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Analysis of Gate Machine Facilities and Train Arrival System for Indonesian Commuter Line Users at Bekasi Station

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Abstract

The daily activities of communities required the movement of people from one place to another. Communities need a service that can help their movement in their daily activities so the time used becomes more effective and efficient. PT Kereta Commuter Indonesia is one of the subsidiaries of PT Kereta Api Indonesia (Persero) which can be a solution for the community to answer urban transportation problems, especially the Jabodetabek area which is increasingly crowded and complex. However, users of public transportation services, including commuter line users, have to wait to get the service. Based on this background, this study focus is to discuss related to gate machine facility services and train services using concept of queueing theory. This research was conducted at Bekasi Station which has nine gate machines for check in with First Come First Serve service and four train platforms to serve the trains with Priority Service. The service model using Multiple Channel Single Phase service model. The result of this study indicate that the activity level of Indonesia's Commuter Line service at Bekasi Station in term of check in is quiet high, while the train service has a low level activity so that the service system is not optimal. The level of activity in commuter line service can be more optimal if there is a reduction in facilities for the train service into three platforms that used in 09.00 – 18.00 WIB at Bekasi Station.

Keywords: Service system, train station, public transportation, queueing theory.

1. Introduction

Daily activities that require moving between places and locations require cheap and fast transportation access, resulting in frequent congestion during peak hours in transportation facilities. The high number of people needing transportation facilities at the same time, coupled with the total number of service users exceeding the available service facilities, leads to service congestion.

At Bekasi Station, service issues and passenger congestion on each platform are unavoidable. Its strategic location near residential areas attracts many passengers who choose to use the commuter train service as their primary mode of transportation, especially towards the capital city of Jakarta. Bekasi Station provides several tracks, but due to ongoing renovations, only four tracks are currently available for commuter line activities. The large number of passengers intending to use the train service and the relatively long arrival time of the trains contribute to service congestion. The resulting queues are one of the reasons passengers feel discomfort, necessitating an analysis of a service system or a model to address these issues.

In a previous study, Vikaliana (2017) compared the performance of efficient service models at the Bogor Station ticket counters between manual service and machine-assisted service. It was found that machine-assisted service reduced the queue length because the average service time was less than one minute. Sulaeman and Haryadi (2018) analyzed the passenger capacity served by the Light Rail Transit (LRT) in Palembang. They created three different arrival conditions of LRTs at the Depot Station within 45 minutes, with varying numbers of trains. The study concluded that an increase in the number of train carriages was necessary to accommodate passengers optimally. Manggala Putri et al. (2017) conducted a study on improving non-steady-state queue models in the service system at Dr. Yap Eye Hospital in Yogyakarta. They found that using Monte Carlo simulation helped optimize queue system size by limiting the queue system's capacity and increasing the number of available servers. Sihotang (2020) analyzed the related traction system of the vehicle on the automatic toll gate Muktiharjo using the type (Norm/Norm/4:(GD/∞/∞) which results in that the existing automated toll gate booth that is the sum of four is already optimal and if adding the auto toll door booth in place will lower the level of activity. Muhajir and Binatari (2017) investigated related model of the backbone system on the insurance company XYZ in the city of Tasikmalaya using the type (M/M/4):(GD/∞/ ∞) resulted that the company needed the addition of one server on customer service to improve performance on the customer service section.

Based on the aforementioned background regarding various service issues and previous research related to service problems in public facilities, an analysis will be conducted on the implementation of service issues at Bekasi Station.

2. Concept of Service System

The definition of the concept of a service system itself refers to the problem of queueing system where queueing in the service system is a common phenomenon that can be found anywhere and anytime. According to Gross and Harris (2008), a queuing system can be defined as a situation where users of a service arrive to receive a service, then they have to wait if the service is not immediately available, and they leave the system once they receive the service. It is an occurrence where a service user arrives and has to wait for a certain amount of time to receive the service, as described by Hillier and Lieberman (2010).

According to Hillier and Lieberman (2010), there are three components:

a. Arrival

The arrival rate can be observed as limited or unlimited. When the service has a limited number or a restricted number of users, the arrival rate is limited. On the other hand, if the service has an unrestricted number of users arriving and requesting the service, the arrival rate is unlimited.

b. Service

The characteristics of service are related to service discipline. There are several service disciplines used, such as First Come First Served (FCFS), Last Come First Serve (LCFS), Priority Service (PS), and Service In Random Order (SIRO).

c. Queue

The basic design of a service system can be categorized into four types: Single Channel Single Phase, Single Channel Multi Phase, Multi Channel Single Phase, and Multi Channel Multi Phase.

2.1. Service System Model

According to Taha (2015), characteristics to indicate service discipline and maximum system capacity of a model are written in the form of notation, which can be represented as

$$(a/\ b/c\ ):(d/e\ /f)$$

where:

a : arrival distribution
b : service time distribution
c : number of servers
d : service discipline
e : maximum system capacity
f : input source

Notation a and b represent the form of arrival and service time distribution, which can be:

M : Poisson-distributed arrival rate or exponential interarrival time and service time
D : deterministic interarrival time
E_k : Erlang-distributed interarrival time with parameter k
GI : general interarrival time distribution
G : general departure distribution

2.2. General Service Model (G/G/C)

The $(G/G/C)$ service model is a model where the interarrival time follows a general distribution, the service time follows a general distribution, and there are c servers. The average for all services in the queuing system is the average service rate, where service users who have received the service leave the queue with an arrival rate of λ and an average service rate of μ. According to Gross and Harris (2008), the performance metrics for the general model follow the performance metrics for the $(M/M/C)$ model, except for the estimated number of users in service (L_q). The performance metrics for the $(G/G/C)$ service model are determined as follows:

1. System Utilization Rate denoted by ρ

$$\rho = \frac{\lambda}{c\mu} \tag{1}$$

2. Probability of the system being idle

$$P_0 = \frac{1}{\sum_{n=0}^{c-1} \frac{\left(\frac{\lambda}{\mu}\right)^n}{n!} + \frac{\left(\frac{\lambda}{\mu}\right)^c}{c!} \frac{1}{1-\frac{\lambda}{c\mu}}}$$

$$P_0 = \frac{1}{\sum_{n=0}^{c-1} \frac{\left(\frac{\lambda}{\mu}\right)^n}{n!} + \frac{\left(\frac{\lambda}{\mu}\right)^c}{c!} \frac{1}{1-\frac{\lambda}{c\mu}}}$$

3. Average number of users in service.

$$Lq = L_{q_{M/M/C}} \frac{\mu^2 v(t) + v(t')\lambda^2}{2} \tag{2}$$

$$Lq = \frac{\left(\frac{\lambda}{\mu}\right)^c \rho}{c!(1-\rho)^2} P_o \frac{\mu^2 v(t) + v(t')\lambda^2}{2} \tag{3}$$

where:
$v(t)$: variance of service time
$v(t')$: variance of interarrival time.

4. Average number of users in the system

$$Ls = L_q + \rho \tag{4}$$

5. Average waiting time for users in service.

$$Wq = \frac{L_q}{\lambda} \tag{5}$$

6. Average waiting time for users in the system.

$$W_s = W_q + \frac{1}{\mu} \tag{6}$$

2.3. Distribution Test

Goodness of Fit Test is a method to examine whether a set of data follows a theoretical distribution. This is done using the Kolmogorov-Smirnov one-sample test. The decision-making process for the Kolmogorov-Smirnov test is as follows:

a. Hypothesis regarding the arrival distribution:
   H_0: Interarrival time follows a Poisson distribution
   H_1: Interarrival time does not follow a Poisson distribution
   If it does not follow a Poisson distribution, then the arrival is assumed to follow a general distribution.
   For a Poisson distribution, the number of arrivals is a random variable that follows a Poisson distribution with parameter λ.
b. Hypothesis regarding the service distribution:
   H_0: Service time follows an exponential distribution
   H_1: Service time does not follow an exponential distribution
   If it does not follow an exponential distribution, then the service is assumed to follow a general distribution.
   The exponential distribution is commonly used to model the interarrival time in a service process.

The distribution form is determined by observations or processing of events per unit of time.

The significance level is a comparison of the $Asymptotic - significance(2{\sim}Tailed)$ value to get the result of determining the hypothesis which is divided into two possibilities.

a. If the $Asymptotic - significance(2{\sim}Tailed) > significance\ level$, then H_0 is accepted.
b. If the $Asymptotic - significance(2{\sim}Tailed) < significance\ level$, then H_0 is rejected.

3. Materials and Methods

3.1. Materials

The data source obtained in this research is secondary data and primary data obtained from observations and directly obtained from PT Kereta Commuter Indonesia. The type of data used is secondary data related to train arrival times, service times, and passenger arrival times when tapping at Bekasi Station.The type of data used is primary data related to services time whene passanger tapping in the machine. Data collection was conducted at Bekasi Station over a one-week period from October 1st to October 7th, 2022, between 9:00 AM and 6:00 PM.

3.2. Methods

The steps taken to obtain the service model from the obtained data are as follows:

1. Identifying problems related to the issues found in the research.
2. Describing the purpose of the research and conducting a literature review related to the research problem.
3. Conducting field observations related to the identified problems.
4. Collecting data from the company related to arrival times, service times, and passenger and train arrival times at Bekasi Station.
5. Analyzing the data by performing a goodness-of-fit test using IBM SPSS Statistics 27 software for data testing.
6. Making assumptions about the data obtained regarding the suitability of the data, namely whether the arrival model is Poisson distributed and the service model is exponential distributed.
7. Looking at the performance of the service system obtained from the average arrival and average service times at Bekasi Station.
8. Determining the service model. After the data is obtained from the analysis and meets the data testing, the next step is to analyze and process the data to produce the desired service model with the help of the Python programming language.
9. Analyzing the performance of the existing service system. In this step, an analysis is conducted to determine whether additional facilities are needed or whether they are not necessary uses equation (1) to equation (6).
10. Testing the research object facilities when the service system includes the addition or removal of facilities.
11. Drawing conclusions from the research.

4. Results and Discussion

In general, passenger services at Bekasi Station's commuter line are described by the facilities provided, including nine gate machines for commuter line check-ins and four platforms for commuter line train services. The queue and passenger capacity are unlimited, and the service follows a First Come First Serve discipline for passengers entering the station and Priority Service for train services. Data collection was conducted at Bekasi Station over a one-week period from October 1st to October 7th, 2022, between 9:00 AM and 6:00 PM. The arrival rate for commuter line passengers at Bekasi Station was calculated to be 5895,72 passengers/hour, while the train arrival rate was 9,43 trains/hour. The service rate for commuter line check-ins at Bekasi Station was 925,4 passengers/hour, and the train service rate was 7,26 trains/hour.

4.1. Steady State Measurement

Steady state measurements are obtained by calculating the system utilization rate based on the arrival rate and service rate data as given in the Table 1.

Table 1: Measurement Results of Steady State

Service Type	c	λ	μ	$\rho = \frac{\lambda}{c\mu}$
Machine Gate Facility	9	5895.72	925.4	0.7078
Train Arrival	4	9.43	7.26	0.3224

Based on Table 1, the system utilization rate for the existing service types is $< \mathbf{1}$. The arrival rate does not exceed the service speed capacity, thus satisfying the steady state condition.

4.2. Distribution Suitability Test

The Kolmogorov-Smirnov test is used to assess distribution suitability as given in the Table 2 and Table 3.

Table 2: Distribution Suitability Test for Arrival Rate

Arrival Type	Sigma Value	Decision	Model
Machine Gate Facility	0.000	H_0 Rejected	*General*
Train Arrival	0.001	H_0 Rejected	*General*

Table 3: Distribution Suitability Test for Arrival Rate

Arrival Type	Sigma Value	Decision	Model
Machine Gate Facility	0.000	H_0 Rejected	*General*
Train Arrival	0.000	H_0 Rejected	*General*

4.3. Discussion of Commuter Line Service Model Results at Bekasi Station

4.3.1 Machine Gate Facility

The service system at the commuter line machine gate facility at Bekasi Station uses the FCFS (First Come First Serve) service discipline and has a Multiple Channel Single Phase structure, where there are multiple service facilities and only one stage is involved. This service system has a general distribution arrival pattern, and the service analysis uses the $(G/G/9) : (FCFS/\infty/\infty)$ service model.

4.3.2 Train Service Facility

The train service system for the commuter line at Bekasi Station uses Priority Service as the service discipline and has a Multiple Channel Single Phase structure, where there are multiple service facilities and only one stage is involved. This service system uses the $(G/G/4) : (PS/\infty/\infty)$ service model as given in the Table 4.

Table 4: Performance Analysis Results for the Commuter Line Service System at Bekasi Station

Service	c	Arrival Rate (λ)	Service Rate (μ)	Utilization Rate (ρ)	System Performance Metrics P_0	L_q	L_s	W_q	W_s
Mesin *Gate Check In Commuter Line*	9	5895.72	925.44	70.78%	49.26%	1	7	0.0000255 hours	0.0011061 hours
Train Service on Platform	4	9.43	7.26	32.24%	72.27%	1	2	0.0057642 hours	0.1435052 hours

4.4. Evaluation of Service Model Results

From the obtained results, it can be seen that the level of busyness in the train service facility is quite low compared to the passenger arrivals. This causes significant idle time within the system. By reducing the service facilities in the commuter line facility, several options for train service facilities are formed. The system performance metrics of the train service facility after the reduction of facilities are evaluated by making certain assumptions, aiming to reduce idle time in the system as given in the Table 5.

Table 5: Comparison of Assumptions for the Train Service Facility at Bekasi Station

System Performance Metrics						
c	ρ	P_0	L_q	L_s	W_q	W_s
3	43.29%	64.82%	2	3	0.1097978 hours	0.2475388 hours
2	64.94%	50.97%	9	10	0.870494 hours	1.0082955 hours

From Table 5, it can be observed that by utilizing three platforms for train service, the idle time in the system can be reduced. Therefore, the optimal number of platforms for the commuter line service is nine for the machine gate check-in facility and three for the train service facility as given in the Table 6.

Table 6: Comparison of the Commuter Line Service at Bekasi Station

	The number of train service facilities (c)	
	4 platforms	3 platforms
λ	9.43	9.43
μ	7.26	7.26
ρ	32.47%	43.29%
P_0	72.27%	64.82%
L_q	1	2
L_s	2	3
W_q	0.0057642 hours	0.1097978 hours
W_s	0.1435052 hours	0.2475388 hours

The results of the facility reduction can be seen in Table 6, which indicates that by reducing the existing facilities during the studied operational hours, the idle time in the system can be reduced and the average waiting time for trains in the queue becomes longer.

5. Conclussion

Based on the analysis of the service models conducted in the research, the following conclusions can be drawn:

1. The determination of the optimal number of gate machines in the commuter line gate facility at Bekasi Station was done by calculating the general service model for passengers. It was found that the optimal number of check-in machines is nine gates, accompanied by the optimal number of platforms, which is three railway platforms during the research period.
2. The appropriate service structure model to be applied to the commuter line service at Bekasi Station is Multiple Channel Single Phase with the model ($G/G/9: FCFS/\infty/\infty$), and for the train service, the service structure is Multi Channel Single Phase with the model ($G/G/3: PS/\infty/\infty$).
3. The commuter line service at Bekasi Station has a busyness level of 70.78%, and for the train service, it is 32.47%. The low busyness level of the train service results in a large idle time in the system. Therefore, the commuter line service at Bekasi Station would be more optimal by reducing the provided service facilities during the research's operational hours.

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