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# Intersection performance evaluation and designing intersection at concourse between arterial road and ramp of Medan-Kualanamu-Tebing Tinggi Highway

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**Abstract.** In overcoming congestion problems that occur in Medan-Tebing Tinggi route, especially at certain points such as at Pasar Bengkel and Kayu Besar intersection during peak hours, an infrastructure has been built in, that is a highway which connecting Medan-Kualanamu-Tebing Tinggi. Medan-Kualanamu-Tebing Tinggi highway (MKTT) will connect Medan City and Tebing Tinggi City, so that drivers from Medan who will go to Tebing Tinggi will not pass through the main road that is prone to congestion.

There is an intersection that connects arterial roads with each MKTT toll gate. At the intersection, there is a conflict between flows from the opposite direction and intersecting, resulting in delays and queues along the intersection arm. The conflict occurred because of the lack of designing of the intersection that drains the flow of vehicles from ramp to arterial road or vice versa. This needs consideration because of the congestion causes queues and delays, especially during peak hours and holidays, so that it requires intersection performance analysis at concourse between arterial road and ramp of Medan-Kualanamu-Tebing Tinggi highway and design the geometric of intersection which appropriate with this intersection.

From the results of the evaluation analysis, obtained degree of saturation at the intersection of the arterial road and the ramp of Lubuk Pakam toll road at 0.71 with level of service C that is still feasible to be used, so there is no need to change the intersection geometry. While for Sei Rampah, the degree of intersection saturation is 0.79 with the level of service D, which means that it is not feasible, requiring a change in the geometry of the intersection with a signalized roundabout. With the planned roundabout geometry, the degree of saturation is 0.5 which means it is feasible to use.

## 1. Introduction

### 1.1. Background

Road is infrastructure of transportation which is the biggest influence on social and economic development of the community. Therefore, road is compulsory infrastructure in a safe, comfortable and economical situation for serving people and commodity movement in Medan-Tebing Tinggi road especially at certain points like at Pasar Bengkel and Kayu Besar Intersection during rush hour, because the roads are no longer able to accommodate the traffic flow, and adjustment the traffic that is not precise and efficient yet.

In dealing with congestion problems that occur on the road, infrastructure built, that is in the form of a connecting highway Medan-Kualanamu-Tebing Tinggi. The highway which was inaugurated on



October 10, 2017 is divided into 2 (two) sections, namely Section I (Medan-Perbarakan-Kualanamu) for 17.80 km and Section II (Perbarakan-Tebing Tinggi) for 44 km. It is this Medan-Kualanamu-Tebing Tinggi (MKTT) toll road that will connect the city of Medan with Tebing Tinggi, so that riders from Medan who will go to Tebing Tinggi will not pass through the main road which is prone to congestion.

There is a plot crossing with three intersection arms connecting the section of the road with the ramp of the MKTT highway. At this intersection, there is a conflict between the currents from the opposite and intersecting directions which results in delays and queues, so that congestion occurs along the intersection arm. The conflict occurred due to the lack of proper planning of the intersection that drains the flow of vehicles from the toll gate to the crossroad or vice versa. The traffic signal device (APILL) contained in each intersection is not obeyed by the driver and the phase of the signal is inappropriate, including the factors causing the conflict. Therefore, an intersection performance analysis is carried out at each intersection that connects the MKTT toll ramp with arterial roads and intersecting geometric plans along with appropriate traffic regulation.

Along with the increasing flow of people and commodity and the development of North Sumatra, of course increases necessity for transportation. But in reality it is not offset by an increase in adequate transportation facilities and infrastructure, so that the flow of movement that occurs is not optimally supported both in terms of quantity and quality. This proved to be a frequent occurrence of traffic congestion on the traffic.

### *1.2. Problem topics*

By observe to the background as presented above, the subject matter needed for the study is:

1. Signal phase in APILL that is not right.
2. The traffic signaling tool (APILL) contained in each intersection is not obeyed.
3. Inappropriate intersection planning such as intersection type, improper traffic regulation facilities and intersection geometry.

### *1.3. Research purposes*

The purpose of this study is:

1. Knowing the performance of the intersection by analyzing the amount of traffic flow that crosses the intersection based on the analysis of capacity, degree of saturation, delay and queue according to IHCM 1997.
2. Determine the type and arrangement of intersections according to the analytical method used.
3. Plan the intersection geometric with the right traffic settings.

### *1.4. Restriction of problem*

The scope of the discussion in this final project is limited by limitations, including:

1. Crossing performance analysis includes capacity (C), degree of saturation (DS), traffic behavior and level of service calculated by the 1997 IHCM method.
2. The passenger car equivalent (EMP) value is calculated using the 1997 IHCM capacity method.
3. Determination of intersection arrangements used graphs from the Australian Road Research Board (ARRB).
4. The traffic network that will be studied is the network located around the MKTT toll gate, namely at the ramp at the Lubuk Pakam toll gate and the Sei Rampah toll gate.
5. Side barriers refer to existing provisions (IHCM 1997).
6. Vehicles that are the object of the study are two- and four-wheeled vehicles, public transport and trucks.

### *1.5. Data collection and processing techniques*

The method used in this final project report is a component analysis method that presents a material from the data obtained by the survey accompanied by decomposition or analysis in the form of a calculation.

Data processing techniques use the Indonesian Road Capacity Manual (IHCM) in 1997. In writing the final project report, the authors obtain two types of data, namely primary data whose data is obtained directly from the source or directly from the field and secondary data, namely data obtained from relevant agencies. Primary data obtained is:

1. ADT Data (Average Daily Cross)
2. Geometry data on intersections that connect ramp tolls with arterial roads

Secondary data obtained from related agencies is ADT Data (Average Daily Cross) on Lubuk Pakam-Tebing Tinggi road in 2016.

## **2. Theoretical basis**

### *2.1. Intersection*

Intersections can be defined as general areas where two roads or more join or intersect, including roads and roadside facilities for the movement of facilities within them (AASHTO, 2001).

#### **1. Unsignalized Intersection**

In general, intersections that are not equipped with traffic signal or traffic light devices can be called priority intersections or unsignalized intersections.

#### **2. Signalized Intersection**

Signalized intersections which are part of a fixed time control system that is assembled or actuation signals of isolated vehicles, usually require special methods and software in the analysis.

### *2.2. Roundabout*

Roundabouts are considered as sequential links. The roundabout is most effective if the intersection between the road with the same size and current level is used. Therefore the roundabout is very suitable for the intersection between two-lane or four-lane roads.

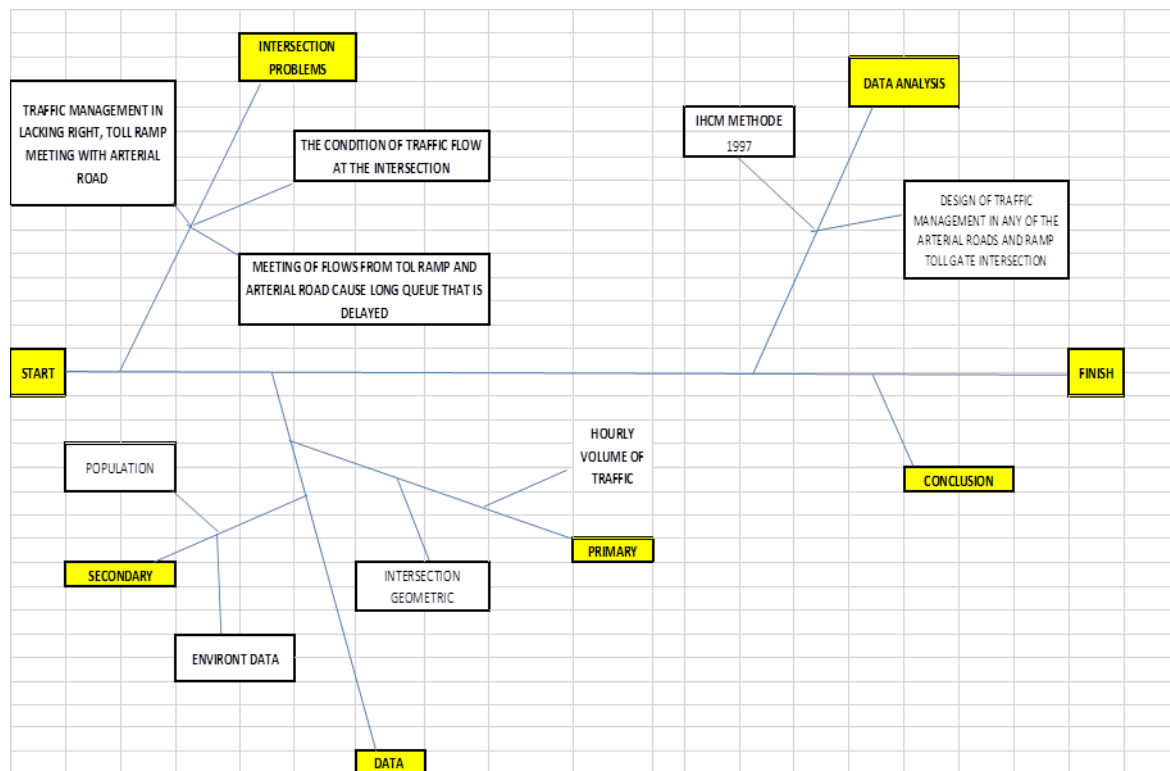
### *2.3. IHCM 1997*

The Indonesian Highway Capacity Manual is a guide that was born in 1997 that serves as a guide in the calculation of the design, planning, and operational analysis of traffic facilities.

## **3. Research methods**

### *3.1. Flowchart of research methods*

In general, the core of the research method is to describe how the procedures for analysis and planning are carried out. The purpose of this methodology is to facilitate implementation in carrying out work in order to obtain problem solving with the stated goals and objectives. In addition, the methodology is also compiled with systematic, orderly and orderly work procedures, so that it can be translated scientifically. The research methodology flow chart can be seen in the following.



**Figure 1.** Flowchart of research methods

### 3.2. Preliminary survey

The implementation of the preliminary survey was conducted before or before the actual survey was conducted. The preliminary survey aims to review a number of things in the field. Some things that need to be reviewed are as follows:

1. Visual description of road conditions and conditions such as geometry, traffic and environmental conditions.
2. Determination of the location of field data collection in accordance with the research method used so that it can be used as a place of research.

### 3.3. Field survey

After conducting a preliminary survey and literature study, then a field survey was conducted for the selection of research sites. The specified research location is at the intersection at each MKTT toll gate, namely at the ramp of the Lubuk Pakam Toll Gate and the Sei Rampah Toll Gate.

### 3.4. Data collection method

Processing and calculating the amount of traffic volume data at the intersection at each toll gate is by using several surveyors who record the volume manually. The surveyor is placed on each intersection arm to record the volume of each movement.

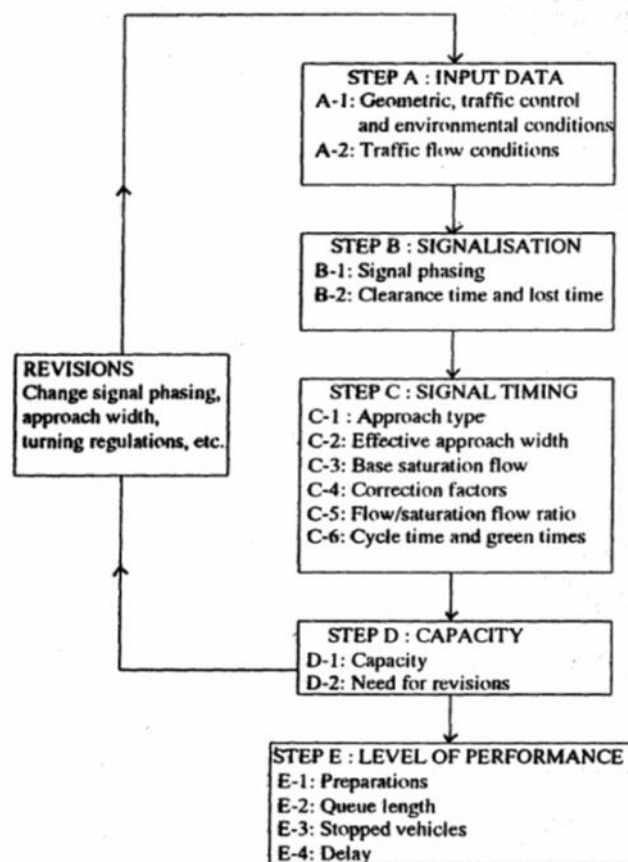
### 3.5. Data analysis method

Primary data and secondary data obtained from the field are inputs for the calculation of unsignalized intersections with IHCM 1997. Analysis of data for signalized intersections and unsignalized intersections and roundabouts by using the Indonesian Road Capacity Manual (IHCM 1997) aims to determine the performance of the intersection is still feasible or not. If the results of the analysis show that the intersection performance is no longer feasible, it is necessary to solve the problem by making primary data and secondary data obtained from the field as input for the calculation of unsignalized

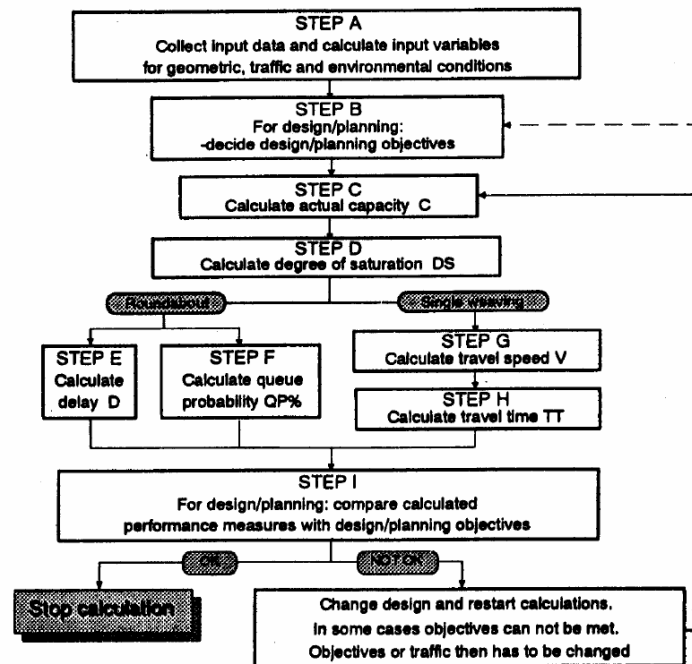
intersections with IHCM 1997. Data analysis for signalized intersections and unsignalized intersections and The roundabout using the Indonesian Road Capacity Manual (IHCM 1997) aims to find out whether the intersection is still feasible or not. If the results of the analysis show that the performance of the intersection is no longer feasible, it is necessary to solve the problem by planning it.

### 3.5.1. Summary of intersection and roundabout procedures

The procedure required for the calculation of signal time, capacity and performance measures for signalized intersections and then capacity and performance measures for the roundabout, both of them are outlined below. Step by step is made in the following order.



**Figure 2.** Flowchart of research methods for signalized intersections (Source : IHCM 1997)



**Figure 3.** Flowchart of the roundabout research method (Source : IHCM 1997)

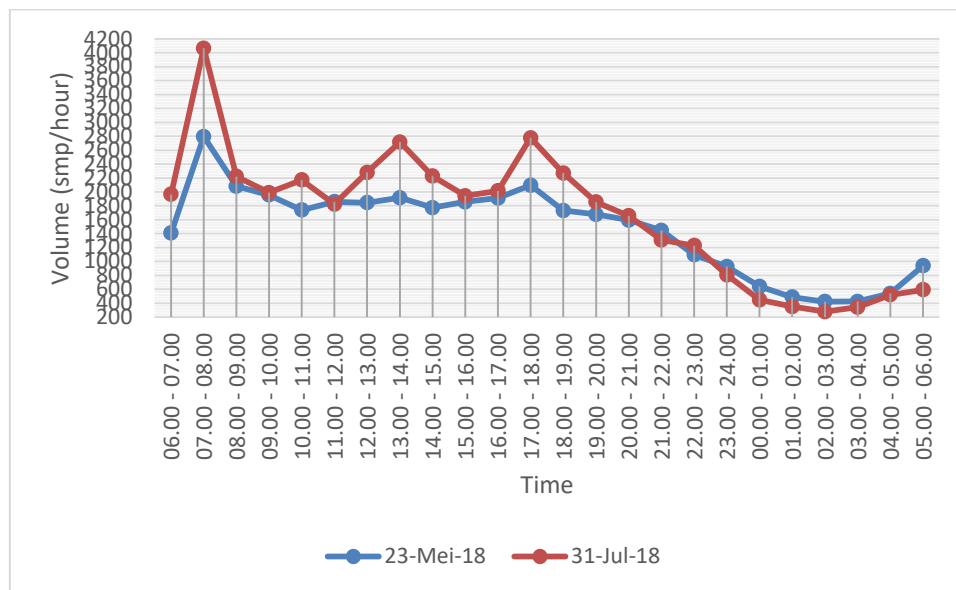
### 3.6. Conclusion

In this case it was concluded that the results of research studies that had been carried out were subsequently made into recommendations for interested parties.

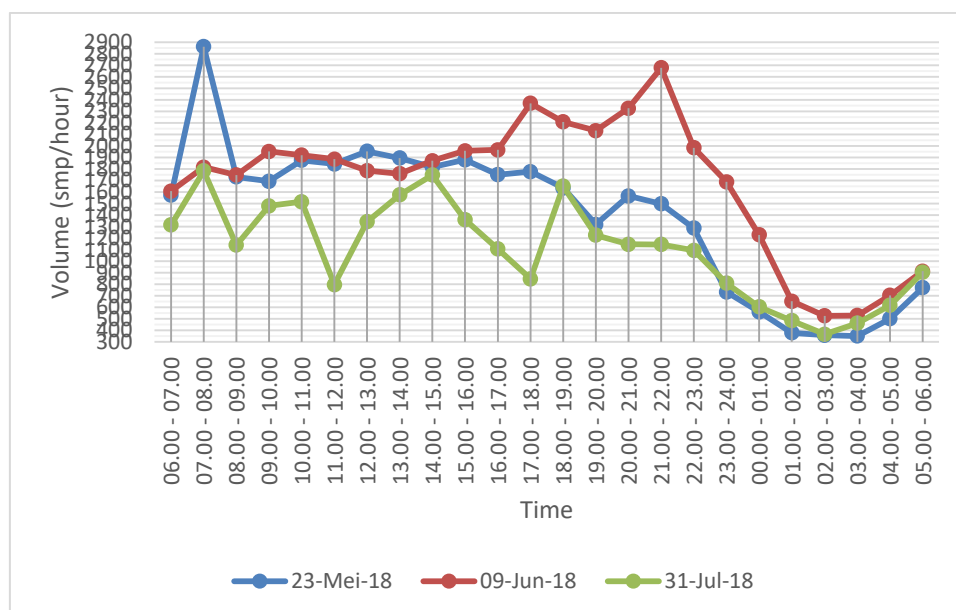
## 4. Analysis and discussion

### 4.1. Traffic volume

From the results of the 24-hour ADT survey, the survey results can be seen in Fig. 3 for the results of the ADT survey at the intersection of arterial roads and the Lubuk Pakam toll ramp for two days and in Fig. 4 for the ADT survey results at the intersection of arterial roads and ramp up the Sei Rampah toll road for three days.



**Figure 4.** Results of the ADT survey at the intersection of the Arterial Road and Ramp Toll Road in Lubuk Pakam (Source: Result of ADT survey)

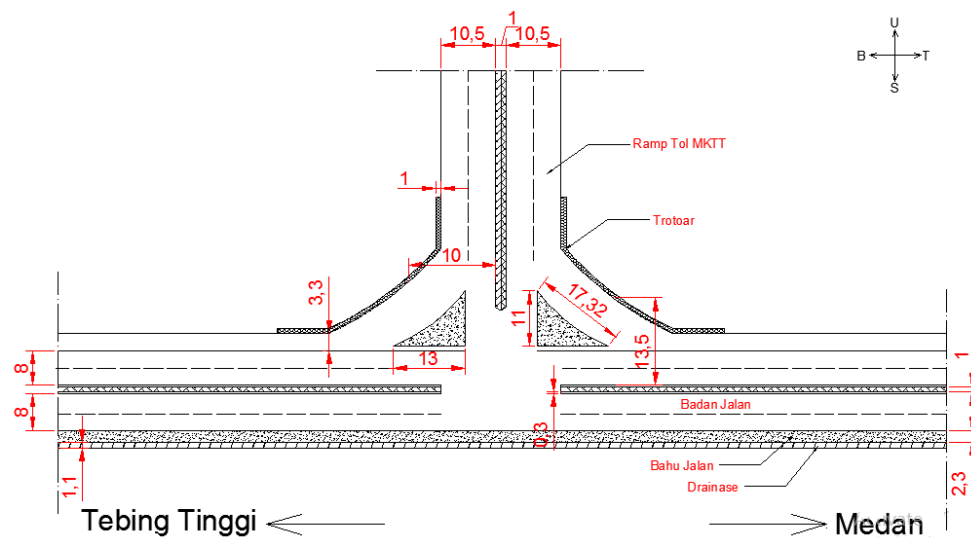


**Figure 5.** Results of the ADT survey at the intersection of the Arterial Road and Ramp Toll Road in Sei Rampah (Source: Result of ADT survey)

#### 4.2. Geometric of intersection

At the intersection that was reviewed was a signalized intersection with three arms. At the intersection of arterial roads and toll roads Lubuk Pakam, the geometry image in the existing state can be seen in Fig. 5 and the geometry data can be seen in Table 1 and Fig. 6 in the Sei Rampah location and geometry data can be seen in Table 2.

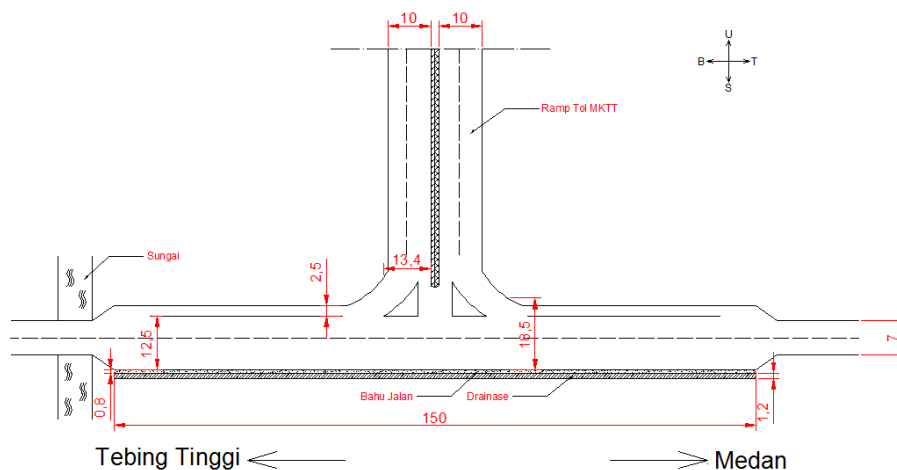




**Figure 6.** Existing geometry of intersection at the intersection of Arterial and Ramp Roads of Lubuk Pakam Highway (Source: Result of survey and documentation)

**Table 1.** Geometric data on arterial road intersection with Lubuk Pakam Toll Road Ramp

Approach to the Main Road		Approach Width (m)	Road markings	Roadside (m)	Minor Road Approach		Approach Width (m)	Road markings	Roadside (m)
Amount of lane	Median				Amount of lane	Median			
2	Yes	13,5	Yes	2,3	2	Yes	10	Yes	1



**Figure 7.** Existing geometry of intersection at the Intersection of Arterial and Ramp Roads of Sei Rampah Highway (Source: Result of survey and documentation)

**Table 2.** Geometric data intersection of Arterial Roads with Ramp Toll Sei Rampah (Source: Results of survey)

Approach to the Main Road		Approach Width (m)	Road markings	Roadside (m)	Minor Road Approach		Approach Width (m)	Road markings	Roadside (m)
Amount of lane	Median				Amount of lane	Median			
2	No	18,5	Yes	1,2	2	Yes	13,4	Yes	-

#### 4.3. Analysis results

The calculation of the signalized intersection is carried out to determine the capacity and behavior of traffic. Data used comes from the results of the ADT survey that has been carried out in a state of maximum ADT.

**Table 3.** Results of recapitulation of traffic capacity and behavior at the Intersection of Arterial and Ramp Roads in Lubuk Pakam Highway (Source: Results of analysis)

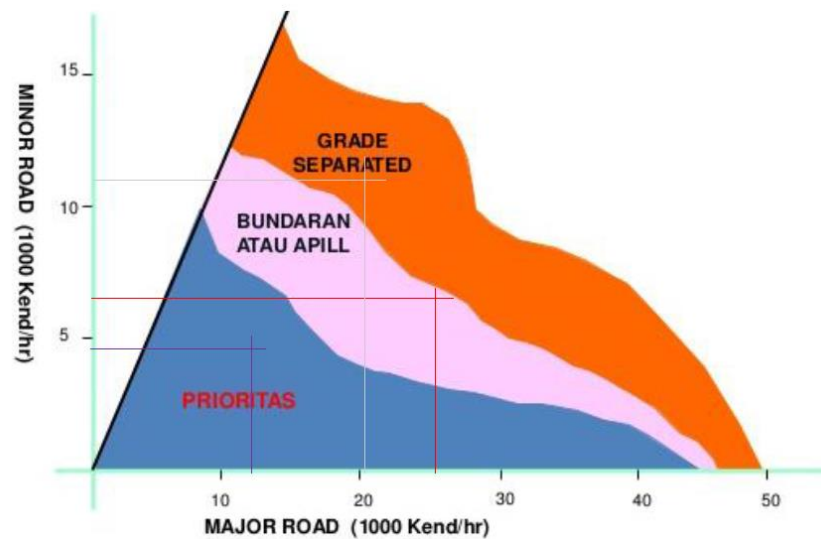
Approach	Flow (Q) (smp/hour)	Capacity (C) (smp/hour)	Degree of saturation (DS)	Average Geometric Delay (DG) (sec/smp)	Average Traffic Delay (DT) (sec/smp)	Level of Service	Average intersection delay (sec/smp)	Service Level of Intersection
North	201,1	282,9	0,71	4,00	31,23	D		
East	709,4	997,9	0,71	4,00	20,81	C	21,29	C
West	978,1	1375,9	0,71	3,85	12,01	B		

**Table 4.** Results of recapitulation of traffic capacity and behavior at the Intersection of Arterial and Ramp Roads in Sei Rampah Highway (Source: Results of analysis)

Approach	Flow (Q) (smp/hour)	Capacity (C) (smp/hour)	Degree of saturation (DS)	Average Geometric Delay (DG) (sec/smp)	Average Traffic Delay (DT) (sec/smp)	Level of Service	Average intersection delay (sec/smp)	Service Level of Intersection
North	320,7	408,5	0,79	4,00	36,56	D		
East	778,4	991,5677	0,79	4,00	25,10	C	26,15	D
West	971,2	1237,167	0,79	3,60	15,42	B		

#### 4.4. Discussion

Based on the results of the analysis on the initial conditions (existing) it can be seen that the degree of saturation at the intersection of the arterial road and the Lubuk Pakam toll ramp does not exceed 0.75 which was indicated by the Indonesian Road Capacity Manual (IHCM) 1997. So at the intersection, no further action is taken. While at the intersection of the arterial road and the ramp of the Sei Rampah toll road, the degree of saturation exceeds 0.75, which is 0.79. High degree of saturation is caused by high traffic flow at the intersection, this shows that the intersection conditions do not meet the requirements anymore in terms of traffic performance. For this reason, changes are needed to improve the quality of the intersection. To determine the right type of intersection setting for the intersection, a chart for determining the intersection setting of the Australian Road Research Board (ARRB) is used where the graph can be seen in Figure 7. Determination of the intersection arrangement comes from the relationship between the number of ADT on major and minor roads. The results of the analysis of the determination of intersection settings can be seen in Figure 8.



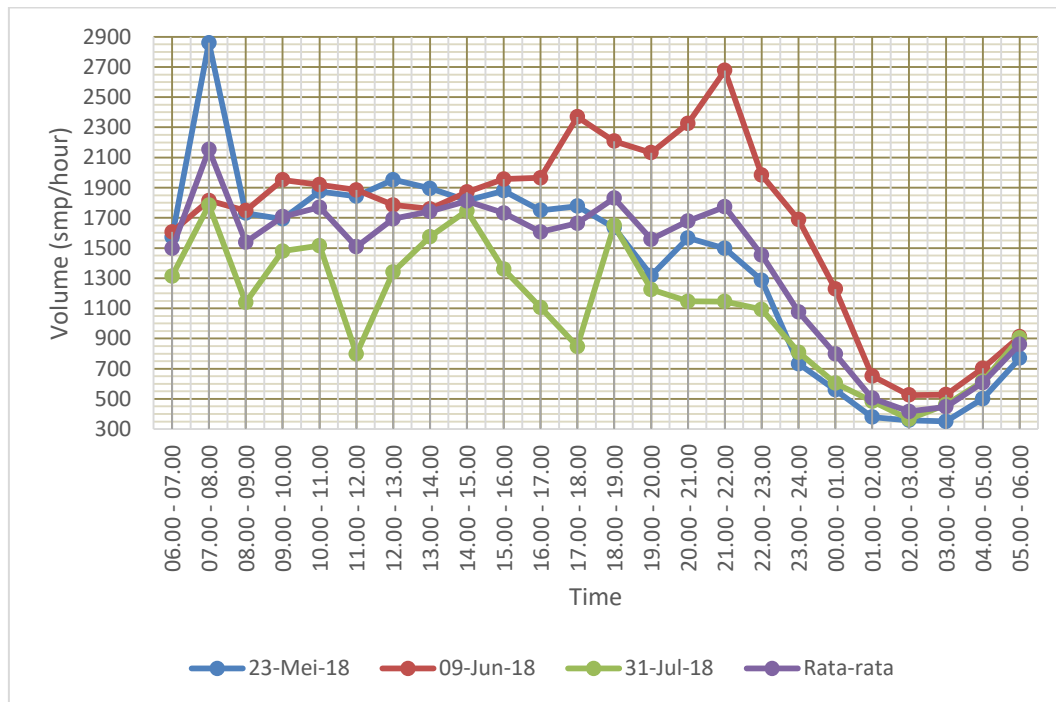
**Figure 8.** Determination of intersection arrangements at the Intersection of Arterial and Ramp Roads Sei Rampah Highway (Graph source: Australian Road Research Board)

From the graph in Figure 7, the results of the 24-hour survey on May 23, 2018 (red line) indicate that the number of vehicles on the major and minor roads leads to the intersection / APILL intersection arrangement. The results of a 24-hour survey on June 9, 2018 (gray line), intersection adjustment at the intersection is a grade separated intersection. This is because the number of vehicles passing has experienced a high increase in Eid ul-Fitr. 24 hour survey results on the normal condition on July 31,

2018 (purple line), the intersection setting is located in the priority intersection area. So, the intersection setting that is determined is a roundabout with traffic signal device (APILL).

#### 4.5. Intersection planning

For roundabout design, the average data from the 24-hour ADT survey is used, namely on May 23, June 9 and July 31 2018. ADT data can be seen in Figure 8.



**Figure 9.** Average volume of ADT at the Intersection of Arterial and Ramp Roads Sei Rampah Highway (Source: ADT Survey and Analysis)

#### 4.5.1. Roundabout planning

Determine the appropriate roundabout type based on life cycle cost analysis (BSH) and traffic behavior for the following conditions:

Traffic:  $ADT_N = 5.024$  vehicle/day

$ADT_E = 12.891$  vehicle/day

$ADT_W = 15.521$  vehicle/day

Annual traffic growth: 1,27%

(North Sumatra Province Transportation Agency)

Environment: Commercial

Low side resistance

City size > 3 million people

manufacture:

Traffic flows in the ADT are converted to plan clock currents (QDH) with factor k in Table A-2: 1 page 4-25 IHCM 1997 book.  $QDH_U = 5.024 \times 0,07 = 352$  vehicle/hour

$QDH_T = 12.891 \times 0,07 = 902$  vehicle/hour

$QDH_B = 15.521 \times 0,07 = 1086$  vehicle/hour Major road currents =  $902 + 1086 = 1.989$  vehicle/hour Minor road currents =  $511 + 341 = 352$  vehicle/hour

Considered turn ratio  $LT/RT = 15/15$

Separation of directions =  $1.989/352 = 5,66$

To choose an economical roundabout, the total intersection must be adjusted.

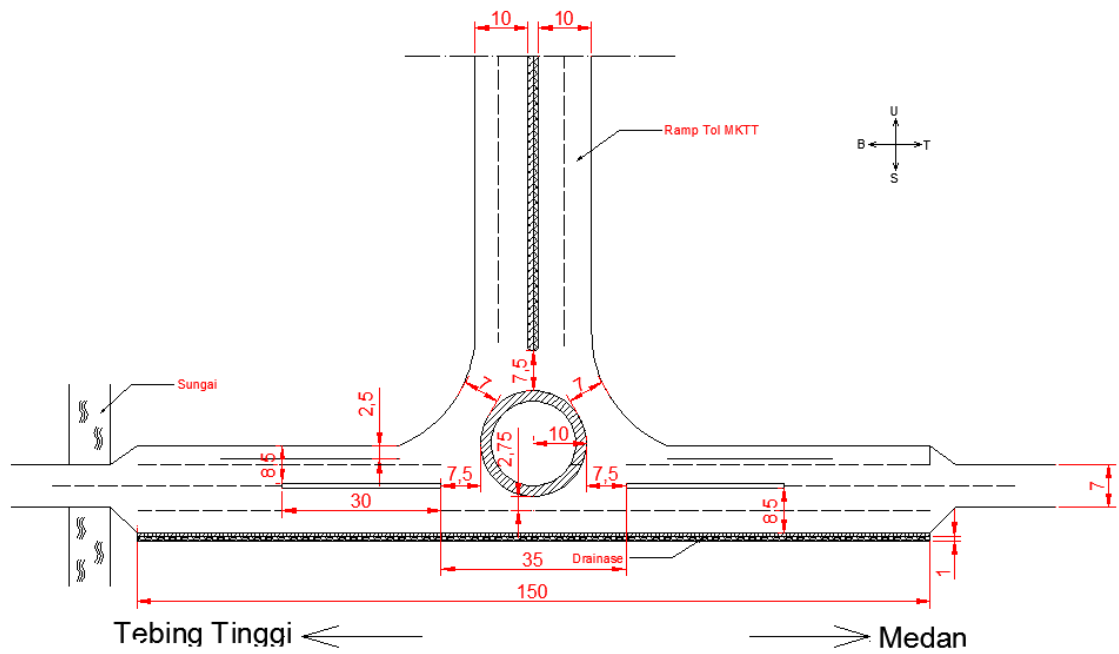
$Q1 = (1.989 + 352) \times (1 + 0,0127) / (1 + 0,065) = 2.226$  vehicle/hour

Based on Table 2.3.3: 1 pages 4-15 in IHCM 1997 book, the roundabout needed to flow 2,226 vehicle/hour is R10-11 with condition  $LT/RT = 25/25$  and ratio  $QMA/QMI = 1/1$ .

After determining the type of roundabout, then roundabout planning calculations.

### 1. Geometric Roundabout Planning

In planning a roundabout, planned geometric roundabouts. The sketch of the location geometry can be seen in Figure 9.



**Figure 10.** Geometry roundabout sketches at the Intersection of Arterial and Ramp Roads Sei Rampah Highway (Source: Results of analysis)

### 2. Roundabout Performance Calculation Results

**Table 5.** Calculation of roundabout capacity

	Braided Section	Factor of $W_w$	Factor of $W_E/W_w$	Factor of $P_w$	Factor of $W_A$	Basic Capacity ( $C_0$ )	Adjustment Factor	Road Environment ( $F_{RS}$ )	Capacity ( $C$ )
						smp/hour	City Size ( $F_{CS}$ )		smp/hour
1	AB	1694,19	3,14	0,57	0,72	2181,72	1,05	0,95	2176,27
2	BC	1694,19	3,38	0,36	0,72	1482,56	1,05	0,95	1478,85
3	CA	1694,19	3,14	0,45	0,72	1722,41	1,05	0,95	1718,11

**Table 6.** Calculation of degrees of roundabout saturation (Source: Results of analysis)

Braided Section	Entry Width		Average Entry Width	Braided Width	$W_E/W_w$	Braided Length	$W_w/L_w$	Capacity (C)	Braided Flow (Q)	Degree of saturation (DS)
	Approach 1	Approach 2	$W_E$	$W_w$		$L_w$		smp/hour	smp/hour	Q/C
1 AB	8,50	7,50	8,00	7,00	1,14	35,00	0,20	2176,27	1086,47	0,50
2 BC	10,00	7,50	8,75	7,00	1,25	35,00	0,20	1478,85	351,66	0,24
3 CA	8,50	7,50	8,00	7,00	1,14	35,00	0,20	1718,11	902,37	0,53

**Table 7.** Signal time calculation results (Source: Results of analysis)

Approach	Q	S (smp/green hour)	Flow Ratio (FR)	Lost Time (LT)	Pre-Adjustment Cycle Time	Green Time (g)	Customized Cycle Time (c)
			Q/S	seconds	seconds	seconds	seconds
North	258,9667	33,3	0,07	10	31	4	33
West	687,2	33,3	0,17	10	31	10	33
East	541,4667	33,3	0,16	10	31	9	33

**Table 8.** Signal phase calculation results (Source: Results of analysis)

Fase	Green Time (g)	Intergreen		Red Time	Cycle Time
		Yellow Time	All Red		
	seconds	seconds	seconds	seconds	seconds
1	10	4	2	9	25
2	10	4	2	19	35
3	10	4	2	17	33

To avoid accidents due to too short a green time, the green time is in phases 1 and 3 to 10 seconds.

From Table V.28 shows that the degree of saturation at the North approach = 0.24; Western approach = 0.50 and Eastern approach = 0.53. This means that the degree of saturation in the intersection planning arrangement using a roundabout with the planned APILL according to what was recommended by IHCM 1997 is  $DS \leq 0.75$ .

## 5. Conclusions and suggestions

### 5.1. Conclusions

1. The results of the performance evaluation of the intersection at the intersection between the arterial road and the Lubuk Pakam toll ramp in the existing condition have a service level C, with a degree of saturation of 0.71 in each approach. The average delay at this intersection is 21.57 det / pcu, which is still feasible to use so there is no need to change the intersection adjustment.
2. The results of the performance evaluation of the intersection at the intersection between the arterial road and the ramp of the existing Sei Rampah toll road have a service level D, with a degree of saturation of 0.79 in each approach. The average delay at this intersection is 26.15 sec / pcu, which is not feasible to be used so it needs to change the intersection adjustment.

3. On the graph of the determination of the intersection arrangement, the intersection between the arterial road and the ramp of the Sei Rampah toll road is determined by the intersection / APILL arrangement. Planning at this intersection is planned, namely roundabout planning with APILL.
4. The results of the roundabout planning with the APILL obtained the degree of saturation = 0.50. This shows that the roundabout with the planned APILL is worthy of use.

### 5.2. Suggestions

Conducted a follow-up study on the conflict at the MKTT toll gate on arterial roads. What kind of intersection is right to resolve conflicts (congestion) that occur in toll roads that are related to arterial roads, especially if the Tebing Tinggi toll gate start to be operated.

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