Performance Study of Gendengan Intersection with the Implementation of a One-way System with Contra Flow Bus Lane

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Abstract. The central government plans to provide operational funding for urban public transport in the form of a Buy the Service (BTS) scheme in order to anticipate the degradation of the Batik Solo Trans (BST) public transport performance. One of the efforts to improve BST public transport services is by providing BST public transport a special lane facility on Brigjend Slamet Riyadi road from East to West direction called One-Way System with Contra Flow Bus Lane. This study discusses the design of traffic signal timing settings at Gendengan Intersection with implementation of One-Way System with Contra Flow Bus Lane on Brigjend Slamet Riyadi road. The signalized intersection performance is calculated by using the Indonesian Highway Capacity Manual 1997 method. Several scenarios of traffic signal timing for the signalized intersection are used to find out the best scenario. The results of signalized intersection performance analysis show that with implementation of One-Way System with Contra Flow Bus Lane, the level of service Gendengan intersection has decreased from D to F in the afternoon peak hours for Protected Scenario case, while in the morning and afternoon peak hours remain constant for all scenarios.

1. Introduction
City is a centre of activity that functions as a service centre for services, production, distribution of people and goods as well as a transportation node for the surrounding area. For this reason, an urban transportation system is needed that is able to facilitate people and goods movement for community activities in urban areas and surrounding areas. The urban transportation system acts as the lifeblood of the city's economic, social, cultural and political life. The transportation system consists of several micro systems, namely a system of activities, networks and movements that are mutually synergistic in providing services for the movement of transportation modes.

Urban transportation problems in the form of congestion and traffic accidents are caused by the city's poor transportation system. In order to anticipate traffic problems in the Surakarta city, therefore, the Surakarta City Government has launched a vision and mission of Solo Towards a City with Sustainable Transportation [1]. One of the efforts taken is to provide public transportation services that are reliable, safe, comfortable and affordable in accordance with the mandate of the applicable law. The government is obliged to guarantee the availability of public transportation for transportation services for people and or goods between cities, provinces and across national borders [2].

With the implementation of the One-Way System on Brigjend. Slamet Riyadi road from Gendengan Intersection to Gladag Roundabout (towards the East), then the BST Corridor 1 route to
the West cannot pass this road, see Figure 1a. Therefore, the BST Corridor 1 route to the West was diverted to Mayor Sunaryo road, Kapten Mulyadi road, Veteran road, Bhayangkara road, Radjiman road and Dr. Wahidin road, see Figure 1b.

The diversion of the BST Corridor 1 route from the Gendengan Roundabout to the Gendengan Intersection towards the south (via Veteran road) resulted in ineffective BST Corridor 1 performance, due to the long distance travelled so that the travel time was long. In addition, the potential demand for public transport users in the area between the Gladag Roundabout and Gendengan Intersection is not accommodated. This has resulted in people who live and work in the area tend not to use BST as their mode of travel [3]. Therefore, to produce an integrated and reliable public transport performance, one of the traffic management and engineering efforts that needs to be done is to implement a special Contra Flow System for public transportation on Brigjend. Slamet Riyadi road from Gladag Roundabout to Gendengan Intersection [4]. This system called Contra Flow Bus Lane. The implementation of Contra Flow Bus Lane has been carried out by many cities around the world in minimizing urban transportation problems, because it has the ability to increase the reliability of public transportation, reduce the potential for traffic accidents and air pollution [5, 6, 7, 8, 9]. With implementation of Contra Flow Bus Lane, the BST Corridor 1 route to the West can be diverted to this road, see Figure 2. Thus, the potential demand in the area can be accommodated, shortening the distance so that the travel time will be faster.

In connection with the One-Way System with Contra Flow Bus Lane implementation plan, a traffic signal control management planning study is needed at signalized intersections. Regulating traffic movements at signalized intersections plays a major role in minimizing intersection delays. In this case, the determination of the number of phases and green split length as well as the cycle time of traffic signal control needs to be designed as effectively as possible. The most common traffic signal control in Indonesia is a Fixed Time Control (FTC). A tool to optimize the FTC signal timing is using the Indonesian Highway Capacity Manual (HCM) 1997 method [10] where this method produces optimum signal timing settings [11]. Regarding the need to design a signal timing setting at the signalized intersection during the Contra Flow Bus Lane implementation, therefore, it is necessary to
conduct research with the aim of designing signal timing settings at the Gendengan intersection by using the IHCM 1997 method.

2. Research Method

2.1. Study Area and Data Collection
The study location is Gendengan Intersection, see Figure 3. Gendengan intersection is a meeting point of major road traffic movements, namely Brigjend. Slamet Riyadi road, Dr. Wahidin road and Dr. Moewardi road. Traffic volume at this intersection is relatively large during peak hours. Traffic movement at Gendengan Intersection is regulated by means of a traffic signal control.

![Figure 3. Study location a) Gendengan Intersection b) Dr. Moewardi road c) Dr Wahidin road d) Brigjend. Slamet Riyadi road - West e) Brigjend. Slamet Riyadi road - East](image)

Data required for modelling includes geometric, traffic volume and signal timing data. Secondary data in the form of signal timing data were obtained from the Department of Transportation Surakarta city, while the primary data for geometric intersection and traffic volume were obtained from field surveys. Primary data related to traffic volume in the study area was taken at the morning, noon and evening peak hours from 07.00 to 08.00 am, 00.45 to 01.45 pm and 03.30 to 04.30 pm, consecutively. Traffic count survey at an intersection was conducted to obtain traffic volume, vehicle type composition, and distribution of turning vehicle movements. Traffic count is done separately for each approach of intersection and direction of traffic. The road and intersection inventory survey are conducted to obtain geometric and road side friction parameters at intersection.

2.2. Stages of Study
The stage of study begins with the preparation stage, which includes a literature review, problem determination, study objectives and research methodology. The next stage is taking secondary and primary data to be used as an input data for models. The next stage is the modeling stage, where the signalized intersections are modeled by using the IHCM 1997 method. In this stage, various scenarios of traffic signal control regulation are carried out. Modeling results are analyzed to determine the best scenario in regulating traffic movement at signalized intersection. The last stage is the conclusion from the results of the model analysis.
3. Result and Discussion

3.1. Signalized Intersection Model

In this study, the signalized intersection performance is calculated by using the IHCM 1997 method [10]. Data obtained from field surveys are processed to calculate the signalized intersection capacity. Signalised intersection capacity is determined by the basic saturation flow and its adjustment factor, green split and cycle time. Signalized intersection performance can be seen from the value of degree of saturation and intersection delay. Based on intersection delay value, therefore, the Level of Service (LOS) of signalized intersection can be determined [12].

In order to determine Gendengan intersection performance before and after implementation of One-Way System with Contra Flow Bus Lane, several modelling scenarios were carried out, namely:

- **Scenario 1**: Existing model, where the intersection conditions before implementation of One-Way System with Contra Flow Bus Lane. Traffic signal control Gendengan intersection has 3 signal phases, namely the phase of traffic movement from west, north and south, consecutively.
- **Scenario 2**: Proposed Protected model, where intersection condition after implementation of One-Way System with Contra Flow Bus Lane. Traffic signal control Gendengan intersection has 4 signal phases, namely the phase of traffic movement from west, north, south and east consecutively. In this case, the bus movement from the east (on Contra Flow Bus Lane) is accommodated by the east phase exclusively (protected).
- **Scenario 3**: Proposed Opposed model, where intersection condition after implementation of One-Way System with Contra Flow Bus Lane. Traffic signal control Gendengan intersection has 3 signal phases, namely the phase of traffic movement from west-east, north and south consecutively. In this case, the bus movement from the east (on Contra Flow Bus Lane) is accommodated by the west phase (opposed).

Figure 4 shows the conditions of Gendengan Intersection before and after implementation of One-Way System with Contra Flow Bus Lane. The existing condition where Brigjend. Slamet Riyadi road (eastern approach) currently with a one-way system (from West to East) see Figure 4a, while the proposed condition Brigjend. Slamet Riyadi road (eastern approach) currently with a one-way system (from West to East) then provides a contra flow bus lane (from East to West) see Figure 4b.

![Figure 4. Gendengan Intersection a) before and b) after implementation of One-Way System with Contra Flow Bus Lane](image-url)
3.2. Simulation Results and Discussions
The intersection performance in the Existing Scenario is based on the current condition before implementation of One-Way System with Contra Flow Bus Lane with input data in modelling includes intersection geometry, traffic volume, and traffic signal timing. After implementation of One-Way System with Contra Flow Bus Lane, the traffic movement settings for each phase changed so that the traffic signal timing setting changed according to protected or opposed scenarios, while traffic volume did not change. In this case, the signal timing settings will be optimized by the model to produce the best intersection performance in terms of degree of saturation and delays. Table 1 shows signal timing of Gendengan Intersection for all scenario’s models.

| Scenario     | Approach | Green Time (sec) | Cycle Time (sec) | Green Time (sec) | Cycle Time (sec) | Green Time (sec) | Cycle Time (sec) |
|--------------|----------|------------------|------------------|------------------|------------------|------------------|------------------|
| Existing     | West     | 10               | 100              | 15               | 105              | 15               | 105              |
|              | South    | 30               | 100              | 35               | 105              | 35               | 105              |
|              | North    | 45               | 100              | 40               | 105              | 40               | 105              |
|              | West     | 10               | 100              | 10               | 105              | 10               | 105              |
|              | South    | 45               | 120              | 43               | 120              | 48               | 120              |
|              | North    | 38               | 120              | 40               | 120              | 38               | 120              |
|              | East     | 7                | 7                | 7                | 7                | 7                | 7                |
| Proposed     | South    | 45               | 120              | 43               | 120              | 48               | 120              |
| Protected    | North    | 38               | 120              | 40               | 120              | 38               | 120              |
|              | East     | 7                | 7                | 7                | 7                | 7                | 7                |
| Proposed     | West-East| 10               | 12               | 10               | 12               | 10               | 12               |
| Opposed      | South    | 50               | 120              | 50               | 120              | 52               | 120              |
|              | North    | 45               | 120              | 43               | 120              | 43               | 120              |

Table 2 shows Gendengan Intersection performance in terms of degree of saturation and average vehicle delay approach for all scenarios models. The intersection performance of Existing Scenario shows that value of degree of saturation and average vehicle delay approach on the evening peak hour is greater than noon and morning peak hours. The lowest values are in the morning peak. This is due to the current condition during the Covid-19 pandemic the school activities were closed so that the traffic volume in the morning peak decreased. The Gendengan intersection performance for Protected and Opposed Scenarios shows the same trend as the Existing Scenario. In general, the value of degree of saturation at intersection approach is close to and has exceeded the saturation condition (> 0.8). This shows that the effective green time of each phase is not enough to release the number of vehicles that will cross the intersection, resulting in high vehicle delays.

Figure 5 shows comparison of intersection delay for all scenarios models. The intersection performance analysis results show that the Protected Scenario produces the greatest delay compared to other scenarios in all peak hour conditions. This is because by providing a special phase of bus movement from the east will increase the number of phases. Thus, the time lost (intergreen) and the cycle time will increase so that the signal timing becomes ineffective. However, in terms of safety, traffic management with Protected Scenario has a relatively low potential for traffic accidents compared to the Opposed Scenarios. Generally, the intersection level of service of all models for all peak hours show at level D, where the traffic flow is nearing unstable with a tolerable delay. For evening peak hour case, the Protected Scenario has level of service F, which means that traffic is stuck.
### Table 2. Gendengan Intersection performance for all scenarios models (in each approach)

| Scenario  | Approach | Morning DoS | Morning Approach Delays (sec/pcu) | Noon DoS | Noon Approach Delays (sec/pcu) | Evening DoS | Evening Approach Delays (sec/pcu) |
|-----------|----------|-------------|-----------------------------------|---------|---------------------------------|-------------|----------------------------------|
| Existing  | West     | 0.42        | 45.7                              | 0.14    | 44.0                            | 0.33        | 43.7                             |
|           | South    | 0.89        | 51.0                              | 0.33    | 53.4                            | 0.95        | 61.3                             |
|           | North    | 0.55        | 23.6                              | 0.38    | 34.3                            | 0.85        | 41.3                             |
|           | West     | 0.51        | 56.2                              | 0.64    | 60.7                            | 0.81        | 79.9                             |
| Proposed  | South    | 0.71        | 37.8                              | 0.84    | 45.7                            | 0.99        | 87.0                             |
| Protected | North    | 0.78        | 45.8                              | 0.84    | 49.4                            | 1.03        | 133.1                            |
|           | East     | 0.11        | 57.0                              | 0.11    | 57.5                            | 0.11        | 57.0                             |
|           | West     | 0.67        | 63.1                              | 0.70    | 62.3                            | 0.75        | 69.6                             |
| Proposed  | South    | 0.64        | 32.3                              | 0.73    | 35.3                            | 0.92        | 49.3                             |
| Opposed   | North    | 0.66        | 36.1                              | 0.78    | 42.2                            | 0.91        | 54.6                             |
|           | East     | 0.14        | 57.1                              | 0.14    | 57.1                            | 0.14        | 57.1                             |

#### Figure 5. Comparison of intersection delay for all scenarios models

The intersection delay in the Existing Scenario was higher than the Opposed Scenario because the signal timing was not optimal. This can be seen from the unbalanced approach degree of saturation value. For example, in the morning peak, the degree of saturation of the south approach is 0.89, while other approaches are 0.42 and 0.55. Optimizing the signal time of the Existing Scenario will result in less delay than in Protected and Opposed Scenarios. This makes sense because implementation of One-Way System with Contra Flow Bus Lane will increase the number of conflict movement at the intersection with additional bus movement from the east approach.

### 4. Conclusion

Traffic congestion and accidents can be minimized by providing reliable public transportation. For this reason, the Surakarta City Government provides Batik Solo Trans public transport facilities with various road infrastructure that support it, one of which is the One-Way System with Contra Flow Bus Lane. It is predicted that implementation of a One-way System with Contra Flow Bus Lane will increase intersection delay at Gendengan Intersection using Protected and Opposed Scenarios. With implementation of One-Way System with Contra Flow Bus Lane, the level of service Gendengan intersection has decreased from D to F in the afternoon peak hours for Protected Scenario case, while in the morning and afternoon peak hours remain constant for all scenarios. The use of Protected Scenario will result in a higher intersection delay than Opposed Scenario, but in terms of safety it is better. It is hoped that by implementation of a One-way System with Contra Flow Bus Lane will
increase the performance of Batik Solo Trans public transport so that the community will switch to using BST as their mode of transportation. Overall, this has an impact on reducing the use of private vehicles and reducing the level of congestion and traffic accidents.

References

[1] Dishubkominfo Surakarta 2013 Solo Menuju Kota Dengan Transportasi yang Berkelanjutan.
[2] Ministry of Transportation 2009 Law Number 22 of 2009 concerning Road Traffic and Transportation (Indonesia: Ministry of Transportation)
[3] Yulianto B and Setiono 2019 Analysis of One-Way System Implementation with Contra-Flow Bus Lane in Supporting Sustainable Transportation Program. Journal of Physics: Conference Series 1376(1), 1-8
[4] Dishub Surakarta 2019 Kajian Jasa Konsultan Evaluasi Koridor Batik Solo Trans
[5] Rose H S and Hinds D H 1976 South Dixie Highway Contra-flow Bus and Car-pool Lane Demonstration Project. Transportation Research Record 606
[6] Polus A and Schofer J L 1979 Contra-flow Bus Priority Lane Performance – A Case Study. Transportation Engineering Journal 105 (3), 297-305
[7] Hellenic Institute of Transport Feasibility Study for the Implementation of a Contra-flow Bus Lane in the Vas. Olgas Road together with the Reversion of the Direction of two Lanes of General Traffic in the Sea-coast Avenue. Final Report (2003)
[8] Berg W D, Smith Jr. R L, Walsh Jr. T W, and Notbohm T N 1981 Evaluation of a Contra-flow Arterial Bus Lane. Transportation Research Record 798, 45-9
[9] Chang K J, Chen H H, and Kuo J H 1993 Effects of Contra-flow Bus Lane on Ridership. Proceeding of the 63 road ITE Annual Meeting, Institute of Transportation Engineers, 322-6
[10] Directorate General Bina Marga Indonesia 1997 Indonesian Highway Capacity Manual.
[11] Yulianto B 2019 Sensitivity Test of HCM 1997 Traffic Signal Timings Using TRANSYT Program and VISSIM. AIP Conference Proceedings 2114(1)
[12] Ministry of Transportation 2006 Government Regulation Number KM 14 of 2006 on Traffic Management and Engineering on the Road

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