Traffic Management and Engineering Analysis of the Manahan Flyover Area by using Traffic Micro-Simulation VISSIM

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Abstract. The location of the Manahan railway level crossing is a meeting point for movement between trains and vehicles which often causes traffic congestion and traffic accidents in the area. In connection with the construction of the double track railway, the intensity of traffic congestion in the Manahan railway level crossing area is increasing. In order to overcome traffic congestion in the area, the Surakarta City Government built Manahan Flyover infrastructure. However, due to traffic management and engineering in the existing conditions is not optimal resulting in a relatively bad traffic congestion in Manahan Flyover area. The aim of this study is to conduct traffic management and engineering analysis to minimize traffic congestion in Manahan Flyover area. The traffic micro-simulation VISSIM model is used to evaluate the performance of road networks at peak traffic conditions with different simulation model scenarios. The existing model is built based on a field survey data and then calibrated to approximate conditions on the field. Then based on the existing model, modelling of several traffic management and engineering scenarios are carried out to obtain the optimal performance of the road network in the Manahan Flyover area. The analysis shows that the simulation model Scenario 3 produces the best performance of road network in terms of vehicle delay, queue length, travel time and speed.

1. Introduction
Uncontrolled growth in vehicle use has an effect on increasing traffic density in cities. This will eventually have the potential to increase the intensity of traffic congestion and accidents. Railway level crossing is a meeting point between railway and highway, where when a train crosses a railway level crossing it will cause vehicle delays and queues. Traffic congestion often occur in the Manahan railway level crossing area because of the high intensity of trains that cross the railway and traffic volume that pass through Dr. Moewardi road. The Central Government's program in improving railway-based mass public transportation services in Java was realized in the construction of the double track railway. This development has the potential to increase the intensity of traffic congestion in the Manahan railway level crossing area. In order to realize smooth, orderly and safe traffic, the Manahan railway level crossing was changed to a non-level crossing by facilitating the movement of traffic with flyover infrastructure.

Imperfect and immature traffic engineering and management studies conducted by Planning and Traffic Impact Analysis Consultants on Manahan Flyover development have caused a negative impact on traffic congestion on roads and intersections in the Manahan Flyover area. The elimination of the Kota Barat Intersection results in Dr. Moewardi road becoming the main road for traffic movement from the south (Dr. Moewardi road) to the north (MT Haryono and Adi Sucipto roads) and vice versa. Thus the capacity of Dr. Moewardi road is unable to accommodate traffic volume that crossed the road.
Traffic movements from Dr. Moewardi road to MT Haryono road is not accommodated by Manahan Flyover, so the traffic movements are diverted towards the KFC Intersection. In order to minimize traffic accidents, vehicle delays and queues, therefore, the KFC Intersection is installed traffic signal control. Ineffective signal timing of the controller has a major impact on vehicle delays and queues at the intersection. In addition, limited road accessibility in the Manahan Flyover area results in traffic violations at the end of the Manahan Flyover ramp which conducts U-Turn movements. This has an effect on traffic congestion and potentially on traffic accidents. Figure 1 shows the traffic conditions after the Manahan Flyover operated. In connection with the traffic problems in the Manahan Flyover area, a further analysis of traffic engineering and management is needed to minimize the impact of Manahan Flyover development on the performance of road network and its improvement efforts.

Figure 1. Traffic congestion on Dr. Moewardi road South of Manahan Flyover

The aim of this study is to conduct traffic engineering and management analysis to minimize traffic congestion in Manahan Flyover area. The traffic micro-simulation VISSIM model is used to evaluate the performance of road network at peak traffic conditions with different simulation model scenarios.

2. Study Methodology
2.1. Site Description and Data Collection
This study is conducted on area covering all roads and intersections around the Manahan Flyover development area. The construction’s location of the Manahan Flyover and study area can be seen in Figure 2. Data primer collected at study area included traffic volume, composition and turning proportions, desired speed vehicle, geometry and signal timing. Secondary data related to Design Engineering Details of the Manahan Flyover is obtained from the Ministry of Public Works, the National Research and Development PUSJATAN [1], see in Figure 3.

2.2. Stages of Study
The study work begins with the preparatory stage, which includes the process of formulating the problem, setting goals and preparing study methods. The next stage is the primary and secondary data collection stage. This data is used as an input data for the road network simulation model. The next step is the analysis stage, which includes modeling the existing road network, modelling of several traffic management and engineering scenarios and evaluating the effectiveness of different simulation model scenarios using the traffic micro-simulation VISSIM. The analysis results of different simulation models are discussed in relation to the performance of the road network under different effort of traffic management and engineering scenarios. The final stage is the conclusion of the analysis results and subsequent research recommendations.
3. Analysis, Results and Discussions

3.1. Simulation Model

Road network modelling is done by using traffic micro-simulation VISSIM Version 10.6. It is a microscopic, time step (1-second) and behavior based simulation model, which is developed to model urban traffic and public transportation operations [2]. It can be used as a tool to evaluate various alternatives according to planning of traffic management and engineering. Road network modelling stage consists of three stages namely network coding and calibration of the existing model, develop the different simulation model scenarios and comparison of the measure of performance for all models.

3.1.1. Development of Road Network Existing Mode.

The road network model is built based on the existing conditions. Traffic conditions in the study area are different from traffic conditions in developed countries where vehicle follows lane based operation, in which vehicles run on the specified lane with the majority of car vehicles. Whereas in the study area, the traffic is untidy where vehicles do not follow the lane based operation and the proportion of
motorcycles is very high (mixed traffic). In order to create a simulation model that can replicate field conditions, therefore the traffic parameters of the simulation model need to be calibrated based on the field data. The calibration process is done by setting the car following, lane change, desired speed distribution, reduced speed area and priority rules parameters [3], [4], [5], [6].

Manahan Flyover Existing model is developed in accordance with the detail engineering designs and road network existing conditions with planned traffic management and engineering efforts based on the consultant's study. Figure 4 shows the screenshot of the Manahan Flyover Existing model.

![Manahan Flyover Existing model](image)

**Figure 4.** Manahan Flyover Existing model

### 3.1.2. Development of Simulation Model Scenarios.

Traffic management and engineering analysis to minimize congestion on Manahan Flyover area by using micro-simulation model is carried out in several scenarios in a gradual process. During each stages of scenario, discussions are held with relevant agencies such as Department of Transportation Surakarta, Department of Public Works to find the optimal solution. The stages of scenario are as follows:

A. Scenario 1 is the Existing model plus the following efforts:
   - Increase Dr. Moewardi road capacity by eliminating on-street parking.
   - Reducing the number of conflict points between vehicles at the Masjid Kota Barat Intersection by changing traffic direction on the Mawar road to become one direction to east. Masjid Kota Barat intersection is separated by barrier so that traffic flows from the west and south cannot enter the Mawar road directly. Traffic flow from the north cannot turn right onto the Kenanga road.

B. Scenario 2 is the Scenario 1 model plus the following efforts:
   - Increase vehicle throughput at the KFC Intersection by changing the signal timing of traffic signal control including phase sequence, green split and cycle time. Prohibit vehicles from Adi Sucipto road (west) turn right onto the KS Tubun road (south).

C. Scenario 3 is the Scenario 2 model plus the following efforts:
   - Reducing the amount of traffic flowing through Kalitan road by implementing a one-way contra flow system on the Brigjend. Slamet Riyadi road.
3.2. Simulation Results and Discussions

The performances of road network under existing model and different simulation model scenarios are compared to each other in terms of performance measure i.e. an average vehicle delay, queue length, travel time and speed. A simulation run is made for approximately one-hour periods to produce the output performance measures. In these comparisons, five simulation runs are undertaken for each model with different random seed values.

Comparison of the average vehicle delay at KFC and Manahan Flyover Intersections for all models can be seen in Figure 5. The simulation results show that the average vehicle delay at intersections of the simulation model Scenario 3 lower than the other models. In general, the simulation model Scenario 3 produces the lowest vehicle queue length at the main approach intersections, see Figure 6. Similarly, for the average travel time of various segments where scenario 3 produces the lowest travel time compared to other models, see Figure 7.

![Figure 5. Comparison of average delay at KFC and Manahan Flyover Intersections](image)

![Figure 6. Comparison of average queue length at KFC, Kalitan and Flyover Manahan Intersections](image)

![Figure 7. Average Travel Time Comparison](image)
Figure 7. Comparison of average travel time

Figure 8 shows comparison of the road network average vehicle delay and speed for all models. The simulation results show that the average vehicle delay of the simulation model Scenario 3 lower than the other models. Vehicle delays on the road network are low due to high vehicle speeds. Simulation model Scenario 3 produces the highest vehicle speed compared to other scenarios.

Figure 8. Comparison of network average delay and average speed

Simulation results show that the acute traffic congestions occur in the Existing model. This is due to the inadequate capacity of Dr. Moewardi road to accommodate traffic volume from the north and many conflicting movements occur at the Masjid Kota Barat Intersection, see Figures 9a and 9b. Stunted traffic flow on Jalan Dr Moewardi resulted in a vehicles queue at Manahan Flyover Intersection, see Figure 9c.

Figure 9. Road network traffic on Existing model

In simulation model Scenario 1, the road capacity of the Dr. Moewardi road is enlarged by eliminating on-street parking and reducing the number of conflict points at the Masjid Kota Barat Intersection. This is to minimize traffic congestion at Dr. Moewardi road. Figures 10a and 10b show the traffic congestion at Dr. Moewardi road reduced. Meanwhile the long vehicle queue occurs at the KFC Intersection, see Figure 10c. This is because of ineffective signal timing of the traffic signal control.
Figure 10. Road network traffic on simulation model Scenario 1

In simulation model scenario 2, the signal timing of the traffic signal control is changed in order to increase the vehicle throughput at the KFC intersection. Figure 11a shows the traffic congestion at KFC Intersection reduced. Setting long green time for the west phase caused large amount of traffic going to east. This has an impact on the traffic movement from MT Haryono road that passes through Manahan Flyover. Assuming that the Adi Sucipto road (direction from the west) is a major road, then the traffic from MT Haryono road (direction from the north) must follow the 'right way rule' rule. This caused traffic congestion on MT Haryono road, because the headway between vehicles from Adi Sucipto road is relatively small so that the vehicle throughput from MT Haryono is small, see Figure 11b. Long vehicle queue occurs at the east approach of Kalitan Intersection. This is due to many vehicles that want to go to the Brigjend. Slamet Riyadi road (to the west) by passing the Kalitan road, see Figure 11c.

Figure 11. Road network traffic on simulation model Scenario 2

In simulation model Scenario 3, optimizing signal timing of the controller is carried out to minimize traffic congestion at intersections, see Figure 12a and 12b. Other than that, the one-way contraflow system on the Brigjend. Slamet Riyadi road is re-functioned to reduce the vehicle passing the Kalitan road, see Figure 12c. Simulation model Scenario 3 produces the best performance of road network in terms of vehicle delay and queue length at intersections as well as vehicle travel time and speed of the road network.

Figure 12. Road network traffic on simulation model Scenario 3

4. Conclusion
During the initial post-operation Manahan Flyover, traffic congestion occurred due to lack of planning and recommendations for traffic management and engineering by consultants. The use of simulation tools is very effective in evaluating the performance of road networks with various scenarios. It is a faster and less expensive experimental tool to carry out repetitive test track experiments under controlled conditions and to produce sufficient data that would be difficult to get in real life [7]. The simulation
results show that simulation model Scenario 3 produces the best performance of road network in terms of vehicle delay and queue length at intersections as well as vehicle travel time and speed of the road network.

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