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Analysis of the Influence on-Ramp to the Vehicle Headway on the Jakarta-Cikampek Toll Road in Indonesia

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ABSTRACT

The distance between vehicles becomes more important in driving safely behind the vehicle in front of a steady stream of traffic or in creating tools that can control autonomous cars. This headway creates a buffer to prevent a rear-end collision, should the driver need to stop in an emergency. The vehicle headway is expressed by the distance between the rear bumper of a vehicle and the front bumper of the vehicle behind it, which is usually expressed in meters. If it is assumed that vehicles are spread evenly along the road, the headway can be calculated by dividing the density by the volume of vehicles in each lane. The method in this study uses the measurement of the instantaneous average speed and volume of vehicles in one lane. The distance between vehicles or the headway is carried out using Greenshield's model. The output of the headway is presented in the form of a relationship between vehicle volume on the main road and vehicle volume on the ramp. Distance between vehicles is stabilize at 4 meters when the flow of traffic reaches more than 6000 pcu/hour. Increasing traffic flow from the on-ramp influence the distance of vehicle by about 5%.

1. Introduction

Traffic volume is the number of vehicles passing a point on a road section (traffic lane) in a certain time. This traffic volume can be expressed in annual, daily, hourly, or even smaller units. The flow level is defined as the hourly equivalent vehicle traffic flow rate that passes one point on a road section in a certain time which is less than 1 hour, and is usually grouped into 15 minutes.

Artificial intelligence (AI) has provided opportunities in various industries ranging from renewable energy [16], use in the field of civil engineering [1], in the field of mechanical engineering, for example, unmanned cars [4,18,27], and security to health services [3,14], as well as the education sector [13], even becoming a substitute for humans in answering light problems, for example, chatGPT, Google Gemini. However, one of the industries that is ready to carry out significant automation through computer vision Open-CV [5,26] is the manufacturing industry and also the

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engineering sector. Manufacturing has a wide scope for automation. However, when dealing with inspections, surface defects can occur in complex forms, making human-performed quality inspections a complex task with many inefficiencies related to human bias, fatigue, cost, and time. These inefficiencies allow open-CV-based solutions to deliver automated quality inspections that can be integrated into existing surface defect inspection processes, increasing efficiency while overcoming barriers that arise through conventional inspection methodologies. CV is one of the main domains that allow for obtaining meaningful and sharp information from digital media, such as images, videos, and other visual input. Correctly detecting and tracking a moving object in streaming video is still a challenging problem in Indonesia.

The challenge that must be solved, is how to increase the accuracy of vehicle detection caused by many vehicle types, high vehicle volume, and video capture, which makes it difficult to identify objects on the road accurately. However, since the launch of the YOLO (You Only Look Once) object detection in 2015, version 5 [25] has been developed, and otherwise, the latest release YOLO-v8 in January 2023 helps us overcome the problems more easily. The YOLO variant is supported by real-time performance principles and high classification, based on limited but efficient computational parameters, so the development of YOLO from v1 to v8 [15,28], provides an increasing intensity of precision, as these variants develop to meet the requirements of automated quality inspection in the industrial surface defect detection domain, such as the need for fast detection, high accuracy, and application in limited areas. Edge device. Detection using YOLO-v8 [9-11,29] which is a development of Artificial Intelligence, provides opportunities for calculating traffic volumes that are more accurate, faster, and in real-time. The development of YOLO, supported by open-CV, provides the opportunity to calculate vehicle volume using video recording results, the accuracy of which, of course, depends on the quality of the video, driver behaviour [8,13], and also depends on the time of night or day when the video was taken [11,20] and also its detection methods [17,21,22,24]. Problems that arise in video calculations are currently limited to 4 (four) types of vehicles, namely motorbikes, cars, buses, and trucks.

You only look once (YOLO) is known as an object detection algorithm that has quite high accuracy when compared to several existing algorithms. YOLO uses a single neural network (SCNN, single convolution neural network) to detect and recognize objects that directly predict bounding boxes and class probabilities. However, the YOLO method is still not perfect for implementation in autonomous driving cars, because there are still errors that can occur, for example in the size of the bounding box being detected, which can cause errors in determining the distance of the detected object. Currently, YOLO version 5 can detect objects in 81 object categories and only 4 (four) categories are grouped as vehicle detection, namely motor cycles, cars, buses and trucks.

This research aims to utilize the advances in YOLO-v5 and open-CV combined using the help of the Python program to create additional classifications of vehicle types as a novelty by increasing the previously only 4 vehicle groups to 7 (seven) vehicle groups, namely motorbikes, cars, mini-cars, small buses, large buses, small trucks and large trucks, which YOLO initially only gave 4 (four) vehicle classifications. This goal can be achieved with advances in roboflow technology [2,6], which is a device for creating groups of vehicles according to pre-determined vehicle images.

2. Methodology

2.1 Equipment

The main equipment in this research is a camera with a minimum resolution of 720p (720 pixels x 1280 pixels). A greater level of resolution will be better at producing images and differences between the background and the original image and will provide good differences between one type of vehicle and another. Other equipment that is needed is a tripod to support the recording camera, a memory card of at least 64 GB, battery charger equipment, to supply the required cell phone battery resources, and no less important is a laptop or desktop computer with a minimum memory of 8 MB. This equipment can be seen in Figure 1.

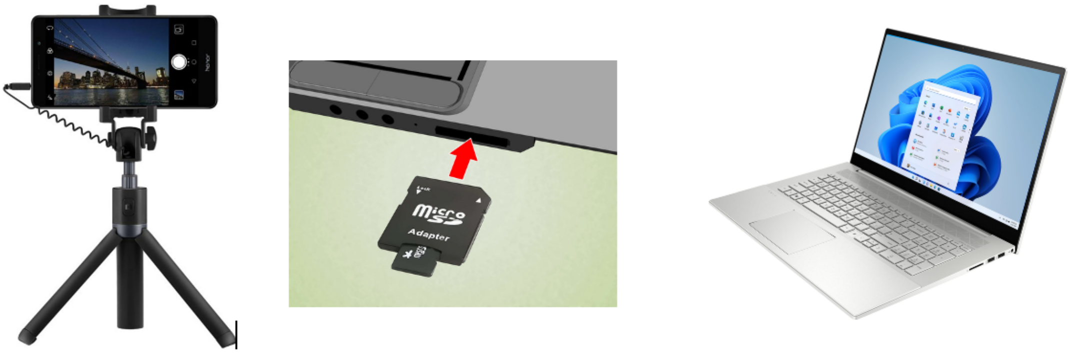


Fig. 1. Research equipment

2.2 Survey Location

The research location was carried out at 2 (two) locations, consisting of one location on the Jakarta-Tangerang toll road, and one location of national road, namely the Daan Mogot Arterial Roady, West Jakarta, Indonesia. These locations are presented in Figure 2**.**

2a. Jalan tol Jakarta–Tangerang (Kebon Jeruk)

2b. Jalan Arteri Daan Mogot, Cengkareng

Fig. 2. Survey location

So that the actual survey can run well and can be carried out efficiently and effectively, it is necessary to carry out a preliminary survey which will provide initial guidance regarding: whether the sample frame is sufficient, whether the survey method applied is appropriate, estimated time, and survey costs, the exact hours for the survey [11,20]. The camera is positioned in the middle of the road to obtain a symmetrical image in the recorded video.

2.3 Research Method

The objective of this study is to design and develop a real-time traffic volume calculation from video recorded. The methodology of this research is divided into three phases which are requirement analysis, design and development, and evaluation of the system. The research began by collecting video recordings of traffic at the 2 (two) predetermined locations. The next step is to create a vehicle dataset from 2000 vehicles which are grouped into 7 types of vehicles according to conditions in

Indonesia using the help of the roboflow's program [7]. This dataset will be used to detect recorded videos to calculate the number of vehicles with classifications that have been determined using the dataset.

From 2000 vehicles type data that has been grouped into 7 (seven) vehicle types with roboflow's program and trained 150 times to get YOLO training results YOLO-verdar7, which will then be tested with the data that has been prepared, namely a data dataset which is named valid dataset. A valid dataset is a collection of vehicle types that have been grouped according to what is desired and this data is useful for validating the train results that have been carried out by YOLO-V5

The test results of the vehicle counting software model through the training process (train with functions provided by roboflow) on the software that has been created and the results are presented in Figure 3. This greater grouping will of course be useful in the practice of calculations related to traffic flow parameters including capacity, passenger car equivalents, axle load calculations and so on.

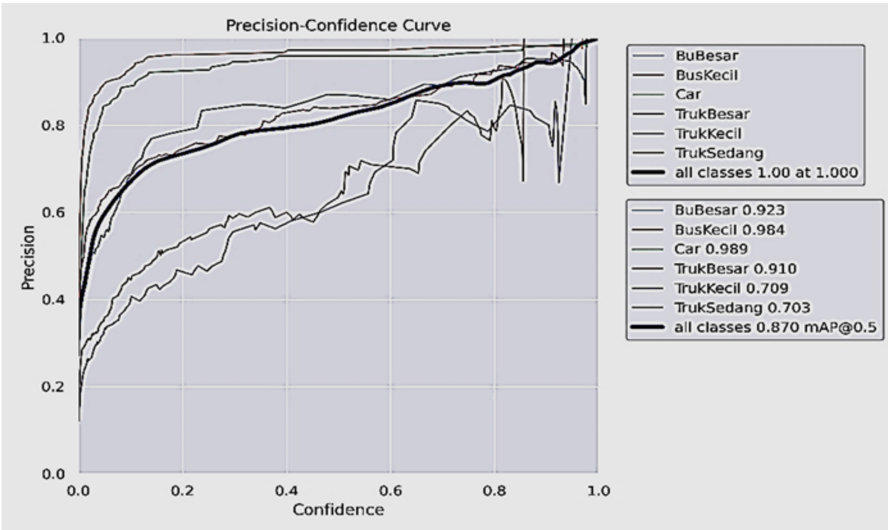


Fig. 3. Level of software model test accuracy

Figure 3 above shows the results of model validation using the Roboflow facility. This Roboflow facility is very useful in developing datasets from various types of vehicles into groupings of vehicle types that match what is expected. In the process, roboflow will form a train dataset, and it will be valid. This collection of trains will be used to train or teach YOLO-V5 (such as teaching children to recognize objects) in this case specifically for the types of vehicles in Indonesia. The longer the repetition carried out in training, the better the accuracy of the results, as in the results in Figure 5. who were trained 150 times.

Traffic volume calculations are also carried out manually to be used as a comparison of the level of accuracy compared to using software that has been created using artificial intelligence methods, namely You Only Look Once (YOLO-V8) and the open-source programming language PYTHON, and open-cv. The research process flowchart outlines the steps involved in conducting a research study. The step of the research are presented in Figure 4.

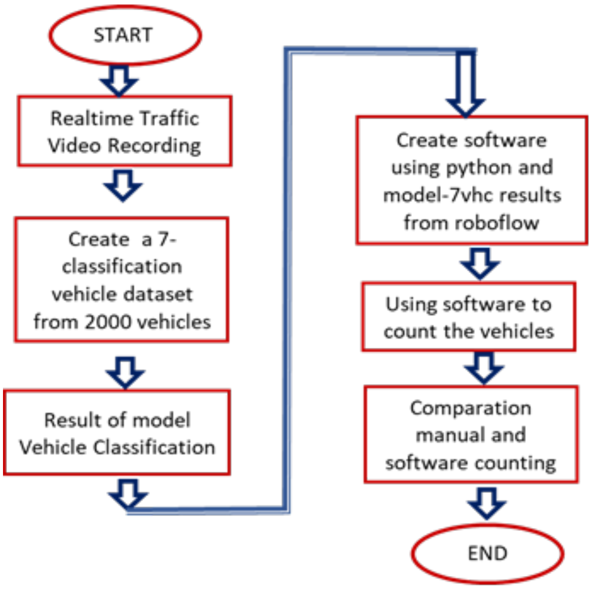
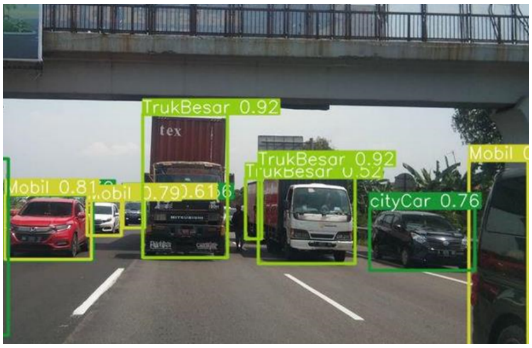


Fig. 4. Step of the research

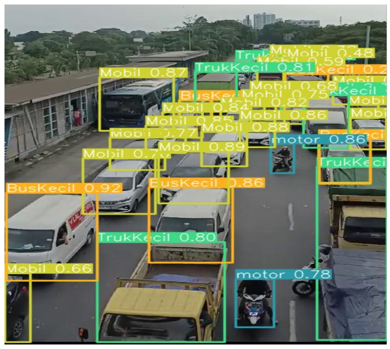
3. Results

3.1 Processing Video

Video recorded from the field is processed using software that is created with a Python combination program, YOLO, open-CV, and torch, which will produce a vehicle classification of 7 (seven) types of vehicles, namely motor-cycle, mini-cars, passenger cars, small buses, large buses, small trucks and large trucks, as shown in Figure 5.



4a. Jakarta – Tangerang Toll Roads



4b. Daan Mogot Arterial Road

Fig. 5. Sample processing results

3.2 Comparation of the Volume Result

The results volume traffic for the Jakarta-Tangerang toll Road is in Table 1. Otherwise, The results volume traffic for the Daan Mogot Arterial Road is in Table 2**.**

Table 1
The comparation results manual vs software traffic volume (Toll Road)

Time	Manual						Software					
	city-Car	Car	Small Bus	Large Bus	Small Truck	Large Truck	city-Car	Car	Small Bus	Large Bus	Small Truck	Large Truck
11.00 - 11.15	161	706	66	161	159	54	160	701	62	158	156	52
11.15 - 11.30	99	703	122	51	213	77	98	698	118	50	208	75
11.30 - 11.45	164	721	120	70	329	123	161	716	117	68	326	121
11.45 - 12.00	21	655	180	155	197	136	22	650	176	151	195	134
12.00 - 12.15	107	634	295	147	278	188	105	629	293	147	274	186
12.15 - 12.30	90	642	347	111	219	210	89	637	343	109	216	209
12.30 - 12.45	98	639	226	109	263	161	96	634	222	109	260	158
12.45 - 13.00	87	614	159	107	250	124	85	609	154	103	245	122
Sum	**827**	**5314**	**1515**	**911**	**1908**	**1073**	**816**	**5274**	**1485**	**895**	**1880**	**1057**
					software/manual ==>>		**98.67%**	**99.25%**	**98.02%**	**98.24%**	**98.53%**	**98.51%**

Table 2
The comparation results manual vs software traffic volume (Arterial Road)

Time	Manual						Software					
	city-Car	Car	Small Bus	Large Bus	Small Truck	Large Truck	city-Car	Car	Small Bus	Large Bus	Small Truck	Large Truck
11.00 - 11.15	57	954	29	57	85	32	54	947	26	54	82	29
11.15 - 11.30	38	873	46	24	98	44	36	866	43	22	95	43
11.30 - 11.45	60	946	45	35	137	59	57	939	43	33	134	57
11.45 - 12.00	21	960	64	58	126	59	20	953	61	55	123	54
12.00 - 12.15	43	963	89	55	108	57	41	956	86	53	105	55
12.15 - 12.30	41	974	114	46	109	66	39	967	111	45	106	65
12.30 - 12.45	42	1050	70	42	108	52	40	1043	67	41	105	49
12.45 - 13.00	36	518	69	41	99	42	35	515	67	39	97	41
SUM	**338**	**7238**	**526**	**358**	**870**	**411**	**322**	**7186**	**504**	**342**	**847**	**393**
					software/manual ==>>		**95.27%**	**99.28%**	**95.82%**	**95.53%**	**97.36%**	**95.62%**

4. Conclusions

Advances in Artificial Intelligence Technology, and Machine Learning in the form of YOLO are very helpful in various fields for work automation, which makes it easier and faster to complete repetitive work. This research shows the excellent benefits of using the YOLO-V5 in accurately classifying the type of vehicle that passes along a highway segment.

The results obtained using the small version of YOLO (yolov5s.pt) show very good accuracy for vehicle classification detection. The measurement accuracy for vehicles on toll roads is city-car 98.67%, passenger car 99.25%, small bus vehicles 98.02%, large bus vehicles 98.24%, small truck vehicles 98.53%, and large truck vehicles 98.51%. The measurement accuracy for vehicles on arterial roads is city-car 95.27%, passenger car 99.28%, small bus vehicles 95.82%, large bus vehicles 95.53%, small truck vehicles 97.36%, and large truck vehicles 95.62%.

It is found that the arterial road has less accuracy than the toll roads, due to the large number of irregular motorized vehicles and the density between vehicles, as well as the video quality when recording process in the field.

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