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Preliminary study on Bandung sustainable urban mobility policy: the contribution of public transportation on emission

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Abstract. Transportation policy in Bandung has advanced to fundamental changes that are environmentally oriented. Mobility is the key driver for development, while type of transportation links between areas and connecting each other to facilitate their economic and social needs. Development of Bus Rapid Transit (BRT) is one of the solutions to reduce the use of private vehicles with the provision of mass transportation. The objective of this study was to describe the existing service of Trans Metro Bandung (TMB) and its emission. The TMB's emission factor is analyzed by using Vehicle Kilometers Travelled (VKT) and fuel consumption in a year. The results showed that the emissions of TMB have influenced the air quality of Bandung. Thus, other alternatives energy is suggested in the development of public transportation (BRT) that supports eco-transportation.

1. Introduction

Increased gas emissions have serious impacts on environmental sustainability, such as pollution, extreme weather, or global warming, and trigger other natural disasters, which can disrupt agricultural production, resources, infrastructure, and public health [1,2,3]. From various research results, it has been known that the source of gas emissions in urban areas consists of three sectors, namely the industrial sector, the transportation sector, and the housing sector [4]. Mitigation efforts need to be done to overcome these problems so that the idea of increasing energy efficiency in the urban transportation sector will arise and buildings have great potential to overcome carbon gas emissions mitigation [4]. Reduction of fuel use and production of exhaust emissions in the transportation sector became the basis for the application of the concept of sustainability transportation. Besides that, there were also terms of eco-transportation and green mobility [5,6,7,8]. As a step towards realizing eco-transportation, the choice of fuel use and the improvement of vehicle engines are important components in the fuel combustion engine to reduce exhaust emissions [7].

Bus Rapid Transit (BRT) is an alternative mode of public transportation that become the choice of countries in the world to reduce the problem of public transportation, especially for developing countries with limitations in funding of urban transportation infrastructure such as train-based mode of transportation [9,10,11]. BRT is also considered as one of the mitigation efforts in reducing carbon emission, which is more effective than the use of public transportation similar to conventional buses with diesel engines in each gram of CO_2 produced by passengers per distance of travel [12,13]. Indonesia's contribution to increasing greenhouse gas emissions was also quite high, with a 4.6% emission rate as the highest increase in Southeast Asia in 2016 [14]. For this transportation problem, in 2006 the City of Bandung began to adapt BRT by implementing Trans Metro Bandung (TMB).

TMB travel routes continue to grow until now they have four travel routes. The implementation of TMB as planned public transportation will continue to be developed. However, there has been no publication that presents data regarding carbon gas emissions resulting from the use of TMB and its relation to the environmental sustainability of Bandung. This research attempts to identify data related to carbon gas emissions produced by TMB. It is expected that with the identification data of TMB carbon gas emissions, it can be known the possible impacts on the environment. In the future, the choice of the best mitigation measures can then be determined for the environmental sustainability of Bandung, which is better and more beneficial for Bandung residents.

2. Method

Data collection was carried out by employing primary and secondary data sources, which were obtained directly from the Bandung City Transportation Agency and direct observations from TMB operations in the city of Bandung. The research is carried out by conducting a review of literature in advance to determine the point of view that can explain the research problem and the right method for calculating emissions.

Transport Emissions	=	Emissions per unit of fuel	x	Total transport service demanded	x	Fuel consumption per unit of transport service

(Sources: Gwilliam et al. 2004)

Figure 1 Factors contributing to Transport Emissions

In calculating carbon dioxide gas emissions from the TMB, we referred method from the IPCC document [15] as follow:

Equation 1 Estimation of Carbon Dioxide Gas Emissions (CO_2)

$$Emission = \sum_{a} \left[Fuel_a \bullet EF_a \right]$$

Emission = Emission of CO_2
$Fuel_a$ = fuel sold (TJ)
EF_a = emission factor (kg/TJ)
a = Type of fuel (e.g. petrol, diesel, natural gas, etc

3. Findings and Discussion

As a country with an annual increase in population and vehicles, Indonesia experiences phenomena that is also happening in other developing countries, where the dependence on private vehicles is quite high and the growth of fuel consumption reaches 4.5% every year [16]. Meanwhile, an increase in the population in the city of Bandung, which is known to increase to 2.6 million annually [17], is also accompanied by the number of motorized vehicles each year, especially private motorized vehicles (see Table 1).

Table 1 The Vehicle Potency in Bandung in 2013-2017

No	Vehicle Type	Amount /Year (Unit)		
		2013	**2015**	**2017**
1	Cars			
	A. Private	318,598	357,580	388,420
	B. Public	7,757	7,749	7,112
	C. Government owned	3,727	4,044	4,330
2	Bus/Microbus			
	A. Private	2,181	2,390	2,616
	B. Public	3,166	3,326	3,742
	C. Government owned	221	345	390
3	Truck, light truck, pick up			
	A. Private	61,604	65,037	70,138
	B. Public	3,181	3,740	4,285
	C. Government owned	1,356	1,516	1,675
4	Heavy Vehicle			
	A. Private	2	3	3
	B. Public	-	-	-
	C. Government owned	3	4	4
5	Motorcycle			
	A. Private	1,030,729	1,158,239	1,314,726
	B. Public	-	-	-
	C. Government owned	10,692	13,049	14,057
	Total	**1,443,217**	**1,617,022**	**1,811,498**

So far, emissions emitted by private vehicles dominate the transportation sector's contribution to urban emissions in several developing countries where increasing numbers of motorized vehicles continue to increase [18]. Bus Rapid Transit (BRT) has become an alternative mode of public transportation, which is the choice of countries in the world to reduce the problem of public transportation related to the effectiveness and magnitude of emissions issued. This alternative mode in the form of BRT is particularly useful for developing countries with limitations in funding of urban transport infrastructure such as train-based mode of transportation [9,10,11]. BRT is also considered one of the mitigation efforts in reducing carbon emission that is more effective than the use of public transportation similar to conventional buses with diesel engines in each gram of CO_2 produced by passengers per distance of travel [12,13]. In another study, it is also stated that in calculating CO_2 estimates, BRT has the greatest potential in reducing emissions with relatively low capital and operational costs compared to Light Rail Transit (LRT) [19]. The use of BRT can accommodate mass transportation needs with more efficient operational and maintenance costs, flexibility in the route of travel, and the use of fuel [13]. In line with various sources and experiences of several countries, in 2006, the city of Bandung adapted BRT by implementing Trans Metro Bandung (TMB). Until now, TMB has four travel routes. The characteristics and maps of the four TMB travel routes are as follows:

Table 2 Characteristics of Trans Metro Bandung

CHARACTERISTICS	CORRIDOR 1			CORRIDOR 2			CORRIDOR 3			CORRIDOR 4		
Route	Cibeureum - Cibiru			Cicaheum - Cibeureum			Cicaheum - Sarijadi			Antapani - Leuwipanjang		
Mileage	22 Km			12 Km			10.5 Km			11.5 Km		
	Type	*Amount*	*Year*	*Type*	*Amount*	*Year*	*Type*	*Amount*	*Year*	*Type*	*Amount*	*Year*
Number of Bus	Micro	10	2006	Micro	-	-	Micro	-	-	Micro	-	-
	Bus	10	2015	Bus	15	2011	Bus	10	2014	Bus	10	2015
$\bar{X}$ Speed	29.2 Km/Hour (min – max: 0 – 35 Km/Hour)											
$\bar{X}$ Idle Traffic Light	85 seconds											
$\bar{X}$ Idle at the stop	30 seconds											
Distance to Pool	3,8 Km			8,9 Km			8,9 Km			12,3 Km		
Vehicle Characteristics	Micro	-		Micro	-		Micro	-		Micro	-	
	Bus	Hino		Bus	Hino		Bus	Hino		Bus	Hino	

Figure 2 TMB Travel Route Map

Of the four TMB travel routes, the distance traveled and estimated TMB fuel consumption in the related routes is analyzed (Table 2).

Table 3 Mileage and TMB Fuel Consumption Estimation

Corridor	Number of Bus	Mileage	Fuel consumption Liter/Year	Fuel consumption TJ/Year	Brand/Type
1. Cibeureum – Cibiru	20	44 Km	1,000,421.05	38.31	Hino RKT
2. Cicaheum – Cibeureum	15	24 Km	409,263.16	15.67	Hino RKT
3. Cicaheum – Sarijadi	10	21 Km	238,736.84	9.14	Hino RKT
4. Antapani – Leuwipanjang	10	23 Km	255,789.47	9.79	Hino RKT

At present, corridor 1 of Trans Metro Bandung has a 22 Km journey with a route from the Cibeureum area to Cibiru and back to Cibeureum, thus traveling 44 Km on one route. In one year, one bus unit on corridor 1 travels 190,080 Km with 20 bus units up to now. Corridor 2 of Trans Metro Bandung has a 12 Km journey with the route from Cicaheum area to Cibeureum and back to Cicaheum, so that it travels

24 Km on one route. Within one year, one bus unit on the corridor 2 travels 103,680 Km with 15 bus units up to now. Corridor 3 of Trans Metro Bandung has a 10.5 Km journey with the route from Cicaheum area to Sarijadi and back to Cicaheum, so that it travels 21 Km on one route. In one year, one bus unit on corridor 3 travels 90,720 Km with 10 buses units up to now. Corridor 4 of Trans Metro Bandung has an 11.5 Km trip with a route from Antapani to Leuwipanjang and back to Antapani, so that it travels 23 Km on one route. In one year, one bus unit on corridor 3 travels 97,200 Km with 10 bus units up to now.

Consumption of fuel oil (solar) on the average of Trans Metro Bandung Hino RK8 brand/type with R 260 bus engine is 1 Liter: 3.8 Km = 0.263157895 Liter/Km. Based on the details of the number of buses and the length of travel in every corridor of Trans Metro Bandung above, the total journey of all corridors in one year is 7,236,000 Km with fuel/oil (solar) consumption of all Trans Metro Bandung buses reaching 1,904,210 Liters/year. If it is converted in terajoules (TJ), where 1 Liter solar is equal to 38.2904317 megajoule (MJ), then solar consumption is 1,904,210 Liters/year which is equal to 72,913 terajoules (TJ). The magnitude of the CO_2 Emission Factors in Indonesia based on the Research and Development Centre For Oil and Gas Technology [20] is 74.10 Tons/TJ, and based on this calculation, it can be known the total emissions in one year:

Emission = ∑ (Fuel x EF)
Fuel = 1,904,210 Liters/year = 72,913 terajoule (TJ)
Emission Factor = 74.10 Ton/TJ
Emission = 5,402.86 Ton/year

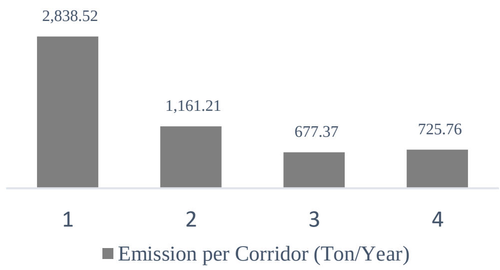

Figure 3 Total Emission per TMB Corridor in 2018

The above calculation shows that TMB contributed 5,402.86 Tons/year of emission to the air environment in the city of Bandung. This is in line with what has been described in various studies that increasing the number of motorized vehicles causes people's dependence on motorized vehicles where these emissions are directly related to the amount of fuel used and the distance of the vehicle [21,22,23,10]. The amount of emissions produced by TMB every year must begin to become our concern, especially regarding its impact on the environment and health. Based on the health sector, it is known that air pollution that includes transportation exhaust emissions with CO_2 and other substances such as Methane (CH_4) and Nitrogen Oxide (N_2O), can turn into toxins and have a major impact on public health, which has the potential to cause diseases, especially in the respiratory problem, heart, or cancer [24,25,26]. Other risks of air pollution are hormonal disturbances in the reproductive system and the neurological system so that monitoring is needed by monitoring policies in air quality control [27].

The priority of the development of public transportation is one of the important alternatives in reducing motorized vehicle use and at the same time reducing carbon emissions, given that the high length of travel and driving intensity are one of the main sources of carbon emissions [28,23,10,29]. This can be seen from various studies conducted in China, India, and South Africa that vehicle exhaust emissions, especially CO_2, are calculated based on the length of the trip with fuel consumption which then results in emission factors [30,31,32,33]. The more often people use private vehicles for mobility, the increased use of fuel and exhaust gases is higher for the contribution of greenhouse gas emissions

[34]. Various alternative modes of transportation that provide options for mobility are expected to reduce the contribution of greenhouse gas emissions in the long-term transportation sector such as electric vehicles, automation, and mobility [34].

Table 4 Three Evolution in Urban Transport
(Source: ITDP, 2017 (www.itdp.org/2017/05/03/3rs-in-urban-transport/))

For illustration, if TMB is operating like business as usual and the assumption of TMB travel demand growth 3% each year hence, there will also be an increase in emissions up to 8,357 Ton in 2022. Regarding the situation, the alternative policy concerning the fuel consumption to reduce the emission is needed.

Business as Usual Scenario	**2 Revolutions (2R) Scenario**	**3 Revolutions (3R) Scenario**
20th Century Technology	*Electrification and Automation*	*Electrification, Automation and Sharing*
Through 2050, we continue to use vehicles with internal combustion engines at an increase rate, and use transit and shared vehicles at the current rate, as population and income growth over time.	We embrace more technology. Electric vehicles become common by 2030, and automated electric vehicles become dominant by 2040. However, we continue our current embrace of single occupancy vehicles, with even more car travel than in the BAU.	We take the embrace of the technology in the 2R scenario and the maximize the use of shared vehicles trips. By 2030, there is widespread ride sharing, increased transit performance-with on-demand avaibility-and strengthened infrastructure for walking and cycling, allowing maximum energy efficiency.
Number of Vehicle on The Road by 2050 = 250 million vehicles		
2.1 billion	2.1 billion	0.5 billion
CO2 Emissions by 2050 = 500 megatonnes of CO2		
4.600 megatonnes	1.700 megatonnes	700 megatonnes

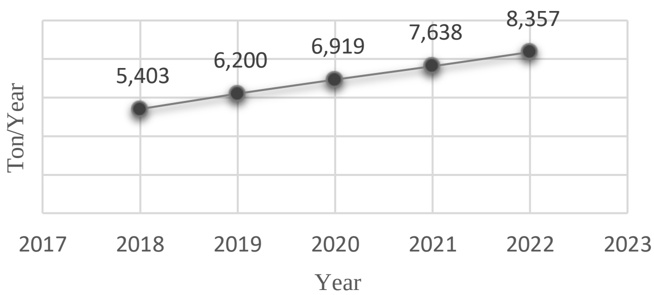

Figure 4 The Increase of Emission from TMB (Business as Usual Scenario)

Deciding on alternatives to public transportation, such as the development of transportation based on roads, railways, or air, which have been carried out by developed countries, especially Asian countries with high population density and heterogeneity of the population, need to be a concern for development planners [35,28,36,29]. Mitigation efforts in environmental preservation, especially the reduction of exhaust emissions from transportation must also be supported by environmental policies in institutional capacity building that are in line with policies in the regional scope. It aims at building air quality management, monitoring systems, fuel conversion implementation, improvement of technology and vehicle (engine) quality, and regular vehicle inspection facilities [37].

Policies related to emissions both national and regional policies have supported efforts to reduce the contribution of greenhouse gas emissions as can presented in the following table.

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Table 5 Legal Framework of Emission Policy in Bandung Municipality

Moving Source Emission Test Policy	Emission Measurement Method	Regional Policy of Bandung
1. Regulation of the President of Republic Indonesia Number 61 of 2011 concerning National Action Plan for Greenhouse Gas; 2. Regulation of the Minister of the Environment Number 05 of 2006 concerning the Threshold of Exhaust Emissions of old motor vehicles; 3. Regulation of the Minister of Environment Number 04 of 2009 concerning the Threshold of Exhaust Emissions of new type motor vehicles.	1. SNI 19-17118.1-2005 concerning the testing of CO/HC levels for motorized vehicles in the category of M, N, and O (four or more wheels) that driven by the fire at idle conditions; 2. SNI 19-17118.2-2005 concerning smoke opacity level test methods for vehicles in the category of M, N, and O (four or more wheels) driven by compression ignition under conditions of free acceleration 3. SNI 19-17118.3-2005 concerning testing of CO/HC levels for motorized vehicles in the category L (motorbike) that driven by the fire at idle conditions; 4. SNI 19-17118.4-2005 concerning immovable source of exhaust emissions by using the method of opacity testing of Ringelmann's scale for black smoke.	1. Regulation of the Mayor of Bandung Number 572 of 2010 concerning Testing of Motor Vehicle Exhaust Emissions Thresholds; 2. Decree of the Mayor of Bandung Number 660/Kep.730-BPLH/2016 Concerning the Formation of a Technical Team for Executing Motor Vehicle Exhaust Emissions in Bandung.

In addition to the support from the above policies, the Bandung City Government is currently implementing a program to convert oil fuel (BBM, *Bahan Bakar Minyak*) to gas fuel (BBG, *Bahan Bakar Gas*) for public transportation. Based on observations and information from the Bandung City Transportation Agency (*Dinas Perhubungan Kota Bandung*), the implementation of the program has not been maximized and the gas fuel users tend to decrease. This is due to the lack of gas fuel infrastructure support compared to oil fuel, gas supply sources, gas fuel user characteristics, and other non-technical constraints such as community habits and awareness. Thus, it is necessary to have a holistic and comprehensive alternative policy from the Government of Bandung that covers various aspects in the effort to mitigate environmental conservation and improve the quality of public services in the transportation sector within the framework of sustainable urban mobility.

4. Conclusion

The application of sustainable urban mobility through TMB, as the basis for BRT development, aims at improving the quality of public transportation services, which can accommodate the needs of mass transportation in the city of Bandung while still paying attention to environmental aspects and the effectiveness and efficiency of operational aspects of TMB.

The policies issued by the Government of Bandung and the national government support the efforts to reduce the contribution of greenhouse gas emissions. However, aspects such as infrastructure support, political commitment, technology and alternative energy, and public awareness support need to be a concern for the Government of Bandung in drafting alternative policies in environmental conservation of mitigation efforts and improving the quality of public transport services that support eco transportation within the framework of sustainable urban mobility.

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