Bandung sustainable urban mobility policy – angkot contribution on public transport emission

A Z Miftah¹,², C K Hesti², M A Raharjo² and A F Khairani³,⁴
¹Public Administration Department, Universitas Muhammadiyah Bandung
²Quadran Energi Rekayasa, AP Management and Policy Research Group, Bandung
³Research Centre of Health System, Faculty of Medicine, Universitas Padjadjaran
⁴Department of Biomedical Sciences, Faculty of Medicine, Universitas Padjadjaran

Abstract. The trend of urban transportation policy has led to the sustainable development agenda specifically in reducing greenhouse gas production. Improvement in public transportation services was needed to decrease the number of private vehicles, which was directly proportional to fuel consumption. Our previous study regarding public transport had been carried out by measuring the contribution of Trans Metro Bandung (TMB) to the emissions in Bandung City. Emissions from other modes of public transportation such as Angkot (fleet of minibus), which had a greater number of units and routes compared to other modes was also needed to be elucidated. This research seeks to identify the contributions of Angkot emissions based on fuel consumption (Tier 2). The results showed that Angkot had a higher contribution to the emissions in Bandung City compared to the contribution of TMB. Therefore, a comprehensive transportation policy scheme was required to create a more integrated management of public transportation and emission standard. Enforcement to the Angkot operators was needed to apply and improve their service management. Thus, in the future, Angkot will be more environmentally friendly.

1. Introduction
Urbanization in developing countries has been recorded to be faster than in developed countries, which is accompanied by various policy challenges due to diversity in development such as the level of economic growth, political-administrative institutions, and culture [1]. Urbanization that is considered as a process of transition and development of urban areas also involves the level of population, land use, economic or cultural activities that result in demographic changes, economic flows, and the environment between rural and urban areas [2]. These developments are generally directly proportional to the growth and population density and the increasing demand for goods and services in urban areas [3][4][5]. Another consequence of population growth is the high mobility or movement of people in accessing various facilities (such as employment, education, health, and entertainment), which then affect the demand for transportation services such as road networks and the availability of transportation [6][7].

Adequate and appropriate transportation policy is one development component that can support productivity, economic growth, and equitable distribution of infrastructure development [8][9]. However, providing transportation is inadequate. Several studies explain the existence of several problems from population growth with transportation systems that are not sustainably managed,
including the increase of private vehicle ownership, road congestion, fuel consumption, and vehicle emissions [10][11][12]. The awareness of the interaction between transportation and the environment that tends to harm the quality of the environment is a trigger in studies related to the transportation system. It is important to be able to meet the demand for services that are also environmentally friendly [13][14]. Therefore, the concept of transportation policy that has become the focus of the past few years is the role of each sector, both public and private, in realizing the development agenda for a sustainable transportation system.

Referring to the Climate Transparency Report in 2019, greenhouse gas emissions in Indonesia increased by 90% over the period of 17 years in 1990-2016 [15]. The transportation sector is said to have contributed to 28% of carbon emissions production in Indonesia. The main energy source of motor vehicles comes from fossil fuels such as gasoline and diesel. Overall, the estimated ratio of the number of vehicles and population in Indonesia is 1:20, which means that there are 50 motorized vehicles in every 1,000 population [15]. This situation shows the rapid growth of motor vehicles in Indonesia, which also has significantly affected the production of carbon emissions.

The transportation sector is one of the biggest contributors to air emissions. Several studies related to the impact of transportation on the environment are mostly focused on land transportation [16]. In developing countries, the link between the use of fuel consumption and the land transportation sector is very strong. It increases air pollution and adversely affects the composition of the atmosphere, air quality, and health [12]. Thus, a solution for decarbonization with changes in modes such as the use of public transportation and non-motorized vehicles is one of the choices on the transportation sector transformation agenda for global emission reduction [17].

In the last few years, public transportation in Indonesia has continued to experience improvements. This is indicated by the use of electric trains, bus rapid transit (BRT) in several cities with high population density, and mass rapid transportation (MRT), which was recently inaugurated in Jakarta [18][19][20][21]. However, the existence of 'traditional' modes of public transportation still dominates Indonesia, one of which is Angkot (Angkutan Kota). Angkot is paratransit transportation that is generally in a form of minibus car [20]. The existence of public transportation is a common sight that can be found in various regions in Indonesia. Angkot is managed independently by individuals, groups, or cooperatives. Formally, Angkot operations are regulated by the government through the regulation of the Minister of Transportation related to its route and also regional regulations that adjust to the needs and interests of the region concerned.

Angkot as a paratransit mode of transport usually has a wider scope of coverage compared to other road-based public transportation [22][23]. Bandung City as the Capital City of West Java Province has a problem in the implementation of public transportation. The growth of private vehicles continues to increase and there is no integration of public transportation between modes. Our previous study on vehicle emissions was carried out by measuring the contribution of Trans Metro Bandung (TMB) to the emissions in Bandung City. The results of the study showed that TMB contributed 5,402.86 tons of emissions per year to environmental air in Bandung City. It had long-term impact on the environment and health. Therefore, corrective steps were needed to solve the problem of integration and also public transportation emissions with alternative energy source alternatives [24]. Thus, further research was conducted to identify emissions from other public transportation modes such as Angkot, which had more units and routes than TMB buses. So far, there were no data presenting the carbon gas emissions resulting from the use of public transportation in Bandung City. This research seeks to identify and compare Angkot’s and TMB’s services and emission contributions based on the fuel consumption. It was expected that the impact that might occur on the environment could be seen by identifying the service and contribution of Angkot and TMB. Therefore, a comprehensive transportation policy scheme for public transportation management and integrated emission standards in Bandung City can be found. Enforcement to Angkot operators is needed to improve their service management and initiate to create more environmentally friendly Angkot modes.

2. Methods
Emission sources in the greenhouse gas (GHG) calculation method were obtained based on the results of fuel combustion that were grouped into two main categories, as proposed by Boer et al. (2012) namely, stationary sources and mobile sources [25]. Angkot as road transportation is included as a mobile source with estimates of carbon dioxide (CO₂) emissions based on the type of fuel consumed. Therefore, in accordance with the IPCC 2006 provisions, this research uses emission calculations based on road transportation (i.e. cars with a capacity of less than 12 people).

This research was conducted quantitatively with the data obtained directly from the Department of Transportation of Bandung City and Angkot entrepreneurs. The obtained data include: number of Angkot fleets per route, length of Angkot route, and the type of vehicle each route. Hence, it can be inferred that the main data sources were secondary data from the Department of Transportation of Bandung City. In specific, the data were related to the Angkot management, terminals, and vehicle eligibility. In addition, literature studies were also conducted to develop a research framework and policy strategies related to reducing GHG emissions from the transportation sector that can be implemented by local governments. The calculation of route length and the average trip with the type of vehicle for each Angkot route would produce an estimate of the average daily fuel consumption. This study employed the formula of estimating the emission that is the same as the formula in the previous TMB related studies [26]. The method used was:

**Equation 1 Conversion from Liter to Terajoule (TJ)**

\[
\text{Fuel Consumption (TJ)} = \text{Fuel Consumption (liter) \times Calorific Value (TJ/liter)}
\]

**Equation 2 Estimated Measurement of Aggregate Fuel Consumption on Emissions**

\[
Emission = \sum_a \left[ Fuel_a \times EF_a \right]
\]

- Emission = Emission of CO₂
- Fuelₐ = Fuel Consumption [TJ]
- EFₐ = Emission Factor [kg/TJ]
- a = Type of fuel [gasoline or RON88]

As explained in various emission calculation guidelines, this Tier 2 method used more detailed activity data compared than Tier 1 that only refers to the IPCC 2006. The calculation of these emissions was carried out by considering the type of vehicle and emission factors that apply specifically to fuel from Indonesia, namely the category premium RON88. Based on this information, in the next section we would try to calculate the estimated emissions produced by Angkot for a year, more precisely in 2019.

3. Result and Discussions

The transportation sector in several cities in the world has been facing major challenges due to the growth of urban populations, private vehicle ownership, road congestion, high dependence on fossil fuels, air pollution, and high levels of greenhouse gas emissions [27][28][29]. The complexity in transportation with population growth and the number of motorized vehicles was experienced by developing countries with high population levels [30]. In addition to the increase in private vehicles, road density and uncontrolled population could also cause other negative impacts starting from traffic accidents to social problems [7]. Although various technological innovations in transportation continued to be developed, the successful implementation could not be guaranteed. Therefore, one of the main agendas of transportation policy is the handling of the problem of personal vehicle growth that occurred every year and its various implications for the environment and public health sectors [30].
This was also a problem in Indonesia, especially in Bandung City that has a high population and vehicle growth [31]. In 2019, there were 1,738,672 motor vehicles in Bandung with a composition of 1,706,573 private vehicles, 14,178 public vehicles, and 17,921 official vehicles. Even so, there was a decrease of 1.042% in the number of vehicles compared to 2018 data. The problem of public transportation services has become an unresolved problem in Bandung City. In 2019, the Asian Development Bank report states that Bandung was the most congested city in Indonesia [32]. Although it cannot be denied that this label can be different if it is measured by different indicators and methods, considering that the lack of adequate transportation services was considered to be the cause of congestion in urban areas, accompanied by population density, availability of infrastructure and road networks that were sufficient for mobility needs.

Direct government intervention was needed to reduce the negative impacts of urbanization and to increase mobility based on motor vehicles. Therefore, a sustainable transportation policy needs to be developed. The provision of qualified public transportation was one solution to reduce the dependence on motorized vehicles [33]. Furthermore, as an effort to reduce the consumption of fossil fuels, there are several alternative sources of energy, namely electric vehicles that could be used by public transportation modes and could support the development agenda. However, mapping and strategy towards political and policy commitments in the operation of electric vehicles as a mode of public transportation was a crucial factor in its success [34].

Based on the initial identification, Bandung City as the capital of West Java Province had a complex public transportation policy. The existence of Trans Metro Bandung (TMB) and Angkot as the main providers of public transportation was not well integrated. Both had the same or intersecting route and they were seen to 'compete' in getting passengers. Related to the issue of vehicle emissions, the large number of fleets and operating routes of Angkot in Bandung City had become a complex issue. Based on the data from the Department of Transportation, in 2018 the number of Angkot in Bandung City had reached 5,489 units. Recognizing the importance of improving public transportation, this research tried to examine how the current conditions of public transportation, especially Angkot, contributed to vehicle emissions. The following is the calculation of fuel consumption for Angkot for one year in Bandung City:

Table 1 Mileage and Angkot Fuel Consumption Estimation

| Corridor                  | Route No. | Number of Cars | Mileage [km] | Fuel consumption [liter/year] | Brand/Type        |
|---------------------------|-----------|----------------|--------------|-------------------------------|-------------------|
| 1  Abdul Muis - Cicaheum  | 01.A      | 355            | 16.3         | 2,688,092.27                  | 94.08             |
| 2  Abdul Muis - Cicaheum  | 01.B      | 100            | 11.55        | 536,550.00                    | 18.78             |
| 3  Abdul Muis - Dago      | 2         | 271            | 9.3          | 1,170,793.91                  | 40.98             |
| 4  Abdul Muis - Ledeng    | 3         | 245            | 16           | 1,821,018.18                  | 63.74             |
| 5  Abdul Muis - Elang     | 4         | 101            | 9.75         | 457,461.14                    | 16.01             |
| 6  Cicaheum - Ledeng      | 5         | 214            | 14.25        | 1,416,631.36                  | 49.58             |
| 7  Cicaheum - Ciroym      | 6         | 206            | 17           | 1,789,522.00                  | 62.63             |
| 8  Cicaheum - Ciswastra   | 7         | 200            | 17           | 1,579,454.55                  | 55.28             |
| 9  Cicaheum - Chaduyut    | 8         | 150            | 16.1         | 1,121,477.27                  | 39.27             |
| 10 Stasion Hall - Dago    | 9         | 52             | 10           | 241,563.64                    | 8.45              |
| 11 Sadang Serang - Ciroym | 10        | 150            | 11           | 766,500.00                    | 26.83             |
| 12 Stasion Hall - Ciumbuleut | 11.A   | 53             | 9.8          | 241,284.91                    | 8.44              |
| 13 Stasion Hall - Ciumbuleut | 11.B   | 30             | 8.3          | 115,671.82                    | 4.05              |
| 14 Stasion Hall - Gede Bage| 12        | 200            | 21           | 1,951,090.91                  | 68.29             |
| 15 Stasion Hall - Sarijadi | 13        | 80             | 10.2         | 379,069.09                    | 13.27             |
| 16 Stasion Hall - Gunung Batu | 14      | 53             | 8.5          | 209,277.73                    | 7.32              |
Next, the basic calculation of the consumption of fuel oil (RON 88) on the average of Angkot in Bandung City based on brands/types is listed below:

**Table 2 Cars Brand/Type of Angkot Bandung**

| Brand/Type          | Production Year | Cylinder Capacity | Fuel Consumption (liter : km) |
|---------------------|-----------------|-------------------|-----------------------------|
| Mitsubishi – Colt (T120SS) | 1997 - 2019     | 1468              | 1 : 11                      |
| Toyota – Kijang (KF60-80) | 1997 - 2007     | 1781              | 1 : 10                      |
| Suzuki – Carry (SL415)    | 1991 - 2017     | 1493              | 1 : 11                      |

Based on the details of the number of cars and the length of travel in every corridor of Angkot in Bandung City above, the total journey of all corridors in one year was 1,209,128.90 km with fuel/oil (RON 88) consumption of all Angkot in Bandung City reaching 40,398,754.14 liters/year. If it was converted in terajoules (TJ), where 1 liter RON88 was equal to 33 megajoules (MJ), then RON88 consumption was 40,398,754.14 liters/year or equals to 1,333.16 TJ. Based on the 2016 data from the Research and Development Centre For Oil and Gas Technology (*Pusat Data dan Informasi Teknologi Energi dan Sumber Daya Mineral*), the magnitude of the CO₂ Emission Factors in Indonesia was 72.97 Tons/TJ (RON88). Therefore, based on this calculation, the total emissions in one year could be stated as follows:
Emission \( = \sum (\text{Fuel} \times \text{EF}) \)

Fuel \( = 140,398,754.14 \text{ liters/yr} = 1,333.16 \text{ TJ} \)

Emission Factor (EF) \( = 72.97 \text{ tons/TJ} \)

Emission \( = 97,280.60 \text{ tons/yr} \)

\[ \text{Figure 1. Total Fuel Consumption per Angkot Corridor in 2019} \]

Based on the estimated calculation above, it is known that the contribution of emissions from Angkot reached 97,280.60 tons/year. Furthermore, based on the data on the number of Angkot fleets, the number of Angkot fleets had decreased by 1.13% from 2017-2018. Then, the estimated emission reduction from Angkot until 2020 is as follows:

\[ \text{Figure 2. Projection for Reduction of Angkot Emissions} \]

Seen from the perspective of policy, Indonesia as one of the largest emitting countries in the world, has committed to the national development agenda in mitigating climate change since 2008 by developing several sectoral strategy and regional development agenda. Previously, in the 1990s, the government had begun to realize that there would be problems with air pollution in several big cities such as Jakarta, West, Central and East Java. Until then, the government issued regulations to control pollution through motorized vehicle eligibility standards, exhaust gas thresholds to the air pollution standard index [35]. Nevertheless, several policies oriented to reduce emissions had to be formulated and become local commitments so that the direction taken could accurately and effectively address issues related to sustainable transportation in urban areas.
As explained in the previous study [24], improving easily accessible public transportation services should be the main priority of transportation policy in Bandung City. In addition, the study of emissions from public transportation shows that the estimated emissions produced by TMB in 2018 were 5,402.86 tons/year. This amount was not too large compared to the estimated emissions of Angkot, in which it was almost 20 times larger compared to the data presented in Figure 2, considering that at that time there were only 55 TMB buses with 4 service routes. The emission estimation results between Angkot and TMB cannot be compared because, in terms of service routes and number of fleets, they are very different. If viewed from the emission factor for the type of fuel consumed with the same amount, distance and engine, the use of diesel by TMB will result in greater emissions compared to premium by Angkot.

The type of fuel and engine used affected the emissions released from the vehicle. Carbon emissions production would decrease with higher octane levels [36]. The substitution of fuel types could be an alternative in reducing vehicle emissions in the case of Angkot. However, with the current conditions, the change of fuel needed to be accompanied by supporting policy, infrastructure, and service improvements that could support changes in travel behavior and could change people’s choice of transportation modes from private vehicles to public transportation. However, the presence of online transportation in the community also had to be considered because it had become an affordable option to travel [37]. This online transportation has affected the mobility patterns and travel demand of the people in Bandung City. Responding to this phenomenon, it was considered that further research was needed to measure the extent of the influence of online transportation on increasing mobility and its contribution to vehicle emissions and how policies could support patterns of integration between modes of public transportation in Bandung City.

In addition to providing environmentally friendly public transportation, various actions can be taken by the government, such as parking fees, incentives, and regulations that affect vehicle ownership. The government can also invest in public transportation transit infrastructure that is accessible and affordable [26][38]. Furthermore, supervision of the management of Angkot related to vehicle feasibility both in aspects of emission standards and vehicle safety needs to be implemented strictly in accordance with applicable procedure standards.

4. Conclusion

Urban transportation faced increasingly complex problems and innovative solutions had been proposed for those problems. Transport uncertainty in urban areas could be overcome by proposing adaptive and responsive policies and creating a framework for implementing long-term policies that allowed adaptation over time as knowledge of urban transportation technology increases. In the context of transportation, the problem was how to control the dependency on private vehicles that required changes in people’s attitudes and perceptions.

This research needs to be continued by measuring vehicle emissions through more accurate technical parameters such as direct measurement of vehicle exhaust emissions, consideration of driver behavior, traffic conditions, and vehicle loads. The substitution of fuel for Angkot was a short-term step that the government could take as a policy intervention. However, increasing investment through the provision of public transportation infrastructure was not sufficient. Therefore, the socio-economic analysis was also needed in the formulation of transportation integration policies that could change people’s travel behavior to switch to public transportation.

5. References

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