Analysis of One-Way System Implementation with Contra-Flow Bus Lane in Supporting Sustainable Transportation Program

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Abstract. Traffic development in the central business district area along the Brigjend Slamet Riyadi road, Surakarta City, Indonesia, is relatively dense and not in accordance with the development and changes in the environmental situation. This phenomenon creates congestion on several roads and intersections. Transport planning related to traffic management and engineering, and infrastructure needs to be carried out to solve urban transportation problems. Based on the Surakarta City Government's vision related to sustainable transportation, the one-way system with contra-flow bus lane will be implemented along the Brigjend Slamet Riyadi road. With the existence of this system, it is hoped that public transport Batik Solo Trans as one solution of urban transportation problem can be more integrated, fast, safe, comfortable, reliable and efficient. The purpose of this research is to determine the impact of the implementation of one-way system with contra-flow bus lane to the traffic performance in the study area. The research methodology involves modelling and analysing the traffic performance, parking and potential public transport demand in the study area. The existence of one-way system with contra-flow bus lane has the potential to increase the use of public transportation and improve the performance of public transportation. In general, traffic performance decreases, therefore it is necessary to perform transportation demand management such as management parking.

1. Introduction
In order to anticipate traffic problems i.e. congestion, accidents, pollution, the Government of Surakarta City, Indonesia launched a Solo vision towards a Sustainable Transportation City [1]. One of its programs is to revitalize regular urban public transport into public transport based on Bus Rapid Transit, namely Batik Solo Trans (BST) and revitalize paratransit urban transport (Angkot) as a feeder mode that is integrated operationally with the BST.

In regulating vehicles movement in the city, the government implements one-way system at Brigjend. Slamet Riyadi road segment starts from the Gendengan Intersection to the Gladag Roundabout (to the east direction). In connection with this, the BST Corridor 1 cannot serve the community travel needs from the east to the west on this road segment. Due to the one-way system, therefore, the BST Corridor 1 route from east to west is diverted to the Major Sunaryo road, Kapten Mulyadi road, Veteran Street, Bhayangkara road, Radjiman road and Dr. Wahidin road. The BST Corridor 1 routes can be seen in Figure 1.
This phenomenon cause ineffectiveness of BST Corridor 1 performance, because the distance of the BST Corridor 1 east to west become too far so the travel time is longer. In addition, potential demand for public transport users in the area between the Gladag Roundabout and the Gendengan Intersection is not accommodated. This results in people who live or work in those area tend not to use the BST as their mode of transportation.

Contra-flow bus lane is one of strategies to overcome urban transportation problems has been widely used in many cities in the world. This strategy has proven to improve the reliability of bus travel time [2, 3, 4, 5], reduce the number of bus accidents, fuel consumption and pollutant emissions rates [6], increase the bus ridership [7, 3]. In order to yield an integrated and reliable performance of the BST, therefore, one of the efforts of traffic management and engineering that needs to be carried out is to implement one-way system with contra-flow bus lane at Brigjend. Slamet Riyadi road segment starts from the Gladag Roundabout to the Gendengan Intersection.

2. Methodology

2.1. Site Description and Data Collection

The scope of study includes intersections and roads around the location of the one-way system with contra-flow bus lane implementation, which includes Gendengan, Sriwedari, Ngapeman, Pon Market and Nonongan intersections. All intersections are controlled by traffic signal. The location of roads and intersections under studies can be seen in Figure 2.
2.2. Stages of The Study

Stages of study can be explained as follows:

Secondary and primary data collection. Secondary data related to traffic signal timings is obtained from the Department of Transportation, Communication and Information Technology Surakarta. Primary data related to traffic volume are taken at peak hour from 06.30 to 07.30 AM. The traffic count survey at intersection was conducted to obtain traffic volume, vehicle type composition, and turning movement distribution. Traffic count is done separately for each arm and direction of traffic. The road and intersection inventory survey is conducted to obtain geometric data, road side friction parameters and junction control types. On-street parking survey is carried out along Brigjend. Slamet Riyadi Road to collect parking characteristic data.

Data analysis and technical calculation. The data analysis results are used to determine traffic performance i.e. road and intersection performance, parking characteristic and potential public transport demand. Road and intersection performance are calculate based on three conditions namely 1) existing one-way system condition, 2) one-way system with contra-flow bus lane condition and 3) one-way system with contra-flow bus lane and transport demand management effort condition.

Discussion. Discuss efforts to minimize traffic impacts of the one-way system with contra-flow bus lane implementation.

Conclusion. Drawing conclusions from the study results.

3. Analysis and Result

3.1. Traffic Performance

Traffic performance is calculated by using the Indonesian Highway Capacity Manual 1997 [8]. Using this method, road performance is based on degree of saturation value, while for intersection performance is based on delay of intersection value. From these values, the Level of Service (LOS) of road and intersection can be determined [9]. The road cross section of existing one-way system and one-way system with contra-flow bus lane can be seen in Figure 3. Comparison of road and intersection performances between existing one-way system and one-way system with contra-flow bus lane can be seen in Tables 1 and 2.

![Figure 3. The road cross section (a) existing one-way system (b) one-way system with contra-flow bus lane]
Table 1. Road performance comparison between existing one-way system and with contra-flow bus lane.

| No | Road Name                                                  | Existing one-way system | One-way system with contra-flow bus lane |
|----|------------------------------------------------------------|-------------------------|-----------------------------------------|
|    |                                                            | Degree of Saturation    | Level of Service                        | Degree of Saturation | Level of Service |
| 1  | B. Slamet Riyadi road (West of Gendengan Intersection)    | 0.67                    | C                                        | 0.67                 | C                |
| 2  | Doktor Moewardi road                                      | 0.38                    | B                                        | 0.38                 | B                |
| 3  | B. Slamet Riyadi road (East of Gendengan Intersection)    | 0.62                    | C                                        | 0.91                 | E                |
| 4  | B. Slamet Riyadi road (West of Ngapeman Intersection)     | 0.64                    | C                                        | 0.93                 | E                |
| 5  | Gajah Mada road                                           | 0.50                    | C                                        | 0.50                 | C                |
| 6  | B. Slamet Riyadi road (East of Ngapeman Intersection)     | 0.49                    | C                                        | 0.72                 | D                |
| 7  | Diponegoro road                                           | 0.52                    | C                                        | 0.52                 | C                |
| 8  | B. Slamet Riyadi road (West of Nonongan Intersection)     | 0.60                    | C                                        | 0.87                 | E                |
| 9  | K. H. Ahmad Dahlan road                                   | 0.11                    | A                                        | 0.11                 | A                |
| 10 | B. Slamet Riyadi road (East of Nonongan Intersection)    | 0.68                    | C                                        | 0.98                 | E                |
| 11 | Yos Sudarso road                                          | 0.28                    | B                                        | 0.28                 | B                |
| 12 | Gatot Subroto road                                        | 0.46                    | C                                        | 0.46                 | C                |
| 13 | Honggowongso road                                         | 0.35                    | B                                        | 0.35                 | B                |
| 14 | Bhayangkara road                                          | 0.34                    | B                                        | 0.34                 | B                |
| 15 | Wahidin road                                              | 0.35                    | B                                        | 0.35                 | B                |

Note: * Location of the road number can be seen in Figure 2

Table 2. Intersection performance comparison between existing one-way system and with contra-flow bus lane.

| No | Road Name                | Existing one-way system | One-way system with contra-flow bus lane |
|----|--------------------------|-------------------------|-----------------------------------------|
|    |                          | Delay of Intersection (sec) | Level of Service | Delay of Intersection (sec) | Level of Service |
| 1  | Gendengan Intersection   | 33.18                   | D                                        | 27.71                 | D                |
| 2  | Sriwedari Intersection   | 15.45                   | C                                        | 41.09                 | E                |
| 3  | Ngapeman Intersection    | 17.19                   | D                                        | 43.78                 | E                |
| 4  | Market Pon Intersection  | 16.60                   | C                                        | 23.40                 | C                |
| 5  | Nonongan Intersection    | 32.74                   | D                                        | 86.09                 | F                |

The results of road performance analysis show that the value of the degree of saturation of the Brigjend. Slamet Riyadi road has a significant increase. Thus the performance of the Brigjend. Slamet Riyadi road decreases with the LOS from C to D and E. Likewise the results of the intersection performance analysis indicate that the delay of the intersection increases, so that the LOS decreases from C and D to E and F. Traffic flow becomes unstable (LOS E) and traffic is jammed (LOS F). This happens because with contra-flow bus lane implementation, the road capacity for traffic becomes small due to one traffic lane is used as a contra-flow bus lane, see Figure 3b.
3.2. Parking Characteristics
Parking characteristic analysis at Brigjend. Slamet Riyadi road is divided into 4 segments, namely:
Segment 1: between Gladag – Nonongan Intersection
Segment 2: between Nonongan Intersection – Pon Market Intersection
Segment 3: between Pon Market Intersection – Ngapeman Intersection
Segment 4: Ngapeman Intersection – Sriwedari Intersection
Segment 5: Sriwedari Intersection – Gendengan Intersection

The comparison between parking capacity under the one-way system with contra-flow bus lane implementation and vehicle parking accumulation under the existing one-way system conditions can be seen in Table 3. The results of parking characteristic analysis show that in general the parking capacity of motorcycle vehicles under the one-way system with contra-flow bus lane implementation can accommodate the existing vehicle parking needs. Whereas for parking capacity of light vehicles cannot accommodate the existing vehicle parking needs. For this reason, it is necessary to provide off-street parking facilities in the vicinity of Brigjend. Slamet Riyadi road to accommodate vehicle parking needs.

| Table 3. Comparison of parking capacity and vehicle parking accumulation. |
|-----------------------------|------------------|------------------|------------------|
| Road Segment | Parking Capacity* | Vehicle parking accumulation# | Difference |
|               | Motorcycle (veh) | Light Vehicle (veh) | Motorcycle (veh) | Light Vehicle (veh) | Motorcycle (veh) | Light Vehicle (veh) |
| 1             | 63              | 50               | 53              | 68               | 10              | -18              |
| 2             | 70              | 23               | 52              | 36               | 18              | -13              |
| 3             | 161             | 33               | 120             | 66               | 41              | -33              |
| 4             | -               | 66               | 2               | 43               | -2              | -23              |
| 5             | -               | 57               | 0               | 90               | 0               | -33              |

Note: * parking capacity under the one-way system with contra-flow bus lane implementation condition
# vehicle parking accumulation under existing one-way system condition

3.3. Potential Public Transport Demand
Potential public transport demand is one of the important factors that must be considered in determining a public transport route. Potential public transport demand surveys are carried out in several land-use i.e. school, government agencies, private agencies and shops that are passed by BST Corridor 1 in the vicinity of the one-way system with contra-flow bus lane implementation at Brigjend. Slamet Riyadi road. The respondents are asked whether they are interested or not interested in using BST Corridor 1 if the one-way system with contra-flow bus lane is implemented. The number of respondents who are interested or not interested in using BST Corridor 1 for each land-use can be seen in Table 4 [10, 11, 12, 13]. The number of respondents (in %) who are interested includes respondents who have and have not used BST Corridor 1.

| Table 4. Potential public transport demand. |
|--------------------------------------------|
| Schools | Government Agencies | Private Agencies | Shops |
| Interested | Not Interested | Interested | Not Interested | Interested | Not Interested | Interested | Not Interested |
| 56.7      | 43.3            | 65.1        | 34.9        | 65.5        | 34.5          | 62.5       | 37.5          |

Respondents who have not used BST Corridor 1 and are interested in switching from the use of private vehicles to buses after the one-way system with contra-flow bus lane implementation and improvement of the quality of BST services are 46.2%, 57.0%, 57.7% and 54.9% for school, government agencies, private agencies and shops, consecutively. Hence, the average potential public transport demand of BST Corridor 1 is equal to 54.0%.
3.4. Traffic Performance with Transport Demand Management

The problem of traffic congestion can be minimized by implementing the concept of Transport Demand Management (TDM). This concept is oriented towards the policy of controlling the use of private vehicles, namely through the policy of using mass public transport, vehicle parking management and so on. In relation to the one-way system with contra-flow bus lane implementation, the effort is to reduce the use of private vehicles. The Government of Surakarta City has been and is working on an urban public transport revitalization program, a ban on the use of private vehicles for vehicle users that are not yet aged and parking management. Efforts to reduce private vehicles can also be done for employees of Government Agencies. The results of the analysis of potential public transport demand indicate that the average number of respondents who are interested in moving using public transportation is 54.0%. From this data it can be assumed that with the implementation of a reliable BST mass transit system and parking management, it can be predicted that there will be a 10% decrease in private vehicle use.

The performance of road and intersection with a reduction in private vehicle use can be seen in Tables 5 and 6. The results of analysis show that the value of the degree of saturation of the Brigjend Slamet Riyadi road has decreased (compared to without a decrease in the use of private vehicles). The LOS has increased from E to D. The value of vehicle delays in intersections decreases, so the LOS increases.

**Table 5.** Road performance with contra-flow bus lane and TDM effort.

| No | Road Name                                      | Degree of Saturation | Level of Service |
|----|-----------------------------------------------|----------------------|------------------|
| 1* | B. Slamet Riyadi road (West of Gendengan Intersection) | 0.62                 | C                |
| 2  | Doktor Moewardi road                           | 0.38                 | B                |
| 3  | B. Slamet Riyadi road (East of Gendengan Intersection) | 0.82                 | D                |
| 4  | B. Slamet Riyadi road (West of Ngapeman Intersection) | 0.84                 | D                |
| 5  | Gajah Mada road                                | 0.50                 | C                |
| 6  | B. Slamet Riyadi road (East of Ngapeman Intersection) | 0.64                 | C                |
| 7  | Diponegoro road                                | 0.52                 | C                |
| 8  | B. Slamet Riyadi road (West of Nonongan Intersection) | 0.79                 | D                |
| 9  | K. H. Ahmad Dahlan road                        | 0.11                 | A                |
| 10 | B. Slamet Riyadi road (East of Nonongan Intersection) | 0.89                 | E                |
| 11 | Yos Sudarso road                               | 0.28                 | B                |
| 12 | Gatot Subroto road                             | 0.46                 | C                |
| 13 | Honggowongso road                              | 0.35                 | B                |
| 14 | Bhayangkara road                               | 0.34                 | B                |
| 15 | Wahidin road                                   | 0.35                 | B                |

**Table 6.** Intersection performance with contra-flow bus lane and TDM effort

| No | Intersection Name           | Delay of Intersection (sec) | Level of Service |
|----|----------------------------|-----------------------------|------------------|
| 1  | Gendengan Intersection      | 23.91                       | C                |
| 2  | Sriwedari Intersection      | 18.70                       | C                |
| 3  | Ngapeman Intersection       | 30.31                       | D                |
| 4  | Market Pon Intersection     | 20.04                       | C                |
| 5  | Nonongan Intersection       | 39.01                       | D                |
4. Discussion
Several efforts need to be done to minimize traffic impacts of the one-way system with contra-flow bus lane implementation such as:
- Enforcement of Regional Regulation No. 8 of 2009 about Building [14]. Each building must fulfill the requirements of the completeness of infrastructure and facilities in the form of parking lots. This action is to anticipate illegal on-street parking violations because businessmen cannot provide sufficient parking space.
- Installation of traffic directions and bus lane marking in the contra-flow bus lane.
- Installation of warning signs that there is a public transport fleet going from east to west, prohibited signs from entering the contra-flow bus lane, installation of delineator.
- Law enforcement system for road users who use the contra-flow bus lane.
- Implementation of a traffic signal system that coordinates between intersections and signaling bus priority to improve traffic performance.
- Special attention is paid to the protection of vulnerable road users i.e. pedestrian and cyclist at crossing facilities.

5. Conclusion
The results of traffic performance analysis related to the one-way system with contra-flow bus lane implementation show that the use of the 1st lane Brigjend. Slamet Riyadi road for the contra-flow bus lane reduces road and intersection capacity. This resulted in decreasing LOS of road and intersection.

The results of parking characteristics analysis show that the existing on-street parking at Brigjend. Slamet Riyadi is not enough to accommodate vehicle parking needs when the one-way system with contra-flow bus lane is implemented. Therefore, it is necessary to provide off-street parking facilities.

The results of potential public transport demand analysis indicate the enthusiasm of the people who are interested in switching to using public transportation is relatively high at an average of 54.0%. This affects road and intersection performance because the number of private vehicle users is reduced. The implementation of a reliable BST mass transit system and good parking management (TDM effort) will decrease the number of private vehicle use. Thus the level of road and intersection services will increase.

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