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Jakarta Outer Ring Road (JORR) Toll Road Off-Ramp Connectivity Queuing With Local Roads: A Case Study of T.B. Simatupang Road and JORR Toll Off-Ramp

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ABSTRACT: TB Simatupang Road is one of the main arterial roads in South Jakarta, Indonesia, connecting various important areas. Efficient connectivity between major expressways and local roads is crucial for facilitating smooth traffic flow in urban areas. However, in some cases, the connection between toll road off-ramps and local roads experiences queues and traffic delays. This study aims to analyze the impact of off-ramps on local roads by incorporating the JORR Toll Road off-ramp and the signalized intersection at Fatmawati Street into the model in detail. The research methodology combines data analysis, traffic simulation, and field observations. Relevant traffic data, such as vehicle volume, average speed, and vehicle movement patterns, will be collected from the areas surrounding the toll road off-ramp intersection, TB Simatupang Road, and Fatmawati Road intersection. The results of the VISSIM simulation indicate that the degree of saturation exceeds 1, and the queue length reflects severe congestion. The conclusion is that to reduce congestion and improve traffic efficiency, an underpass should be constructed in the direction of Kampung Rambutan or from the off-ramp to Blok M. Additionally, eliminating lane merging is recommended to achieve smoother and more effective traffic flow.

KEYWORDS: Toll Road, Local Road, TB Simatupang Road, JORR off-ramp, Traffic Simulation, VISSIM.

I. INTRODUCTION

1. Background Research:

Efficient connectivity between major toll roads and local roads is essential for ensuring smooth traffic flow and reducing congestion in urban areas. However, congestion often occurs at connection points between toll road off-ramps and local roads, resulting in queues and traffic delays.

This research examines the issue of queue formation at the connection point between the Jakarta Outer Ring Road (JORR) Toll Road off-ramp and T.B. Simatupang Street in Jakarta, Indonesia.

The JORR Toll Road functions as a primary transportation artery and a vital link for residents traveling to and from the city center and surrounding areas. Meanwhile, T.B. Simatupang Street, located in South Jakarta, serves as a key local road connecting various business districts, residential neighborhoods, and commercial hubs.

2. Research objectives

To evaluate the factors causing queue formation at the off-ramp intersection of the JORR Toll Road, T.B. Simatupang Street, and the Fatmawati intersection, this study analyzes the current traffic impact and proposes potential solutions to reduce congestion. A detailed analysis of this case can provide valuable insights to inform urban planning projects and infrastructure development in the future.

Figure 1. JORR Toll Exit Ramp Research Location, TB Simatupang road and Fatmawati intersection

The connectivity between toll roads and surrounding areas not only supports existing zones but also fosters the formation of new activity centers. However, off-ramps connecting toll roads to collector roads experience a decline in road performance during peak hours, such as morning and evening rush hours. Road performance is evaluated based on the Volume-to-Capacity (V/C) ratio, which is a key indicator of the Level of Service (LOS) [1].

Road networks have a finite capacity for the number of vehicles they can accommodate. When this capacity is exceeded, the road network system becomes ineffective. [2] A critical infrastructure component in this context is the ramp, which serves as a connector between toll road networks and city roads. Ramp performance is significantly influenced by ramp configuration. Wang et al. conducted research evaluating travel time, distance, and vehicle emissions on two-lane on- and off-ramps [3].

Congestion has become a major socio-economic issue affecting several countries. It impacts mobility, travel time, quality of life, and the economy. To address this, governments have conducted advanced research involving Intelligent Transportation Systems (ITS) to reduce or resolve traffic issues. Hidden Markov Models (HMM) have also been proposed as a suitable method for predicting traffic congestion and identifying peak hours within a 2D spatial framework [4].

This study adopts a multidisciplinary approach, including data analysis, traffic simulation modeling, and field observation. Other factors, such as road geometry, traffic volume, signal timing, driver behavior, and infrastructure conditions, are also taken into account. Furthermore, input from residents, pedestrians, local businesses, and authorities is considered to ensure the road remains free of obstacles and efficiently connects with local traffic on and off ramps. [5].

Constructing roads, toll roads, and bridges is a crucial aspect of infrastructure development. These projects aim to enhance connectivity and facilitate the movement of people and goods. During the construction stage, internal supervision is conducted to ensure that the outcomes align with expectations and plans. Additionally, monitoring, identifying, and anticipating potential problems are essential steps for taking corrective action as early as possible [6].

3. Literature Review

Surrounding the off-ramp network, road designs should minimize obstacles and adhere to standard considerations, as illustrated in Figure 2.

In this network, vehicles leaving the toll road via the off-ramp merge at node M, either from a local service road or roadside surface. Node M physically represents a group of vehicles or a priority signalized intersection. The performance of node M depends on the timing of signals or the merging of traffic with the priority road. The figure below highlights a selected subset of the closest road network, relevant for our analysis and objectives. [7]

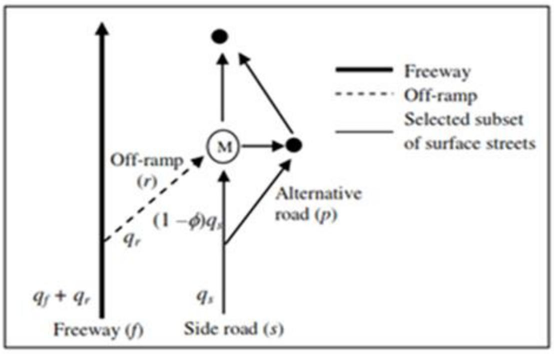

Figure 2. Network around the off-ramp

In analyzing the performance of urban roads, particularly Majapahit Road at the research site, it is evident that congestion plays a significant role in causing vehicle queues, traffic jams, delays in travel times, and reduced road service levels. To evaluate the performance of this road section, various indicators are used, including traffic flow, capacity, degree of saturation, free-flow speed, and level of service (LOS) [8].

Delays and queues are critical considerations in intersection planning and optimizing traffic light operations. The use of the VISSIM application facilitates multimodal traffic flow simulations, including the incorporation of pedestrian movements [9].

In the VISSIM simulation, comprehensive features are available, making it more realistic and adaptable to actual local field conditions and modelling [10].

The Swedish Transport Administration (STA) has applied recommended procedures for designing roads at maximum saturation levels during peak hours for many years. These procedures include a design saturation degree of less than 0.8 for 30 theoretical hours and 8–15% of the Annual Average Daily Traffic (AADT), depending on road type. These designs are intended for traffic conditions 20 years after opening, with travel speeds less than 10 km/h below the general reference speed [11].

It is essential to consider the level of road service when evaluating road congestion. The level of service (LOS) measures the quality of a road segment, reflecting how effectively it accommodates traffic flow. Understanding these characteristics is crucial for accurately assessing congestion levels [12].

Traffic jams disrupt schedules, cause frustration, and result in financial losses for many individuals. While congestion is a significant challenge in large cities, some residents may have grown accustomed to it and accept it as a normal aspect of urban living. However, addressing the economic implications of traffic and transportation systems in major cities remains vital [13].

Ramps play a critical role in connecting toll roads with inner-city environments. In their research, Wang et al. evaluated travel time and vehicle emissions in a two-lane ramp entry and exit scenario [14].

The flow of toll road traffic significantly affects acceleration and deceleration rates, lane length, and the surrounding local road network. A geometric element optimization model can be proposed to design toll road entrances and exits based on driver behavior and characteristics. Using VISSIM traffic simulation, the optimization effect can be evaluated in greater depth [15].

According to queuing theory, the level of saturation in a system is determined by the balance between demand and capacity. Periods of overcapacity or underutilization may occur. By measuring potential overflow and demand cycles, system capacity can be estimated and adjusted to optimize functionality [16].

The term "vehicle movement on the highway and out of the flow of the highway" refers to traffic movement on main roads or toll roads. Congestion on motorways and local roads is primarily caused by two factors: significant reductions in speed and excessive congestion around intersections. Lane changes, both mandatory and discretionary, are prevalent due to the large volume of vehicles on the freeway [17].

Signalized intersections are among the most complex areas in urban networks. The operational efficiency of these networks decreases as traffic volumes increase. Therefore, evaluating the current conditions and performance of signalized intersections is crucial for managing and improving urban traffic systems [18].

This discussion focuses on the relationship between road safety and the minimum access and exit distances on toll roads. Specifically, it examines how the geometric design of toll roads influences accident levels. Accidents are categorized into three types: fatal accidents, injury-causing accidents, and total accidents. A prediction model will be developed to analyze the relationship between toll road geometry and these accident categories [19].

The lane change model can be extended between main through lanes based on the analysis of lane change data from congested through lanes, toll roads, and ramp lanes along the observed study corridor. A macroscopic lane change model has been developed to analyze the disruptive effects of lane-changing behavior among drivers with varying objectives. [20].

Traffic volumes are analyzed, and peak hour volumes are estimated for morning and evening periods. The Volume/Capacity (V/C) ratio is calculated using IRC 106-1990 standards. Vehicle delays are estimated using the classic Webster formula to determine the level of service (LOS). Traffic volume projections for the next 10 years are also included. The V/C ratio and delay values are recorded as 0.801 and 39 seconds, respectively. Based on these values, the performance results at the Retteri intersection indicate a LOS classification of D [21].

II. RESEARCH METHOD

An implementation survey was conducted at the meeting point of TB Simatupang Road and the JORR exit ramp, as well as at the signalized intersection of Fatmawati Road. The intersection signal arrangement uses a four-phase system.

This study aims to combine data analysis, modeling simulations, and field observations. Relevant historical data, including vehicle volume, average speed, and movement patterns near the Toll-road off-ramp intersection, TB Simatupang Road, and Fatmawati intersection, will be collected.

Description method:

- Current traffic flow data is recorded using standard deep video recording methods.
- The video recordings are manually analyzed, with repetitive observations for each traffic flow change. The data is then tabulated, and the Equivalent Passenger Car Units (EPCU) per hour for all recorded vehicles are calculated.
- Roadway characteristics are measured in the field using a wheel meter, with an accuracy level of up to 10 cm. The measurements are recorded in a table.
- Obstacles such as sidewalks, parked vehicles, pedestrians, and road shoulders are also documented.
- Historical volume data is analyzed and input into the VISSIM simulation in three categories:
  a) Merging Traffic Flow: Traffic merging from the off-ramp with TB Simatupang Road and diverging toward the existing Blok M area.
  b) Crossing Traffic Flow: Traffic flow from the off-ramp and TB Simatupang Road, which stops due to the traffic signal at the Fatmawati intersection.
  c) Alternative Traffic Scenarios: Three alternative constructions are simulated to address congestion caused by merging, diverging, and the traffic signal system.

The results from these simulations will provide insights into potential improvements for traffic flow management and congestion reduction in the study area.

III.RESULT AND DISCUSSION

Surveys are conducted to collect data on average traffic volumes at specific locations and to evaluate factors such as congestion, long queues, and delays. The survey results are useful for determining the current traffic situation and identifying issues that need to be addressed. With this information, appropriate measures can be taken to improve traffic flow and reduce congestion, long queues, and delays.

Furthermore, in detail, the results of survey activities at each point observed are presented in the following description: Location survey results study outlined in the description below: Peak hour volume at off-ramp JORR, TB Simatupang Street, and Fatmawati is 3540 pcu/ hours at 07.00 - 08.00, peak hour of 2740 pcu / hours occurs at 07.00 - 08.00, and the peak hour of 928 pcu / hours occurs at 06.00 – 07.00 as in Table 1. Average Daily Traffic Volume per hour.

Table 1. Average Daily Traffic Volume -average per hour

Hours (WIB)	Direction Volume Simatupang - Kp. Rambutan	Direction Volume Exit Toll Jor - Kp. Rambutan	Direction Volume Exit Toll Jor - Blok M
Morning Rush Hour			
06.00 - 07.00	3312	2352	928
07.00 - 08.00	3540	2740	696
Afternoon Rush Hour			
13.00 - 14.00	2157	816	548
14.00 - 15.00	2630	796	500
Evening Rush Hour			
18.00 - 19.00	3560	1776	956
19.00 - 20.00	1988	1828	564

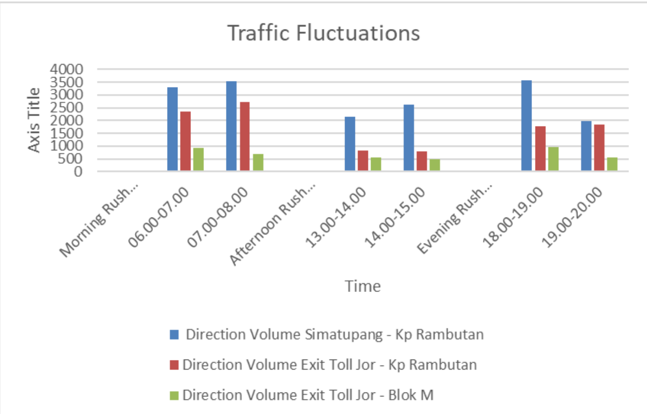

Figure 3. Chart Traffic Fluctuations

Degree analysis saturation every hour during rush hour in calculation with method Indonesian Road Capacity Manual 1997. The population of Greater Jakarta from the Central Statistics Agency (CSA) period December 2022 is amounting to 10,748,820.00 people.

The factors influencing road capacity in a city include the width of the lanes, the presence or absence of road dividers/medians, the condition of road shoulders or curb barriers, road gradients, whether the area is urban or rural, and the size of the city. The formula for urban areas is as follows.

$$C = Co \times Fcw \times Fsp \times Fcf \times Fccs \quad (1)$$

Description:

C = Capacity (pcu / hour)

Co = Basic capacity (pcu /hour), usually used figure 2300 pcu / hour

Fcw = Adjustment factor wide road

Fsp = Adjustment factor separation direction

Fcf = Adjustment factor obstacle side and shoulder of the road / curb

$Fccs$ = Adjustment factor size city

Table 2. Calculation Results capacity

Periode	Co	Fcw	Fsp	Fcf	Fcs	C
07.00 - 08.00	3540	1	1	0.94	1.04	3461
07.00 - 08.00	2740	1	1	0.94	1.04	2679
06.00 - 07.00	928	1	1	0.94	1.04	907

Finding the Degree of Saturation (DS)

$$DS = Q/C < 1 \quad (2)$$

Where:
Q = C0

Table 3. Results of calculation of Degrees of Saturation (DS)

Hour	From	Total Vehicles (Q) (pcu/hour)	Capacity (C) (pcu/hour)	Degree of Saturation (DS) (Q/C)
07.00 - 08.00	West	3540	3461	1.02
07.00 - 08.00	West	2740	2679	1.02
06.00 - 07.00	West	928	907	1.02

Traffic signal system Intersection Survey Results Fatmawati: Phase 1 From Pondok Labu direction to road Fatmawati and Rambutan Village

Phase 2 from Kampung Rambutan direction to Lebak Bulus and Blok M

Phase 3 From Fatmawati Street direction to Pondok Labu and to Lebak Bulus

Phase 4 From TB Simatupang Street towards Kampung Rambutan

1. Simulation results

In analyzing traffic surveys at the research location, existing data is used as the input volume for each type of vehicle, expressed in terms of passenger car units/hour. The queue length, delay, and loss values obtained from the degree of saturation are calculated based on the MKJI '97 formula, as shown in the results below.

Average Daily Traffic (ADT) during the morning rush hour (07:00–08:00) obtained an LOS F (DS > 1), which includes the route from TB Simatupang Road to Kampung Rambutan and Blok M with a DS of 1.02 in the LOS F category. This indicates forced flow, low speed, volume exceeding capacity, and long queues (congestion).

The results of the VISSIM study showed long queues of merging and diverging vehicles from the JORR Toll off-ramp to TB Simatupang Street, resulting in a delay of 97.045 seconds per passenger car unit (PCU) during peak hours from 06:00 to 08:00. The off-ramp was found to be 512 meters long. The simulation of TB Simatupang Road congestion and the exit ramp towards Blok M and Kampung Rambutan in the morning can be seen in Figure 4. The merging and diverging weaving movements of vehicles on the TB Simatupang local road often form a single stream of traffic, leading to traffic jams and delays.

Figure 4. Vissim Simulation of Existing Road Congestion

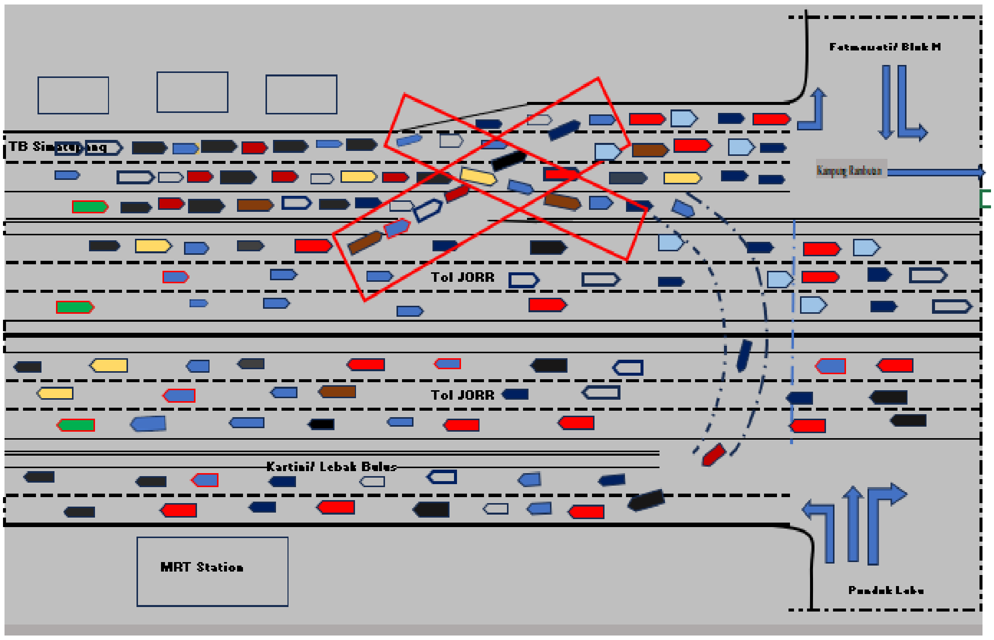

Figure 5. The merging and weaving movements cross paths, both divergent and merging

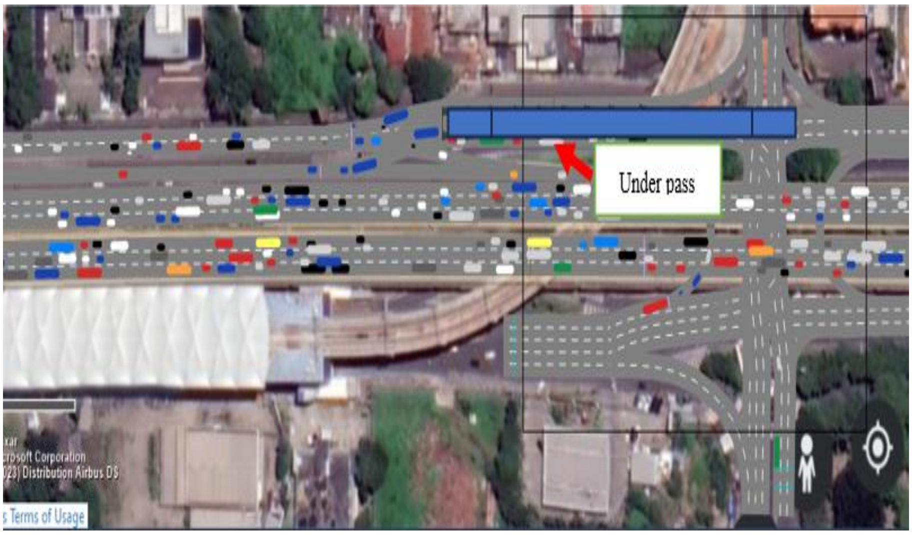

Figure 6. Simulation of the flow to Kampung Rambutan by building an underpass

One proposed solution to alleviate traffic congestion at the study location is the construction of an underpass leading to Kampung Rambutan, as indicated by the VISSIM simulation. The simulation study of the proposed underpass connecting the JORR Toll exit ramp to Kampung Rambutan revealed significant improvements in traffic conditions. The results showed no queue formation, with a Level of Service (LOS) rating of A, indicating free-flow conditions. The density simulation (DS) values ranged from 0.00 to 0.20, and the maximum delay recorded was only 4.43 seconds per passenger car unit (PCU).

IV. CONCLUSIONS

Conclusions from the results of the analysis and calculations: the exit ramp or off-ramp during rush hour consistently experiences traffic congestion, marked by the lowest road performance at LOS F during morning and evening peak hours. The VISSIM simulation, with the proposed underpass construction at the approach to the Fatmawati intersection, shows that the performance of the road improves to LOS A. The delay of 97.045 seconds per PCU is reduced to a maximum of 5.27 seconds per PCU, and the maximum queue length decreases to 0–10 meters.

Lastly, the VISSIM simulation method successfully coordinates the change and merging processes cooperatively, ensuring continuous traffic flow. It is proven that VISSIM is capable of performing validation simulations and creating real-time optimization animations for every vehicle trajectory.

All findings can be considered in this study and are recommended for evaluating the timing system of the Fatmawati intersection signals. As a suggestion, due to the limited survey time, it is recommended that the research be extended to other locations.

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