IOP Conference Series: Earth and Environmental Science

PAPER • OPEN ACCESS

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To cite this article: H S Huboyo *et al* 2018 *IOP Conf. Ser.: Earth Environ. Sci.* **106** 012075

Activities of four bus terminals of Semarang City gateway and the related GHG emission

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Abstract. The activities of the bus terminal, including loading-unloading passengers, bus idling, and bus movements at the terminal, will emit GHG's emission. This research analyzes GHG emission from four terminals, i.e., Mangkang, Terboyo, Penggaron, and Sukun in Semarang City. The emission was estimated by observing detail activities of public transport means, especially for moving and idling time. The emission was calculated by Tier 2 method based on the vehicle type as well as fuel consumption. The highest CO_2e during vehicle movements at Sukun area was contributed by large bus about 2.08 tons/year, while at Terboyo terminal was contributed by medium bus about 347.97 tons/year. At Mangkang terminals, the highest emission for vehicle movements was attributed by medium bus as well of about 53.18 tons/year. At last, Penggaron terminal's highest GHG emission was attributed by BRT about 26.47 tons/year. During idling time, the highest contributor to CO_2e was the large bus at the three terminals, i.e., Sukun of 43.53 tons/year, Terboyo of 196.56 tons/year, and Mangkang of 84.26 tons/year, while at Penggaron, BRT dominated with CO_2e of 26.47 tons/year. The management of public transport in terminals is crucial to mitigate the emission related to bus terminals activities.
Keywords: air pollution, bus, CO_2e, Semarang, terminals, vehicle

1. Introduction

The demand for travel in cities worldwide is increasing. This travel is closely related to economic and social needs of the people. In Indonesia, the growth rate of motorization is about 7–12% per year which far beyond the rate of road development. Other developing nations share the same condition where road capacities fail to compensate the traffic growth [1]. Transport activities consist of road and non-road activities. In the case of public transport, road activities mean serving passengers to their specific destination, while non-road transports are usually related to the activities of vehicles at terminals where they will substantially emit air pollutants due to small movements, idling, and engine starting (hot-cold start). In the case of running mode, the fuel consumption commonly will increase as the vehicle engine speed escalates [2]. During idle time, the fuel consumption is higher than in running operation [3]. The engine cold start mode means initiating the vehicle after 6–12 hours of being shut down [4]. In general, cold start mode will emit much higher air pollutants compared with the hot start mode [5]. In fact, there are many other factors which significantly affect the vehicle's emission while it is in running mode, e.g., vehicle size, engine displacement, and driving conditions [6].

The emission of air pollutants will affect the workers as well as the passengers in bus terminals. The cyclist with low movements, long idling time, and cold start engine will simultaneously add up to the air pollutants near the vehicles. Cheng [7] studied that the ultrafine particles (UFP) concentration inside the bus terminal is more than ten times of ambient urban background UFP. Thus, knowing the potential emission of air pollutants in the bus terminal is a fundamental part to mitigate the air pollution comprehensively. This study aims to identify the potential emission of GHG due to bus terminal activities, particularly from vehicle movements and idling time.

2. Research Method

2.1. Location of study
The study took place at four bus terminals in Semarang City as listed in Table 1.

Table 1. Bus terminals location.

Bus Terminals	*Lat Long Coordinates*	*Corridor Connection*	Remarks
Mangkang	6°58'06.0"S 110°17'22.8"E	West	Gateway fromWest
Penggaron	7°01'03.2"S 110°29'36.8"E	East	Gateway from East (Purwodadi)
Sukun	7°03'43.9"S 110°24'48.3"E	South	Gateway from South not intended as an official bus terminal
Terboyo	6°57'04.8"S 110°27'45.5"E	East	Gateway from East (Demak)

2.2. Data collection
The primary data were collected by observation as well as inspection of vehicles while they were running or idling. This idle time means the engine was on, but the vehicle did not move, waiting for passengers to get on it. The vehicles' time and route length to travel within the terminal were also recorded. We define the vehicle route as the course where the vehicle was beginning to enter the bus terminal, passing through the retribution fee, collecting passengers, until leaving the terminal. The data of vehicles' engine capacity were gathered as well to estimate the idling emission. The emission calculation related to idle time [8]:

$$\text{Idling fuel use (L/year)} = (\text{idling fuel flow}) \times (\text{idling time per day}) \times (\text{total vehicle in a year}) \qquad (1)$$

$$\text{Idling emission} = (\text{idling fuel use}) \times (\text{GHG emission factor}) \qquad (2)$$

The number of vehicles entering the terminal for the whole year was gathered from Local Transportation Agency to be compared with those we counted manually on the spot. In this case, the vehicles were classified by the year of manufacturing, i.e., ≤2010, 2011, 2012, 2013, and 2014.

2.3. Emission calculation
The GHG emission was estimated using an equation derived from IPCC [9] as the basis of calculation. The formula is as follows:

$$\text{Emission} = \text{Activity data x Emission Factor} \qquad (3)$$

$$\text{Emission} = \Sigma_{a,b,c}[\text{Fuel}_{a,b,c} \text{ x } \text{EF}_{a,b,c}] \qquad (4)$$

$\text{Fuel}_{a,b}$: fuel consumptions of fuel a and b EF : emission factor (g/L)

The relation between fuel consumption and the vehicle speed was derived as seen in Table 2 using the method researched by JICA through SITRAMP [10]. This approach is useful when the vehicle speed varies. However, it should be noted that these formulas have a limited application, particularly for a very slow speed of the vehicle.

Table 2.The relation between vehicle speed and fuel consumption.

Vehicle Types	Formulas
PC (private car)	y = 7E-05x2 – 0.0077x + 0.2579
MC (motorcycle)	y = 1E-05x2 – 0.0009x + 0.0601
SB (small bus)	y = 3E-05x2 – 0.0029x + 0.1285
MB (medium bus)	y = 5E-05x2 – 0.0056x + 0.2961
Patas-AC, LB (large bus)	y = 3E-05x2 – 0.0029x + 0.1533
S/MT (small/medium truck)	y = 5E-05x2 – 0.0053x + 0.2771
LT (large truck)	y = 5E-05x2 – 0.0060x + 0.3147

x: vehicle speed variable (km/h) y: fuel consumption (L/km)

The emission factors acquired from IPCC and other studies were then combined. The emission factors used in this study are listed in Table 3.

Table 3. Emission factors used in this study.

Vehicle Types		Emission Factors (g/L)					
		Gasoline			Diesel		
		CO_2[a]	CH_4[a]	N_2O[b]	CO_2[a]	CH_4[a]	N_2O[b]
Light vehicle	Paratransit	2780.5	0.3243	0.041			
	Mini bus				4,586.2	0.1157	0.022
Heavy vehicle	Bus				1,593.7	0.0804	0.051

Notes : a[9], b[11]

The observation schedule was arranged sequentially and simultaneously to capture the habitual situation in the field. The observations were conducted twice on weekdays and the weekend for each terminal. Sampling time was set at daytime where the vehicles usually have daily activities (Table 4).

Table 4. Observation schedule at the terminals.

Terminals	Categories	Dates	Sampling Time
Mangkang	Weekdays	16 May 2016	05.30 – 19.00
		27 May 2016	05.30 – 19.00
	Weekend	21 May 2016	05.30 – 19.00
		29 May 2016	05.30 – 19.00
Penggaron	Weekdays	20 May 2016	05.30 – 18.00
		23 May 2016	05.30 – 18.00
	Weekend	22 May 2016	05.30 – 18.00
		28 May 2016	05.30 – 18.00
Sukun	Weekdays	23 May 2016	06.00 – 17.30
		27 May 2016	06.00 – 17.30
	Weekend	14 May 2016	06.00 – 17.30
		22 May 2016	06.00 – 17.30
Terboyo	Weekdays	16 May 2016	06.00 – 17.30
		3 June 2016	06.00 – 17.30
	Weekend	15 May 2016	06.00 – 17.30
		21 May 2016	06.00 – 17.30

3. Results and Discussion

3.1. The condition of the terminals their activities

Mangkang, as an A class terminal, serves transfer passengers from outer cities (Westward) to Semarang. This terminal was initially operated in 2002, and it is more than 21.000 ha wide. Based on the observation, the vehicle speeds within this terminal were around 7–30 km/h. For large bus, the primary idling time was 15 min, while for the small bus was around 5 min. On the other hand, BRT bus had idling time around 20 min, while small bus had 5 min and paratransit had 4 min of idling time.

Penggaron terminal, as a B class terminal, connects passengers from East cities such as Purwodadi, Blora, and Cepu, by smaller vehicles compared to Mangkang. Penggaron terminal, which has been operating since 1997, has an area of 5.7 ha. Due to the lower occupancy of vehicles, the vehicle speeds were a bit higher than those for Mangkang, reaching 12–30 km/h. In this terminal, the BRT, large bus, small bus, and paratransit had the idling time of 17 min, 7 min, 3 min, 3 min, and 3 min, respectively.

Sukun terminal acts as pseudo terminal since it was not intended as an official vehicle terminal. However, due to its strategic location for passenger transfers, many drivers, passengers, and vehicle enterprises make use of this location as a terminal. Beyond idling time, the vehicle speed passing through this terminal was around 10–45 km/h. The idling time for many vehicles was around 2–10 min due to the lacking capacity of the parking area. The large bus had an idling time of 10 min, the medium bus had 4 min, the small bus had 3 min, and paratransit had the smallest duration of 40–50 seconds.

Terboyo terminal, as an A class terminal, serves passengers from or to Semarang from the East such as Demak Regency, Kudus Regency, and Jepara Regency. The vehicle speeds within Terboyo terminal were recorded a bit higher of 20–50 km/h. This terminal has a problem of the diurnal sea water rise. Thus, every time the sea floods occurred, many passengers were reluctant to await the vehicles inside the terminal. The idling time of the large bus, medium bus, and small bus was around 20 min, 15 min, and 5 min, respectively.

From the data provided by Local Transportation Authority, the numbers of vehicles entering these terminals were recorded as follows (Table 5):

Table 5. Numbers of vehicles entering the terminals in 2015.

Terminals	Large Bus	Medium Bus	Small Bus	Paratransit	BRT
Mangkang	63,264	31,671	35,539	64,962	17,160
Penggaron	6,648	5,989	3,021	19,087	17,160
Sukun (*pseudo* terminal)	42,684	15,276	14,556	10,152	9,732
Terboyo	101,242	58,507	33,864	-	-

3.2. Fuel consumption and GHG emission

After inspecting the travel time for each vehicle inside the terminal, the speeds could be predicted, then the fuel consumption for each vehicle could be estimated. The classification refers to the grouping used by Local Transportation Agency (see Table 3). The estimates of fuel consumption are shown in Table 6.

Table 6. Estimated average fuel consumption (L/day) based on vehicle types.

Vehicle Types	Mangkang	Penggaron	Sukun	Terboyo
Large Bus	0.157	0.234	0.030	0.657
Medium Bus	0.417	0.155	0.011	1.423
Small Bus	0.117	0.066	0.004	0.414
BRT	0.100	0.111	0.006	-
Paratransit	0.161	0.159	-	-
Shuttle travel	-	-	0.016	-

It is clear that when the terminal is quite busy, then the fuel consumption also rises. Terboyo terminal is the busiest terminal connecting major cities at the East. The highest emission of moving vehicles was recorded at Terboyo terminal, followed by Mangkang and Penggaron. Interestingly, during idling time, the emission of vehicles at Sukun terminal was higher than that of Penggaron. Based on Figure 1, it is concluded that the moving mode of vehicles does not always yield higher GHG emission compared to idling mode. In general, the large bus has higher emission related to idling mode rather than moving mode. It is due to the long distance routes that these buses had to take so that they took longer idling time awaiting passengers. The emission ratio of moving to idling is even small in Sukun terminal since no regulation prohibits the duration of vehicles to stay at the terminal.

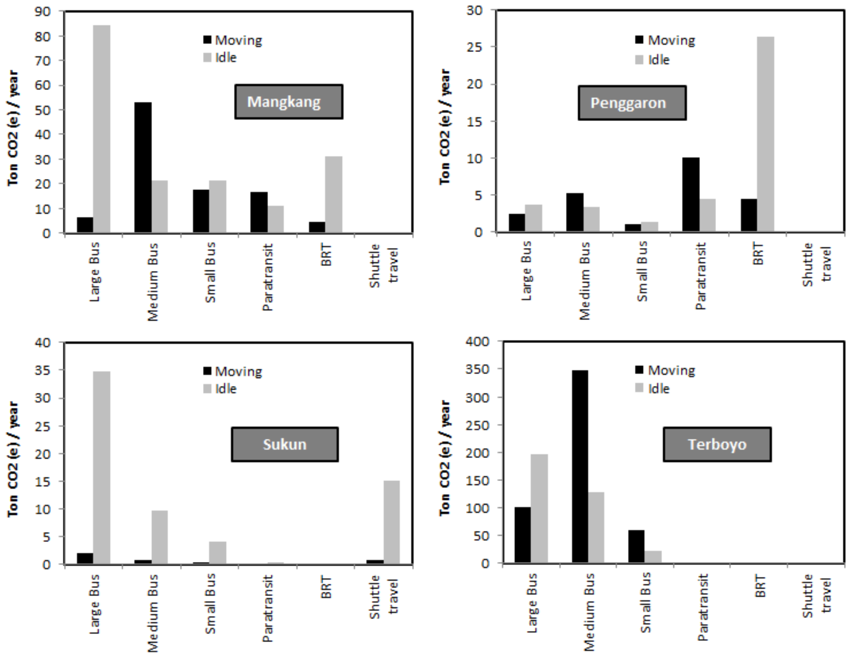

Figure 1. Comparison of moving emission and idling emission.

Based on the field observation and the account that vehicle emissions are closely related to the distance travelled, vehicle speed, the number of vehicles entering the terminal, engine displacement, idling time, and driver behavior, several recommendations are made as follows:
1) Reduce the idling time and shut off the engine if the vehicle is going to stop for a long time.
2) Conduct regular check of engine inspection and rejuvenate the vehicle.
3) Improve the road infrastructure to optimize the vehicle speed within the terminal.
4) Improve the parking management in terminal areas, particularly to minimize on-street parking which may disturb the flow of vehicles entering the terminal.
5) Apply smart driving to the drivers.

4. Conclusion
Activities in the bus terminal of major cities are very complex which may pose a high threatofGHG emission. Therefore, the emission inventory for transportation in the city should consider these activities for depictingthe complete inventory. Valuable information of terminal emission was obtained by calculating the emission regarding the moving mode and idling mode of the vehicles entering the terminals (Mangkang, Penggaron, Sukun, and Terboyo) using Tier 2 method. The activities of each vehicle were summarized based on the vehicle type. The highest CO_2 during vehicle movement at Sukunarea is contributed by large bus about 2.08 tons/year, while at Terboyo terminals is contributed by medium bus about 347,97 tons/year. At Mangkang terminals, the highest emission for vehicle movement is contributed by medium bus about 53.18 tons/year. Lastly, at Penggaron terminal, the highest GHG

emission is attributed to BRT about 26.47 tons/year. During idling time, the highest contributor to CO_2e emission is the large bus at the three terminals, i.e., Sukun of 43.53 tons/year, Terboyo of 196.56 tons/year, and Mangkang of 84.26 tons/year, while at Penggaron, BRT is dominating with CO_2e of 26.47 tons/year. The management of public transport in terminals is crucial to mitigate the emission related to bus terminals activities.

Acknowledgment

This study was supported by Cluster Research Group on Air Pollution Management at Environmental Engineering Department, Diponegoro University. Semarang City Transportation Agency is acknowledged for providing permission to take primary data at the terminals.

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