Street-service-level approach towards the calculation of CO emission in Malang City, Indonesia

D M Utomo, A Bakkara and K E Sari

Department of Urban and Regional Planning, Faculty of Engineering, Universitas Brawijaya, Malang, Indonesia

dadang.utomo@ub.ac.id

Abstract. Malang has shown an annual vehicle growth of 15%. However, it is an umfortunate fact that 32% of 44 main streets are identified as having low service level, according to a local transportation ranking report. Such condition results in the decline of average vehicle velocity, approaching to the level of velocity (v) = 0; or in other words, street saturation degree could reach >1. The condition is not proportional to the increase of CO concentration in Malang in 2013-2014 as shown in the result of Evaluation of City Air Quality in 2014 which jumped from 3000 μm/m^3 in 2013 to almost 5000 μm/m^3 in 2014. This study was aimed at evaluating the extend to which street-service-level variables influence the production of CO emission from motorized transportation activity in an urban street in Malang. Gatot Subroto Street is chosen as a case study according to Multi Criteria Analysis. Furthermore, the street-service-level variables being evaluated include vehicle volume, velocity, side friction, effective roadside width and effective street width. Through a qualitative statistical analysis approach using a multiple linear regression analysis, the result suggests that vehicle volume and side friction are the most dominant factors (Xi) that significantly influence CO emission loads (Y).

1. Introduction

The number of motor vehicle registered in City of Malang in 2015 reached 512,072 vehicles and based on Document of Local Transportation Ranking in City of Malang in 2015-2035, the number of vehicle increases 15% annually. The number excludes vehicles that come from other regions as a result of regional movement. The geographical location of Malang is considered strategic in East Java because City of Malang is surrounded by Regency of Malang and has regional connection with City of Surabaya, Blitar, Lumajang, Pasuruan, Kediri and with some tourism objects. Such condition becomes the main factor of the intensity of external-external and external-internal movements in City of Malang.

Unless there is an effective control, the traffic growth in city of Malang as mentioned above will likely result in the decline of average vehicle velocity, approaching to velocity (v) = 0 or in other words, street saturation degree (volume/capacity) could reach >1 [1]. From the data, it can be seen that 32% of 44 main streets in City of Malang have low serviceability level [2]. Beside the growth of vehicle as its prominent cause, traffic jam is also caused by lack of existing street facility capacity or the activities that cause the deterioration of existing capacity. Tamin (2000) explained that activities such as vehicles parking along the roadside or street vendors using roadside for selling-buying activities force pedestrians to use the street and such condition will reduce street capacity in and as its consequence the street does not have capacity as initially planned [3]. The condition of street serviceability as determined by factors such as vehicle volume, velocity and street network characteristics such as effective roadside width, effective street width and side friction as determinants for capacity greatly influences efficiency and effectiveness of vehicle movement [4]. Consequently, if it is not planned optimally or if disruption is still present, vehicle, and volume shows linear growth, and saturation degree will reach >1.

Traffic jam causes environmental issues such as air pollution whose intensity keeps increasing especially for CO gas. Fardiaz (2010) described that 60% emission produced by vehicle is carbon monoxide [1]. Furthermore, transportation contributes 90% CO gas in air. The study tries to analyze how serviceability level influences the production of CO emission load from motor vehicle through the evaluation of determinant factors of street serviceability level. The study will evaluate whether factors that so far have been regarded as the base of estimation for street serviceability level can significantly influence the existing CO emission production. The focus of this study is limited only on the production of emission gas. Its background builds upon the evaluation result of Indonesia's National Department of Environment (2014) that showed the concentration increased in 2013-2014 in City of Malang as well as CO gas concentration that is much more dominant in comparison to other emission gas from total emission produced by motor vehicle [5]. Street corridor that would be analyzed was street corridor considered a prioritized artery that had been previously determined through the use of Multi Criteria Analysis method.

2. Methodology

2.1. Multi Criteria Analysis

We carried out Multi Criteria Analysis to determine 1 prioritized street out of 44 artery streets in City of Malang. The decision was made by at least 6 experts who have expertise in research area [6]. The applied criteria to determine prioritized street in this study consisted of pavement quality, street dimension, traffic pattern, saturation degree, and area usage. The determination of those criteria was based on past studies.

2.2. Characteristic Analysis of Determinant Factors of Street Serviceability Level

In this study we applied characteristic analysis of determinant factors of street serviceability level to describe or illustrate effective street width, velocity, effective roadside, vehicle's volume and side friction. For vehicle volume, vehicle unit was converted into passenger car unit (pcu). We carried out the analysis of side friction by summing up all present weight based on MKJI 1997 with weighting categories such as the number of pedestrians walking and crossing along street segment (Pedestrian/PED) with weight of 0.5, the number of stationary vehicles with weight of 1.0, the number of vehicles moving in and out parking area (Parking and Slow Vehicles/PSV) with weight of 0.7 and the number of slow moving vehicles (Slow Moving Vehicles/SMV) with weight of 0.4.

2.3. Analysis of Vehicle CO Emission Load

We conducted the analysis of vehicle emission load to reveal the production of CO gas emission in street under our study by previously collecting data of vehicle volume in accordance with vehicle type, total street length and CO emission factor [7]. The applied formula was

$$E_p = \sum_{i=1}^{n} L \times Ni \times Fpi \tag{1}$$

Where:

L = Street length under current study
Ni = Number of type i vehicles that pass on the street (vehicle/hour)
Fpi = Emission factor of type i vehicle (g/Km)
i = Vehicle type (1 ñn)
Ep = Emission intensity from certain street (g/hour/km)
P = Estimated pollutant type

2.4. Multiple Linear Regression Analysis
In this study, we applied Multiple Linear Regression Analysis to know the influence of determinant factors of street serviceability level on the emission production (CO) of motor vehicle. Subsequently some tests were also conducted to ensure whether the resulted model was feasible or not. The applied test would be Model Feasibility Test that comprised of Model Reliability Test (F Test), Determination Coefficient Test, Regression Coefficient Test (T Test), and Classical Assumption Test that consisted of Normality Test, Multicolinearity Test and Heteroscedasticity Test.

2.5. Research Variables
Variables used in the study were based on previous studies as shown in the following table:

Table 1. Research variables.

No	Variable	Sub Variables
1	Street Condition	Street Pavement Quality
		Street Dimension
2	Activity	Area Usage
3	Accessibility	Traffic pattern
		Saturation Degree
4	CO emission load from motor vehicle	Street length
		CO gas emission factor
		Vehicle volume
5	Determinant Factors of Street Serviceability Level	Effective street width
		Velocity
		Effective roadside
		Vehicle volume
		Side Friction

3. Results

3.1. Prioritized Street
There were 19 primary artery streets and 23 secondary artery streets included into multi criteria analyses. Based on secondary data and the result of 5 criteria weighting by 10 experts from Transportation Department of City of Malang, Environment Department of City of Malang, Regional Planning and Development of City of Malang and Street Construction and Maintenance Division in Public Works Department, it was recognized that criterion with the highest weight was saturation degree. Moreover, Gatot Subroto Street showed the highest total score out of other 41 streets with total weight of 2933.33 or normalized score of 3.25%. It showed that Gatot Subroto Street had AN existing condition that was assumed to be able to produce emission load from motor vehicle that was higher than that of other streets. General Gatot Subroto Street is located in Kelurahan Jodipan, Kecamatan Blimbing that spans 0.713 km long. This street is A primary artery street that functions as national road to connect City of Malang with Malang Regency and Pasuruan Regency. The location of Gatot Subroto Street and the division of research segments can be seen in the following figure:

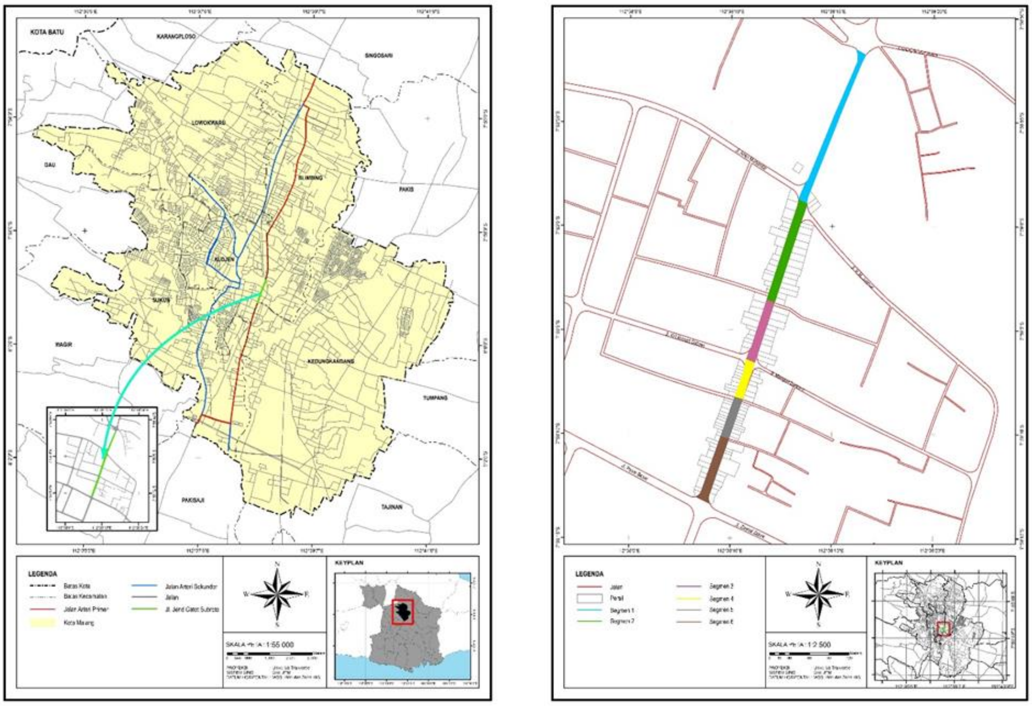

Figure 1. (a) The location of General Gatot Subroto Street; (b) The division of Gatot Subroto Street segments.

3.2. Characteristic of Determinant Factors of Gatot Subroto Street Serviceability Level

3.2.1. Vehicle volume and average velocity

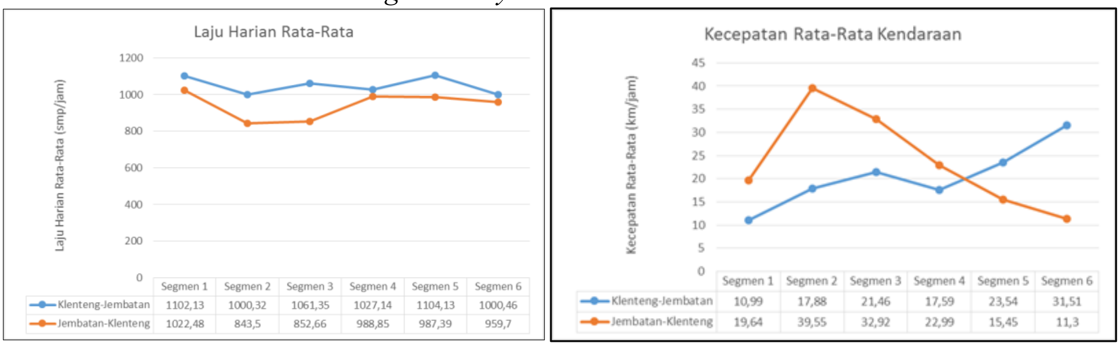

Figure 2. (a) Average daily speed; (b) Average velocity

3.2.2. Street Width and Effective Roadside

Table 2. Characteristic of street width and effective roadside width.

Segment	Side	Roadside Width (m)	Effective Roadside Width (m)	Street Width (m)	Effective Street Width (m)
1	East	0.30	0.30	4.00	4.00
	West	0.35	0.35	4.00	4.00
2	East	1.43	0.72	5.40	5.00
	West	1.60	0.75	5.40	5.00
3	East	1.43	0.72	5.40	5.40
	West	1.60	0.75	5.40	5.00

Segment	Side	Roadside Width (m)	Effective Roadside Width (m)	Street Width (m)	Effective Street Width (m)
4	East	3.06	0.70	4.00	4.00
	West	2.20	0.70	4.50	4.50
5	East	3.06	0.70	4.00	4.00
	West	2.20	0.70	4.50	4.50
6	East	3.06	0.70	4.00	4.00
	West	2.20	0.70	4.50	4.50

3.2.3. Side Friction
There were 3 types of side friction in Gatot Subroto Street; the number of pedestrians who walk and cross along the street in each segment (PED), the number of parking and slow vehicles (PSV) and slow moving vehicles (SMV).

Table 3. Side friction.

Segment	West Side				East Side				Total Weight for Both Sides	Side Friction Class
	PED	PSV	SMV	Total Weight	PED	PSV	SMV	Total Weight		
1	0.00	30.00	24.00	54.00	0.00	20.00	30.00	50.00	104.00	Low
2	18.00	26.00	25.20	69.20	13.50	30.00	23.20	66.70	135.90	Low
3	10.00	25.00	29.20	64.20	12.50	22.00	28.00	62.50	126.70	Low
4	24.50	13.00	18..00	55.50	18.50	9.00	17.20	44.70	100.20	Low
5	15.50	10.00	18.80	44.30	11.00	12.00	19.20	42.20	86.50	Very Low
6	12.00	17.00	26.00	55.00	16.50	8.00	17.20	41.70	96.70	Very Low

3.3. CO Emission Load of Gatot Subroto Street
The analysis of CO Emission Load was carried out for six segments and routes. After carrying out the analysis of load emission for 1 week, the data conversion of total CO emission load was conducted for 1 year with the use of the following formula: Emission Load in 1 year (ton/year) = Total Emission Load in 1 week (gr/week) X 48 (weeks) X 10-6. The result of the analysis of CO emission load for 1 year is presented as follows:

Table 4. CO emission load of Gatot Subroto street.

Segment	Flow Direction	Total Emission Load for 1 week (gram/week)	Emission Load in 1 year (ton/year)	Emission Load in 1 year per segment (ton/year)
1	Klenteng-Jembatan	1289797.22	61.91	115.90
	Jembatan-Klenteng	1124763.74	53.99	
2	Klenteng-Jembatan	772740.87	37.09	66.36
	Jembatan-Klenteng	609712.84	29.27	
3	Klenteng-Jembatan	482994.81	23.18	40.76

Segment	Flow Direction	Total Emission Load for 1 week (gram/week)	Emission Load in 1 year (ton/year)	Emission Load in 1 year per segment (ton/year)
	Jembatan-Klenteng	366137.66	17.57	
4	Klenteng-Jembatan	290305.32	13.93	26.43
	Jembatan-Klenteng	260253.97	12.49	
5	Klenteng-Jembatan	345804.07	16.60	30.26
	Jembatan-Klenteng	284574.54	13.66	
6	Klenteng-Jembatan	518328.72	24.88	46.63
	Jembatan-Klenteng	453030.03	21.75	
Total		**6798443.80**	**326.33**	**326.34**

3.4. Multiple Linear Regression Analysis

There were 3 times OF modeling with the different number of independent variables. However 12 samples (6 segments and 2 directions) and 1 dependent variable (CO emission load) were still used. Model 1 showed that velocity variable and effective street width variable had coefficient value that positively influenced Y so the result could not be accepted because it didn’t conform to the existing theory. In model 2, those two variables were excluded and the result showed that only volume variable and side friction variable had sig value <0.05. Consequently, in model 3 vehicle volume variable and friction side variable were included with the following result:

3.4.1. Feasibility Test Model

1) Model Reliability Test (F test)

Count prob. F values (sig) in model 1, model 2 and model 3 were 0.000. Three models had significant values smaller than error (alpha) that was 0.05. As a result, we concluded that the estimated linear regression model was feasible to apply in order to describe the influence of Side Friction, Effective Roadside Width, Volume, Velocity and Effective Street Width on Emission Load (dependent variable).

2) Determination Coefficient

R value in model 3 was 0.986 so it means that the influence of vehicle volume and side friction on Load Emission was 98.6% (0.986 x 100%). Moreover, R square value of 0.973 showed that the influence proportion of vehicle volume variable and side friction variable on Emission Load was 97.3% while the rest, 2.7% (100%-97.3%) was influenced by other variables that were not included in this model.

3) Regression Coefficient Test (T Test)

Table 5. Regression coefficient test

Model		t	Sig.
1	(Constant)	-3.327	.016
	Volume	12.114	.000
	Effective Roadside Width	-.096	.926
	Velocity	.388	.712
	Effective Street Width	.208	.842
	Side Friction	.772	.469

Model		t	Sig.
2	(Constant)	-4.156	.003
	Volume	15.773	.000
	Effective Roadside Width	.126	.903
	Side Friction	2.330	.048
3	(Constant)	-4.906	.001
	Volume	17.596	.000
	Side Friction	2.494	.034

The previous table describes that in model 1 the variable that significantly influenced dependent variable was vehicle volume while in model 2 in which velocity and effective street width were excluded the result showed that the variables that significantly influenced dependent variable were vehicle volume and side friction so in model 3 the included variables were volume and side friction and the result showed that both variables were significant in the model.

3.4.2. Classical Assumption Test

1. Normality Test

In model 1 skewness ratio was 0.278/0,637 = 0.436; while kurtosis ratio was -0.522/1,232 = -0.424. In model 2 skewness ratio was 0.426/0.637 = 0.669; while kurtosis ratio was -0.007/1.232 = -0.006. In model 3 skewness ratio was 0.448/0.637 = 0.703; while kurtosis ratio was 0.025/1.232 = 0.020. Because skewness ratio and kurtosis ratio in all models were between -2 and +2, so it could be concluded that data distribution was normal.

2. Multicollinearity Test

From the result of multicollinearity test we knew that all independent variables either in model 1, 2, OR 3 had VIF value smaller than 10 and tolerance value bigger than 0.1. Consequently, we concluded that those variables didn’t have any multicollinearity issue.

3. Heteroscedasticity Test

After carrying out heteroscedasticity test with glejser method, the result showed that t-statistic values from all independent variables either in model 1, 2 OR 3 were not significant so we concluded that this model did not have any heteroscedasticity issue.

3.4.3. Model Interpretation

Table 6. Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
3	(Constant)	-17.857	3.639		-4.906	.001
	Volume	.052	.003	1.025	17.596	.000
	Side Friction	.062	.025	.145	2.494	.034

The formed equilibrium is as follows:

$$Y = -17.857 + 0.052 X_1 + 0.062 X_5 \quad (2)$$

Where:
Y = Emmision Load (gr/hour per meter of street length)
a = -17.857 (Constant)
X1 = Vehicle volume (pcu/hour)
X5 = Side Friction (present weight/hour)
b1 = 0.052 (Variable coefficient of vehicle volume)
b5 = 0,062 (Variable coefficient of side friction)
Model interpretation can be carried out as follows:

1. b1 value = +0.052

When side friction (X5) is constant, each increase in vehicle volume value (X1) of one pcu/hour will increase emission load (Y) to 0.050 gr/hour per meter of street length.

2. b5 value = +0.062
   When vehicle volume (X1) is constant, each increase in side friction value (X5) of one present weight/hour will increase emission load (Y) to 0.062 gr/hour per meter of street length.

4. Conclusion

The result of Multiple Linear Regression analysis shows that from 5 variables, variables that significantly influence dependent variable are vehicle volume and side friction. When volume and side friction increase, CO emission load from vehicle will also increase. And the comparison of two coefficients shows that coefficient of side friction variable has higher value than coefficient of vehicle volume variable. It shows that side friction gives more influence on CO emission production than vehicle volume.

References

[1] Panjaitan, T. P. M., 2010. Model Pengelolaan Transportasi Berkelanjutan Di Kawasan Pinggiran Metropolitan. Disertasi. Postgraduate Program Institute of Agriculture Bogor. Bogor
[2] Tataran Transportasi Lokal Kota Malang Tahun 2015-2035. Dinas Perhubungan Kota Malang. Malang.
[3] Tamin, O. Z. Perencanaan Dan Permodelan Transportasi. 2 ed. Bandung: Penerbit ITB; 2000.
[4] Manual Kapasitas Jalan Indonesia. 1997. Directorate General Bina Marga. South Jakarta.
[5] Evaluasi Kualitas Udara Perkotaan Tahun 2014. Kementerian Lingkungan Hidup. East Jakarta.
[6] Mendoza, G. A and Macoun, P. Panduan Untuk Menerapkan Analisis Multikriteria Dalam Menilai Kriteria Dan Indikator. 1 ed. Jakarta: Center For International Forestry Research (CIFOR); 1999.
[7] Minister of Environment Regulation No. 12 Year 2010. Pelaksanaa Pengendalian Pencemaran Udara Di Daerah. 26 March 2010. Minister of Agriculture in Environmental Planning. Jakarta.