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Emission and Noise Level Prediction on Mixed Traffic in Local Road, Indonesia

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Abstract In the context of transportation, sustainable development aims to create transportation systems that are efficient, environmentally friendly, and minimize negative impacts, including exhaust emissions and traffic noise. The same situation occurs on the local primary road, Indonesia. The aim of the research is to determine the value of emission prediction and noise level, and the relationship between vehicle type proportions to the prediction of emissions and noise levels on a 2-way and 2-lane undivided primary local road with mixed land use and mixed traffic. Primary data collection was conducted for 4 days. The guidelines used in this analysis are based on the Noise Level Prediction reference, Ministry of Public Works, Indonesia in 2004 and the 2010 Environmental Guidelines, Indonesia. The findings of study are that total vehicle emissions were 148,880 tons/hour, and the 1-hour noise level exceeded the standard noise quality threshold for commercial and public facility areas. Predictions of emissions and PNL increase along with the increase of number of traffic flow and the proportion of vehicle types that dominate the traffic. Conversely, the proportion of non-motorized vehicle, heavy vehicles, and light vehicle, as well as the space mean speed, has a negative impact on the prediction of emissions and PNL.

Keywords Emission, Local Road, Prediction of Noise Level

1. Introduction

The impacts and concerns regarding global warming have increased over the past few decades. In the context of transportation, sustainable development aims to create transportation systems that are efficient, environmentally friendly, and minimize negative impacts, including exhaust emissions and traffic noise. Recently, activities of transportation generate three-quarter of total environmental CO_2 emissions. With unprecedented urban development, growth in car usage, road networks, road traffic noise has become an environmental problem. The noise caused by traffic not only disturbs traffic users but also residents in buildings around the road [1]. A 30% reduction in exposure to noise pollution from transportation activities by 2030 is the action plan for realization of a city without pollution [2].

Barombong Road is a road with mixed land use. Commercial and service activities are evident here. The traffic conditions on this section are heterogeneous, with pedestrian activity utilizing the road shoulders for walking and crossing directly on the road. This road is also one of the routes for trucks distributing building materials and logistics. Buses are frequently seen in this area because it is a route to the Barombong tourist area. Motorcycles are the dominant mode of transportation chosen by the community every day. The traffic activity on this road causes noise and emission problems. The motivation of research is that there is still a lack of research examining the prediction of emissions and noise on 2/2 undivided primary local roads that have mixed land use and mixed traffic, and also the relationship between vehicle type proportions to the prediction of emissions and noise levels.

In developing countries, the environmental impact of traffic needs to be considered for economic, environmental and social improvement [3]. Environmental noise is the sound that arises from human activities carried out outdoors which can cause harmful impacts [4].

Reducing emissions from transportation is a global goal in addressing climate change [5]. Increase in vehicle emissions leaves as a negative impact of urban communities' dependence on the use of private transportation [6]. Monitoring air quality regularly is important, because high-frequency exposure to pollution from exhaust emissions reduces public health, especially for vulnerable groups. On roads in less green areas, the worst pollution occurs during the summer [7]. In urban areas with significant impacts of traffic emission, characterizing direct traffic emissions and their contribution to air pollutant concentrations on or near roadways is crucial for assessing vehicle emissions and effectively managing urban air quality [8]. The increasing road area ratio can reduce air pollution. Other research adds that widening roads does not significantly impact air pollution. In the future, traffic development priorities can focus on improving traffic efficiency [9]. It is important to implement improvements in the quality of urban life through efforts to enhance air quality sourced from vehicle emissions [10, 11]. The main challenge of pollution issue is the increasing consumption of vehicle fuel. Improvement in the quality of life of society will be realized with the improvement of air quality. When the percentage of heavy vehicles, degree of approach, and green time increase, pollutant concentrations also increase. Conversely, pollutant concentrations decrease when lane width and wind speed increase [12].

Besides emissions, another impact of traffic activity is noise. The decline in quality and comfort of life for urban communities is influenced by noise from activities [13]. Poor cognitive development and poor mental health result from high levels of pollution exposure [14].

2. Methods

Traffic counting, speed, and noise assessments were carried out in the morning until afternoon. This is aimed at predicting emissions and noise during peak hours on weekdays (Monday and Friday represent workdays at the beginning and end of the weekday) and off days (Saturday and Sunday). Traffic counting and speed surveyed are distinguished based on the 11 class types of motor vehicles, namely:

1 Motorcycles and three-wheeled vehicles,
2 Light vehicles - sedan, jeep, and station wagon
3 Light vehicles – medium public transport
4 light vehicles - micro truck, pick-up
5 5A Small bus
6 5B Large bus
7 6A 2 axle truck (light truck)
8 6B 2 axle truck (medium truck)
9 7A 3 axle truck
10 7B 4 axle truck
11 7C 5 or more axle truck
12 and non-motorized vehicle

The land use in the observation area includes commercial, residential, office, and school zones. This road also provides access to a natural tourist destination, namely the Barombong beach tourism.

The calculation of fuel consumption is differentiated according to vehicle type. The results of this calculation are used as one of the parameters for predicting emissions. Subsequently, an analysis is conducted to predict noise levels and the relationship between traffic volume, space mean speed, the proportion of motorcycles (motorcycles and three-wheeled vehicles), light vehicles (classes 2, 3, and 4), heavy vehicles (classes 5A, 5B, 6A, 6B, 7A, 7B, and 7C), as well as non-motorized vehicles, in relation to predicted emissions and noise level predictions.

2.1. Fuel Consumption

Fuel consumption of motor vehicles uses the equation published by Affiliated Research Institute of Bandung Institute of Technology [15]. The Affiliate and Research Institute of Bandung Institute of Technology developed an equation to determine the impact of exhaust emissions and vehicle fuel consumption on traffic performance indicators (from an environmental perspective). The number of vehicles included in the formula parameter is the quantity of vehicles that have been converted to passenger car units. The calculation of fuel consumption is divided into three conditions, namely idle conditions, fuel consumption when the vehicle is accelerating or decelerating, and the vehicle is moving at constant conditions (liters/100 pcu/km). The following is the predicted equation for vehicle fuel consumption.

$$F = F1 + F2 + F3 \quad (1)$$

$$F1 = a + bV + cV^2 \quad (2)$$

$$F2 = eV^2 \quad (3)$$

$$F3 = d \quad (4)$$

$a = 170 \times 10^{-1}$
$b = -455 \times 10^{-3}$
$c = 490 \times 10^{-5}$
$d = 140 \times 10^{-2}$
$e = 770 \times 10^{-8}$

F1: fuel consumption when the vehicle is moving at a constant speed (liters/100 pcu/km)

F2: fuel consumption when the vehicle is accelerating or decelerating (liters/pcu)

F3: fuel consumption at idle (liters/pcu/hour)

V: speed (km/h)

2.2. Emission

Emission prediction in this study uses the 2010 Environmental Guidelines, Indonesia [16]. This guideline explains the inventory of pollutant sources from motor vehicles (moving emission sources) for all provinces in Indonesia. Emissions are derived from emission factor values based on pollutant loads and vehicle types (motorcycles and three-wheeled vehicles, cars, buses, and trucks), the number of vehicles per type, vehicle kilometers traveled, and fuel consumption for each type of vehicle.

$$Ei = F_{ei} \text{ x } VKT \text{ x } V_i \text{ x } F_{ci} \quad (5)$$

Ei : emission
Fe : emission factor
VKT : vehicle kilometer travelled (km)
V_i : vehicle volume
F_{ci} : fuel consumption (litre)

2.3. Prediction of Noise Level

Road traffic activity also has an impact on noise levels. Prediction of noise levels uses the Traffic Noise Level Prediction reference, Ministry of Public Works, Indonesia in 2005 [17]. This guideline is prepared to assist efforts in managing noise generated by traffic so that the resulting noise does not worsen the environmental conditions in an area. However, due to sector limitations, this guideline restricts the discussion to measures that can be implemented through traffic engineering, road pavement, buffer area management, corrections to receiving buildings, and engineering of noise barrier structures within the public road space. Observations at the location were taken in front of the public facilities, and there is a noise-reducing building along 200 meters. The type of road surface is cement concrete, the road is classified as flat terrain (no inclines and declines), road width is 5 meters, and the height of the noise-reducing building is 5 meters. There is a green area or trees on one side of the road. In addition to the above data, data on space mean speed data and heavy vehicles percentage are also used.

1-hour base noise level

$$(L_{10}) = 42.2 + 10 \text{ Log } q \quad (6)$$

$$L_{eq} = L_{10} - 3.0 \quad (7)$$

Correction of average speed and proportion of heavy vehicles

$$33 \text{ Log } (V+40+500/V)+10 \text{ Log } (1+5p/V)-68.8 \text{ dB(A)} \quad (8)$$

Gradient correction

$$0.3 \text{ G dB(A)} \quad (9)$$

Pavement surface correction

$$+1.0 \text{ dB(A)} \quad (10)$$

Correction of the horizontal distance from the edge of the road segment (d) and the relative height between the receiver point and the effective sound source position (h).

$$-10 \text{ Log } (d'/13.5) \quad (11)$$

$$d' = [(d+3,5)^2 + h^2]^{0.5} \quad (12)$$

Reflection effect correction factor (1 meter in front of the building) =

$$+2.5 \text{ dB(A)} \quad (13)$$

d' : the nearest angle distance from the effective sound source position (meters)
d : horizontal distance from the effective sound source position (meters)
h : receiver high point (meters)
G : gradient (%)
Q : traffic volume (1 hour)
V : space mean speed (km/h)
P : heavy vehicle percentage (%)

3. Results and Discussion

3.1. Traffic Volume

The hourly vehicle volume is obtained from the total vehicles observed. The types of vehicles observed are motorcycles and three-wheeled vehicles, which are categorized into the motorcycle group. The Indonesian Road Capacity Manual 2023 defines a passenger car unit (pcu) as a unit for traffic flow where various types of vehicles are converted into light vehicle flow (including passenger cars) using passenger car equivalent (PCE). PCE value for motorcycle is 0.35. Passenger cars are differentiated based on the type of fuel used, namely RON 90 gasoline and diesel. These vehicle types are grouped into the light vehicle category, for which the PCE value is 1. The heavy vehicle category (bus and truck) with the PCE value is 1.2. The vehicle volume on Monday was 5605 vehicles/hour (2980.415 pcu/hour), consisting of 99.49% motorized vehicles using engine fuel and 0.51% non-motorized vehicles. On Friday, the reduction is nearly 50% of the total number of vehicles on Monday, The vehicle volume is dominated by motorcycles, 70.30% of the total volume. The vehicle volume on Saturday increased by about 68% compared to Friday, which was due to the public holiday being used by people to travel with family, go shopping, or socialize. The number of vehicles decreases on Sundays, because Sundays are often used for resting. Traffic volume on Sunday was 4271 vehicles/hour. According to the 2023 Indonesian Highway Capacity Manual, if the total vehicle volume (2 directions/hour) exceeds 1800 vehicles and the lane width is less than 6 meters, then the passenger car equivalent (pce) for medium vehicles is 1.2 and for motorcycles is 0.35, while for light vehicles it is 1. Thus, the vehicle volume on Sunday obtained was 2218,573 pcu/hour. Volume of traffic during the observation days can be seen in Figure 1.

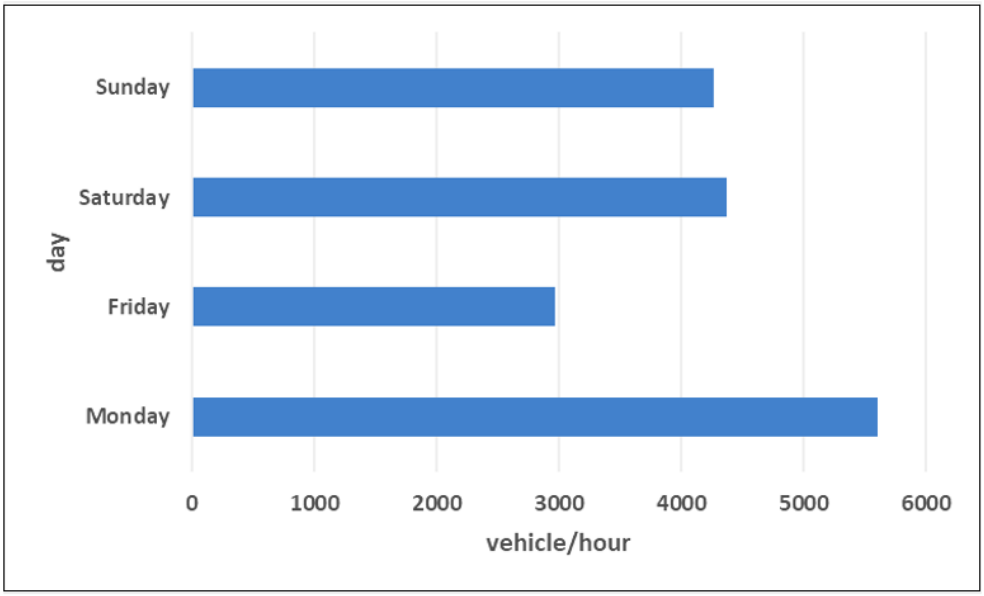

Figure 1. Traffic Volume Based on Observation Time

Of all observation days, the proportion of motorcycles is the highest compared to other types of vehicles. Motorcycles are a favorite mode of transportation chosen by many people in developing countries. The smaller dimensions of motorcycles, the freedom to maneuver, and the much more economical prices compared to light vehicles are the choices for the community. The composition of vehicle types that use fossil fuels affects air pollution. On the first day of work, the proportion of motorcycles exceeds 70%, while on Friday it is less than 70%. On weekends, the proportion of motorcycles exceeds 70%. Light vehicles are the second choice for people in choosing a mode of personal transportation, especially if the considerations are long distances, comfort (from the weather), and the number of occupancies and loading of goods which are greater than the type of motorcycle. The proportion of light vehicles on Saturday, the largest amounted to 28.39%. While on Friday, Monday, and Sunday, respectively, the proportion of light vehicles was 27.21%, 26.40%, and 22.84%. Heavy vehicles that have a large load capacity also help in improving the economy of a region, especially the distribution of logistics or natural resource products and services. The distribution of logistics and services by heavy vehicles on this route is the largest on Sunday, namely 2.60%, where the largest proportion is class 6A vehicles and there are no class 7B. For Friday, the proportion of heavy vehicles is less compared to Sunday, of which the proportion of class 6B vehicles was the largest, then followed by classes 5B, 6A, and 7A. The class 6B vehicle group had the highest proportion of heavy vehicles on Monday, followed by class 5A, while classes 7B and 7C vehicles were not present on this day. The 6B vehicle class also passes the most on Saturdays, followed by the 5A class. On this segment there are several housing development areas, so that the trucks carrying construction materials that pass through are mostly vehicle class 6B. Vehicle class 7C is seen on Saturdays and Sundays, while buses used as recreational vehicles are often seen on Sunday. Proportion of vehicle type is presented in Figure 2.

Non-motorized vehicles (NMV), especially on roads with mixed traffic, have quite an impact on traffic performance, especially the smooth movement of motorized vehicles. Although non-motorized vehicles generally use the side lanes to travel, they have the effect of reducing travel time for motorized vehicles and the risk of accidents for non-motorized vehicle users [18, 19]. Although non-motorized vehicles are environmentally friendly vehicles and do not cause emissions or pollution [20]. This section is not equipped with a NMV exclusive lane. The types of NMV recorded during the traffic flow census were carts and bicycles. The average speed of NMV was 20-30 km/hour. The proportion of NMV was highest on Saturday. The NMV that was seen was a bicycle. People used bicycles as a means of exercise/sport. Meanwhile, on Sunday, there was the least number of NMV on this route. The non-motorized vehicles seen on this observation day were carts and bicycles. On weekdays, the highest number of NMV was on Monday, namely carts (food street vendors) and bicycles (vegetable and fish vendors). In contrast to Mondays, there were fewer non-motorized vehicles on Friday. Non-motorized vehicle proportion is presented in Figure 3.

3.2. Space Mean Speed

The space mean speed (SMS) is influenced by the number both of non-motorized and motorized vehicles. Vehicle dimensions and load also affect SMS. The average space mean speed based on observation day can be seen in Figure 4.

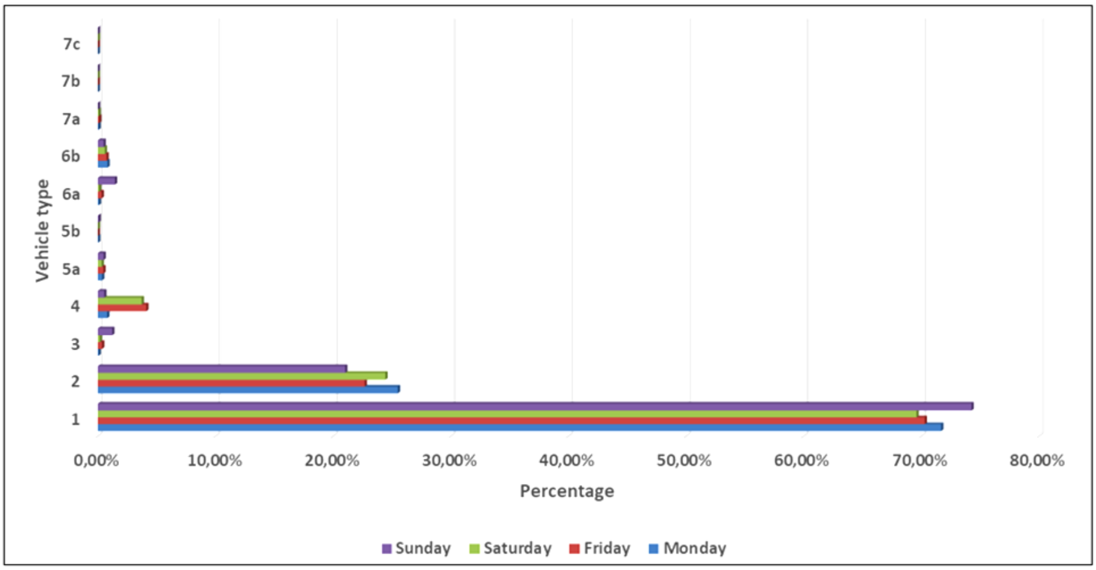

Figure 2. Proportion of Vehicle Types

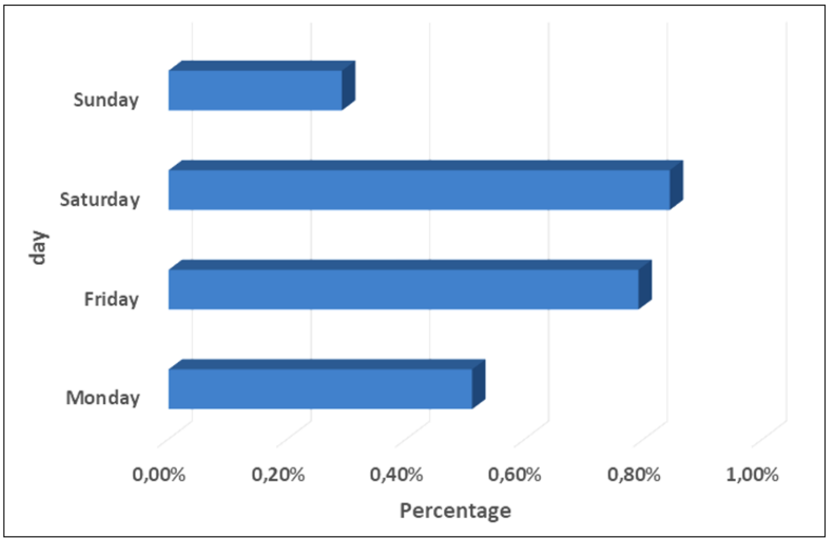

Figure 3. Proportion of Non-Motorized Vehicle

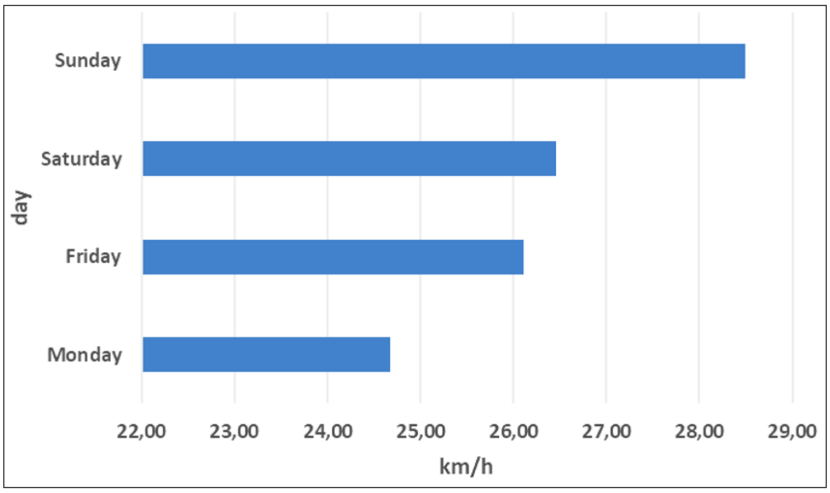

Figure 4. Space Mean Speed Based on Observation Time

The average speed of space of 24.68 km/h on Monday is influenced by the number of motorized vehicle compositions, the largest being motorcycles, then passenger cars, non-motorized vehicles , and heavy vehicles. The average speed of motorcycles is the largest compared to other types of motorized vehicles, because of the smaller dimensions, lighter vehicle/load weight, and it makes possible to freely perform maneuvering movements. The average speed per type of vehicle motorcycles, passenger cars (using RON 90 fuel), passenger cars (using diesel fuel), vehicle classes 5A, 6A, 6B, 7A, and 7C, is respectively 30.03 km/h, 25.26 km/h, 25.54 km/h, 21.58 km/h, 22.62 km/h, 22.34 km/h, 27.83 km/h, 21.56km/h, and 24.48 km/h. On Friday, space mean speed increased compared to Monday, which was 26.11 km/h, and this condition was due to the proportion of motorcycles being lower than Monday. Class 6A vehicles have the highest speed, followed by class 6B vehicles, while the lowest speed is by class 7B vehicles, although the number of class 6 vehicles is small, but from observations in the field, these vehicles do not carry loads/passengers. The average speed of space was 26.46 km/h on Saturday, where the volume of vehicles increased by 32% and the proportion of motorcycles decreased by almost 1% compared to Friday. The following are the average speeds of vehicle class 1, vehicle class 1, passenger cars using RON 90 (classes 2 and 3), vehicle classes 4, 5A, 6A, 6B, 7A, and 7C respectively 27.31 km/h, 24.74 km/h, 24.63 km/h, 25.22 km/h, 25.44 km/h, 29.13 km/h, 34.67 km/h, and 23.58 km/h. Space mean speed on Sunday was 28.50 km/h, where the proportion of light vehicle decreased to 22.84%, but the proportion of motorcycles and three-wheeled vehicles increased to 74.27%. The proportion of heavy vehicle was 2.60% and 0.29% non-motorized vehicles. The increasing proportion of heavy vehicles has an impact on the maneuvering space of other types of vehicles that have smaller dimensions, including motorcycles and tricycles. The following are the average speeds of vehicle classes 1, 2, 3, 4, 5A, 6A, 6B, 7A, and 7C respectively 26.81 km/h, 27.30 km/h, 29.46 km/h, 27.44 km/h, 31.63 km/h, 34.67 km/h, and 23.58 km/h. The use of passenger cars on Sundays is less than on weekdays, because people prefer to use buses for long-distance travel and recreation on holidays.

The proportion of motorcycles is the largest in traffic, where the motorcycle driving pattern affects the speed of cars and buses or trucks. The driving pattern of motorcycle users who travel beside, in front of, or behind cars and trucks/buses causes car and truck/bus drivers to reduce their speed and adjust to the speed of the motorcycle drivers around them. However, the load is also a factor in the velocity of the truck. Classes 7B and 7C vehicles based on observations on site, did not carry loads on the truck box, thus the speed can be higher than classes 6A and 6B vehicles that carried full materials on the truck box. The speed of vehicle class can be seen in Figure 5.

3.3. Fuel Consumption

Total fuel consumption on Monday, Friday, Saturday, and Sunday was 28,671.00 liters, 15,572.04 liters, 23,465.75 liters, and 29,749.46 liters, respectively. The highest fuel consumption for class 1 vehicles occurs on Friday and Sunday. Class 2 vehicles on Monday and Saturday are the highest compared to other types of motor vehicles. Class 5B vehicles have the lowest fuel consumption on Monday and Saturday. On Friday and Sunday, class 7A vehicles have the lowest fuel consumption. The types of fuel used by motor vehicles in Indonesia are diesel, RON 90, RON 92, and RON 95. Fuel consumption is influenced by vehicle speed, the number of vehicles, and vehicle type.

Other studies have revealed that there is an influence of condition of motorway, speed, trip distance, and temperature to fuel consumption [21].

Fuel consumption based on vehicle type can be seen in Figure 6.

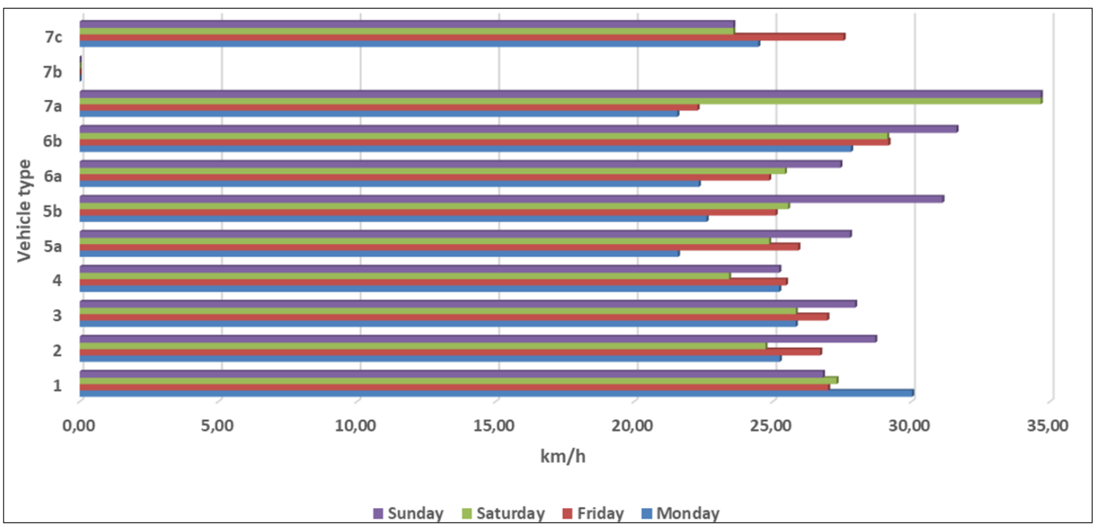

Figure 5. Vehicle Speed Based on Vehicle Type

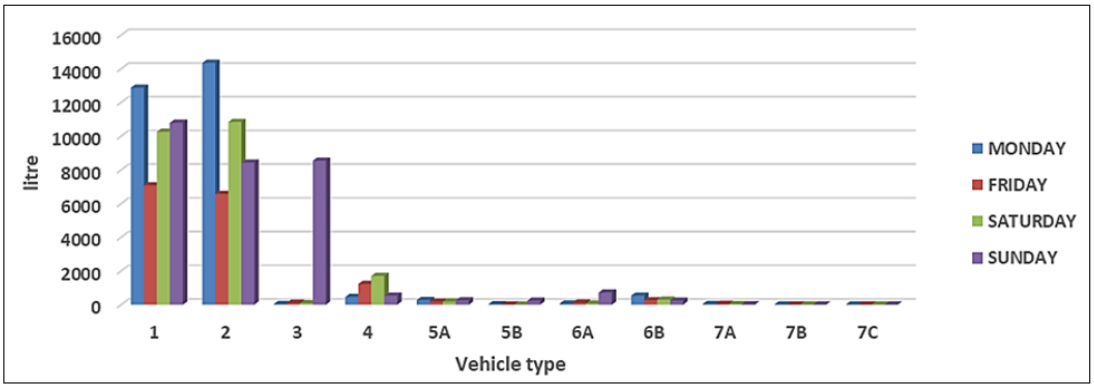

Figure 6. Fuel Consumption Based on Vehicle Type

3.4. Emission Prediction

Emissions from traffic volume and fuel consumption, on Monday were 148,880 tons/hour. Emissions on Friday, Saturday, and Sunday, respectively, were 81,334 tons/hour, 120,439 tons/hour, and 117,382 tons/hour. The pollutant loads included in the emission prediction calculation were CO, HC, NOx, PM10, CO_2, and SO_2. As much as 70, 145% of emissions on Monday were contributed by motorcycles, 1,434% were contributed by the number of heavy vehicles, while the rest were contributed by light vehicles. Motorcycles produced emissions of 54,417 tons/hour and 1,288 tons/hour due to heavy vehicles, while the rest was 22,628 tons/hour due to light vehicles. The emissions on Saturday observation were 120,439 tons/hour, of which 69,033% from motorcycles, 29,897% from light vehicles, and 1,071% from heavy vehicles. The emissions on Sunday decreased compared to Saturday, which were 117,382 tons/hour. Motorcycles contributed 87,555 tons/hour of emissions, 26,897 tons/hour due to light vehicles, and 2,930 tons/hour due to heavy vehicles. All types of fuels had a significant impact on CO_2 emissions, while gasoline-powered vehicles were responsible for the highest exposure of VOC and CO. In contrast, diesel-powered vehicles were responsible for the highest PM and NOx production [22]. CO_2, HC, CO, NOx, FC and PM factor emissions all decrease as bus speed increases, and increase as bus acceleration increases [23, 24].

In addition to the number of vehicles, acceleration, and average speed, other studies also add that vehicle fuel consumption is also influenced by road gradient and payload share [21]. Figure 7 shows the vehicle emission prediction based on observation time.

3.5. Prediction Noise Level

The research results reveal that on Monday, Saturday, and Sunday, the PNL exceed the noise quality standards for commercial and service area, which is 70 dB (A). Meanwhile, the PNL on Friday nearly reaches the noise quality standard. PNL on Monday is the highest noise with a value of 72.60 dB (A), which is due to the low average speed and high percentage of heavy vehicles, then PNL. Conversely, on Friday the PNL value dropped to 69.90 dB (A), because the average speed increased from Monday. While on Saturday and Sunday, the PNL values were 71.59 dB (A) and 71.61 dB (A). The increase in noise levels on Sundays was due to the percentage of heavy vehicles increasing from the previous day, although the average speed was higher than the previous day. During the observation period, in terms of composition, more than 50% of motorcycles dominated traffic. Although in terms of dimensions, motorcycles are simpler than light and heavy vehicles, the movement pattern of motorcycle drivers in Indonesia is to walk in convoys/in tandem, thus strengthening the noise effect because the sound from each tire friction and vehicle engine overlap. In urban areas, high frequencies can increase noise [24]. This is supported by previous research which states that the discomfort response due to noise from motorcycle engines is too high compared to other traffic noise [25]. In Indonesia, as a developing country, motorcycles dominate the number of motorized vehicles. This large number collectively produces significant emissions.

PNL on observation days Monday, Saturday, and Sunday exceeded the PNL of noise standard quality with trade and service locations, which was 70,00 dB(A). When the noise exceeds 70 decibels, the ears will feel the sound loud and may be uncomfortable (tinnitus, headaches and fatigue) [26]. Prediction noise level based on observation time is presented in Figure 8.

Some research findings support this, and the shape of terrain and features of topographic affect sound propagation [27]. Noise attenuation can be aided by distance, ground surface, and atmospheric conditions [28, 29]. The traffic volume, traffic speed, road pavement condition have a significant impact on noise levels [30, 31]. Road surface conditions are not significant to road noise levels [30]. Mixed asphalt road surfaces reduce noise by up to 6.8dB compared to concrete asphalt roads [31].

This area/road is still considered safe for the ears, and there is no risk to the ears and is included in the safe threshold for trade and service areas located close to roads/traffic. Noise caused by traffic activity is a contributing factor to public health problems in urban areas with a high population density [32]. When compared to the number of vehicles, it is vehicle speed that has a greater impact on noise levels. Noise emissions decrease and travel times increase as environmental demands increase [33, 34].

The number of vehicles on the road has a strong correlation with the level of environmental noise [35]. The implementation of low emission zones, zero emission vehicles, restrictions on diesel engine vehicles are examples of more specific pollution reduction policies on highways than traffic volume restrictions [36, 37].

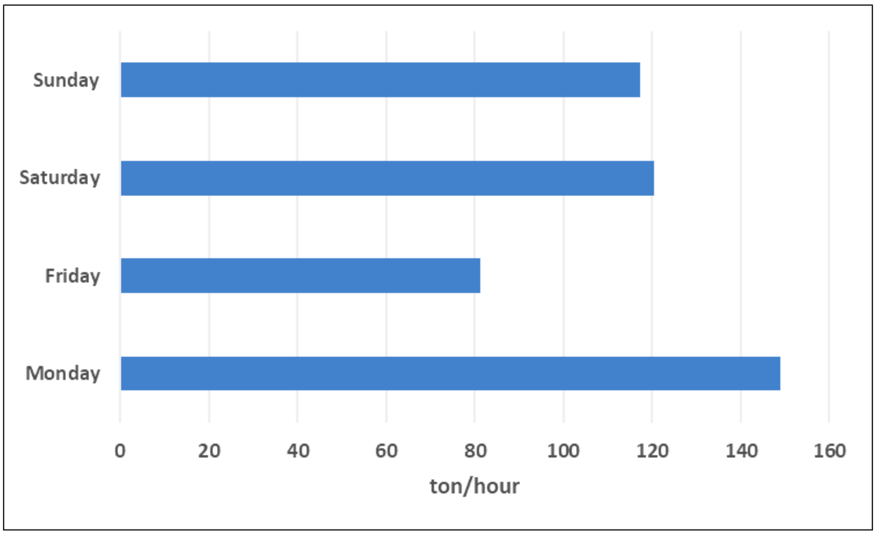

Figure 7. Vehicle Emission Prediction Based on Observation Time

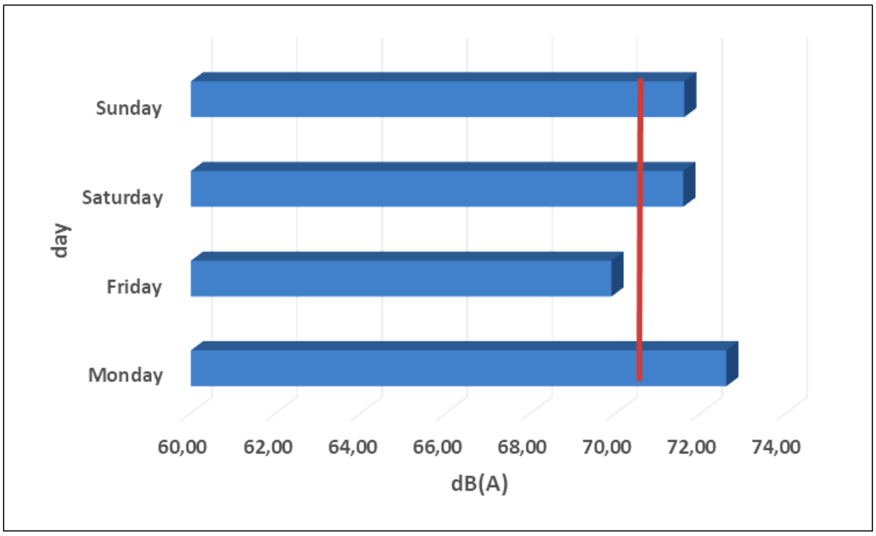

Figure 8. Prediction Noise Level (PNL) Based on Observation Time

3.6. Relationship between Traffic Volume and Emission, PNL

Heavy traffic conditions, reduce vehicle speed, where vehicles travel by adjusting the speed and space left to drive. Reduction in road capacity due to increased traffic volume will increase travel time and reduce vehicle speeds. The relationship between traffic volume and emission, PNL can be seen in Figure 9.

Increasing of PNL and emission is caused by traffic congestion. As the volume of vehicles increases, it can approach the capacity of road. This condition reduces operational speeds, which can increase fuel combustion and the engine's roaring noise.

3.7. Relationship between Motorcycle Proportion and Emission, PNL

The high proportion of motorcycles increases emissions and PNL. This result is supported by previous research showing that short-distance trips by motorcycle increase emissions and traffic noise [38]. The relationship between motorcycle proportion and emission, PNL can be seen in Figure 10.

Dust, congestion and pollution increase as a consequence of the dominant type of vehicle in traffic [39, 40], despite the increased proportion of motorcycle not having a significant positive effect on improving the prediction of total emissions and noise levels.

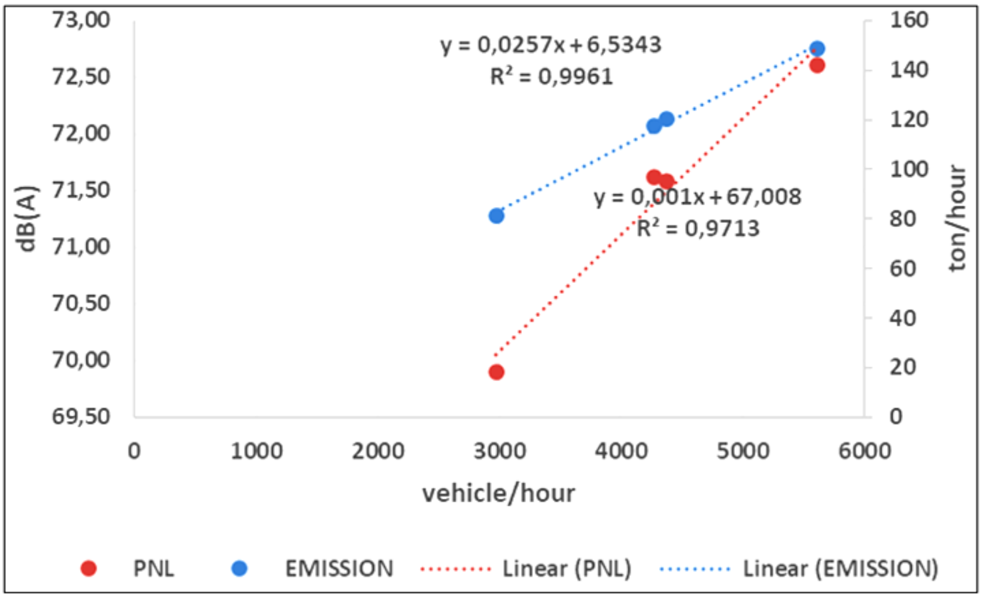

Figure 9. Relationship Between Traffic Volume and Emission, PNL

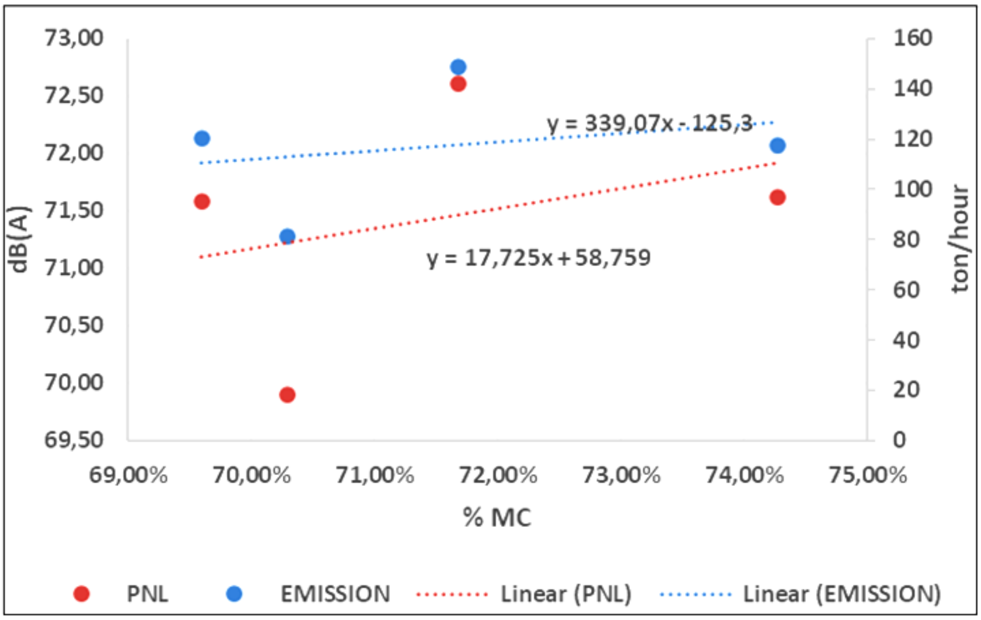

Figure 10. Relationship Between Motorcycle Proportion and Emission, PNL

3.8. Relationship between Space Mean Speed and Emission, PNL

The average speed of the space has a negative effect on emissions and PNL. As the vehicle movement space is wide, then the vehicle is free to move at high speed and is less affected by obstacles on the road. This condition causes less use of brakes/sudden speed drops and constant low speeds for a long time. This will reduce emissions and noise on the road [41]. In off-peak conditions, the reduction in emissions and noise is more pronounced, and due to stable vehicle speeds and reduced congestion [42], rolling noise is more dominant at stable vehicle speed conditions [43, 44]. Vehicle carbon emissions are greatly influenced by the percentage of engine load and engine speed [45, 46]. The relationship between space mean speed and emission, PNL can be seen in Figure 11.

3.9. Relationship between Light Vehicle Proportion and Emission, PNL

Compared to the proportion of motorcycles in heterogeneous traffic, the passenger cars proportion is far below that of motorcycles. The relationship between light vehicle proportion and emission, PNL is presented in Figure 12.

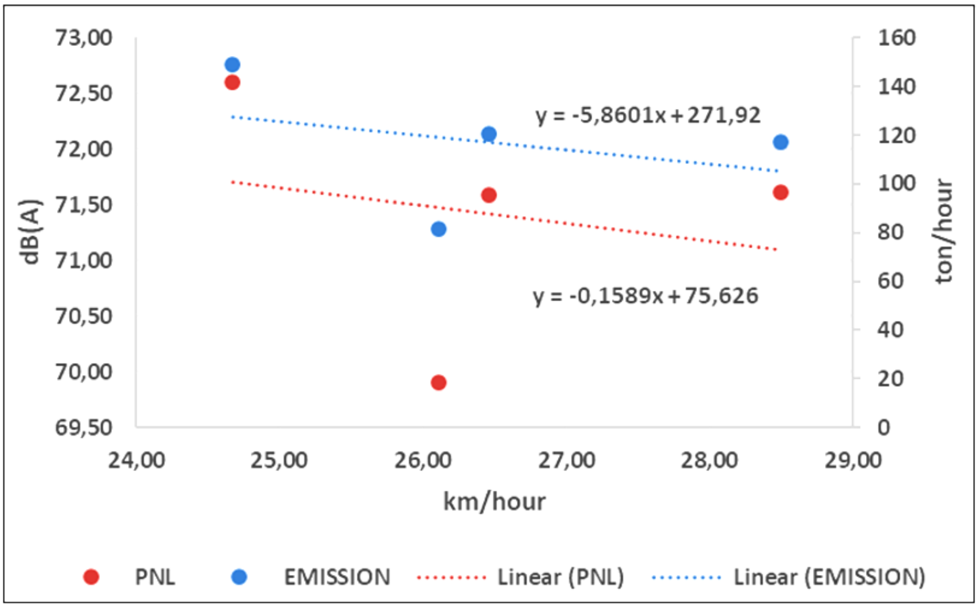

Figure 11. Relationship Between Space Mean Speed and Emission,PNL

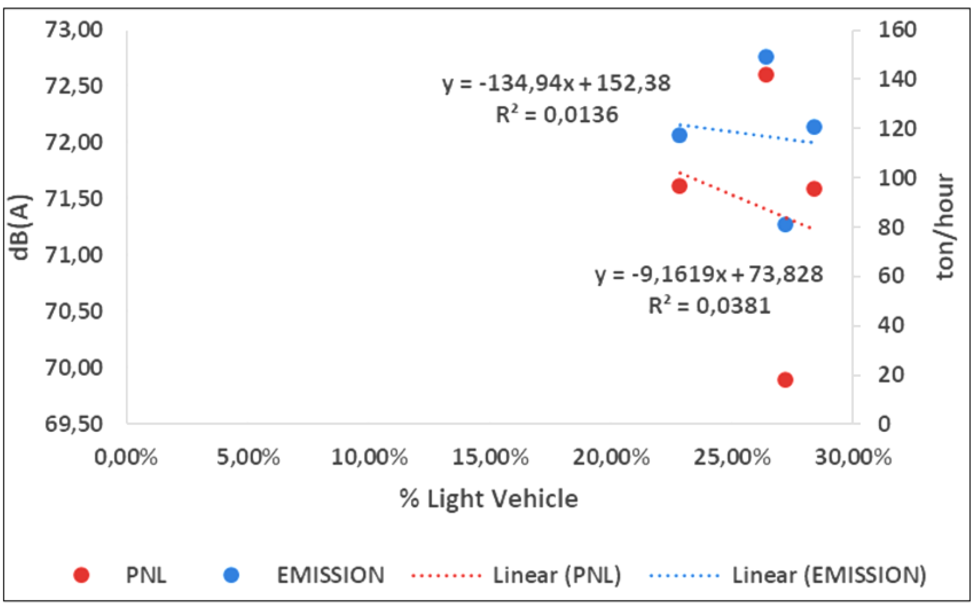

Figure 12. Relationship Between Light Vehicle Proportion and Emission, PNL

3.10. Relationship between Heavy Vehicle Proportion and Emission, PNL

More interestingly, in this research with small proportion of heavy vehicles, they do not contribute much to the increase in emissions and noise on the road. Diesel-powered vehicles are responsible for a significant reduction in air quality. Previous research has revealed that one way to reduce air pollution on roads is that the combination of lubricating oil and fuel reduces vehicle particulate emissions [47]. The relationship between heavy vehicle proportion and emission, PNL can be seen in Figure 13.

3.11. Relationship between Non-Motorized Vehicle Proportion and Emission, PNL

The addition of NMV proportion affects 22.94% of PNL and 17.47% of emissions. Non-motorized vehicles help reduce emissions and PNL. By shifting of motorcycle and car users to non-motorized vehicle modes, exposure to noise and emissions is reduced [48, 49]. The relationship between non-motorized vehicle proportion and emission, PNL can be seen in Figure 14.

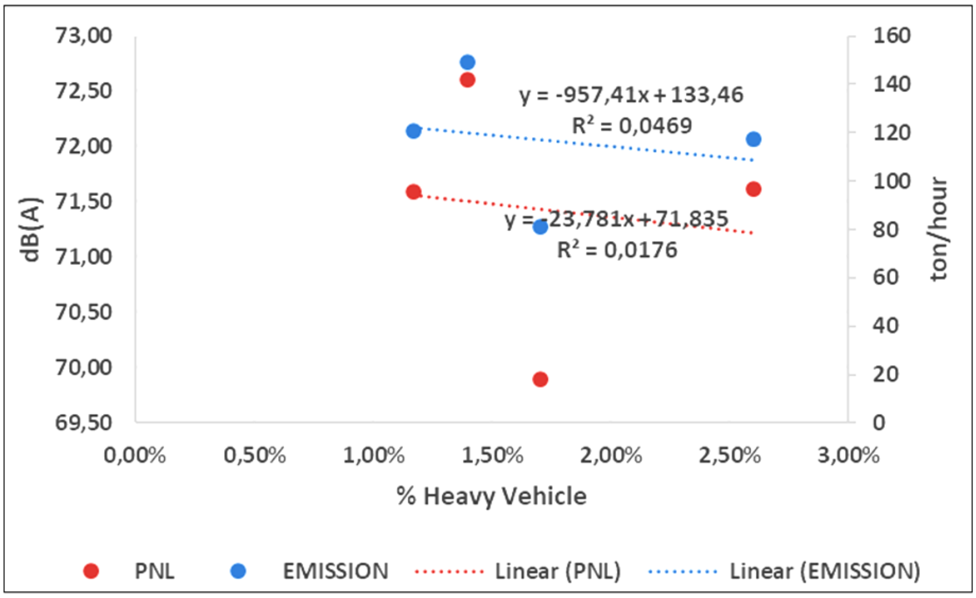

Figure 13. Relationship Between Heavy Vehicle Proportion and Emission, PNL

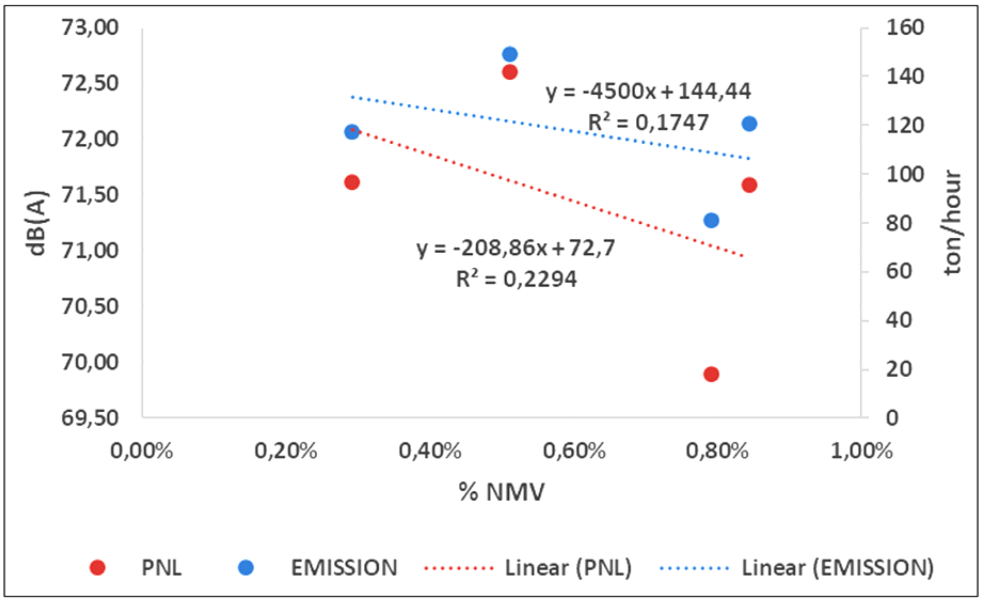

Figure 14. Relationship Between Non-Motorized Vehicle Proportion and Emission, PNL

4. Conclusions

The findings of research are on local primary road, with a width of 5 meters, 2/2 undivided, mixed land use, and mixed traffic, the traffic volume is 5605 vehicles/hour. Motorcycles dominate the volume, exceeding 60%. The average space mean speed is 24.68 km/hour, the highest predicted emissions on Monday morning are 148.880 tons/hour, and the PNL is 72.60 dB(A). A positive linear relationship exists between predicted emissions and PNL with traffic volume and the proportion of motorcycles. Predictions of emissions and PNL increase along with the rising number of traffic flow and the proportion of vehicle types that dominate the traffic. Conversely, the proportion of NMV, heavy vehicle, and light vehicle, as well as the space mean speed, has a negative impact on the prediction of emissions and PNL. A potential solution to reduce emissions and noise in this location is to decrease the number of motor vehicles, through transportation policies such as the 3-in-1 system, increasing the use of public transportation (four wheels or more), using non-motorized vehicles during working hours, planting vegetation that has sufficient and even leaf density and density from the ground surface to the desired height (for example, a heliconia sp tree with a volume of 1,792 m^3 of foliage, a distance from the noise source to the plant of 3.2 m, can reduce 3.40 dB(A)) or applying artificial barriers from materials that can reduce noise and emissions. The limitation of this research is that it does not include traffic conditions at night and the survey days are restricted to representative weekdays only. It is hoped that future research will collect data from morning to night and 7 days in a week.

Declaration of Conflicting Interests

The authors declare no conflicts of interest in preparing this article.

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