Traffic Noise Level Comparison between Direct Measurement and Empirical Equation on Several Education Zones in Surakarta: Noise Mitigation for Students

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Abstract: One of transportation negative impact to environment is traffic noise. At some specific location such as education zone, traffic noise can interfere student's learning process. The aim of this paper is to compare traffic noise level obtained by using SLM and empirical equation, and to provide alternative problems solving for each location.

This research was conducted on six schools: SD Al Islam and MA Al Islam Jamsaren (Jl. Veteran), SMKN 5 and SLTPN 12 (Jl. A. Yani), and SDN Kleco II and SMP Muhammadiyah 5 (Jl. Slamet Riyadi). Data obtained such as traffic flow, vehicles speed, and percentage of heavy vehicles were analyzed with noise level models based on Pd T-10-2004-B. Direct measurement was done by using Sound Level Meter (SLM) which was put down near the road and near the school's building in each location during school time.

In conclusion, noise level by direct measurement and empirical equation were generally exceeding noise standard for education zone, i.e. 55 dB (A). Noise mitigation can be done by planting vegetation as barriers and designing school wall with combination material (bricks and glasses).

Keywords: education zone, noise, traffic , Sound Level Meter

I. Introduction

O ur road system provides extensive benefits in terms of the economic and social wellbeing of the community. However, we need to reach a balance between providing efficient road transport infrastructure and controlling the adverse effects of road use.

The increasing in revenue per capita affects the amount of public ownership of private vehicles such as motorcycles and cars. The development of regional

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economy resulted in a progressively increasing community activities so that the movement of vehicles on roads has increased as well. Road segments in Surakarta city have already crowded with traffic flow which gives negative impact of noise pollution. Noise at some sensitive locations such as education zone, particularly those located in major urban road, is needed to be addressed in order not to become more severe.

SDN Kleco 2 and SMP Muhammadiyah 5 are located at Jl. Slamet Riyadi, which is the arterial road in Surakarta. SMKN 6 and SLTPN 12, located at Jl. A. Yani which is the entrance to Surakarta from the west, so that the daily traffic volume is very high. While SD Al Islam and MA Al Islam Jamsaren is located at Jl. Veteran, which is linked to East Java and Central Java by south route, in which many heavy vehicles and buses passed by.

Noise is more than just a nuisance since it constitutes a real and present danger to people's health. Day and night, at any places, noise can produce serious physical and psychological stress. No one is immune to this stress. People appear to adjust to noise by ignoring it but the ear, in fact, never closes. The body at times still responds with extreme tension, such as to a strange sound in the night.

II. Objective

The objective of this paper is to compare traffic noise level value between direct measurement and empirical equation, to determine how traffic noise conditions in the zone of education and suggest alternatives ways to solve the problem. It is important because noise exposure in the long term and continuously is very dangerous for human health. Traffic noise could be a problem if the value exceeds the threshold noise standard for land use that have been defined. To obtain noise level by direct measurement, SLM was located at close to road side and receiver (the outer side of school wall) and predicted traffic noise by using empirical equations from data such as traffic volume, traffic characteristics, and environmental condition. Based on noise standard if noise level exceed the acceptable value, then this study also suggest some alternatives noise mitigation that can be applied on each location.

III. Traffic Volume

Total traffic volume is the sum of all types of vehicles, except un-motorized vehicles (andhong, becak, bicycle) during certain time periods except the number of un-motorized vehicles :

$$Q_{total} = Q_{LV} + Q_{HV} + Q_{MC} \tag{2}$$

Heavy vehicles percentage can be calculated by equation:

$$\%P_{HV} = \frac{Q_{HV}}{Q_{total}} x100\% \tag{3}$$

IV. Understanding Noise

A. Noise Scale and Definition

Sound is technically described in terms of the loudness (amplitude) of the sound and frequency (pitch) of the sound. The standard unit of measurement of the loudness of sound is the Decibel (dB). Since the human ear is not equally sensitive to sound at all frequencies, a special frequency-dependent rating scale has been revised to relate noise to human sensitivity. The A-weighted decibel scale (dBA) compensates for this study by discriminating against frequencies in a manner approximating the sensitivity of the human ear. Decibels are based on the logarithmic scale. The logarithmic scale compresses the wide range in sound pressure levels to a more usable range of numbers in a manner similar to the Richter scale used to measure earthquakes. In terms of human response to noise, the difference of 10 dBA is judged to be twice as loud and with 20 dB (A) being four times as loud and so forth. Everyday sounds normally range from 30 dBA (very quiet) to 100 dB (A) (very loud).
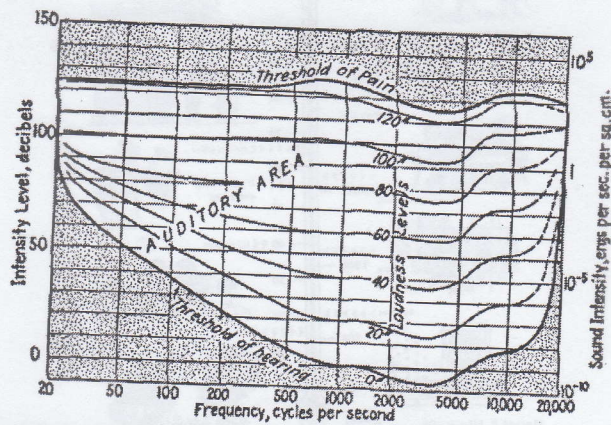

Figure 1. Contours of equal loudness, plotted against intensity and frequency for the average ear

Noise is defined by the World Health Organisation (WHO) as "unwanted sound". The intensity of perceived noise depends on sound pressure, which is measured using a logarithmic scale and the conventional unit of measurement known as the decibel. The diagram shows some examples of noise sources and related levels of sound pressure.

The human ear responds to a frequency range of about 10 octaves. It responds to air vibrations whose amplitude is hardly more than molecular size; it also responds without damage to sounds of intensity 10^{13} to 10^{14} times greater without damage.

The response of the ear is not proportional to the intensity, however. It is more nearly proportional to the logarithm of the intensity. Since the ear responds differently to different frequencies, the logarithmic relation of intensity to loudness is not generally perfect, but it is easier to handle than the enormous numbers involved in the audible intensity range. Therefore, the intensity level of sound is defined in decibels as 10 times the logarithm of the ratio of the intensity of a sound, I, to a reference level defined as 10^{-9} erg/cm^2/sec. Thus:

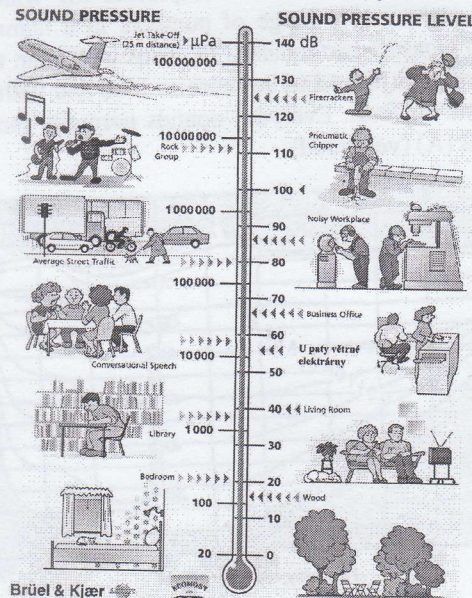$$\text{Sound intensity level (SPL)}, \quad decibels = 10 log_{10} \frac{I}{10^{-9}} \tag{1}$$

Fig. 3. Decibel scale: sound levels typically created by souces of noise in the home and community (http://www.vetrnaelektrarna.cz/Documents/HS.jpg)
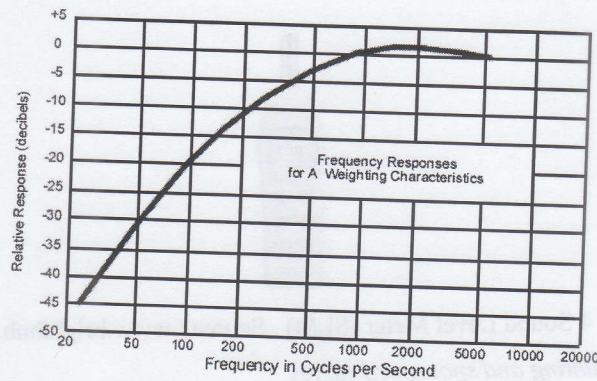
Figure 2. Frequency response weighing for the "A" scale. (From Peterson and Gross, 1967, p.9).

B. Effects of Noise on Human Beings

Noise can cause various disorders such as disorders of physiological, psychological disorders, communication disorders and deafness. There is a disorder characterized form of auditory disorders, such as disruption of the hearing and non auditory disorders such as communication failure, safety hazard, and the decline in work performance, stress and fatigue.

V. Methodology

A. Measurement noise

To measure the amount of noise commonly uses Sound Level Meter. Since sound levels are logarithmic, a small increase in decibels represents a large increase in sound energy. For example, an addition of 10 dB (A) would sound as if the sound source had doubled in loudness. Therefore, a 70 dB (A) would sound twice as loud as a 60 dB (A) sound source. SLM is placed at two observation points, first at the road (on sidewalk or kerb) and the second is at the outside wall of the school facing highway. Equipment must not be blocked by objects or buildings and cultivated similar altitude with the height of receiver.

Fig. 4 Sound Level Meter (SLM) . Source : www.brighthub.com

B. *Traffic counting and spot speed survey*

Traffic counting is distinguished by the direction of movement, vehicle type and time of the survey. Type of vehicle consists of motorcycles, light vehicles, heavy vehicles (buses, trucks, containers). The data was collected during school days, from beginning to end (the break not observed) that was depend on study time on each location, with observation periods of 15 minutes.

Travel time data was obtained by measuring the amount of time required by each type of vehicle to go through a segment of road (100 meters).

For the implementation of these surveys, this study required the following tools: hand counter, stopwatch, tape measure, stationery, forms.

C. *Noise calculation procedures*

The empirical equation used to predict traffic noise levels based on Pd T-10-2004-B (Indonesian Ministry of Settlements and Regional Infrastructure) model, which adopted from 'Calculation of Road Traffic Noise'—the CORTN model from UK Department of Transport or UK Department of Environment.

Calculation procedure is divided into the form of mathematical equations and graphs, and calculation can be used for distance from the side of the road no more than 300 meters and wind speeds below 2 m / sec. The above steps in the procedures are shown in Figure 5.

Dividing the road scheme into segments

If the noise levels vary significantly along the length of the road, then the road is divided into a small number of separate segments so that within any one segment the noise level variation is less than 2 dBA. Each segment is treated as a separate noise source and its contribution is determined accordingly.

Prediction of basic noise levels

The basic noise level hourly is predicted at 10 meters away from the nearside carriageway according to the following equation:

$$L \ (hourly) = 42.2 + 10 \log q, \ dBA \tag{3}$$

In which q is the hourly traffic flow (vehicles/hour).

Here it is assumed that the basic velocity V = 75 km/h, percentage of heavy vehicles p = 0 and gradient G = 0%. It is also assumed that the source line is 3.5 m from the nearside edge of the road for carriageways separated by less than 5.0 meters.

Correction for mean traffic speed, percentage of heavy vehicles

The correction for percentage of heavy vehicles and traffic speed are determined using the following expressions:

$$\Delta_{pV} = 33\log_{10}(V + 40 + \frac{500}{V}) + 10\log_{10}(1 + \frac{5p}{V}) - 68.8, dB(A) \ (4) \quad \text{In this expression}$$

sion the percentage of heavy vehicles is given by:

$$p = \frac{100f}{q} \tag{5}$$

In which f is the hourly of heavy vehicles.

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┌─────────────────────────────────────────┐
│ Stage 1: Divide road scheme into segments │
└─────────────────────────────────────────┘
              │
┌─────────────────────────────────────────┐
│     Calculate noise level contribution    │
│            from a segment                 │
└─────────────────────────────────────────┘
              │
┌─────────────────────────────────────────┐
│        Stage 2: Basic noise level         │
└─────────────────────────────────────────┘
              │
┌─────────────────────────────────────────┐
│ Calculate corrections for:                │
│   • traffic speed                         │
│   • percentage of heavies                 │
│   • gradient                              │
│   • road surface                          │
└─────────────────────────────────────────┘
              │
┌─────────────────────────────────────────┐
│        Stage 3: Propagation               │
└─────────────────────────────────────────┘
              │
┌─────────────────────────────────────────┐
│        Distance correction                │
└─────────────────────────────────────────┘
              │
         ◇ Is barrier installed? ◇ ── No ──┐
              │ Yes                          │
┌─────────────────────────────────┐   ┌──────────────────┐
│       Screening correction       │   │ Calculate ground │
└─────────────────────────────────┘   │ cover correction │
              │                         └──────────────────┘
┌─────────────────────────────────────────┐
│        Stage 4: Site layout               │
└─────────────────────────────────────────┘
              │
┌─────────────────────────────────────────┐
│        Correct for reflections            │
└─────────────────────────────────────────┘
              │
┌─────────────────────────────────────────┐
│     Apply angle of view correction        │
└─────────────────────────────────────────┘
              │
      ◇ Any more segments? ◇ ── Yes ──┐
              │ No
┌─────────────────────────────────────────────────────┐
│ Stage 5: Combine contributions from all the segments │
└─────────────────────────────────────────────────────┘
              │
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│        Predicted noise level              │
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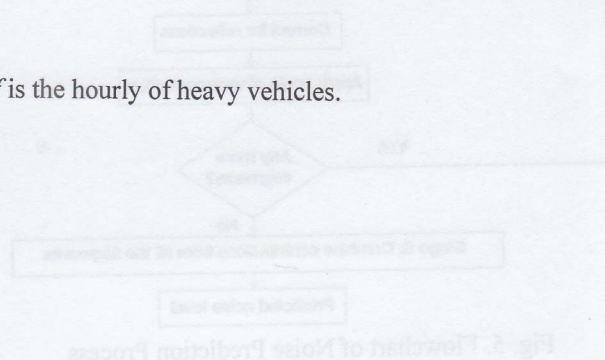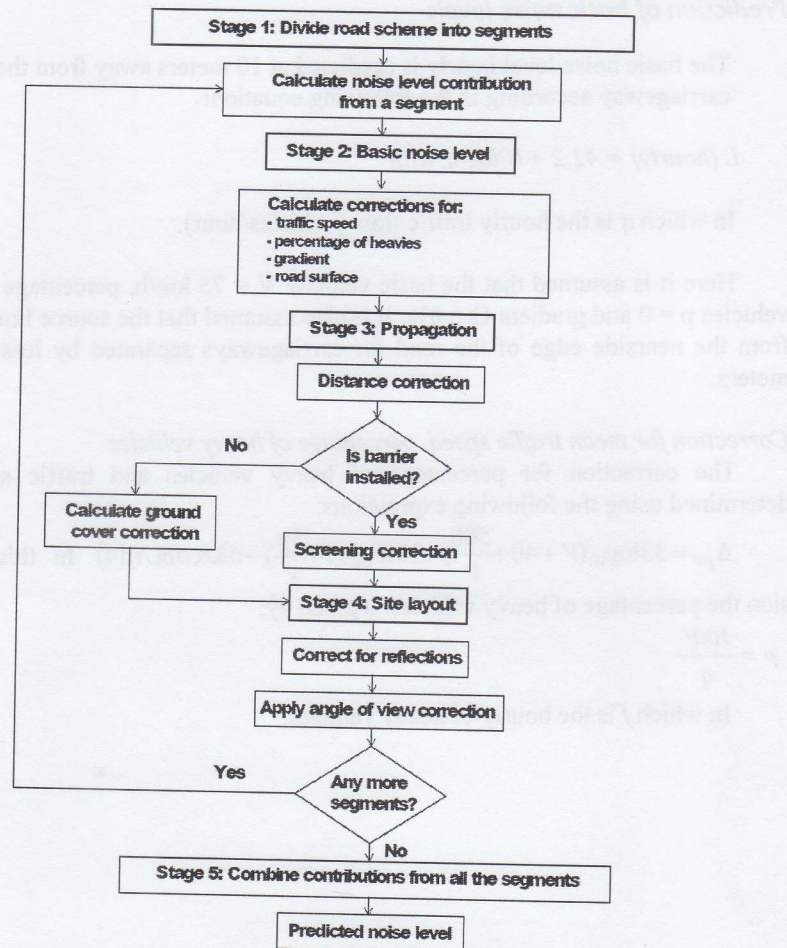
Fig. 5. Flowchart of Noise Prediction Process

Correction for mean traffic speed, road gradient

Once the speed of traffic is known, then the adjustment for the extra noise from traffic on a gradient is calculated from

$$Correction = 0.3\ G,\ dBA \tag{6}$$

Correction for mean traffic speed, road surface

Table I. Road Pavement Surface Correction

No	Description	Correction , dB(A)
1	Chip seal	+ 3,0
2	Portland cement concrete	+ 1,0
3	Dense graded asphalt concrete	- 1,0
4	Open graded asphalt concrete	- 5,0

Distance correction

For the reception points located at distances $d \geq 4.0$ meters from the edge of the nearside carriageway, the distance correction is given by:

$$\Delta_d = -10 \log_{10}\left(\frac{d'}{13.5}\right), dB(A) \tag{7}$$

In which d' is the shortest slant distance between the effective source and the receiver.

$$d' = [h^2 + (d+3.5)^2]^{\frac{1}{2}}$$
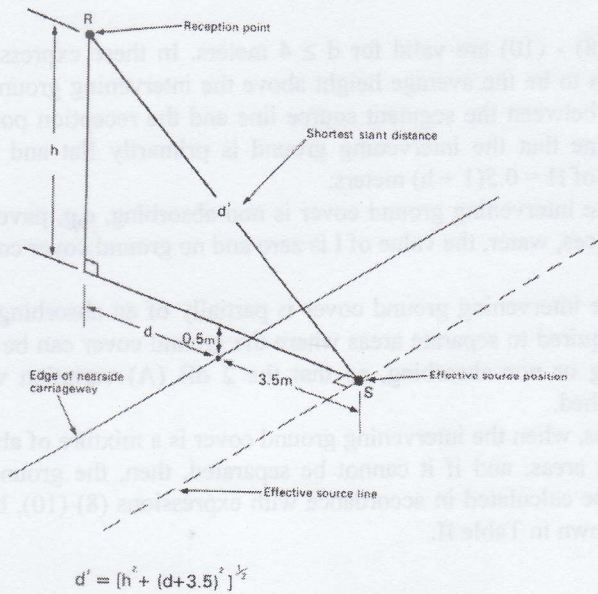
Fig. 6 An illustration of shortest slant distance between a reception point and an effective source line representing a flow of traffic sound.

Ground cover correction

If the ground surface between the edge of the nearside carriageway of the road or road segment and the reception point is totally or partially of an absorbing nature, (e.g. grass land, cultivated fields or plantations) an additional correction for ground cover is required. This correction is progressive with distance and particularly affects the reception points closed to the ground. The correction for ground absorption as a function of horizontal distance from edge of nearside carriageway d m, the average height of propagation, $H = 0.5(h +1)$, and the proportion of absorbent ground, I, is given by:

$$\Delta_{GC} = 5.2I \log_{10}(\frac{6H-1.5}{d+3.5}), dB(A) \text{ if } 0.75 \leq H < \frac{d+5}{6} \tag{8}$$

$$\Delta_{GC} = 5.2I \log_{10}(\frac{3}{d+3.5}), dB(A) \text{ if } H < 0.75 \tag{9}$$

$$\Delta_{GC} = 0, dB(A) \text{ if } H \geq \frac{d+5}{6} \tag{10}$$

Expressions (8) - (10) are valid for d ≥ 4 meters. In these expressions the value of H is taken to be the average height above the intervening ground of the propagation paths between the segment source line and the reception point. It is suggested to assume that the intervening ground is primarily flat and that the approximate value of H = 0.5(1 + h) meters.

NB. Where the intervening ground cover is non-absorbing, e.g. paved areas, rolled asphalt surfaces, water, the value of I is zero and no ground cover correction is applied.

NB. When the intervening ground cover is partially of an absorbing, nature segmentation is required to separate areas where the ground cover can be defined as either absorbing or non-absorbing, so that the 2 dB (A) variation within a segment is not reached.

In certain cases, when the intervening ground cover is a mixture of absorbing and non absorbing areas, and if it cannot be separated, then, the ground cover correction should be calculated in accordance with expressions (8)-(10), but with the value of I as shown in Table II.

Table II. On The Choice Of Value I

% of absorbent ground cover within the segment *	value of I be used with chart 8
< 10	0 **
10 - 39	0.25
40 - 59	0.5
60 - 89	0.75
≥90	1

Obstructed propagation

The path difference is used to calculate the potential barrier correction:
For the shadow zone:

$$A = 15.4 - 8.26 \log_{10}(\delta) - 2.787 \log_{10}(\delta)^2 - 0.83 \log_{10}(\delta)^3 -$$
$$0.198 \log_{10}(\delta)^4 + 0.1539 \log_{10}(\delta)^5 + 0.12248 \log_{10}(\delta)^6$$
$$+ 0.02175 \log_{10}(\delta)^7 \tag{11}$$

For the illuminated zone:

$$A = 0.109 \log_{10}(\delta) - 0.815 \log_{10}(\delta)^2 + 0.47983 \log_{10}(\delta)^3 +$$
$$0.3284 \log_{10}(\delta)^4 + 0.04385 \log_{10}(\delta)^5 \tag{12}$$

Size of segment

The noise level at the reception point from the segment of the road scheme depends upon the angle q (degrees) subtended by the segment boundaries at the reception point. This angle is often referred to as the angle of view. The correction for angle of view is obtained using the following expression:

$$\Delta_S = 10 \log_{10}(\frac{\theta}{180}), dB(A) \tag{13}$$

Site layout

The effects of reflections from buildings and other rigid surfaces have

resulted in the increase of noise level and need to be considered. If the receiver is 1 m in front of a façade, then a correction of 2.5 dB (A) is added to the basic noise level. Calculations of noise levels along side roads lined with houses but away from the facades has also required similar addition of the 2.5 dB(A). If there is a continuous line of houses along the opposite side of the road, then a correction for the reflections is required. The correction only applies if the height of the reflecting surface is at least 1.5 m above the road surface.

Combining contribution from segments

The final stage of the calculation process, to arrive at the predicted noise level, requires the combination of noise levels contributions from all the source segments, which comprise the total road scheme. For a single road segment road scheme there is no adjustment to be made. For road schemes consisting of more than one segment the predicted level at the reception point shall be calculated by combining the contributions, Li, from N segments using the following expression:

$$L_{10}^{tot} = 10 \log_{10} \left(\sum_{i=1}^{N} 10^{\frac{L_i}{10}} \right), dB(A) \tag{14}$$

D. Indonesian's Noise Standard

It is difficult to specify noise levels which are generally acceptable to everyone. What is annoying to one person may be unnoticed by another. Standards may be based on documented complaint activity in response to documented noise levels, or based on studies on the ability of people to sleep, talk, or work under various noise conditions. All such studies, however, recognize that individual responses vary considerably. Standards usually address the needs of most of the general population. The Environmental Ministries of Indonesia has established guidelines for acceptable noise levels for various land use types.

VI. Traffic Noise Mitigation

In theory, there are a number of options that can be used to reduce or mitigate traffic noise. These include traffic management, highway design, and noise barriers including earthen berms. In reality, noise mitigation is often infeasible due to space requirements, aesthetic issues and financial costs, or because the costs

outweigh the benefits. Any specific mitigation measure recommended as part of a project must be feasible and have a reasonable cost in relation to the benefit.

Table III. Indonesia Noise Standard

Land use category	Acceptable noise level dB (A)
1. Allotment area	
a. Residential - Multiple Family	55
b. Trade and Business Commercial	70
c. Office Buildings, and Professional	65
d. Playgrounds, Neighbourhood Parks	50
e. Industrial, Manufacturing	70
f. Government building and public facilities	60
g. Recreation place	70
2. Scope of activity	
a. Hospitals, Nursing Homes	55
b. Schools, Libraries,	55
c. Places of worship	55

Source: *Kep-48/MENLH/1996/25 November 1996*

Potential mitigation measures are described as follows: (1) traffic management, (2) roadway design, and (3) construction of noise barrier.

Traffic management measures include modification of speed limits and restricting or prohibiting truck traffic. Restricting truck use on a given roadway would reduce noise levels at nearby receivers since trucks are louder than cars. However, displacing truck traffic from one roadway to another would only shift noise impacts from one area to another and may conflict with the planned function of the roadway (e.g., an arterial generally carries truck traffic). While reducing speeds may reduce noise, a reduction of at least 10 mph is needed for a noticeable difference in noise to get better result. As roadways are planned and designed to support speeds consistent with their functional classification (e.g., 35-45 mph on an arterial), changing speeds for the purpose of noise mitigation is not common.

Roadway design measures include altering the roadway alignment and depressing roadway cut sections. Alteration of roadway alignment could decrease noise levels by moving the traffic farther away from the affected receivers.

Construction of noise barriers between the roadways and the affected

receivers would reduce noise levels by physically blocking the transmission of traffic-generated noise. Barriers can be constructed as walls or earthen berms. Earthen berms require more right-of-way than walls and are usually constructed with a 3-to-1 slope. Using this requirement, a berm 8 feet tall would slope 24 feet in each direction, for a total width of 48 feet. Noise walls should be high enough to break the line-of-sight between the noise source and the receiver. They must also be long enough to prevent significant flanking of noise around the ends of the walls. Open wall, such as for drive ways and walkways can significantly reduce the barrier effectiveness.

VII. Results And Discussion

E. Road condition and environment

The road condition and environment at all locations in general are quite similar. The three roads are main roads in the city of Surakarta with mixed traffic flow conditions (motorcycle, light vehicles, heavy vehicles, and un-motorized vehicles). The slope of the road is considered 0% (flat road) and the condition of the road is asphalt concrete pavement.

The difference is type of road: Jl. Slamet Riyadi is a four lane two-way street with no median separator (4 / 2 UD), Jl. A. Yani is a four lane two-way street with median separator (4 / 2 D), and Jl. Veteran are two-lane two-way street which is not divided (2 / 2 UD).

Environmental conditions at all school areas have barrier with a road made of bricks (on the SDN Kleco 2, SD Al-Islam Jamsaren, MA Al Islam Jamsaren), the combination of bricks and plant (on SMP Muhammadiyah 5 and SLTPN 12), and large trees (on SMKN 6), although the height and density of plants are varying.

Fences and plants can absorb the noise so that the sound received by a person that is across the barrier will be lower than the sound heard by people when there was no obstacle between the sound source and the receiver.

F. Existing traffic noise level

Traffic noise level based on direct measurement by using SLM is described on Fig. 7 – Fig. 12. It can be immediately seen that for all location, noise level which are reached more than 55 dB (A), both near the road side and near the receiver (outer side of school wall), is a very disturbance and it is very important to conduct noise mitigation.
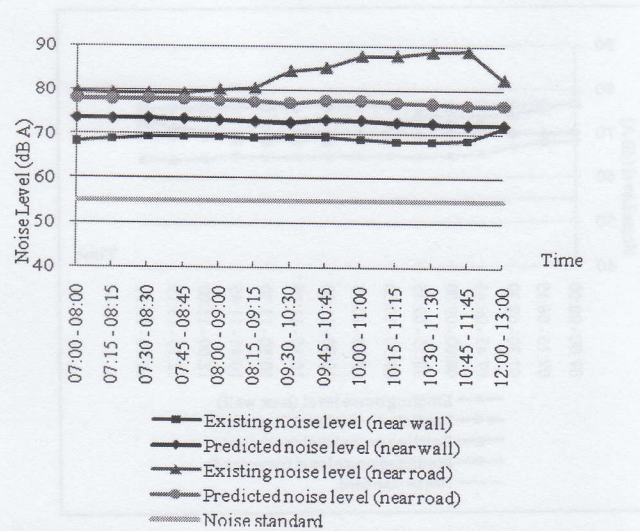
Fig. 7. Noise Level on Jl. Slamet Riyadi (SDN Kleco 2 Surakarta)

At location close to road side, existing noise measurement on SDN Kleco 2 reached the higher value, maximum 88, 86 dB (A) (Fig. 7). It is reasonable that traffic volume on that location is very crowded because there is a big mall in front of the school. The higher traffic volume occur at 07:00-08:00 am, approximately 4175 vehicle per hour, dominated by motor vehicles (MC) although heavy vehicle percentage is low (0%-4%). Peak traffic hour in every road have no similar behavior time. If peak traffic hour occurs during the school time, traffic noise becomes very annoying and uncomfortable for everyone near the road, especially for sensitive area such as school.
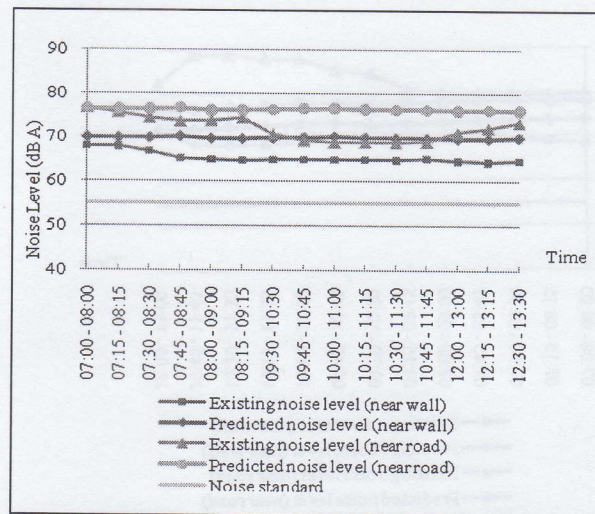
Fig. 8. Noise Level on Jl. Slamet Riyadi (SMP Muhammadiyah 5 Surakarta)

Existing noise level trend on SMP Muhammadiyah 5 (Fig. 7) have the value below the existing noise measurement on SDN Kleco 2, although they both located at Jl. Slamet Riyadi. Peak traffic hour at Jl. Slamet Riyadi, in front of SMP Muhammadiyah 5, occurs at 07:30-08:30 a.m., maximum traffic volume is 4303 vehicle per hour and dominated by motor vehicles (MC). These two schools are separated by a signalized intersection, so traffic flow from west turn to the left approaching Jl. A. Yani.

At the location close to receiver, existing noise measurement on SDN Kleco 2 and SMP Muhammadiyah 5 describes the similar trend and the value is above 55 dB (A). Although both locations have barrier fence with brick material and there are some vegetation plants in school yard but it seem that noise from road is very loud and the barrier have not yet functioned effectively to reduce the noise.

From the previous data, it can be seen that the noise near the wall less than the measurements on the roadside, but all of them are above noise standard value, 55 dB(A).

Traffic noise condition at Jl. A. Yani (in front of SMKN 6) is described in Fig.9. It values steady at 75 dB (A) near roadside and approximately 70-75 dB (A) for measurements done near the wall. It seem that at SLTPN 12 noise level trend (Fig.10) is just steady at 70 dB (A) for measurement near wall and 73 dB(A) for location near noise source.

Noise contour line is being obtained at primary al-Islam and M.A. Islam Jamaan show the sim...
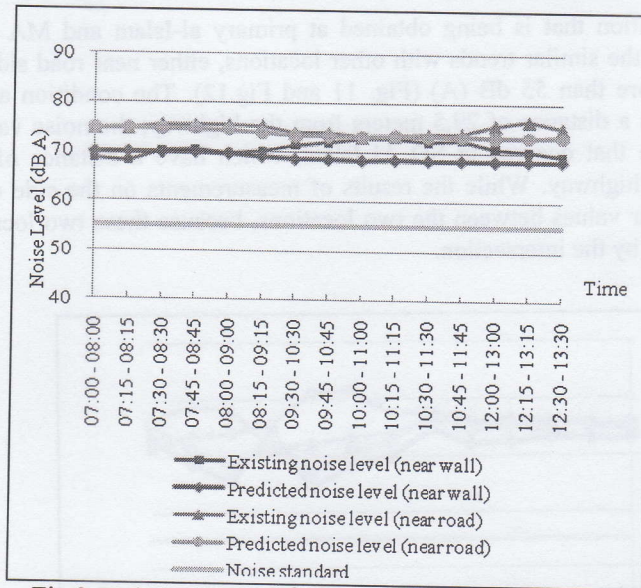

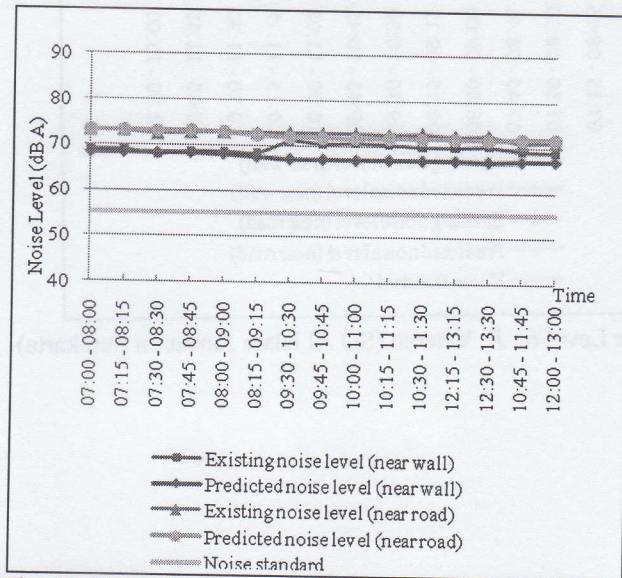Fig.9. Noise Level on Jl. A. Yani (SMKN 6 Surakarta)

Fig. 10. Noise Level on Jl. A. Yani (SLTPN 12 Surakarta)

Noise condition that is being obtained at primary al-Islam and MA Islam Jamsaren shows the similar trends with other locations, either near road side and near receiver more than 55 dB (A) (Fig. 11 and Fig.12). The condition at MA Islam, which has a distance of 29.5 meters from the highway, the noise value is better than those that occured at SD Al Islam, which have a distance of 21.5 meters from the highway. While the results of measurements on the side of the road show similar values between the two locations, because these two locations are not separated by the intersection.
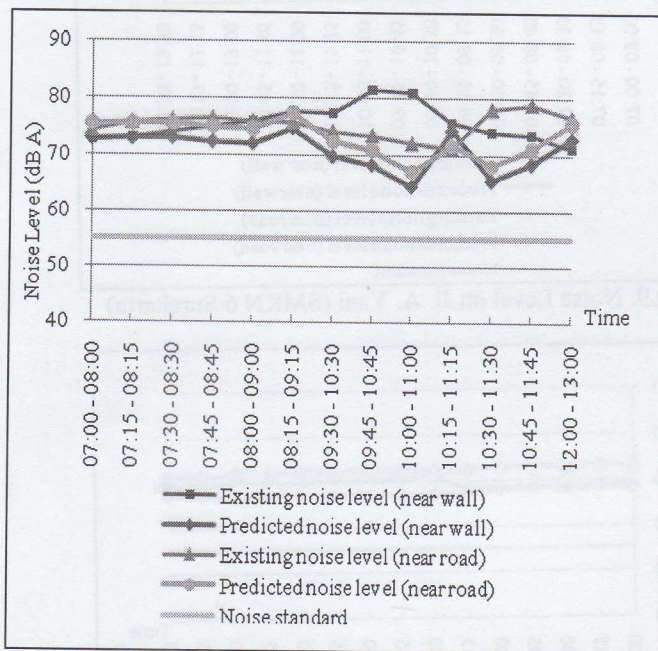
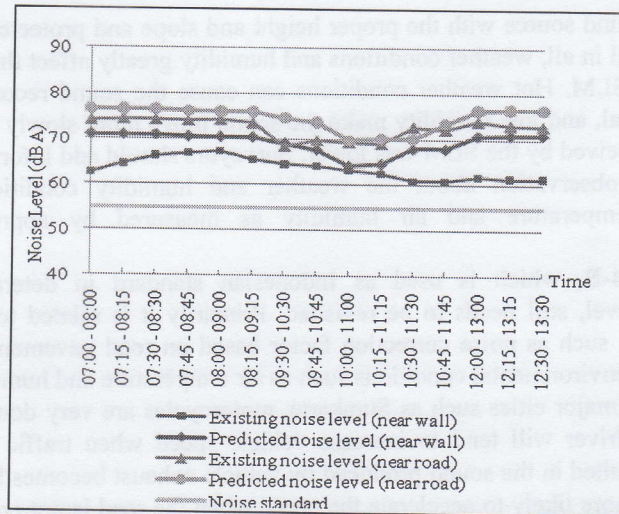Fig. 11. Noise Level on Jl. Veteran (SD Al Islam Jamsaren Surakarta)

Fig. 12. Noise Level on Jl. Veteran (MA Al Islam Jamsaren Surakarta)

G. Predicted noise level

Noise calculation based on empirical equation (Pd-T-10-2004-B model) illustrates that noise level in near road and near wall are above 55 dB (A). The result of empirical equation is based on some environmental factor and traffic condition which described the condition of location that noise level tried to be predicted. Predicting noise level is a simple way knowing noise level if direct measurement not possible to conduct, or if data traffic and environment are available.

In all location, there is a deviation between direct measurement and empirical equation. Noise mean bias at Jl. A. Yani is about 0,91 – 2,25 dB (A), at Jl. Slamet Riyadi is 3,58 – 5,58 dB (A), and at Jl. Veteran is 2,58 – 5,67 dB(A). From Fig. 7 – Fig. 12, there are shown that empirical equation produced lower result than existing condition.

There are many factors affected this condition. There are some important notes to consider when doing the measurement noise by using the SLM. First of all, it is important to check SLM tool condition before using it because this tool is so sensitive to sound so surveyor must not have any conversation during the observation. It must be ensured that the recorded noise is noise from traffic as noise source and not from other sources such as noisy crowd of people, radio, etc., or called as background noise. Secondly, SLM microphone must be precisely

directed to the sound source with the proper height and slope and protected from direct sunlight. All in all, weather conditions and humidity greatly affect the noise recorded by the SLM. Hot weather conditions can cause the sound recorded is higher than the real, and low humidity make the sound move more slowly so that the noise level received by the SLM was lower. Surveyors should add information in the form of observation about the weather and humidity conditions, if necessary, air temperature and air humidity as measured by appropriate observations.

Pd-T-10-2004-B, which is used as Indonesian standard in determining predicted noise level, still needs to be revisited. Primarily it is related to some correction factors, such as noise correction factor based on road pavement type, vehicle type, and environmental conditions such as air temperature and humidity.

In almost all major cities such as Surakarta, motorcycles are very dominant. The motorcycle driver will tend to increase vehicle speed when traffic is not crowded. This resulted in the sound produced by vehicle exhaust becomes higher. Motorcycles are more likely to accelerate the speed when the road is not crowded and this affected sound produced from vehicle exhaust.

H. Alternative noise mitigation action

Noise mitigation alternatives on Jl. Slamet Riyadi (both on SDN Kleco 2 and SMP Muhammadiyah 5):

- Traffic management: modification of speed limits and restricting or prohibiting heavy vehicles traffic, especially at SMP Muhammadiyah 5, because it is a major route of buses and heavy vehicles from East Jawa to Surakarta. However, to apply this, it needs a policy of detailed transportation planning.
- Vegetation barrier can reduce noise. Both locations have brick wall as a barrier but it will be more effective, if it combines plant and massive barrier.
- For a long term design, to build school wall from glasses materials will be needed to reduce noise.

Noise mitigation alternatives on Jl. A. Yani (both on SMKN 5 and SLTPN 12):

- Traffic management: modification of speed limits and restricting or prohibiting heavy vehicles traffic. It would reduce noise levels at nearby receivers since trucks are louder than cars. However, this policy need detail transportation planning and cannot be applied in a short period of time. As the roadways are planned and designed to support speeds consistent with their functional classification (e.g., 35-45 mph on an arterial), changing speeds for the purpose of noise mitigation is not common
- It is possible to plant some vegetation to reduce noise and function as noise

barrier because in both location open space are still available.

- For long term design, to build school wall from combination of materials between 1 / 8 to 1 / 4 glass and the rest with the material to reduce massive noise from outside the buildings about 26-29 dB will be needed.

Noise mitigation alternatives at Jl. Veteran (both on SD Al Islam Jamsaren and MA Al Islam Jamsaren):

- Traffic management: modification of speed limits and restricting or prohibiting heavy vehicles traffic. It would reduce noise levels at nearby receivers since trucks are louder than cars. However, this policy needed detail transportation planning and cannot be applied on a short period of time.

- Noise reduction can be performed several stages. The first stage is by providing plants that serves as a noise filter. The next stage, at SD Al Islam Jamsaren, it needed special classroom wall planning, precisely those facing the highway, with a combination 1/8-1/4 material made of glass and the rest with massive material that can reduce noise by 26-29 dB. MA Al Islam Jamsaren just needed a decrease of 12, 4 dB to achieve comfortable conditions. It is recommended to change bricks wall with glasses wall.

VIII. Appendix
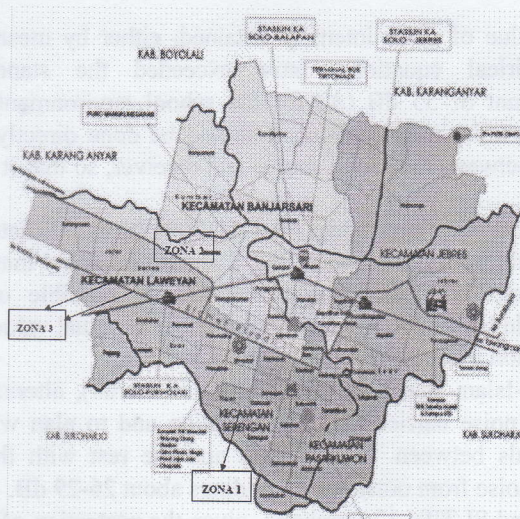
Map of Research Location
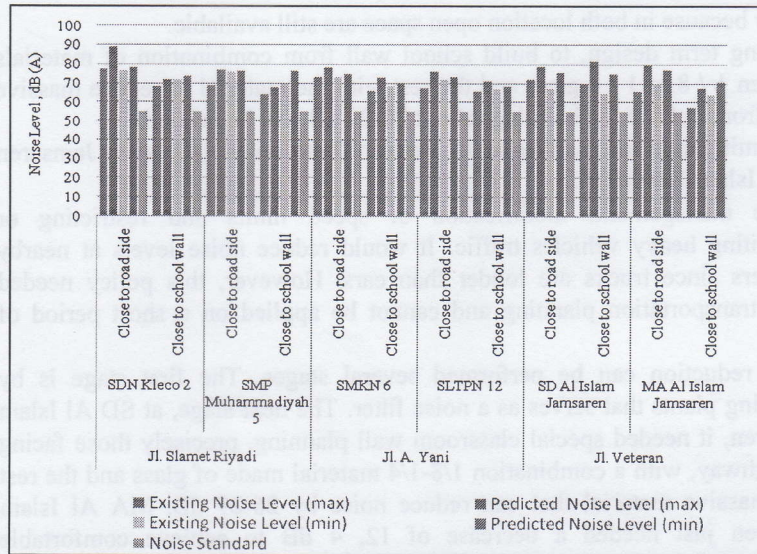
Comparison among noise level value in all location

IX. Conclusion

In general, the value of noise intensity obtained, either by means of noise measuring and empirical equations, have exceeded the standard level permitted, in the amount of 55 dB (A) for the school environment. If future researcher wants to do noise measurement, it should be done directly along the propagation of sound between the sound source and receiver, so that it can obtain more precise value.

The use of empirical equation (model Pd-T-10-2004-b) to calculate the value of noise at a place could be recommended, but it should be noted that there is a difference in the results with direct measurements. If possible other noise calculation models could be tried to reach a close number to actual value.

Three noise mitigation that can be recommended include:

a. In SD and MA Al-Islam Jamsaren Surakarta (Jl. Veteran), alternative treatment with a given noise barrier wall of vegetation and to plan with a combination of materials between 1/8-1/4 glass and the rest with the massive material to reduce noise from outside the buildings about 26-29 dB.

b. In SMK Negeri 6 and SLTPN 12 Surakarta, given the protection of vegetation on early stage and plan on a second wall buildings using 100% glass material

to reduce noise by 20 dB.

c. In SDN Kleco II, treatment with giving the dominant vegetation, and in SMP Muhammadiyah 5 Surakarta by creating a barrier of vegetation and planning of the wall to the election glass material.

X. Acknowledgment

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XII. Biographies

Ika Setiyaningsih was born in Surakarta, Indonesia, on September 29, 1975. She graduated from Universitas Muhammadiyah Surakarta, and reach Master Degree in Transportation Engineering from Institut Teknologi Bandung. Her employment experience included the Muhammadiyah University of Surakarta. Her special fields of interest included Traffic System and Management, Public Transport and its environmental issues.