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Instrumentation of Carbon Monoxide to Indentify Traffic Jams

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***Abstract*—This paper studies the influence of the number of motor vehicles to the level of carbon monoxide (CO). While the number of motor vehicles' increases significantly and affects many traffic jams, it could be indicated by the high CO level in the air. This indication is used to observe the points of the traffic jams in Malang, i.e., Jl. Sukarno-Hatta and Jl. Sumbersari as the samples of heavy traffic. These roads have characteristic, such as, similar users, two ways, and close to each other, while Jl. Sukarno-Hatta has more open air and plants comparing to Jl. Sumbersari. The observation showed that the levels of CO have significantly been affected by the number of vehicles. This result is used to design a detector system of traffic jams in Malang.**

Keywords—Instrumentation; Carbon Monoxide; Traffic jams

I. INTRODUCTION

The number of motor vehicles' increases significantly, which causes air pollution to be twice at 2000 since 1990, and it could be ten times at year 2020 [1]. Moore said that increasing the number of motor vehicles at a point of roads influences the high level of the pollution [2]. Transportation and gas combustion are the main pollution sources, there are five air pollution, i.e., PM10 (*particulate matter, 10μ or smaller*), SOx, CO, NOx, VOCs (*volatile organic compounds /hydrocarbon*). Among those sources, CO is the biggest polluter [3], while it can be dangerous if the level of this gas is high.

Another problem faced by the developing countries is that increasing the number of vehicles is not followed by expanding of roads, so there are many traffic jams occur. This situation also happens in Malang-Indonesia, which is shown in the website of the government [4]. There are at least 15 points where the traffic jams always occur, the two of them are Jl. Sukarno-Hatta and Jl. Sumbersari. These points are studied in this research, because they have characteristics, such as, the users of the roads are similar, those roads are two ways, and they close to each other, while the topography of these roads is different, that is, Jl. Sukarno-Hatta has more open air and plants comparing to Jl. Sumbersari.

Based on those reasons, this paper studies the instrumentation of CO gases to indicate the traffic jams. The calibration of gas sensors is done according the data logging of CO gases at Jl. Sukarno-Hatta and Jl. Sumbersari, which represents of all situations of traffic jams in Malang.

TABLE 1. PEAK TIME ON JL.SUMBERSARI

Direction / day	Morning	Daylight	Afternoon	Vol.Max (vehicles/hour)
Sumbersari-Dinoyo				
Monday	06.45 – 07.00	12.15 – 12.30	14.45 – 15.00	1066,80
Friday	06.15 – 06.30	11.00 – 11.15	14.45 – 15.00	1090,80
Saturday	06.45 – 07.00	12.15 – 12.30	16.45 – 17.00	1047,20
Dinoyo-Sumbersari				
Monday	06.45 – 07.00	09.45 – 10.00	15.45 – 16.00	1265,40
Friday	06.45 – 07.00	09.45 – 10.00	15.15 – 15.30	1266,40
Saturday	06.45 – 07.00	10.15 – 10.30	16.45 – 17.00	1259,40

The rest, this paper is organized as follows. Section II describes the gas sensor to indicate the traffic jams. Section III describes the method to calibrate the sensor. Section IV shows the results, and Section V is devoted to conclusions.

II. GAS SENSORS TO INDICATE TRAFFIC JAMS

A. CO Gases

Carbon and Oxygen can combine to produce carbon monoxide (CO) as a result of imperfect combustion, where this gas is odorless, tasteless and colorless at the ambient air temperature. Furthermore, CO can also be potential as a dangerous toxin, which able to be bound strongly with hemoglobin [1]. In 1992, WHO revealed that 90% of CO in urban air comes from motor vehicle's emission. Thus, increasing the number of motor vehicles' influences the high CO levels.

On the other hand, the traffic density is shown by a comparison between the volume of traffic represented by the number of passing vehicles, and the road capacity represented by the ability of the road to pass a number of vehicles. When the capacity of the road does not be enhanced, while the huge number of vehicles passes on the roads, it causes disruption on the road, so that the speed of the motor becomes unstable and causes imperfect combustion; thus, the pollution is increased more [5].

The CO levels in urban area are quite varied depending on the density of motor vehicles that use gasoline. Generally, maximum levels of CO are found to coincide in the rush hours in the morning and evening. Besides of that, the weather and topography of the surrounding streets also influence the levels of CO. Winayati [6] studied the peak time of the rush hours on Jl. Sumbersari as shown in Table [1]. These peak times are used as the base time of this paper.

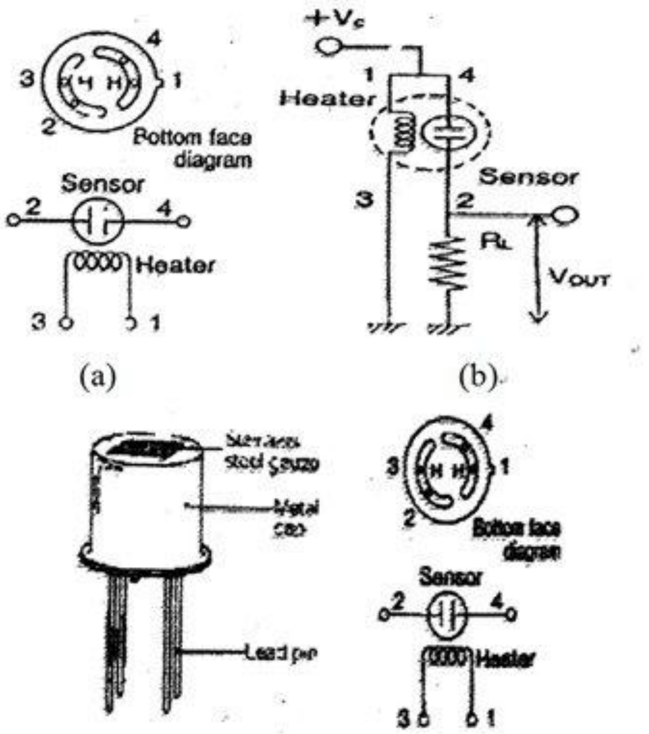


Figure 1. Gas sensor of AF series

(a). Pin configuration (b) Method to calibrate, (c) Physical graph

(source : tic film gas sensr gas AF-series data sheet)

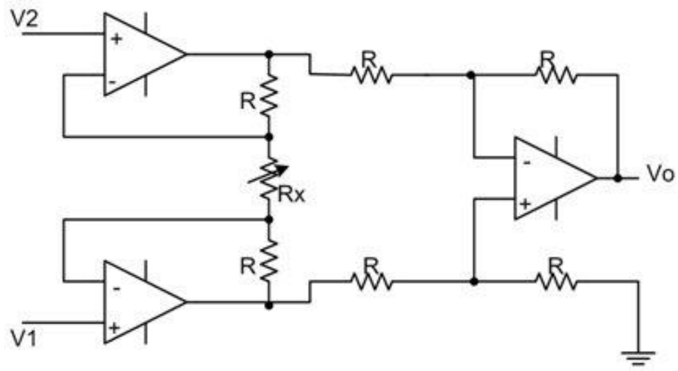


Figure 2. Instrumentation Amplifier Circuit

B. Selecting Gas Sensor

In order to detect the CO level on the roads, the gas sensors are needed. One of the types is the AF series, which is produced from thick films. This sensor works by binding and uptake of gases on the surface of it, which is related to the decreasing resistance of the sensor. The pin configuration, a method to calibrate, and a physical graph of gas sensor is shown in Fig. 1.

The resistance of the gas sensor (Rs) can be calculated from the output voltage (V_{OUT}) as follows

$$Rs = \frac{Vc - V_{OUT}}{Vout} \cdot R_L \qquad (1),$$

where, V_C is the common voltaje, and R_L is the load resistance. The sensitivity of the sensor is defined as a comparison between the resistance of the air contaminated by the gas (R_{GAS}) and that of the uncontaminated air (R_{AIR}).

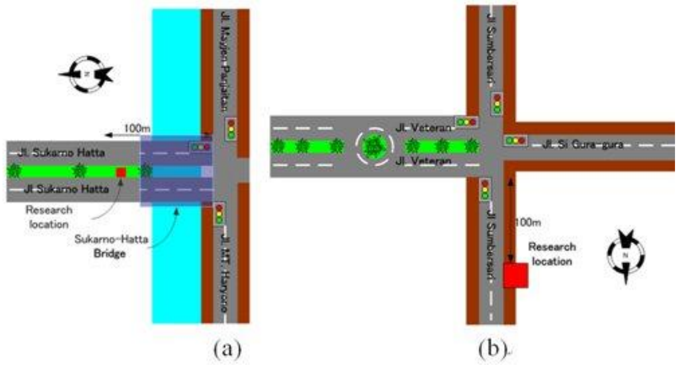


Figure 3. 3 Map of the research location
(a). on Jl. Sukarno-Hatta
(b). on Jl. Sumbersari

C. Signal Conditioning for Gas Sensor

A Signal conditioning is needed to change the level of a signal so it can be suitable for the other components. An instrumentation amplifier can be applied as a signal conditioning, which is developed using Op-Amps as shown in Fig. 2.

An instrumentation amplifier has some advantages; that is, it has high impedance inputs, and the gain of the amplifier can be tuned easily and appropriately by setting the variable resistance Rx. The gain of instrumentation amplifier is defined as follows,

$$\frac{V_o}{V_1 - V_2} = 1 + \frac{2}{a}, \quad a = \frac{Rx}{R} \qquad (2),$$

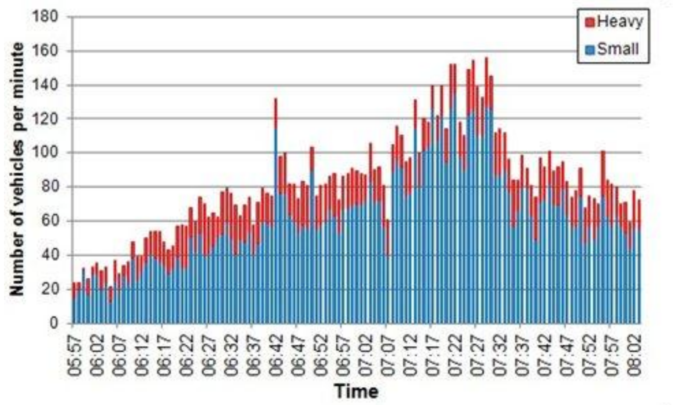
where, V_1 and V_2 are the voltage input at the channel (+) and that at the channel (-), respectively. V_o is the output voltage of the instrumentation amplifier, which is proportional to the differential inputs (V_1-V_2). The characteristics of the instrumentation amplifier are (1) the gain is determined by Rx, (2) the impedance inputs are high and are not changed when the gain is changed, and (3) the output Vo is only depended on V_1 and V_2 and is not depended on the common mode.

III. RESEARCH METHODS

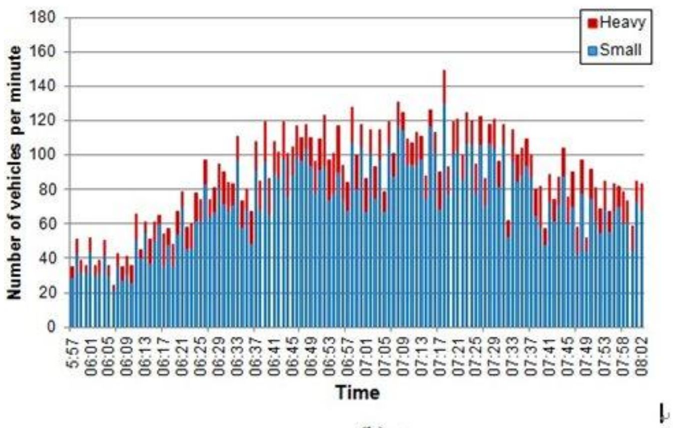
The research is done using the steps as follows.

The first step is done by selecting the appropriate location, Since there are more than 15 points where the traffic jams always occur [4], Jl. Sumbersari and Jl. Sukarno-Hatta are selected. The reasons are the different topograph of those roads, i.e., Jl. Sumbersari is a two-way street, which has narrow width and has little open air, while Jl. Sukarno-Hatta is a wide street, where it has more open air and green line in the middle of the street. The characteristic of these roads are shown in Fig. 3. The differences are used as bases comparation of the CO level to the topograph.

The second step is to select the appropriate data. The time selected is a busy hour ranging from solitary – normal – busy – normal. This step is selected to observe the influence of the volume street to the CO level. According to Winayati's



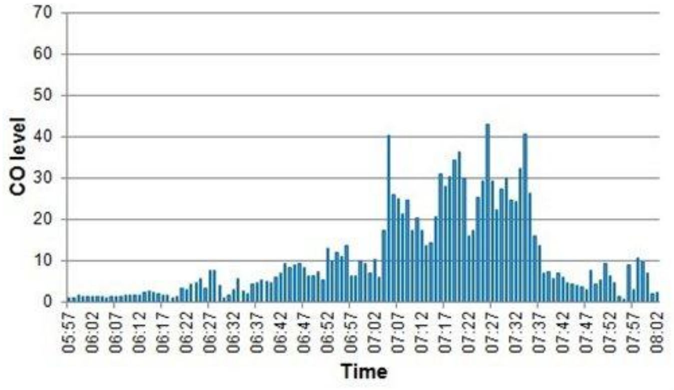
(a)



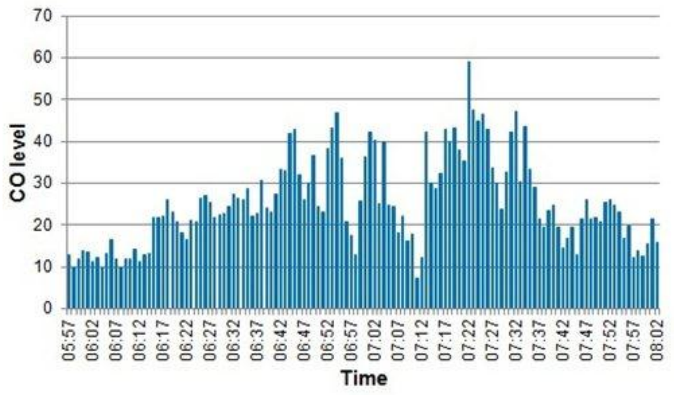
(b)

Figure 4. Number of vehicles passes on the street
(a). on Jl. Sukarno-Hatta
(b). on Jl. Sumbersari

research [6], this research is done at the peak time on Jl. Sukarno-Hatta and Jl. Sumbersari, which occurs at 06.00 – 8.30 a.m., here, the data is counting every minute.



(a)



(b)

Figure 5. CO level on the street
(a). on Jl. Sukarno-Hatta
(b). on Jl. Sumbersari

TABLE 2. NUMBER OF VEHICLES PASSES ON JL. SUKARNO-HATTA AND JL.SUMBERSARI

	Small	Heavy	Total
Jalan Sukarno-Hatta			
average	63	19	82
max	135	30	156
Jalan Sumbersari			
average	72	15	86
max	130	29	149

The third step is to determine the research variables, i.e., independent and dependent variables represented by the number of vehicles and the CO level, respectively. Here, the number of vehicles is grouped by three categories, i.e., small, heavy, and total representing motors, cars, and total of motors and cars.

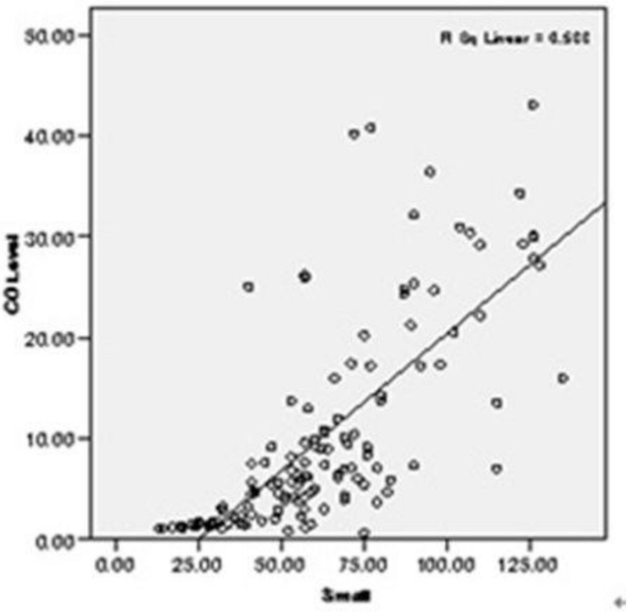
The fourth step is the mechanisms of data retrieval. The traffic density is calculated as the number of vehicles passed the street per minute, which is counted based on the video records taken at the times. On the other hand, the CO level is taken using data logger using EL-USB-CO [7]. This instrument count six times per minute; then the average level per minute is used. This data is used as calibration of sensor used in the system designed.

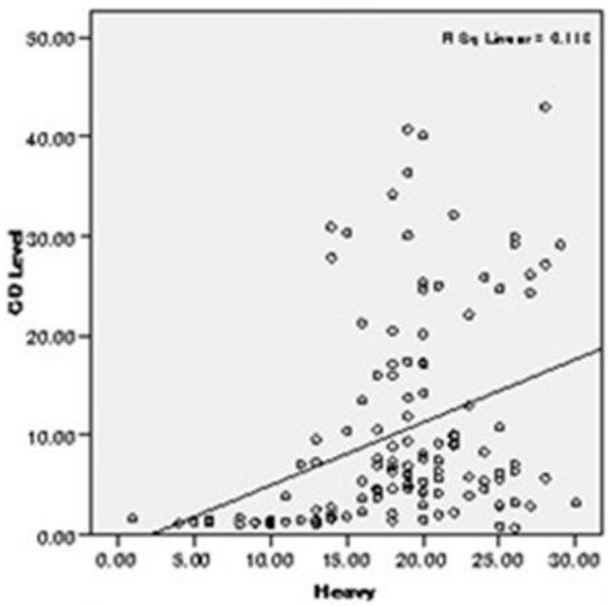
The fifth step is the mechanisms of analysis data. The analysis is carried out by calculating (1) vehicles' volume, (2) CO levels, and (3) influence of the number of vehicles to the CO levels.

The last step is an experiment to calibrate the sensor, here AF sensor is used, which convert the CO level to the suitable voltage.

IV. Results

The measurement of the traffic density, CO level, and the influence of the number vehicles to the CO level are shown as follows.





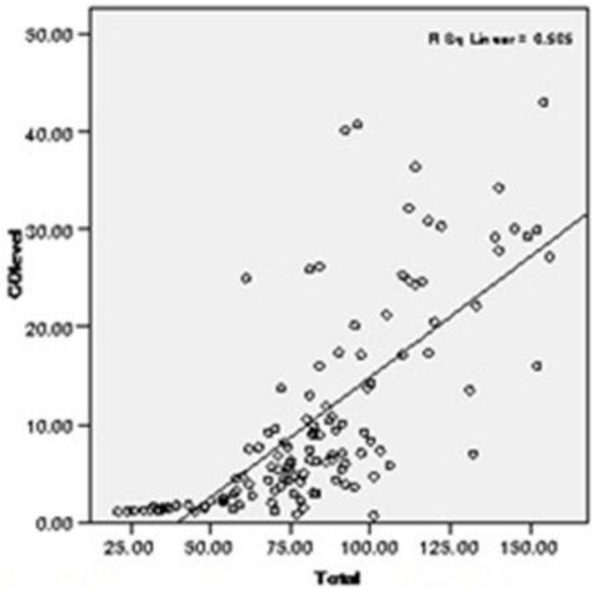
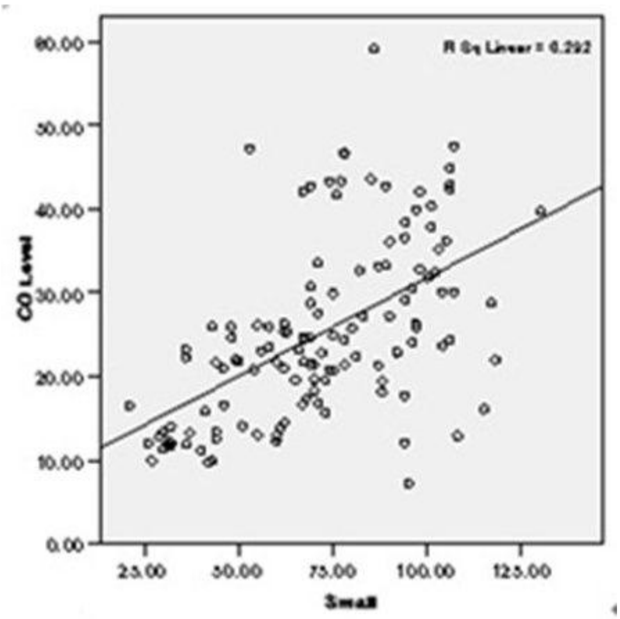
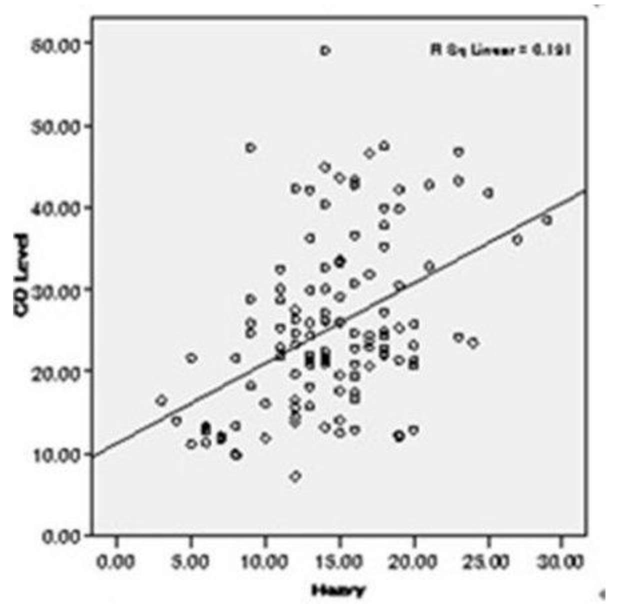


Figure 6. Influences of vehicles number to CO level on Jl.Sukarno-Hatta





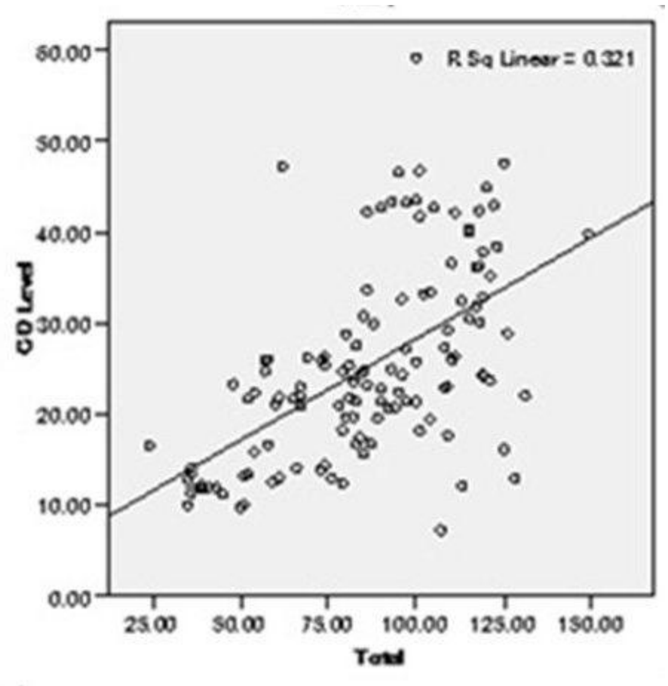


Figure 7. Influences of vehicles number to CO level on Jl.Sumbersari

TABLE 3. INFLUENCE COEFFICIENTS OF THE VEHICES' NUMBER TO THE CO LEVEL

Location	Type of vehicles	Coefficient	t-test	sig
Jl. Sukarno-Hatta	Small	Y=-6.747 +0.271X	1.69e-45	0.000
	Heavy	Y=-1.370 +0.634X	1.69e-13	0.000
	Total	Y=-9.792 +0.247X	5.39e-56	0.000
Jl. Sumbersari	Small	Y=8.297 +0.235X	2.01e-46	0.000
	Heavy	Y=11.278+0.975X	6.71e-25	0.000
	Total	Y=5.969+0.223X	9.24e-60	0.000

TABLE 4. T-TEST OF CO LEVELS ON Jl.SUKARNO-HATTA AND Jl.SUMBERSARI

	Jl. Sukarno-Hatta	Jl. Sumbersari
Mean	10.39	25.15
Stdev	10.35	10.63
t-statistic	-11.21	-
p-value (1-sided)	3.22e-24	-

A. Measurement of Volume of Density Traffic

The measurements of the traffic density on Jl. Sukarno-Hatta and Jl. Sumbersari are counted at the busy hours; that is, at 06.00 to 08.30 a.m. as shown in Fig. 4. The figure shows that the peak number of vehicles on Jl. Sukarno-Hatta is at 7.00 to 7.30 a.m., while that on Jl. Sumbersari is at 6.30 to 7.50 a.m. As shown in Table. 2, the maximum number of the vehicles which was passed on Jl. Sukarno-Hatta is 156, while Jl. Sumbersari is 149. It is because that Jl. Sukarno-Hatta is wider than Jl. Sumbersari. However, the average of the vehicles on Jl. Sumbersari is larger than Jl. Sukarno-Hatta; it is because that Jl. Sumbersari narrower than Jl. Sukarno-Hatta. Then it is supposed that the CO level on Jl. Sumbersari higher than Jl. Sukarno-Hatta

B. Measurement CO level

The measurements of the CO level on Jl. Sukarno-Hatta and Jl. Sumbersari are shown in Fig. 5. The average and highest level of CO on Jl. Sukarno are 10.4 ppm and 43 ppm, respectively, while those on Jl. Sumbersari are 24.6 ppm and 59.2 ppm.

Although the number of vehicles which pass on Jl. Subersari is smaller than those on Jl. Sukarno-Hatta, and since the characteristics of Jl. Sumbersari are narrow and has no much open air compared to Jl. Sukarno-Hatta, the CO level on Jl. Subersari is higher than Jl. Sukarno-Hatta It is confirmed that the topograph of the road can influence the level CO level.

C. Influence of Number of Motor Vehicles to CO Level

The influences of the number of motor vehicles to the CO level on Jl. Sukarno-Hatta and Jl. Sumbersari are analyzed using regression analysis, which was performed using SPSS 15. These analyses are carried out to observe the influences of the small, heavy and total vehicles on the CO level. The scattered charts of are shown in Fig. 6 and Fig. 7.

The coefficients of influences of the number of vehicles to the CO level are shown in Table 3. The results show that the significance is less than 0.05, which mean the influence of the number of the vehicles influent significantly to the CO levels.

D. Influence of topography to CO level

In order to observe the influence of the topographies on Jl. Sukarno-Hatta and Jl. Sumbersari to the CO level, a comparison test is conducted using independent t-test. The CO level on Jl. Sukarno-Hatta, which are collected from 5.57 a.m. to 8.03 a.m, is compared to that on Jl. Sumbersari. The comparative results show that F value is 0.95, while F table is 1.34. It means that data is homogenous. The influence of the topography is analyzed using t-test as shown in Table 4.

This results show that the CO levels on Jl. Sukarno-Hatta and Jl. Sumbersari are different significantly with p value 3.22e-24, which mean the topographies of those roads influence the CO levels. The averaged CO levels on Jl. Sumbersari are higher than those on Jl. Sukarno-Hatta, i.e., 25.15 ppm and 10.39 ppm, respectively.

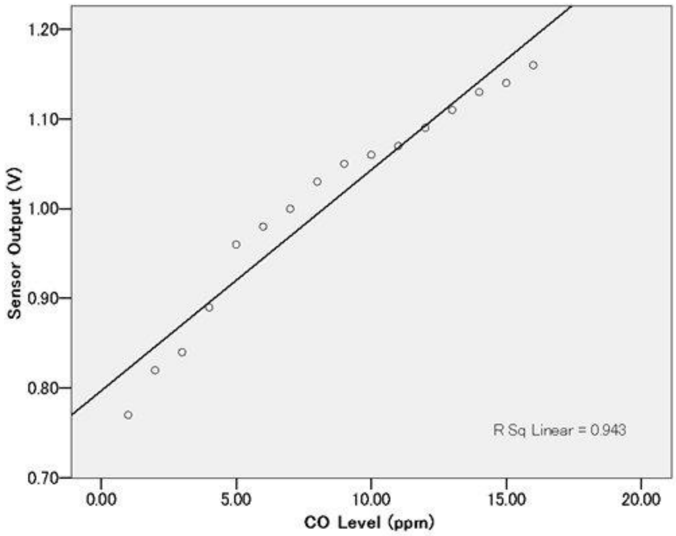


Figure 8. Gas sensor calibration

E. Calibration of Gas Sensor Based on CO Levels

The results of the CO levels of the previous steps are used as the base for calibrating the gas sensors, where this sensor is used as an input of the traffic density indicator. This gas sensor converts the CO levels to the electric voltage so it could represent the actual situations on the roads. The conversion of the CO levels to electric voltage is shown in Fig. 8.

The result of the sensor calibration is analyzed using linier regression, which shows that the relation between CO levels and voltage levels can be expressed as $Y = 0.797 + 0.025X$, here Y is the sensor output and X is the CO level. In order to use the output sensor as a traffic density indicator, the sensor is connected to the signal processing, where the output sensor changes from 0 V to 4.49V when the CO levels vary from 0 ppm to 50ppm.

V. CONCLUSIONS

This research shows the CO levels can be used as an indicator of a traffic density, that is, increasing the number of vehicles on the roads, it can influence the CO levels. Furthermore, The results also show the different CO levels, while the topograph of the road is different. So, when designing an indicator of a traffic density, it also should consider the topograph of the roads.

The future work of this research is going to design an integrating system which could collect the data from traffic density indicators.

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