Model emission estimation of light vehicle based on the driving cycle with using moves program on national roads in Makassar city

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Abstract. Traffic is one of the main sources of atmospheric pollution in cities around the globe and Athens is no exception. The tremendous increase in vehicles resulted in serious traffic problems consisting of frequent stops and intense driving (vigorous accelerations and decelerations). The increase in vehicles in urban areas caused by congestion and decreases air quality. Transportation emissions must be modeling more accurate to reduce the impact of air quality on roads. The purpose of this study was to analyze the emission estimation of a light vehicle based on the driving cycle using the moves program on national roads in Makassar city. The method of this research used the MOVES program, that program could calculate how many emissions was that resulted by vehicles. Furthermore, the survey of a light vehicle driving cycle was used GPS equipment and used AVANZA car as a light vehicle, which many people are using it in the city. The result showed that the emission along in Perintis Kemerdekaan on peak hour morning and afternoon, CO was the large pollutants than Nox and HC. The smallest pollutant is HC and the pollutant isn’t more than 0.055 gram/km in all way and peak hour. The biggest pollutant is CO in the morning peak hour in Away is 5.605 gram/km. The Average speed vs pollutants HC, Nox, and CO describes that the pollutant will decrease if the speed increase and the average speed was between 5 – 35 km/jam. The $R^2$ of model pollutant (gram/km) and average speed (km/jam) is more than 0.8 near than 1 means that the variable has a strong attachment.

1. Introduction
Traffic is one of the main sources of atmospheric pollution in cities around the globe and Athens is no exception. The tremendous increase in vehicles resulted in serious traffic problems consisting of frequent stops and intense driving (vigorous accelerations and decelerations). Vehicles are responsible for almost all of the Carbon Monoxide (CO) emissions, for about 75% of the Hydrocarbon (HC) emissions and volatile organic compounds (VOC), and about 65% of the Nitrogen Oxide (NOx) emissions. [1].

The increase in vehicles in urban areas causes congestion and decreases air quality. Transportation emissions must be modeling more accurately to control the impact of air quality on roads [2].

The data statistic in Makassar city [3] shows, where the total of the light vehicles in 2015 is 190.428 or increase until 8% from 2014, and motorcycle Tahun 2015 is 1.062.943 or increase until 13% from 2014.
The statistics data showed that every vehicle increases every year and will increase along with the population and needs an increase. Causing the emission in the atmosphere also can be an increase.

So far, there only a few studies in Indonesia to focus on quantity emission and the impact of the environment. The previous study just analyzes the data emission from the vehicle in the idle situation in 2013 have already done the study with an analysis emission vehicle in the move situation [4].

Emissions from vehicles are affected by the driving patterns, which mainly depend on traffic conditions. “Driving Cycles” have been developed to provide a speed-time profile that is representative of urban driving [5]. They are used to assimilate driving conditions on a laboratory chassis dynamometer for the evaluation of fuel consumption, exhaust emissions and emission coefficient [1].

The motor vehicle emission simulator (MOVES) developed by U. S. Environmental Protection Agency (U. S. EPA) Office of Transportation and Air Quality (OTAQ) is a new emission modeling system estimating emissions for mobile sources covering a broad range of pollutants and allows multiple-scale analysis [6]. MOVES as the new generation regulatory mobile source emissions model for developing state emission budgets, transportation conformity, and project-level analyses in the United States. This model is built on Vehicle Specific Power (VSP) based emission rates, and that makes it suitable to apply anywhere in the world as long as users have VSP related operating mode distributions [7].

Regarding the background, the present paper aims to model the emission estimation of the light vehicles based on the driving cycle using the moves program on national roads in Makassar city.

This paper is organized as follows in Section 2 study literature; section 3 describes the study methods such as the route location, the equipment survey, and survey method of driving cycle, and the analysis method. Section 4 presents the results of the survey, the parameters of the light vehicle driving cycle and the estimation of emission using moves program. In the final section, Section 5 provides a conclusion.

2. Literature review
2.1. The drive cycle concept
As an important component to quantify the vehicle emissions, drive cycles, a series of data points showing speeds over time, is usually presented as an array in company with external information, such as roadway types and vehicle types. Figure 1 shows an example of such drive cycles developed for an Urban Principal Arterial roadway under Level of Service (LOS) A (2). As it shows, the figure of drive cycles provides the information of a sequence of emission-related factors, such as instantaneous acceleration and second-by-second speed. Also, it gives the analyst a way of translating the factors to microscopic emission and from the microscopic level into the macroscopic level by combining the microscopic data captured by the drive cycle.
2.1.1. What is MOVES?

The MOVES, the EPA’s latest emission model, follows some characteristics of previous models. First of all, it still utilizes a database centered software framework. Also, it calculates the emission by coupling emission factors and vehicle information together. However, new features are added and successfully functioned. The most important one is that it applies a disaggregate emission algorithm that includes many new external factors for both input and output to provide more options to analyze multiple levels. Also, MOVES incorporates energy consumption, geographic information, sort of pollutants, time of the year, vehicle operating characteristics and roadway types together to establish a platform for a more comprehensive analysis than previously.

2.1.2. Emission estimation process of moves

The disaggregate approach in the MOVES is termed Vehicle Specific Power (VSP), which is a measurement of all vehicle factors and non-vehicle factors, such as instantaneous velocity, acceleration, and geographical information. VSP is calculated on a second-by-second basis for a vehicle operating over these drive schedules based on Equation 1 for light-duty vehicles and Equation 2 for heavy-duty vehicles. When it is applied to heavy-duty vehicles, it is also termed Scaled Tractive Power (STP).

\[
VSP = \frac{A \times u + B \times u^2 + C \times u^3 + M \times u \times a}{M}
\]

\[
STP = VSP \frac{M}{f_m}
\]

Where:
A: the constant based on vehicle size
B: the constant based on vehicle front area
C: the constant based on the height of the vehicle
U: Instantaneous Speed
A: instantaneous acceleration of the vehicle including the impact of grade \(a = a + \sin(a \times \tan(G / 100))\)
where G is road grade in percent,
M: vehicle mass or source mass, and a fixed mass factor
Figure 2. OpeMode Bin for Running Emissions.

Figure 3. Emissions Estimation in MOVES.
2.1.3. Input Data MOVES Program

![Figure 4. input data MOVES program.](image)

1. Meteorology data is temperature and humidity data
2. The age distribution is the vehicle age data
3. Links are data on road characteristics, vehicle volume, average speed
4. Link source Input is data used to determine the mix of vehicles on each link or road
5. Fuel is vehicle fuel data
6. Operating mode distribution is data running emissions
7. Linkdrive is data on the driving cycle pattern

3. The study methods
This section will explain the study methods in the following subsections

3.1. The survey location
The survey location is one of the national roads in Makassar city, called JL. Perintis Kemerdekaan. The road is the orange line, as shown in Figure. 5. The length of the road is 12.5 km, respectively and is categorized as six lanes and two directions road type, which each direction is separated by the physical median in the middle of the roads.
3.2. The Equipment of the Survey
The light survey vehicle driving cycle uses a global position system (GPS) equipment to track the vehicle velocity in second by second along through the road. We use the GPS Garmin as shown in Fig. 6a. The test vehicle in this survey uses AVANZA, a light vehicle type for passenger cars, which produced by TOYOTA, which many people are using it in the city.

![Equipment driving cycle survey](image)

Figure 5. The tracked road location of the driving survey.

a. GPS (Etrex 30) b. Light Vehicle (TOYOTA)

Figure 6. Equipment driving cycle survey

3.3. The survey method
The driving cycle survey adopts a floating car survey method using the vehicle test to capture the real-world traffic flow situation on the road. The method is to determine the vehicle speed on the road network. It is based on the collection of localization of data, speed, directions of travel and time information from mobile sources in vehicles that are being driven. In this method, the test vehicle with an active mobile source (such as GPS) acts as a sensor for the road.

By using the equipment and the method, we carried out the driving cycle survey of the light vehicle on the road in October, 1st, 2019. The survey tracks from the starting point to the endpoint of the road location. Tracking is carried out at peak hours at 7-10 am and the afternoon 15-17 am. The light vehicle driver drives on the road at the natural speed of the surrounding traffic. At the same time, the driver or one
passenger or assistant sets the GPS to record the vehicle speed second by second and the travel time over the road. The driver drives at the ambient speed, which the driver did not travel faster (overtaking more vehicles than overtook the test car) or slower (being overtaken by more vehicles than being overtaken by the test car) than the surrounding traffic.

3.4. The data analysis method

Analysis characteristics of driving cycle
1. Input driving cycle recording data from GPS to the computer using the map source mapping application
2. Process and grouping driving cycle data on Microsoft excel
3. Analyzing the parameters of the driving cycle from data speed, acceleration, deceleration, creeping, and idling
   Analysis of output Emission using Moves Program
1. Download the MOVES program application
2. Fill in all the data needed in the navigation channel program moves until the checks green
3. Menginput MOVES project data manager like a data Meteorology, Age distribution, Links, Link source, Fuel, Oppmode, Linkdrive
4. Output emisi MOVES program

4. The Results
4.1. Analysis parameters of the light vehicle of driving cycle

Figure 7. Time vs speed graph Perintis Kemerdekaan A & B Way morning peak hour 07-10 AM.
Figure 8. Time vs speed graph Perintis Kemerdekaan A & B Way afternoon peak hour 15-17 PM.

From Figures 7 and 8 show the driving cycles plotting of the light vehicle for each traffic direction and each peak hour period. The driving cycle shows that the travel speeds of the vehicle fluctuate second by second along the road, and it shows that the driving cycle needs more than 1500 seconds to finish the track in the link roads, except Jl. Perintis Kemerdekaan A way in the morning peak hour only needs more than 450 seconds.

The parameter values of the light vehicles driving cycle are presented in Table 1. Table 1 shows that creeping is had more preventable than other activity, and the acceleration and deceleration percentage is almost the same, and idling has little percentage than other activity.

Table 1. The Parameters of the light vehicle driving cycle in perintis kemerdekaan road in Makassar

| No | Pollutan   | Morning peak hour 7-10 AM | Afternoon peak hour 15-17 PM |
|----|------------|---------------------------|-----------------------------|
|    | A Way (%)  | B Way (%)                 | A Way (%)                   | B Way (%)                 |
| 1  | Idling     | 0.34                      | 0.22                        | 0.29                      | 0.2                        |
| 2  | Acceleration | 33.31                 | 27.04                       | 24.17                      | 29.80                      |
| 3  | Deceleration | 31.60                 | 29.82                       | 24.97                      | 31.76                      |
| 4  | Creaping   | 34.74                      | 42.93                       | 50.57                      | 38.24                      |
4.2. Analysis output Estimation Emission using Moves Program

Table 2. Output Estimation Emission using Moves Program

| No | Pollutan | Jl. Perintis Kemerdekan | Morning peak hour 7-10 AM | Afternoon peak hour 15-17 PM |
|----|----------|-------------------------|---------------------------|-------------------------------|
|    |          |                         | G Way Gram/Km             | B Way Gram/Km                |
| 1  | HC       | 0.038                   | 0.055                     | 0.041                        | 0.050                        |
| 2  | CO       | 5.605                   | 4.512                     | 3.374                        | 4.141                        |
| 3  | NOx      | 0.111                   | 0.090                     | 0.067                        | 0.083                        |

Table 2 presents how many pollutants in Jl. Perintis Kemerdekaan roads using moves emission program on peak hour morning and afternoon. The table shows that CO is the large pollutants than Nox and HC. The smallest pollutant is HC the pollutant isn’t more than 0.055 gram/km in all way and peak hour. The biggest pollutant is in the morning peak hour in A way the CO is 5.605 gram/km.

The Average speed vs pollutants HC, Nox, and CO, from figure 8 show that the pollutant will decrease if the speed increase and the average speed is between 5- 35 km/jam. The R2 of model pollutant (gram/km) and average speed (km/jam) is more than 0.8 near than 1 it means that the variable have a strong attachman.
5. Conclusion
The survey of the light vehicles driving cycle was used as a global position system (GPS) equipment and used AVANZA car as a light vehicle. The emission along in Perintis Kemerdekaan on peak hour morning and afternoon shows that the CO is the large pollutant than Nox and HC. The smallest pollutant is HC and the pollutant isn’t more than 0.055 gram/km in all way and peak hour. The biggest pollutant is in the morning peak hour in A way the CO is 5.605 gram/km.

The Average speed vs pollutants HC, Nox, and CO describes that the pollutant will decrease if the speed increase and the average speed was between 5 - 350 km/jam. The R2 of model pollutant (gram/km) and average speed (km/jam) is more than 0.8 near than 1 it means that the variable have a strong attachment.

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Figure 9. Average speed vs pollutants HC, Nox, and CO.