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Analysis Of Multi Lane Free Flow Implementation At Toll Gates In Indonesia (Case Study Of Cililitan Toll Gate 2)

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Abstract

As the volume of vehicles on toll roads and non-toll roads increases, congestion occurs when the road capacity can no longer accommodate the volume of vehicles passing through it. one of the most crowded toll roads in Indonesia is the Jagorawi Toll Road. Congestion often occurs at several points along the Jagorawi Toll Road, especially the Cililitan Toll Gate. Congestion at the Toll Gate often occurs because the level of service at the Toll Gate does not match the level of vehicle arrivals during peak hours. Therefore, in the research "Analysis of Multi lane Free Flow Implementation at Toll Gates in Indonesia (Case Study of Cililitan Toll Gate 2)", this study aims to determine the performance and impact on vehicles at Cililitan Toll Gate 2 that are still using E-Toll and its effect on Vehicle Operating Costs (VOC) if the E-Toll system and MLFF system are installed at Cililitan Toll Gate 2. Therefore, using the analysis method with the help of Microsoft Excel can analyze data on the performance of E-Toll and VOC and survey data processing using SPSS. Based on the research findings, on Wednesday, March 6, 2024 has a delay time on the E-Toll payment system of 49 seconds. And also obtained the value of VOC when MLFF is applied (at a speed of 60 km / h) is lower than the value of VOC when E-Toll is applied (at a speed of 9.72 km / h) resulting in congestion costs of Rp. 3,653.75 / km for passenger cars, Rp. 1,113.66 / km for medium vehicles, Rp. 4,014.32 / km for large buses and Rp. 8,045.89 / km for large trucks.

Keywords: **Multi lane Free Flow, E-toll, Vehicle Operating Costs**

INTRODUCTION

A Freeway is a public road used for continuous traffic with a driveway control system without any side obstacles in the form of a level crossing (Kementerian Pekerjaan Umum dan Perumahan Rakyat Direktorat Jenderal Bina Marga, 2023). One of the advantages of a freeway is that it can facilitate multimodal access and will affect transportation costs, so that the costs charged will be cheaper. (Budisiswanto et al., 2023). Currently, several road sections, both toll roads and non-toll roads, often experience congestion caused by the high volume of vehicles that exceed the capacity of the road (Rivaldi & Novriani, 2024). One of the toll roads in Indonesia that is crowded with vehicles is the Jagorawi Toll Road (KURNIAWAN, 2024). On toll roads, one of the congestion points occurs around the Toll Gate. The reason is because the level of service at the Toll Gate is not proportional to the level of vehicle arrivals at peak hours. Currently, the use of tap-in card (e-toll) system is still a popular tollgate service system in Indonesia. The E-Toll system will result in a time delay during the payment transaction process. If it occurs at peak hours, the delay time will cause a queue of vehicles. The E-Toll system requires a service time of about 5 seconds with the speed will reach 0 km / h (stop) when the (Budisiswanto et al., 2023)vehicle will make a payment transaction at the toll booth. While using the MLFF system, there is no service time required with the speed of the vehicle can reach the maximum speed when crossing the toll booth (Maulana & Prasetyanto, 2023). The higher the speed traveled, there will be a reduction in queues, delays and vehicle operating costs, especially in fuel use (Munawar et al., 2020).

Multi Lane Free Flow (MLFF) system is a contactless cashless transaction carried out on toll roads as a more efficient transaction system when compared to the current E-Toll system (Badan Pengatur Jalan Tol, 2022). The MLFF system in Indonesia is a sign that Indonesia will enter the era of Toll Roads Technology 4.0 (Lestarini, 2023). The MLFF system will use GNSS (Global Navigation Satellite System) which will detect the movement of each vehicle using satellites (Badan Pengatur Jalan Tol, 2022). In the process, the MLFF system will use an e-OBU (electronic OnBoard Unit) or smartphone application that will be developed under the name CANTAS (cepat tanpa stop/fast without stopping) (Badan Pengatur Jalan Tol, 2022). (Umum & Rakyat, 1997).

Therefore, in the research "Analysis of Multi lane Free Flow Implementation at Toll Gates in Indonesia (Case Study of Cililitan Toll Gate 2)", this study aims to determine the performance of Cililitan Toll Gate 2 which still uses the e-toll system and its effect on vehicle operating costs so that the potential magnitude of MLFF implementation at Cililitan Toll Gate 2 can be known based on the resulting congestion costs.

From the results of the literature review that has been researched, the research "Analysis of the Application of Multi lane Free Flow at Toll Gates in Indonesia (Case Study of Cililitan Toll Gate 2)" is more focused on the performance of E-Toll and its effect on Vehicle Operating Costs when E-Toll and MLFF are applied at Cililitan Toll Gate 2. Comparison between the results of previous research with this research obtained the following novelty:

1. The results of research by Luthfi Ramadhansyah Rangkuti (2023) entitled "Comparative Analysis of the Use of E-Toll with Multi Lane Free Flow (MLFF) (Case study: Pasteur Toll Gate). This study aims to compare the entrance control system using the E-Toll card tap-in system with the Multi Lane Free Flow (MLFF) system by analyzing the amount of delay, queue length and service time on the use of fuel oil (RANGKUTI, 2023).
2. The results of Victoria Sunartio and Leksmon Suryo Putranto's research (2023) entitled "Opinions of Jabodetabek Toll Road Users About Multi Lane Free Flow". This study aims to determine people's perceptions if the Toll payment system changes to the MLFF payment system and the success of MLFF if implemented in the Jabodetabek Toll Road (Sunartio & Putranto, 2023).
3. The results of Anton Budiharjo and Sekar Ratri Margarani's research (2019) entitled "Study of Multi Lane Free Flow (MLFF) Implementation on Indonesian Toll Roads". The aim is to find out the problems faced in the toll payment transaction system in Indonesia and find out whether MLFF can be applied (Budiharjo & Margarani, 2019).
4. The results of research by Alwin Maulana and Dwi Prasetyanto (2023) entitled "The Effect of the Implementation of the Nonstop Toll Payment System on Traffic at the Buah Batu Toll Gate in Bandung City". The purpose of this study was to determine and analyze the impact of vehicle queues and the impact of the implementation of a non-stop toll payment system on traffic at the Buah Batu Toll Gate, as well as comparing the idea of implementing a non-stop traffic toll payment system with an electronic card system (Maulana & Prasetyanto, 2023).
5. The results of research by Ahmad Munawar, Imam Muthohar, and Arif Ardiyanto (2020) entitled "The Effect of Multilane Free Flow on Toll Road Performance". This study aims to analyze the benefits of the electronic tolling system in terms of queue length, delay, and fuel usage (Munawar et al., 2020).
6. Nazwa Shefa Salsabila, Fitria Nur Azizah, Fitriyani, Shinta Novriani, Nurullah Budisiswanto (2024) entitled "Analysis of the Application of Multi lane Free Flow at Toll Gates in Indonesia (Case Study of Cililitan Toll Gate 2)" this study aims to determine the performance of E-Toll at Cililitan Toll Gate 2 and its effect on BOK and determine the potential for implementing MLFF at Cililitan Toll Gate 2. What distinguishes this research from other research is that this research discusses the effect

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of MLFF and E-Toll on BOK and congestion costs so that it can be used as a reference for future research.

RESEARCH METHODS

This study uses Indonesian Road Capacity Guidelines (PKJI) 2023 for E-Toll performance analysis and uses guidelines from the Department of Public Works for Vehicle Operating Cost Analysis.

1. Research Flow

The flow chart is used to organize the stages in the research, so that it will be easier when the research is carried out. The flow chart is shown in Figure 1.

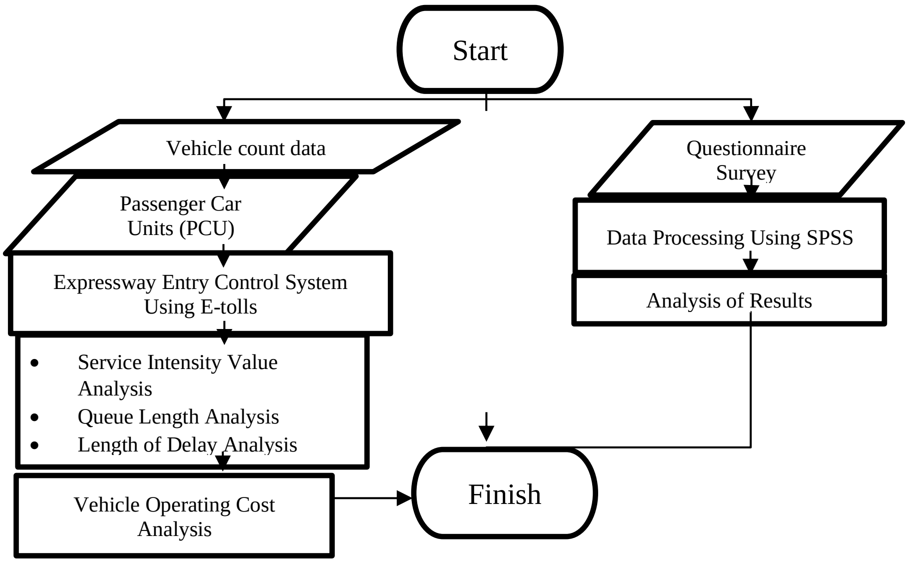

Figure 1. Research Flow Chart

2. Data Collection Technique

This research took place at the Cililitan 2 Semi-Automatic Toll Gate located in East Jakarta because at the Cililitan Toll Gate 2 the traffic flow and types of vehicles passing through are quite dense and varied. Determination of the research object based on visual observation through CCTV on the Travoy application and Google Maps. The Travoy application utilizes CCTV to collect data on traffic flow, average speed, and time headway. While data collection of transaction time is done directly at Cililitan Toll Gate 2. Data collection for Vehicle Operating Cost analysis by conducting surveys to several showrooms and information through Google. Traffic flow data was collected for four days of observation: Tuesday, March 5, 2024; Wednesday, March 6, 2024; Saturday, March 9, 2024; and Monday, March 11, 2024. Data collection was conducted for 12 hours/day. The other data was sampled during peak hour on Wednesday, March 6, 2024, which had the highest volume of traffic flow among the four observation days.

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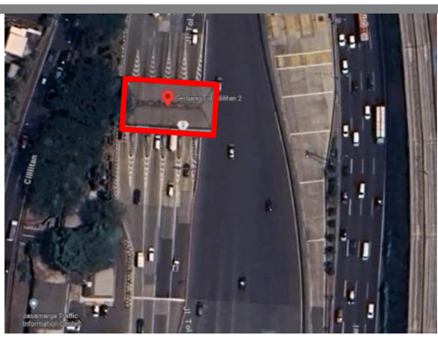

Figure 2. Location of Cililitan Toll Gate 2

Figure 3. CCTV Survey on Travoy App

A questionnaire survey was also distributed to Jagorawi Toll Road users to find out the potential for MLFF implementation from the view of Jagorawi Toll Road users. The questionnaire was distributed through Google form with a total of 100 respondents based on the Slovin equation that has been done.

3. **Analysis Method**

The analysis method is used to process the data obtained and then analyze it with the help of Microsoft Excel. The data analysis carried out is by analyzing the performance of E-Toll and analyzing Vehicle Operating Costs. E-toll performance analysis includes the level of service, service intensity, queuing, and delay time. While the analysis of Vehicle Operating Costs includes analysis at an average speed of 9.72 km / h which represents the speed of the E-Toll system and analysis at a speed of 60 km / h which represents the minimum speed if the MLFF system is applied to then proceed with the analysis of congestion costs and also the SPSS method is used to process data from questionnaire surveys of Jagorawi Toll road users. Tests conducted with SPSS software include normality test, validity test, and reliability test.

a) E-Toll Performance Analysis

Service Level

$$\mu = \frac{3600}{WT} \quad \text{(1)}$$

Service Intensity

$$\rho = \frac{\lambda}{s\mu} < 1 \quad \text{(2)}$$

Probability of no arrival in the system

$$parent P_0 = \frac{1}{\left[\sum_{n=0}^{s-1}\left(\frac{\left(\frac{\lambda}{\mu}\right)^n}{n!}\right)\right] + \left[\left(\frac{\frac{\lambda}{\mu}^s}{s!}\right)\frac{1}{1-\frac{\lambda}{s\mu}}\right]} \quad \text{(3)}$$

Queue Length

$$L_q = \frac{P_0\left(\frac{\lambda}{\mu}\right)^s \rho}{s!\,(1-\rho)^2} \quad \text{(4)}$$

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$$L = L_q + \frac{\lambda}{\mu} \quad \text{.........} \quad (5)$$

$$Queue\ length = (L_q + L) x\ spacing \quad \text{.........} \quad (6)$$

$$Vehicles\ in\ queue = Lq + L \quad \text{.........} \quad (7)$$

Length of Delay Analysis

$$W_q = \frac{L_q}{\lambda} x\ 3600 \quad \text{.........} \quad (8)$$

$$W = \frac{L}{\lambda} x\ 3600 \quad \text{.........} \quad (9)$$

$$Total\ time\ delay = W_q + \quad \text{.........} \quad (10)$$

b) Vehicle Operating Cost Analysis

1. Fixed Cost

Depreciation Value

$$\frac{Vehicle\ Price\ -\ Residual\ Value}{Depreciation\ Period\ x\ mileage/year} \quad \text{.........} \quad (11)$$

Vehicle Crew Fee

$$\frac{Crew\ cost/year}{Production} \quad \text{.........} \quad (12)$$

Administration Fee

I. Vehicle registration

$$\frac{Vehicle\ registration\ fee}{Vehicle\ Production\ -\ km/year} \quad \text{.........} \quad (13)$$

II. Vehicle Feasibility Test

$$\frac{Vehicle\ feasibility\ test\ fee}{Vehicle\ Production\ -\ km/year} \quad \text{.........} \quad (14)$$

III. Administration Fee

$$Adm\ Fee = vehicle\ registration + vehicle\ feasibility\ test \quad \text{...} \quad (15)$$

Fixed Cost

$$Fixed\ Cost = Depreciation\ value + Crew\ cost + Adm\ fees \quad \text{.........} \quad (16)$$

2. Non-Fixed Cost

Fuel Usage Cost

$$\text{BiBBMj} = \text{KBBMi x HBBMj} \quad \text{.........} \quad (17)$$

Lubricant Cost

$$BO_i = KO_i\ X\ HO_j \quad \text{.........} \quad (18)$$

Tire Purchase Cost

$$BBi = KBi\ X\ HBj/1000 \quad \text{.........} \quad (19)$$

Spare Parts Cost

$$BP_i = P_i\ x\ HKB_i\ /1.000.000 \quad \text{.........} \quad (20)$$

Maintenance Labor Cost

$$BU_i = JP_i\ x\ UTP/1000 \quad \text{.........} \quad (21)$$

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Non-Fixed Costs

$$Nonfixed\ cost = BiBBMj + BOi + BBi + BPi \quad (22)$$

Vehicle Operating Costs

$$VOC = BT + BTT \quad (23)$$

Congestion Charge

$$Congestion\ Charge = VOC_{actual} - VOC_{plan} \quad (24)$$

RESULTS AND DISCUSSION

1. Cililitan Toll Gate 2 Data

Number of Semi-Automated Toll Gates (s) = 5 Toll Gates
Average transaction time (WT) = 8,64 seconds
Average speed (Vr) = 2,7 m/s ~ 9,72 km/h
Time headway (t) = 4,01 seconds
Spacing = 10,852 m/pcu
Freeway capacity (C) = 10.300 pcu/h (Kementerian Pekerjaan Umum dan Perumahan Rakyat Direktorat Jenderal Bina Marga, 2023)
Mileage/year$_{MP}$ = 74.880 km/year
Mileage/year = 13.680 km/year
Mileage/year$_{BB}$ = 152.640 km/ year
Mileage/year$_{TB}$ = 252.000 km/ year

Figure 4. Road Geometrics at Cililitan Toll Gate 2

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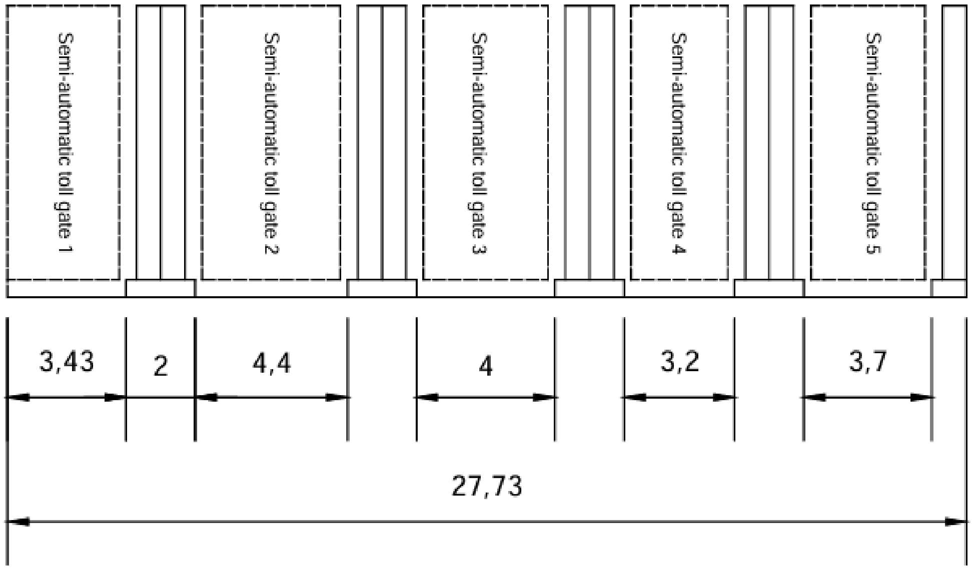

Figure 5. Cililitan Toll Gate 2 Dimensions

2. Daily Traffic Data

Observations were made on 2 weekdays, Tuesday, March 5, 2024, and Wednesday, March 6, 2024, as well as 1 weekend day on Saturday, March 9, 2024, and an additional public holiday on Monday, March 11, 2024. The observation time was conducted for 12 hours, with observation intervals conducted every 15 minutes for 1 hour to obtain peak-hour traffic flow. After obtaining the traffic volume at peak hours, it is multiplied by the PCE value of each vehicle based on PKJI 2023. Example of traffic volume calculation (pcu/hr) on Wednesday, March 6, 2024:

Passenger car (MP) = 1.381 x 1 = 1.381 pcu/h
Medium vehicle (KS) = 98 x 1,4 = 137,2 pcu/h
Large Bus (BB) = 147 x 1,4 = 205,8 pcu/h
Large Trucks (TB) = 105 x 2,0 = 210,0 pcu/h
Total Q = 1.934 pcu/h

The total traffic volume can also be referred to as the arrival rate (λ), so the arrival rate at Cililitan Toll Gate 2 on Wednesday, March 6, 2024, was 1,934 pcu/hour.

Table 1. Daily Traffic Data

Day, Date	Time	Vehicle Classification (vehicle/hour)				PCE				Total
		MP	KS	BB	TB	MP 1	KS 1,4	BB 1,4	TB 2,0	Q (λ) pcu/h
Tuesday, March 5, 2024	06.00-07.00	956	89	183	64	956	124,6	256,2	128	1465
Wednesday, March 6, 2024	07.00-08.00	1381	98	147	105	1381	137,2	205,8	210	1934
Day, Date	**Time**	**Vehicle Classification (vehicle/hour)**				**PCE**				**Total**
		MP	**KS**	**BB**	**TB**	**MP**	**KS**	**BB**	**TB**	**Q (λ)**

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						1	1,2	1,2	1,6	pcu/h
Saturday, March 9, 2024	14.00-15.00	1200	18	6	14	1200	21,6	7,2	22,4	1251
Monday. March 11, 2024	15.00-16.00	519	10	9	3	519	12	10,8	4,8	547

Source: Analysis Results

3. E-Toll Performance Analysis

E-toll performance analysis is carried out to determine the delay value at Cililitan Toll Gate 2 when implementing the E-toll system. The level of service is used to determine the number of vehicles that can be served by each Toll Gate in 1 hour.

a. Service Level

The following is the calculation of the level of service at the Cililitan Toll Gate 2:

$$Service\ level\ (\mu) = \frac{3.600}{WT} = \frac{3.600}{8{,}64} = 417\ pcu/h$$

b. Service Intensity Level (ρ)

The following is the calculation of the level of service intensity (ρ) on Wednesday, March 6, 2024 at 07:00-08:00 as follows:

$$\rho = \frac{Arrival\ rate\ (\lambda)}{Number\ of\ Toll\ Gates\ x\ level\ of\ service\ (\mu)} = \frac{1.934}{5\ x\ 417} = 0{,}929 < 1$$

The level of service intensity on Tuesday, March 5, 2024, Saturday, March 9, 2024, and Monday, March 11, 2024 is presented in **Table 2**.

Table 2. Service Intensity Level Analysis (ρ)

Day, Date	Time	Arrival Rate (λ) (pcu/h)	Service Level (μ) (pcu/h)	Number of Toll Gates (s)	Service Intensity Level (ρ=λ/ (s.μ))
Tuesday, March 5, 2024	06.00-07.00	1465	417	5	0,703
Wednesday, March 6, 2024	07.00-08.00	1934	417	5	0,929
Saturday, March 9, 2024	14.00-15.00	1251	417	5	0,601
Monday. March 11, 2024	15.00-16.00	547	417	5	0,262

Source: Analysis Results

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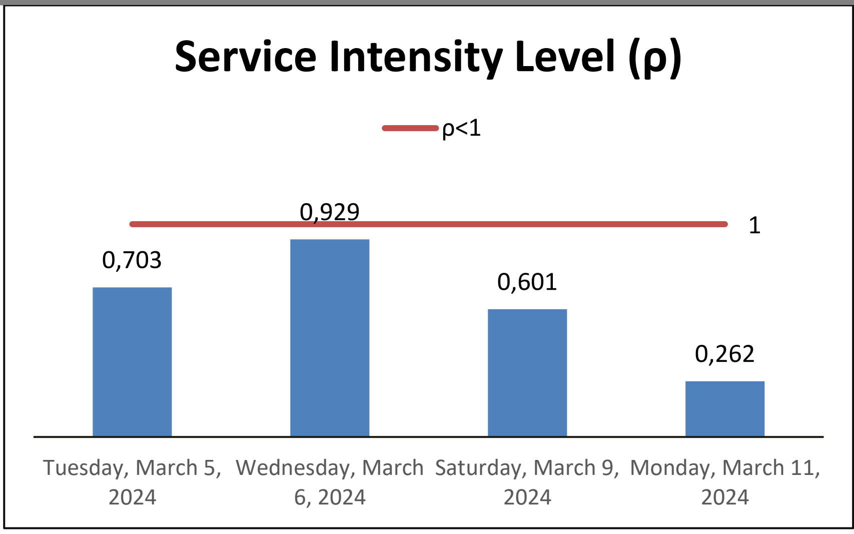

Graphics 1. Service Intensity Level (ρ)
Source: Analysis Results

If ρ> 1 then the arrival rate is greater than the service level. If this happens, then there will definitely be a queue that always gets longer (infinitely) (SAID, 2019). This ensures that the queue at Cililitan Toll Gate 2 is reduced at certain times.

c. Probability of No Arrival

In determining the length of the queue, the chance value of no arrival in the system (P0) is required. An example of calculating the chances of no arrival in the system (P0) on Wednesday, March 6, 2024, at 07:00-08:00 as follows:

$$P_0 = \frac{1}{\left[\sum_{n=0}^{s-1}\left(\frac{\left(\frac{\lambda}{\mu}\right)^n}{n!}\right)\right] + \left[\left(\frac{\frac{\lambda}{\mu}^s}{s!}\right)\frac{1}{1-\frac{\lambda}{s\mu}}\right]} = \frac{1}{\left[\left(\frac{\left(\frac{1934}{417}\right)^0}{0!}\right) + \cdots.(n)\right] + \left[\left(\frac{\frac{1934}{417}^5}{5!}\right)x\frac{1}{1-\frac{1934}{5x417}}\right]}$$

$$P_0 = \frac{1}{[52{,}474]+[252{,}041]} = \frac{1}{304{,}515} = 0{,}003 = 0{,}3\%$$

d. Queue Length

After knowing the value of the chance of no arrival (P0), we can proceed with the calculation of the queue length. An example of calculating queue length on Wednesday, March 6, 2024, at 07:00-08:00 as follows:

$$Vehicles\ waiting\ to\ be\ served\ (L_q) = \frac{P_0\left(\frac{\lambda}{\mu}\right)^s \rho}{s!\,(1-\rho)^2} = \frac{0.003\left(\frac{1934}{417}\right)^5 0{,}93}{5!\,(1-0{,}93)^2} = 10{,}771\ pcu$$

$$Average\ vehicle\ in\ queue\ (L) = 10{,}771 + \frac{1934}{417} = 15{,}415\ pcu$$

$$Total\ vehicles\ in\ queue = Lq + L = 10{,}771 + 15{,}415 = 26{,}186{\sim}27\ pcu$$

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$$Queue\ length = (L_q + L) x\ spacing = (10{,}771 + 15{,}415)\ x\ 10{,}852 = 284\ m$$

The queue lengths on Tuesday, March 5, 2024, Saturday, March 9, 2024, and Monday, March 11, 2024 are presented in **Table 3.**

The high traffic volume on Wednesday, March 6, 2024, is proportional to the length of the queue which is also high at 284m. Tuesday and Saturday have values of 58 m and 40 m, and the lowest queue length occurs on Monday, March 11, 2024, which also has a low traffic volume when compared to other observation days, namely 14 m.

e. Delay

The E-Toll analysis is continued by calculating the delay time. Example of calculation of delay time on Wednesday, March 6, 2024, at 07:00-08:00 hours

$$Average\ vehicle\ in\ service\ (W_q) = \frac{10{,}771}{1934} x\ 3600 = 20{,}050\ seconds$$

$$Average\ vehicle\ in\ queue\ (W) = \frac{15{,}415}{1934} x\ 3600 = 28{,}693\ seconds$$

$$Delay\ time = Wq + W = 20{,}050 + 28{,}693 = 48{,}743 \sim 49\ seconds$$

The delay times on Tuesday, March 5, 2024, Saturday, March 9, 2024, and Monday, March 11, 2024, are presented in **Table 3**.

Table 3. Queue Length and Delay Time

Day, Date	Time	Number of Toll Gates (s)	*Po*	Total Vehicles In Queue (pcu)	Queue (m)	Delay (Seconds)
Tuesday, March 5, 2024	06.00-07.00	5	0,025	6	58	13
Wednesday, March 6, 2024	07.00-08.00	5	0,003	27	284	49
Saturday, March 9, 2024	14.00-15.00	5	0,046	4	40	11
Monday. March 11, 2024	15.00-16.00	5	0,269	2	14	9

Source: Analysis Results

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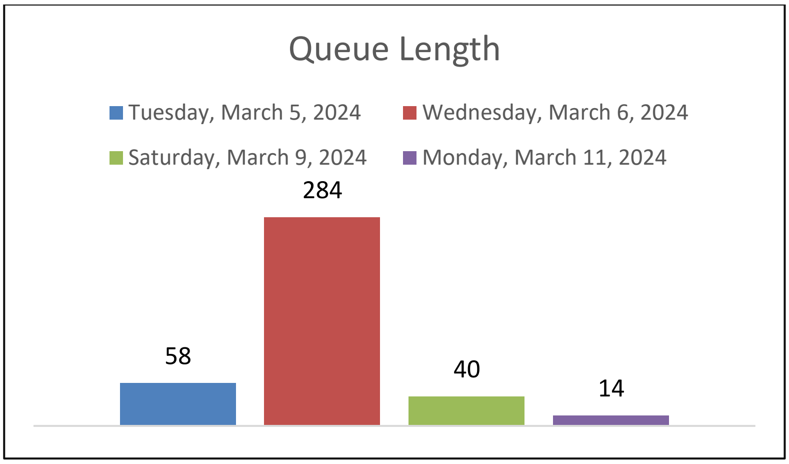
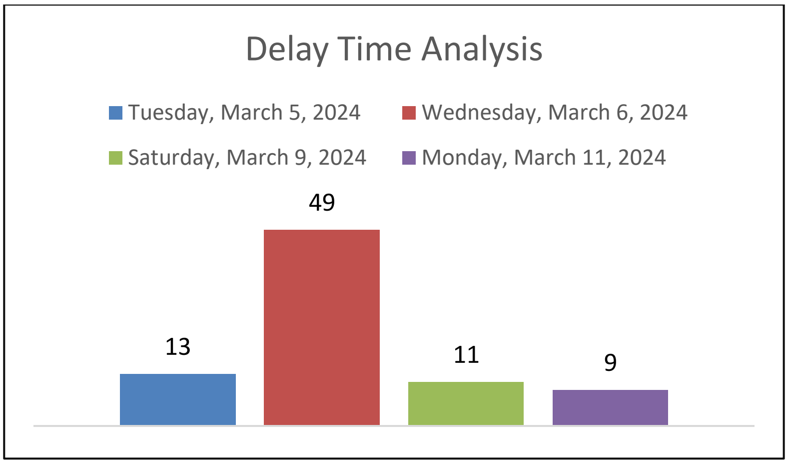


Graphics 2. Queue Length
Source: Analysis Results



Graphics 3. Delay Time Analysis
Source: Analysis Results

In line with traffic volume and queue length, the delay time on Wednesday, March 6, 2024, has the highest value when compared to other observation days. So traffic volume, queue length, and delay time are interrelated.

4. Vehicle Operating Cost Analysis

The BOK analysis was conducted using a sample of traffic volumes on Wednesday, March 6, 2024, which had the largest traffic volume among the other observation days. The BOK analysis has two components, namely fixed costs and non-fixed costs. Fixed costs are not affected by plan speed or average speed. The fixed cost calculation will be the same at any speed condition.

a. Fixed Costs

Examples of fixed cost calculations are carried out on Passenger Car (MP) type vehicles while for other types of vehicles following the same formula with the required data are contained in Table 4.

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Table 4. Fixed Cost Data

Vehicle Type	New Vehicle Price/HKBi (Rp)	Residual Value (%)	Depreciation Period (year)	Crew Cost/year (Rp)	STNK renewal price/year (Rp)	Renewal Price Vehicle Feasibility Test/year (Rp)
MP	236.000.000	20	8	51.000.000	40.000	150.000
KS	166.500.000	20	9	35.196.000	40.000	150.000
BB	1.149.000.000	20	10	32.400.000	160.000	280.000
TB	336.000.000	20	11	39.132.000	40.000	150.000

Source: Observation Results

$$Depreciation\,Value = \frac{(new\ vehicle\ price - residual\ value)}{Depreciation\ period\ x\ km\ traveled/year}$$

$$= \frac{(236.000.000 - 20\%)}{8\ x\ 74.880} = 393{,}96\ rupiah/km$$

$$Vehicle\ Crew\ Fee = \frac{Vehicle\ crew\ cost/year}{km\ traveled/year}$$

$$= \frac{51.000.000}{74.880} = 681{,}09\ rupiah/km$$

$$Administration\ Fee = \frac{STNK\ renewal\ fee/year}{km\ traveled/year} + \frac{Vehicle\ Feasibility\ Test\ renewal\ fee/year}{km\ traveled/year}$$

$$= \frac{40.000}{74.880} + \frac{150.000}{74.880} = 2{,}54\ rupiah/km$$

$$Fixed\ Cost = Depreciation\ value + Vehicle\ crew\ cost + Administration\ cost$$
$$= 393{,}96 + 681{,}09 + 2{,}54 = 1.077{,}59\ rupiah/km$$

Table 5. Fixed Cost

Vehicle Type	Depreciation (Rp/km)	Crew (Rp/km)	Administration (Rp/km)	Fixed Cost (Rp/km)
MP	393,96	681,09	2,54	1.077,59
KS	1.352,34	2.572,81	13,89	3.939,04
BB	752,75	212,26	2,88	967,90
TB	121,21	155,29	0,75	277,25

Source: Analysis Results

b. Non-Fixed Costs

Table 6. Item Price Non-Fixed Cost

Vehicle Type	Fuel Price/ HBBMi (Rp/lt)	Lubricant Price/OHj (Rp/lt)	Tire Price/HBj (Rp/piece)	Maintenance Labor Price/ UTP (Rp/h)
MP	10.000	425.000	640.000	10.000
KS	6.800	69.000	328.040	12.000
BB	6.800	46.000	3.605.000	14.000
TB	6.800	45.000	2.827.550	16.000

Source: Observation Results

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Table 7.Other Variable Non-Fixed Costs

Vehicle Type	AR	SA (m/s^2)	KBBMi (VR=9,72 km/h) (lt/km)	KBBMi (VR=60 km/h) (lt/km)	KOi (VR=9,72 km/h) (lt/km)	KOi (VR=60 km/h) (lt/km)	KBi (lt/km)	Pi	JPi (h/1000km)
MP	0,0024	0,50	0,48	0,12	0,0017513	0,0017503	0,04	0,50	52,58
KS			0,42	0,25	0,0030012	0,0030007	0,15	0,11	77,17
BB			0,86	0,27	0,0060024	0,0060007	0,02	0,19	122,79
TB			1,76	0,58	0,0120049	0,0120016	0,18	0,03	45,80

Source: Calculation Results of Non-Fixed Costs (Departemen Pekerjaan Umum, 2005)

For each item price required in the calculation of non-fixed costs is shown in **Table 6**. Other variables required are shown in **Table 7** by following the equation contained in the Guidelines for Calculating Vehicle Operating Costs (Departemen Pekerjaan Umum, 2005). The calculation of non-fixed costs was carried out using a sample of Average Daily Traffic on Wednesday, March 6, 2024, at an average speed of 9.72 km/h (or 2.7 m/s) and a planned speed of 60 km/h (or 16.67 m/s). This resulted in the Non-Fixed Cost value on Wednesday, March 6, 2024, as shown in **Table 8**.

Table 8. Non-Fixed Cost Value

VR	Vehicle Type	BiBBMj (Rp/km)	BOi (Rp/km)	BBi (Rp/km)	BPi (Rp/km)	BUi (Rp/km)	Non-Fixed Costs (Rp/km)
9,72	MP	4.805,56	744,32	28,70	117,10	525,77	6.221,45
	KS	2.835,61	207,08	49,71	18,40	925,98	4.036,79
	BB	5.819,70	276,11	67,15	213,07	1.719,13	8.095,16
	TB	11.989,50	540,22	495,81	8,90	732,85	13.767,29
60	MP	1.152,25	743,89	28,70	117,10	525,77	2.567,70
	KS	1.721,98	207,05	49,71	18,40	925,98	2.923,13
	BB	1.805,46	276,03	67,15	213,07	1.719,13	4.080,84
	TB	3.943,77	540,07	495,81	8,90	732,85	5.721,41

Source: Calculation Results of Non-Fixed Costs (Departemen Pekerjaan Umum, 2005)

c. Vehicle Operating Costs and Congestion Costs

So that it can be known the value of Vehicle Operating Costs at each speed and the congestion costs incurred for MP vehicle types, as follows:

$$VOC(VR = 9{,}72\ km/jam) = BT + BTT = 1.077{,}59 + 6.221{,}45 = 7.299{,}04\ rupiah/km$$
$$VOC(VR = 60km/jam) = BT + BTT = 1.077{,}59 + 2567{,}70 = 3.645{,}29\ rupiah/km$$
$$Congestion\ Charge = 7.299{,}04 - 3.645{,}29 = 3.653{,}75\ rupiah/km$$

Table 9. Congestion Charge

Vehicle Type	VOC (VR= 9,72 km/h)	VOC (VR= 60 km/h)	Congestion Charge (Rp/km)
MP	7.299,04	3.645,29	3.653,75
KS	7.975,82	6.862,16	1.113,66
BB	9.063,06	5.048,74	4.014,32
TB	14.044,54	5.998,66	8.045,89

Source: Analysis Results

5. Questionnaire Survey

Population is the number of all people consisting of individuals, or units of objects to be studied. In the study, the population used was Jagorawi Toll Road users in 2023. The

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sample is all individuals, objects, or events that will be studied in a study (Hertanto, 2020). A questionnaire survey was conducted by distributing 16 questions regarding the application of MLFF at Cililitan Toll Gate 2 with a total of 100 respondents determined based on the Slovin formula. The results of the questionnaire survey were processed using SPSS software by conducting normality, validity, and reliability tests.

a. Normality Test

The normality test aims to assess the distribution of data on a variable data whether the data distribution is normally distributed or not. The test is normally distributed if the Kolmogorov-Smirnov Test value has a value> 0.05 (Lembaga Administrasi Negara Republik Indonesia, 2010).

Table 10. Normality Test Results

One-Sample Kolmogorov-Smirnov Test

		Standardized Residual
N		100
Normal Parameters[a, b]	Mean	.0000000
	Std. Deviation	.99493668
Most Extreme Differences	Absolute	.073
	Positive	.060
	Negative	-.073
Test Statistic		.073
Asymp. Sig. (2-tailed)		.200[c, d]

a. Test distribution is Normal.
b. Calculated from data.
c. Lilliefors Significance Correction.
d. This is a lower bound of the true significance.

Source: SPSS analysis

From the normality test that has been carried out, it is obtained that the Kolmogorov-Smirnov Test value has a value> 0.05, which is> 0.200, so the data is normally distributed.

b. Validity Test

The validity test is a test conducted to show the extent to which the measuring instrument used in a data collection is a valid measuring instrument or not (Annisa & Mukhsin, 2024).

The validity test is declared valid if the value of r count> r table. The r table value for each indicator must exceed 0.195 if the number of respondents is 100 people.

c. Reliability Test

A reliability test is a test conducted to ensure that the research questionnaire is reliable or not if the questionnaire is carried out repeatedly by achieving the same results. The reliability test is said to be reliable, Cronbach's alpha value is> 0.6 (Annisa & Mukhsin, 2024).

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Table 11. Validity and Reliability Test Results

No	Variables	Answer Options	Results (%)	Validity	Reliability
	MLFF Question Indicator				
1	Did you know about Multi-Lane Free Flow before? (X1)	Yes, I know No, I don't know	63 37	0,243	0,820
2	If so, where did you learn about Multi-Lane Free Flow? (X2)	Television Website Friends/Relatives Social Media Don't Know	6 13 12 32 37	0,418	
3	Are you a driver or a passenger? (X3)	Driver Passengers	37 63	0,219	
4	Do you know the procedures of the Multi-Lane Free Flow system? (X4)	Yes No	42 58	0,244	
5	Have you ever passed through Cililitan Toll Gate 2? (X5)	Yes Ever Never	54 46	0,250	
6	How often do you pass through Cililitan Toll Gate 2? (X6)	Yes, Very Often Yes, Often Rarely Rarely Not at All	5 14 22 13 46	0,264	
7	Does the traffic jam bother you when approaching Cililitan Toll Gate 2? (X7)	1 (Not Disturbing) 2 3 4 5 (Yes Very Disturbing)	4 10 24 24 38	0,585	
8	Do you agree that Multi-Lane Free Flow is implemented at Cililitan Toll Gate 2? (X8)	1 (Strongly Disagree) 2 3 4 5 (Strongly Agree)	1 4 15 34 46	0,604	
9	Will the implementation of Multi-Lane Free Flow at Cililitan Toll Gate 2 be effective and efficient? (X9)	1 (Not at all) 2 3 4 5 (Yes Very Effective and Efficient)	0 1 25 36 38	0,776	
10	Can the implementation of Multi-Lane Free Flow reduce congestion at the Cililitan Toll Gate 2 queue? (X10)	1 (Not at all) 2 3 4 5 (Yes Absolutely)	0 2 18 42 38	0,764	
11	Do you think implementing Multi-Lane Free Flow can speed up the payment process at Cililitan Toll Gate 2? (X11)	1 (Not at all) 2 3 4 5 (Yes Greatly Accelerate Payment)	0 1 12 37 50	0,736	
12	Will the Multi-Lane free-flow system reduce fuel	1 (Not at all) 2	2 4	0,588	

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MLFF Question Indicator					
No	**Variables**	**Answer Options**	**Results (%)**	**Validity**	**Reliability**
	usage? (X12)	3 4 5 (Yes Absolutely)	23 33 38		0,820
13	Do you think this Multi-Lane Free Flow System can be applied to Cililitan Toll Gate 2? (X13)	1 (Not Suitable at All) 2 3 4 5 (Very Suitable)	0 0 18 42 40	0,654	
14	If implemented at Cililitan Toll Gate 2, is this Multi-Lane free-flow system better than the current E-Toll system? (X14)	1 (Not Better) 2 3 4 5 (Better)	0 0 18 42 40	0,695	
15	Will the transition from E-Toll system to Multi-Lane Free Flow be easy? (X15)	1 (Not Easy at All) 2 3 4 5 (Very Easy)	6 20 22 19 33	0,677	
16	In your opinion, with the facilities and infrastructure in Indonesia, support the implementation of the Multi-Lane Free Flow system? (X16)	1 (Very unfavorable) 2 3 4 5 (Very Favorable)	0 8 26 28 38	0,697	

Source: SPSS Analysis

From the results of the analysis using SPSS in Table 11, it is obtained that the validity test value (Pearson Correlation) for each indicator is more than the r table value, precisely 0.195. So that the validity test for each indicator is valid.

From the results of the SPSS analysis in Table 11, for the reliability test that has been carried out, the Cronbach's alpha value is 0.820. So that the data is reliable because it has a Cronbach's alpha value> 0.6 (Lembaga Administrasi Negara Republik Indonesia, 2010).

CONCLUSIONS

Traffic volume at Cililitan Toll Gate 2 has a higher frequency on weekdays, while on weekends and national holidays, the volume of traffic passing through the Cililitan Toll Gate 2 is relatively quieter. The highest peak hour arrival rate on the observation day occurred on Wednesday, March 6, 2024, at 07:00-08:00 with a total of 1,934 vehicles passing through the Cililitan Toll Gate 2 with a queue length of 284 m and a delay time of 49 seconds. The arrival rate on Tuesday, March 5, 2024, at 06:00-07:00 is 1,465 smp / hour with a queue length of 58 m and a delay time of 13 seconds. The arrival rate on Saturday, March 9, 2024, at 14:00-15:00 is worth 1,251 SMP / hour with a queue length of 40 m and a delay time of 11 seconds. The arrival rate on Monday, March 11, 2024, at 15:00-16:00 is worth 547 smp / hour with a queue length of 14 m and a delay time of 9 seconds. If MLFF is applied at Cililitan Toll Gate 2, the speed that

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will be traveled by vehicles is the minimum plan speed of 60 km / h because no toll gate will slow down the speed of the vehicle so that the congestion costs incurred from the use of E-Toll and MLFF are the results obtained from the calculation of BOK at the plan speed (60 km / h) and the actual speed (9.72 km / h) which is worth Rp. 3,653.75/km for MP vehicle types, Rp. 1,113.66/km for KS vehicle types, Rp. 4,014.32/km for BB vehicle types, and Rp. 8,045.89/km for TB vehicle types. Based on the results of the questionnaire survey, 46% of respondents answered strongly agree if MLFF was applied at the Cililitan Toll Gate 2, with 38% answering that if MLFF was applied at the Cililitan Toll Gate 2 it would be very effective and efficient. However, if many respondents disagree if MLFF is implemented, it will affect the BOK and will continue to use the E-Toll system so that it affect congestion costs, and will be more expensive.

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