Road traffic noise prediction model for heterogeneous traffic based on ASJ-RTN Model 2008 with consideration of horn

M Hustim[1], Z Arifin[2], S H Aly[1], M I Ramli[2], R Zakaria[1], and A Liputo[2]

[1] Department of Environmental Engineering, Hasanuddin University, Jl. Poros Malino, Kota Makassar, Sulawesi Selatan 90245, Indonesia

[2] Department of Civil Engineering, Hasanuddin University, Jl. Poros Malino, Kota Makassar, Sulawesi Selatan 90245, Indonesia

[3] Magister Graduated of Department of Civil Engineering, Hasanuddin University, Jl. Poros Malino, Kota Makassar, Sulawesi Selatan 90245, Indonesia

Abstract. This research aimed to predict the noise produced by the traffic in the road network in Makassar City using ASJ-RTN Model 2008 by calculating the horn sound. Observations were taken at 37 survey points on road side. The observations were conducted at 06.00 - 18.00 and 06.00 - 21.00 which research objects were motorcycle (MC), light vehicle (LV) and heavy vehicle (HV). The observed data were traffic volume, vehicle speed, number of horn and traffic noise using Sound Level Meter Tenmars TM-103. The research result indicates that prediction noise model by calculating the horn sound produces the average noise level value of 78.5 dB having the Pearson's correlation and RMSE of 0.95 and 0.87. Therefore, ASJ-RTN Model 2008 prediction model by calculating the horn sound is said to be sufficiently good for predicting noise level.

1. Introduction

Issue on traffic noise is one of factors affecting environmental safety in developed as well as developing countries. Research in Tehran, Iran as a developing country showed that traffic noise level had influence on health particularly in terms of psychology [1]. As one of developing countries, Indonesia too is not free from this issue. Former researches have shown the average noise level at 4-way intersection in Makassar City had exceeded quality standards set where average $L_{Aeq,day}$ was 79.2 dB [2]. Most of vehicles were motorcycles having percentage 63.6% and average velocity were below 30 km/hour. The average of noise level on the side of the road in Makassar City had reached to 74 dB [3]. This shows that the noise level have exceeded the environmental quality standards which set between 55 dB to 70 dB. Then the noise level on arterial and collector roads in Makassar City was 78.6 dBwhich already exceeded quality standards set by the government, where majority was motorcycles having percentage 69.1 % and average velocity below 35 km/hour [5].

Noise prediction is used in order to find a model closest to conditions in the field. The resulted model is expected to be used to predict noise in the future. Noise prediction model of road traffic ASJ-RTN 2008 uses technical methods to sum up sound propagation by calculating power level value for each type of vehicles. The ASJ-RTN 2008 is based on latest technological developments [6] and had been used by [7] to predict heterogeneous traffic noise in Makassar City.

Based on the problems mentioned above, the authors proposed to conduct research about "Heterogeneous Traffic Noise Level Prediction Model Based on ASJ-RTN 2008 by Calculating Horn

Sound of Vehicles". This research aims to predict noise produced by road network traffic in Makassar City using ASJ-RTN 2008 model by calculating the horn sound of vehicles.

2. Methodology of the study

2.1. Data collection

The measurements were conducted on roads in Makassar which consist of 37 points, where the arterial and collector roads are shown in Table 1. One point of observation location was selected on each road. This point was selected by considering suitable location condition criteria such as not blocked and distance between instruments reflecting the sound.

Measurement of traffic volume, velocity, number of horn sounds, and road traffic noise level were conducted simultaneously. Times of measurement were on Monday-Friday at 06.00-18.00 and 06.00-21.00 for several points on the road having high traffic volume in night. The measurement of traffic volume was conducted using speed gun by pointing it to the vehicle passing the point of measurement. The velocity measured was the velocity at the moment when the vehicle passing the point of measurement. The number of horn sounds was counted by categorizing the type of vehicles passing the point of measurement. The data was obtained by replaying the recorded video of the traffic when the survey take place then noted the number of horn sounds from the vehicles.

Table 1. Point of measurement location.

Road Code	Road name	Road Code	Road name
R01	Jl. Perintis Kemerdekaan 4	R20	Jl. Nusantara
R02	Jl. Perintis Kemerdekaan 6	R21	Jl. Arief Rate
R03	Jl. G. Bawakaraeng	R22	Jl. Dr. Ratulangi 2
R04	Jl. Masjid Raya	R23	Jl. Hertasning
R05	Jl. Cakalang	R24	Jl. Aroepala
R06	Jl. Ahmad Yani	R25	Jl. Tun Abdul Razak
R07	Jl. Sungai Saddang	R26	Jl. Sultan Alauddin 2
R08	Jl. Haji Bau	R27	Jl. Perintis Kemerdekaan 1
R09	Jl. Penghibur	R28	Jl. Perintis Kemerdekaan 2
R10	Jl. Cendrawasih	R29	Jl. Urip Sumoharjo 2
R11	Jl. Dr. Ratulangi 3	R30	Jl. Veteran Utara
R12	Jl. Kakatua	R31	Jl. Veteran Selatan
R13	Jl. Rajawali	R32	Jl. Bandang
R14	Jl. Dr. Ratulangi 1	R33	Jl. Riburane
R15	Jl. Sultan Alauddin 1	R34	Jl. Jend. Sudirman
R16	Jl. Perintis Kemerdekaan 3	R35	Jl. AP. Pettarani 1
R17	Jl. Perintis Kemerdekaan 5	R36	Jl. AP. Pettarani 2
R18	Jl. Urip Sumoharjo 1	R37	Jl. Boulevard
R19	Jl. Tentara Pelajar		

The noise level measurement was conducted using simple SLM (Sound Level Meter) placed at 1 meter from side of the road with height 1.2 meter from road surface and omit the background noise by using windscreen from the SLM. Period of measurement were 10 minutes in every hour. In order to obtained more accurate noise level, the SLM was configured to record every second resulting 600

recorded data. Therefore, there were 12 measurements for every hour in a day from 06.00-18.00 with total of data were 7200. While from 06.00-21.00, there were 15 measurements for every hour with total 9000 data. The measurement method can be seen in the figure 1 below.
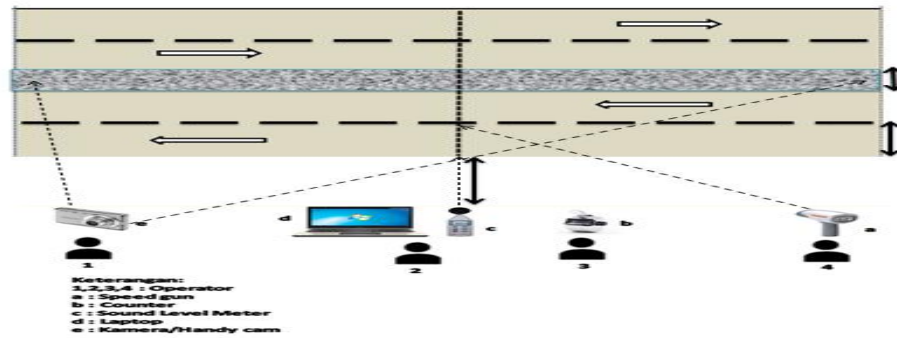
Figure 1. Measurement Method

2.2. *Methodology of data analysis*

Value of L_{Aeq} dan $L_{Aeq,day}$ (daily equivalent) obtained by calculation of equation (1) and equation (2).

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

where:

L_{Aeq}	=	Noise level equivalent (dB),
L_{50}	=	Noise level 50% (dB),
L_1	=	Noise level 99% (dB).

$$L_{Aeq,day} = 10 \log 10 \left[\left(\frac{1}{tn}\right) . \left(10^{\frac{Leq1}{10}}\right) + \cdots + \left(10^{\frac{Leqtn}{10}}\right) \right] \tag{2}$$

where:

$L_{Aeq,day}$	=	Daily noise level equivalent (dB),
$L_{eq}tn$	=	Day-n noise level (dB),
tn	=	Daily number of measurement.

Steps of calculation model of ASJ-RTN 2008 are as follows:

a.   Calculation of *sound power level* (L_{wA}).

Sound power level (L_{wA}) is calculated using equation (3).

$$L_{wA} = a + b \log V \tag{3}$$

where:

L_{wA}	=	Sound power level (dB)
V	=	Vehicle velocity (km/hour)
a, b	=	Regression coefficient

The value of regression coefficient is shown in Table 2.

Table 2. Regression coefficient a dan b for traffic flow [8]

Classification	Steady (40 km/hour≤ V ≤ 140 km/hour)		Unsteady (10 km/hour≤ V ≤ 60 km/hour)	
	a	b	a	b
Light vehicles	46.4	30	82.0	10
Heavy vehicles	51.5	30	87.1	10
Motorcycles	52.4	30	85.2	10

b.   Calculation of *sound pressure level* (L_A).
Sound pressure level (L_A) in dB for sound propagating from source to prediction point is calculated based on tempering resulted by various factors. Equation of sound pressure level is shown by equation (4).

$$L_A = L_{wA} - 8 - 20 \log r \tag{4}$$

where:

L_A =   Sound pressure level (dB)
L_{wA} =   Sound power level (dB)
r =   Distance from prediction point to source (m)

c.   Calculation of *sound exposure level* (L_{AE}).
Calculation of sound exposure leve is using equation (5) and equation (6).

$$L_{AE} = 10 \log \frac{E_A}{E_0}$$
$$= 10 \log \left(\frac{1}{T} \sum 10^{\frac{L_A}{10}} \Delta t \right) \tag{5}$$

$$\Delta t = \frac{3.6 \, \Delta l}{V} \tag{6}$$

where:

L_{AE} =   Sound exposure level (dB)
L_A =   Sound pressure level (dB)
T =   Number of daily measurement
Δl =   Road width at measurement point (m)
V =   Vehicle velocity (km/hour)

d.   Calculation of *equivalent continuous A-weighted sound pressure level* (L_{Aeq}).
By entering the value of vehicles volume and times of measurement, the sound pressure level equivalent can be determined using equation (7).

$$L_{Aeq} = L_{AE} + 10 \log \frac{N_T}{T} \tag{7}$$

where:

L_{Aeq} =   Sound pressure level equivalent (dB)
L_{AE} =   Sound exposure level (dB)

N_T =   Vehicles volume (vehicles/hour)

T =   Number of daily measurement

Calculation of horn sounds noise level referring to research by [3] is determined using equation (8) and equation (9).

$$L_{Ah} = 10 \log 10 \left(\sum 10^{\frac{L_A}{10}} \right) \Delta t \left(41 \times 3.6 \times \left(\frac{d}{V} \right) \right) \tag{8}$$

where:

L_{Ah} =   Sound pressure level (dB)

L_A =   Predicted sound pressure level by ASJ-RTN 2008 (dB)

Δt =   Period of horn sound (second)

d =   Horn distance (m)

V =   Vehicle velocity (km/jam)

$$L_{Atotal} = 10 \log 10 \left(10^{\frac{L_{Aeq}}{10}} + 10^{\frac{L_{Ah}}{10}} \right) \tag{9}$$

where:

L_{Atotal} =   Predicted sound pressure level by ASJ-RTN 2008 in addition of horn sounds (dB)

L_{Aeq} =   Predicted sound pressure level by ASJ-RTN 2008 (dB)

L_{Ah} =   Horn sound pressure level (dB)

3. Results and discussion

3.1. Results of measurement of volume, velocity, number of horns and noise level

The value of noise level resulted from the measurements can be seen in figure 2 where $L_{Aeq,day}$ maximum value was obtained on Jalan Urip Sumoharjo 2 with amount of 82.4 dB. While the minimum value of $L_{Aeq,day}$ was obtained on Jalan Urip Sumoharjo with amount of 74.4 dB. The average $L_{Aeq,day}$ of each point measurements was 79.1 dB. As shown in figure 3, maximum vehicles volume was obtained from motorcycles and the minimum value was obtained from heavy vehicles. Point of measurement having highest traffic volume was on Jalan Perintis Kemerdekaan 2, while the lowest was on Jalan Haji Bau. The average traffic volume for motorcycles was 4571 vehicles/hour, for light vehicles was 1785 vehicles/hour, and for heavy vehicles was 86 vehicles/hour.
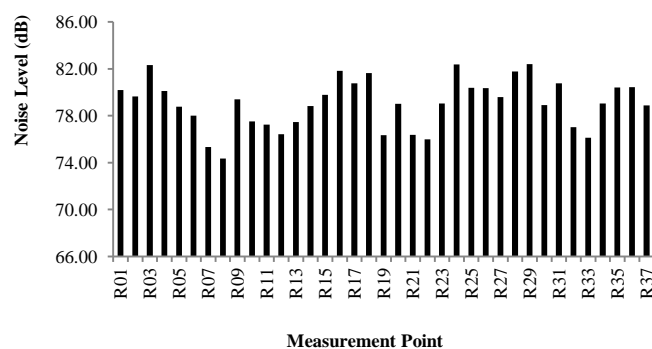

Figure 2. Noise level from measurement
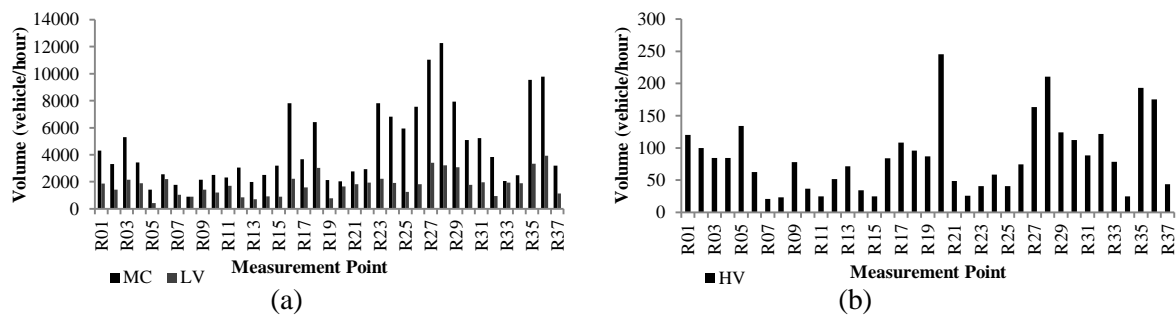
Figure 3. (a) Motorcycles and light vehicles traffic volume, (b) Heavy vehicles traffic volume.

Figure 4 shows that motorcycles had average velocity 30 km/hour, light vehicles had 26 km/hour, and heavy vehicles had 24 km/hour. Point of observation on road Jalan Sultan Alauddin 1 had highest average velocity with amount of 32 km/hour, while point of observation on road Jalan Mesjid Raya had lowest average velocity with amount of 21 km/hour. The measurement results for number of horn sounds in figure 4 shows that range of horn sounds by motorcycles was 122-738 times/hour, light vehicles was 90-662 times/hour, and heavy vehicles was 1-89 times/hour. Highest number 1433 times/hour was obtained on road Jalan AP Pettarani 1 and the lowest was on road Jalan Perintis Kemerdekaan 3.

(a)

(b)
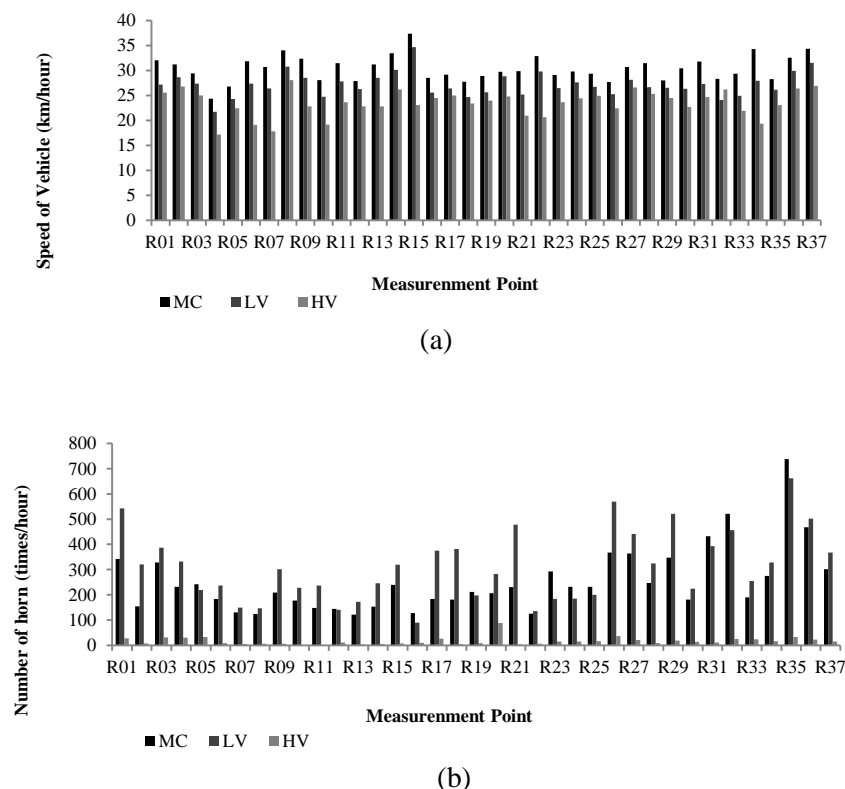
**Figure 4.** (a) Average velocity of vehicles, (b) Number of horn sounds.

Based on the analysis, the noise level is affected by several variables such as traffic volume, vehicles velocity, and number of horn sounds. The traffic volume on each road varies resulting different noise level. In addition to traffic volume, the vehicles velocity also affects the noise level.

The vehicles velocity depends on capacity and volume of the road. Roads having low capacity with low volume can increase velocity so that the noise level also can increase. However, if the volume is high then the velocity will decrease but it does not ensure the low noise level due to the high traffic volume. As on road Jalan Veteran Selatan which considered as main road (6/2D) but due to high volume during busy time, the noise level also increases even the velocity decreases.

Other variable that affects the traffic noise level was number of horn sounds from vehicles passing the point of measurement. The point of measurement having high percentage of horn sounds number resulting high noise level. Road Jalan AP. Pettarani 1 with road type 8/2D and had high volume resulted high number of horn sounds so it also had high noise level.

3.2. Noise level predicted by ASJ-RTN 2008

Value of predicted $L_{Aeq,day}$ for all point of measurement was below than $L_{Aeq,day}$ measurement with *pearson correlation* 0.93 and RMSE 2.09 as shown in figure 5. Based on that result, we predicted the $L_{Aeq,day}$ with consider horn sound of vehicle. The Value of predicted average $L_{Aeq,day}$ for was 78.5 dB where maximum $L_{Aeq,day}$ obtained at point of measurement on road Jalan Urip Sumoharjo 2 with amount of 82.7 dB. While minimum $L_{Aeq,day}$ obtained at point of measurement on road Jalan Haji Bau with amount of 73.5 dB. The data validation was also conducted on predicted noise level value so that a pearson correlation value of 0.95 and RMSE 0.87 were obtained. The validation results showed that this model was sufficiently valid. Noise level $L_{Aeq,day}$ prediction model ASJ-RTN Model 2008 by calculating hornd sounds was closer to noise level $L_{Aeq,day}$ from measurements as shown in figure 5.

(a) Without Horn Sound Consideration   (b) With Horn Sound Consideration
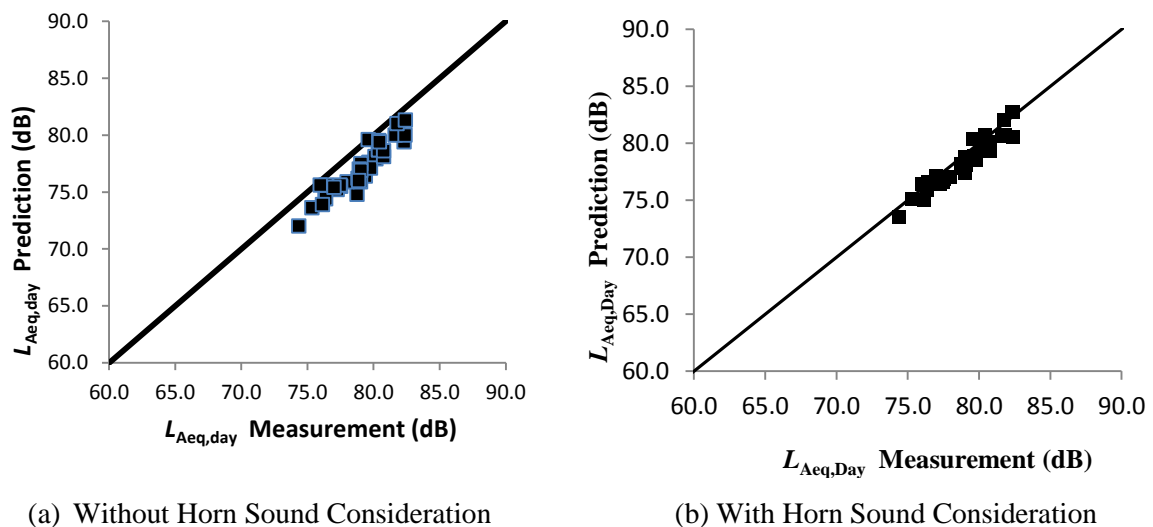
Figure 5. Comparison of $L_{Aeq,day}$ measurements with $L_{Aeq,day}$ ASJ-RTN Model 2008 prediction

4. Conclusion and suggestions

4.1. Conclusion

1. Average $L_{Aeq,day}$ obtained from measurements was 79.05 dB where majority of vehicles were motorcycles with percentage of 70.8%, average velocity below 30 km/hour and horn sounds average number was 553 for all points of measurement.
2. Average noise level ASJ-RTN 2008 $L_{Aeq,day}$ prediction by calculating horn sounds was 78.5 dB having *Pearson* correlation and RMSE with amount of 0.95 dan 0.87.
3. Model ASJ-RTN 2008 by calculating horn sounds is to be said sufficiently good to be used to predict noise level.

4.2. Suggestions
1. In measuring the noise, it isadvised to select point of measurement on road having dimension suitable with the instrument to record data.
2. It is advised to further research to consider factors around point of measurement mwhich can affect the result of noise level measurement

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