An Analysis on The Determination of Bus Lane Priority on Urban Public Transportation (A Case Study: Trans Jogja, Indonesia)

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***Abstract*—Currently, Trans Jogja Bus has replaced the other transportation vehicles existing since 2008. There are 129 units of Trans Jogja Buses operating and serving 17 routes. In its development, the operation of Trans Jogja Bus experienced obstacles, namely the number of sections and crossroads traffic congestion and the mix of various types of vehicles in one lane. It resulted in the poor performance of Trans Jogja buses in service timeliness, load factor, and impact on the value of the government subsidies for the operation of the Trans Jogja Bus. The widening of the road and the construction of new roads that function specifically as the Trans Jogja Busway are very difficult to build in the city of Yogyakarta due to the limited availability of land for road widening. This condition requires quick responses in terms of making a study of the application of Trans Jogja Bus priority path. Based on the results of the study, the determination of the Bus Lane path was carried out by considering the road width of more than (>) 9 meter, if the road width is less than (<) 9 meter, the assessment was carried out by looking at the V/C Ratio close to 1 and handling road widening. The application of Bus Lane in accommodating Trans Jogja Buses is done in two stages, namely; the first stage is by removing the median, eliminating on street parking, and the width of the sidewalk on the specified road segment. The Bus Lane application in the second stage was emphasized on the roads that have a one-way traffic flow and the implementation of the Contra Flow Bus Lane system.**

Keywords—bus priority, urban, public transport, performance

I. INTRODUCTION

Since February 2008, The Special Region of Yogyakarta Government has carried out urban public transport services with a new system called "Trans Jogja Bus" (Fig. 1) having better quality services compared to the previous deposit-based system. Most of the principles of public transport services have been implemented: subsidies, sufficient mass services, fixed routes and regular schedules, fixed bus stop points and operated with minimum service standards. The Special Region of Yogyakarta Government hopes that Trans Jogja Bus is able to function as a public transportation service system that is able to facilitate community mobility throughout the city of Yogyakarta as well as some parts of Sleman Regency and Bantul Regency, which are located in Yogyakarta Urban Area. The operation of Trans Jogja Bus has passed its eleventh year. Since being operated on February 18, 2008, it must be consistent with other bus has gone through a new round of systems and management of public transport in Yogyakarta urban area using a new system called Buy the Service or a service purchase system replacing the old deposit-based public transport system. This new system allows a subsidy mechanism from the Regional Government. In this case, the subsidies provided by The Special Region of Yogyakarta Government to the community using urban public transportation.

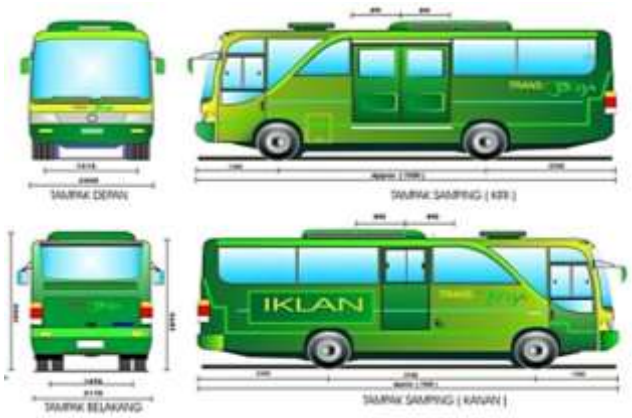

Fig. 1. The Dimension of Trans Jogja Bus

The expected role of the Trans Jogja service is to function as the mainline of urban transportation in Yogyakarta. That means that the service would connect the residential centers with activity centers that have large travel volumes and have a definite travel pattern. The basic goal of this system is to serve. This service has some disadvantages related to low regional coverage when viewed from direct services and low access to door-to-door services due to its passivity. This condition resulted in poor public access to Trans Jogja. In 2018, all Trans Jogja routes is 17 (Fig. 2) with a fleet of 129 units. However, in its development, the operation of Trans Jogja is hindered by the number of sections and intersections having traffic congestion, especially along the Trans Jogja Bus service area in the Yogyakarta Urban Area. The high growth of private vehicles in Yogyakarta, which reaches 10-12 percent per year, is linearly correlated with the high number of traffic jams in intersections in the Yogyakarta Urban Area, including the obstacles to Trans Jogja Bus travel due to the mixed nature of its operations with other traffic (mix traffic). This problem also affects the downward trend in the number of Trans Jogja Bus passengers. A survey reported that the reliability aspect of travel time is a very important variable. However, it is

considered poor by the passengers. This requires responses in terms of making a study of the existence of a priority system for Trans Jogja Bus operations on the road. This study recommends creating a Trans Jogja Bus priority system that can be implemented in short, middle, and long term. Thus, it is expected that the quality of Trans Jogja Urban Transport services will improve particularly in the timeliness aspect.

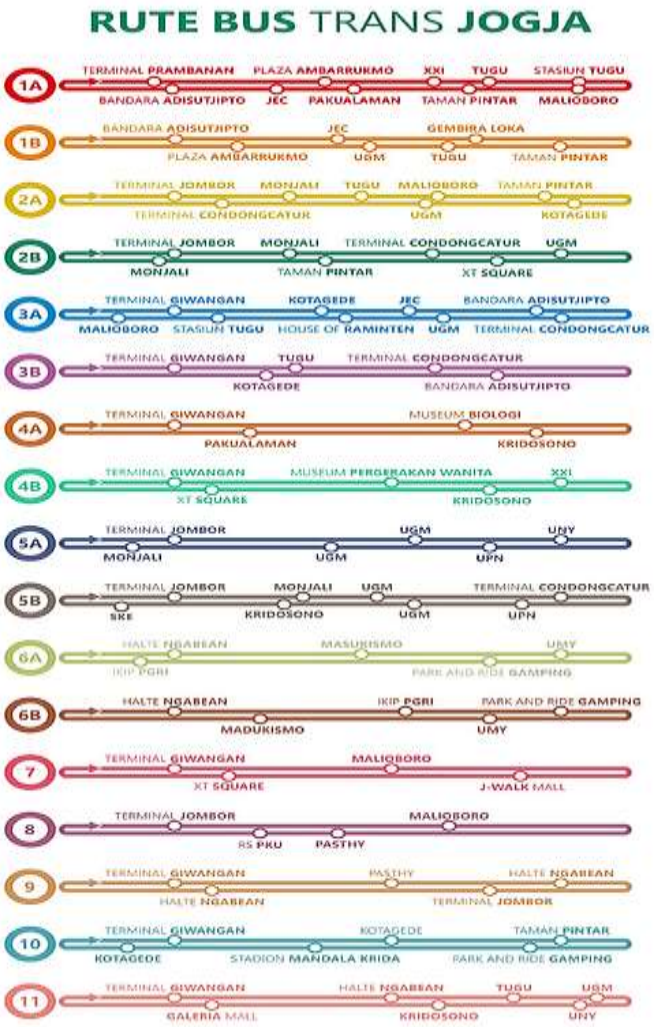

Fig. 2. Route Map of Trans Jogja Bus

II. BUS LANE PRIORITY

Bus Rapid Transit (BRT) is an increase in regular bus services through infrastructure changes that result in better bus operation speeds and service reliability [1]. BRT, which is called Bus Priority, is a fast mass public transportation by using bus lane priority [2]. Bus Priority services are needed since the traffic is getting heavier and the road has low capacity for free ways. There are three types of bus lanes. Bus Lane Type 1 does not use any priority lane; Bus Lane Type 2 share the lane with other vehicles. Meanwhile, Bus Lane Type 3 employs an exclusive use for buses. At the curb lanes for Type 1 and 2 are shared with other vehicles, conflicts may occur. When the lane is primarily used for mixed traffic, there will be more conflicts due to the shared lanes [3]. Bus priority is needed because there is too much traffic on the network and too little capacity for catering all vehicles to smoothly run. Giving buses priority over cars recognizes the bus's greater efficiency in the use of road space. The emphasis is placed on maximizing the throughput of people, rather than the number of vehicles [4]. The existing roads range between 17.0 and 24.0 meters wide and consist of either 4-lanes or 6-lanes. Bus priority is due to the increasing traffic and the low road capacity for freeways. The minimum bus lane width is supposed to be 3.0 meters or depends on the dimension of buses [5]. By giving more priority to the bus, bus efficiency is greater in using road space. Bus priority ensures that buses operate in accordance with the existing schedule; reduce travel time from existing schedules so that buses are more competitive than other cars and private vehicles; increase travel times consistency; avoid the length of cycle time at signaled intersections, and maintain a good bus access, such as trips to the city center [3]. The treatment of bus priority is a modification between the environment passed in the bus operation to increase speed, reduce delay, increase reliability or attractiveness for bus usage [6]. There are several types of priority buses that could be applied to roads. They are as follows [7].

A. With-Flow Bus Lane

A type of priority bus that is commonly used and able to apply full time 24 hours/day or part time at peak hours. The bus runs in the direction of the traffic and this bus lane is usually located next to the curb. The requirement and design of the path depends on the purpose set. The aim is to minimize travel costs and travel time. The design at the is required to allow the bus to pass through the queue when there is a jam. When the bus passengers flow is rather low, the bus lane is allowed to be used by other vehicles such as taxis, cars, and others. The benefits of bus lines depend on local conditions, lane length, congestion levels, bus passenger flows and others. The higher profits are also possibly measured along with the faster travel time [4]. The location of the lane bus is divided into 4 locations including Outside Lane, Middle Lane, Center Lane, and Median Lane (Fig. 3). Each location of the bus lane has the pros and cons as well as other features to consider. There are no definite rules for determining the location of each bus lane. The characteristic analysis for providing bus lane is to pay attention to traffic flow, road design, parking restrictions on roads that are also passed by buses, and traffic signal design.

B. Contra Flow Bus Lane

This bus lane allows buses to fight traffic flow, generally applied to one-way roads. The reverse current bus line could shorten the bus route (if compared to a one-way road system). Then, it can save road time and operational costs. Another goal is to make the bus able to pick and drop passengers comfortably so that the passengers are able to save more time. The contra flow of bus lane could be seen in Fig. 4 [8].

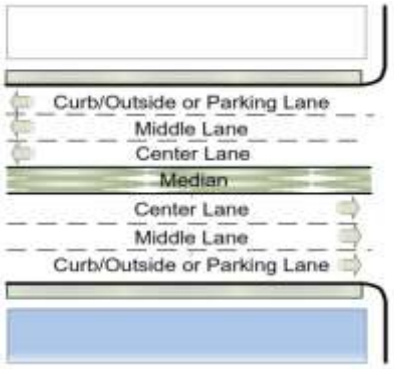

Fig. 3. The Bus Lane Layout

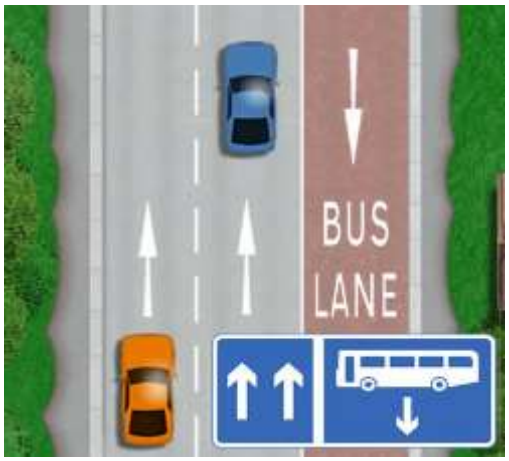

Fig. 4. Contra Flow Bus Lane

III. METHODOLOGY

This research was conducted to determine the performance of Trans Jogja buses and to conduct feasibility simulations in implementing bus priority on all Trans Jogja bus routes. The analysis taken was short-term plan, mid-term plan and long-term plan.

There were two types of data that were gathered, covering primary and secondary data. The primary data consisted of traffic flow, headway, load factor, turning proportion, queue length, time signal and travel times whilst the secondary data consisted of the geometric layout and routes of Trans Jogja.

This research was started by reviewing the literature related to bus priority. After that, survey was conducted to collect the data. After all of data were collected, the next stage was to analyze the data. The data analysis was used to make plan of the bus priority scheme.

IV. RESULTS AND DISCUSSION

Speed is one of the important parameter for evaluating the facility quality of service in view of road users. Travel time and cost are other influential parameters in choosing the best travel path. Operating speed is the most common index in geometric road design evaluation [9]. Determining the width of the road becomes a factory to be taken into account in the vehicle traffic. The vehicles such as buses, trucks, bicycles, motorbikes and parked cars are a sensitive and crucial aspect in designing road. Lane widths should be considered within the assemblage of a given road delineating space to serve all needs, including travel lanes, bike lanes, and sidewalks. The traffic space should be adjusted with the purposes as well as making space for larger vehicles, such as trucks and buses [10]. There are actions taken in analyzing the operational performance of Trans Jogja buses and supporting priority studies in answering the purpose of this study. One of them is by providing recommendations on priority handling for Trans Jogja Urban Transport in order to improve service quality from the aspect of timeliness. Therefore, the following factors such as is Load Factor, Headway, and Geometric Roads are crucial to be analyzed. The results of the field survey and analysis of the 17 Trans Jogja Bus routes are obtained as shown in Table 1.

Based on the indicators of load factor and headway, the value of the allowed load factor is 70% and the allowed headway is 10-20 minutes [11, 12]. Based on the data in Tables I, it is shown that the load factor value on all Trans Jogja bus routes is <70% or in safe conditions, alternative: while in the Trans Jogja bus headway routes such as route 4A, route 5B , route 7, route 8, route 10, and route 11 have not met the standard (>20 minutes).

TABLE I. THE RESULT OF THE LOAD FACTOR, HEADWAY AND RUNNING TIME ON THE TRANS JOGJA BUS ROUTE

Route	Load Factor (%)	Headway (Hour)	Running Time (Hour)
1A	33.40	0:08	1:52
1B	13.32	0:13	1:53
2A	19.61	0:13	2:03
2B	19.61	0:13	2:01
3A	34.88	0:19	2:30
3B	24.29	0:13	2:28
4A	13.45	0:24	2:06
4B	18.36	0:19	1:47
5A	11.41	0:20	1:41
5B	17.46	0:21	1:48
6A	10.04	0:20	1:01
6B	26.65	0:20	1:00
7	7.73	0:27	1:21
8	26.65	0:26	2:09
9	17.08	0:19	2:01
10	16.79	0:24	2:02
11	13.59	0:36	2:25

A signalized intersection priority is a method that changes the signal time plan at a signal intersection. The priority strategy is to run with a sign controller in an intersection. Priority is given to the bus by extending the green light phase and by reducing green time on the other intersection arm (Fig. 5) [13].

Delays at red lights are one of the main factors in bus delays on arterial roads (main). The bus delay on the red light consists of 10% and 20% of the total bus travel time and is close to 50% of the delay experienced by the bus. By giving priority to buses at signalized intersections, bus delays could be reduced. The possible short-term benefits of bus priority include are by increasing speed and reducing travel time. However, the presence of bus priority makes it possible for passengers to be more interested in public transportation modes and allow passengers to increase. In other words, high levels of need on bus priority could disrupt other traffic, especially on road crossings.

Fig. 5. The Application of Bus Priority in an Intersection

In organizing the plan for implementing Bus Lane on the Trans Jogja Bus line that is applied to 17 routes, prioritizing

the intersection/road section is arranged at the first place. Sorting of priority scale is divided into 3 (three) stages, namely short-term plan, mid-term plan, and long-term plan.

A. Short-Term Plan

Trans Jogja bus priority plans are mapped into several destination points based on Load Factor, meaning that they are mapped based on the percentage of the number of passengers heading to a destination point. From the data in Table I, it is known that a good Load Factor value is found in Route 1A. The headways on each route have different times among Route 1A-Route 11. The smallest headway is on Route 1 with a length of time of 0:08 minutes (Table I). The thing that is related to the headway is the number of routes that cross particular roads and intersection. Running time required for Trans Jogja bus starts for one round from the starting point and back. Running time is a vital variable in this study. With the priority, it is expected the running time would be reduced and become more efficient.

In Table I, it could be seen that the longest travel time is on route 3A and the shortest is route 6B. The routes of long travel times also go through several road segments which are also passed by Route 1A. In additional, it is also expected that the application of bus lane on certain road segments could reduce the travel time of Trans Jogja. The traffic conditions reviewed are the traffic volume at the peak hours in the morning, afternoon and evening. This it is used to determine whether a road/intersection requires the priority for Trans Jogja buses. The width of the road influences the priority of the Trans Jogja bus in the form of a lane bus. The priority that could be tested is the road with a width of more than or equal to 9 meters.

Based on the road geometry, the application of the bus priority / bus lane could be viewed from the width of the road and the intersection that is passed by Trans Jogja Buses. Certainly, not all roads and intersections have the same width. The road and intersection that would be applied to bus priority / bus lane are those that have sufficient width to be prioritized by Trans Jogja Bus. The plan for implementing a bus lane is to use a road that has a width of more than or equal to 9 meters. The determination of road width of more than (>) 9 meters is based on traffic conditions then it could run smoothly. Table II presents the width of particular roads.

In addition to road geometry, one of the factors as used to consider the use of bus lane are the performance level of the road. The level of road performance is a qualitative measure to explain the operational conditions in the traffic flow and its assessment by road users. In addition to roads, lane buses could also be used in intersections. Based on the priority of the road segments that have been made, these roads are connected by several intersections. The intersections are prioritized following the sections of the road. In some signalized intersections, there are frequent conditions having queues. There are some characteristics of intersections that determine whether or not an intersection will be given the same priority as roads. The list of intersections that usually experience long queues could be seen in Fig. 6 (the intersection are that is Demangan Intersection, UIN Intersection, Janti Intersection, Maguwoharjo Intersection, and Adisutjipto Airport Intersection). Therefore, the intersections prioritized for the application of the lane bus are as follows.

The intersection was finally chosen based on the performance at the intersection and the condition of the intersection. The intersection performance is seen based on the degree of saturation. The degree of saturation is the ratio between the volume of traffic flow (V) compared to capacity (C) at the intersection [14]. If the ratio of volume is close to number 1, the intersection could be said to be saturated (solid). In addition, in the intersection above, there is often a queue in one direction of its arm, while the route that passes a lot. Therefore, priority is required for Trans Jogja buses.

A special marker for the lane bus marker is to give a specific color for the bus lane. Giving color does not have to be full along the bus lane but it can be divided into several segments. Based on [15], the color for bus-specific lane markers is red (Fig. 7). Traffic cone is one of the traffic signs that are not permanent. Traffic cones are usually used to drive traffic to avoid parts of the road that are undergoing repairs or diverting traffic when there is a treatment at a waypoint. The use of traffic cone as a trial of the application of bus lane and the absence of specific regulations / regulations regarding the application of lane buses in Indonesia. Pre-signal transit traffic is a traffic light that is placed before the main traffic light. This Pre-Signal for bus priority functions to give priority to the bus to first head to the intersection [16]. Then, the shape of the bus lane would be applied to the selected intersection as shown in Fig. 7.

TABLE II. ROAD SECTION FOR THE IMPLEMENTATION OF BUS LANE (SHORT-TERM PLAN)

Street	Route	Road Type	Width (meters)	Bus Traffic / Hours	Obstacles
Yogyakarta - Solo (Section 2) (see Figure7)	1A	4/2 D	9.7	20	Medium
	1B				
	3A				
	3B				
Yogyakarta - Solo (Section 1) (see Figure 7)	1A	4/2 D	10.3	15	Medium
	1B				
	3A				
Laksda Adisucipto (see figure 7)	1A	4/2 D	9.1	10	Medium
	5B				

Fig. 6. The Intersection Priority

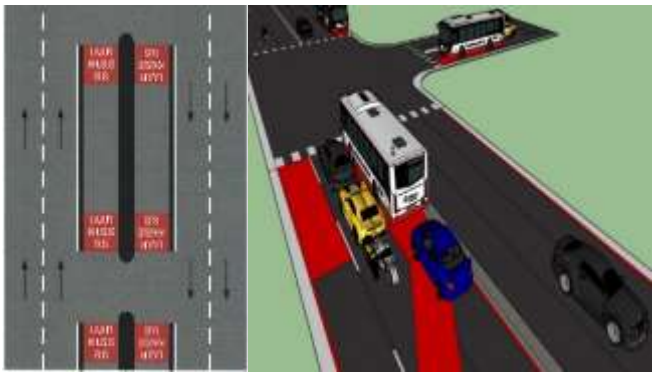

Fig. 7. The Marker for Bus Lane

B. Mid-Term Plan

The initial step for the plan to implement the contra flow lane for the Trans Jogja Bus is implemented by inventorying road sections that are running in one direction. After being inventoried, the width of the sections and the conditions around the road are seen. The intended road conditions are the presence or absence of on-street parking. A list of road segments that run in one direction could be seen in Table III.

The opposite bus lane could complicate intersections on a one-way road system. The benefits to the bus depend on the length of the route and the distance that must be taken by the passengers to walk to the bus and the losses suffered by other road users depending on the additional obstacles time experienced in the intersection due to the bus lane. One of visible differences between with-flow and contra-flow is that the with-flow is usually operated only during rush hour. Meanwhile, it could be operated for 24 hours. However, contra-flow has the potential to cause accidents to pedestrians. Thus, traffic signs are more necessary than with-flow lanes. Another difference between the two types of bus lines is that there are more violations in the contra-flow bus lane. The costs required for contra-flow bus lanes are greater than with-flow because of additional problems that arise in intersections. Therefore, a separator is needed between the contra-flow bus lanes and normal traffic lanes.

To control the level of traffic safety by the implementation of bus lane with the contra flow system, regulations are required for the operation of lane buses in the Trans Jogja Bus. As a result, public could understand the provisions that apply in the implementation of lane buses in Yogyakarta City. In Table II, it is explains the recommended application of Bus Lane with a the road width is more than (>) 9 metes in order to obtain good traffic performance. However, in the application of Bus Lane with a contra flow system on roads that have one-way flows. As shown in Table 3, the recommended road width is more than (>) 7 meters. The examples of intersections using Contra-Flow Bus Lane could be seen in Fig. 8.

C. Long-Term Plan

The long-term plan for implementing the bus lane on the Trans Jogja Bus route as a whole in 17 routes, is recommended after finding the results of implementation over the short-term plan and medium-term plan or the results of performance evaluations. If the results of the road segments are good during the short term and medium term of the implementation period, it can be then applied to other Trans Jogja Bus routes in the long-term plan. It is required that the road width is not more than (<) 9 meters and traffic conditions those who have a V / C ratio close to number 1. Of the 17 Trans Jogja Bus routes that have been implemented in short and medium term mapping, there are some roads that have a width of less than (<) 9 meters and V / C ratio close to number 1. The list of road sections could be seen in Table IV. For some of the above roads with widths less than (<) 9 meters and with traffic conditions and road performance levels in Table IV, it is impossible to prioritize the lane bus. The plan for follow-up to give priority to Trans Jogja is with several recommendations that is by reducing street parking and close the U-Turn.

On some roads, the application of lane buses is not possible in Yogyakarta. Some roads that are not possible to be applied to lane buses are all Ringroad. These road segments are divided into 6 way-2 lane road type (6/2 D) (Fig. 9). Whereas the Trans Jogja stops on the track are located on a slow lane (motorbike lane). On the contrary, if a bus lane is located in the show lane, it would reduce the lane capacity intended for motorbikes.

TABLE III. ROAD SECTION FOR IMPLEMENTATION OF CONTRA-FLOW BUS LANE (MID-TERM PLAN)

Street	Route	Road Type	Width (meters)	Bus Traffic / Hours	Obstacles
Urip Sumoharjo	1A	2/1 UD	14.7	10	High
	4B				
Jenderal Sudirman	1A		12	12	High
	2A				
C Simanjuntak	5A		7.7	3	High
Margo Utomo	1A		7	12	Low
	2A				
Malioboro	1A		7	19	Low
	2A				
	3A				
	8				
Prof Yohanes	4B		8.7	3	High

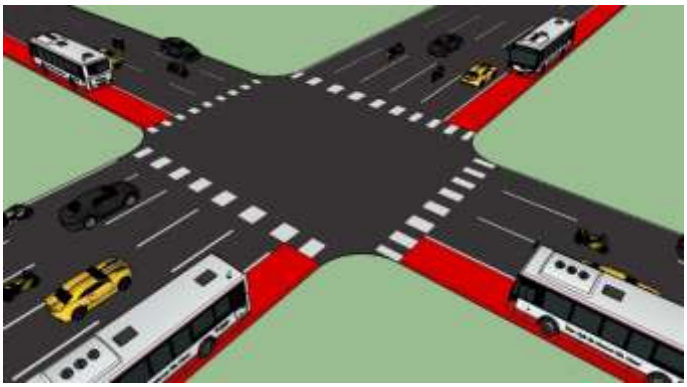

Fig. 8. Intersection Using Contra-Flow Bus Lane

TABLE IV. ROAD SECTION FOR THE IMPLEMENTATION OF BUS LANE (LONG-TERM PLAN)

Street	Route	Road Type	Width (meters)	Bus Traffic/ Hours	Obstacles
Cik Di Tiro	2B	4/2 D	6.5	18	High
	3A				
	4A				
	5B				
	11				
	1B	4/2 D	6.5	21	High
	2A				
	3B				
	4A				
	5B				
Colombo	1B	4/2 UD	6.1	15	High
	2A				
	5A				
	11				
	2B	4/2 UD	6.1	13	High
	4A				
	5B				
	11				
Affandi	2B	4/2 D	7.6	7	High
	11				
	2A	4/2 D	6.8	8	High
	11				
Kaliurang	3A	4/2 UD	7	8	High
	5A				
	3B	4/2 UD	7	8	High
	5B				

Fig. 9. Ring Road Segment

V. CONCLUSION

The determination of the Bus Lane route implementation considering the road width which is more than (>) 9 m, if the road width is less than (<) 9 m then the assessment is carried out by looking at the V / C Ratio close to 1 and handling / recommendation on road widening. The application of Bus Lane in accommodating Trans Jogja Buses is done in two stages, namely; the first stage is by removing the median, eliminating the street parking, and reducing the width of the sidewalk on the specified road segment. The Bus Lane application in the second stage was emphasized on roads that have a one-way traffic flow, and the implementation of the Contra Flow Bus Lane system. The application of bus lane trials can be done using traffic cones and traffic signs. It is due to the absence of specific regulations regarding the implementation of bus lanes in Indonesia. If the regulation has been established, the application of the bus lane could be applied and the bus lane markers will be red as stated in the Minister of Relation of Indonesia Regulation Number PM 67 of 2018 concerning Road Markings. There are several roads in Yogyakarta that are not possible to implement the lane bus, namely on Ringroad Road, Yogyakarta. This is because the road sections are divided into 6-way 2-lane road types (6/2 D). It is because Trans Jogja stops on the track located in a slow lane (motorbike lane). Then, if a bus lane is located in made on a slow lane it would reduce the lane capacity intended for motorbikes. In improving the performance of the Trans Jogja Buses particular in increasing the load factor and improving the headway and travel time, it is necessary to improve the traffic system by using the Bus Lane / special lane system for the Trans Jogja Buses. With the existence of Bus Lane, it is expected that it would be increase public interest in using Trans Jogja Buses. Then, it will improve the service of waiting time, headway, travel time, load factor, and as well as decrease the government subsidies on the operational costs of Trans Jogja Buses.

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