Algorithm Analysis of Polynomial Mathematical Models of Noise Pollution due to Traffic Volume in The Region of West Surabaya

Cintantya Budi Casita¹, Hendrata Wibisana², Zetta Rasullia Kamandang³
¹,²,³Civil Engineering Department, Universitas Pembangunan Nasional “Veteran” Jawa Timur, Surabaya, Indonesia

cintantyabudi.ts@upnjatim.ac.id

Abstract. The systemsatics of analysis process can be done by compiling some algorithm, based on the accuracy from the parameter. This research objective is to find and analyze mathematical models for noise pollution on arterial roads due to high traffic volume. Data are collected during on site surveys in West Surabaya by using manual traffic counter for recording light vehicle volume and Digital Sound Level (DSL) for recording the noise levels. Least Square Analysis Method is used to find the optimum mathematical model based on the highest value of $R^2$ using polynomial of degree one (linear function), degree two, degree three, and degree four. The result shows that the polynomial of degree four obtained the highest value of $R^2 = 0.733$ and the value of standard error = 2.8933, with the result that can be used as a reference to represent the condition of noise levels on that region.

1. Introduction

Algorithm is a step by step method of solving a mathematical problem to obtain a required output. A systematic steps are absolutely necessary in order to obtain results as expected.

Types of pedestrians can be defined using a mathematical models which are one of the steps of an algorithm based on some variables [1] [2]. High traffic volume can cause traffic congestion [3] [4] that may lead to traffic crashes [5] [6] [7], also can cause high level of noise exposure that has a negative effect on human health, especially near the heavy traffic roads [8][9][10]. The level of noise is measured in decibel (dB) which is a unit of measurement of sound intensity.

In recent years, several researchers make some experiments with different approaches, such as noise pollution [11] [12]and air pollution [13] [14], noise pollution and its impact on human health [15] [16] [17], hearing loss due to noise pollution [18], effect of noise pollution on physiological and phisical health [19] [20] [21].

The objective of this research is to find and analyze an optimum mathematical model of correlation between traffic volume and noise pollution of West Surabaya using Least Square Analysis. So, the condition of noise pollution on that region can be represented and then the health issues due to high level of noise exposure can be minimized.
2. Data, Methodology, and Variables

2.1 Research Data

Surabaya is one of the busiest capital city in Indonesia and it consist of some region: North Surabaya, South Surabaya, West Surabaya, East Surabaya, and Central Surabaya. This research took place in the West Surabaya, whose arterial roads are still relatively new between other regions of Surabaya. Arterial roads in this region became crowded especially in working hours, also because of the increasing number of apartments and some of comercial buildings. This heavy traffic causes high noise level which can lead to many health issues.

Six locations are selected as shown in Figure 1. It has been previously observed that has high traffic volume, those are Lontar Main Road, Mayjen Yono Suwoyo, Graha Bukit Darmo, HR Muhammad, Dukuh Kupang Barat.

![Figure 1. Case study location at the region of West Surabaya](Source: Google Earth)

The each value of latitude and longitude coordinates are obtained using Google Maps as shown in Table 1.

| Road Name           | Latitude      | Longitude      |
|---------------------|---------------|----------------|
| Raya Lontar         | 7°17’2.41”S   | 112°40’3.89”E  |
| Yono Suwoyo         | 7°17’5.93”S   | 112°40’51.82”E|
| Graha Bukit Darmo   | 7°17’36.16”S  | 112°41’27.14”E|
| HR.Muhammad         | 7°17’6.47”S   | 112°41’42.61”E|
| Dukuh Kupang Barat  | 7°17’6.19”S   | 112°42’55.60”E|
| Mayjen Sungkono     | 7°17’30.97”S  | 112°43’12.90”E|

(Source: Google Earth)

Raya Lontar, Graha Bukit Darmo, and Dukuh Kupang does not have a road median. The otherwise for Yono Suwoyo, HR. Muhammad, and Mayjen Sungkono.

2.2 Methodology and Variables

In order to analyze each polynomial, four mathematical models are used and the value of correlation between the noise and traffic volume are compared.

Degree 1 Polynomial (Linear Function)

\[ y = ax + b \]  \hspace{1cm} (1)
Degree 2 Polynomial
\[ y = ax^2 + bx + c \]  \hspace{1cm} (2)
Degree 3 Polynomial
\[ y = ax^3 + bx^2 + cx + d \]  \hspace{1cm} (3)
Degree 4 Polynomial
\[ y = ax^4 + bx^3 + cx^2 + dx + e \]  \hspace{1cm} (4)

where:
y is the dependent variable;
x is the independent variable;
a, b, c, d, e are the coefficients of each independent variable.

3. Result and Discussion

Table 2 reports the survey results of light vehicles volume and the noise levels that collected during on site survey by using manual traffic counter for 2.5 hours.

| Road Name          | Vehicles/h | Noise (dB) |
|--------------------|------------|------------|
| Yono Suwoyo        | 356        | 54.6       |
|                    | 427        | 52.7       |
|                    | 381        | 48.5       |
|                    | 326        | 52.4       |
| HR. Muhammad       | 419        | 57.2       |
|                    | 457        | 56.8       |
|                    | 562        | 64.4       |
| Mayjen Sungkono    | 487        | 62.8       |
|                    | 368        | 57.9       |
| Raya Lontar        | 418        | 55.3       |
|                    | 328        | 52.6       |
| Graha Bukit Darmo  | 366        | 54.1       |
|                    | 375        | 56.7       |
| Dukuh Kupang       | 411        | 61.4       |
|                    | 437        | 59.3       |

(Source: Surveys Data)

The data that shown in Table 2 are used as input data for each algorithm: polynomial of degree one (linear function), degree two, degree three, and degree four. The mathematical models for calculating the value of predicted noise levels and the value of \( R^2 \) and its standart error are summarized in Table 3.

| Algorithm            | Mathematical models                      | \( R^2 \) | Standart error |
|----------------------|------------------------------------------|-----------|----------------|
| Linear function      | dB = 0.05.vec + 35.25                     | 0.609     | 2.929          |
| Degree 2 polynomial  | dB = 0.00017.vec^2 - 0.0947.vec + 65.97  | 0.648     | 2.927          |
| Degree 3 polynomial  | dB = -1.74.10^-6.vec^3 + 0.0025.vec^2 - 1.088.vec + 206.378 | 0.663     | 3.040          |
| Degree 4 polynomial  | dB = -7.76.10^-8.vec^4 + 0.00013.vec^3 - 0.0848.vec^2 + 23.625.vec - 2385.03 | 0.733     | 2.893          |
According to Table 3 above, the value of $R^2$ from degree 1 polynomial to degree 4 polynomial are continuously increasing, whereas the value of standard error are decreasing.

**Figure 2.** Correlation between light vehicles volume per hour and noise levels of degree one polynomial (linear function)

**Figure 3.** Correlation between light vehicles volume per hour and noise levels of degree two polynomial

**Figure 4.** Correlation between light vehicles volume per hour and noise levels of degree three polynomial
Figure 5. Correlation between light vehicles volume per hour and noise levels of degree four polynomial

Table 4 presents the value of predicted noise after calculated using degree four polynomial and the actual noise which obtained during the survey.

Table 4. Predicted noise value, actual noise data, and its variances

| Observation | Predicted Noise (dB) | Actual noise (dB) | Variances |
|-------------|----------------------|-------------------|-----------|
| 1           | 54.3163              | 54.6              | 0.2837    |
| 2           | 54.5536              | 52.7              | -1.8536   |
| 3           | 53.9187              | 48.5              | -5.4187   |
| 4           | 52.5039              | 52.4              | -0.1039   |
| 5           | 54.1118              | 57.2              | 3.0882    |
| 6           | 57.6968              | 56.8              | -0.8968   |
| 7           | 64.4029              | 64.4              | -0.0029   |
| 8           | 62.5247              | 62.8              | 0.2753    |
| 9           | 54.1948              | 57.9              | 3.7052    |
| 10          | 54.0684              | 55.3              | 1.2316    |
| 11          | 52.7783              | 52.6              | -0.1783   |
| 12          | 54.2297              | 54.1              | -0.1297   |

4. Conclusion
According to the analysis above, the highest value of $R^2 = 0.733$ is obtained in degree 4 polynomial, and it has the lowest value of standard error $= 2.893$. Its predicted noise value and actual noise value have no significant difference in results. It showed that degree 4 polynomial has the optimum mathematical model, so it has the best representation of the noise levels condition of West Surabaya amongst those four models.

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