Jurnal Presipitasi
Media Komunikasi dan Pengembangan Teknik Lingkungan
e-ISSN: 2550-0023

Vol 19, No 2, 2022, 222-230
Article available at homepage presipitasi

Regional Case Study

Bus Rapid Transport System in Semarang City: Views of Current Users, Potential Users and Related Emission

Haryono Setiyo Huboyo[1*], Wiwandari Handayani[2], Budi Prasetyo Samadikun[1], Didin Agustian Permadi[3]

[1] Department of Environmental Engineering, Diponegoro University, Tembalang, Semarang, Indonesia
[2] Urban and Regional Planning Department, Diponegoro University, Tembalang, Semarang, Indonesia
[3] Environmental Engineering Department, Institut Teknologi Nasional, Bandung, Indonesia
* Corresponding Author. email: huboyo@lecturer.undip.ac.id; huboyo@gmail.com.

Abstract

Abating the air emission related to the transportation sector by operation of the Bus Rapid Transport (BRT) system has been adopted in Indonesia. This study was conducted to obtain an overview of the implementation of BRT, the success of shifting private vehicles to BRT, and the number of emissions resulting from the operation of BRT. The study was conducted using a questionnaire and observations in BRT vehicles. A questionnaire survey was conducted randomly across Semarang sub-districts for 701 private vehicles consisting of cars and motorcycles in a parking lot. Questionnaires were distributed to BRT users in the waiting room and among those who left the BRT. The emission quantity is obtained from GPS observations installed in the BRT and quantified by the emission generation equation based on the bus speed. Even though they are not BRT users for daily activities, motorcycle users use BRT more frequently than private car users. For the private car and motorcycle users, the BRT coverage area is the first barrier to using the BRT system, followed by travel time (due to congestion and traffic jams). Based on current BRT users, the shifting of motorcycle users is far higher than private car users. About 30% of public transport users (besides BRT) shift to BRT users. The BRT emissions (CO and TSP) in the east-west corridor on weekdays and weekends are higher than those in the south-north corridor. Based on this study's results, the BRT application has not significantly reduced the use of private vehicles. Instead, shifting occurs from former public transport to BRT. BRT emissions are related to traffic route conditions and topography. BRT implementation needs to comprehensively consider social, economic and technical (infrastructure) aspects.

Keywords: BRT; emission; route; Semarang; transportation

1. Introduction

Appropriate measures for abating the air emission related to the transportation sector have been adopted in Indonesia. Several measures that have already been implemented in recent years for managing the transport sector have benefited pollution reduction. These policies include applying an Intelligent Transportation System (ITS), implementing Traffic Impact Control, introducing a Bus Rapid Transport (BRT) system, developing non-motorized transport, renewing paratransit public transportation and introducing smart driving training. These measures are implemented initially in big cities and claimed to reduce air pollutants and Greenhouse gases (GHGs). However, such policies lack supporting data to calculate hypothetical reductions. For example, on the ITS application, how great is vehicle speed before and after deploying ITS devices, how much shifting is there of private vehicles to the pedestrian in the NMT program, and how much shifting is there from the mode of private vehicles to the BRT system in the BRT system program. Hence, many kinds of research can be applied to reveal such data to calculate potential emission reduction better.

BRT systems have progressively appeared as an appropriate solution in the transportation sector. BRT has become a popular worldwide transit mode, especially in Europe, South America, and Asia, due to its value for money, service capacity, affordability, relative flexibility, and network coverage (Hensher, 2007). Organizing BRT implementation can be very different between countries and cities within a country (Pedro and Macário, 2016). Many case studies have shown that BRT can be a cost-effective way to provide a high-performance transport service (Levinson et al., 2003). In Pakistan, BRT users generally have low incomes, and students and employees of various age groups from young to middle-aged (Malik et al., 2021). About 70% of Curitiba commuters in Brazil use BRT to work (Prestes et al., 2022). Some developing Asian cities also consider BRT in their public transport planning because of its lower investment cost and flexible implementation of rail systems (Jaensirisak and Klungboonkrong, 2009). Providing BRT in Bogota has a positive impact on the city investment (Hidalgo et al., 2013). Many factors related to BRT management should be handled orderly. For example, BRT right of way is an essential aspect of BRT ridership (Currie and Delbosc, 2011), and the headway to reduce waiting time is set to 5 minutes only (Dantas et al., 2021). However, the residential area has less impact on BRT accessibility than the non-residential area (Jun, 2012). In addition, BRT is recommended to realize the low carbon society target for Asian developing cities since it would shift private vehicle users to a transport sector which emits lower CO2 (Satiennam et al., 2016). However, it is not easy to achieve the high modal shift to BRT in developing countries as here an increase in wealth profile is making private vehicles a more affordable means of transport, as well as conferring elements of status causing a high passenger car (PC) and motorcycle (MC) share. Travel time and cost affect the modal shift from private vehicles to BRT systems (Satiennam et al., 2016). In Bogota, BRT's more complex route network is preferred over a simplified route network (Triviño and Garcia, 2021). The implementation of BRT systems worldwide emerges as a result of different policy packages, which depend, among others, on the cities' cultural, political, institutional and technical backgrounds. Policy packages may include various possibilities, from operational to regulatory measures.

Semarang city has been experiencing a road congestion problem, especially during peak hours. As commonly found in the other Indonesian big cities, road infrastructure could be one of the leading causes in addition to the driving behaviour and other factors. In total, there exists only 2,800 km of road in the city, of which there are only 68 km of primary arterial road and 27 km of primary collector road. Currently, public transportation in the city of Semarang is mainly provided by conventional bus services, BRT of Trans Semarang, paratransit, MC taxi (*ojek*) and taxis. Paratransit, taxis, and MC taxi are operated by independent private owners and comprise most of the transport services. The government keeps improving the operation of Trans Semarang BRT, which serves four corridors with 46 buses and 155 elevated bus shelters. The government has also committed to integrating the BRT with the existing transportation modes, for example, by providing feeders for each corridor. Based on the above conditions, the early stages must see the potential success of BRT in terms of potential demand and environmental impact.

For this reason, this study aims to describe existing BRT users, potential shifting from private vehicle users to BRT and analyze BRT emissions that occur. This aim is to obtain an overview of the implementation of BRT on the success of shifting private vehicles to BRT and the number of emissions resulting from the operation of BRT so that the right policy for BRT implementation can be formulated and smoothly executed.

2. Methodology

This study is a part of an integrated study on research for the Development of Co-Benefits Action Plan on Public Transport and Non-Motorized Transport for Semarang City promoted by the Institute for Global Environmental Studies (IGES). Japan collaborated with the Asian Institute of Technology, Thailand and Diponegoro University, Indonesia.

2.1. Parking Lot Survey

About 411 private motorcycles and 298 private cars were surveyed at parking lots across Semarang city, Central Java province. The questionnaire's design number was 300 personal cars and 400 motorcycles. However, due to the complexity of delivery in the field, the number of cars surveyed decreased and compensated by increasing the number of motorcycles. The questionnaire distribution represents the ownership of vehicles for each sub-district. Based on the location, 16 sub-districts of Semarang (see Figure 1) were surveyed from October – to November 2016. This questionnaire elicited information about the frequency of using BRT for private vehicle (car-motorcycle) users.

2.2. BRT Users Survey

Along with the parking lot survey, we surveyed the current BRT users. The survey was delivered to the BRT passengers while waiting in the shelter or after getting off the BRT. About 184 questionnaires were delivered to the BRT users. We surveyed the existing four BRT corridors/routes as depicted in Figure 2. In this survey, we want to know the frequency of usage of BRT and former transportation mode before using BRT.

Figure 1. Map of sub-districts in Semarang City (Subiyanto and Janu Amarrohman, 2018)

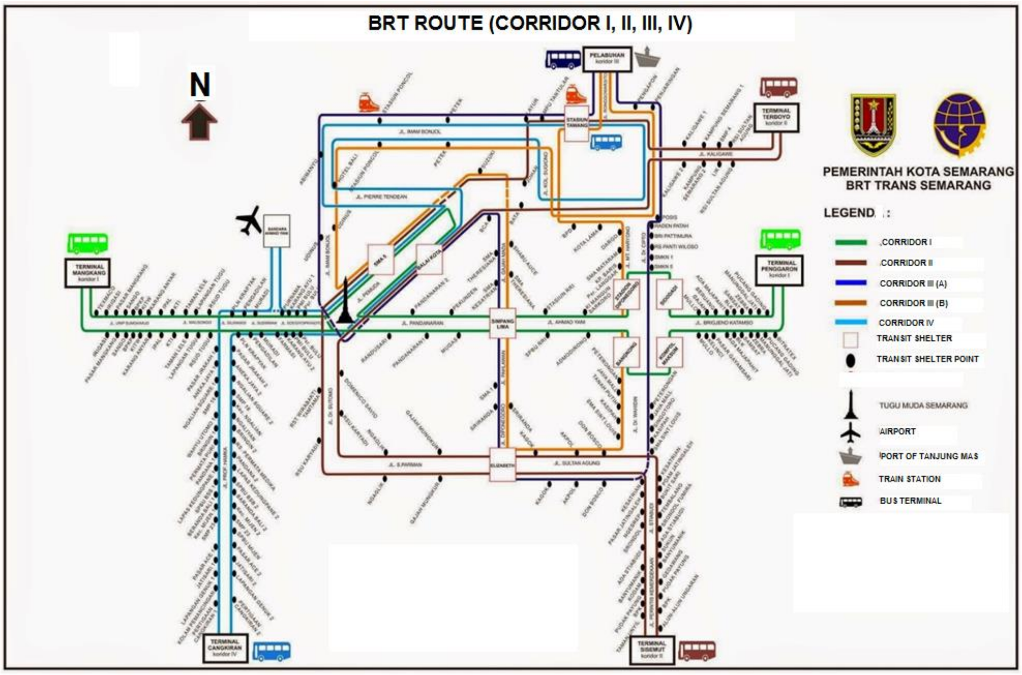
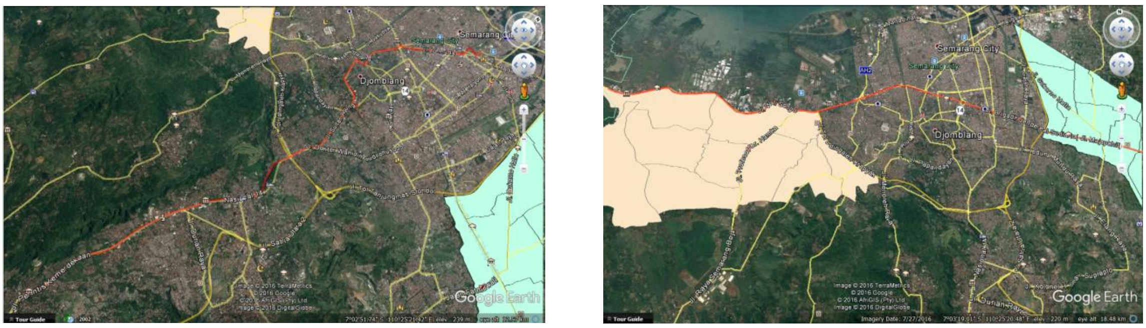


Figure 2. Map of BRT system routes/corridors (Refaramadhani, 2016)

2.3. GPS Survey

We use GlobalSat DG-100 GPS Data Logger to monitor their routes' BRT speed profile. The DG-100 GPS will record the time, travelling speed, altitude and location of each monitored vehicle on a second-by-second basis. To get BRT emissions, the speed recapitulation results from GPS are estimated for fuel consumption according to the formula for calculating fuel consumption for large buses in the previous article (Huboyo et al., 2017). The fuel consumption results are used to predict vehicle emissions based on the database in CORINAIR (European Environment Agency, 2021). This study focuses on CO and TSP emissions as the initial identification of air pollutants from BRT vehicles. Other pollutants are dominant, namely SO_2 and NOx, but they are not shown here. The GPSs were placed next to the drivers at a convenient place. Although current BRT has four routes/corridors, we collected only two routes, BRT north-south and west-east. The routes of BRT that we measured using GPS are depicted in Figure 3. This corridor starts from the Mangkang bus terminal in the west and goes east through the city centre, namely Tugu Muda and Simpang Lima and ends at the Penggaron bus terminal in the East.



(A) (B)

Figure 3. Surveyed routes of BRT using GPS

Figure 3A shows the corridor II BRT line connecting north and south (map rotated to the right from North orientation to match Figure 3B). Corridor II of the BRT route (red color line) originates from Terboyo bus terminal, Pemuda street, S Parman street, Sultan Agung street and heads south to Perintis Kemerdekaan street. This BRT route will end at the Sisemut bus terminal in the Semarang Regency area. Figure 3B shows the BRT corridor I (west-east), indicated by a line with red colour.

2.4. Data Acquisition

In order to obtain reliable data, the data acquisition process needs to be well-controlled. For the results of the survey of private vehicles in the parking lot, only those having complete vehicle data (having a vehicle number) are selected. All data (including vehicle information in detail but not discussed here) are entered in a log book that is easy to retrieve. For the survey of BRT users, data acquisition is immediately carried out on users from the questionnaire considering the limited survey time, especially when users get off the BRT. For GPS data on the BRT, considering the data displayed in seconds, the data from the GPS installed on the BRT for one trip reaches more than 3000 data. The data in the GPS are exported in a spreadsheet with CSV format and to Google Earth kml file format.

3. Results and Discussion

3.1. Private Car and Motorcycle Users

In the majority, the private vehicle users do not use BRT for their daily activities. Figure 4 shows a relatively small percentage of private car and motorcycle users who sometimes use BRT. This result shows that the potential for shifting private vehicles to BRT is still minimal. Among the private vehicle users, the private car users are less frequent in BRT than motorcycle users. They generally use BRT less than once a week. Probably they use BRT just for sightseeing or so on. Interesting results were shown for motorcycle users that they use BRT more frequently every month, as shown in Figure 4.

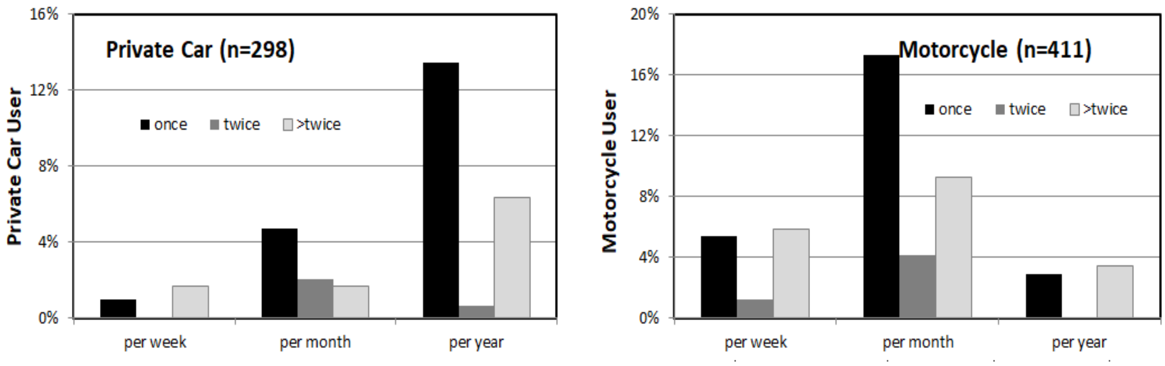


Figure 4. Private car and motorcycle users on their BRT use

For private car users, the BRT coverage area is the first barrier to using the BRT system, followed by travel time (due to congestion and traffic jams). This reason is also valid for motorcycle users. This situation might be confirmed as the commuters in the city of Semarang generally come from the Semarang periphery or other regions. Complete reasons for barriers to using the BRT system in Semarang city are depicted in Figure 5. Accessibility, BRT frequency and operating hours are essential, considering that BRT users must be able to reach BRT shelters that are close by and have short waiting times. This situation can be a driving factor for shifting private vehicles. Interestingly, the current BRT tariff is not a problem for using private vehicles; this can be an attractive factor for new BRT users. This is different from the Thailand case, where BRT tariffs are still a determining factor for the success of BRT (Satiennam et al., 2016). Figure 5 also shows that the transportation system (travel time, coverage, connectivity, operating hours) and BRT infrastructure (coverage, accessibility, safety) need to be improved to shift from private vehicles to BRT. Other factors, i.e. vehicles' accessibility, accessible low floor and wheelchair accessible bus, might be other factors to increase the BRT ridership (Currie and Delbosc, 2011). Meanwhile, higher economic efficiency is one of the reasons why BRT is preferred over trams in Thailand (Jaensirisak and Klungboonkrong, 2009). Low shifting of private vehicles to BRT might be attributed to local economic factors and social and environmental realities that are not considered for bringing this BRT system to Indonesia (Kent, 2021). So the success of BRT implementation needs to start at the initiation of BRT development that accommodates local factors, namely social, economic and environmental. To be successful in the implementation of BRT, innovation is also needed that can come from good practices in other countries and be adopted in the local context (Prestes et al., 2022) This is to overcome shortcomings that commonly occur in the implementation of BRT, namely the lack of passengers, insufficient financing, length of integration with other transport modes and ticket price problems.

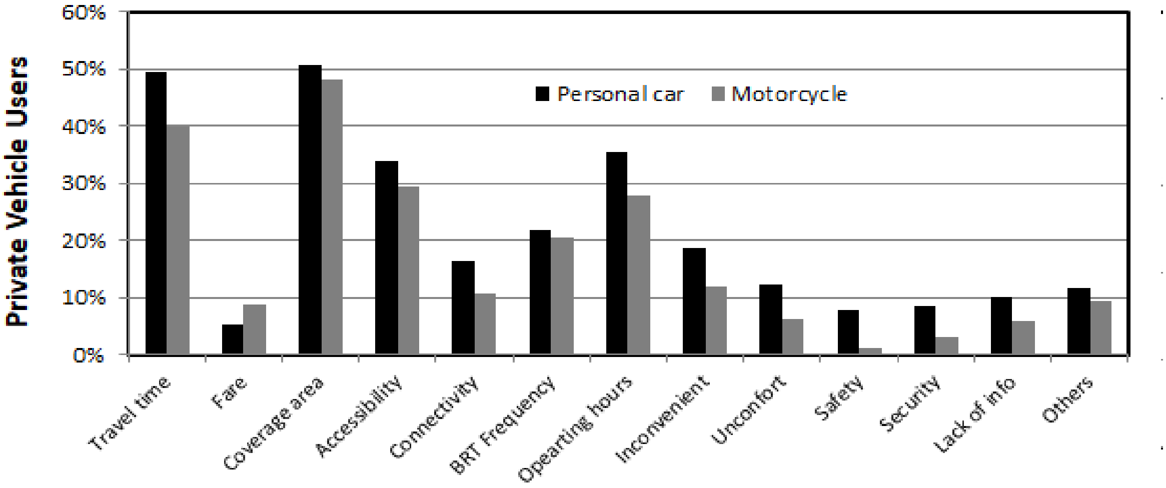


Figure 5. Barriers to using BRT system in Semarang City for private vehicles

3.2. BRT Users

184 questionnaires were delivered to the BRT users. However, about 62% of respondents use the BRT system for daily activities (frequent users). Motorists mostly dominate both frequent and infrequent BRT users. From Figure 6, it can be seen that 100% of BRT frequent users are dominated by former motorists, followed by former users of paratransit and other public transport. The same condition also happened to infrequent BRT users where 67% of them were former motorists, followed by 20% of other former users of public transport and paratransit. The shift from motorcycle users is far higher than private car users, indicating that private car owners deem this BRT to have not given a comfortable service for them. The use of BRT is perceived to reduce congestion, but BRT users do not necessarily get adequate benefits. For example, BRT users in Tanzania experience long waiting times, overcrowding, difficulties in commuting with goods, and a lack of safety and security (Joseph et al., 2021). Interestingly the shifting from other public transport means is higher too. About 30% of public transport users (besides BRT) shift to BRT users. This feature indicates that BRT is more convenient than other public transport means (paratransit, taxis and medium bus). If this condition persists, it might be that the other public transport will lose their passengers. To increase BRT users, it is necessary to integrate the BRT system with other transportation modes. The development of the BRT system towards Transit Oriented Development in the development of urban areas is vital (Bian and Ding, 2012). Several regions in Indonesia have also adopted the BRT system, like those implemented in Jakarta. The difference is that the BRT has a particular BRT line in Jakarta, while in several big cities in Indonesia, the BRT route is still diffused from the conventional route. As a result, the added value of BRT, namely the save time factor, is not much different from private transportation. This condition causes BRT's occupancy rate outside Jakarta to be still low compared to private vehicle users.

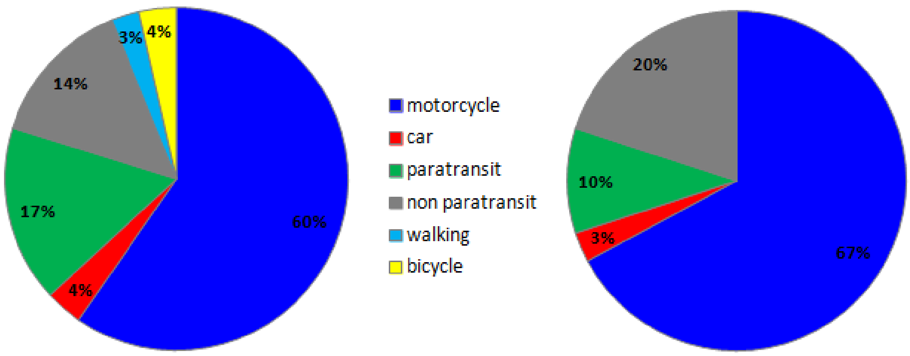


Figure 6. Former transport mode before BRT users: (A) frequent users (B) not frequent users

3.3. Air Pollutant Emission

As a big city located in the coastal area, Semarang has different altitudes (about 300 m in height) from the north to the south side, while the terrain is relatively flat in the east-west direction. Consequently, vehicles travelling south to north and vice versa will have different movements beyond other factors such as traffic jams or congestive roads. The emission of an air pollutant is closely related to the vehicle's speed during travel. As shown in Figure 6, the BRT emission (both CO and TSP) in the east-west corridor on weekdays and weekends is higher than in the south-north corridor. This might be caused by higher road congestion in the east-west corridor. There is no difference in emission between days (either weekday or weekend). The implementation of BRT is predicted to reduce air pollutant emissions due to the high load of passengers within a single-vehicle. In Hanoi, replacing regular buses with BRT is predicted to reduce pollutant emissions by 17 - 23% with almost the same driving characteristics (Nguyen et al., 2021). In Tehran, with a unique route, the BRT scenario can reduce CO emissions by 1.5 - 2 g/km and PM by 1.5 - 1.8 g/km (Abbasi et al., 2020). Based on an analysis of the structural equation model in Jakarta, PM air pollutant emissions near the roadside can be reduced by building parking lots for motorists near BRT stations, thus encouraging motorists to switch to BRT (Nugroho et al., 2010). So, this environmental factor, i.e. emission reduction, should be a co-benefit for the implementation of BRT. The co-benefit from the economy side is the reduction in fuel oil consumption, which has been used widely by private vehicle drivers. This means that the intensity of fuel consumption per person will be lower. For developing countries such as Indonesia, where most of the fuel oil is imported, it will be an advantage if the mobilization of people is maintained with a low level of fuel consumption. The use of BRT will also support the SDG's program, especially the 7th goal (ensure access to affordable, reliable, sustainable and modern energy for all), 8th goal (promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all) and the 9th goal, namely build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.

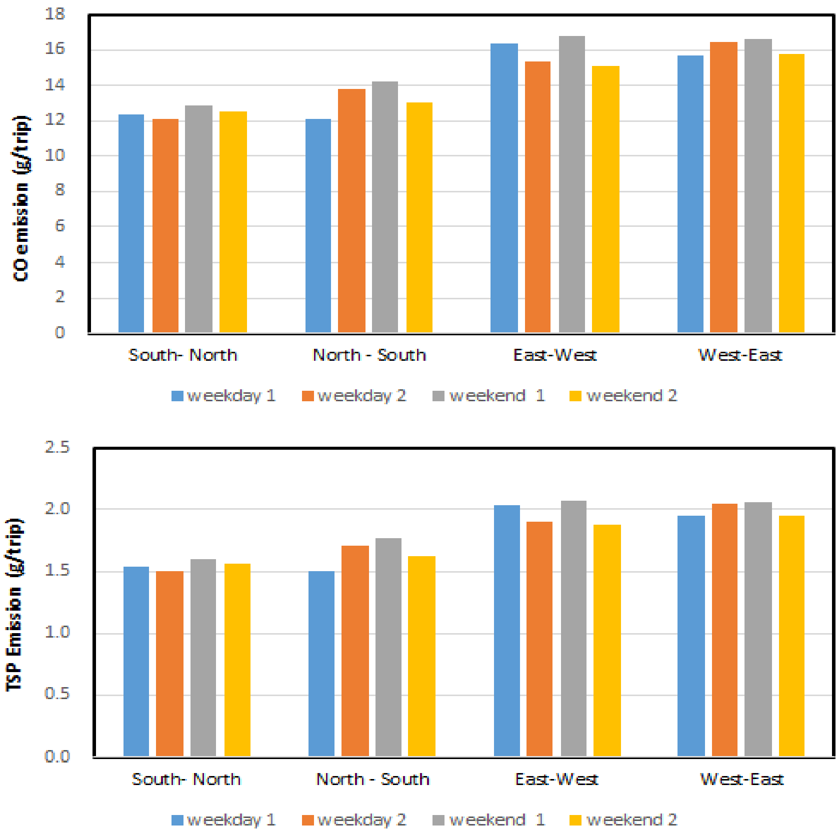


Figure 7. Air pollutants emission (CO and TSP) on weekdays and weekend

4. Conclusion

BRT operation in Semarang city will still have a big challenge in minimizing the air pollution problem. In the majority, the private vehicle users do not use BRT for their daily activities. Thus the potential for shifting from private vehicles to BRT users is minimal. Motorcycle users use BRT more frequently than private car users. For private car users, the BRT coverage area is the first barrier to using the BRT system, followed by travel time (due to congestion and traffic jams). This reason is also valid for motorcycle users. Based on current BRT users, the shift from motorcycle users is far higher than private car users, indicating that private car users deem this BRT to have not given a comfortable service. About 30% of public transport (besides BRT) shifts to BRT users. This feature indicates that BRT is more convenient than other public transport means (paratransit, taxis and medium bus). So, the potential for shifting is likely to occur from existing public transport users to BRT users, which makes the proportion of public transport users remain not significantly changed. The BRT emission (both CO and TSP) in the east-west corridor on weekdays and weekends is higher than in the south-north corridor. This might be caused by higher road congestion in the east-west corridor. There is no difference in emissions between days (either weekday or weekend). Based on this study's results, BRT's application has not significantly reduced the use of private vehicles; shifting occurs from former public transport to BRT. BRT emissions depend on the road situation and the route taken. For this reason, an effective BRT route system needs to be implemented.

Acknowledgement

This work was partially funded by PNBP DIPA Diponegoro University Contract Number: SP DIPA-042.01.2.400898/2016 and partially supported by the Japan Ministry of Environment under the IGES research project.

References

Abbasi, M.H., Hadji Hosseinlou, M., JafarzadehFadaki, S.M., 2020. An investigation of bus rapid transit system (BRT) based on economic and air pollution analysis (Tehran, Iran). Case Studies Transport Policy 8, 553–563.

Bian, J.W., Ding, M., 2012. The effectiveness of the construction of the bus rapid transit in Xiamen city. Sustainable Transport for Chinese Cities, Emerald Group Publishing Limited.

Currie, G., Delbosc, A., 2011. Understanding bus rapid transit route ridership drivers: an empirical study of Australian BRT systems. Transport Policy 18, 755–764.

Dantas, R., Dantas, J., Melo, C., Maciel, P., 2021. Performance evaluation in BRT systems: an analysis to predict the BRT systems planning. Case Studies on Transport Policy 9, 1141–1150.

European Environment Agency, 2021. EMEP/EEA air pollutant emission inventory guidebook 2019 (Passenger cars, light commercial trucks, heavy-duty vehicles including buses and motorcycles) 1, 144.

Hensher, D.A., 2007. Sustainable public transport systems: moving towards a value for money and network-based approach and away from blind commitment. Transport Policy 14, 98–102.

Hidalgo, D., Pereira, L., Estupiñán, N., Jiménez, P.L., 2013. TransMilenio BRT system in Bogota, high performance and positive impact - main results of an ex-post evaluation. Research Transportation Economics 39, 133–138.

Huboyo, H.S., Handayani, W., Samadikun, B.P., 2017. Potential air pollutant emission from private vehicles based on vehicle route. IOP Conference Series Earth and Environmental Science 70.

Jaensirisak, S., Klungboonkrong, P., 2009. Why bus rapid transit (BRT) is interested by transport planners and travellers in Thailand. Proceedings of the Eastern Asia Society for Transportation Studies 7, 266–266.

Joseph, L., Neven, A., Martens, K., Kweka, O., Wets, G., Janssens, D., 2021. Exploring changes in mobility experiences and perceptions after implementation of the bus rapid transit system in Dar es Salaam. Case Studies on Transport Policy 9, 930–938.

Jun, M.J., 2012. Redistributive effects of bus rapid transit (BRT) on development patterns and property values in Seoul, Korea. Transport Policy 19, 85–92.

Kent, A., 2021. Moving the masses: bus-rapid transit (BRT) policies in low income Asian Cities. case studies from Indonesia. Urban Policy and Research 39, 309–311.

Levinson, H., Zimmerman, S., Clinger, J., Rutherford, S., Smith, R.L., Cracknell, J., Soberman, R., 2003. Bus rapid transit. Transit Cooperative Research Program 1, report 90.

Malik, B.Z., Rehman, Z. ur, Khan, A.H., Akram, W., 2021. Investigating users' travel behaviours and perceptions of single-corridor BRT: Lessons from Lahore. Journal of Transport Geography 91, 102942.

Nguyen, Y.L.T., Nghiem, T.D., Le, A.T., Duc, K.N., Nguyen, D.H., 2021. Emission characterization and co-benefits of bus rapid transit: a case study in Hanoi, Vietnam. Atmospheric Pollution Research 12, 101148.

Nugroho, S.B., Fujiwara, A., Zhang, J., 2010. The influence of BRT on the ambient PM10 concentration at roadside sites of Trans Jakarta Corridors. Procedia Environmental Science 2, 914–924.

Pedro, M.J.G., Macário, R., 2016. A review of general practice in contracting public transport services and transfer to BRT systems. Research Transportation Economics 59, 94–106.

Prestes, O.M., Ultramari, C., Caetano, F.D., 2022. Public transport innovation and transfer of BRT ideas: Curitiba, Brazil as a reference model. Case Studies on Transport Policy 10, 700–709.

Refaramadhani, 2016. Bus rapid trans (BRT) Semarang.

Satiennam, T., Jaensirisak, S., Satiennam, W., Detdamrong, S., 2016. Potential for modal shift by passenger car and motorcycle users towards bus rapid transit (BRT) in an Asian developing city. IATSS Research 39, 121–129.

Subiyanto, S., Janu Amarrohman, F., 2018. Spatial studies and juridical utilization of vacant land and abandoned land control in efforts of regional authority in Semarang city. MATEC Web Conference 159.

Triviño, J.M., Garcia, W.C., 2021. General guidelines for the design of BRT routes in the public transport integrated System of Bogota. Transportation Research Procedia 58, 622–629.