# Prediction Model of Traffic Noise in Padang City

**Deded Chandra*, Eri Barlian, Heldi**
Doctoral Program of Environmental Science, Postgraduate School – Universitas Negeri Padang
*Email: dededchandra@yahoo.com



**ABTSRACT:**
Traffic noise is a major environmental problem in urban areas. Padang City as the capital of West Sumatra Province has the potential to be exposed to traffic noise due to population growth and motorized vehicles. This study aims to determine the prediction model of traffic noise in Padang City. This type of research is quantitative. The population in this study is all designated to the area/environment of activities in the city of Padang. While the sample was taken purposively as many as 14 points. Traffic characteristics and noise level data were measured using a sound level meter. Noise predictions were made using the Calculation of Road Traffic Noise (CRTN) model. The results showed that the traffic noise level in Padang City ranged from 65.2 to 84.8 dBA. The highest noise is found in the Semen Padang Hospital area due to heavy vehicles and high speeds. On the other hand, the lowest noise is in the Pasar Raya Market area. The performance of the basic CRTN model on the measurement is classified as good with a coefficient of determination ($R^2$) ranging from 0.629 to 0.805 and an average difference of 2.1 dBA. Adjustment of the CRTN model with measurements resulted in a revised CRTN model. This model can then be applied to predict traffic noise levels in Padang City.
**Keywords**: noise, modeling, traffic, padang city
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## INTRODUCTION

In recent years, noise pollution has become a common environmental problem, especially in developing country cities. Where the strong negative impact on people's lives and health has become one of the biggest urban environmental problems today (Xu *et al.,* 2020). Urban areas in general contribute the most to environmental pollution because all human activities are centered in urban areas, especially in metropolitan areas. One of the pollutions in metropolitan cities is noise pollution or better known as noise, there are several sources of noise, namely traffic (transportation), industrial areas, dense settlements, trade centers, and other public facilities. The increase in urbanization is very fast happening globally. As a result, living things face new environmental stresses associated with urban expansion, artificial light, and noise (Dominoni *et al.,* 2019).

Noise is one of the most identifiable environmental problems related to rapid urbanization, industrialization, and expansion of road networks and infrastructure causing severe noise pollution problems. Noise is one type of environmental pollution as well as air pollution that interferes with the human sense of smell, noise is very disturbing to the sense of hearing which causes discomfort and decreased health in humans, especially those living in urban centers. The impact of noise includes disturbances in the form of decreased sleep quality and hearing damage, physiological disorders, disturbances in daily activities, hypertension, and heart disease schemes (Argarwal & Swani, 2010).

The noise quality standard according to the Decree of the State Minister of the Environment No. 48/MENLH/11/1996 describes the noise level standard that can be used for the designation of an area/activity environment in the safe category, namely 1) housing and settlements 55 dB; 2) trade and services 70 dB; 3) office and trade 65 dB; 4) green open space 50 dB; 5) Industry 70 dB; 6) government and public facilities 60 dB; 7) recreation 70 dB; and 8) hospitals, schools, and places of worship 55 dB. The development of settlements in urban areas will affect noise, especially in dense residential areas. City development in the past tends to minimize Green Open Space (GOS) and eliminate the face of nature (Yosieguspa, 2015).

Padang City is one of the big cities with a fairly high population density in Indonesia. Padang City has a population of 950,871 people in 2019 with a population growth rate of 1.43% from 2010-2019 (Fadhli & Andayono, 2022). With a population of almost one million people, Padang City is a fairly dense city and has fairly high mobility as well. High mobility will be related to the presence of vehicles as a means of transportation which is also one of the biggest contributors to noise in urban areas. The number of motorized vehicles in Padang City reached 407,141 units in 2019, which was an increase from the previous year's 315,590 units (Satria, 2019). The increase in population and the increase in the number of vehicles that are not accompanied by an increase in the transportation circulation regulation system, lanes, and highways that are built make noise in Padang City increase.

The solution to environmental problems related to traffic noise is to make traffic noise modeling so that traffic flow control and vehicle path design can be carried out. Recommendations for solutions in handling traffic noise in addition to regulating traffic lanes must also be reviewed to provide multiple solutions in handling noise. Another solution that is also effective and efficient is to present vegetation that acts as a noise absorber (Kuo & Morgan, 1999).). Based on the description of the background above, the purpose of this study is to determine a traffic noise prediction model in the city of Padang. The novelty of this research is a modification of the Calculation of Road Traffic Noise (CRTN) model which is adapted to traffic conditions in Padang City.

## METHODS

The population in this research is all designated to the area/environment of activities in Padang City. Samples were taken purposively for as many as 14 points. Sampling was based on the criteria for the designation of the area/environment of activities contained in the Decree of the Minister of Environment No. 48/MENLH/11/1996. In addition, the location distribution in the city of Padang is also considered. The measurement locations are mainly located on arterial roads, namely Adinegoro street, Prof. Dr. Hamka street, Khatib Sulaiman street, By Pass street, Padang-Solok causeways, and Padang-Painan causeways. The following is the distribution of sample points in Table 1 below.

Table 1. Distribution of sample points in Padang City

| No | Population | Sample | Latitude | Longitude |
|---|---|---|---|---|
| 1 | Housing and settlement | Siteba housing | -0,89540647943 | 100,37241424400 |
| 2 | Trade and services | Padang Raya Market | -0,95170872471 | 100,35743635300 |
| | | Lubuk Buaya Market | -0,83280421363 | 100,32746600800 |
| 3 | Offices | West Sumatra Governor's Office | -0,93757056228 | 100,36116794300 |
| 4 | Green Open Space (GOS) | GOS Imam Bonjol | -0,95319648270 | 100,36268603900 |
| 5 | Industry | PT Semen Padang | -0,95604905780 | 100,46791012100 |
| 6 | Recreation | Padang Beach | -0,92884031985 | 100,35018197100 |
| 7 | Railway station | Tabing Station | -0,86645415901 | 100,34231715600 |
| 8 | Seaports | Bayur Bay Harbor | -0,99052993871 | 100,38242455100 |

| | | | | |
|---|---|---|---|---|
| | | Bungus Harbor | -1,02824287555 | 100,40051918500 |
| 9 | Hospitals and the like | Siti Rahmah Hospital | -0,87169489918 | 100,38312131200 |
| | | Semen Padang Hospital | -0,94162328157 | 100,39976586800 |
| 10 | School or the like | Campus of Universitas Negeri Padang | -0,89765027204 | 100,35149781500 |
| 11 | Place of Worship or the like | West Sumatra Grand Mosque | -0,92437179344 | 100,36149546500 |



**Data analysis technique**

*Noise level analysis*

According to Kep-48/MENLH/11/1996, regarding the "Noise Level Standard" to calculate the noise level, the calculation of the Equivalent Continuous Noise Level is used, namely the value of the noise level of the noise that changes (fluctuates) over time. which is equivalent to a steady (steady) noise level at the same time interval with the unit used dB(A) (Xie *et al.,* 2011).

*Determination of equivalent noise level*

The calculation of the 1-hour average noise level was carried out using the Equivalent Noise Level Analysis (Leq) (Brink *et al.,* 2018). The equivalent noise level statement is a model used to express the noise level which is the average sound pressure level in a certain time interval. The mathematical model is presented in the equation.

$$L_{eq} = 10\text{Log}\left(\sum_{i=1}^{n} \text{Fi} \cdot 10^{\text{Li}/10}\right) \text{ dBA}$$

$L_{eq}$ = Equivalent noise level

$F_i$ = The time faction of the occurrence of the noise level at a certain measurement time interval

$L_i$ = Mean value of noise level at specified measurement time interval (dBA)

*Noise level mapping*

The data from the noise measurement was made into a mapping model using ArcGIS software. Noise data were interpolated using IDW interpolated geostatistical spatial analysis on ArcGis 10.3 software (Davis *et al.,* 2009; Dewata & Putra, 2021). In this IDW analysis, the input sample data are noise sources in Padang City. Interpolation is an analysis based on logical distance. This analysis will combine location sources that are close to one another. The distance and orientation between data samples greatly determine the accuracy of the interpolation. The result of this analysis is a map of traffic noise levels in Padang City.

**RESULTS**

**Measured noise level**

The traffic noise level measurement is the result of measuring the traffic noise level at 14 measurement locations using a sound level meter. The following is the result of measuring the level of traffic noise on weekdays and holidayss which can be seen in Table 2 below.

Table 2. Results of measurement of traffic noise levels

| No | Locations | Measurement time | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Working days (dBA) | | | | Holidayss (dBA) | | | |
| | | 07.00 (morning) | 13.00 (noon) | 17.00 (afternoon) | 20.00 (night) | 07.00 (morning) | 13.00 (noon) | 17.00 (afternoon) | 20.00 (night) |
| 1 | Siteba housing | 71.1 | 74.1 | 72.9 | 67.4 | 71.1 | 74.1 | 72.9 | 67.4 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2 | Padang Raya Market | 77.2 | 81.8 | 79.1 | 84.8 | 77.2 | 81.8 | 80.1 | 84.8 |
| 3 | Lubuk Buaya Market | 75.2 | 80.0 | 80.4 | 80.9 | 75.2 | 81.0 | 81.4 | 75.0 |
| 4 | West Sumatra Governor's Office | 77.7 | 77.5 | 76.9 | 78.1 | 75.0 | 76.9 | 75.5 | 78.8 |
| 5 | GOS Imam Bonjol | 72.6 | 73.1 | 74.5 | 71.2 | 70.9 | 72.9 | 72.4 | 72.5 |
| 6 | PT Semen Padang | 66.8 | 70.3 | 69.2 | 68.3 | 65.2 | 69.2 | 67.4 | 70.5 |
| 7 | Padang Beach | 75.0 | 72.3 | 71.3 | 67.5 | 66.9 | 71.6 | 71.9 | 75.6 |
| 8 | Tabing Station | 73.8 | 74.9 | 74.4 | 73.9 | 72.2 | 73.1 | 78.1 | 73.8 |
| 9 | Bayur Bay Harbor | 82.0 | 81.5 | 81.5 | 82.7 | 82.5 | 82.1 | 81.9 | 80.5 |
| 10 | Bungus Harbor | 74.1 | 74.0 | 75.8 | 74.0 | 67.8 | 72.0 | 76.4 | 73.2 |
| 11 | Siti Rahmah Hospital | 74.7 | 76.6 | 77.3 | 78.1 | 79.0 | 73.3 | 75.9 | 79.5 |
| 12 | Semen Padang Hospital | 76.4 | 73.3 | 74.3 | 74.4 | 73.2 | 74.8 | 73.3 | 75.1 |
| 13 | Campus of Universitas Negeri Padang | 70.4 | 71.0 | 72.1 | 72.7 | 70.5 | 72.6 | 72.8 | 74.2 |
| 14 | West Sumatra Grand Mosque | 76.2 | 74.9 | 77.6 | 79.8 | 76.5 | 74.0 | 74.6 | 75.5 |
| | average | 74.5 | 75.4 | 75.5 | 75.3 | 73.1 | 75.0 | 75.3 | 75.5 |

Source: Primary data processing, 2022.



Based on Table 2 above, it can be seen that the traffic noise level at the measurement point ranges from 66.8-84.8 dBA on weekdays, and between 65.2-84.8 dBA on holidayss. On weekdays, the average noise level in the morning, noon, afternoon, and night is 74.5; 75.4; 75.5; and 75.3 dBA. While on holidayss, the value is 73.1; 75.0; 75.3; and 75.5 dBA. The highest noise is found in the Semen Padang Hospital area at night both on holidayss and weekdays with a value of 84.8 dBA each, while the lowest is in the Pasar Raya area on Morning weekday s at 66.8 dBA and on holidayss at 65.2 dBA.

Based on the analysis of the noise level map on weekdays (Fig 2), it can be seen that the noise in Padang City is distributed heterogeneously. Noise level classification consists of 4 classes, namely > 70 symbolized by a red, 65-70 orange, 60-65 yellow, 55-60 light green, and <50 dark green. Based on this classification, there are 12 measurement points with noise levels above > 70 dBA, including Semen Padang Hospital, Lubuk Buaya Market, West Sumatra Grand Mosque, Campus of Universitas Negeri Padang, Teluk Bayur Harbor, Tabing Station, Siteba Market, Siti Rahmah Hospital, West Sumatra Governor's Office, Imam Bonjol RTH, PT Semen Padang, Teluk Bayur Harbor, and Padang Beach. While the other 2 points, namely Pasar Raya Market, and Bungus Harbor the noise level is between 65-70 dBA.

During the day (Fig 2), there are 11 points with noise levels above > 70 dBA namely Semen Padang Hospital, Lubuk Buaya Market, West Sumatra Grand Mosque, Campus of Universitas Negeri Padang, Teluk Bayur Harbor, Tabing Station, Siteba Market, Siti Rahmah Hospital, West Sumatra Governor's Office, GOS Imam Bonjol, PT Semen Padang, Teluk Bayur Harbor, and 3 points at 65-70 dBA in the east to south, namely Pasar Raya Market, Padang Beach, and Bungus Harbor. In the afternoon (Fig 2), there are 12 points with noise levels above >70 dBA spread from the north to the south-central and spreading to the east with the location points of Semen Padang Hospital, Lubuk Buaya Market, Raya West Sumatra, Campus of Universitas Negeri Padang, Teluk Bayur Harbor, Tabing Station, Siteba Market, Siti Rahmah Hospital, West Sumatra Governor's Office, GOS Imam Bonjol, PT Semen Padang, Teluk Bayur Harbor, Padang Beach, and 2 points at 65-70 dBA in the south, namely Pasar Raya Market, and Bungus Harbor. Then at night (Fig 2), there are 11 points with noise levels above >

70 dBA spread in the north to the south-central part and spreading to the east with the location point of Semen Padang Hospital, Lubuk Buaya Market, West Sumatra Grand Mosque, Campus of Universitas Negeri Padang, Teluk Bayur Harbor, Tabing Station, Siteba Market, Siti Rahmah Hospital, West Sumatra Governor's Office, PT Semen Padang, Teluk Bayur Harbor, Padang Beach, and 3 points at 65-70 dBA in the south, namely Pasar Raya Market, GOS Imam Bonjol, and Bungus Harbor. The noise level map in Padang City can be seen in Fig 2 below.

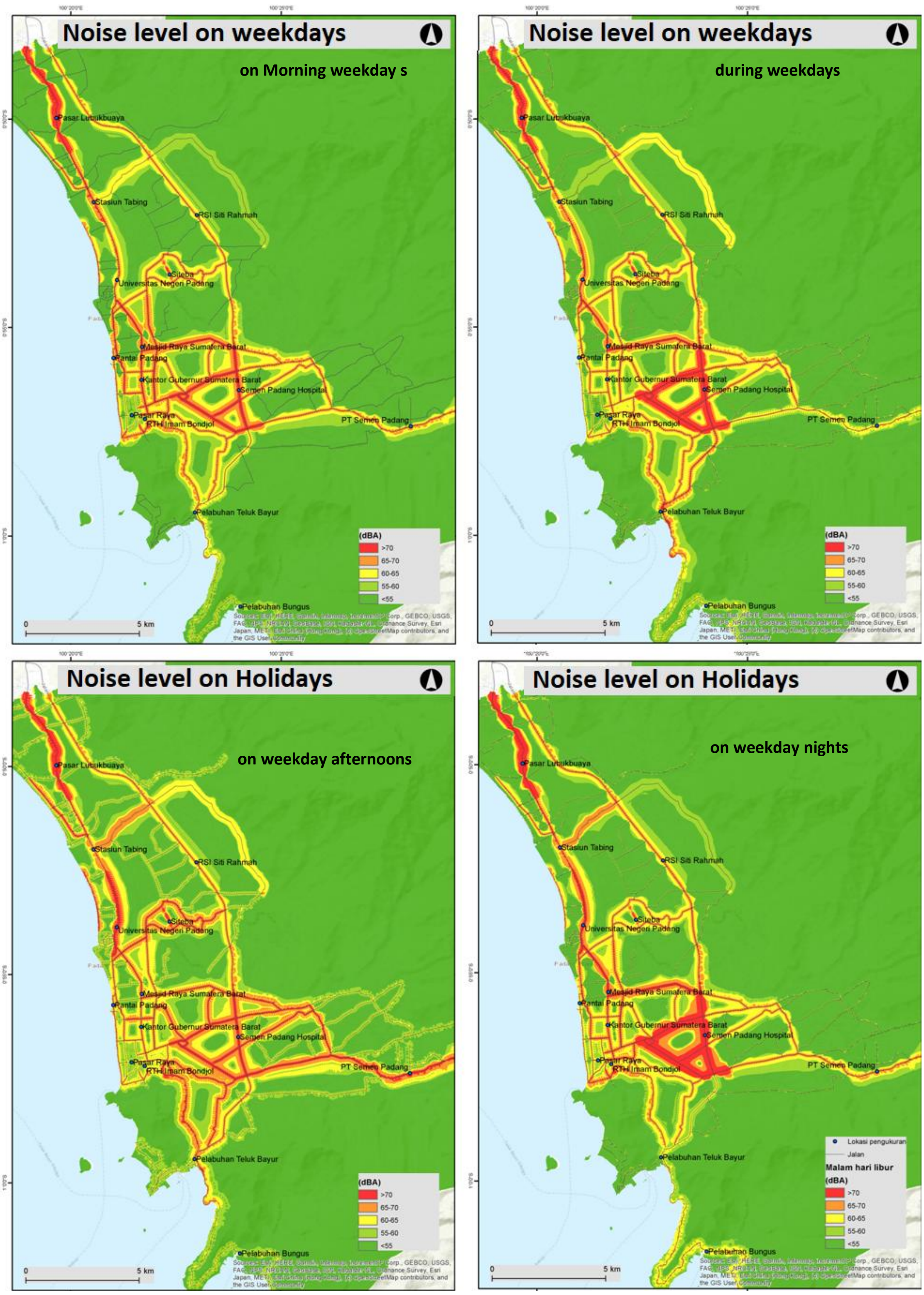


Figure 2. Distribution of traffic noise levels in Padang City (Source: Primary data processing, 2022).

**Noise level prediction**

Tables 3 and 4 show a comparison of the CRTN predictions with the noise level measured in Padang City.

Table 3. Comparison between measured and predicted noise levels (CRTN) on weekdays

| No | Locations | Prediction (CRTN)(dBA) | | | | Measurement | | | | Difference | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | morning | noon | afternoon | night | morning | noon | afternoon | night | morning | noon | afternoon | night |
| 1 | Siteba housing | 73.7 | 75.7 | 75.0 | 71.8 | 71.1 | 74.1 | 72.9 | 67.4 | 2.6 | 1.6 | 2.1 | 4.4 |
| 2 | Padang Raya Market | 79.3 | 80.9 | 81.2 | 81.5 | 77.2 | 81.8 | 79.1 | 84.8 | 2.0 | -0.9 | 2.1 | -3.3 |
| 3 | Lubuk Buaya Market | 75.2 | 80.0 | 80.4 | 80.9 | 75.2 | 80.0 | 80.4 | 80.9 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 | West Sumatra Governor's Office | 81.0 | 80.4 | 80.5 | 80.0 | 77.7 | 77.5 | 76.9 | 78.1 | 3.3 | 2.9 | 3.6 | 1.9 |
| 5 | GOS Imam Bonjol | 75.2 | 75.4 | 77.9 | 76.4 | 72.6 | 73.1 | 74.5 | 71.2 | 2.6 | 2.3 | 3.4 | 5.2 |
| 6 | PT Semen Padang | 70.0 | 72.0 | 72.0 | 69.2 | 66.8 | 70.3 | 69.2 | 68.3 | 3.3 | 1.7 | 2.8 | 0.9 |
| 7 | Padang Beach | 73.5 | 73.4 | 74.3 | 72.2 | 75.0 | 72.3 | 71.3 | 67.5 | -1.5 | 1.0 | 3.0 | 4.7 |
| 8 | Tabing Station | 77.7 | 77.1 | 78.0 | 76.4 | 73.8 | 74.9 | 74.4 | 73.9 | 3.9 | 2.2 | 3.6 | 2.5 |
| 9 | Bayur Bay Harbor | 79.6 | 78.4 | 79.7 | 80.1 | 82.0 | 81.5 | 81.5 | 82.7 | -2.4 | -3.1 | -1.9 | -2.6 |
| 10 | Bungus Harbor | 72.5 | 72.5 | 73.3 | 70.9 | 74.1 | 74.0 | 75.8 | 74.0 | -1.6 | -1.5 | -2.5 | -3.1 |
| 11 | Siti Rahmah Hospital | 76.1 | 76.9 | 76.8 | 76.4 | 74.7 | 76.6 | 77.3 | 78.1 | 1.4 | 0.3 | -0.6 | -1.8 |
| 12 | Semen Padang Hospital | 77.5 | 77.6 | 77.4 | 77.5 | 76.4 | 73.3 | 74.3 | 74.4 | 1.2 | 4.3 | 3.1 | 3.1 |
| 13 | Campus of Universitas Negeri Padang | 75.3 | 74.8 | 75.0 | 73.5 | 70.4 | 71.0 | 72.1 | 72.7 | 4.9 | 3.8 | 2.9 | 0.8 |
| 14 | West Sumatra Grand Mosque | 76.5 | 77.8 | 78.1 | 77.0 | 76.2 | 74.9 | 77.6 | 79.8 | 0.2 | 2.9 | 0.4 | -2.8 |

Source: Primary data processing, 2022.

Table 4. Comparison between measured and predicted noise levels (CRTN) on holidayss

| No | Locations | Prediction (CRTN)(dBA) | | | | Measurement | | | | Difference | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | morning | noon | afternoon | night | morning | noon | afternoon | night | morning | noon | afternoon | night |
| 1 | Siteba housing | 73.7 | 75.7 | 75.0 | 71.8 | 71.1 | 74.1 | 72.9 | 67.4 | 2.6 | 1.6 | 2.1 | 4.4 |
| 2 | Padang Raya Market | 79.3 | 80.9 | 81.2 | 81.5 | 77.2 | 81.8 | 79.1 | 84.8 | 2.0 | -0.9 | 2.1 | -3.3 |
| 3 | Lubuk Buaya Market | 75.2 | 80.0 | 80.4 | 80.9 | 75.2 | 80.0 | 80.4 | 80.9 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 | West Sumatra Governor's | 81.0 | 80.4 | 80.5 | 80.0 | 77.7 | 77.5 | 76.9 | 78.1 | 3.3 | 2.9 | 3.6 | 1.9 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Office | | | | | | | | | | | | |
| 5 | GOS Imam Bonjol | 75.2 | 75.4 | 77.9 | 76.4 | 72.6 | 73.1 | 74.5 | 71.2 | 2.6 | 2.3 | 3.4 | 5.2 |
| 6 | PT Semen Padang | 70.0 | 72.0 | 72.0 | 69.2 | 66.8 | 70.3 | 69.2 | 68.3 | 3.3 | 1.7 | 2.8 | 0.9 |
| 7 | Padang Beach | 73.5 | 73.4 | 74.3 | 72.2 | 75.0 | 72.3 | 71.3 | 67.5 | -1.5 | 1.0 | 3.0 | 4.7 |
| 8 | Tabing Station | 77.7 | 77.1 | 78.0 | 76.4 | 73.8 | 74.9 | 74.4 | 73.9 | 3.9 | 2.2 | 3.6 | 2.5 |
| 9 | Bayur Bay Harbor | 79.6 | 78.4 | 79.7 | 80.1 | 82.0 | 81.5 | 81.5 | 82.7 | -2.4 | -3.1 | -1.9 | -2.6 |
| 10 | Bungus Harbor | 72.5 | 72.5 | 73.3 | 70.9 | 74.1 | 74.0 | 75.8 | 74.0 | -1.6 | -1.5 | -2.5 | -3.1 |
| 11 | Siti Rahmah Hospital | 76.1 | 76.9 | 76.8 | 76.4 | 74.7 | 76.6 | 77.3 | 78.1 | 1.4 | 0.3 | -0.6 | -1.8 |
| 12 | Semen Padang Hospital | 77.5 | 77.6 | 77.4 | 77.5 | 76.4 | 73.3 | 74.3 | 74.4 | 1.2 | 4.3 | 3.1 | 3.1 |
| 13 | Campus of Universitas Negeri Padang | 75.3 | 74.8 | 75.0 | 73.5 | 70.4 | 71.0 | 72.1 | 72.7 | 4.9 | 3.8 | 2.9 | 0.8 |
| 14 | West Sumatra Grand Mosque | 76.5 | 77.8 | 78.1 | 77.0 | 76.2 | 74.9 | 77.6 | 79.8 | 0.2 | 2.9 | 0.4 | -2.8 |

Source: Primary data processing, 2022.

The accuracy of the prediction of noise level with the CRTN model on the measured noise level was carried out using linear regression analysis. Fig 3-10 shows the results of a simple regression analysis of noise levels. The coefficient of determination ($R^2$) 1.0 is considered the best, while values above 0.6 are considered good.

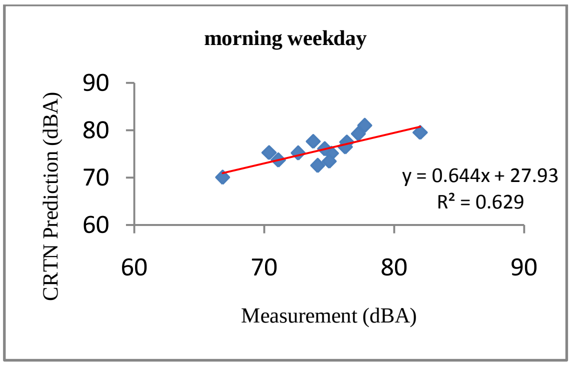


Figure 3. Comparison of CRTN with actual noise on morning weekday.

By substituting the $L_{CRTN}$ value, the general form of the revised equation is.

$$L_{Prediction} = 0{,}6441 L_{CRTN} + 27{,}935;\ R^2 = 0{,}6291$$

$$L_{Prediction} = 6{,}44 \log_{10} q + 21{,}26 \log_{10}\left(V + 40 + \frac{500}{V}\right) + 6{,}44 \log\left(1 + \frac{5P}{V}\right) + 0{,}19G - 6{,}44 \log\left(\frac{\sqrt{(d+3{,}5)^2 + 0{,}49}}{13{,}5}\right) + 10{,}80$$

On morning weekday s it can be observed that the difference between the measured noise and the predicted noise level is in the range of -4.9 to +2.4 dBA with the coefficient of determination ($R^2$)

being 0.6291. The average difference is +2.2 dBA. Deviation at 6 points does not exceed 2 dBA. Deviations of more than 2 dBA were found at the 8 highest points due to high vehicle flows. The results of the verification of the model designed in this study showed the predicted average Leq was 75.9 ± 0.8 dBA. The comparison of the mean predicted Leq and the measured Leq (74.5 ± 1.0 dBA) shows a small difference of 1.4 dBA.

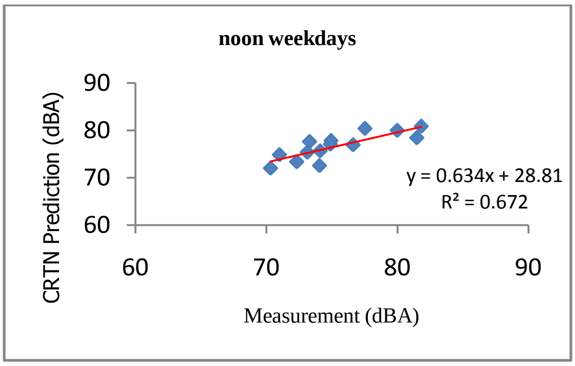


Figure 4. Comparison of CRTN with actual noise on noon weekday

By substituting the $L_{CRTN}$ value, the general form of the revised equation is.

$$L_{Prediction} = 0{,}6441 L_{CRTN} + 28{,}815;\ R^2 = 0{,}6728$$

$$L_{Prediction} = 6{,}34 \log_{10} q + 20{,}94 \log_{10}\left(V + 40 + \frac{500}{V}\right) + 6{,}34 \log\left(1 + \frac{5P}{V}\right) + 0{,}19G - 6{,}34 \log\left(\frac{\sqrt{(d+3{,}5)^2 + 0{,}49}}{13{,}5}\right) + 11{,}94$$

On noon weekdays, it can be observed that the difference between the measured noise and the predicted noise level is in the range of -4.3 to +3.1 dBA with the coefficient of determination ($R^2$) being 0.6728. The average difference is +2 dBA. The deviation at 7 points does not exceed 2 dBA. Deviations of more than 2 dBA were found at the 7 highest points due to high vehicle flows. The results of the verification of the model designed in this study showed the predicted average Leq was 76.6 ± 0.8 dBA. The comparison of the mean predicted Leq and the measured Leq (75.4 ± 1.0 dBA) shows a small difference of 1.3 dBA.

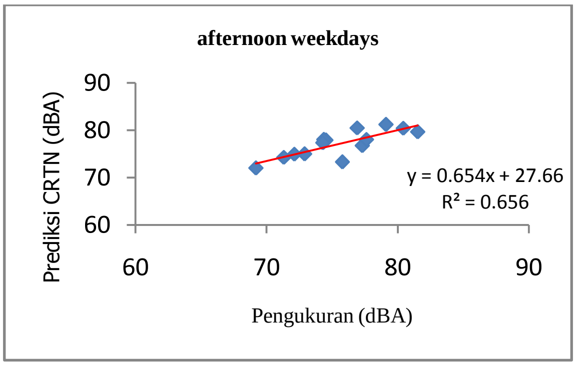


Figure 4. Comparison of CRTN with actual noise on afternoon weekday

By substituting the $L_{CRTN}$ value, the general form of the revised equation is.

$$L_{Prediction} = 0{,}6545 L_{CRTN} + 27{,}667;\ R^2 = 0{,}6561$$

$$L_{Prediction} = 6{,}55 \log_{10} q + 21{,}60 \log_{10}\left(V + 40 + \frac{500}{V}\right) + 6{,}55 \log\left(1 + \frac{5P}{V}\right) + 0{,}20G - 6{,}55 \log\left(\frac{\sqrt{(d+3{,}5)^2 + 0{,}49}}{13{,}5}\right) + 10{,}26$$

On weekday afternoons it can be observed that the difference between the measured noise and the predicted noise level is in the range of -3.6 to +2.5 dBA with the coefficient of determination ($R^2$)

being 0.6561. The average difference is +2.3 dBA. The deviation at 4 points does not exceed 2 dBA. Deviations of more than 2 dBA were found at the highest 10 points due to high vehicle flows. The results of the verification of the model designed in this study showed that the predicted average Leq was 77.1 ± 0.8 dBA. The comparison of the mean predicted Leq and the measured Leq (75.5 ± 0.9 dBA) showed a small difference of 1.6 dBA.

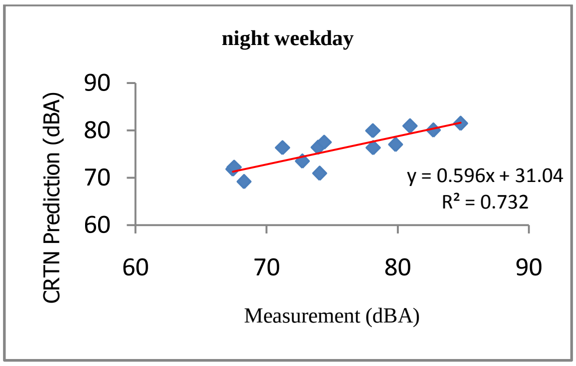


Figure 5. Comparison of CRTN with actual noise on night weekday

By substituting the $L_{CRTN}$ value, the general form of the revised equation is.

$$L_{Prediction} = 0{,}5969 L_{CRTN} + 31{,}047;\ R^2 = 0{,}7326$$

$$L_{Prediction} = 5{,}97 \log_{10} q + 19{,}70 \log_{10}\left(V + 40 + \frac{500}{V}\right) + 5{,}97 \log\left(1 + \frac{5P}{V}\right) + 0{,}18G - 5{,}97 \log\left(\frac{\sqrt{(d+3{,}5)^2 + 0{,}49}}{13{,}5}\right) + 15{,}17$$

On night weekdays it can be observed that the difference between the measured noise and the predicted noise level is in the range of -5.2 to +3.3 dBA with the coefficient of determination ($R^2$) being 0.7326. The average difference is +2.6 dBA. The deviation at 5 points does not exceed 2 dBA. Deviations of more than 2 dBA were found at the 9 highest points due to high vehicle flows. The results of the verification of the model designed in this study showed that the predicted average Leq was 76.0 ± 1.1 dBA. The comparison of the mean predicted Leq and the measured Leq (75.3 ± 1.5 dBA) showed a small difference of 0.7 dBA.

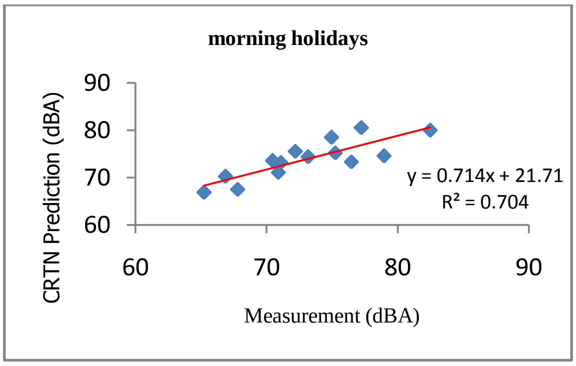


Figure 6. Comparison of CRTN with actual noise on morning week holidays

By substituting the $L_{CRTN}$ value, the general form of the revised equation is.

$$L_{Prediction} = 0{,}7142 L_{CRTN} + 21{,}719;\ R^2 = 0{,}7045$$

$$L_{Prediction} = 7{,}14 \log_{10} q + 23{,}57 \log_{10}\left(V + 40 + \frac{500}{V}\right) + 7{,}14 \log\left(1 + \frac{5P}{V}\right) + 0{,}21G - 7{,}14 \log\left(\frac{\sqrt{(d+3{,}5)^2 + 0{,}49}}{13{,}5}\right) + 2{,}72$$

On the morning holidays it can be observed that the difference between the measured noise and the predicted noise level is in the range of -3.6 to +4.4 dBA with the coefficient of determination ($R^2$)

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being 0.7045. The average difference is +2.3 dBA. The deviation at 5 points does not exceed 2 dBA. Deviations of more than 2 dBA were found at the 9 highest points due to high vehicle flows. The results of the verification of the model designed in this study showed that the predicted average Leq was 73.9 ± 1.1 dBA. The comparison of the predicted means Leq and the measured Leq (73.1 ± 1.3 dBA) showed a small difference of 0.8 dBA.

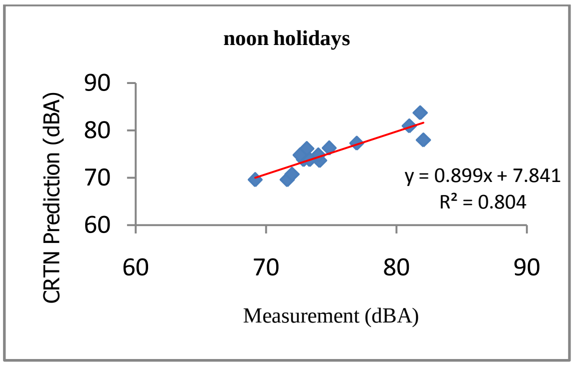


Figure 7. Comparison of CRTN with actual noise on noon holidays

By substituting the L¬CRTN value, the general form of the revised equation is.

$$L_{Prediction} = 0{,}8990 L_{CRTN} + 7{,}8414;\ R^2 = 0{,}8047$$

$$L_{Prediction} = 8{,}99 \log_{10} q + 29{,}67 \log_{10}\left(V + 40 + \frac{500}{V}\right) + 8{,}99 \log\left(1 + \frac{5P}{V}\right) + 0{,}27G - 8{,}99 \log\left(\frac{\sqrt{(d + 3{,}5)^2 + 0{,}49}}{13{,}5}\right) - 16{,}07$$

On the noon holidays, it can be observed that the difference between the measured noise and the predicted noise level is in the range of -3.0 to +4.1 dBA with the coefficient of determination ($R^2$) being 0.8047. The average difference is +1.4 dBA. The deviation at 10 points does not exceed 2 dBA. Deviations of more than 2 dBA were found at the 4 highest points due to high vehicle flows. The results of the verification of the model designed in this study showed that the predicted average Leq was 75.2 ± 1.1 dBA. The comparison of the predicted means Leq and the measured Leq (75.0 ± 1.1 dBA) shows a small difference of 0.2 dBA.

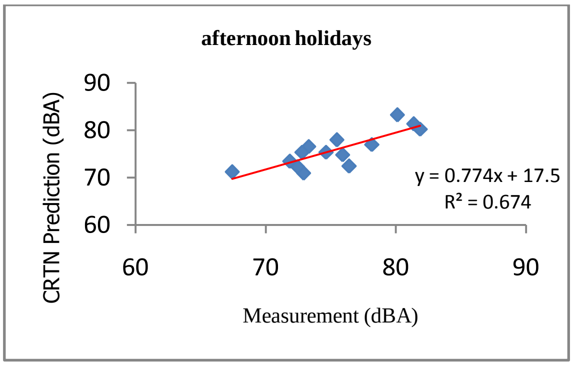


Figure 8. Comparison of CRTN with actual noise on afternoon holidays

By substituting the L¬CRTN value, the general form of the revised equation is.

$$L_{Prediction} = 0{,}7749 L_{CRTN} + 17{,}500\ \ R^2 = 0{,}6748$$

$$L_{Prediction} = 7{,}75 \log_{10} q + 25{,}57 \log_{10}\left(V + 40 + \frac{500}{V}\right) + 7{,}75 \log\left(1 + \frac{5P}{V}\right) + 0{,}23G - 7{,}75 \log\left(\frac{\sqrt{(d + 3{,}5)^2 + 0{,}49}}{13{,}5}\right) - 3{,}11$$

On afternoon holidays it can be observed that the difference between the measured noise and the predicted noise level is in the range of -3.8 to +4.0 dBA with the coefficient of determination ($R^2$)

being 0.6748. The average difference is +2.0 dBA. The deviation at 8 points does not exceed 2 dBA. Deviations of more than 2 dBA were found at the highest 6 points due to high vehicle flows. The results of the verification of the model designed in this study showed that the predicted average Leq was 75.9 ± 1.0 dBA. The comparison of the predicted means Leq and the measured Leq (75.3 ± 1.1 dBA) shows a small difference of 0.5 dBA.

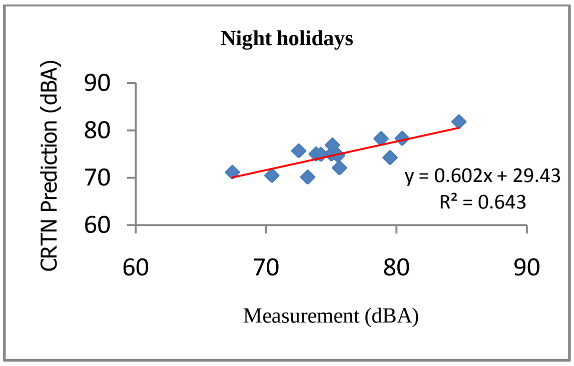


Figure 9. Comparison of CRTN with actual noise on night holidays

By substituting the $L_{CRTN}$ value, the general form of the revised equation is.

$$L_{Prediction} = 0{,}6027 L_{CRTN} + 29{,}433;\ R^2 = 0{,}6433$$

$$L_{Prediction} = 6{,}03 \log_{10} q + 19{,}89 \log_{10}\left(V + 40 + \frac{500}{V}\right) + 6{,}03 \log\left(1 + \frac{5P}{V}\right) + 0{,}18G - 6{,}03 \log\left(\frac{\sqrt{(d+3{,}5)^2 + 0{,}49}}{13{,}5}\right) + 13{,}40$$

On night holidays it can be observed that the difference between the measured noise and the predicted noise level is in the range of -3.8 to +5.3 dBA with the coefficient of determination ($R^2$) being 0.6433. The average difference is +2.1 dBA. The deviation at 7 points does not exceed 2 dBA. Deviations of more than 2 dBA were found at the 7 highest points due to high vehicle flows. The results of the verification of the model designed in this study showed that the predicted average Leq was 74.9 ± 0.9 dBA. The comparison of the predicted means Leq and the measured Leq (75.5 ± 1.2) showed a small difference of 0.5 dBA.

**Discussions**

*Measured noise (Measured noise level)*

The highest level of traffic noise is in the Semen Padang Hospital area on weekdays with a value of 85.4 dBA, while the lowest is 64.7 dBA in the Bungus Harbor area. This can be explained by looking at their respective locations. Semen Padang Hospital is located on Bypass street which is a primary arterial road characterized by high speed and traversed by many heavy vehicles. This condition makes it prone to noise. The Bungus Harbor area, which is also located on a primary arterial road, but with undivided road characteristics and a relatively small number of vehicles makes the noise level also low.

In general, the noise will increase with vehicle speed. But some research goes further and studies this occurrence to measure it. At a distance of 7.5 m, it can be seen that a speed difference of 10 km/h causes the noise level to increase by more than 1 dBA for each passing vehicle. There is indeed a difference between passenger cars and heavy vehicles (trucks). Trucks not only increase the noise in absolute terms, but noise level growth is also greater as their speed increases compared to passenger cars (approximately 1.7 dBA per 10 km/h for trucks, 1.2 dBA per 10 km/h for passenger cars) (Deok-Soon, 2016; Ohm *et al.,* 2017).

The noise mapping in this study was made on a relatively rough scale. Further studies are needed to account for the effects of obstacles such as terrain, buildings, and vegetation. However, this study supports the assertion that large-scale traffic noise modeling and mapping is possible in Padang City. In particular, public housing authorities, cities, and neighborhoods may consider this study as an example of creating a traffic noise map.

*Noise level prediction*

The performance of the CRTN model in this study is quite good with a coefficient of determination ($R^2$) ranging from 0.629 to 0.805. This level of performance is because most (63.8%) of CRTN's predicted Leq exceeds the measured Leq. As with previous relevant studies, the coefficient of determination ranges from 0.6 to 0.85 for cities in Asia. Sheng *et al.,* (2015) tested whether the CRTN model is reliable and suitable for predicting traffic noise in cities with high motorcycle use. The 31 on-site measurements taken by the roadside represent different road types and traffic characteristics in Macau, where more than half of licensed motor vehicles are motorcycles. The difference between the measurement and the associated CRTN predictions on the 31 sides of the road was in the range of -1.47 dBA to +2.96 dBA, and the mean difference was +0.52 dBA. CRTN predictions correlated well with the value measured by the coefficient of determination ($R^2$) of 0.832.

Dirgawati *et al.,* (2021) used the CRTN model to predict traffic noise on several roads in Bandung City, where the use of motorcycles is very high. The difference between L10 measurements and predictions for the Suci and Dago streets ranges from -4.3 to +7.3 dBA. The CRTN model exceeds the measured L10 noise level at most of the measurement locations and times. Correspondingly, To *et al.,* (2002) also applied the CRTN model in Hong Kong with the difference between the measured and predicted L10 being in the range of 2–6 dBA. Leung & Mak (2008) have reported that an overestimation of at least 10 dBA can occur when the CRTN model is adopted in areas where buildings are located on both sides of the road. However, the CRTN model needs to be adapted and updated especially for Asian cities where traffic is dominated by motorcycles. Moreover, at this time the sound produced by the vehicle is relatively smaller than when the CRTN model was issued.

**CONCLUSIONS**

Based on the results of this study, it can be concluded that the level of traffic noise in Padang City is between 65.2-84.8 dBA. The highest noise is found in the Semen Padang Hospital area due to heavy vehicles and high speeds. While the lowest is in the Pasar Raya Market area due to the lack of heavy vehicles and low speed. The performance of the basic CRTN model on the measurement is classified as good with a coefficient of determination ($R^2$) ranging from 0.629 to 0.805 and an average difference of 2.1 dBA. Adjustment of the CRTN model with measurements resulted in a revised CRTN model. This model can then be applied to predict traffic noise levels in Padang City. It is hoped that the Padang City Government will consider planting appropriate noise-reducing vegetation, especially in places prone to noise to maintain public safety and comfort. Proposed noise modeling with more complex variables such as topography, presence of building objects, existing vegetation, atmospheric conditions, and other related variables. This refinement to the noise prediction model allows for more accurate predictions so that control measures can be taken.

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