Gedebage – Tasikmalaya Toll Gate Planning

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ARTICLE INFO

Article Information
Article Received: 2021-02-12
Article Revised: 2022-10-14
Article Accepted:

Keywords
Toll Gate Planning, Gedebage – Tasikmalaya Toll Gate

ABSTRACT

In general, transportation is the movement of people or objects from one place to another using a vehicle driven by humans or machines. Transportation is used to make it easier for humans to carry out their daily activities. A toll road is a road specifically for vehicles with two or more axles (cars, container trucks, buses, etc.) and aims to shorten the distance and travel time from one place to another. However, toll road often aims to shorten distances and time encounter obstacles. Obstacles occur because there are long queues at the toll gate. The method used in the Gedebage – Tasikmalaya toll gate planning was the *First In First Out* (FIFO) method, and the basic queue structure used *Single Channel – Single Phase* as the basic structure in the queuing process, which used 3 Automatic Toll Gate systems, *On Board Unit* (OBU), and *Single Lane Free Flow* using the FLO application. The planned gates included the Gedebage Gate with 7 substations, the Majalaya Gate with 6 substations, the Nagreg Gate with 4 substations, the North Garut Gate with 4 substations, the South Garut Gate with 4 substations, the Singaparna Gate with 4 substations, and the Tasikmalaya Gate with 4 substations.

INTRODUCTION

In general, transportation is the movement of people or objects from one place to another using a vehicle driven by humans or machines. Transportation is used to make it easier for humans to carry out their daily activities. In the movement of goods and services, land transportation greatly influences economic growth in Indonesia. According to data from the Central Statistics Agency (BPS), it was noted that the average percentage growth in motorized vehicle ownership each year from 2009 to 2018 reached an increase of 9.05 percent. Nowadays, road construction is being intensified to decrease the high congestion level in big cities. In addition, toll road construction is one of the intensified developments as a development step that can equalize the economic level in Indonesia.

Toll roads are roads specifically for a minimum of 2 axles vehicles (trucks, cars, buses, etc.), and before entering the toll road, there is a toll gate to pay the entrance fee to the toll road with various fees for each class. Building toll roads aims to facilitate traffic in developed areas and to improve goods and services distribution services to support economic growth. The benefits provided by toll roads, such as toll road users, will benefit in the form of savings in vehicle operating costs compared to using non-toll roads and increasing mobility and accessibility of people and goods.

Toll road users will benefit in the form of savings in Vehicle Operating Costs (VOC) and time compared to non-toll roads. In addition, business entities will receive a return on investment through toll revenues that depend on the certainty of toll tariffs.

LITERATURE REVIEW

A. *Toll Gate Planning*

According to Construction and Building Standards number 007/BM/2009 concerning Freeway Geometry for Toll Roads, toll substations need to be planned in such a way as to create comfortable and safe working conditions for toll collectors. Thus, toll substations must be equipped with temperature control, fresh air supply, and communication tools between substations and gate offices or toll posts. The minimum size of toll substations is 1.25 m wide, 2.00 m long, and 2.5 m high. The toll substation door is in the form of a sliding door and is placed at the rear of the substation, with a minimum width of 0.60 m [1].

B. *Queuing System*

The definition of a queuing system is a collection of customers, services (counters), and a rule that regulates the arrival of customers and the processing of queue service problems. It is characterized by five components, namely customer arrival patterns, service patterns, number of services, facility capacity to accommodate customers, and rules in which customers are served [2].

C. *Movement Distribution Model*

Movement in the transportation system is described in terms of movement flows (vehicles, passengers, and goods) that move from the origin zone to the destination zone within a certain area and over a certain period. Origin Destination Matrix (ODM) or Movement Matrix is often used to describe these movement patterns (Transportation Planning and Modeling). Origin Destination Matrix (ODM) is a two-dimensional matrix

Stages	Input	Process	Output
INTRODUCTION •Problems Identification: Volume measurement of the Gedebage – Tasikmalaya toll gate •Literature collection to support the writting of the Author's Final Project	•GAP Analysis •Literature •Previous Research	Preparation → Problems Identification → Literature Review	•Background •Problem Formulations •Literature Study •Aims of Study •Research Location •Research Time •Research Methodology
DATA COLLECTION 1.Primary Data: Survey results on volume conditions at toll gates that have been designated as study locations (data in the field) 2.Secondary Data: Data measurement results by agencies	•Permission letter for research data collection •Data collection form	Data Collection	**Primary Data:** •Actual condition of the toll gate that has been determined in the writing of this final project **Secondary Data:** •Toll road database and toll gate locations •Toll road alignment Traffic volume data for the Origin-Destination Matrix planning

Figure 1. Data Collection Stage

Analysis and Data Processing •Arrival volume analysis in certain segments •Vehicles distribution calculation •Service time calculation while at the toll gate •Analyze the level of density and congestion at the toll gate	•How does the toll gate arrival volume for toll road users? •How does the vehicle distribution analysis when entering the toll road? •How long does it take to pass through the toll gate with the calculated volume?	Data Processing → Conclusions and Suggestions	•Volume calculation results at conventional toll gates with an Automated Toll Gate (ATG) system •Identify the arrivals distribution according to the type and need of the vehicle •User travel time at the toll gate
Conclusion of Study Results		Finish	1.Achieved problem formulations 2.Suggestions for future research 3.Conclusions

Figure 2. Flowchart

containing information about the amount of movement between locations (zones) within a certain area. The row represents the origin zone, and the column represents the destination zone, so the matrix cells describe the amount of flow from the origin zone to the destination zone [3]

D. *Multi-Lane Free Flow Gates Planning*

Toll gates that use the MLFF system use the same RFID technology as a payment system using the same RFID technology as the SLFF system, namely FLO, or in short, a contactless payment system. However, MLFF applies to all lanes with a scan tool that spans over the toll road. Thus, toll gates are not required with substations on each lane.

For the arrival rate, reviewing the planned number of lanes, this study plans a 6/2D toll road, namely 3 lanes and 2 directions, but the planned ramp is a 4/2 road, so the arrival rate is divided by the number of lanes, namely 2. For the level of service, it can be determined by looking at the speed-flow relationship graph [4].

METHODOLOGY

A. *Preparation Stage*

This stage functioned to expedite the following stages of work, which will be carried out during the writing and preparation of this study, the time and place of study, and the study preparation flow chart.

B. *Data Collection Stage*

The next stage was data collection. This stage started with primary data, including field surveys. Secondary data were the toll road planning route data and the average daily traffic data (ADTD) for Rail Road Construction, as shown in Figure 1.

C. *Design Stage*

This stage was presented in the form of a flowchart. A flowchart is a series of symbols showing the study's working stages, as shown in Figure 2.

DATA COLLECTION

Data collection is the initial stage in carrying out this study. This stage involved collecting and analyzing the necessary data to obtain the expected final results. There were two data required in carrying out this study, namely primary data and secondary data. Primary data was obtained through field surveys, while secondary data was obtained from agencies from related projects.

A. *Primary Data*

1). Automatic Toll Gate (ATG) Service Time

The service time data for Automatic Toll Gates can be seen in Table 1.

2). On Board Unit (OBU) Service Time

The service time data for On Board Unit can be seen in Table 2.

3). Single Lane Free Flow (SLFF) Service Time

The service time data for *Single Lane Free Flow* can be seen in Table 3.

B. *Secondary Data*

The secondary data required in carrying out this study was the daily traffic data for the Gedebage – Tasikmalaya national road (because Section 1 and Section 2 was planned, the Gedebage – Tasikmalaya daily traffic data was required), which will be carried out by Trip Assignment, the Gedebage – Tasikmalaya toll road alignment data, and the toll gate location.

ANALYSIS AND DISCUSSIONS

1). Traffic Data Analysis for Vehicle Class I – V

Traffic data analysis for vehicle classes I – V can be seen in Figure 3.

2). ADTD Use

After calculating trip assignments for all routes, the volume used was the class I – V vehicle volume on toll routes, as summarized in Figure 4.

Convert units to vehicle/hour by dividing the volume by PCE (Passenger Car Equivalent) according to the

Table 1. ATG Service Time

No	Vehicle Class	Service Time
1	I	14.15
2	I	19.03
3	I	18.56
4	I	10.86
5	I	14.84
6	I	7.9
7	I	10.12
8	I	13.97
9	I	8.03
10	I	13.56
11	I	9.33
12	I	11.95
13	I	14.75
14	I	8.14
15	I	11.06
16	I	19.31

vehicle class. Furthermore, the vehicle volume in vehicle/hour units will be converted to vehicle/day units (Daily Traffic) which will be used for subsequent calculations later. The volume of Figure 4 is divided by 9-15% [4].

3). Toll Gate Intensity Analysis

In planning the Gedebage – Tasikmalaya toll gate, it uses the proportion of vehicles entering the toll gate, where 70% of class I go to the ATG specifically for class I; 15% go to ATG; 7.5% go to SLFF; and 7.5% go to OBU. The service time was used to analyze the toll gate intensity based on the service time survey that the author carried out. The following is an example of calculating the gate intensity at the Majalaya gate.

Entrance Toll Gate:

a. Obtained from planning calculations:

Specific ATG	: N1	: 2 substations
ATG	: N2	: 2 substations
ATG and FLO	: N3	: 1 substation
OBU	: N4	: 1 substation

b. Time Service

b. Time Service	: WP1	: 11 seconds
	: WP2	: 11 seconds
	: WP3	: 4 seconds
	: WP4	: 6 seconds

c. Number of Vehicles (λ)

Number of vehicles entering the Majalaya Gate can be seen in Table 4.

λ Class I	: 292 vehicle/hour	
λ Class II – V	: 115 + 66 + 12 + 11	= 204 vehic/hour
λ1 (Specific ATG)	: 70% x 292	= 205 vehic/hour
λ2 (ATG)	: (15% x 292) + 204	= 248 vehic/hour
λ3 (SLFF)	: 7.5% x 292	= 22 vehicles/hour
λ4 (OBU)	: 7.5% x 292	= 22 vehicles/hour

d. Service Level (μ)

$\mu 1 = 3600/WP = 3600/11 = 327$ vehicles/hour

$\mu 2 = 3600/WP = 3600/11 = 327$ vehicles/hour

$\mu 3 = 3600/WP = 3600/4 = 900$ vehicles/hour

$\mu 4 = 3600/WP = 3600/6 = 600$ vehicles/hour

e. Vehicle Intensity (ρ)

Specific ATG

Table 2. OBU Service Time

No	Vehicle Class	Service Time
1	I	3.93
2	I	6.11
3	I	5.82
4	I	3.67
5	I	5.17
6	I	2.26
7	I	9.45
8	I	3.01
9	I	3.64
10	I	1.77
11	I	5.80
12	I	8.45
13	I	3.62
14	I	2.59
15	I	4.90
16	I	4.54
17	I	3.66
18	I	4.29
19	I	3.47
20	I	6.30

Table 3. Service Time

No	Vehicle Class	Service Time
1	I	3.91
2	I	3.53
3	I	4.23
4	I	2.90
5	I	3.92
6	I	3.44
7	I	2.32
8	I	1.94
9	I	4.92
10	I	2.23
11	I	3.24
12	I	2.90
13	I	1.35
14	I	3.20
15	I	2.06
16	I	3.15
17	I	3.82

$\rho 1 = (\lambda 1/N1) / \mu 1 < 1$

$\rho 1 = (205/2) / (327) < 1$

$\rho 1 = 0.313 < 1$ (OK)

ATG

$\rho 2 = (\lambda 2/N2) / \mu 2 < 1$

$\rho 2 = (248/2) / (327) < 1$

$\rho 2 = 0.379 < 1$ (OK)

SLFF

$\rho 3 = (\lambda 3/N3) / \mu 3 < 1$

$\rho 3 = (22/1) / 900 < 1$

$\rho 3 = 0.024 < 1$ (OK)

OBU

$\rho 4 = (\lambda 4/N4) / \mu 4 < 1$

$\rho 4 = (22/1) / 600 < 1$

$\rho 4 = 0.036 < 1$ (OK)

Exit Toll Gate:

a. Obtained from planning calculations:

Specific ATG	: N1	: 2 substations
ATG	: N2	: 2 substations
ATG and FLO	: N3	: 1 substation
OBU	: N4	: 1 substation

b. Service Time	: WP1	: 11 seconds
	: WP2	: 11 seconds
	: WP3	: 4 seconds
	: WP4	: 6 seconds

Number of Each Route (Class I – V)	
Gedebage - Majalaya	794
Majalaya - Nagrek	724
Nagrek - Garut U	2022
Garut U - Garut S	381
Garut S - Singapama	787
Singapama - Tasikmalaya	850

Figure 3. Number of Vehicle for Each Route

Number of Each Route (Class I – V)	
Gedebage - Majalaya	450
Majalaya - Nagrek	450
Nagrek - Garut U	600
Garut U - Garut S	350
Garut S - Singapama	600
Singapama - Tasikmalaya	350

Figure 4. Recapitulation of Toll Route Vehicle Volumes

More details can be seen in Table 5.

c. Number of Vehicles (λ):

λ Class I : 292 vehicles/hour
λ Class II – V : 115 + 66 + 12 + 11 = 204 vehic/hour
λ_1 (Specific ATG) : 70% x 292 = 205 vehic/hour
λ_2 (ATG) : (15% x 292) + 204 = 248 vehic/hour
λ_3 (SLFF) : 7.5% x 292 = 22 vehic/hour
λ_4 (OBU) : 7.5% x 292 = 22 vehic/hour

d. Service Level (μ):

μ_1=3600/WP = 3600/11=327 vehicles/hour
μ_2=3600/WP = 3600/11=327 vehicles/hour
μ_3=3600/WP = 3600/4=900 vehicles/hour
μ_4=3600/WP = 3600/6=600 vehicles/hour

e. Vehicle Intensity (ρ)

Specific ATG
$\rho_1 = (\lambda_1/N_1) / \mu_1 < 1$
$\rho_1 = (205/2) / (327) < 1$
$\rho_1 = 0.313 < 1$ (OK)

ATG
$\rho_2 = (\lambda_2/N_2) / \mu_2 < 1$
$\rho_2 = (248/2) / (327) < 1$
$\rho_2 = 0.379 < 1$ (OK)

SLFF
$\rho_3 = (\lambda_3/N_3) / \mu_3 < 1$
$\rho_3 = (22/1) / 900 < 1$
$\rho_3 = 0.024 < 1$ (OK)

OBU
$\rho_4 = (\lambda_4/N_4) / \mu_4 < 1$
$\rho_4 = (22/1) / 600 < 1$
$\rho_4 = 0.036 < 1$ (OK)

4). Toll Gate Queuing Analysis

After obtaining the results from the gate intensity analysis calculation, then it will be used to calculate the queuing analysis using the FIFO (First in First Out) queuing method. Queuing analysis at the gate aimed to obtain the queue length and queue time at the toll gate. An example of queuing analysis calculation will be carried out at the Majalaya toll gate [5]

Entrance Toll Gate:

N1 (Number of Specific ATG Substations) : 2 Substations
N2 (number of ATG substation) : 2 Substations

Table 4. Vehicles Entering the Majalaya Gate

Entrance Vehicle	
Class	MAJALAYA
I	292
II	115
III	66
IV	12
V	11
Total	496

Table 5. Vehicles Exiting the Majalaya Gate

Exit Vehicle	
Class	MAJALAYA
I	292
II	115
III	66
IV	12
V	11
Total	496

N3 (number of SLFF substations) : 1 Substation
N4 (number of OBU substations) : 1 Substation
λ_1 (number of specific ATG vehicles) : 205 vehicles/hour
λ_2 (number of ATG vehicles) : 248 vehicles/hour
λ_3 (number of SLFF vehicles) : 22 vehicles/hour
λ_4 (number of OBU vehicles : 22 vehicles/hour
μ_1 (specific ATG service level) : 327 vehicles/hour
μ_2 (ATG service level) : 327 vehicles/hour
μ_3 (SLFF service level) : 900 vehicles/hour
μ_4 (OBU service level) : 600 vehicles/hour

ρ_1 : 0.313
ρ_2 : 0.379
ρ_3 : 0.024
ρ_4 : 0.037

Based on the obtained data above, FIFO analysis is carried out as follows:

a. Specific ATG

$$\bar{n} = \frac{\rho 1}{1-\rho 1} = \frac{0.313}{1-0.313} = 0.456 \approx 1 \text{ vehicle}$$

$$\bar{q} = \frac{\rho 1^2}{1-\rho 1} = \frac{0.098}{1-0.313} = 0.143 \approx 1 \text{ vehicle} < 10 \text{ vehicles (OK)}$$

$$\bar{d} = \frac{1}{\mu 1 - \frac{\lambda 1}{\mu 1}} = \frac{1}{327 - \frac{205}{2}} \times 3600 = 16.035 \approx 16 \text{ seconds}$$

$$\bar{w} = d - \frac{1}{\mu 1} \times 3600 = 16.035 - \frac{1}{327} \times 3600 = 5.02 \approx 5$$

b. ATG

$$\bar{n} = \frac{\rho 2}{1-\rho 2} = \frac{0.609}{1-0.609} = 1{,}554 \approx 2 \text{ vehicles}$$

Toll Gate	MLFF (Directions)	n (vehicle)	q (vehicle)	d (second)	w (second)
GEDEBAGE	Entrance Gantry	0	0	2	1
	Exit Gantry	0	0	2	1
MAJALAYA	Entrance Gantry	0	0	2	1
	Exit Gantry	0	0	2	1
NAGREK	Entrance Gantry	0	0	2	1
	Exit Gantry	0	0	2	1
GARUT UTARA	Entrance Gantry	0	0	2	1
	Exit Gantry	0	0	2	1
GARUT SELATAN	Entrance Gantry	0	0	2	1
	Exit Gantry	0	0	2	1
SINGAPARNA	Entrance Gantry	0	0	2	1
	Exit Gantry	0	0	2	1
TASIKMALAYA	Entrance Gantry	0	0	2	1
	Exit Gantry	0	0	2	1

Figure 5. Results of MLFF Queuing and Gate Delay Analysis

$\bar{q} = \frac{\rho 2^2}{1 - \rho 2} = \frac{0.370}{1 - 0.609} = 0.946 \approx 1$ vehicle < 10 vehicles (OK)

$\bar{d} = \frac{1}{\mu 2 - \frac{\lambda 2}{\mu 2}} = \frac{1}{327 - \frac{248}{2}} \times 3600 = 17.734 \approx 18$ seconds

$$\bar{w} = d - \frac{1}{\mu 2} \times 3600 = 17.734 - \frac{1}{327} \times 3600 = 6.72 \approx 7$$

c. SLFF

$\bar{n} = \frac{\rho 3}{1 - \rho 3} = \frac{0.024}{1 - 0.024} = 0.025 \approx 1$ vehicle

$\bar{q} = \frac{\rho 3^2}{1 - \rho 3} = \frac{0.001}{1 - 0.024} = 0.00061 \approx 1$ vehicle < 10 vehicles (OK)

$\bar{d} = \frac{1}{\mu 3 - \frac{\lambda 3}{\mu 3}} = \frac{1}{900 - \frac{22}{1}} \times 3600 = 4.100 \approx 4$ seconds

$\bar{w} = d - \frac{1}{\mu 3} \times 3600 = 4.100 - \frac{1}{900} \times 3600 = 0.100 \approx 1$

d. OBU

$\bar{n} = \frac{\rho 4}{1 - \rho 4} = \frac{0.037}{1 - 0.037} = 0.038 \approx 1$ vehicle

$\bar{q} = \frac{\rho 4^2}{1 - \rho 4} = \frac{0.001}{1 - 0.037} = 0{,}0014 \approx 1$ vehicle < 10 vehicles (OK)

$\bar{d} = \frac{1}{\mu 4 - \frac{\lambda 4}{\mu 4}} = \frac{1}{600 - \frac{22}{1}} \times 3600 = 6.228 \approx 6$ seconds

$$\bar{w} = d - \frac{1}{\mu 4} \times 3600 = 6.228 - \frac{1}{600} \times 3600 = 0.228 \approx 1$$

Exit Toll Gate:

N1 (number of specific ATG substations): 2 substations
N2 (number of ATG substations) : 2 substations
N3 (number of SLFF substations) : 1 substation
N4 (number of OBU substation) : 1 substation
λ1 (number of specific ATG vehicles): 205 vehicles/hour

λ2 (number of ATG vehicles) : 248 vehicles/hour

λ3 (number of SLFF vehicles) : 22 vehicles/hour

λ4 (number of OBU vehicles) : 22 vehicles/hour
μ1 (specific ATG service level) : 327 vehicles/hour

μ2 (ATG service level) : 327 vehicles/hour

μ3 (SLFF service level) : 900 vehicles/hour

μ4 (OBU service level) : 600 vehicles/hour

ρ1 : 0.313

ρ2 : 0.379

ρ3 : 0.024

ρ4 : 0.037

Based on the obtained data above, FIFO analysis is carried out as follows:

a. Specific ATG

$\bar{n} = \frac{\rho 1}{1 - \rho 1} = \frac{0.313}{1 - 0.313} = 0.456 \approx 1$ vehicle

$\bar{q} = \frac{\rho 1^2}{1 - \rho 1} = \frac{0.098}{1 - 0.313} = 0.143 \approx 1$ vehicle < 10 vehicles (OK)

$\bar{d} = \frac{1}{\mu 1 - \frac{\lambda 1}{\mu 1}} = \frac{1}{327 - \frac{205}{2}} \times 3600 = 16.035 \approx 16$ seconds

$$\bar{w} = d - \frac{1}{\mu 1} \times 3600 = 16.035 - \frac{1}{327} \times 3600 = 5.02 \approx 5$$

b. ATG

$\bar{n} = \frac{\rho 2}{1 - \rho 2} = \frac{0.609}{1 - 0.609} = 1.554 \approx 2$ vehicles

$\bar{q} = \frac{\rho 2^2}{1 - \rho 2} = \frac{0.370}{1 - 0.609} = 0.946 \approx 1$ vehicle < 10 vehicles (OK)

$\bar{d} = \frac{1}{\mu 2 - \frac{\lambda 2}{\mu 2}} = \frac{1}{327 - \frac{248}{2}} \times 3600 = 17.734 \approx 18$ seconds

$$\bar{w} = d - \frac{1}{\mu 2} \times 3600 = 17.734 - \frac{1}{327} \times 3600 = 6.72 \approx 7$$

c. SLFF

$\bar{n} = \frac{\rho 3}{1 - \rho 3} = \frac{0.024}{1 - 0.024} = 0.025 \approx 1$ vehicle

$\bar{q} = \frac{\rho 3^2}{1 - \rho 3} = \frac{0.001}{1 - 0.024} = 0.00061 \approx 1$ vehicle < 10 vehicles (OK)

$\bar{d} = \frac{1}{\mu 3 - \frac{\lambda 3}{\mu 3}} = \frac{1}{900 - \frac{22}{1}} \times 3600 = 4.100 \approx 4$ seconds

$\bar{w} = d - \frac{1}{\mu 3} \times 3600 = 4.100 - \frac{1}{900} \times 3600 = 0.100 \approx 1$

d. OBU

$\bar{n} = \frac{\rho 4}{1 - \rho 4} = \frac{0.037}{1 - 0.037} = 0.038 \approx 1$ vehicle

$\bar{q} = \frac{\rho 4^2}{1-\rho 4} = \frac{0.001}{1-0.037} = 0.0014 \approx 1$ vehicle < 10 vehicles (OK)

$\bar{d} = \frac{1}{\mu 4 - \frac{\lambda 4}{\mu 4}} = \frac{1}{600-\frac{22}{1}} \times 3600 = 6.228 \approx 6$ seconds

$$\bar{w} = d - \frac{1}{\mu 4} \times 3600 = 6.228 - \frac{1}{600} \times 3600 = 0.228 \approx 1$$

5). Multi Lane Free Flow (MLFF) Toll Gate Planning

MLFF toll gate planning can be viewed from three things, namely as follows:

1. Vehicle Speed (v)
2. Arrival Rate (λ)
3. Level of Service (μ)

However, the level of service is obtained from the speed-flow relationship graph with the previously planned speed. Then, it can obtain the level of service in units of pcu/hour/flow. Furthermore, the arrival rate is divided by the number of lanes because there are no substations in the MLFF (Multi Lane Free Flow) toll system) [4].

The following is an example of calculating the Majalaya MLFF gate. Thus, it is planned with the calculation as follows:

JBH 4/2

Entrance Gantry with v = 30 km/hour

Exit Gantry with v =30 km/hour

1. Arrival Rate

λ *entrance* = 496 vehicles/hour
= 248 vehicles/hour/lane (divided by the number of lanes)

λ *exit* = 496 vehicles/hour
= 248 vehicles/hour/lane (divided by the number of lanes)

Changing the arrival rate unit to pcu/hour/flow, by dividing the vehicles according to the proportion of vehicle classes and multiplied by pce (passenger car equivalent) according to the provisions of the Indonesian Highway Capacity Manual (IHCM) 1997 [4].

Obtained:

λ *entrance* = ((248×63%×1) + (248×25%×1) (248×8%×1,3) + (284×4%×2,5))
= 156 + 62 + 26 + 25 = 269 pcu/hour/lane

λ *exit* = ((248×63%×1) + (248×25%×1)+ (248×8%×1,3) + (284×4%×2,5))
= 156 + 62 + 26 + 25
= 269 pcu/hour/lane

2. Level of Service

Looking at the speed-flow relationship graph to get the level of service according to the speed that has been planned:

μ *Entrance* = 2250 pcu/hour/lane
μ *Exit* = 2250 pcu/hour/lane

3. FIFO *(First In First Out)* Queuing Analysis

Calculating ρ (comparison of arrival rate (λ) with level of service (μ))

Entrance Gantry

$\rho = \frac{\lambda}{\mu} < 1$

$\rho = \frac{269}{2250} < 1$

ρ = 0,119 < 1 (OK)

Exit Gantry

$\rho = \frac{\lambda}{\mu} < 1$

$\rho = \frac{269}{2250} < 1$

ρ = 0.119 < 1 (OK)

Queuing and Delay Analysis

Entrance Gantry

$\bar{n} = \frac{\rho}{1-\rho} = \frac{0.120}{1-0.120} = 0.135 \approx 0$ vehicle

$\bar{q} = \frac{\rho^2}{1-\rho} = \frac{0.014}{1-0.120} = 0.016 \approx 0$ vehicle < 10 vehicles (OK)

$\bar{d} = \frac{1}{\mu-\lambda} = \frac{1}{2250-269} \times 3600 = 1.817 \approx 2$ seconds

$\bar{w} = d - \frac{1}{\mu} \times 3600 = 1.817 - \frac{1}{2250} \times 3600 = 0.217 \approx 1$

Exit Gantry

$\bar{n} = \frac{\rho}{1-\rho} = \frac{0.120}{1-0.120} = 0.135 \approx 0$ vehicle

$\bar{q} = \frac{\rho^2}{1-\rho} = \frac{0.014}{1-0.120} = 0.016 \approx 0$ vehicle < 10 vehicles (OK)

$\bar{d} = \frac{1}{\mu-\lambda} = \frac{1}{2250-269} \times 3600 = 1.817 \approx 2$ seconds

$\bar{w} = d - \frac{1}{\mu} \times 3600 = 1.817 - \frac{1}{2250} \times 3600 = 0.217 \approx 1$

The MLFF calculation results on other gates can be seen in Table 7.

CONCLUSIONS AND SUGGESTIONS

A. *Conclusions*

Based on the author's calculation results, conclusions can be drawn to answer the problems that occur in the planning of the Gedebage – Tasikmalaya toll gate. The conclusions can be seen as follows.

Number of substations on the Gedebage – Tasikmalaya toll road:

1. Gedebage Gates
   In and Out Directions
   a. Specific ATG : 2 substations
   b. ATG : 3 substations
   c. SLFF Substation : 1 substation
   d. OBU Substation : 1 substation
2. Majalaya Gates
   In and Out Directions
   a. Specific ATG : 2 substations
   b. ATG : 2 substations
   c. SLFF Substation : 1 substation
   d. OBU Substation : 1 substation
3. Nagreg Gates
   In and Out Directions
   a. Specific ATG : 1 substation

b. ATG : 2 substations
c. SLFF Substation : 1 substation
d. OBU Substation : 1 substation

4. North Garut Gates
   In and Out Directions
   a. Specific ATG : 1 substation
   b. ATG : 2 substations
   c. SLFF Substation : 1 substation
   d. OBU Substation : 1 substation
5. South Garut Gates
   In and Out Directions
   a. Specific ATG : 1 substation
   b. ATG : 2 substations
   c. SLFF Substation : 1 substation
   d. OBU Substation : 1 substation
6. Singaparna Gates
   In and Out Directions
   a. Specific ATG : 1 substation
   b. ATG : 2 substations
   c. SLFF Substation : 1 substation
   d. OBU Substation : 1 substation
7. Tasikmalaya Gates
   In and Out Directions
   a. Specific ATG : 1 substation
   b. ATG : 2 substations
   c. SLFF Substation : 1 substation
   d. OBU Substation : 1 substation

Queues and Delays that occur at each gate if planned with the MLFF (Multi Lane Free Flow) system at the Gedebage to Tasikmalaya toll gate planning.

1. Gedebage Gates
   In and Out Directions
   a. Queue : 0 vehicle
   b. Delay : 1 to 2 seconds
2. Majalaya Gates
   In and Out Directions
   a. Queue : 0 vehicle
   b. Delay : 1 to 2 seconds
3. Nagreg Gates
   In and Out Directions
   a. Queue : 0 vehicle
   b. Delay : 1 to 2 seconds
4. North Garut Gates
   In and Out Directions
   a. Queue : 0 vehicle
   b. Delay : 1 to 2 seconds
5. South Garut Gates
   In and Out Directions
   a. Queue : 0 vehicle
   b. Delay : 1 to 2 seconds
6. Singaparna Gates
   In and Out Directions
   a. Queue : 0 vehicle
   b. Delay : 1 to 2 seconds
7. Tasikmalaya Gates
   In and Out Directions
   a. Queue : 0 vehicle
   b. Delay : 1 to 2 seconds

B. Suggestions

Some things must be considered in the planning that has been done by the author, namely as follows:

1. There should be intensive socialization shortly to road users, especially toll road users, to increase SLFF gate users as the MLFF gate will be implemented in the next few years, considering that the procedure for using it is easy and fast.
2. Carrying out further development of the SLFF application, which in my opinion, is less current from the people’s perspective whose knowledge of technology is not evenly distributed.

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