Analysis of Noise Pollution due to Traffic Volume Based on The Types of Automotive Vehicles: A Study of West Surabaya Region

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Abstract. Noise pollution often disturbs the people surrounding. The noise levels caused by traffic volume of automotive vehicles is one of the common causes. In order to examine the correlation of automotive vehicles with noise levels, this study implements linear and multiple regression methods into six case study locations in West Surabaya region that has dynamic of both economy and society. This study concludes that based on the obtained R square results, heavy vehicles (HV) has 70.80% of influence contribution with noise levels on the case study locations. It indicates that HV has the largest part in influencing the noise pollution compared to motorcycle (MC) and light vehicles (LV) that has 66.63% and 30.21%. On the other hand, for every 10% of MC, LV and HV volume increasing, the noise levels also increase by 1.726%, 2.032%, and 1.733% respectively. The correlation of MC, LV and HV vehicles with noise levels is represented in dB = 0.0025mc – 0.0056lv + 0.56hv + 49.539 of multiple regression model.

1. Introduction
Noise pollution can be described as regular exposure to high sound levels that can cause adverse effects on humans or other living organisms. According to the World Health Organization (WHO), sound levels less than 70 dB is not damaging to living organisms, regardless of how long or consistent the exposure is. Exposure for more than 8 hours to constant noise beyond 85 dB may be hazardous.

Types of noise pollution that commonly occur in our daily lives are road traffic noise, construction noise, airport/port noise, industrial noise, and railway noise. Every day, people travel from places to other places by using automotive vehicles such as motorcycle, cars, buses, trucks and off-road vehicles. As people travel, there will be an adverse side effect caused by high traffic volume in the form of traffic congestion [1], [2], [3] and traffic noise pollution [4], [5] that might cause in traffic crashes [6], [7], [8]. Therefore, road traffic is the biggest cause of community noise and typically noise levels increase with higher traffic volumes and speeds.

Previous research stated that traffic noise pollution is not only quite disturbing for road users (pedestrian, automotive vehicles users) [9] but also for the people living around the area especially who lives near shopping centers or theater [10], [11]. Effects of traffic noise pollution contribute to human health issues [12], [13], [14] such as a hearing loss, mental illness, and loss of vehicle control [15], [16], [17] that caused into traffic accident [18]. Traffic noise pollution has adverse effects not only on physiological but also human physical health [19], [20], [21]. Therefore, conducting research
that examines the correlation of traffic volume with noise pollution levels is necessary. In term of examining the correlation of traffic volume with noise pollution levels, this study implements linear and multiple regression method to case study data that has to be collected before.

2. Case Study
The case study of this research is located in West Surabaya. The traffic volume and noise levels data caused by automotive vehicles in Mayjend Sungkono Rd., H.R. Muhammad Rd., Graha Bukit Darmo Regency, Dukuh Kupang Barat Rd., Mayjen Jono Suwojo Rd., and Raya Lontar Rd., has to be collected. The reason behind choosing West Surabaya as the location of the case study project is because it was known as a dynamic region of both economy and society. In the last 10 years, many commercial and business buildings have been built. This phenomenon triggers people to travel more in the area and also increase the use of automotive vehicles, the main transportation of urban people.

Figure 1 presents the location of case study project in open street maps collected from Dinas Perumahan Rakyat and Kawasan Pemukiman Cipta Karya and Tata Ruang Provinsi Jawa Timur and Table 1 describes the coordinate of each case study location.

![Figure 1. Location of Case Study.](Source: Dinas Perumahan Rakyat and Kawasan Pemukiman Cipta Karya and Tata Ruang Provinsi Jawa Timur.)

3. Material and Methodology
As stated in the introduction section, this study implements linear and multiple regression method to case study data that has collected before. Therefore, surveys that collected traffic volume and noise levels data are the starting points in conducting this research. The research flowchart is presented in Figure 2.

In term of collecting the traffic volume and noise levels data of automotive vehicles, the surveys of each case study location are completed in 2.5-hours observation with every 10-minutes of recording. The automotive vehicles are also divided into motorcycle (MC), light vehicles (LV) and heavy vehicles (HV). Table 1 presents the survey results of MC, LV, HV volume and the noise levels in dB that occurred on each location.

This research applied a linear regression to calculate the correlation of each automotive vehicle with noise levels. Table 2 presents the example of motorcycle (MC) volume and the noise levels in dB that occurred on each location.
Conducting an intensive literature review in the areas of identifying the correlation of traffic volume with noise levels

Conducting traffic and noise levels surveys in case study locations

Motorcycle (MC) Volume
Light Vehicles (LV) Volume
Heavy Vehicles (HV) Volume
Noise Levels (dB)

Calculate the correlation of each MC, LV, HV volume and noise levels with linear regression method

Calculate the correlation of MC, LV, HV volume and noise levels with multiple regression method

Correlation of each MC, LV, HV volume and noise levels in regression models

Correlation of MC, LV, HV volume and noise levels in regression models

Calculating the noise levels increasing caused by automotive vehicles volume increase

Summarizing the results

Figure 2. Flowchart of the research.

Table 1. MC, LV, HV volume and noise levels.

| Road Name                | MC  | LV  | HV  | Noise Levels (dB) |
|--------------------------|-----|-----|-----|-------------------|
| Raya Lontar              | 1645| 428 | 14  | 66                |
| Yono Suwoyo              | 1258| 824 | 12  | 52                |
| Graha Bukit Darmo        | 3542| 764 | 24  | 61                |
| HR.Muhammad              | 4385| 1278| 26  | 72                |
| Dukuh Kupang Barat       | 852 | 478 | 2   | 48                |
| Mayjen Sungkono          | 1065| 622 | 4   | 52                |

(Source: Surveys Data)
Table 2. MC volume and noise levels.

| Road Name            | MC     | Noise Levels (dB) |
|----------------------|--------|-------------------|
| Raya Lontar          | 1645   | 66                |
| Yono Suwoyo          | 1258   | 52                |
| Graha Bukit Darmo    | 3542   | 61                |
| HR.Muhammad          | 4385   | 72                |
| Dukuh Kupang Barat   | 852    | 48                |
| Mayjen Sungkono      | 1065   | 52                |

(Source: Surveys Data)

MC volume later can be classified as the independent variable (variable x) and noise levels as the dependent variable (variable y). In this calculation, a linear regression method is applied by using software to obtain an accurate result. The calculation method is also applied to LV and HV respectively. In order to identify the correlation of MC, LV and HV volume with noise levels, a multiple regression method is applied. After obtaining the results, the estimation to calculate the noise levels increasing caused by each automotive vehicles volume increasing is conducted.

4. Calculation Results

A linear regression method is applied to obtain a regression model of correlation of each MC, LV, HV volume with noise levels by using a software. Furthermore, the correlation of traffic volume caused by automotive vehicles with noise levels can be achieved by applying the case study data into multiple regression method.

4.1. Linear Regression Results

After collected the traffic volume and noise levels data from case study locations, a calculation of each automotive vehicle can be conducted. As described in the material and methodology section, MC, LV and HV volume can be classified as independent variable (variable x) and noise levels as dependent variable (variable y). The calculation later can be done by using software.

Based on the calculation, the obtained R square of motorcycle and noise levels is 0.6663 with $y = 0.005mc + 47,459$ as the regression model. So, in this case, the motorcycle has influence contribution in noise level as much as 66.66%. The further results are presented in Table 3.

Table 3. Linear Regression Results.

| Independent Variable (Variable x) | Dependent Variable (Variable y) | R Square | Linear Regression Models |
|-----------------------------------|---------------------------------|----------|--------------------------|
| Motorcycle (MC)                   | Noise Levels (dB)               | 0.6663   | dB = 0.005mc + 47,459    |
| Light Vehicle (LV)               |                                 | 0.3021   | dB = 0.0166lv + 46, 277  |
| Heavy Vehicles (HV)              |                                 | 0.7080   | dB = 0.795hv + 47,624    |

As the MC, LV and HV volume is calculated partially to achieve the correlation with noise levels, this research also predicts the noise levels of case study locations if the volume of vehicles increasing into 10%, 20%, and 30%. The MC volume and noise levels results are presented in Table 4.

As shown at Table 4, for every 10% of MC volume increasing, the noise levels also increase by 1.726%. The same calculation method is applied to LV and HV volume and obtained 2.032% and 1.733% of every 10% of volume increasing respectively.

4.2. Multiple Regression Results

If the linear regression calculates the correlation of MC, LV and HV volume with noise levels partially, the multiple regression involves the three independent variables in one calculation to achieve the correlation with noise levels. Based on the calculation, the obtained R square is 0.7255 with $y =$
0.0025x₁ – 0.0056x₂ + 0.56x₃ + 49,539 as the regression model. Table 5 presents the residual outputs of the calculation.

Table 4. Noise levels increasing caused by MC volume.

| Road Name        | MC Volume | Noise Levels Increasing with 10% of vol. increasing | Noise Levels Increasing with 20% of vol. increasing | Noise Levels Increasing with 30% of vol. increasing |
|------------------|-----------|--------------------------------------------------|--------------------------------------------------|--------------------------------------------------|
| Raya Lontar      | 1645      | 1,477 %                                          | 2,954 %                                          | 4,431 %                                          |
| Yono Suwoyo      | 1258      | 1,170 %                                          | 2,341 %                                          | 3,511 %                                          |
| Graha Bukit Darmo| 3542      | 2,718 %                                          | 5,435 %                                          | 8,153 %                                          |
| HR.Muhammad      | 4385      | 3,160 %                                          | 6,320 %                                          | 9,480 %                                          |
| Dukuh Kupang Barat| 852      | 0,824 %                                          | 1,647 %                                          | 2,471 %                                          |
| Mayjen Sungkono  | 1065      | 1,009 %                                          | 2,018 %                                          | 3,026 %                                          |
| Average          |           | 1,726 %                                          | 3,452 %                                          | 5,179 %                                          |
| For every 10% vol. increasing | | 1,726 % | |

Table 5. Residual outputs of Multiple Regression Calculation.

| Observation | Noise Levels (dB) | Predicted Noise (dB) | Residuals | Standard Residuals |
|-------------|-------------------|----------------------|-----------|--------------------|
| 1           | 66                | 59,187155            | 6,812884504 | 1,386860718 |
| 2           | 52                | 54,82178904          | -2,821789038 | -0,57415781 |
| 3           | 61                | 67,75737186          | -6,757371858 | -1,37556032 |
| 4           | 72                | 68,12129167          | 3,878708335  | 0,789566919  |
| 5           | 48                | 50,13066053          | -2,130660527 | -0,433726623 |
| 6           | 52                | 50,98177142          | 1,018228584  | 0,207275087  |

Observation 1 represents Raya Lontar Rd. condition. With 66 dB of noise levels and combine the volume of MC, LV, and HV with noise levels in multiple regression model, the predicted noise is 59,1871 dB. This number is obtained by inserting 1645, 428 and 14 as MC, LV and HV volume into regression model. The other observations represent the other case study locations.

5. Conclusions
As presented at linear regression results section, MC volume with noise level regression has 0.6663 of R square, LV volume has 0.3021 and LV has 0.7080. Therefore, HV has 70.80% of influence contribution with noise levels on the case study locations. It indicates that HV has the largest part in influencing the noise pollution. On the other hand, for every 10% of MC, LV and HV volume increasing, the noise levels also increase by 1,726%, 2,032%, and 1,733% respectively. The correlation of MC, LV and HV vehicles with noise levels is represented in dB = 0.0025mc – 0.0056lv + 0.56hv + 49,539 of multiple regression model. This model determines the relationship direction between independent variables (automotive vehicles; MC, LV, HV volume) and dependent variable (noise levels) is positively or negatively related and to predict the value of noise levels if the value of automotive vehicles volume increases or decreases.

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