ANALYSIS OF SRONDOL-JATINGALEH TOLL QUEUE SYSTEM AT SEMARANG CITY IN THE END OF YEAR 2018 WITH AUTOMATIC TOLL GATE SYSTEM USING LOGISTIC DISTRIBUTION APPROACH

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Abstract: The transportation sector is one sector that plays an essential role in economic growth. The transportation sector can increase economic growth. Semarang City is one of the provincial capitals in Central Java. The Srondol-Jatingaleh toll road is one of the toll roads in the city of Semarang that has implemented the Automatic Toll Gate. Based on the results of the analysis, so that the queue model is (logistic/logistic/ 4) :(FIFO / ∞ / ∞). It shows that the distribution of the queuing system of the number of arrivals and the number of vehicle services are Logistic-Distribution. The number of service facilities is 4, the service discipline used is First In First Out (FIFO), the size in the queue, and the source of calls are unlimited.

1. INTRODUCTION

Queues can be seen in various situations that occur in everyday life, such as vehicles waiting at traffic lights, customers waiting for payment at the supermarket cashier, patients waiting for treatment services at the hospital, customers who will save or take cash at the office banking, train passengers are lining up at the station, buses waiting to take passengers at the terminal, ships waiting to dock at the dock, planes waiting to take off, and many more can be found in daily life. The purpose of queuing theory is to examine the activities of service facilities in a series of random conditions from a queue system that occurs (Kakiay, 2004).

Srondol-Jatingaleh Toll Gate is a toll gate that provides Automatic Toll Gate facilities for vehicles coming from the direction of Banyumanik to the port / Terboyo, Demak, and Kudus. A large number of vehicles that come at a particular time and the lack of information that the drivers have regarding the Automatic Toll Station can cause a long queue. Research on the queuing system at the Toll Srondol-Jatingaleh Gate has never been done before. In connection with the issuance of government's regulation doesn't to impose regular substations, the researchers wanted to examine how the queue system at the Srondol-Jatingaleh toll gate with a service system using automatic toll booths.

As a way to find out the service performance of automated toll booths, we analyze the queue system and system performance at the automatic toll booth. The results of the analysis will be used as a study for making decisions on the development of an effective toll

booth queue system for the future. The basic objective of the queue models is to minimize both at the same time two types of costs, namely direct costs for providing services and costs of individuals waiting to obtain services (Taha, 2007). (Manou et al., 2014) has conducted research traffic transportation by queue model approaches and has found the optimal servers. (Chydzinski, 2020) has conducted research to approaches General Distribution. (Nakade & Niwa, 2017) also implemented the M/G/1 of queue model to their research in control radio program. (Bedell & Smith, 2012) has implemented the queue model for transportation sectors. (Legros, 2018) applied M/G/1 queue model for dependent arrival. (Wrediningsih et al., 2019) has developed Non-Poisson queue in terminal or bus stop in Surakarta.

Logistic Distribution has similarity with Normal Distribution. It has two parameters, are μ and σ. In the queue theory, we have to analyze the number of arrivals, the number of served, the time between arrival and the time of served (Liao et al., 2019). For the number of arrival and the number of served with test with Poisson Distribution. If it failed, then it shows that the distribution of them are General Distribution (Yayat et al., 2016). Also, for the time between arrivals and the time of served, we testing with Exponential Distribution. If it failed, then it shows that the distribution of them are General Distribution. One of distribution approaches the General Distribution is Logistic Distribution. Based on the background, the formulation of the problem in this paper is as follows: determine the queue model at the Automatic Toll Station Service at Srondol-Jatingaleh Toll Gate, conduct a queue simulation at the Automatic Toll Station Service at Srondol-Jatingaleh Toll Gate, and determine the size of the queue system performance at the Service Automatic Toll Substation at Srondol-Jatingaleh Toll Gate.

2. MATERIAL
2.1. Logistic Distribution

The Logistic Distribution is a continuous probability density function that is symmetric and uni-modal. It is similar in appearance to the Normal Distribution and practical applications. The two distribution cannot be distinguished from one another (Dey & Kundu, 2012). X is a random variable that has μ and σ as parameters that follow Logistic Distribution. The probability density function is (Elsherpieny et al., 2007)

$$f(x) = \frac{1}{\sigma} \frac{e^{-(x-\mu)/\sigma}}{1 + e^{\left(-(x-\mu)/\sigma\right)^2}} \tag{1}$$

The cumulative distribution of Logistic Distribution as follows as:

$$F(x) = \frac{1}{1 + e^{-(x-\mu)/\sigma}} \tag{2}$$

2.2. Distribution Fit Test using Kolmogorov-Smirnov

The fit of distribution using Kolmogorov-Smirnov (Daniel, 1989). The hypothesis as follows as:

H_0: The sample distribution follows the specified distribution

H_1: The sample distribution unfollows the specified distribution

The Statistic test as follow as

$$D = \sup_x |S(x) - F_0(x)| \tag{3}$$

with

S(x): cumulative probability function calculated from sample data

F₀(x): The hypothesized distribution function (cumulative probability function)

The criteria of the test are rejected H_0 if the D value $\geq$ the value of D_{table} (1- α).

2.3. The Measurement Performance Systems

According to (Taha, 2007) the queuing model (G/G/c):(FIFO /∞/∞) is a queuing model with a general distributed arrival pattern and a general distribution service pattern with c. , c = 1, 2, 3, ... The queue discipline used in this model is general, namely FIFO (First In First Out), the maximum capacity allowed in the system is infinite, and has infinite call sources.

For counting the estimated number of customers in queue (L_q) based on measurement performance in model (M/M/c):(GD/∞/∞) as follows (Bedell & Smith, 2012):

$$L_q = \frac{\rho^{c+1}}{(c-1)!(c-\rho)^2} p_0 \frac{\mu^2 v(t)+v(t')\lambda^2}{2} = L_{qM/M/c} \frac{\mu^2 v(t)+v(t')\lambda^2}{2} \qquad (4)$$

For $v(t)$ is variance from time of served; $v(t')$ is variance from time between arrivals. The number of customers in the system as follows (Ahdika, 2019):

$$L_s = L_q + \rho \qquad (5)$$

The estimated waiting time in the system as follows (Jeyakumar & Rameshkumar, 2017):

$$W_q = \frac{L_q}{\lambda} \qquad (6)$$

The estimated waiting time in line as follows:

$$W_s = W_q + \frac{1}{\mu} \qquad (7)$$

3.   METHODOLOGY OF RESEARCH

The research variables used in this paper are the number of vehicle arrivals, the time between the arrival of vehicles, the time the vehicle is served, and the time when the vehicle is finished. Every vehicle that comes from the direction of Srondol is calculated as the number of vehicles coming. The difference between the arrival time of the vehicle and the time of arrival of the previous vehicle will be obtained between the arrival times. The service time is calculated when the vehicle stops next to the GTO and then attaches the e-toll card. Service completion time is calculated when the vehicle has left the Automatic Toll Station (GTO). The data collected in December 28ᵗʰ until 31ˢᵗ 2018 and also January 2ⁿᵈ 2019. Data on the amount of vehicle traffic for the direction of Srondol-Jatingaleh can be seen in Table 1.

Table 1. The Total Vehicle Traffic at Srondol-Jatingaleh

Day	The Number of Arrivals	The Number of Served
Friday	5946	5946
Saturday	5537	5535
Sunday	4124	4122
Monday	4844	4843
Wednesday	5122	5117

Most vehicles on Srondol-Jatingaleh occur on Friday, with the total number of vehicles arriving is 5946 vehicles and the least number occurring on Sundays with a total of 4124 vehicles.

4.   RESULTS AND DISCUSSION
4.1. Steady State Size

Steady State size symbolized by (ρ) can be defined as comparison customer arrival (λ) with an average of customers served at that time (μ). The steady-state conditions for the Automatic Toll Substation service facilities are met if $\rho < 1$. To calculate the size of the steady-state formula is used: $\rho = \dfrac{\lambda}{c\,\mu}$ so that it is necessary to know in advance the average arrival and average service, obtained the value of the level of use of service facilities for the Srondol-Jatingaleh Toll Gate as follows:

Table 2. Level of Use of GTO Service Facilities

Toll Gate	λ	μ	c	$\rho = \dfrac{\lambda}{c\mu}$
Srondol-Jatingaleh	255.73	255.63	4	0.250

From table 2, it can be seen that the level of service facilities for Srondol-Jatingaleh is less than one, so it can be concluded that the service system at the automatic toll booth is steady state. It is means that the systems served the customer arrival. From table 2 shows that the arrival rate average is 255.73; the serviced rate average is 255.63; the number service facilities is 4 and the usefulness is 0.25.

4.2. Fit Distribution Testing

The distribution match test used to test data on the number of arrivals and the number of services at the Srondol-Jatingaleh Toll Gate is the Kolmogorov Smirnov test. By using this test, we want to know whether the data on the number of arrivals and the number of services that have been obtained from the research are Poisson Distribution.

Distribution Test of Arrival Amount and Number of vehicles Services in Srondol-Jatingaleh with the hypothesis as follows:

> H_0: Data on the number of arrivals and the number of services with a Poisson Distribution
> H_1: Data on the number of arrivals and the number of services with Non-Poisson Distribution

The statistics testing follow in equation (3) with the value of Kolmogorov-Smirnov for the number arrivals is 0.261 with p-value 0.000. Also the value of number of services with statistic testing is 0.254 with p-value 0.000.

We reject H_0 for significant level $\alpha = 5\%$ if the value of D $\geq$ the value of $D_{table}(1 - \alpha)$, or if the value of significant $< \alpha$ (5%). From Kolmogorov-Smirnov table results $D_{table} = 0.136$.

Based on the results for the data on the number of arrivals in Tol Srondol-Jatingaleh Gate has D > D_{table} and p-value < the value of α. It can be concluded in level of significant α = 5% Reject H_0, so the data on the number of arrivals in Srondol-Jatingaleh Toll Gate, not Poisson Distribution. Also for the data on the number of services in Srondol-Jatingaleh Toll Gate has D > D_{table} and p-value < the value of α. It can be concluded in the level of significant α = 5% reject H_0, so the data on the number of services in Srondol-Jatingaleh Toll Gate, not Poisson Distribution.

4.3. Model of the GTO ("Gerbang Toll Otomatis" or Automatic Toll Gate) Queue System for the Srondol-Jatingaleh Toll Gate

After the analysis, the data obtained that met the steady-state conditions and through the distribution of compatibility tests concluded that data on the number of arrivals and the number of services in the Srondol GTO fulfilled the Non-Poisson Distribution. In queue theory, if the distribution of the number of arrival or the number services unfullfilled the Poisson Distribution, then the distribution assumed General Distribution.

Therefore, it can be determined that the queue system model for the GTO on Srondol is (G/G/4):(FIFO/∞/∞). The notation of this model interprets that the distribution of the number of arrivals and the number of service vehicles is General Distribution, the number of service facilities provided is four. To find out the actual distribution of the General Distribution for the number of arrivals and the number of vehicle services, a distribution suitability test was conducted using the R program to test the Kolmogorov Smirnov. The fit distribution test of arrival distribution and services distribution using the Kolmogorov-Smirnov test with the hypothesis as follows:

H_0: Data on the number of arrivals/ the number of services has Logistic Distribution

H_1: Data on the number of arrivals/ the number of services does not have Logistic Distribution

The statistics testing of number arrival with Kolmogorov-Smirnov's value (D) is 0.044 with p-value 0.99. The statistics testing of number services (D) is 0.046 with p-value 0.9829. So that we reject H_0 for significant level α = 5% if the value of D ≥ the value of $D_{table}(1 - \alpha)$, or if the value of significant < α (5%). From Kolmogorov-Smirnov table results $D_{table} = 0.136$. However, the data on the number of arrivals in Srondol-Jatingaleh Toll Gate has D < D_{table} and p-value > the value of α. It can be concluded in level of significant α = 5% accept H_0, so the data on the number of arrivals in Srondol-Jatingaleh Toll Gate has Logistic Distribution. Then the data on the number of services in Srondol-Jatingaleh Toll Gate has D < D_{table} and p-value > the value of α. It can be concluded in level of significant α = 5% accept H_0, so the data on the number of services in Srondol-Jatingaleh Toll Gate has Logistic Distribution. The final model was obtained for the queuing model at the Srondol-Jatingaleh Toll Gate as (Logistic/Logistic/4) :(FIFO/~/~).

4.4. Size of the Srondol-Jatingaleh Toll Gate Queue System Performance

Based on the Srondol-Jatingaleh queue model (Logistic/Logistic/4) :(FIFO/~/~), measurements of vehicle queue system performance at the GTO at the Srondol-Jatingaleh Toll Gate were obtained with ten-minute intervals as follows:

Table 3. Size of the Performance of the Srondol-Jatingaleh Toll Gate System

c	λ	μ	L_q	L_s	W_q	W_s	P_o
4	255.73	255.63	392.959	393.959	1.53662	1.54053	0.3672

Table 3 shows that the average arrival rate (λ): 255.73 vehicles, the average service rate (μ): 255.63 vehicles. The number of vehicles expected inline (L_q): 392.959 vehicles. Number of vehicles expected in the system (L_s): 393.959 vehicles. Time to wait for the expected vehicle in the queue is (W_q): 1.53662. Time to wait for the vehicle that is expected in the system is (W_s): 1.54053. The probability of a GTO service facility is idle when no vehicle arrives (P_o) is 0.3672 or 36.720 %.

5. CONCLUSION

The first queue model of Srondol-Jatingaleh Toll gate is (G/G/4): (FIFO/~/~). The general approaches with Logistic Distribution. However The queue model of Srondol-Jatingaleh Toll Gate is (Logistic/Logistics/4):(FIFO/~/~). It is mean that a queue system model with distribution of the number of arrivals and the number of served are Logistic Distribution. The number of service facilities is 4, the service discipline used is FIFO, the size of the queue and the source of the call are unlimited. Based on measurement performance system shows that the services of Srondol-Jatingaleh Toll Gate were optimal.

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