Traffic Detection Program using Image Processing and the 1997 Indonesian Highway Capacity Manual (MKJI)

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Abstract. As a part of transport planning and assessment, traffic volume is essential data. However, many Indonesian’s transports engineers, in particular, still use manual traffic counting to collect data series for traffic volume in 24 hours or more. This method is considered inefficient and expensive along with technological developments in this modern era. The purpose of this study tries to simplify the traffic counting method by developing an automatic vehicle detection program based on the 1997 Indonesian Highway Capacity Manual (MKJI) classification. The application that used in this study is KS Traffic Analyzer as open-source code traffic counting based on Java and OpenCV library. This application then modifies as MKJI 1997 vehicles classification to measure traffic data in urban and rural road using drone quadcopter. This tool using Gaussian Mixture Model (GMM) method for processing images/videos of traffic based on the background and foreground. Traffic footage was tested at different times, height, and angle of shooting. The accuracy was measured by comparing the volume from the program and manual counting. The results showed that the best accuracy between real traffic volume and automatic counting in the program is in the urban street with the best accuracy reached 93.66% which was taken video in the morning and the height is 5 m. This result of this study also answers the function of road performance based on volume per capacity.

1. Introduction

Nowadays, people live in a complex and rapidly developing world. The problem of urban congestion is the consequence of high growth in the number of vehicles worldwide [1], particularly in intersection [2] where spend expensive money as congestion cost [3]. Thus, the involvement of a traffic engineer takes an important role to figure out the problem of traffic congestion. One of the crucial issues in the modern era is developing an Intelligent Transport System (ITS) as a key element in traffic engineering [4].

ITS development should be able to answer the problem of traffic congestion. The innovation of data collection of traffic speed and vehicle classification can be an important part of ITS. Based on [5], traffic speed and vehicle classification are very essential data as input for traffic operations, maintenance, pavement design, and transport planning. Thus, this study tries to develop a traffic counting application program to replace the manual method with hand counters. This program is a combination of image processing based on the Gaussian Mixture Model and vehicle classification from The 1997 Indonesian Highway Capacity Manual (MKJI) [6].

Previous studies about vehicle detection based on image processing have been conducted by many researchers, particularly in Indonesia. One of the researches that have been done in Indonesia about...
vehicle detection came from [7] who used GMM and background subtraction, and some researchers have been successfully identified Indonesian vehicle images for toll road tariff [8], [9] have been trying to compare the GMM and Kalmar Filter method. Early research using GMM and background subtraction has been developed from [10] who captured multiple vehicle videos. [11] have been using GMM with single-loop measurement for 3 vehicle classes classification and they argued that their methodology is efficient to count speed and vehicle in various traffic conditions.

However, most of the researchers came from an IT background and miss to dig deeper to collaborate with the transportation aspect. Questioning what the next step from the counted vehicle and speed that has been obtained is very important. Therefore, this study aims to take one step further in using vehicle data. For vehicle class data to be used, the classification of vehicles is based on references from MKJI 1997. The study about the detection vehicle classification from MKJI 1997 [6] based is very limited. Even though, the result from the traffic counting program can be used calculate the v/c (volume/capacity) ratio which can determine the level of service of the roads. Apart from being old, many researchers tried to update from the actual condition in MKJI 1997, see [12-15] who tried to approach by updating actual conditions compare with the first edition of MKJI in 1997. However, the government keep using MKJI 1997 and has not officially issued the latest update since 1997.

Therefore, this study aims to count the actual size of the vehicle and classifying based on the type of road (rural and urban) from MKJI 1997. This study will focus on modification program of traffic counting program based on KS Traffic Analyzer application to measure speed and vehicle counting to determine the level of service (LOS) of the roads with the value of volume per capacity (v/c) ratio. This LOS will be used to compare traffic counting from the manual (with hand counter) and vehicle automatic detection program with the GMM method from the video that has been recorded from the drone. This study also will determine the conversion value of vehicle dimensions with pixel area, test the accuracy and number of errors on the program against manual calculations, and analyze factors that affect the accuracy of the program. The benefit of this research is to facilitate field observers in carrying out data collection on traffic flow volumes and become a reference for further research on vehicle detection programs.

2. Background subtraction
According to [16] in [17] image is an image, imitation, or similarity of an object. Image processing (image processing) is an attempt made to transform an image or image into another image by using certain techniques. Image processing based on image processing operations can be categorized as improving image quality and image recovery. Background Subtraction is often used in applications to count the number of vehicles passing a path in a traffic information system. Background Subtraction is used to distinguish between the foreground (object) and the background. Background Subtraction uses the current image comparison method with background images to detect a movement. The process of working background subtraction can be seen in figure 1. According to [18] background subtraction has a weakness in the video that conditions outside the room such as rain, the wind that makes the video unstable, and changes in lighting.

![Figure 1](image1.png)

**Figure 1.** (a) Object, (b) Background, (c) Foreground Object.

3. Gaussian Mixture Model (GMM)
According to [19] The Gaussian Mixture Model (GMM) is one of the popular methods of detecting and counting vehicles. GMM is one of the methods in background subtraction. This method is used to
describe the pixels of a background. Each pixel will be given the functions of a Gaussian component by GMM, with inputs in the form of pixel colors where GMM models are formed based on time. Two main components will be formed from the model, namely the background model with the foreground model. The background model is a model that reflects the background of an area being observed, while the foreground model is a model that reflects observable objects. Based on [20], the approach about GMM with M component is:

\[ p(x|X_T, BG + FG) = \sum_{m=1}^{M} \alpha_m N(\tilde{x}; \mu_m, \sigma^2_m I) \]  

where \(\tilde{x}_1, ..., \tilde{x}_M\) are the estimates of the means and \(\sigma_1, ..., \sigma_M\) are the estimates of variances that describe the Gaussian components. However, this study modifies the codes related vehicle size while maintaining the algorithm of GMM in KS Traffic Analyzer which obtained as open source code from GitHub.

4. Experimental methods
The methodology of this study used Gaussian Mixture Model (GMM) which has been provided as open sources code in the KS Traffic Analyzer program obtained on GitHub. The template of the coding then modifies for the vehicle’s pixel dimension refers to The 1997 Indonesian Highway Capacity Manual (MKJI) [6] vehicle classification in the urban and rural roads. The vehicle counted results from the program will be compared with the results of manual counting to determine the accuracy and percent errors. The location of this study location takes 2 different types of roads which are Jl. Brawijaya (Ringroad) - Bantul where is the primary road in rural areas and Jl. Malioboro – Yogyakarta where represent secondary road in the urban area particularly as Central Business District (CBD) in Yogyakarta city.

The period of this study was carried out from April 4-7, 2019. To compare the result of counted vehicles, this study determines the sessional period which is in the morning (06:30-09:00) and the afternoon (16:00-18:00). The drone was easily used to experiment with the variation of the height which are 5 and 6 meters (in the urban road) and 6 and 7 meters (in the rural road). The comparison between manual counting and the result from the program is pretty challenging due to the different times, different height, different traffic congestion, and also different weather and the strength of lighting. The tools used in this study are camera drones as shown in figure 2 for retrieving traffic video data, Java Version 8 Update software, IntelliJ IDEA Community Edition 2018.3.2 software, and computers.

4.1. Vehicle classification
Based on the 1997 Indonesian Road Capacity Manual, classification of vehicles separated from the type of the road. For the rural road, type vehicles can be seen are as in table 1:

![Figure 2. (a) Quadcopter drone  (b) Remote control.](image-url)
| No. | Classification of Vehicle                                                                 | Rural Road                                                                                                                                                                                                 | Urban Road                                                                                                                                                                                                 |
|-----|-------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | Motorcycle (MC), a motorcycle with two or three wheels (motorbikes and three-wheeled vehicles). The equivalent of passenger cars on motorbike vehicles (MC) is 0.7. | Motorcycle (MC), a motorcycle with two or three wheels (motorbikes and three-wheeled vehicles). The equivalent of passenger cars on motorbike vehicles (MC) is 0.7.                                                |
| 2   | Light Vehicles (LV), four-wheeled motorized vehicles with two axles that are 2-3 meters away (passenger vehicles, three-wheels, microbuses, pick-ups, and small trucks). The equivalent of passenger cars in light vehicles (LV) is 1.0. | Light Vehicles (LV), four-wheeled motorized vehicles with two axles that are 2-3 meters away (passenger vehicles, three-wheels, microbuses, pick-ups, and small trucks). The equivalent of passenger cars in light vehicles (LV) is 1.0. |
| 3   | Medium-weight vehicles (MHV), motorized vehicles with two axles within 3.5-5 meters (small buses, two axles with six wheels). The equivalent of passenger cars in medium-heavy vehicles (MHV) is 2.00. | Heavy vehicles (HV) are motorized vehicles with axles over 3.50 m, usually with more than 4 wheels, for example, buses, 2 axles trucks, 3 axles trucks, and combination.                                                                 |
| 4   | Long Bus (LB), a bus with two or three axles with an axle distance of 5-6 meters. The equivalent of passenger cars in large bus vehicles (LB) is 2.5. | Non-motorized / Unmotorized vehicles (UM) are vehicles powered by humans or animals on wheels, for example, bicycles, rickshaws, horse-drawn carriages, and wheelbarrows.                                                                 |
| 5   | Long Trucks (LT), three-axle trucks, and combination trucks at axle distance (first to the second axle) < 3.5 meters. The equivalent of passenger cars in large truck vehicles (LT) is 4.00. | -                                                                                                                                                                                                         |
| 6   | Non-motorized / Unmotorized vehicles (UM) are vehicles powered by humans or animals on wheels, for example, bicycles, rickshaws, horse-drawn carriages, and wheelbarrows. | -                                                                                                                                                                                                         |

The dimensions of vehicles based on the area can be seen in table 2.
Table 2. The dimension of urban and rural vehicle types.

| Type of Roads       | Type of Vehicle | Length (m) | Wide (m) | Height (m) | Volume (m³) |
|---------------------|-----------------|------------|----------|------------|-------------|
| Rural and Urban     | LV              | 4.19       | 1.66     | 1.7        | 11.82       |
| Vehicle Types       | MC              | 2          | 0.8      | 1.1        | 1.76        |
| Urban Vehicle Types | HV              | 7.5        | 2.2      | 3.05       | 50.33       |
|                     | Rickshaw        | 2.12       | 1.01     | 1.32       | 2.83        |
|                     | Two-wheeled     | 2.25       | 1.7      | 5.25       | 20.08       |
|                     | horse-drawn     |            |          |            |             |
|                     | carriage        |            |          |            |             |
|                     | Bike            | 1.8        | 0.7      | 1.05       | 1.32        |
| Rural Vehicle Types | MHV             | 7.5        | 2.2      | 3          | 49.5        |
|                     | LB              | 12.5       | 2.5      | 3.2        | 100         |
|                     | LT              | 12.94      | 2.6      | 3.3        | 111.03      |

The different type of road between rural and urban road is contained on the heavy vehicle classes. The urban road only has 4 types of vehicles and for a heavy vehicle just in the one type whether as a bus or truck, because in the urban area is very limited for heavy vehicles. However, in the rural road has 6 types of vehicle which divide heavy vehicle into 3 types (MHV, LB, LT). These classes due to the level of the road as the primary level which has high frequency and important levels for passengers and freight transportation.

4.2. Program analysis process
The first step taken in the process of analyzing this program is the input video file that will be used, then the program will read the frame on the video input to initialize the foreground and background using KS Traffic Analyzer. The next step is the vehicle classification process using the bounding box method using the pixel area on the object. The results of this process are vehicle classification calculation data based on the MKJI 199 vehicle classification on rural and urban roads. The process of program analysis can be seen in figure 3.

Figure 3. CountVehicle.Java source code display after modification with MKJI 1997.

5. Results and discussion

5.1. Results of the vehicle detection and classification program
This program is a result of the modification of the KS Traffic Analyzer program obtained on GitHub. For the modified part, the classification of vehicles is based on MKJI 1997, dimensions of the pixel area,
and several other vehicles. In this study, a trial and error method was used to obtain accurate pixel area dimensions in the program. The pixel area obtained by the trial and error method is adjusted to the size of each type of vehicle. The determination of the area of the pixel is obtained from the angle of the drone with an angle of 85 degrees. So that each height difference will also affect the pixel area. Meanwhile, the conversion value is obtained from the ratio of the pixel area to the number of vehicles caught by the manual counting method. Pixel area dimensions and conversion values from vehicle dimensions in this program can be seen in Table 3.

**Table 3.** Trial Dimensions of pixel area and value of conversion of urban and rural roads.

| Description       | Dimension of Vehicle (Pixel Area) | Conversion Value |
|-------------------|-----------------------------------|------------------|
| **Rural (Brawijaya Street)** |                                   |                  |
| Type of Vehicle   | Real Volume | 5 m Height | 6 m Height | 5 m Height | 6 m Height |
| Motorcycle (MC)   | 2           | 0.12       | 0.11       | 0.068      | 0.063      |
| Light Vehicle (LV)| 12          | 0.34       | 0.25       | 0.029      | 0.021      |
| Heavy Vehicle (HV)| 50          | >0.36      | >0.28      | >7.15x10^{-3} | >5.56x10^{-3} |
| Bicycle (UM)      | 1           | 0.08       | 0.07       | 0.061      | 0.053      |
| Rickshaw (UM)     | 3           | 0.15       | 0.13       | 0.053      | 0.046      |
| Carriage (UM)     | 20          | 0.36       | 0.28       | 0.018      | 0.014      |
| **Urban (Malioboro Street)** | | | | | |
| Type of Vehicle   | Real Volume | 6 m | 7 m | 6 m | 7 m |
| Motorcycle (MC)   | 2           | 0.2  | 0.15 | 0.113 | 0.085 |
| Light Vehicle (LV)| 12          | 0.5  | 0.4  | 0.042 | 0.033 |
| Medium Heavy Vehicle (MHV) | 50          | 0.9  | 0.5  | 0.018 | 0.01 |
| Long Bus (LB)     | 100         | 1.4  | 0.6  | 0.014 | 0.006 |
| Long Truck (LT)   | 111         | >1.4 | >0.6 | >0.013 | >0.005 |

This study used 8 videos recorded from 2 different roads, different sessional periods (morning and evening), and 2 different of height based on the type of the road. For the urban road where we used Brawijaya Street as the primary road in Yogyakarta Special Region, the height of drone was tested are 6 m and 7 m height. While for the urban road, Malioboro Street, the height was tested are 5 m and 6 m.
Videos are taken using a drone camera. Each video will be input into the program that has been made and then describe the line and speed of the video in the program, illustrating the video data collection at a height of 6 m can be seen in figure 4. This program we give the name as U-COUNTER, refer to our institution “U” for UMY. And we divide into “U-Counter Urban Area” and “U-Counter Rural Area”.

**Figure 4.** Illustration of video data collection from drone and user interface of U-COUNTER.

Based on the traffic counting results obtained from the resulting program, the number of vehicles is compared between the automatic program and manual counting. The difference in the results of the number of vehicles than used in the traffic performance analysis using the MKJI 1997 method to determine the road capacity and Degree of Saturation (DS) which is shown from volume per capacity (vc ratio). The following (Table 4) is the capacity based on the type of road.

**Table 4.** Road capacity based on MKJI 1997.

| Capacity Factors                  | Rural Road (Brawijaya Street) | Urban Road (Malioboro Street) |
|----------------------------------|-------------------------------|--------------------------------|
| Co Basic Capacity                | 5700                          | 3300                           |
| FCw Traffic Lane Width Adjustment Factor | 1                            | 0.92                           |
| FCsp Direction Separator Adjustment Factor | 1                            | 1                              |
| FCsf Side Friction Adjustment Factor | 1                            | 0.94                           |
| FCcs City Size Adjustment Factor  | -                             | 0.92                           |
| C Capacity (pcu/hour)            | 5700                          | 2625.53                        |

Because the results of traffic volume were counted from program and manual counting is tested in 5 minutes, therefore, to obtain one hour traffic counting, this value is multiplied by 12 as vehicles per hour. Based on [6], traffic volume should be converted into a passenger car unit (pcu) per hour to equalize the size of each vehicle. Thus, this is the value of the Degree of Saturation to determine the road performance based on the volume per-capacity.

To obtain degree of saturation (vc ratio), each traffic volume which was captured in different method (manual and automatic counting), divided by road capacity based on different type of the road. As the result of volume per capacity at figure 5, we can highlight that in the urban road, the degree of saturation (vc ratio) with automatic vehicle counting seems higher than manual counting except in the evening with the height of 6 meter. In this regard, this high estimation of automatic vehicle traffic counting considers the traffic density in urban road rather than in rural road. In that situation, automatic traffic counting will difficult to read combined several adjacent vehicles and it will translate as one object with big size (bus or truck). For example, two close motorcycles can be interpreted as one car or bus. Therefore, the value of traffic congestion which represented from vc ratio is higher than rural.
5.2. Discussion

Based on the results of the U-COUNTER program and manual counting, the result of U-COUNTER on rural area roads is lower than the result of manual counting. Meanwhile, the U-COUNTER result on urban area roads was higher than the manual counting, even though in the afternoon the recording height was 6 m higher using the manual counting method. This case can be happened due to the traffic condition between urban and rural roads whereas urban roads have traffic congestion than in the rural road. Based on [7], the density of vehicle can affect the vehicle counting. Thus, it is important to update the foreground to calibrate the number of traffic volume. The density of this traffic resulted in the calculation of vehicles in the program becoming less effective, for example to the type of car or Light Vehicle (LV).

The research conducted by [21] regarding the classification of vehicles using the Gaussian Mixture Model (GMM) also explained that traffic density affects the classification process because adjacent objects will form 1 object. It can be seen in figure 6 whereas the density of traffic causes the vehicle that should be counted as a car, but because there are 2 motorcycles approach the car, the U-COUNTER program captured as a bus or Heavy Vehicle size (HV) and 2 motorbikes were not detected as motorbikes.

Choosing a different time period (morning and evening) is also crucial to affect the counted traffic result. This can be occurred due to the strength of the light for video recording. As [22] mentioned before that variation of lighting and condition of the weather is pretty important to determine the object because it makes a shadow that can detect the as bigger size of the object. The reason for choosing different times is to make sure the count is not affected by the light condition.
height of the drone is because it adjusts to the height of the pole which is usually used for lighting and other utility functions. The percentage error value and accuracy can be seen in Table 5.

### Table 5. Error percentage and accuracy value.

| Type of Roads | Video Height | Period  | Error Percentage (%) | Accuracy (%) |
|---------------|--------------|---------|----------------------|--------------|
| Rural         | 6 m          | Morning | 23.52                | 76.48        |
|               | 7 m          |         | 38.32                | 61.68        |
|               | 6 m          | Evening | 26.97                | 73.03        |
|               | 7 m          |         | 57                   | 43           |
| Urban         | 5 m          | Morning | 6.34                 | 93.66        |
|               | 6 m          |         | 17.2                 | 82.8         |
|               | 5 m          | Evening | 28.29                | 71.71        |
|               | 6 m          |         | 43.7                 | 56.3         |

From the results of the percent error (error) and the value of accuracy, obtained the highest program accuracy is 93.66% in videos with a height of 5 m in the morning in the urban road and for the lowest accuracy value found in the video height 7 m in the afternoon that is 43%. The lowest accuracy was captured in the evening whereas the condition of traffic congestion and unstable weather during taking videos. And the best accuracy was captured in the morning with low traffic and had good lighting.

In a study conducted by [23] regarding the detection of types of vehicles on the road using the OpenCV library also experienced the same thing during heavy traffic conditions, in his study obtained a low accuracy value of 28.2% while in this study get the results of an accuracy value of 43% for road conditions that are congested with traffic. With a similar study, using the GMM and bounding box methods that have been done by [24], she just obtained an accuracy of 79.22% whereas the best accuracy of this research can obtain 93.66%.

### 6. Conclusions

To conclude, this study has the best accuracy in urban and rural road morning with the height of the drone are 5 and 6 meter in a good weather condition. Most of the poor accuracy occurred in the evening where has low light and has a strong shadow that affects to the result of vehicle detection. The advantage of using drone is easy to modify the height and angle beside the disadvantage is the stability of the video just only 5 minutes. However, this study has tried as an initial step to develop further research in automatic traffic counting.

The advantage of using drones is it can easily make variation height and angle of taking objects. However, the disadvantage of using drones is also inseparable from the instability of drones so that it can be risky to change the video background which is calibrated many times. Thus, it's important in the next real applications, this program can use a solid stand that can be stuck by CCTV to record video stably.

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