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Comparative Analysis of Road Network Simulation Model Performance of Pahlawan Road Area

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ABSTRACT

The solution to the transportation problem lies in assessing the performance of related road sections and intersections, and analyzing different traffic management schemes to optimize efficiency. This study aims to compare the performance of a road network simulation model for the Pahlawan road area. Data analysis includes examining origin-destination matrices, vehicle free speeds, vehicle behavior, and intersection control. The simulation model, calibrated and validated using Vissim, represents real-world conditions. Implementing SLFF (Single Lane Free Flow) and MLFF (Multi Lane Free Flow) systems at toll gates (scenarios 1 and 2) reduced queues, particularly at the Pancasila Monument Roundabout and Jalan Jati Raya. Adding a new toll gate via Jalan Kahuripan further improved traffic on Jalan Pahlawan compared to scenarios 1 and 2. However, converting the Gelora Delta roundabout into an underpass without additional measures worsened toll gate queues. Effective traffic performance can be achieved by combining the Gelora Delta roundabout underpass with either the SLFF toll payment system (scenario 5), MLFF (scenario 6), or the addition of a new toll gate (scenario 3).

Keywords: Road Network Performance, Traffic Engineering Management, Simulation

1. Introduction

Road traffic problems in this decade have increased due to the indiscipline of road users as well as the limited land to build or widen roads and the increasing growth in the number of vehicles accompanied by the increasing standard of living of the people (Ardiansyah et al., 2023). The rapid increase in the number of vehicles affects the increase in community movement in fulfilling their needs. However, this is not balanced by the fulfillment of adequate road capacity so that it can cause traffic problems such as congestion (Rusmandani et al., 2021). Congestion is a situation where vehicles experience a decrease in speed below normal conditions. Congestion is detrimental to road users because it creates obstacles and disrupts travel, causing longer travel times. The cause of congestion is usually caused by a decrease in road performance due to activities in an area that have not been properly regulated. Congestion is one of the problems that is often experienced by every city in the world. One of them is happening in Sidoarjo Regency, namely in the Pahlawan Road area (Ardiansyah et al., 2023).

Heterogeneous and irregular traffic conditions with both motorized and non-motorized vehicles competing with each other in one lane have the potential for traffic accidents (Yatmar et al., 2021). Traffic accidents are events that are difficult to predict when and where they will occur. Traffic accidents have become a negative stigma of the rapid increase in transportation mobility. To reduce the risk of accidents and improve the comfort and safety of road users in the Pahlawan Road area of Sidoarjo Regency, appropriate and effective traffic engineering management is needed (Afrianti et al., 2023).

Overall, the placement and design of public transport stops, on-street parking spaces, pedestrian crossings, and traffic signal settings in the Jalan Pahlawan area must be managed properly to improve traffic performance in the Jalan Pahlawan area (Pamungkas et al., 2022). The combination of these factors has a significant impact on traffic smoothness and safety, so special attention needs to be given to their planning and implementation (Setiawan, 2017). The Jalan Pahlawan area is a very busy area. Around the road there are a lot of trip generators and pulls such as settlements, shopping centers, health facilities, sports facilities, and access to toll roads. This makes the volume of vehicles passing through the sections and intersections on Jalan Pahlawan very high, especially during peak time. The increase in the volume of vehicles passing through the sections and intersections on Jalan Pahlawan resulted in the creation of a fairly long queue of vehicles at the intersection in the Jalan Pahlawan area of Sidoarjo Regency, especially at the level crossing which is also located in the Jalan Pahlawan area.

Jalan Jati Raya and Jalan Pahlawan are connected to the Sidoarjo Toll Gate. The distance between the Sidoarjo Toll Gate location and the arterial road, Jati Raya Road, is very close (+ 130 meters). This causes problems because when the volume of traffic entering the Sidoarjo Toll Road is high and the payment process at the toll gate takes a relatively long time, causing a long queue on the Toll Exit Road to reach Jalan Jati Raya (Maulana, 2020). This results in congestion on Jalan Jati Raya (west approach of Pancasila Monument Roundabout) and Jalan Pahlawan (east approach of Pancasila Monument Roundabout). If the arrangement of vehicle movements that will enter the Sidoarjo Toll gate is not good, it could result in GridLock or queues of vehicles blocking the entire road network at the intersection so that traffic in all directions stops completely at the Pancasila Monument Roundabout, Jalan Jati Raya and Jalan Pahlawan (Mellyarti & Zulkifli, 2020).

This study aims to analyze traffic engineering management on Jalan Pahlawan, Sidoarjo Regency, in order to provide the right solution to overcome traffic problems in the area (Anwar, 2022). Through in-depth analysis, it is expected to find effective strategies that can be applied to improve traffic performance, reduce congestion, and improve road user safety (Tamin, 2000). The results of this research are also expected to be taken into consideration for the Sidoarjo Regency Government and related stakeholders in making better policies in transportation management in this region.

2. Methodology

2.1. Research Design

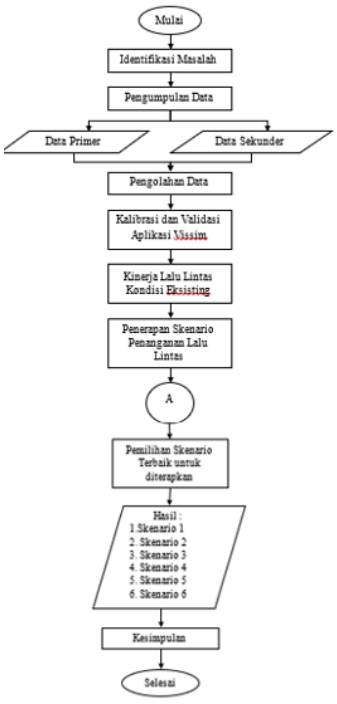

Figure 1. Research Flow Chart

2.2. Data Collection

Data collection is carried out in two ways, namely primary data and secondary data, primary data is obtained from direct survey results in the field by directly calculating and measuring, while secondary data is obtained from certain agencies or institutions related to supporting research.

2.3. Data Processing

After all the data is collected, the next stage is data processing or data analysis to obtain traffic performance in existing conditions in the study area. In this study, the authors used segment and intersection performance analysis. The results of the analysis will be processed so as to obtain the results of traffic performance on the analyzed sections and intersections.

a. Simulation Model Calibration and Validation
   The performance of sections and intersections that have been analyzed and the results obtained are then calibrated and validated so that the model in the Vissim application can be used and can represent the real situation in the field (Hutahaean & Susilo, 2021).
b. Implementation of Traffic Engineering Management handling scenarios
   Several traffic management and engineering scenarios were carried out in the Vissim application and then re-simulated so as to determine the impact of the scenarios carried out so as to improve the traffic performance of the Jalan Pahlawan network (Prasetyo et al., 2022).
c. Recommendations and Suggestions
   After all stages have been carried out, the last stage is the recommendation for the best problem-solving handling which can later be used as a consideration in determining policies to overcome problems.

2.4. Research Subjects

The subjects in this research are road users both motorized and pedestrian users on Pahlawan Street, Sidoarjo Regency.

2.5. Research Location

The research location is the road area along Jalan Jati Raya - Jalan Pahlawan - Jalan Thamrin from Pancasila Monument Roundabout to Babalayar Intersection 4 or Tugu Hikayat Intersection 4 in Sidoarjo Regency, East Java Province.

2.6. Data Collection Procedure

a. Primary data
   a) Road Section Inventory Survey
   b) Intersection Inventory Survey
   c) Traffic Counting (TC) Survey
   d) Classified Turning Movement Counting (CTMC) Survey
   e) Queue and delay survey
   f) Delay Survey
   g) Speed survey / travel time survey

b. Secondary Data
   a) Regional Spatial Plan Map (RTRW)
   b) Sidoarjo District Data in Figures 2023
   c) Road Network Map

2.7. Data Analysis Technique

The stages carried out include data analysis of survey results in the form of analysis of the origin destination matrix of traffic trips, vehicle free speed, vehicle behavior and intersection control. Based on the results of data analysis, a simulation model is then made with the Vissim application to determine the performance of the study area road network traffic in existing conditions, the results of the existing conditions are then calibrated and validated so that the model used can represent real conditions in the field and after traffic management and engineering efforts (in this case several scenarios are carried out) (Prihiyandhoko, 2023).

In this study, the traffic performance analysis of the study area road network was carried out under the busiest hour conditions . To determine the traffic performance of the study area road network, it is necessary to calculate travel time and vehicle speed due to obstruction of vehicle travel due to control of signalized intersections, roundabouts and other factors, as well as calculating the average vehicle delay on the road network. The tool or method used to calculate the traffic performance of the study area road network is to use the Vissim simulation program. This is because the study of the traffic performance of the study area road network is not limited to motorized vehicles, but also non-motorized vehicles, namely cyclists and pedestrians.

3. Results and Discussion

To determine the traffic performance of the Jalan Pahlawan area road network, it is necessary to output a simulation model in the form of average delay, average vehicle speed, total travel time, and total vehicle delay for the Jalan Pahlawan area road network. Vehicle delay is the difference between travel time under actual conditions and free traffic flow conditions without obstacles. The average vehicle delay is the delay per vehicle in units of seconds, while the total vehicle delay is the total delay of all simulated vehicles in units of hours. Vehicle travel time is the total travel time of all simulated vehicles in hour units. In this case, the network traffic performance parameters represent the macro traffic performance of the entire modeled network.

To obtain the output results of the simulation model, the simulation model was run for a period of 1.0 hour. The simulation model was run four times using different random seeds. The results of the traffic performance analysis of the Jalan Pahlawan area road network can be seen in Table 1. The average vehicle delay that occurs on the Jalan Pahlawan area road network is 96.5 seconds with a total vehicle delay of 725.2 hours. The average vehicle speed that occurs on the Jalan Pahlawan area road network is 23.7 km / hour with a total vehicle travel time of 1,691.6 hours.

Table 1. Network Traffic Performance Parameters of the Road Network Simulation Model of Pahlawan Road Area (existing)

Network Traffic Performance Parameters	Value	Unit
Average vehicle delay	96,5	detik
Average vehicle speed	23,7	km/jam
Total vehicle travel time	1.691,6	jam
Total vehicle delay	725,2	jam

In addition to macro traffic performance, the traffic performance of the road network is evaluated based on the travel time of vehicles on several segments that cross intersections and roundabouts on the road network. The four road segments analyzed are segment 1 (TT1) with the route from Jalan Diponegoro to Jalan Jati Raya, segment 2 (TT2) with the route from Jalan Jati Raya to Jalan Teuku Umar, segment 3 (TT3) with the route from Jalan Diponegoro to Jalan Tol, and segment 4 (TT4) with the route from Jalan Tol to Jalan Thamrin, see Figure 1.

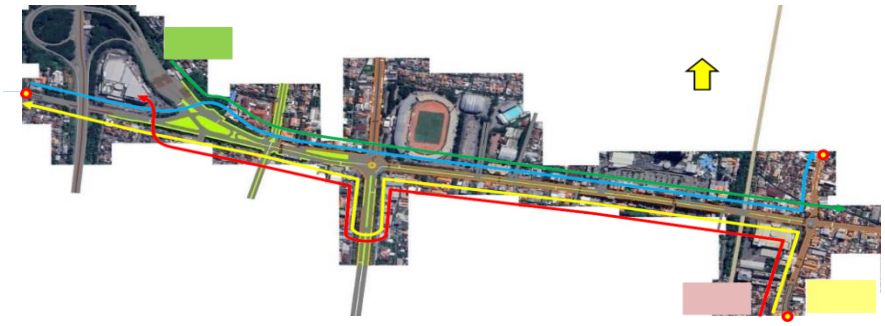

Figure 2. Travel Time Segment

The travel time of vehicles in the four segments analyzed from the Existing simulation model can be seen in Figure 2.

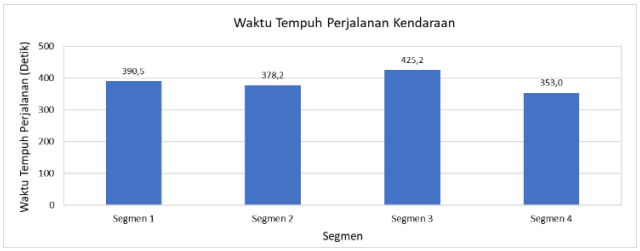

Figure 3. Travel Time in the Four Segments Analyzed (Existing)

The traffic performance of the Jalan Pahlawan area road network from the modeling results in the existing conditions and the conditions for implementing traffic management and engineering efforts (scenarios) are compared with one another. Comparison of the average value of vehicle delay, average vehicle speed, total vehicle travel time and total vehicle delay on the Jalan Pahlawan area road network can be seen in Figure 3 and Figure 4.

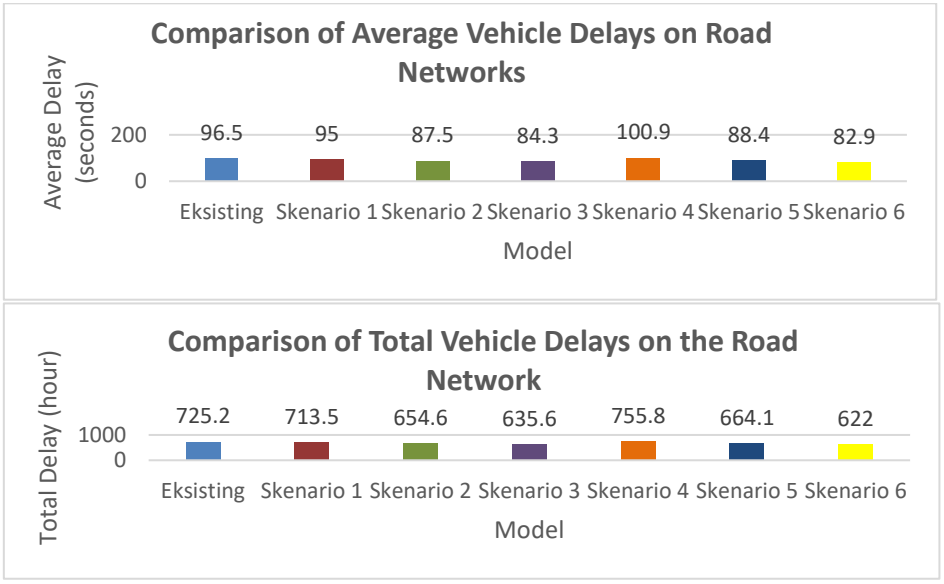

Figure 4. Comparison of Traffic Performance Parameters of the Road Network of the Pahlawan Road Area - Average and Total Vehicle Delay

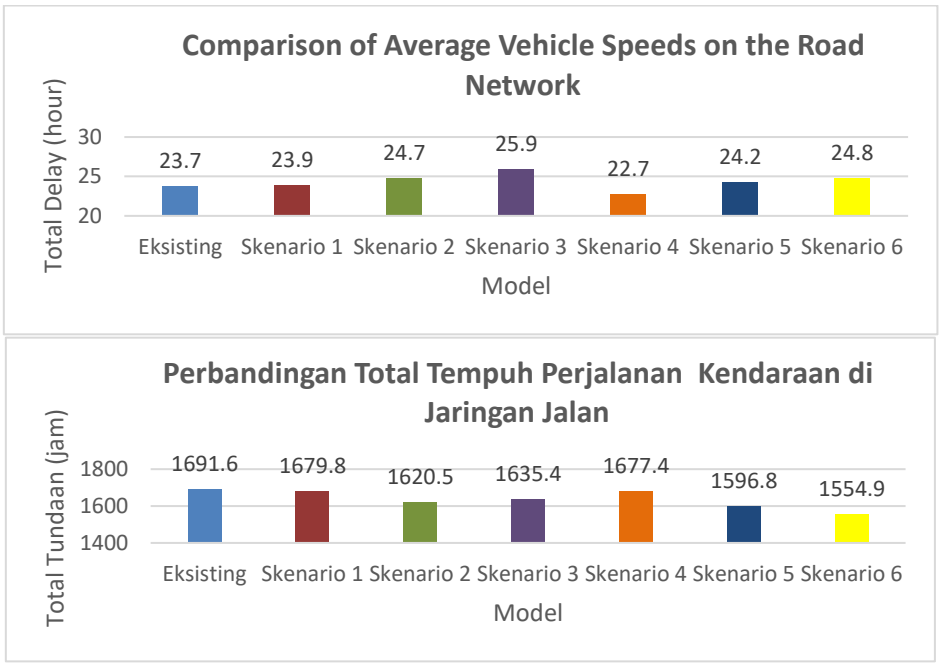

Figure 5. Comparison Of Traffic Performance Parameters Of The Jalan Pahlawan Road Network - Average Vehicle Speed And Total Vehicle Travel Time

Average and total vehicle delays and total vehicle travel time have the same trend, where the higher the value, the worse the traffic performance of the road network. This is inversely proportional to the average vehicle speed, where the higher the value, the better the traffic performance of the road network. To make it easier to understand the differences in road network traffic performance between the existing model and various scenarios, the comparison is divided into several categories for road network traffic performance parameters, namely average delay and average vehicle speed.

The first category is related to changes in the toll gate payment system SLFF concept (Scenario 1) and MLFF concept (Scenario 2) as well as the transfer of existing toll gate functions to new toll gates (Scenario 3) (Rakha et al., 1996). These traffic management and engineering efforts aim to improve the effectiveness of toll gate performance to minimize the occurrence of vehicle queues and vehicle delays in the area in front of the toll gate entrance. Figure 6 bellow shows a comparison of the average delay and vehicle speed of the Existing Conditions, Scenario 1, 2, and 3 simulation models.

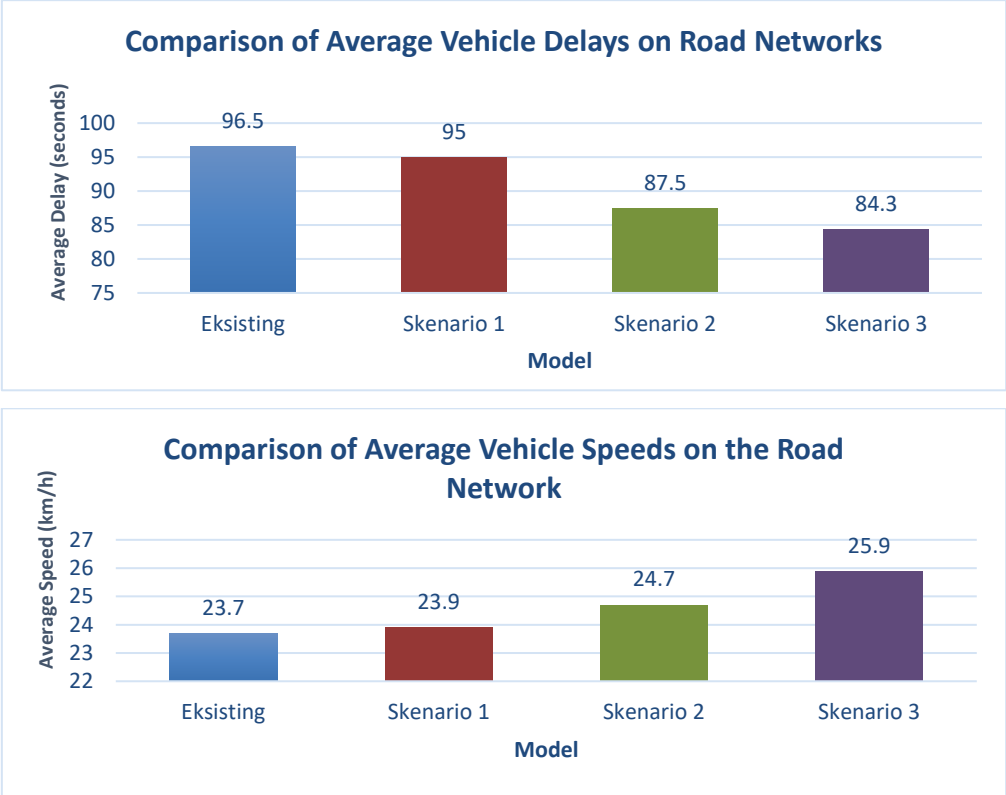

Figure 6. Comparison of Average Delays And Vehicle Speeds Between Simulation Models of Existing Conditions, Scenarios 1, 2, and 3

The results of the comparison of average delays and vehicle speeds between the Existing Conditions simulation model, Scenarios 1, 2 and 3 show that by increasing the speed of the toll gate payment system or transferring the function of the existing toll gate to the new toll gate can improve the traffic performance of the Jalan Pahlawan area road network. The implementation of the SLFF concept reduces the average vehicle delay by 1.5 seconds, the MLFF concept reduces the average vehicle delay by 9.0 seconds, while the new toll gate reduces the average vehicle delay by 12.2 seconds compared to the Existing Conditions. The average vehicle speed increases by 0.2 km/h with the SLFF concept, 1.0 km/h with the MLFF concept, and 2.2 km/h with the new toll gate.

The second category is related to changes in intersection control from roundabouts to signalized intersections with underpass infrastructure and the existing toll gate payment system (Scenario 4), the SLFF concept (Scenario 5) and the MLFF concept (Scenario 6). These traffic management and engineering efforts aim to improve the performance effectiveness of the Gelora Delta GOR intersection and toll gate. Figure 7 shows a comparison of the average delay and vehicle speed of the Existing Conditions, Scenario 4, 5, and 6 simulation models.

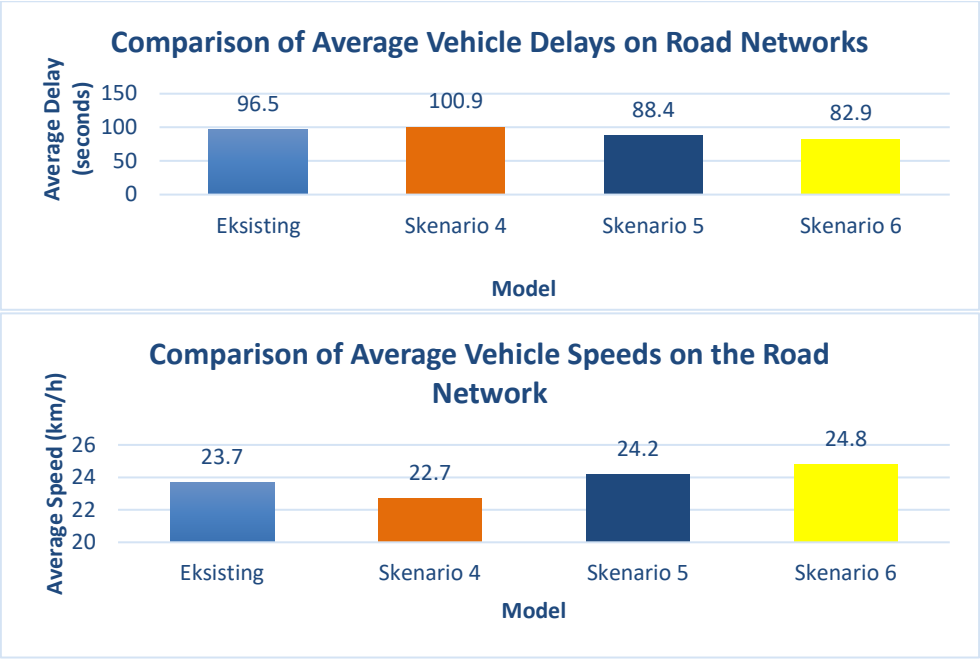

Figure 7. Comparison of Average Delays And Vehicle Speeds Between Simulation Models of Existing Conditions, Scenarios 4, 5, and 6

The results of the comparison of average delays and vehicle speeds between the Existing Conditions simulation model and Scenario 4, where the GOR Gelora Delta Roundabout is replaced by a signalized intersection with underpass infrastructure, show that the traffic performance of the Pahlawan Road area road network deteriorates compared to the Existing Conditions. The presence of the underpass will increase the number of vehicles heading towards the Pancasila Monument Roundabout from Jalan Pahlawan towards the East without the bottleneck at Intersection 4 GOR Gelora Delta. This results in a buildup of vehicle queues at the Pancasila Monument Roundabout due to the ineffective performance of the toll gate with the existing payment system (queue of vehicles entering the toll gate).

The traffic performance of the Jalan Pahlawan area road network will be better if the payment system is improved with the SLFF or MLFF concept. The implementation of a signalized intersection with underpass infrastructure and the SLFF concept reduces the average vehicle delay by 8.1 seconds, while the MLFF concept reduces the average vehicle delay by 13.6 seconds compared to the Existing Conditions. The average vehicle speed increases by 0.5 km / hour with the SLFF concept and 1.1 km / hour with the MLFF concept compared to the Existing Conditions. Looking at the results of the analysis of the traffic performance of the Jalan Pahlawan area road network with Scenario 3, if the implementation of a signalized intersection with underpass infrastructure is accompanied by the transfer of the function of the existing toll gate to the new toll gate, the traffic performance of the Jalan Pahlawan area road network will be better than Scenario 6.

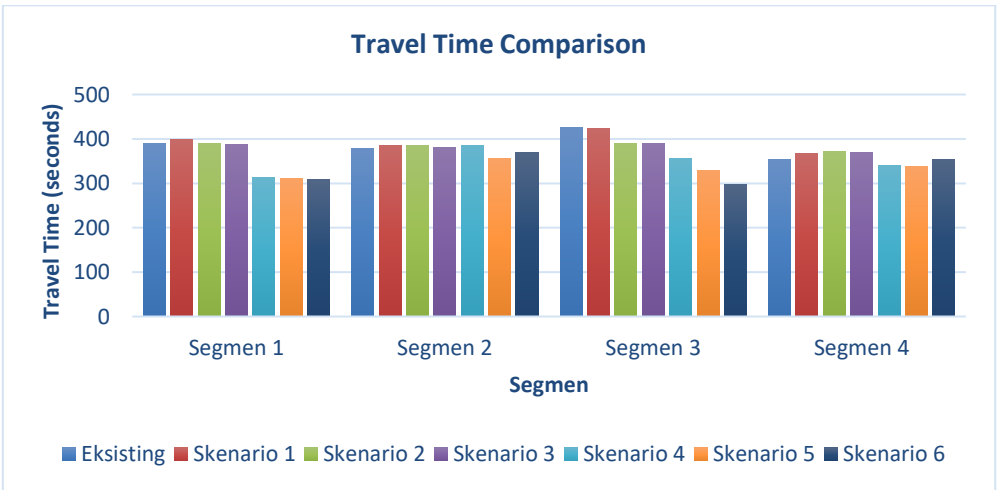

Figure 8. Comparison of vehicle travel time in Existing Conditions and scenarios

Efforts to improve the performance of Sidoarjo Toll Gate by speeding up the process of paying toll services at the toll gate have an impact on reducing the length of the vehicle queue at the toll entrance gate. The faster the time it takes for vehicles to pass through the toll gate, the shorter the queue of vehicles that occurs at the toll entrance gate. This will provide smooth traffic at the Pancasila Monument Roundabout and Jalan Jati Raya, because the potential for blocking back queues of vehicles at the toll gate is low so that it does not have an impact on the smooth flow of traffic at the Pancasila Monument Roundabout and surrounding roads. The low vehicle queues will have an impact on the low average and total vehicle delays so that the average vehicle speed and total travel time of vehicles on the road network will be high. The best traffic performance of the Jalan Pahlawan area road network is by implementing the MLFF concept payment system (Scenario 2), followed by the SLFF concept (Scenario 1) and card tapping (Existing Conditions).

Switching the function of the existing toll gate to a new toll gate (Scenario 3) results in better traffic performance of the Jalan Pahlawan area road network than the Existing Conditions, Scenarios 1 and 2. Replacement of the Gelora Delta GOR Roundabout into a signalized intersection with underpass infrastructure (Scenario 4) results in worse traffic performance of the Jalan Pahlawan area road network compared to the Existing Conditions. The underpass infrastructure increases the number of vehicles heading to the Pancasila Monument Roundabout from Jalan Pahlawan towards the East without obstacles at Intersection 4 GOR Gelora Delta, resulting in a buildup of vehicle queues at the Pancasila Monument Roundabout due to the ineffective performance of the toll gate with the existing payment system (queuing vehicles entering the toll gate).

The traffic performance of the Jalan Pahlawan area road network will improve if the replacement of the Gelora Delta GOR Roundabout to a signalized intersection with underpass infrastructure is accompanied by an improved payment system with the concept of SLFF (Scenario 5) or MLFF (Scenario 6) or the transfer of the existing toll gate function to a new toll gate (Scenario 3).

4. Conclusion

In the application of scenarios 1 to 6, some make traffic better, but some make traffic less good than traffic in the existing period. Efforts to increase toll gates with SLFF (scenario 1) and MLFF (scenario 2) systems make traffic performance at the Pancasila Monument Roundabout and Jalan Jati Raya because the potential for blocking back queues at toll gates will be minimal. The implementation of the new toll gate through Jalan Kahuripan access also has a good impact on the traffic performance of Jalan Pahlawan compared to scenarios 1 and 2, the implementation of geometric replacement of Gor Gelora Delta Roundabout into an underpass has a less favorable impact on the traffic performance of Jalan Pahlawan due to the unimpeded flow which causes long queues of vehicles at the toll gate (existing conditions). Traffic performance will be effective if the replacement of the Gelora Delta Roundabout geometric is accompanied by the payment of SLFF (scenario 5), MLFF (scenario 6) and or the addition of new toll gates (scenario 3).

The most optimal traffic engineering management recommendation to be applied on Jalan Pahlawan is the implementation of scenario 6 which implements the MLFF system at the toll gate and the replacement of the intersection geometric into an underpass at the Gor Gelora Delta Roundabout with the average vehicle delay that occurs on Jalan Pahlawan of 82.9 with the average vehicle speed on Jalan Parhlawan of 24.8 km/hour.

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