Validation of CO dispersion model due to the road position on the dominant wind direction on transport sector

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Abstract. This study aims to validate CO dispersion model due to the position of the road toward the dominant wind direction on the transport sector. Sampling for modelling was done on the road with the road angle to wind direction is 0 degree (Jend. A. Yani Road), 30 degree (Andalas Road) and 60 degree (Prof. Dr. Hamka Road). CO dispersion model was obtained from the relations between CO concentration with traffic volume, traffic speed, wind speed and dominant wind direction. Sampling for validation was done at three location points, i.e. Jend. Ahmad Yani Road, By Pass Road and Dr. Wahidin Road, each of which has a position of 0, 45 and 90 degrees toward dominant wind direction. Sampling for CO was done using impinger. Measurement of traffic characteristics and meteorological conditions was performed in conjunction with CO sampling. Validation test was done by using Pearson Product Moment formula and Test of Two Variance. Results of the Two-Variance Test showed no significant difference between two concentrations of CO model and CO measurement. It showed the Test Ratio (RUf) smaller than the Critical Point. Validation test using Pearson Product Moment showed that the CO model can be used for predicting CO dispersion.

1 Introduction

Air pollution is one of a set problems in the urban area. Some of them caused by transportation [1]. According to [2], the main polutants of transportation activities are carbon dioxide, nitrogen oxides and fine particulates. [3] evaluated the impact of transportation on air quality on the roadside.
Study of Carbon Monoxide (CO) concentrations have been done on the roadside area (for example, [4-6]). Some study of CO concentration on the roadside in Padang City were conducted [7]. Furthermore, [8] monitored the influence of the dominant wind direction on CO dispersion on roadside area in Padang City. In this study, modelling of set of data from [8] were developed to get CO concentrations model based on wind coming angle direction on the roadside and validated the model.
This research aims to model and validate the effect of wind angle to the road, toward CO concentration in the roadside area. The wind angle to the road (hereinafter called α) used in this research are 0º, 30º, and 60º for modelling, then 0º, 45º, and 90º for validating.

2 Methods

The research was conducted by doing field sampling and laboratory analysis. Data collections include secondary data and primary data.

2.1 Secondary data collection

Secondary data include the map of road network of Padang City from Google Map, then wind speeds and wind directions from the Meteorology Climatology and Geophysics Agency (BMKG) Padang City for years 2012-2016 for detecting the wind angle reference point of zero degrees, then used for representing wind coming angle to road (α). Then, traffic characteristics, CO concentrations and wind speeds from [8] for modelling of CO concentrations based on wind coming angle direction. The wind coming angle to road (α) for modelling can be seen in Figure 1, were that conducted on A.Yani Road (α = 0), Andalas Road (α = 30) and prof. Dr. Hamka Road (α= 60).

2.2 Primary data collection

Primary data collected for validating the CO concentration models are traffic characteristics (traffic volume and traffic speed), meteorological conditions, such as air pressure (mmHg) and temperature (K), wind velocity (ms^{-1}) and wind direction. Sampling of CO concentrations were conducted with α values range between 0º and 90º, at 3 points representing wind coming angle to the road (α), i.e. at Jend. A. Yani Road with α is 0°, By Pass Road with α is 45° and Dr. Wahidin Road with α is 90 °, that is shown in Figure 2. The α were chosen from 0°, 45° and 90° to represent α value that have ranged between 0° and 90°.

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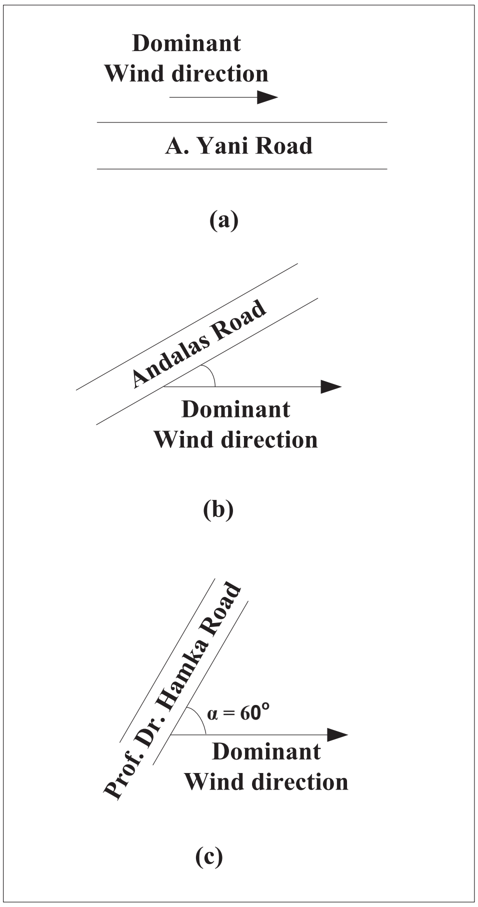

Fig. 1. Sketches of wind angle direction to the road for modelling.

For collecting CO concentrations data, sampling is conducted using impinger and analyzed by spectrophotometer. Sampling of CO was conducted for 3 days with measurements every 1 hour for 10 hours per day starting at 07.00-17.00 at sampling point separately. Total samples collected for 3 points were 30 samples. Measurement of traffic characteristics including traffic volume, traffic speed and traffic density, which were carried out in conjunction with the measurement of CO concentrations. Measurement of the number of vehicles in 3 CO monitoring locations was done manually at the sampling point using counter.

2.3 Data analysis

Data analysis contain comparison of meteorological conditions, traffic characteristics, and CO concentrations between modelling data and validation data. Furthermore, modelling of CO concentrations based on the wind coming angle directions. The CO concentration was developed using set of data of traffic volume, traffic speed, wind speed and wind coming angle direction. Finally, validation of CO concentration model using The Two-Variance Test Formula [9] and The Pearson Product Moment Formula [10].

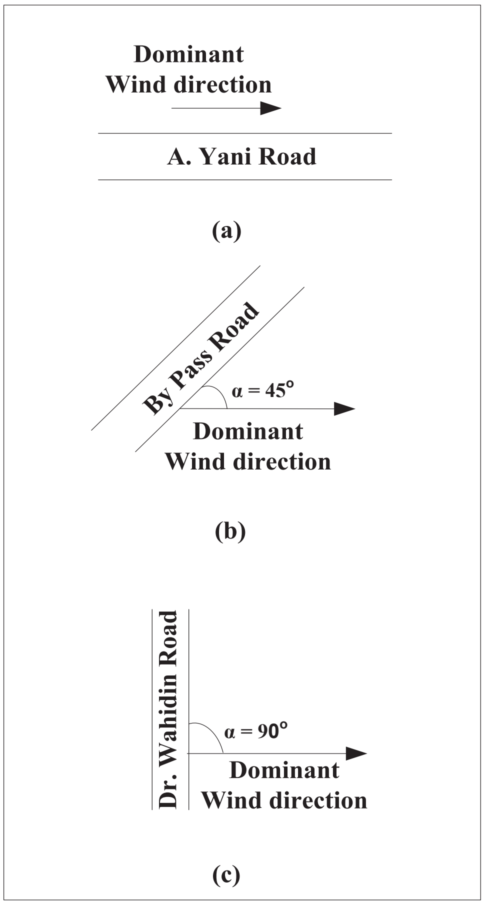

Fig. 2. Sketches of wind angle direction to the road for validation.

3 Result and discussion

3.1 Comparison of meteorological conditions

Comparison of meteorological conditions between model and validation data can be done on A.Yani Road because α is 0° respectively. The Meteorological conditions during sampling on modelling and validation can be seen in Figure 3, Figure 4 and Figure 5.

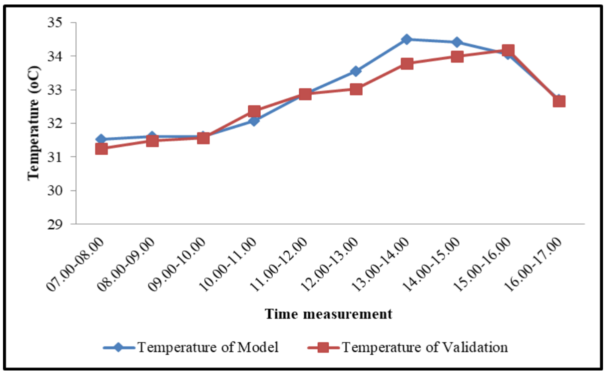

Fig. 3. Comparison of Temperature on A. Yani Road between modelling data and validation data.

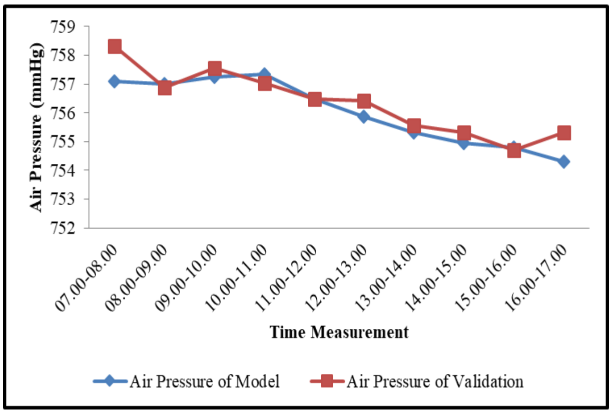

Fig. 4. Comparison of Air Pressure on A. Yani Road between modelling data and validation data.

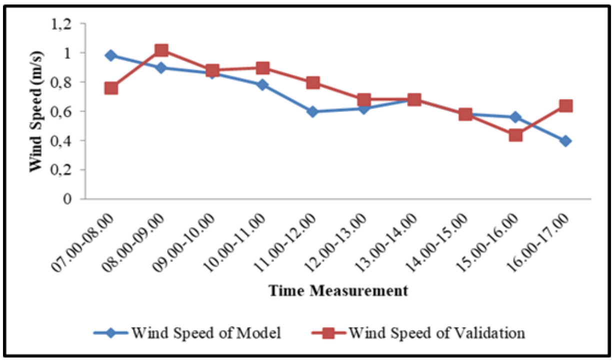

Fig. 5. Comparison of Wind Speed on A. Yani Road between modelling data and validation data.

Figure 3 shows the temperature increase from morning to daytime and then decrease to afternoon, both model data and validation data. The maximum temperature in figure 3 is relatively similar to the maximum temperature in the [11] study. Statistical analysis also proves that the temperature influnces the concentration of air polutan [12]. It can be seen in Figure 4 and Figure 5 that air pressure and wind speeds inversely proportional with temperature in Figure 3.

3.2 Comparison of traffic characteristics

Traffic characteristics between modelling data and validation data can be seen in Figure 6 and Figure 7

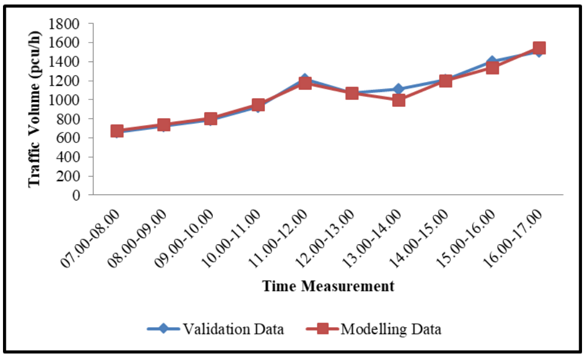

Fig. 6. Comparison of Traffic Volume on A. Yani Road between modelling data and validation data.

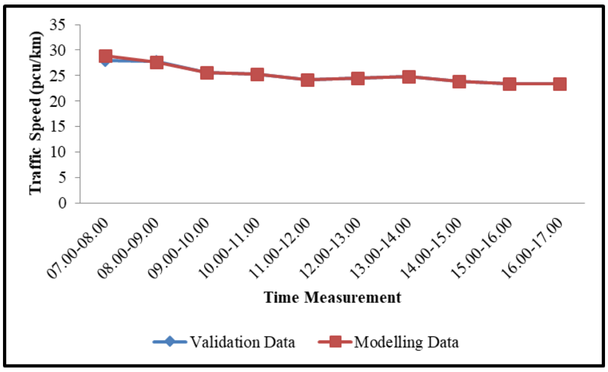

Fig. 7. Comparison of Trafic Speeds on A. Yani Road between modelling data and validation data

It can be seen from Figure 6 and Figure 7 that traffic volume have inversely proportional with traffic speeds, that is the higher the traffic volume, the lower the traffic speed.

3.3 Comparison of CO concentrations

Comparison of CO concentrations on A.Yani Road between modelling and validation measurement can be seen in Figure 8. It can be seen that CO concentrations have similar patern and have increasingly values from morning to afternoon.

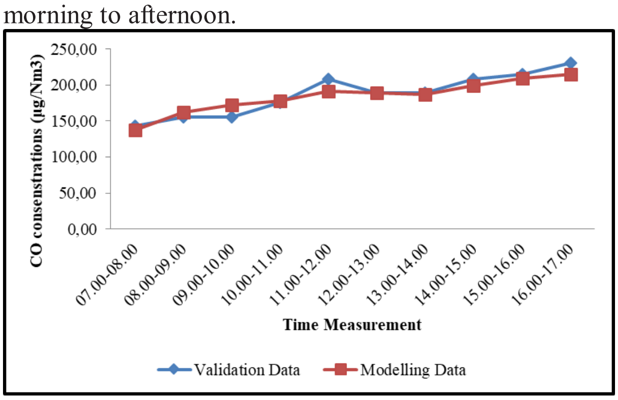

Fig. 8. Comparison of CO concentrations on A. Yani Road between modelling data and validation data

Figure 8 shows CO concentration increases from morning to afternoon, that is along with traffic volume in Figure 6. It can be seen that CO concentration has very strong correlation with Traffic volume [13].

3.4 CO concentrations model based on the wind coming angle directions

The amount of pollutant concentration depends on wind speed, wind direction, atmospheric boundary layer, solar radiation and temperature [14-15]. Beside that, pollutant concentration also effected by dynamics of wind strength and wind direction [16]. According to [8], wind coming angle directions (α) influence the amount of CO concentration in the roadside area. CO concentration based on traffic volume decreased by 27.09% from α 90° to α 60°, 37.77% from α 90° to α 30° and α 90° to 0° by 64.62%. Meanwhile, based on traffic density, CO concentration decreased by 22.95% from α 90° to α 60° , 38,61% from α 90° to α 30° and by 65,50% from α 90° to 0° [8]. Based on the data of traffic characteristics and meteorological conditions by [8], statistical model of CO concentration is resulted as model 1.

$$C_{CO} = 0{,}03V_T - 10{,}577S_T - 4{,}129S_W + 6{,}28\,\alpha + 429{,}897 \quad (1)$$

Where: C_{CO} = CO concentration
V_T = traffic volume
S_T = traffic speed
S_W = wind speed
α = wind coming angle direction (0 to 90)

3.5 Validation of model using the two-variance test formula

The result of two variance test done for CO concentration between validation value and concentration of model value can be seen in Table 1.

Table 1. Two-variance test of CO model

Parameter	Critical Point	R_{uf}	Test Result
CO	2.102	0.480	not significant differrent

From the test results of two variances obtained R_{Uf} value of 0.480. This value is smaller than the critical point limit value (R_{Uf} < 2.102), this means that there is no significant difference between the CO model concentration and the CO concentration of validation.

3.6 Validation of model using the Pearson product moment formula

The result of two variance test is done for CO concentration between validation value and concentration of model value can be seen in Table 2.

Table 2. The Pearson product moment formula.

Parameter	R_{count}	R_{table}	Test Result
CO	0,961	0,361	valid

It can be seen that R_{count} is higher than R_{table}, it means that the model is valid and can be used in determining CO concentrations. Figure 9, Figure 10 and Figure 11 show the comparison of CO concentrations between data from measurement and data from model 1.

Coefficient of determination is a statistical analysis that evaluate how well a model explains and predicts the real condition. In this case, comparison between CO model and CO measurement show the high coefficient of determinations. It means CO model can predict CO concentration for the roadside area with different meteorological condition and traffic characteristics. However, the model predicted CO with small value of α is better than larger α.

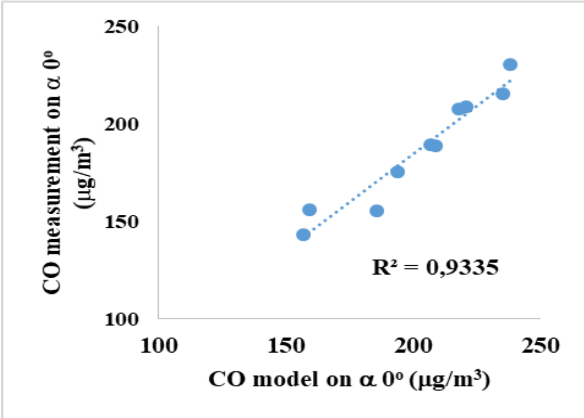

Fig. 9. Comparison between CO model and CO measurement on α 0°

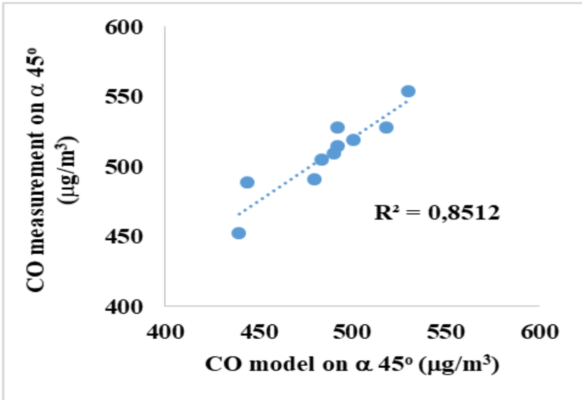

Fig. 10. Comparison between CO model and CO measurement on α 45°

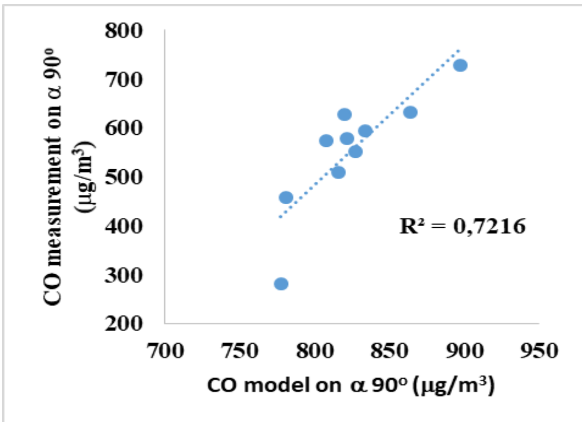

Fig. 11. Comparison between CO model and CO measurement on α 90°

4 Conclusions

Validation test using Test Two Variance got the critical point value equal to 2,102. The Test Ratio (R_{Uf}) value of the CO model has a value smaller than the critical point value. This shows no significant difference between the concentration of model and the concentration of the validation data. Since the R_{Uf} value is small from the critical point, the model can be declared valid and can be used in predicting CO concentrations. The validation test using Pearson Moment Formula yields R table value of 0.361. The Pearson Moment Formula shows the value of R is greater than R_{table}. This shows a model is valid for use in predicting CO concentrations. The coeficient of determination shows the model with small α can predict CO concentration better than larger α.

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