ranged from 63-80 dBA [12]. Moderate risk in area standards noise levels over 75 dBA [1]. Noise traffic was produced by the sound of motorized vehicles, especially from vehicle engines, exhaust, and due to the interaction between the wheels to the road. Heavy vehicles (trucks, buses) and passenger cars are the main source of noise on the highway [2].

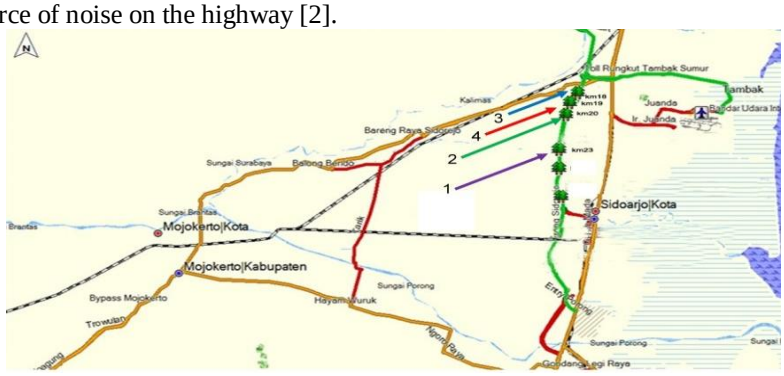

Figure 1: The Location of Highway Waru – Sidoarjo in East Java, Indonesia

(1 was *Pterocarpus indicus* vegetation, 2 was *Tectona grandis* vegetation, 3 was *Samanea saman* vegetation, 4 was *Pithecellobium dulce* vegetation)

The position of vegetation types was not sequential in the rows. Furthermore, the distance between tree is about 5 m. According to the conditions on the field, all kinds of vegetation that are used as the object of study can be seen in Figure 2. The row of main vegetation lies on the side of highway. There are four observation places in different four types of vegetation.

Figure 2: Types of vegetation in highway along Waru-Sidoarjo
2a. *Samanea saman*, 2b. *Tectona grandis*, 2c. *Pterocarpus indicus*, 2d. *Pithecellobium dulce*

2.2 Measurement of Noise Reduction

The survey was conducted by observing the vegetation types. Noise was measured with a Sound Level Meter (SLM), CE mark, model AZ8925, made in Taichung Taiwan. Seven units of SLM are placed on 4 different dots at a distance of 5 m (1 unit), 16 m (2 units), 18 m (2 units), and 20 m (2 units) from the center of the road, 1.5 m above ground (Figure 3). Each pair of SLM are on the place with vegetation and places without vegetation, except the one that has 5 m distance, is placed on the side of the road. All of these measurements will be repeated 5 times.

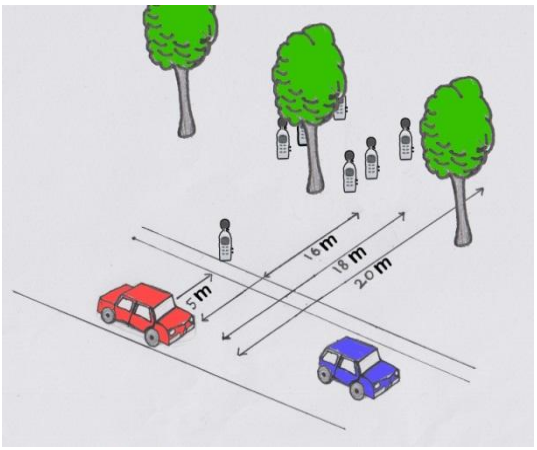

Figure 3: Sketch of the Position of SLM Placement Relative to Highway

2.3 Data Analysis

Having been grouped, the data are processed using Ms. Excel, looking for the difference between the sound intensity level at a distance of 16 meters by 5 meters, 18 meters by 5 meters and 20 meters with a distance of 5 m for each vegetation type. Then the results of sound intensity level is the difference between noise with vegetation and without vegetation , then an average of each distance and each type of vegetation is made. The significance of noise reduction is calculated based on the average using ANOVA. Then line graphs are made from the result of percentage and equations created using the regression equation with the coefficient of determination (R^2) using MS. Excel for graphics and equations [13].

III. RESULT AND DISCUSSION

3.1 The Result

The average of Noise value shown on Table 1 .

Vegetation Type	Distance (m)						
	5	16		18		20	
	Without vegetation	Without vegetation	With vegetation	Without vegetation	With vegetation	Without vegetation	With vegetation
Samanea Saman	86.20±1.76	85.20±1.76	72.60±2.35	74.20±1.76	70.80±2.53	73.20±1.76	69.76±2.49
Tektona Grandis	86.20±1.89	75.40±1.50	71.84±1.40	75.20±1.89	70.84±1.40	74.20±1.89	69.84±1.40
Pterocarpus indicus	84.04±1.37	73.76±1.27	69.48±1.85	73.04±1.37	68.48±1.85	72.04±1.37	67.48±1.85
Pithecellobium dulce	83.20±1.15	72.84±1.14	65.88±2.52	72.20±1.15	64.88±2.52	71.20±1.15	63.88±2.52

Tabel 1: Noise Average Value with Vegetation and Without Vegetation in Different Vegetation Type and Distance

Vegetation Type	Distances (m), Mean ± Std. Deviation			
	5	16	18	20
Samanea Saman	0.00 ± 0.00^{a} (0%)	2.88 ± 1.69^{ac} (3.82%)	3.40 ± 1.85^{ac} (4.41%)	3.44 ± 1.85^{ac} (4.65%)
Tektona Grandis	0.00 ± 0.00^{a} (0%)	3.56 ± 1.39^{ab} (4.7%)	4.36 ± 1.52^{ab} (5.64%)	4.36 ± 1.52^{abc} (5.71%)
Pterocarpus indicus	0.00 ± 0.00^{a} (0%)	4.28 ± 1.28^{abc} (5.81%)	4.56 ± 1.08^{ac} (6.12%)	4.56 ± 1.08^{ac} (6.20%)
Pithecellobium dulce	0.00 ± 0.00^{a} (0%)	6.96 ± 2.84^{abc} (9.53%)	7.32 ± 2.73^{ac} (9.99%)	7.32 ± 2.73^{ac} (10.12%)
Total average	0.00 ± 0.00	4.42 ± 2.43	4.91 ± 2.37	4.92 ± 2.37

Table 2: Noise Reduction Based on the Different Vegetation Type and Distance of Observation to Noise Source

In the Table 1. as shown, at a distance of 16 m, 18 m, and 20 m, *Pithecellobium dulce* have highest noise reduction. This was in accordance with the formula that noise can be reduced when the location of the listener is away from the noise source [5].

In the Table 2, the different superscripts in the same row was significant ($P < 0.001$). Noise reduction at a distance of 5 m, had a very real difference among all types of vegetation. While at a distance of 16, 18 and 20, the difference was almost the same. In the distance of approximately 60 m the noise is not really reduced if it is of meadow (only 17 dB), and 24 dB if it is of forest [11]. The reduction of noise caused by high-speed vehicles can be obtained with the best results by growing trees and shrubs in width 20 – 30 m, buffer of 16 – 20 m from the center of the nearest traffic lane [3].

The noise reduction by vegetation ranges from 3.82% to 10.12%. The best result of noise reduction obtained at 10.12 % for *Pithecellobium dulce*. This is due to this vegetation has a dense leaf position and shape of the canopy which dangle above the soil surface. That plants are effective at reducing noise is the dense leaves throughout the year and leaves pattern spread to the surface of the ground [14].

3.2 The Graph of Noise Reduction and Equation by Each Vegetation

The graph of Noise Reduction and its equation can be made from data by Excel program as shown at Figure 5.

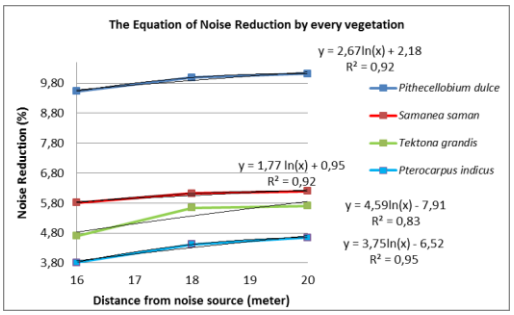

Figure 5: The Equation of Noise Reduction by each vegetation

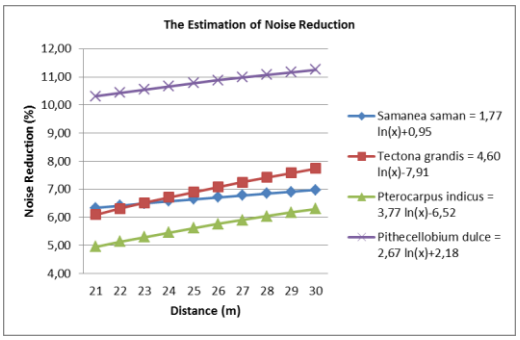

Figure 6. The Estimation of Noise Reduction

From the chart at Figure 5 can be made a summary table (Table 3.) as shown.

Vegetation	Noise Reduction Equation	R^2
Pithecellobium dulce	y = 2,67 ln(x) + 2,18	0,92
Samanea saman	y = 1,77 ln(x) + 0,95	0,81
Tectona grandis	y = 4,60 ln(x) – 7,91	0,83
Pterocarpus indicus	y = 3,77 ln(x) - 6,52	0,96

Table 3: Noise Reduction Equation by every vegetation

The *Pterocarpus indicus*' coefficient determination (R^2) is 0.96 or 96%, it means the influence of vegetation types of noise reduction is 96%, and 4% is the influence of other conditions.

3.3 Estimation of Noise Reduction by Each Vegetation for a Certain Distance

From the resulting equations, can be made an estimate of the amount of noise reduction by each vegetation type in the distance between the center of the toll road to the location of settlements to be built as shown in the Figure 6.

The vegetation which is can reduce the noise among vegetation sample, the greatest is *Pithecellobium dulce* by equation : y=2.67 ln(x) +2.18. To help decrease the noise going on the highway, should the developers who will use the land around the highway of the type of barrier. For this type of barrier should still pay attention to the environment, by utilizing the function of vegetation so that in addition to the noise looks beautiful. As for the settlement position of the motorway, should also consider the distance between the highway with residential location and type of vegetation planted. To estimate the distance of settlement that will be built with the noise source can be helped by using Table 5.

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