PERENCANAAN WILAYAH DAN KOTA

LAPORAN PENELITIAN

KATEGORI A

PENGARUH TINGKAT PELAYANAN JALAN TERHADAP JEJAK KARBON TRANSPORTASI KOTA MALANG

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TATA LOKA

The Effect of Street Level of Service (LOS) on CO Emission in Malang City

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Abstract: Vehicle emissions are closely related to the degree of saturation, namely traffic flow with a degree of saturation more than 0.8 will cause an increase of emissions. Based on Rencana Induk Jaringan Jalan Terintegrasi Malang Raya in 2016, there are several roads in Malang City with a degree of saturation more than 0.8 so that gas emissions on these roads have a high concentration. This study aims to determine the street level of service factors that affect motor vehicle CO emissions in Malang City through multiple linear regression analysis. In this study, the dependent variable is CO emissions and the independent variables are the effective road and shoulder width, average vehicle speed, traffic volume, side friction and road type. The results of the multiple linear regression equation indicate that the variable volume of vehicles (X1), width of the effective road (X4) and road type (X6) have a significant effect on the CO emissions load.

Keywords: Carbon Monoxide Emission, Multiple Linear Regression, Street Level of Service,

Introduction

Transportation sector has contributed 80% to air pollution followed by emissions from industry, forest fires and household activities (Haryanto, 2018). This shows that the transportation sector has the largest contribution to air pollution. Motor vehicles produce various types of emissions such as carbon monoxide (CO), nitrogen oxides (NOx), hydro carbon (HC), sulfur dioxide (SO2), lead (Pb) and carbon dioxide (CO2). From several types of motor vehicle emissions, carbon monoxide (CO) is one of the most common types of emission gases produced by motor vehicles with a percentage of 76.4% (Hodijah & Amin, 2014)

The concentration of CO emission in the air in one day is influenced by motor vehicle activity. The more crowded the motori vehicles, the higher the level of emissions produced (Zhang et al, 2013). Cities with heavy traffic will produce relatively higher CO emission so that it can have a bad impact on health (Diken et al., 2017).

Malang City as the second largest city in East Java which has a population of 927,285 people, has a tendency to use private vehicles as the main choice in carrying out transportation activities (Ekawati et al., 2013). Data from the Central Statistics Agency of Malang City notes that in 2019 the number of motor vehicles in Malang City has reached 602,973 units of vehicles with an average development of about 15% per year and does not include the number of vehicles from outside the region entering Malang every day or every holiday. (Department of Transportation Malang City, 2016).

The movement of motor vehicles from another region to Malang City is getting easier with the Malang-Pandaan Toll Road as an alternative road from Surabaya City to Malang City. The existence of the Malang-Pandaan Toll Road has an impact on increasing the volume of vehicles due to the large number of road users moving towards the entrance and exit of the toll road, which can cause the decreasing of street level of service on surrounding street (Ravanelli, 2018). According to the Document of Local Transportation Malang City in 2016, the street network that will be directly affected by the operation of the toll road is the street that becomes access to continuous movement to the south (Kepanjen, Turen and Blitar). while for access to the west to Batu City, some will still pass-through Malang City.

Based on the Masterplan for the Integrated Street Network of Greater Malang in 2016, there are 21 street in Malang City that have a street level of service more than or equal to D with a degree of saturation greater than 0.8 which has unstable and restrained traffic flow conditions. The street sections include North A. Yani Street in the South-North direction, SP Sudarmo Street, Panji Suroso Street, A. Yani Street north-south direction, A. Yani Street south-north direction, J.A. Suprapto north-south direction, L. Sutoyo street north-south, Arif Margono street, Kyai Ageng Gribig street, Lesanpuro street, Gatot Subroto street, M. Sungkono street, K. Sugiyono street, Ranu Grati street, Soekarno Hatta street, Satsuit Tubun street, S. Supriadi street, Kauman street, Mayjend Panjaitan street, MT. Haryono street and Tlogomas street. This shows that the direct or indirect impact on the operation of the toll road has an impact on the decrease of street level of service in Malang City. According to Muziansyah et al., (2015), street level of service is closely related to vehicle emissions. If the traffic flow is close to capacity or has a degree of saturation more than 0.8, i.e., unstable vehicle conditions (stop and moving), will cause an increase in emissions and noise.

When viewed from the level of air pollution, the concentration of CO emissions in Malang City has increased from 2013-2014. In 2013, the production of CO emissions in Malang City was 3000 μg/m3 and increased by 5000 μg/m3 in 2014 (Utomo et al., 2017). The increase in CO emission production indicates that CO emissions in Malang City have the potential to continue to increase every year along with the increasing number of motor vehicles on Malang City.

The relationship between vehicle emissions and a low street level of service is not only caused by traffic volume, but also by activities that disrupt road space that reducing road capacity (Sari et al., 2016). Referring to the street level of service data that listed in Masterplan for the Integrated Street Network of Greater Malang in 2016, this study will identify roads that have low street level of service with the assumption that roads with low service levels are roads that produce high CO emission load.

Method

This study was conducted on the Malang City roads which have a degree of saturation greater than 0.8, namely on North A. Yani Street in the South-North direction, SP Sudarmo Street, Panji Suroso Street, A. Yani Street north-south direction, A. Yani Street south-north direction, J.A. Suprapto north-south direction, L. Sutoyo street north-south, Arif Margono street, Kyai Ageng Gribig street, Lesanpuro street, Gatot Subroto street, M. Sungkono street, K. Sugiyono street, Ranu Grati street, Soekarno Hatta street, Satsuit Tubun street, S. Supriadi street, Kauman street, Mayjend Panjaitan street, MT. Haryono street and Tlogomas street. This study was conducted by analyzing motor vehicle CO emissions, street level of service analysis and multiple linear regression analysis to determine the street level of service factors that affect the amount of motor vehicle CO emissions in Malang City.

The data collection on the type of vehicle in this study was carried out through a primary survey to to find out the categories of motor vehicles that pass the study location. The data from the survey then will be used as a comparison to convert the volume of vehicles that have been listed in the Masterplan for the Integrated Street Network of Greater Malang in 2016. The survey to count the volume of vehicle was not carried out primarily considering that during the current Covid-19 pandemic conditions, restrictions on activities outside the home are imposed. so that the movement of motor vehicles is reduced.

The first analysis is a street level of service analysis that identified based on the degree of saturation based on the Indonesian Road Capacity Guidelines (PKJI) 2014 with the following equation (Jatmika et al, 2018)

$$D_J = Q/C$$

Where:
DJ = degree of saturation
Q = vehicle volume
C = capacity

Through that equation, it is known that the street level of service is determined by the volume of vehicle and the capacity of the road. The road capacity is then known from the following equation:

$$C = Co \times FCw \times FCsp \times FCsf \times FCcs$$

Where:
C = Capacity (skr/hour)
Co = Basic Capacity (skr/hour)
FCLJ = Road width adjustment factor
FCPA = Direction separation adjustment factor
FCHS = Side friction adjustment factor

FCUK = City scale adjustment factor

The second analysis is the emission analysis which is determined based on the number of vehicles (vehicle/hour), emission factor (g/km/vehicle) and road length (km). The equation used in calculating the amount of motor vehicle emissions is then known from the following equation (Sekaryadi & Wimpy 2017):

$$E = \sum_{i=1}^{n} L \times Ni \times Fi$$

Where:

L = Street length (km)
N = Number of type i vehicle (vehicle/hour)
F = CO emission factor for type i vehicle (gr/km)
i = Vehicle type
E = Emission intensity (gr/hour)

The third analysis is multiple linear regression analysis which is used to find out the relationship of more than one independent variable (Agustin et al, 2017). Multiple linear regression analysis in this study was used to determine the effect of the street level of service on the amount of CO emissions of motor vehicles.

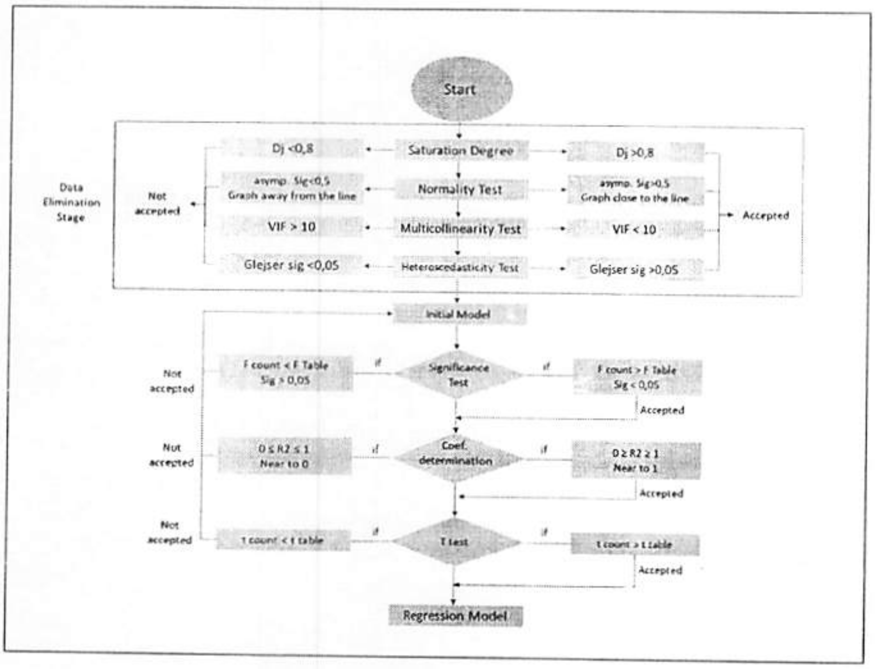

Figure 1. Multiple Linear Regression Analysis Flowchart

In this study, the dependent variable is the amount of CO emissions of motor vehicles (gr/hour) while the independent variables are the effective road width (meters), average vehicle speed (m/hour), roadside width (meters), traffic volume (skr/hour), side friction (weight/hour) and road type (score). The city scale factor is not included in the independent variable because the population used is the population of Malang City so that the city size factor for each street is same. In addition, the data used in this analysis are roads that are classified as low service based on the results of the street level of service analysis, with a degree of saturation more than 0.8.

Result and Discussion

Street Level of Service

The level of road service is determined based on the comparison of the volume of vehicles with road capacity. The road capacity then measured based on the basic capacity (Co), the effective road width adjustment factor (FCLJ), the direction separation adjustment factor (FCPA), side friction adjustment factor (FCHS), and city scale adjustment factor (FCUK). The results of the road service level analysis are as follows:

Table 1. Factor and Street Level of Service

Street Name	Basic Capacity (Co)	Road Width (FC_W)	Direc. separation (FC_{SP})	Side Friction (FC_{HS})	City Scale (FC_{UK})	Capacity (C)	Volume	Degree of saturation (D_j)	Street Level of Service
a	*b*	*c*	*d*	*e*	*f*	*b.c.d.e.f=g*	*h*	*g/h*	*i*
North A. Yani Utara (South-North)	1650	1,08	1,00	0,96	0,94	1608,1	3102	1,93	F
Panji Suroso Street	2900	1,29	1,00	0,96	0,94	3375,9	4689	1,39	F
Sunandar Priyo Sudarmo	2900	1,29	1,00	0,96	0,94	3375,9	4438	1,31	F
A. Yani (North-South)	1650	1,08	1,00	0,96	0,94	1608,1	3216	2,00	F
A. Yani (South-North)	1650	1,08	1,00	0,96	0,94	1608,1	3478	2,16	F
J.A Suprapto (North-South)	1650	1,08	1,00	0,94	0,94	1574,6	3016	1,92	F
L. Sutoyo (North-South)	1650	1,08	1,00	0,94	0,94	1574,6	3016	1,92	F
Arif Margono	2900	1,25	1,00	0,96	0,94	3271,2	4201	1,28	F
Kyai Ageng Gribig	2900	1,25	1,00	0,94	0,94	3203,1	2509	0,78	D
Lesanpuro	2900	1,00	1,00	0,96	0,94	2616,96	2643	1,01	F
Gatot Subroto	2900	1,34	1,00	0,94	0,94	3433,7	4627	1,90	F
Mayjend Sungkono	2900	1,34	1,00	0,96	0,94	3506,7	2599	0,74	C
Kolonel Sugiono	2900	1,34	1,00	0,96	0,94	3506,7	3694	1,05	F
Ranu Grati	2900	1,25	1,00	0,96	0,94	3271,2	3928	1,20	F
Soekarno Hatta	3300	1,08	1,00	0,97	0,94	3249,7	5580	1,72	F
Satsuit Tubun	2900	1,14	1,00	0,94	0,94	2921,2	4201	1,44	F
S. Supriadi	2900	1,34	1,00	0,96	0,94	3506,7	3696	1,05	F
Kauman	1650	1,08	1,00	0,96	0,94	1608,1	2224	1,38	F
Mayjend Pandjaitan	2900	1,34	1,00	0,94	0,94	3433,7	3162	0,92	E
MT. Haryono	2900	1,34	1,00	0,94	0,94	3433,7	2967	0,86	E
Tlogomas	2900	1,34	1,00	0,94	0,94	3433,7	1943	0,57	C

Based on the calculation of the street level of service in Table 1, almost all of the roads in the study area are categorized with level F of service with a degree of saturation more than or equal to 1. The level F of service represents traffic jams at low speeds. Tlogomas Street and Mayjend Sungkono Street have C service category, where vehicles have speed limits. Then, Ki Ageng Gribig street has a D service category, where the traffic flow is approaching unstable. As well as MT Haryono street and Mayjend Pandjaitan street have E service category, where the flow is at its capacity and the traffic flow often stops. Based on the results of the analysis, it can be seen that the Ki Ageng Gribig street, Mayjend Sungkono street and Tlogomas street have a degree of saturation less than 0.8 so it can be assumed that these roads have no effect on CO emissions on the Malang City roads.

Carbon Monoxide (CO) Emission Load

CO emissions of motor vehicle in this study are influenced by the length of the road, the number of vehicles and vehicle emission factors. Vehicle emission factors based on the Minister of Environment Regulation No. 12 in 2010 are divided into 5 groups, motorcycles, diesel cars (diesel vans/minibuses, diesel jeeps, and diesel pickups), gasoline cars (sedans, gasoline vans/minibuses, taxis, gasoline jeeps and gasoline pickups), buses and trucks.

Table 2. CO Emission Load in Malang City

Street Name	Emission Total (gr/hour)
North A. Yani Utara (South-North)	85497,55
Panji Suroso Street	278326,68
Sunandar Priyo Sudarmo	386102,22
A. Yani (North-South)	291589,96
A. Yani (South-North)	289365,44
J.A Suprapto (North-South)	153449,04
L. Sutoyo (North-South)	148826,48
Arif Margono	94372,54
Kyai Ageng Gribig	434714,18
Lesanpuro	71859,44
Gatot Subroto	150908,05
Mayjend Sungkono	612233,43
Kolonel Sugiono	524684,87
Ranu Grati	98792,74
Soekarno Hatta	1386634,66
Satsuit Tubun	166953,98
S. Supriadi	668165,94
Kauman	34749,22
Mayjend Pandjaitan	250014,58
MT. Haryono	233793,86
Tlogomas	178814,64

Carbon monoxide (CO) emissions load from motor vehicles based on Table 2. can be seen that the highest emission load is produced on Jalan Soekarno Hatta, which has 1,386,634,66 gr/hour, this is because the number of motor vehicles on that road also has high volume. Overall, the types of vehicles that produce the most emissions are motorcycles at 55.3%, then gasoline cars at 43.4%, diesel cars at 0.4%, buses at 0.1% and trucks at 0.8%.

Multiple Linear Regression Analysis

Multiple linear regression analysis in this study uses 1 dependent variable, namely emission load and 6 independent variables, namely volume of vehicles, effective roadside width, average vehicle speed, effective road width, side friction and road type.

Table 3. Multiple Linear Regression Analysis Input Data

No	Street Name	Y CO Emission (kg/hour/km)	X_1 Volume (skr/hour)	X_2 Effectife Roadside Width (m)	X_3 Vehicle Speed (km/jam)	X_4 Effectife Road Width (m)	X_5 Side Friction (weight/hour)	X_6 Road Type
1	North A. Yani Utara (South-North)	85,49	3102,00	0,81	37,00	6,00	68,90	4,00
2	Panji Suroso Street	278,33	4689,00	0,75	28,00	10,00	37,30	1,00
3	Sunandar Priyo Sudarmo	386,10	4438,00	0,65	39,00	10,50	17,10	1,00
4	A. Yani (North-South)	291,59	3216,00	0,56	21,00	6,00	63,00	4,00
5	A. Yani (South-North)	289,37	3478,00	0,56	23,00	6,00	72,10	4,00
6	J.A Suprapto (North-South)	153,45	3016,00	0,65	36,00	8,00	176,00	4,00
7	L. Sutoyo (North-South)	148,83	3016,00	0,47	28,00	8,00	37,30	4,00
8	Arif Margono	94,37	4201,00	0,77	22,00	9,00	94,70	1,00
9	Lesanpuro	71,86	2643,00	0,56	25,00	7,50	81,90	1,00
10	Gatot Subroto	150,91	4627,00	0,69	21,00	11,00	143,20	1,00
11	Kolonel Sugiono	524,68	3694,00	0,50	26,00	13,00	81,70	1,00
12	Ranu Grati	98,79	3928,00	0,50	37,00	9,00	20,80	1,00

No	Street Name	Y CO Emission (kg/hour/km)	X_1 Volume (skr/hour)	X_2 Effectife Roadside Width (m)	X_3 Vehicle Speed (km/jam)	X_4 Effectife Road Width (m)	X_5 Side Friction (weight/hour)	X_6 Road Type
13	Soekarno Hatta	1386,63	5580,00	0,58	38,00	16,00	142,00	2,00
14	Satsuit Tubun	166,95	4201,00	0,37	29,00	8,00	33,20	1,00
15	S. Supriadi	668,17	3696,00	0,63	22,00	12,00	45,70	1,00
16	Kauman	34,75	2224,00	0,59	28,00	9,00	26,80	4,00
17	Mayjend Pandjaitan	250,01	3162,00	0,52	36,00	11,00	104,70	1,00
18	MT. Haryono	233,79	2967,00	0,65	20,00	11,00	141,20	1,00

There are 2 models in this multiple linear regression analysis, where the first model uses the independent variables of volume of vehicles, effective roadside width, average vehicle speed, effective road width, side friction and road type, it is known that only the variable volume of vehicles, effective road width and the type of road that has a significant value less than 0.05. So that the second model only uses the variable volume of vehicles, effective road width and road type.

Multiple linear regression analysis is carried out by conducting several tests to ensure the accuracy of the regression function, including the Classic Assumption Test consisting of the Multicollinearity Test, Heteroscedasticity Test and Normality Test and the Model Feasibility Test consisting of the F Test, T Test and Coefficient of Determination Test.

The classic assumption test used in this study is the normality test, multicollinearity test and heteroscedasticity test. The normality test was carried out using a p-plot graph and the Kolmogorov-Smirnov test which in both models showed that the data were normally distributed. The results of the multicollinearity test showed that there was no multicollinearity between the independent variables in the regression model. And the heteroscedasticity test was carried out through the Glejser test with both regression model results not containing heteroscedasticity. So that both regression models have fulfilled all of the classical assumptions.

The model feasibility test on the F test results in the first model is 0.004 with an R square value of 0.779 and in the second model it is 0.000 with an R square value of 0.762. This explains that the two regression models are feasible to use and shows that the influence of the independent variables in the first model is 77.9% while the remaining 22.1% is influenced by other variables that not included in the model, while the influence of the independent variables in the second model is 76.2% while the remaining 23.8% is influenced by other variables that not included in the model.

After the classical assumption test and model feasibility test fulfilled, then it is known that the coefficient of each independent variable (X) which shows the magnitude of its contribution to the dependent variable (Y). The results of the regression analysis in this study are as follows:

Table 4. Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1143.579	396.395		-2.885	.015
	volume	.156	.069	.414	2.252	.046
	lbahu	-360.311	428.026	-.127	-.842	.418
	kecepatan	-1.959	7.100	-.042	-.276	.788
	ljalan	97.053	24.996	.801	3.883	.003
	hambatan	-.072	1.063	-.011	-.068	.947
	tipejalan	109.251	41.071	.493	2.660	.022
2	(Constant)	-1361.233	281.507		-4.836	.000
	volume	.142	.061	.377	2.321	.036
	ljalan	97.212	20.826	.803	4.668	.000
	tipejalan	103.877	35.779	.469	2.903	.012

a. Dependent Variable: emisi

The following are the results of the multiple linear regression model:

$$Y = -1361{,}233 + 0{,}142X1 + 97{,}212X4 + 103{,}877X6$$

Where:

Y = CO emission load (kg/hour/km)

A = -1361,233 (constant)
X1 = volume of vehicle (skr/hour)
X4 = effective road width (meter)
X6 = road type
b1 =+0,142 (volume of vehicle coefficient)
b4 = +97,212 (road width coefficient)
b6 = +103,877 (road type coefficient)

Discussion

The constant value of the regression equation model shows the estimated of CO emission load (Y) when all independent variables (X) are zero. That means, if the volume of vehicles (X1), effective road width (X4) and road type (X6) are zero, then the estimated amount of CO emission load (Y) is -1361,233 kg/hour/km. This condition can be said that the reduction in CO emission production can still occur from the influence of other variables besides of volume of vehicles, effective roadside width, average vehicle speed, effective road width, side friction and road type. Given the results of the coefficient of determination (R2), namely in the resulting model, 23.8% is influenced by other variables not included in the model.

The variable volume of vehicles (X1) in the model has a significance value of <0.05 so that the variable volume of vehicles has a significant effect on the CO emissions load. The regression coefficient on the variable volume of vehicles is positive, which means that every increase in the value of the variable volume of vehicles by 1 skr/hour will increase the CO emissions load by the value of the coefficient b1. In the regression model, an increase in the volume of vehicles by 1 skr/hour will increase the CO emissions load by 0.142 kg/hour/km. Increasing the volume of vehicles can affect the CO emissions load. The survey results show that the contribution of motorcycles and gasoline cars is 98.7% where according to Bachtiar & Alfirna (2017) vehicles with gasoline fuel produce more CO emissions than vehicles with diesel fuel. Thus, if the volume of vehicles in Malang City increases, the CO emissions load in Malang City will also increase.

The effective road width variable (X4) in the model has a significance value of <0.05 so that the effective road width variable has a significant effect on the CO emissions load. The regression coefficient on the effective road width variable is positive, which means that every increase in the value of the effective road width variable by 1 meter will increase the production of CO emissions by the value of the coefficient b4. In the regression model, an increase in the effective road width of 1 meter will increase the production of CO emissions by 97.212 kg/hour/km. Thus, if the effective road width in Malang City widening, then the CO emissions load in Malang City will also increase. This can happen because with the widening road, there will be an increase in the volume of vehicles, according to Puspasari (2016), road widening and additional lanes on roads in urban areas will have a positive effect on increasing road capacity. However, the increasing of road capacity mean that there will be an increase in traffic volume on these roads, that has a negative impact on the environment, namely air and noise pollution.

The road type variable (X6) in the model has a significance value of <0.05 so that the road type variable has a significant effect on the production of CO emissions. The regression coefficient on the road type variable is positive, which means that every increase in the value of the effective road type variable by 1 unit will increase the production of CO emissions by the coefficient value b6. In the regression model, increasing the type of road, such as adding 1 unit of lane, will increase the production of CO emissions by 103.877 kg/hour/km. The positive relationship between road type and emissions can be explained based on the statement of Purnawan et al., (2010) and Pangesty et al., (2021) that increasing the number of lanes will increase the average speed of the vehicle and if the average speed increases, fuel consumption will also increase. Where, the higher used of fuel consumption, the higher the amount of emissions (Sukarno et al., 2016).

Conclusion

The results of the CO emissions analysis shows that the most emissions are produced by motorcycles by 55.3% then gasoline cars by 43.4%, diesel cars by 0.4%, buses by 0.1% and trucks by 0.8 %. Based on the results of multiple linear regression analysis where the dependent variable (Y) is the CO emissions load and the independent variable (X) is the volume of vehicles, the effective road width and the type of road, it can be seen that the linear regression model is feasible to use to explain the effect of volume of vehicle, width effective road and road type on CO emissions load. The effect of volume of vehicles, effective road width and road type is 76.2% while the remaining 23.8% is influenced by other variables that not included in the model. So that the results of the multiple linear regression equation are Y= -1361,233 + 0.142X1 + 97,212X4 + 103.877X6. From the results of these equations, it shows that the variable volume of vehicles (X1), the variable effective road width (X4) and the variable type of road (X6) have a significant influence on the production of CO emissions load.

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