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Measurement of Carbon Dioxide Emission Level at Urban Intersections in Bandar Maharani Muar

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Abstract: Nowadys, the amount of carbon dioxide emissions, which is one of the most dangerous greenhouse gasses, is getting worsen . Increasing amount of traffic on roads might be one the main contributing factors. The aim of this study is to analyse the measurement of carbon dioxide emission level at urban intersections in Bandar Maharani, Muar. Therefore, the objectives that need to be fulfilled are to measure the emission of carbon dioxide at urban signalized intersection and to determine correlation between carbon dioxide emission and intersection's measure of effectiveness parameters such as degree of saturation, delay, and queue distance. Data were collected from secondary data that was taken from previous traffic studies in Bandar Maharani Muar. The data were then analysed using SIDRA Intersection 8.0. The outcomes were obtained from the output of carbon dioxide emission model and tabulated to the Microsoft Excel for statistical analysis. Other outcomes from all intersections such as degree of saturation, delay and queue distance were used to determine the correlation with cardon dioxide emission. Based on the analysis, each intersection produces different amount of carbon dioxide. the highest emission of carbon dioxide was recorded at intersection 006, while the least amount of the carbon dioxide emission was recorded at intersection 005. The values of correlation coefficient obtained shows that the relationship is a strong linear relationship between carbon dioxide emission and all parameters. In conclusion, the higher the degree of saturation, delay and queue distance of intersection, the higher its carbon dioxide emission produce. Therefore, intervention to reduce the emission of carbon dioxide should be implemented in order to develop a low carbon district.

Keywords: Bandar Maharani Muar, CO_2 Emission, Sidra Intersection 8.0, Urban Intersection

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1. Introduction

Nowadays age of increased globalisation, everyday carbon dioxide (CO_2) emissions are on the rise. As it has reached the greatest level ever recorded, carbon dioxide is considered to be one of the

most dangerous greenhouse gases. The weather and climate systems of our planet have been altered as a result of the impact that CO_2 has had. The term "global warming" refers to an increase in average global temperatures; however, climate change encompasses not just this phenomenon, but also the occurrence of severe weather, the elevation of sea levels, and the movement of animal populations and their habitats..

The emissions produced by urban transportation represent a major portion of the total emissions produced in metropolitan regions [1]. CO_2 reduction is one of the potential solutions. It is very necessary for the general viability and sustainability of the earth. According to the International Energy Agency (IEA), the world's transportation industry was the second greatest emitter of CO_2 in 2008, accounting for 22 percent of worldwide CO_2 emissions. This ranking was based on the sector's contribution to global transportation [2]. Because of the constant flow of traffic, urban areas are also responsible for the production of significant volumes of carbon dioxide. It has been projected for a very long time that the increased traffic movements that would likely follow from global growth and higher prosperity is likely result in an increase in transportation CO_2 emissions if the usage of fossil fuel energy is not limited [3].

Ministry of Environment and Water (KASA) has also chosen a different method of sustaining Malaysia's current level of carbon emissions in order to avoid the possibility of further development of Malaysia's climate change [4]. This decision was made in order to prevent possible further development of Malaysia's climate change.

The objectives of this study are to measure the emission of carbon dioxide at urban signalized intersection and to determine correlation between carbon dioxide emission and intersection’s measure of effectiveness parameters such as degree of saturation, delay, and queue distance.

2. Methodology

This section provides explanation of the methodology used in this research. The flow chart for the whole methodology is depicted in **Figure 1**.

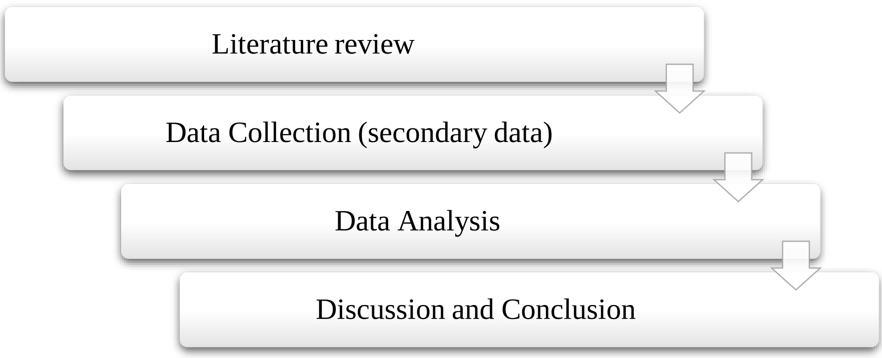

Figure 1: Flow chart of overall study

This study starts with literature review to survey the method use for running the analysis of carbon emission in intersection. Then, this study continue with finding raw secondary data which contain level of service at the intersection along Jalan Bakri. This leads to analyse the carbon emission based on the secondary data. The software used for analyse the carbon emission is Sidra Intersection 8.0. It shows the exact amount of carbon emission produced at every intersection. Lastly, all of the data discussed are taken from the most busiest intersections in Bandar Maharani Muar.

3.1 Study Location

This study uses secondary raw data from the intersection studies in Bandar Maharani particularly at Jalan Bakri. On top of that, the data were completely relevant and ready to be analysed using the Sidra Intersection 8.0 software.

List of study location can be referred in **Table 1**.

Table 1: Study locations

No	Intersection of Jalan Bakri -
001	Muar Bypass
002	Jalan Dato Haji Kosai
003	Jalan Haji Abdullah
004	Jalan Sialin
005	Jalan Haji Jaib
006	Jalan Pesta 2
007	Jalan Sakeh
008	Jalan Dato Haji Hassan/ Jalan Bentayan
009	Jalan Bakri Roundabout

2.2 Sidra Intersection

Sidra Intersection is a software that supports the modelling of various Movement Classes (Light Vehicles, Heavy Vehicles, Buses, Bicycles, Large Trucks, Light Rail/Trams, and six User Classes) with varying vehicle characteristics. Standard performance measurements such as delay, queue length, and number of stops are supplied, as well as measures to aid in environmental and economic analyses. Extensive graphical displays show signal timing and output performance [5]. The evaluated data are required to calculate the corelataion coefficient based on carbon emission level at the intersections.

The emission of Carbon Dioxide (CO_2) is calculated by the emission models function from Sidra Intersection 8.0 software with some steps [6].

Step 1 $$f_t = \alpha + \beta_1 P_T + [\beta_2 a P_I]_a > 0 \quad \text{for } P_T > 0$$
$$= \alpha \quad \text{for } P_T \leq 0 \qquad \textbf{Eq. 1}$$

Step 2 $$P_T = \min(P_{max}, P_c + P_1 + P_G) \qquad \textbf{Eq. 2}$$

Step 3 $$P_C = b_1 v + b_2 v^3 \qquad \textbf{Eq. 3}$$

Step 4 $$P_1 = M_V\, a\, v / 1000 \qquad \textbf{Eq. 4}$$

Step 5 $$P_G = 9.81 M_V \left(\frac{G}{100}\right) v/1000 \qquad \textbf{Eq. 5}$$

Step 6 $$\alpha = \frac{f_i}{3600}$$ **Eq. 6**

Where,

f_t	=	instantaneous fuel consumption rate (mL/s),
P_T	=	total tractive power (kilowatts, kW),
P_{max}	=	maximum engine power (kW),
P_C	=	cruise component of total power (kW),
P_I	=	inertia component of total power (kW),
P_G	=	grade component of total power (kW),
R_T	=	total tractive force (kilonewtons, kN) required to drive the vehicle,
G	=	road grade (per cent), negative if downhill,
M_v	=	vehicle mass (kg) including occupants and any other load,
v	=	instantaneous speed (m/s) = v (km/h) / 3.6,
a	=	instantaneous acceleration rate (m/s^2), negative for deceleration,
α	=	constant idle fuel consumption rate (mL/s), which applies during all modes of driving (as an estimate of fuel used to maintain engine operation),
f_i	=	3600α = constant idle fuel consumption rate in mL/h,
b_1	=	vehicle parameter related mainly to the rolling resistance (kN),
b_2	=	vehicle parameter related mainly to the aerodynamic drag ($kN/(m/s)^2$),
β_1	=	the efficiency parameter which relates fuel consumed to the total power provided by the engine, it can be shown to be fuel consumption per unit of energy (mL/kJ or g/kJ), and
β_2	=	the efficiency parameter which relates fuel consumed during positive acceleration to the product of acceleration rate and inertia power when n = 1.0 [$mL/(kJ.m/s^2)$ or $g/(kJ.m/s^2)$].

The instantaneous cruise fuel consumption rate $(a = 0, P_I = 0)$ on a on a level road $(G = 0, P_G = 0)$ is given by:

$$fct = \alpha + \beta_1 P_C$$ **Eq. 7**

$$fct = \alpha + \beta_1 (b_1 v + b_2 v^3)$$ **Eq. 8**

$$fct = \alpha + c_1 v + c_2 v^3$$ **Eq. 9**

Where,

$$C_1 = b_1\beta_1$$ **Eq. 10**

$$C_2 = b_2\beta_1$$ **Eq. 11**

Where the parameter units are mL/m for c_1 and $(mL/m)/(m/s)2$ for c_2.

Eq. 9 is used as an important part of the model calibration method for fuel consumption. After parameters c_1, c_2 and β_1 are determined through calibration, the following model parameters are calculated.

Parameters A and B specified as input for software are calculated from:

$$A = 1000\ C_1$$ **Eq. 12**

$$B = C_2 / 0.01296 \quad \textbf{Eq. 13}$$

Where the parameter units are mL/km for A and $(mL/km)/(km/h)2$ for B.

Parameters b_1 and b_2 are determined indirectly from:

$$b_1 = c_1 / \beta_1 \quad \text{if } \beta_1 > 0 \quad \textbf{Eq. 14}$$
$$= 0 \quad \text{if } \beta_1 = 0$$

$$b_2 = c_2 / \beta_1 \quad \text{if } \beta_1 > 0 \quad \textbf{Eq. 15}$$
$$= 0 \quad \text{if } \beta_1 = 0$$

The following simpler model is obtained as an alternative model by dropping the (a P_I) term of *Equation (1)*:

$$f_t = \alpha + \beta\, P_T \quad \textbf{Eq. 16}$$
$$= \alpha$$

Where parameters are as in **Eq. 1**.

The values of instantaneous *Carbon Dioxide (CO_2)* emission rate (g/s as a value per unittime) are estimated directly from the instantaneous fuel consumption rate:

$$f_t(CO_2) = f_{CO_2} ft(fuel) \quad \textbf{Eq. 17}$$

Where,

$f_t(fuel)$ = fuel consumption rate in mL/s and,
f_{CO_2} = CO_2 to Fuel Consumption Rate in grams per milliliter (kg per liter) of fuel $(g/mL \text{ or } kg/L)$

The model for calculating instantaneous Carbon Monoxide (CO), Hydrocarbons (HC), and Nitrogen Oxides (NOx) emission rates (mg/s), which represents the emission production rate at any instant during the trip as a value per unit time, has the same structure as the model for estimating instantaneous fuel consumption with different parameters.

3. Results and Discussion

The results of this research being analyse by using Sidra Intersection software because it can produce various type of data such as total carbon emission, degree of saturation, delay and queue distance. This data are required to make correlation between carbon emission and other data.

3.1 Carbon Dioxide emission

The emissions of greenhouse gases are commonly related to industrial activities and transportation sectors [7]. Carbon dioxide (CO_2) emissions from urban transportation are causing increasing concern around the world [8]. Carbon dioxide emission have three factors indicators which are supply factors, demand factors and environmental factors. Population density and growth rates are both a demographic and economic variable. Population growth increases traffic turnover, demand, and pressure.. The intersections are divided into nine and each approaches have their own carbon dioxide emissions. Each approaches and total carbon dioxide emission are as shown in **Table 2**.

Table 2: Results of carbon dioxide emission at intersections

Intersection	**Carbon Dioxide Emission(kg/h)**					**Total Carbon Dioxide Emission (kg/h)**
	Aproaches					
	South	**East**	**Northeast**	**North**	**West**	
001	402.9	1124.6		231.9	1445.8	3205.2
002	1174.6	183.2		-	408.5	1766.3
003		322.8		478.5	403.1	1204.5
004	29.3	339.9			124.5	493.8
005	258.8	211.1			119.2	589.2
006		2517.6		559.6	171.6	3248.8
007		191.8	256.0		1775.2	2223.0
008	64.1	217.8		228.2	228.2	663.6
009	629.2	85.8		100.0	731.0	1546.0

3.2 Degree of saturation, delay and queue distance

Degree of saturation or volume capacity ratio is symbolize as a key indication of traffic performance. When flow increases, the travel time also increase, which is how the link between the two can be described mathematically [9]. The poorer the traffic performance, the higher the saturation value. Besides, The total delay in a time period is calculated by integrating the queue size over time [10]. Delay in traffic is vehicle's increased travel time after entering an intersection and before reaching free-flow speed is referred to as junction delay. The distance from the stop line to the rear of the most recent vehicle stopped in a single lane during a red light within one signal cycle is known as the queue length [11]. All of this data is shown in **Table 3**.

Table 3: Results of degree of saturation, delay and queue distance

Intersection	Degree of Saturation (volume/capacity ratio)	Delay (s)	Queue Distance (Average) (m)
001	2.35	437.7	1297
002	3.36	445.4	746
003	1.46	187.4	594
004	0.97	38.9	826
005	1.16	75.8	411
006	3.96	905.2	1904
007	1.97	522.8	1193
008	1.66	89.2	229
009	1.52	293.7	741

3.3 Correlation Coefficient

Correlation is a statistical link or measure of dependency between two random variables or two sets of data. The relationship between two variables is a strong positive The analysis of accumulating and dispersing nodes as well as correlative influence variables of traffic demand improved the traditional correlation coefficient method for forecasting corridor traffic demand. **Table 4** shows the correlation coefficient value.

Table 4: Correlation Coefficient

Between Carbon Emission	Correlation Coefficient
Degree saturation	0.76
Delay	0.90
Queue distance	0.88

Referring to **Table 4**, the value of correlation coeffiecient between degree of saturation and carbon dioxide is 0.76.Then the correlation between carbon dioxide and delay is 0.9 and lastly between carbon dioxide and queue distance produced a value 0.88. These value shows strong linear positive value because nearly 1.

3.3 Discussions

Figure 2 is the summary of all the data collected for analyse the Carbon Dioxide Emission in Bandar Maharani Muar.

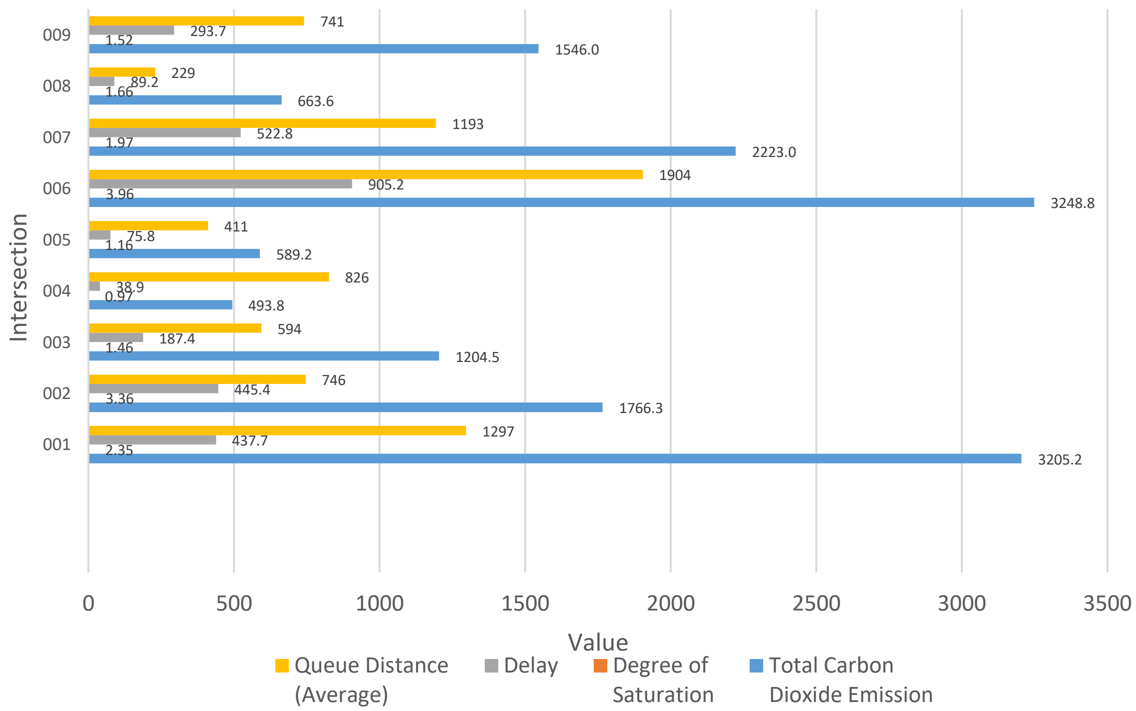

Figure 2: Charted bar collected along Jalan Bakri, Muar

Referring to Figure 2, Jalan Pesta 2 (006) recorded the highest value of amount of the CO_2 emission, while intersection 005, which is Jalan Haji Jaib recorded the least amount of the CO_2 emission. As the amount of CO_2 emissions recorded, the value is compared to the degree of the saturation, delay and queue distance. All of the data are tabulated and used to generate a clustered bar to compare all of the data obtained from all of the intersection. Lastly, the correlation coefficient is determined to prove whether there is a presence of relationship between the amount of CO_2 and degree of saturation, delay and queue distance.

4. Conclusion

In conclusion, the objectives of the research were fulfilled. The emission of CO_2 at urban signalized intersection, consists of 9 intersections along Jalan Bakri, Muar were measured. The correlation coefficient between CO_2 emission and degree of saturation, delay, and queue distance were also determined. From the result of correlation coefficient, there is a strong positive linear relationship between the CO_2 emission and degree of saturation, delay, queue distance and queue distance, as the value is nearly to the value of 1 because it produces such accurate results, Sidra is one of the better software options for calculating carbon emissions. So, the higher the degree of saturation, delay and queue distance of any intersections, the higher the amount of CO_2 emissions. Hopefully in the future, there will be a study that able to identify the allowable amount of CO_2 at signalized intersection so that the amount of CO_2 emission can be controlled and fulfil the low carbon policies stated by KASA. Future study needs to find the value of allowable amount of CO_2 emission that have a similar unit between the standard and the software used.

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