

# Evaluation of Capacity and Level of Service of Kuningan 2 Toll Gate on the Cawang-Tomang Toll Road Section, South Jakarta

Muhammad Adiwirawan, and Anak Agung Gde Kartika

Department of Civil Engineering, Sepuluh Nopember Institute of Technology (ITS)

Corresponding Author: kartika@ce.its.ac.id

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## ABSTRACT

Toll Road is classified as a public road and is part of the road network system where everyone who passes through it is required to pay a toll. The main function of toll roads is to provide barrier-free traffic, therefore, to achieve this, toll roads must have a minimum level of service. One of the factors that affect the occurrence of congestion on the toll road is the queuing process at the toll gate. In fact, at Kuningan Toll Gate 2 there is often a long queue causing congestion on both roads accessing the toll gate, namely Jl. Kapten Tendean and Jl. Gatot Subroto. To create barrier-free toll access, it is necessary to research and study the existing problems, whether they meet the required standards. Head of the Toll Road Regulatory Agency (BPJT) of the Ministry of Public Works and Public Housing (PUPR) Danang Parkesit stated that the MLFF construction implementation target will be started in 2021. This Multi Lane Free Flow (MLFF) system will eliminate the queue at the toll gate, therefore it is necessary to study the capacity of each lane at the toll gate with this MLFF system to get the maximum capacity and level of service of the toll gate. The FIFO queuing method is used to analyse the arrival rate, level of service and queue length that occurs at the toll gate and the PKJI road capacity analysis method is used to determine the capacity of the MLFF toll gate. Based on the analysis results, the Kuningan 2 toll gate had a queue of 599 vehicles with a service time of 12 seconds from the arrival rate that occurred. The arrival rate was found to be 1198 vehicles/hour with 628.5 vehicles/hour at Gate 1 and 569.5 vehicles/hour at Gate 2. At the level of service, the average service time of the toll gate is 4 seconds / vehicle. For the number of gates, it was found that it is necessary to add 2 GTOs in tandem at Kuningan 2 toll gate. For the Multi Lane Free Flow gate at the Kuningan 2 toll gate, the capacity is obtained at 1033,1 lv/ hour/ lane with the volume of vehicles occurring at 671,506 lv/hour/lane.

## INTRODUCTION

The transportation sector has a major influence on the movement of goods and services, which determines the pace of economic improvement and the level of prosperity of the community. Because the smooth flow of traffic in and out of an area can lead to certainty in the provision of the need for goods and services in the region. Toll Road is public roads that are part of the road network system and as national roads whose use is required to pay tolls. (Law No. 38 of 2004). [1]. Toll roads function as an alternative route for users to shorten the travel time, therefore, the implementation of toll roads aims to increase the efficiency of distribution services to support the economic growth, especially in areas that have a high level of development. (Government Regulation No.15 Year 2005 Chapter II Article 2) [2].

One of the factors affecting traffic congestion on toll roads is the condition and capacity of the toll road itself and the queuing process at the toll gate. Kuningan Toll Gate 2 is a toll gate that uses an automatic system (ATG). In fact, the Kuningan 2 Toll Gate which is located in the Cawang-Tomang toll area often has long queues causing congestion on both roads accessing the toll gate, namely Jl. Kapten Tendean and Jl. Gatot Subroto.

To create barrier-free toll access, it is necessary to research and study the existing problems, whether they meet the required standards or not. The standard used is the Minimum Service Standard (MSS). Minimum Service Standards (MSS) are measurements that must be achieved in the implementation of toll road operations.

Head of the Toll Road Regulatory Agency (BPJT) of the Ministry of Public Works and Public Housing (PUPR) Danang Parkesit stated that, MLFF construction target

Tabel 1. Transaction Data of Kuningan 2 Toll Gate

CLASS Date	Kuningan 2 Toll Gate					Total
	I	II	III	IV	V	
December 2020	359461	305	103	143	132	360144
January 2021	326160	280	103	151	142	326836
February 2021	318002	296	74	160	172	318704

Table 2. The Survey Data of Arrival Rate of Kuningan 2 Toll Gate at Gate 1

Class Time	Gate 1					V
	I	II	III	IV	V	
17.00-18.00	638	1,2	0	0	0	0
18.00-19.00	600	0	0	0	0	0
19.00-20.00	672	0	0	0	0	0
20.00-21.00	598	6	0	0	0	0
Total	2508	7,2	0	0	0	0
Percentage	99,71%	0,29%	0,00%	0,00%	0,00%	0,00%
Total			2515,2			

Table 3. The Survey Data of Arrival Rate of Kuningan 2 Toll Gate at Gate 2

Class Time	Gate 2					V
	I	II	III	IV	V	
17.00-18.00	492	1,2	0	0	0	0
18.00-19.00	423	0	0	0	0	0
19.00-20.00	757	3,6	0	0	0	0
20.00-21.00	600	2,4	0	0	0	0
Total	2272	7,2	0	0	0	0
Percentage	99,68%	0,32%	0,00%	0,00%	0,00%	0,00%
Total			2279,2			

will be started in 2021 (BPJT, 2021). This Multi Lane Free Flow (MLFF) system will eliminate queues at the toll gate, therefore it is necessary to study the capacity of each lane at the toll gate with this MLFF system to obtain the maximum capacity and level of service of the toll gate. After seeing the problems above, it is necessary to evaluate the capacity and level of service of the Kuningan 2 toll gate.

RESEARCH METHODOLOGY

A. Reducing the Number of Passengers during the Pandemic.

The data used in this research work is divided into two, primary and secondary data. Where the primary data consists of:

1. Arrival rate survey conducted by counting the number of vehicles classified by vehicle class.
2. The service time survey is conducted when the vehicle stops in front of the gate to make a transaction (while the toll payment is in progress) until the vehicle moves out of the gate.
3. Whereas, the secondary data includes toll gate transaction data and toll gate configuration obtained from PT Jasa Marga as the management board of the Cawang-Tomang Toll road.

B. Analysis Steps

To further understand the object analysed, the details of the object analysed will be explained first. After that, arrival rate analysis, service time analysis, intensity analysis, and queue analysis will be carried out to evaluate the capacity and level of service of the Kuningan 2 toll gate with the First In First Out (FIFO) queuing method to find out the number of toll booths that can meet

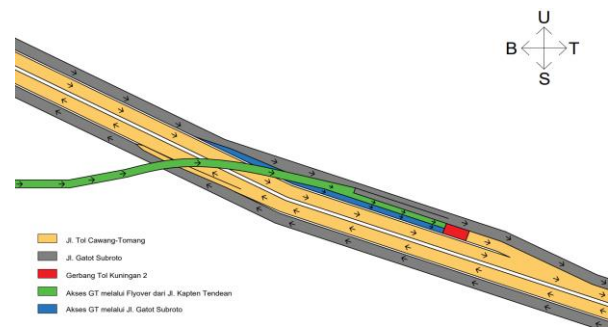


Figure 1. The Layout of Kuningan 2 Toll Gate

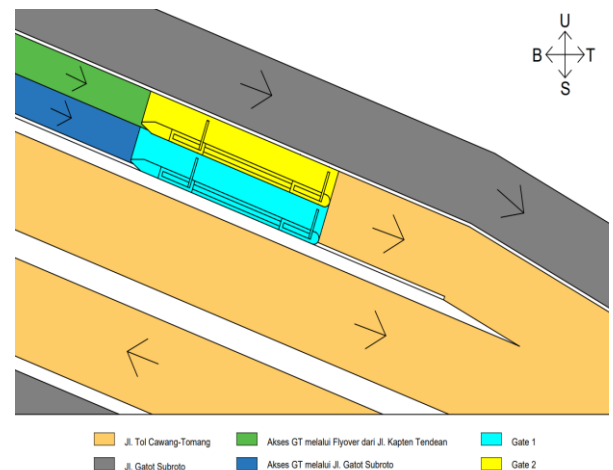


Figure 2. The Layout Gate of Kuningan 2 Toll Gate

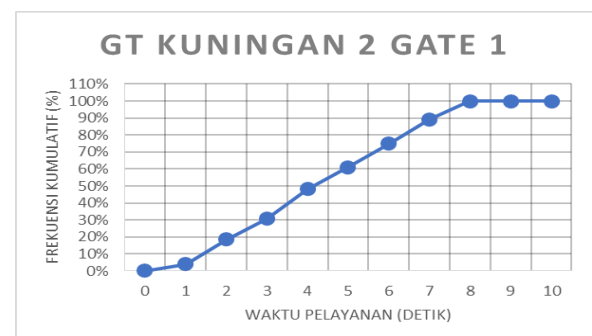


Figure 3. Cumulative Frequency Graph of Service Time of Kuningan 2 Toll Gate at Gate 1

the existing vehicle volume and lane capacity for Multi Lane Free Flow (MLFF) with the Outer City Road Capacity method from PKJI 2014.

C. Analysis Object

Kuningan 2 Toll Gate is a toll gate with an open system with two gates operating with 2 tandem gates at each gate located on the Cawang-Tomang Toll Road section. The analysis is carried out separately and thoroughly. Gate 1 can be accessed via Jl. Kapten Tendean while Gate 2 can be accessed via Jl. Gatot Subroto. The analysis will be conducted separately to determine the ability of each gate related to its different accesses and will be carried out as a whole to determine the ability of the toll gate as a unit. For the illustration of the access to Kuningan 2 toll gate can be seen in Figure 1. and Figure 2.

D. Arrival Rate Analysis.

In the arrival rate analysis, the arrival rate unit will be calculated using the number of vehicles passing through

Table 4. Arrival Rate Survey Data of Kuningan 2 Toll Gate

Class Time	Kuningan 2 Toll Gate				
	I	II	III	IV	V
	Light Vehicle Unit				
17.00-18.00	1130	2,4	0	0	0
18.00-19.00	1023	0	0	0	0
19.00-20.00	1429	3,6	0	0	0
20.00-21.00	1198	8,4	0	0	0
Total	4780	14,4	0	0	0
Percentage Total	99,70%	0,30%	0,00%	0,00%	0,00%
		4794,4			

Table 5. Intensity of Kuningan 2 Toll Gate at Gate 1

T (second/vehicle)	Gate 1 with LVE			
	N	$\lambda$ (l/vu/hour)	$\mu$ (l/vu/hour)	$\rho$
2	2	628,8	1800	0,175
3	2	628,8	1200	0,262
4	2	628,8	900	0,349
5	2	628,8	720	0,437
6	2	628,8	600	0,524
7	2	628,8	514	0,612
8	2	628,8	450	0,699
9	2	628,8	400	0,786
10	2	628,8	360	0,873
11	2	628,8	327	0,961
12	2	628,8	300	1,048

Table 6. Intensity of Kuningan 2 Toll Gate at Gate 2

T (second/vehicle)	Gate 2 Dengan EKR			
	N	$\lambda$ (l/vu/hour)	$\mu$ (l/vu/hour)	$\rho$
2	2	569,8	1800	0,158
3	2	569,8	1200	0,237
4	2	569,8	900	0,317
5	2	569,8	720	0,396
6	2	569,8	600	0,475
7	2	569,8	514	0,554
8	2	569,8	450	0,633
9	2	569,8	400	0,712
10	2	569,8	360	0,791
11	2	569,8	327	0,871
12	2	569,8	300	0,950

the toll gate according to the results of field surveys that have been carried out. For the arrival rate analysis, a light vehicle equivalency conversion according to PKJI will be used. The equation of the arrival rate can be seen below.

$$\lambda = \frac{\sum x}{N} \tag{1}$$

Given:

$\lambda$  = The average arrival rate (vehicle/h)

N = The amount of time required (hour)

$\sum x$  = Number of all vehicles

E. Service Time Analysis

The service time analysis is carried out by processing data obtained from service time surveys conducted in the field, then from the service time data is processed into a cumulative frequency graph of the toll gate being analyzed. After that, the maximum service time value is sought to obtain the service rate of the toll gate. The time of service and the level of service equation can be seen below.

$$T = \frac{1}{\mu} \tag{2}$$

Given:

T = Service Time

$\mu$  = Service Rate

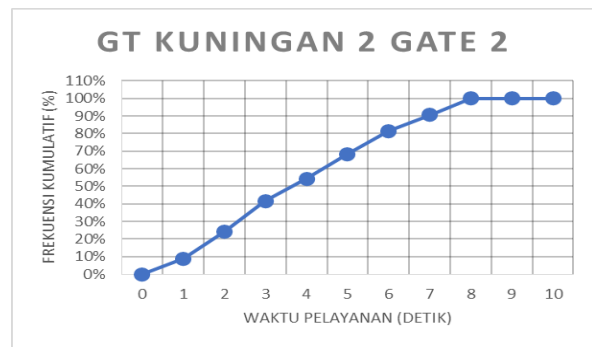


Figure 4. Cumulative Frequency Graph of Service Time of Kuningan 2 Toll Gate at Gate 2

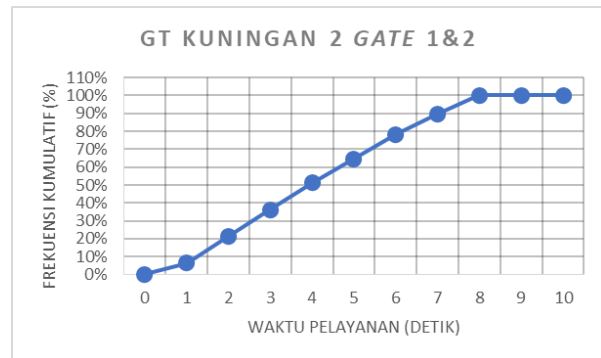


Figure 5. Cumulative Frequency Graph of Service Time of Kuningan 2 Toll Gate

F. Toll Gate Intensity Analysis

Traffic intensity analysis ( $\rho$ ) of the open toll gates and service gates are conducted to find out how much the intensity of the traffic intensity is. his analysis is carried out by using the data from the analysis of arrival rate ( $\lambda$ ) and by using the data from the analysis of service time from the smallest service time to the maximum limit, thus the traffic intensity in each service time condition can be determined. The traffic intensity equation can be seen below.

$$\rho = \frac{\lambda}{\mu} \tag{3}$$

Given:

$\Lambda$  = Arrival Rate

$\mu$  = Service Rate

$\rho$  = Comparison between arrival rate and service rate

N = Number of gates in operation

G. Toll Gate Queue Analysis

Queue analysis at the toll gates is conducted to find out how many vehicles are queuing and how long it takes to queue and to find out the actual number of gates required for each service time condition. This analysis is conducted using data from the analysis of arrival rate ( $\lambda$ ) and data from the analysis of toll gate intensity ( $\rho$ ) and by using data from the analysis of service time from the smallest service time to the maximum limit, therefore, the queue can be determined in each service time condition. The calculation of queue analysis with the FIFO or First in first out method is used. The FIFO queue analysis formula can be seen as follows.

Table 8. Queue at Kuningan 2 Toll Gate at Gate 1

Gate 1 with Light Vehicle Equivalency				
T (second/lvu)	n (lvu)	q (lvu)	d (second)	w (second)
2	1	1	3	1
3	1	1	5	2
4	1	1	7	3
5	1	1	9	4
6	2	1	13	7
7	2	1	19	12
8	3	2	27	19
9	4	3	43	34
10	7	7	79	69
11	25	24	286	275

Table 9. Queue at Kuningan 2 Toll Gate at Gate 2

Gate 2 with Light Vehicle Equivalency				
T (second/lvu)	n (lvu)	q (lvu)	d (second)	w (second)
2	1	1	3	1
3	1	1	4	1
4	1	1	6	2
5	1	1	9	4
6	1	1	12	6
7	2	1	16	9
8	2	2	22	14
9	3	2	32	23
10	4	4	48	38
11	7	6	86	75

$$n = \frac{\lambda}{\mu - \lambda} = \frac{\rho}{1 - \rho} \tag{4}$$

$$q = \frac{\lambda^2}{\mu(\mu - \lambda)} = \frac{\rho^2}{1 - \rho} \tag{5}$$

$$d = \frac{1}{(\mu - \lambda)} \tag{6}$$

$$w = \frac{\lambda}{\mu(\mu - \lambda)} = d - \frac{1}{\mu} \tag{7}$$

Given:

- n = Average number of vehicles in the system
- q = Average number of vehicles in the queue
- d = Average time of vehicles in the system
- w = Average time of vehicles in the queue
- λ = Arrival rate
- μ = Service rate
- ρ = Comparison between arrival rate and service

H. Toll Gate Planning.

The planning of the Kuningan 2 toll gate with the number of gates adjusted to the existing arrival rate in order to meet the Minimum Service Standards (MSS) both in capacity and queuing. After adjusting the number of gates, the arrival rate, traffic intensity and queue at the toll gate will be analyzed additionally.

I. MLFF Gate Capacity Planning.

Multi Lane Free Flow (MLFF) capacity planning at Kuningan 2 toll gate is conducted using the Outer City Road Capacity reference from the Indonesian Road Capacity Guidelines (PKJI) to plan the capacity of the Multi Lane Free Flow gate. Gate planning (MLFF) is

Table 10. Queue at Kuningan Toll Gate

Kuningan 2 TG with Light Vehicle Equivalency				
T (second/lv)	n (lvu)	q (lvu)	d (second)	w (second)
2	1	1	3	1
3	1	1	4	1
4	1	1	6	2
5	1	1	9	4
6	1	1	12	6
7	2	1	17	10
8	2	2	24	16
9	3	3	36	27
10	5	5	60	50
11	11	10	132	121
12	857	856	10286	10274

Table 11. Intensity of Kuningan 2 Toll Gate

Kuningan 2 TG With LVE				
T (second/vehicle)	N	λ (lvu/hour)	μ (lvu/hour)	ρ
2	6	1198,6	1800	0,111
3	6	1198,6	1200	0,166
4	6	1198,6	900	0,222
5	6	1198,6	720	0,277
6	6	1198,6	600	0,333
7	6	1198,6	514	0,389
8	6	1198,6	450	0,444
9	6	1198,6	400	0,499
10	6	1198,6	360	0,555
11	6	1198,6	327	0,611
12	6	1198,6	300	0,666
13	6	1198,6	277	0,721

conducted by using the existing land without changing the access road to Kuningan 2 toll gate. However, adjustments will be made for MLFF planning on the lanes located at Kuningan 2 toll gate.

MLFF Capacity Planning based on:

1. The Design Hour Traffic Flow (q<sub>JP</sub>)

To determine the traffic flow of the Kuningan 2 toll gate, the number of vehicles obtained from the Kuningan 2 toll gate transaction data for 7 days (LHRT can be used.). The daily traffic data is used as the basis for determining the design hour traffic flow (q<sub>JP</sub>) which is determined from the LHRT, using k factor.

$$q_{JP} = LHRT \times k \tag{8}$$

Given:

- q<sub>JP</sub> = Traffic Flow lvu/h
- LHRT = daily traffic flow, vehicle/day, or lvu/day
- k = the plan hour factor, determined from a study of hourly traffic flow fluctuations over one year. The k value that can be used is 11%

2. Distance Velocity (V<sub>T</sub>)

According to PKJI 2014 [3] in the Inter Urban Roads Capacity, travel speed is the average speed of traffic flow. The travel speed under field conditions is a function of the road performance parameters, namely DJ with VB. In the VT analysis, the type of vehicle used is light vehicle (LV). The determination of VT is carried out using a graph of the relationship between VT and DS

3. Degree of Saturation (D<sub>s</sub>)

According to PKJI 2014 [3] The value of degree of saturation (D<sub>s</sub>) is used as a key factor in determining the traffic performance. The D<sub>s</sub> value indicates whether the

Table 12. Queue at Kuningan 2 Toll Gate

Kuningan 2 TG With Light Vehicle Equivalent				
T (dsecond/lvu)	n (lvu)	q (lvu)	d (second)	w (second)
2	1	1	3	1
3	1	1	4	1
4	1	1	6	2
5	1	1	7	2
6	1	1	9	3
7	1	1	12	5
8	1	1	15	7
9	1	1	18	9
10	2	1	23	13
11	2	1	29	18
12	2	2	36	24
13	3	2	47	35

Table 13. Traffic Flow of Kuningan 2 Toll Gate

Class	Kuningan 2 Toll Gate					Total
	I	II	III	IV	V	
Total (Vehicle/Day)	12170,3	11,3	2,9	5,7	7,3	12197,4
Total (Vehicle/Hour)	1338,7	1,2	0,3	0,6	0,8	1341,7
lve	1,0	1,2	1,6	1,6	1,6	-
Total (Lvu/Day)	12170,3	13,5	4,6	9,1	11,7	12209,2
Total (Lvu/Hour)	1338,7	1,5	0,5	1,0	1,3	1343,0

Table 14. Data of GT K2 Gate 1 Arrival Rate Survey

Class Of Time	GATE 1				
	I	II	III	IV	V
	NUMBER OF VEHICLES				
17.00-17.15	129	-	-	-	-
17.15-17.30	220	1	-	-	-
17.30-17.45	137	-	-	-	-
17.45-18.00	152	-	-	-	-
18.00-18.15	142	-	-	-	-
18.15-18.30	176	-	-	-	-
18.30-18.45	137	-	-	-	-
18.45-19.00	145	-	-	-	-
19.00-19.15	212	-	-	-	-
19.15-19.30	152	-	-	-	-
19.30-19.45	170	-	-	-	-
19.45-20.00	138	-	-	-	-
20.00-20.15	155	-	-	-	-
20.15-20.30	186	-	-	-	-
20.30-20.45	130	2	-	-	-
20.45-21.00	127	3	-	-	-

Table 15. Data of GT K2 Gate 2 Arrival Rate Survey

Class Of Time	GATE 2				
	I	II	III	IV	V
	NUMBER OF VEHICLES				
17.00-17.15	86	-	-	-	-
17.15-17.30	147	-	-	-	-
17.30-17.45	159	-	-	-	-
17.45-18.00	100	1	-	-	-
18.00-18.15	95	-	-	-	-
18.15-18.30	121	-	-	-	-
18.30-18.45	97	-	-	-	-
18.45-19.00	110	-	-	-	-
19.00-19.15	135	-	-	-	-
19.15-19.30	183	-	-	-	-
19.30-19.45	218	-	-	-	-
19.45-20.00	221	3	-	-	-
20.00-20.15	179	-	-	-	-
20.15-20.30	154	-	-	-	-
20.30-20.45	129	2	-	-	-
20.45-21.00	138	-	-	-	-

road segment will have capacity problems or not. The general formula for degree of saturation is:

$$\lambda = 628,8 \text{ lv/h}$$

1. Gate 2

The results of the calculation of the arrival rate analysis at the Kuningan 2 Gate 2 toll gate can be seen in Table 3. and the following description:

$$\lambda = \frac{2279,2}{4}$$

$$\lambda = 569,8 \text{ lv/h}$$

2. The Kuningan 2 Toll Gate

The overall results of the calculation of the arrival rate analysis at the Kuningan 2 toll gate can be seen in Table 4. and the following description:

$$\lambda = \frac{4794,4}{4}$$

$$\lambda = 1198,6 \text{ lv/hour}$$

A. Service Time Analysis.

Service time analysis in terms of:

1. Gate 1

The results of the calculation of service time analysis with the equivalence of light vehicles at the Kuningan 2 Gate 1 toll gate can be seen in the graph of Figure 3. and the following description:

Based on the cumulative frequency graph of the service time of the Kuningan 2 Gate 1 toll gate with 2 gates operating in tandem, the average service time is obtained in the range of 4 seconds / vehicle.

If the maximum service time allowed at the Kuningan 2 Gate 1 toll gate is taken into account, then:

$$\lambda = 628,8 \text{ lv/hour}$$

$$N = 2 \text{ (number of gates in operation, in tandem)}$$

$$\frac{\lambda}{N} < 1 = \frac{628,8}{2} < 1$$

$$= \frac{314,4}{\mu} < 1$$

Thus, obtained  $\mu$  of 314 vehicles / hour. Therefore, the maximum service time allowed is:

$$314 = \frac{3600}{T}$$

$$T = 11,46 \text{ second/vehicle}$$

2. Gate 2

The results of the calculation of service time analysis with the equivalence of light vehicles at the Kuningan 2 Gate 2 toll gate can be seen in the graph of Figure 4. and the following description:

Based on the cumulative frequency graph of the service time of the Kuningan 2 Gate 2 toll gate with 2 gates operating in tandem, the average service time is obtained in the range of 3 seconds / vehicle.

If the maximum service time allowed at Kuningan 2 toll gate Gate 2 is taken into account, then:

$$\lambda = 569,8 \text{ lv/hour}$$

$$N = 2 \text{ (number of gates in operation, in tandem)}$$

Thus, obtained  $\mu$  of 285 skr / hour. Therefore, the maximum service time allowed is:

$$285 = \frac{3600}{T}$$

$$T = 12,63 \text{ second/vehicle}$$

3. The Kuningan 2 Toll Gate

The results of the calculation of service time analysis with the equivalence of light vehicles at the Kuningan 2

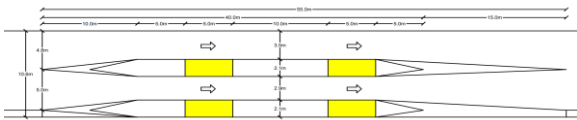


Figure 6. Existing Layout of the Kuningan 2 Toll Gate

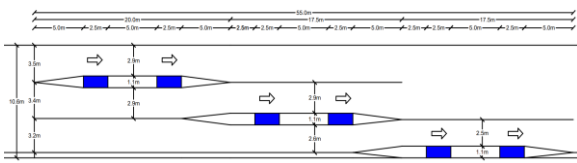


Figure 7. Layout Plan of the Kuningan 2 Toll Gate

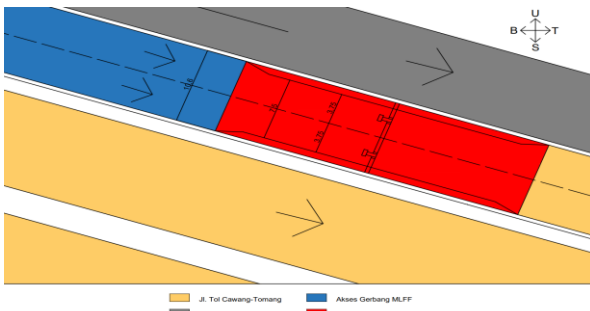


Figure 9. Multi Lane Free Flow Gate Plan Layout

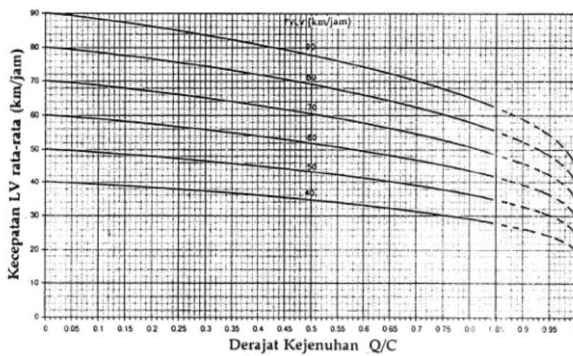


Figure 10. Relationship between  $V_T$  and  $D_j$ , on the 4/2T road type. (Source: Indonesian Road Capacity Manual 2014)

toll gate can be seen in the graph of Figure 5. and the following description:

Based on the cumulative frequency graph of the service time of the Kuningan 2 toll gate with 4 gates operating in tandem, the average service time is obtained in the range of 4 seconds / vehicle.

If the maximum service time allowed at Kuningan 2 toll gate is considered, then:

$$\lambda = 1198,6 \text{ lv/hour}$$

$N = 4$  (number of gates in operation, in tandem)

$$\frac{\lambda}{N} < 1 = \frac{1198}{4} < 1$$

$$= \frac{299,5}{\mu} < 1$$

Thus, obtained  $\mu$  of 300 vehicles / hour. Therefore, the maximum service time allowed is.

$$300 = \frac{3600}{T}$$

$T = 12 \text{ second/vehicle}$

**B. Toll Gate Integrity Analysis.**

The results of the calculation of traffic intensity analysis with the equivalent of light vehicles at Gate 1, Gate 2 and Kuningan 2 Toll Gate can be seen in the Table 8, Table 9, and Table 10.

Table 16. Survey Data of GT K2 Gate 1 Service Time

GATE 1							
TIME							
17.00-18.00	18.00-19.00	19.00-20.00	20.00-21.00	TIME (Second)			
2,08	6,47	8,71	1,72	2,95	2,84	6,64	7,75
7,52	7,24	5,47	4,76	3,77	4,57	6,80	6,73
2,30	3,28	3,77	6,39	4,95	4,35	7,10	4,80
5,10	6,07	6,01	8,00	5,64	5,50	4,97	3,03
3,37	2,74	6,31	4,21	2,62	2,86	7,17	5,00
5,51	8,97	2,55	6,55	2,59	8,54	4,58	1,72
5,86	1,88	3,10	6,80	5,32	4,79	3,29	7,95
5,53	3,69	1,58	8,66	4,03	4,77	2,69	4,20
4,45	4,87	7,02	2,53	2,98	4,74	7,80	3,22
4,35	7,16	2,55	7,08	3,08	7,38	6,64	7,23
4,13	7,60	4,76	8,66	4,40	7,22	2,90	6,53
6,77	2,86	3,67	5,69	7,48	8,18	4,52	2,65
6,96	4,56	8,41	1,79	8,40	6,60	6,41	2,73
7,54	1,99	7,08	5,15	7,07	7,09	5,05	3,13
2,54	5,63	4,21	4,81	7,10	3,89	3,35	6,79
2,37	5,66	2,50	2,92	2,24	8,55	6,55	4,02
3,73	8,10	5,06	5,79	6,66	5,42	5,32	6,91
5,12	8,72	2,20	8,23	2,18	5,36	3,14	1,60
5,40	6,13	1,89	4,23	8,91	6,46	8,21	6,67
4,66	3,89	8,70	4,49	8,89	8,64	4,90	5,23
5,74	2,83	7,50	3,14	7,52	8,94	6,16	
8,90	3,34	5,09	6,73	2,48	4,86	4,91	
4,76	7,31	7,81	6,11	6,92	3,54	2,42	
3,75	7,57	3,13	8,93	3,36	7,04	5,39	
5,17	3,54	4,77	2,65	4,16	7,74	8,17	

Table 17. Survey Data of GT K2 Gate 2 Service Time

GATE 1							
TIME							
17.00-18.00	18.00-19.00	19.00-20.00	20.00-21.00	TIME (Second)			
2,24	6,71	4,58	6,47	7,48	6,02	4,74	5,61
5,95	6,30	5,80	2,56	7,09	7,15	7,70	3,40
8,65	5,65	5,11	4,80	8,08	6,79	4,04	3,57
8,18	5,85	2,51	3,89	7,61	6,25	3,17	8,89
1,79	4,40	6,44	2,47	5,07	3,59	6,31	8,33
8,10	6,12	6,29	3,15	2,12	5,91	5,08	3,27
5,75	4,84	1,86	3,02	3,29	3,72	3,25	7,64
8,51	4,09	1,78	6,42	2,35	3,27	8,03	2,04
3,62	2,35	2,08	8,52	2,08	5,23	5,73	2,65
4,03	2,60	3,84	5,19	5,01	2,40	3,60	4,42
6,28	8,45	3,93	1,52	5,02	2,67	1,65	4,58
6,63	4,65	5,35	3,97	6,12	2,41	1,88	2,70
3,65	5,56	6,46	4,50	1,88	1,86	7,37	4,95
7,05	6,92	7,16	3,27	6,27	1,62	8,93	8,63
3,02	5,06	2,76	4,48	2,86	7,28	7,28	6,32
2,76	4,03	5,43	5,48	2,64	8,38	4,20	
2,40	1,81	3,11	6,01	6,92	8,76	3,08	
3,05	2,94	2,75	5,59	3,33	6,64	2,55	
3,79	6,02	2,40	8,08	2,71	6,55	5,47	
7,68	1,68	3,21	3,15	1,72	3,31	5,64	
8,16	7,40	3,83	4,86	1,61	1,75	2,88	
1,92	4,70	8,42	1,59	2,40	5,55	7,95	
4,25	3,56	5,31	6,78	4,89	4,17	1,77	
4,35	2,11	3,17	3,91	4,30	7,25	5,30	
4,14	7,90	7,77	3,55	6,20	5,44	8,09	

**C. Toll Gate Queue Analysis.**

The results of the calculation of queue analysis with the equivalent of light vehicles at Gate 1, Gate 2 and Kuningan 2 Toll Gate can be seen in the Table 11, Table 12, and Table 13.

**D. Toll Gate Planning.**

The addition of 2 automatic toll gates (ATG) will be carried out at Kuningan 2 Toll Gate which works in tandem at Kuningan 2 toll gate. The layout sketch of the existing Kuningan 2 toll gate can be seen as Figure 6.

It can be seen in the sketch of the existing layout of the Kuningan 2 toll gate that the width of each lane is 3.5m

Appendix 1. K2 TG Gate 1 Arrival Rate Survey Data

CLASS TIME	GATE 1				
	I	II	III	IV	V
	NUMBER OF VEHICLE				
17.00-17.15	129	-	-	-	-
17.15-17.30	220	1	-	-	-
17.30-17.45	137	-	-	-	-
17.45-18.00	152	-	-	-	-
18.00-18.15	142	-	-	-	-
18.15-18.30	176	-	-	-	-
18.30-18.45	137	-	-	-	-
18.45-19.00	145	-	-	-	-
19.00-19.15	212	-	-	-	-
19.15-19.30	152	-	-	-	-
19.30-19.45	170	-	-	-	-
19.45-20.00	138	-	-	-	-
20.00-20.15	155	-	-	-	-
20.15-20.30	186	-	-	-	-
20.30-20.45	130	2	-	-	-
20.45-21.00	127	3	-	-	-

Appendix 2. K2 TG Gate 1 Arrival Rate Survey Data

CLASS TIME	GATE 2				
	I	II	III	IV	V
	NUMBER OF VEHICLE				
17.00-17.15	86	-	-	-	-
17.15-17.30	147	-	-	-	-
17.30-17.45	159	-	-	-	-
17.45-18.00	100	1	-	-	-
18.00-18.15	95	-	-	-	-
18.15-18.30	121	-	-	-	-
18.30-18.45	97	-	-	-	-
18.45-19.00	110	-	-	-	-
19.00-19.15	135	-	-	-	-
19.15-19.30	183	-	-	-	-
19.30-19.45	218	-	-	-	-
19.45-20.00	221	3	-	-	-
20.00-20.15	179	-	-	-	-
20.15-20.30	154	-	-	-	-
20.30-20.45	129	2	-	-	-
20.45-21.00	138	-	-	-	-

K2 TG Gate 1 Service Time Survey Data

TIME	GATE 1							
	17.00-18.00		18.00-19.00		19.00-20.00		20.00-21.00	
	TIME (second)							
2,08	6,47	8,71	1,72	2,95	2,84	6,64	7,75	
7,52	7,24	5,47	4,76	3,77	4,57	6,80	6,73	
2,30	3,28	3,77	6,39	4,95	4,35	7,10	4,80	
5,10	6,07	6,01	8,00	5,64	5,50	4,97	3,03	
3,37	2,74	6,31	4,21	2,62	2,86	7,17	5,00	
5,51	8,97	2,55	6,55	2,59	8,54	4,58	1,72	
5,86	1,88	3,10	6,80	5,32	4,79	3,29	7,95	
5,53	3,69	1,58	8,66	4,03	4,77	2,69	4,20	
4,45	4,87	7,02	2,53	2,98	4,74	7,80	3,22	
4,35	7,16	2,55	7,08	3,08	7,38	6,64	7,23	
4,13	7,60	4,76	8,66	4,40	7,22	2,90	6,53	
6,77	2,86	3,67	5,69	7,48	8,18	4,52	2,65	
6,96	4,56	8,41	1,79	8,40	6,60	6,41	2,73	
7,54	1,99	7,08	5,15	7,07	7,09	5,05	3,13	
2,54	5,63	4,21	4,81	7,10	3,89	3,35	6,79	
2,37	5,66	2,50	2,92	2,24	8,55	6,55	4,02	
3,73	8,10	5,06	5,79	6,66	5,42	5,32	6,91	
5,12	8,72	2,20	8,23	2,18	5,36	3,14	1,60	
5,40	6,13	1,89	4,23	8,91	6,46	8,21	6,67	
4,66	3,89	8,70	4,49	8,89	8,64	4,90	5,23	
5,74	2,83	7,50	3,14	7,52	8,94	6,16		
8,90	3,34	5,09	6,73	2,48	4,86	4,91		
4,76	7,31	7,81	6,11	6,92	3,54	2,42		
3,75	7,57	3,13	8,93	3,36	7,04	5,39		
5,17	3,54	4,77	2,65	4,16	7,74	8,17		

Transaction Data (7 days) February 2021 K2 TG

CLASS Date	Kuningan 2 Toll Gate				
	I	II	III	IV	V
	The Number of Vehicle				
22	12689	10	1	8	5
23	12866	15	5	8	5
24	12818	15	3	7	10
25	13651	15	3	7	5
26	13856	11	2	6	15
27	11075	11	4	1	5
28	8237	2	2	3	6

and 2.9m and with a toll island width of 2.1m. Therefore, the toll island design will be changed to a design with automatic toll booths (GTO) and the lane width will be adjusted in order to build an additional 2 automatic toll gates work in tandem.

In accordance with the toll gate design standards set by BPJT, the width of the toll island with an automatic toll gate is 1.1m. Thus, the lane width at Kuningan 2 toll gate can be adjusted for the gate addition and toll island design with automatic toll gate. The sketch of the layout plan of the Kuningan 2 toll gate can be seen in Figure 7.

Referring to the layout plan of the Kuningan 2 toll gate, it is assumed that every vehicle accessing the Kuningan 2 toll gate from Jl. Gatot Subroto and Jl. Kapten Tendean can cross from one lane to another. Therefore, according to the existing arrival rate of 1198.6 lv / hour at the Kuningan 2 toll gate will be divided into three due to the addition of lanes. The calculation can be seen as follows:

$$\lambda = \frac{1198,6}{3} = 399,53 \text{ lv/hour}$$

Then the arrival rate for each gate will be 399.5 skr / hour. From the results of the arrival rate, the toll gate has met the capacity requirements according to the Minimum Service Standard (SPM), which is  $\leq 450$  vehicles / hour. With the arrival rate obtained previously, the analysis of the intensity and queue of the toll gate will be carried out anymore.

1. Intensity Analysis of Kuningan 2 TG

The results of the calculation of traffic intensity analysis with the light vehicle equivalent at the Kuningan 2 toll gate are as shown in Table 14

2. Queue Analysis of Kuningan 2 TG

The results of the calculation of the light vehicle equivalent queue analysis at the Kuningan 2 toll gate can be seen in Table 15.

E. MLFF Gate Capacity Planning

It can be seen in Figure 6. The Existing Layout of Kuningan 2 Toll Gate that the access width of the two lanes is 10.6 metres and the lane width for Gate 1 is 2.9 metres and the lane width for Gate 2 is 3.5 metres.

In the design of the MLFF gate, there is no longer a need for a toll island for the toll gate. Thus, the design adjustment of the Kuningan 2 toll gate will be made which can be seen in Figure 9.

It can be seen above that the width adjustment will be made at the Multi Lane Free Flow gate to 7.5m with 3.75m for each lane with an effective shoulder width (LBe) of 3.1m by reducing the total width of the land which is 10.6 metres with a total lane width of 7.5 metres at the Kuningan 2 toll gate.

MLFF Capacity Planning can be viewed in terms of:

1. Design Hour Traffic Flow (q<sub>DP</sub>)

The results of the calculation of traffic flow (q<sub>JP</sub>) can be seen in the Table 16.

Then, the traffic flow (q<sub>JP</sub>) is adjusted to the number of the existing lanes therefore, (q<sub>JP</sub>) of 671.5 lvu/hour/lane is obtained.

2. Travelling Speed (V<sub>T</sub>)

At the Multi Lane Free Flow (MLFF) gate, a speed restriction at 40 km/h is imposed on the road section. Thus, by imposing the speed restrictions at 40 km/h, a travelling speed, V<sub>T</sub> of 40 km/h, can be determined. In accordance with PKJI on Inter Urban Road Capacity, the D<sub>J</sub> value can be determined based on V<sub>T</sub> by referring the

Appendix 4. K2 TG Gate 2 Service Time Survey Data

GATE 1							
TIME							
17.00-18.00	18.00-19.00		19.00-20.00		20.00-21.00		
TIME (second)							
2,24	6,71	4,58	6,47	7,48	6,02	4,74	5,61
5,95	6,30	5,80	2,56	7,09	7,15	7,70	3,40
8,65	5,65	5,11	4,80	8,08	6,79	4,04	3,57
8,18	5,85	2,51	3,89	7,61	6,25	3,17	8,89
1,79	4,40	6,44	2,47	5,07	3,59	6,31	8,33
8,10	6,12	6,29	3,15	2,12	5,91	5,08	3,27
5,75	4,84	1,86	3,02	3,29	3,72	3,25	7,64
8,51	4,09	1,78	6,42	2,35	3,27	8,03	2,04
3,62	2,35	2,08	8,52	2,08	5,23	5,73	2,65
4,03	2,60	3,84	5,19	5,01	2,40	3,60	4,42
6,28	8,45	3,93	1,52	5,02	2,67	1,65	4,58
6,63	4,65	5,35	3,97	6,12	2,41	1,88	2,70
3,65	5,56	6,46	4,50	1,88	1,86	7,37	4,95
7,05	6,92	7,16	3,27	6,27	1,62	8,93	8,63
3,02	5,06	2,76	4,48	2,86	7,28	7,28	6,32
2,76	4,03	5,43	5,48	2,64	8,38	4,20	
2,40	1,81	3,11	6,01	6,92	8,76	3,08	
3,05	2,94	2,75	5,59	3,33	6,64	2,55	
3,79	6,02	2,40	8,08	2,71	6,55	5,47	
7,68	1,68	3,21	3,15	1,72	3,31	5,64	
8,16	7,40	3,83	4,86	1,61	1,75	2,88	
1,92	4,70	8,42	1,59	2,40	5,55	7,95	
4,25	3,56	5,31	6,78	4,89	4,17	1,77	
4,35	2,11	3,17	3,91	4,30	7,25	5,30	
4,14	7,90	7,77	3,55	6,20	5,44	8,09	

graph in Figure 10. This results in a free flow speed, FV of 50 km/h and a degree of saturation, D<sub>s</sub> of 0.65.

3. Degree of Saturation (D<sub>s</sub>)

With the value of travel speed, VT of 40 km / h, the free flow speed, FV of 50 km / h and the degree of saturation, D<sub>s</sub> of 0.65. Thus, the change in capacity value is obtained according to the description below.

$$D_s = \frac{q}{C}$$

$$0,65 = \frac{671,5}{C}$$

$$C = \frac{671,5}{0,65}$$

$$C = 1033,1 \text{ lvu/hour/lane}$$

$$C = 2066,2 \text{ lvu/hour}$$

CONCLUSIONS

The conclusions that can be concluded based on the results of the analysis that has been carried out are as follows.

A. The Capacity of Kuningan 2 Toll Gate

1. Gate 1 had an arrival rate of 628,8 lvu/hour.
2. Gate 2 had an arrival rate of 569,8 lvu/hour.
3. Kuningan 2 Toll Gate had an arrival rate of 1198,6 lvu/hour.

From the results of the arrival rate analysis, it can be concluded that the Kuningan 2 Toll Gate did not meet the requirements of the Toll Road Minimum Service Standards (SPM) because the requirements for toll gates with an open system must have an arrival rate of ≤ 450 vehicles / hour / gate.

B. Level of Service of Kuningan Toll Gate 2

1. Gate 1 had a maximum service time of 11,46 seconds/vehicle and an average service time of 4 seconds/vehicle with an intensity value of 0,349.
2. Gate 2 had a maximum service time of 12,63 seconds/vehicle and an average service time of 3 seconds/vehicle with an intensity value of 0,237.
3. Kuningan 2 Toll Gate had a maximum service time of 12 seconds / vehicle and an average service time of 4 seconds / vehicle with an intensity value of 0,333.

Therefore, the Kuningan 2 Toll Gate has met the requirements of the Toll Road Minimum Service Standards (SPM) which requires the transaction time of the open system toll gate to be a maximum of 6 seconds / vehicle and has met the requirements of the value of ρ < 1.

C. Number of Toll Gates According to Arrival Rate

Reviewing the arrival rate that occurred at the Kuningan 2 toll gate, which was 1198,6 lvu / hour, it required the addition of 2 automatic toll gates (ATG) working in tandem to meet the requirements of the Toll Road Minimum Service Standards (SPM) which required the arrival rate at the toll gate to be ≤ 450 vehicles / hour / gate. With the addition of the gate, an arrival rate of 399,53 lvu / hour / gate was obtained with the results of a vehicle queue that did not exceed 10 vehicles and a gate intensity that had a value of <1 which can be considered safe and would not have any queue extension..

D. Multi Lane Free Flow (MLFF) Gate Capacity

From the planning of the capacity of the Kuningan 2 Multi Lane Free Flow (MLFF) gate with lane width adjustments to the available land and with a speed limit (V<sub>T</sub>) of 40 km/h, the gate capacity (C) was obtained at 1033.1 skr/hour/lane with a free flow speed (V<sub>F</sub>) of 50 km/hour. Whereas the volume of vehicles passing through the toll gate was obtained at 671,5 lvu / hour / lane, therefore, the degree of saturation (D<sub>s</sub>) sebesar 0,65. From the value (D<sub>s</sub>) < 1 obtained, it can be concluded that with the existing access road, the capacity of the MLFF gate could fulfil the existing vehicle volume.

APPENDIX

In the appendix, the K2 toll gate arrival rate survey data, and seven-day transaction data are shown.

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