

**ANALYSIS OF QUEUE MODEL ON THE QUEUE SYSTEM FOR
PATIENTS IN THE HEALTH CENTRE OF LUBUK BEGALUNG**

UNDERGRADUATE THESIS
As partial fulfillment for bachelor degree in science



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Hereby declare that the thesis entitled “**Analysis of Queue Model on the Queue System for Patients in the Health Centre of Lubuk Begalung**” is an authentic work of mine, not a plagiarism of any other person’s work arranged in unpermitted ways of citation which violate the code in scientific traditions. If at any time later, it is proven that I have committed plagiarism then I am willing to be processed and receive academic as well as legal sanctions as stated in laws and regulations, both in UNP institutions, in the society and the State.

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ASBTRACT

Siti Aisyah : Analysis of Queue Model On the Queue System for Patients in the Health Centre of Lubuk Begalung

A queue is a line of people or goods waiting to get service. Queues usually occur when people who need services exceed service capacity or when the service facilities are inadequate. Long queues at a service facility result in an accumulation of the number of customers, so that the service time is getting longer. This situation is often found in public service facilities such as health centres, one of which is the public health centre of Lubuk Begalung (HCLB). The purpose of this study was to determine the effectiveness of the queuing model applied to the HCLB and the level of aspiration that can be used.

This research is an applied research using primary data. The study population was all patients seeking for medical treatment at the HCLB and the sample of the study were the patients who were in the registration section and patients who received treatment in the HCLB. The sampling technique used was accidental sampling. The research method used, namely by calculating the average time between arrivals and calculating the average time of service. Furthermore, the Kolmogorov-Smirnov test was carried out to determine the data distribution. A number of analysis are performed to determine the average patient waiting in the queue, the average patient waiting in the system, the average time in the system, and the average time in the queue.

The results showed that the queuing model at the HCLB was less effective since it is found a long waiting time for patients in Monday, Tuesday and Wednesday (103 minutes/person), while for Thursday it was 50 minutes/person, for Friday 100 minutes/person, and for Saturday 79 minutes/ person. The aspiration level used, namely the average waiting time in the system for Monday, Tuesday, Wednesday and Thursday is 68 minutes/person, while for Thursday and Friday 38 minutes/person. The percentage of employee free time is 20%. It suggests that the number of employees needs to be increased, especially on Monday, Tuesday and Wednesday.

Keywords: queue, effectivity, accidental sampling

FOREWORD



Alhamdulillah rabbi all praise and gratitude for the presence of Allah SWT who has given His grace and gifts, so I can complete this thesis entitled "**Analysis of Queue Model On the Queue System for Patients in the Health Centre of Lubuk Begalung**". Furthermore, salawat along with greetings to the prophet Muhammad SAW as role models for all people.

The writing of this thesis is intended to fulfill one of the requirements in order to complete the undergraduate study in the Mathematics Study Program of the State University of Padang. In this research, many troubles have been encountered since the choosing the appropriate topic for this thesis. I would like to deliver my gratitude for all guidance, motivation, prayers, suggestions, assistance, and support from everyone that make possible the complete presence of this tthesis. Therefore, on this occasion the researcher with all humility would like to thank:

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Padang, July 2018

Author

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CHAPTER I

INTRODUCTION

A. Research Background

Queues are people or goods in a line waiting to be served (Heizer and Render, 2006: 658). Queuing is a common activity in everyday life as found in banks, supermarket cashiers, hospitals and others. Queuing occurs when people who need services exceed service capacity or service facilities are inadequate causes users who come cannot immediately get served. Busy service resulting in long queues and accumulation of the number of customers. Therefore, the service time is getting longer, like found in the HC of Lubuk Begalung, one of the busiest HC in Padang Municipality.

The HC of Lubuk Begalung (HCLB) is a public health centre located on Jalan Pulai Air, Lubuk Begalung Subdistrict. HCLB does not serve in-patients. Based on the observation carried out on February 5 2018 at HCLB it is found that patients seeking for medical treatments can be divided into two namely BPJS and non-BPJS customers. The number of BPJS customers is far higher than non-BPJS. There are nine polyclinics available in the HCLB, namely, a general clinic, a dental clinic, an elderly clinic, a childcare clinic, pregnancy clinic, nutrition clinic, immunization clinic, TB (Tuberculosis) clinic, and family planning (KB). Most patients demand services from the general clinic.

The increase in the number of patients in HCLB occurred since the implementation of BPJS as national health insurance system. Those whose insurances are registered in HCLB cannot seek treatment directly from other HC.

Patients who want to receive hospital services must also obtain referral letters from HC except in an emergency. This causes patients who seek treatment during rush hour to queue for a long time, especially in the registration department.

Based on the results of observations, the long time needed by patients to obtain a status seems to be caused by manual method of document management which slowing the searching and storing. The waiting time is recorded the longest in Monday, Tuesday and Wednesday, which is averagely 103 minutes/person, while for Thursday 50 minutes/person, for Friday it is 100 minutes/person, and for Saturday it is 79 minutes/person. According to one patient, the long waiting time often caused the patient feel sicker and finally decided to cancel the treatment.

This problem encourages to carry out a systematic research as an analysis on the current queuing system at the HCLB. The end product expected from this research is a more optimal queuing system which consider the balance between the waiting time and employee idle time.

The optimal queuing system can be viewed from the point of certain aspiration levels determined by the decision maker. The level of aspiration in this study is defined as the target HCLB wants to achieve with the aim of improving its services. This level of aspiration is defined as an upper bound against the values of conflicting measures that the decision maker wants to balance. The level of aspiration according to Devi (2004: 22) is that the average waiting time in the system is not more than 10 minutes, while the employee's idle time is not more than 20%. To achieve this goal, a study entitled "**Analysis of the Queuing Model in the**

Queuing System for Patients in the Health Center of Lubuk Begalung” is presented.

B. Research Scope

Based on the research background stated previously it is known that the HCLB consists of several clinics/departments. This study only focuses the observation on two departments, namely queues at the registration section and the general clinic.

C. Problem Formulation

The research problem in this study is formulated as "how is the effectiveness of the queuing model applied to the queue of patients in HCLB?"

D. Research Approaches and Questions

Based the problem formulated, the approach used is a stochastic concept followed by its application that simulates more ideal queue situations in HCLB. Therefore, this research is an applied research that begins with a literature study to obtain relevant theories and ends with a queue system to solve the problem.

The research questions in this study are:

1. How effective is the queuing model applied to HCLB?
2. What is the aspiration level that can be used to provide an optimal service?

E. Research Objectives

The main objectives to be achieved in this study are to measure the effectiveness of the queuing model when applied to HCLB and to find out the optimal level of aspiration in order to provide an ideal queue service.

F. Research Benefits

The results of this study are expected to provide some benefits as follows:

1. Increasing knowledge and insight as well as understanding of study material to apply to real-world problem
2. Help providing a tool for decision making in employee management in the HCLB.
3. As a reference for other researchers in the similar topic or methodology.

CHAPTER II

THEORETICAL REVIEW

A. Definition of Queue

Queuing is one of applied mathematics theories concerning the waiting lines (Taha, 2007). A queue happens when the need for a service exceeds the available capacity to provide the service.

The average waiting time depends on the average rate of service delivered. The theory of queuing was discovered and developed by A. K. Erlang, an engineer from Denmark who worked for a telephone company in Copenhagen in 1910. Erlang conducted experiments on fluctuations in telephone facility demand related to automatic dialing equipment, namely automatic telephone connection equipment. In busy times, operators are very overwhelmed to serve callers quickly, so callers have to queue to wait their turn (Bagaskara, 2017).

B. Queue System

The queuing system consists of "customers" arriving at random times to several facilities, where they receive particular service from certain service unit and complete the request. Several mathematical symbols to represent the variables and parameters used in discussing a queuing system (Mawengkang, 2013: 13), namely:

- n : number of units (ex: customers, goods, etc) lining up in a queue
- $P_{n(t)}$: the probability there exists n units in the system at time t
- Λ : average arrivals in the system per time unit
- λ_n : average arrivals in the system if n units already lining up in the queue
- μ : average units that have been served by the system per time unit
- μ_n : average units that have been served by the system if n units already lining up in the queue.
- r : number of parallel service units
- L_s : average units in the system
- L_q : average units in a queue
- W_s : average time spent by a unit in the system
- W_q : average time spent by a unit in a queue

C. Notation and Terms

An appropriate notation to summarize the main characteristics of parallel queues, universally standardized in the following format (a / b / c /): (d / e / f) with symbols a, b, c, d, e, and f are the basic elements of this model as described below (Sugito, 2011: 294):

- a : Arrival distribution
- b : Service time (departure) distribution
- c : Number of parallel services ($c = 1, 2, \dots, \infty$)
- d : Service rules (for example: FCFS, LCFS, SIRO, etc)
- e : maximum number of units allowed to queue up in the system
- f : the measure of calling source

D. Queue Model (M/M/c):(GD/∞/∞)

A Queue model has the following properties:

1. The number of arrivals follows a Poisson or exponential distribution
2. Service time also follows a Poisson or exponential distribution
3. The system has more than one service unit
4. Queuing rule is 'first in first out' (FIFO)
5. The number of customers wanted to be in the system is unlimited
6. The number of customers who wish to enter the system is unlimited

Queuing model (M / M / C): (GD / ∞ / ∞) is also known as a dual channel queuing system, because it has more than one service unit. According to Siagian (1987: 418), the average service rate μ_n in a dual channel queuing system is obtained by

$$\mu_n = \begin{cases} n\mu & n < c \\ c\mu & n \geq c \end{cases}$$

For $n < c$,

$$\begin{aligned} P_n &= \frac{\lambda^n}{\mu(2\mu)(3\mu) \dots (n\mu)} P_0 \\ &= \frac{\lambda^n}{n! \mu^n} P_0 \\ P_n &= \frac{\rho^n}{n!} P_0 \end{aligned} \tag{1}$$

While for $n \geq c$,

$$\begin{aligned}
P_n &= \frac{\lambda^n}{\mu(2\mu)(3\mu) \dots (c-1)\mu \underbrace{(c\mu)(c\mu) \dots (c\mu)}_{(n-c)\text{times}}} P_0 \\
&= \frac{\lambda^n}{c! c^{n-c} \mu^n} P_0 \\
P_n &= \frac{\rho^n}{n! c^{n-c}} P_0
\end{aligned} \tag{2}$$

where:

n : the number of customers

c : the number of service units available

ρ : the probability of system being busy

From Eq. (1) and (2), the value of P_0 can be obtained

$$\begin{aligned}
\sum_{n=0}^{\infty} P_n &= 1 \\
\sum_{n=0}^{c-1} \frac{\rho^n}{n!} P_0 + \sum_{n=c}^{\infty} \frac{\rho^n}{c! c^{n-c}} P_0 &= 1 \\
P_0 \left(\sum_{n=0}^{c-1} \frac{\rho^n}{n!} + \sum_{n=c}^{\infty} \frac{\rho^n}{c! c^{n-c}} \right) &= 1 \\
P_0 \left(\sum_{n=0}^{c-1} \frac{\rho^n}{n!} + \frac{\rho^c}{c!} \sum_{n=c}^{\infty} \frac{\rho^{n-c}}{c^{n-c}} \right) &= 1 \\
P_0 \left(\sum_{n=0}^{c-1} \frac{\rho^n}{n!} + \frac{\rho^c}{c!} \sum_{m=0}^{\infty} \frac{\rho^m}{c^m} \right) &= 1 \\
P_0 \left[\sum_{n=0}^{c-1} \frac{\rho^n}{n!} + \frac{\rho^c}{c!} \left(1 + \frac{\rho}{c} + \frac{\rho^2}{c^2} + \dots \right) \right] &= 1 \\
P_0 \left[\sum_{n=0}^{c-1} \frac{\rho^n}{n!} + \frac{\rho^c}{c!} \frac{1}{\left(1 - \frac{\rho}{c} \right)} \right] &= 1 \\
P_0 &= \frac{1}{\sum_{n=0}^{c-1} \frac{\rho^n}{n!} + \frac{\rho^c}{c!} \frac{1}{\left(1 - \frac{\rho}{c} \right)}}, \quad \frac{\rho}{c} < 1
\end{aligned} \tag{3}$$

For the model (M/M/C): (GD/ ∞/∞), steady state condition is that $\frac{\rho}{c} = \frac{\lambda}{c\mu} <$

1. If this condition is not satisfied, then the size of queue increases to infinity (Siagian, 1987: 403).

If a customer is in the system, then one waiter will be busy and $c - 1$ other are vacant/free. If there are two customers in the system, the two waiters will be busy and other $c - 2$ waiters are free. Until $n \geq c$ all services will be busy. The probability of a busy period can be calculated as follows:

$$f(b) = P(n \geq c) = \frac{\rho^c}{c! \left(1 - \frac{\rho}{c}\right)} P_0$$

The concept above can be described further as follows:

1. Let L_q the average customers waiting for service in the system, written that:

$$\begin{aligned} L_q &= \sum_{n=c}^{\infty} (n - c) P_n = \sum_{m=0}^{\infty} m P_{m+c} = \sum_{m=0}^{\infty} m \frac{\rho^{m+c}}{c! c^m} P_0 \\ &= \frac{\rho^c}{c!} \frac{\rho}{c} P_0 \sum_{m=0}^{\infty} m \left(\frac{\rho}{c}\right)^{m-1} \end{aligned}$$

Since $m \left(\frac{\rho}{c}\right)^{m-1}$ is the first derivative on $\frac{\rho}{c}$, i.e:

$$\frac{d}{d\left(\frac{\rho}{c}\right)} \left(\frac{\rho}{c}\right)^m = m \left(\frac{\rho}{c}\right)^{m-1}$$

then,

$$\begin{aligned} &= \frac{\rho^c}{c!} \frac{\rho}{c} P_0 \left[\sum_{m=0}^{\infty} \frac{d}{d\left(\frac{\rho}{c}\right)} \left(\frac{\rho}{c}\right)^m \right] \\ &= \frac{\rho^c}{c!} \frac{\rho}{c} P_0 \frac{d}{d\left(\frac{\rho}{c}\right)} \left[\sum_{m=0}^{\infty} \left(\frac{\rho}{c}\right)^m \right] \end{aligned}$$

$$\begin{aligned}
&= \frac{\rho^c \rho}{c! c} P_0 \frac{\mathbf{d}}{\mathbf{d}\left(\frac{\rho}{c}\right)} \left(\frac{1}{1 - \frac{\rho}{c}} \right) \\
&= \frac{\rho^c \rho}{c! c} P_0 \left[\frac{1}{\left(1 - \frac{\rho}{c}\right)^2} \right] \\
L_q &= f(b) \frac{\frac{\rho}{c}}{1 - \frac{\rho}{c}} = f(b) \left(\frac{\lambda}{c\mu - \lambda} \right) \tag{4}
\end{aligned}$$

Let L_s the average customers in the system:

$$L_s = f(b) \left(\frac{\lambda}{c\mu - \lambda} \right) + \frac{\lambda}{\mu} \tag{5}$$

2. Let W_s the average time spent by customers in the system:

$$w_s = f(b) \left(\frac{1}{c\mu - \lambda} \right) + \frac{1}{\mu} \tag{6}$$

3. Let W_q the average time spent by customers in a queue:

$$w_q = f(b) \left(\frac{1}{c\mu - \lambda} \right) \tag{7}$$

E. Basic Elements in Queue System

A queue system consists of several basic elements. According to Nugroho (2012: 174-175) there are four basic elements in a queue system namely:

1. Customer's arrival

Customer arrival is an input process that describes the number of customers who will enter the queue system. Customers must enter the queue first prior to receiving service.

2. Customer Arrival Patterns

Customer arrivals form up particular pattern. In the queuing system, there are two arrival patterns, namely the pattern of customer arrival which tends to be irregular and the pattern of customer arrival which tends to be constant.

3. Queuing System

The queuing system consists of two parts, namely the queuing process carried out by the customer and service facilities owned by the service provider.

a. Queue

If a customer comes, the customer will automatically enter the queuing system. In a queuing system, customers must first wait for service. In the waiting process, the company applies queuing discipline. Queuing discipline is a policy implemented by companies in providing services to customers.

b. Service facility

It relates to how many resources the service provider possesses to provide services to its customer. The number of service facilities affects the number of customers can be served per time unit and the average time it takes for a customer to be in a queuing system. By the ownership of service facilities, the provider can be classified into single service facilities and non-single service facilities.

4. Service rate

The service rate is associated with the average number of customers that can be served during a certain period of time and the time spent to

deliver services to customers. In a queuing system, the service rate performed by the providers follows an exponential distribution and denoted by μ .

F. Queue disciplines (rules)

Queuing discipline is a policy containing a number of rules implemented by the provider in delivering services to customers. According to Kakiay (2004: 12), the service rules by the order of arrival are as follows:

1. First in first out (FIFO)

FIFO means that those arrive first will be served earlier.

2. Last in first out (LIFO)

LIFO means that the last one who arrived will be served earlier or the earliest

3. Service in Random Order (SIRO)

SIRO means that the service is carried out randomly.

4. Priority Queue (PRI)

Means that the service priority is given to those who needs the service the most (having priority or urgency), even though they come later.

G. Factors affecting a queue system

According to Kakiay (2004: 4), there are several factors related to a queue system which affects the queue line, as follows:

1. Distribution of arrivals

The queuing model is a probabilistic (stochastic) model because certain elements included in the model are random variables. This random variable is often described with probability distribution. Both arrival and service

times in a queuing process are generally expressed as random variables. The distribution of customer arrivals contains the data on the time between arrivals, which is the time between successive arrivals of two customers at a service facility. In the queuing system, arrival distribution is an important factor that has a major influence on the smooth running of services.

2. Distribution of service duration

The service duration is the time needed to serve customers at a service facility. The service duration of one customer does not depend on the service duration given to previous customers, and does not depend on the number of entrants who are waiting to be served.

H. Measure of arrival population

The measure of arrival population can be classified into two types according to Heizer dan Render (2008: 755), as follows:

1. Infinite population, means that there is no limitation to the number of customers asking for service.
2. Finite population, means that the number of service customers is limited.

I. Queuing processes

Lumba (2015: 44) proposed that the queuing process is generally grouped into four basic structures by the characteristics of service facilities, as follows:

1. One channel one stage

A type of queuing process that usually occurs when patients attend a doctor's clinic in which one patient is only served by one doctor.

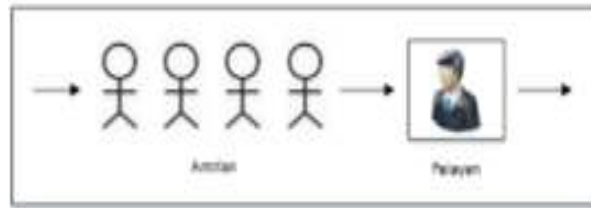


Figure 1 One channel one phase queuing process

2. Multi channels one stage

A type of queuing process that typically occurs when a bank customer is queuing to make money deposit transactions at a bank teller.

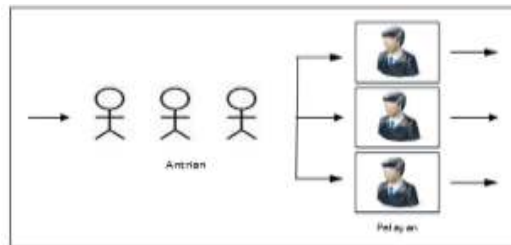


Figure 2 Multi channel one phase queuing process

3. One channel multi stages

A queuing process that usually occurs when a prospective bank customer is queuing to open a new account with a bank officer.

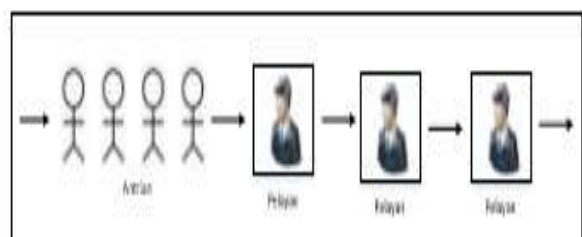


Figure 3 One channel multi phases queuing process

4. Multi channels multi stages

This type of queuing process also usually occurs at the immigration office for the passport creation process. A person who will make a passport will go through several stages but officers are available at several counters.

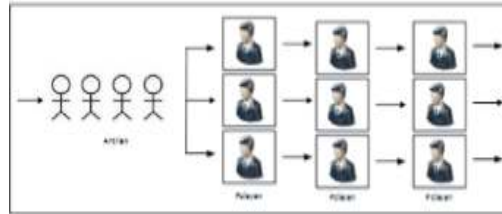


Figure 4 Multi channels multi stages queuing process

J. Exponential distribution

The exponential distribution according to Ross (2003: 270), is a continuous function of random variable with the parameter λ , where $\lambda > 0$, and has a probability density function defined as follows:

$$f(x) = \lambda e^{-\lambda x}, \quad x \geq 0 \quad (8)$$

where

$$E(x) = \int_{-\infty}^{\infty} x f(x) d(x) = \int_0^{\infty} x \lambda e^{-\lambda x} d(x)$$

Let $u = x$, and $dv = \lambda e^{-\lambda x} dx$,

$$\begin{aligned} E(x) &= -x e^{-\lambda x} \Big|_0^{\infty} + \int_0^{\infty} e^{-\lambda x} \\ &= 0 + \left(-\frac{1}{\lambda} e^{-\lambda x} \Big|_0^{\infty} \right) \\ &= -\frac{1}{\lambda} (-1) \\ &= \frac{1}{\lambda} \end{aligned}$$

In this study, the average time between arrivals is denoted by $1/\lambda$, and the patient arrival rate is denoted by λ which is defined as the number of patients arriving per time unit. The average service is denoted by μ which is defined as the number of patients completing to receive service per time unit. The average time required to serve each patient is denoted by $1/\mu$.

K. Decision model

According to Taha (1997), the queue decision depends on the aspiration level. The aspiration rate model directly utilizes the system characteristics to determine the optimal values of the parameters. Optimization in this context means as meeting a certain level of aspiration determined by the decision maker. According to Siagian (1987: 441) in the dual service model, there are two most prominent measures for conflict in determining the optimum value of c , namely:

1. Expected average waiting time in the system
2. Percentage of idle/free time (X), formulated as follows:

$$X = \frac{100}{C} \sum_{n=0}^c (c - n) P^n$$

$$X = 100 \left(1 - \frac{\rho}{C}\right) \quad (9)$$

Let the aspiration rate for $E(t_s)$ and X denoted by a and b . An aspiration rate is an optimum number of service unit c such that $E(t_s) \leq a$ and $X \leq b$. According to Devi (2004: 22), the expected average waiting time in the system should not be more than 10 minutes, with servant idle or free time should not be more than 20%.

L. Data fit test

This is a mechanism to test if the observed data have a certain theoretical distribution. The data fit test used was the Kolmogorov-Smirnov's one-sample test. The Kolmogorov-Smirnov's test is a widely used normality test, especially after a number of statistical programs released to the market (Hidayat, 2012). The test is fairly simple that it may not cause differences in perceptions among observers.

The basic concept of the Kolmogorov-Smirnov's normality test is to compare the data distribution (which will be tested for normality) with the standard normal distribution. In this test, if the significance falls below 0.05, then the data is considered to have a significant difference with standard normal data, or simply, the data is not normally distributed.

If $F_0(x)$ is a theoretical frequency distribution, then the value of $F_0(x)$ is the proportion of cases expected to have a value equal to or less than x . Let $S_N(x)$ be the cumulative frequency distribution of a random sample X with N observations, where x is an arbitrary value, $S_N(x) = \frac{K}{N}$ and K is the number of observations, $K \leq x$.

The Kolmogorov-Smirnov's test focuses on the largest deviation. The value of the largest $F_0(x) - S_N(x)$ is called the maximum deviation. The test statistic used in the Kolmogorov-Smirnov's test is formulated as follows (Siegel, 1990: 59):

$$D_{test} = \max|F_0(x) - S_N(x)| \quad (10)$$

The hypothesis for testing the average time between arrivals is as follows:

H_0 : $F_0(x) = S_N(x)$, the time between arrivals is exponential distributed

H_1 : $F_0(x) \neq S_N(x)$, the time between arrivals is not exponential distributed

The hypothesis for testing the service duration is as follows:

$H_0: F_0(x) = S_N(x)$, the service duration is exponential distributed

$H_1: F_0(x) \neq S_N(x)$, the service duration is not exponential distributed

The criteria for rejecting the hypothesis using $\alpha = 0,05$ are as follows:

If $D_{test} > D_{table}$, then reject H_0

If $D_{test} < D_{table}$, then accept H_0

CHAPTER III

RESEARCH METODOLOGY

A. Research type

This research is classified as an applied research which mainly focuses on providing solutions to certain problems. This research emphasizes the application theories in daily practices and does not intend specifically on developing theoretical concepts and ideas. This research begins with theoretical analysis and data collection.

B. Population and sample

1. Population

According to Sugiyono (2005: 72), population is defined as a general area or set consisting of objects or subjects that have certain qualities and characteristics determined by researchers to be studied and then draw conclusions. The population in this study are all patients demanding medical treatments in HCLB.

2. Sample

Notoatmojo (2003) proposed sample as a portion of the object taken from the whole population being studied and is considered to represent the entire population. The sampling technique used in this study is accidental sampling. According to Usman (1995: 185), accidental sampling is a sampling technique based on chance, where anyone who happens to meet the researcher can be used as a sample, if researcher considers him/her qualified as a data source. In this study, the accidental sampling was

implemented to pick random patients in the registration section and patients being treated in the general clinic in HCLB.

C. Data type

Since the data are collected through accidental sampling, then the data type is said to be primary, which means that the data are obtained directly from the observed sample. These data include several variables such as the time the patient came, the time the patient was served and the time the patient left.

D. Data collection methods

The data collection technique used was a direct observation at the registration section and the general clinic of HCLB. These observations were intended to record the time patient arrived, the time the patient started being served and the time the patient finished being served. The observation required an observer with an assistant, with a digital clock used as time indicator instrument.

E. Data analysis technique

From the observation, the time between the patient's arrival and the patient's service time was recorded for six days, then the data were tabulated. The data analysis is then performed with the following steps:

1. Calculating the average arrival time $\left(\frac{1}{\lambda}\right)$ and calculating the average service duration $\left(\frac{1}{\mu}\right)$.
2. Performing the *Kolmogorov-Smirnov's* test to the data on the average time between arrivals and average service duration in six observation days. The test is carried out using SPSS 19™ program.

3. Performing queue analysis using Pom for Windows™ program:
 - a. Calculating the number of patients per time unit (λ)
 - b. Calculating the number of patients completing the service per time unit (μ) and calculating $\frac{\rho}{c}$
 - c. Calculating average number of patients in the system (L_s)
 - d. Calculating average number of patients in the queue (L_q)
 - e. Calculating average time spent by patients in the system (W_s)
 - f. Calculating average time spent by patients in the queue (W_q)
 - g. Making a decision by using aspiration rate

CHAPTER IV RESULTS AND DISCUSSION

A. Results

1. Data Description

The research data was collected by recording the time the patient arrived, the time the patient began to be served, and the time the patient completes being served, in the HCLB. Observations were carried on from Monday, 5 February 2018 to Saturday 10 February 2018, where in each day started from 08.00 WIB - 13.00 WIB, except on Saturday from 08.00 WIB - 11.30 WIB. The data obtained from the observations are available in Appendix 1. Using these data, the time between the patient arrivals (defined as the time between two consecutive patient arrivals in the registration section) and the patient service duration (defined as the time required to serve a patient) are calculated completely.

Table 1. Time between patient arrivals and the patient service duration in Monday

No	Time between patient arrivals (minute)	Service duration (minute)	No	Time between patient arrivals (minute)	Service duration (minute)
(1)	(2)	(3)	(1)	(2)	(3)
1	0	27	25	9	28
2	5	30	26	11	32
3	3	30	27	12	23
4	1	37	28	1	20
5	4	34	29	5	30
6	3	36	30	2	31
7	1	30	31	2	28
8	2	35	32	4	41
9	3	29	33	0	39
10	3	33	34	4	56
11	5	33	35	1	53
12	8	43	36	2	43

No	Time between patient arrivals (minute)	Service duration (minute)	No	Time between patient arrivals (minute)	Service duration (minute)
13	7	44	37	6	72
14	7	44	38	4	54
15	11	44	39	10	61
16	5	3	40	1	56
17	1	35	41	2	61
18	9	45	42	5	69
19	3	47	43	2	66
20	4	59	44	5	69
21	15	59	45	1	68
22	9	51	46	2	73
23	6	44	47	1	69
24	15	39	48	0	70
			\bar{x}	4.625	44.229

Table 1 shows that the time between patient arrivals on Monday ranged from 0 minutes to 17 minutes with the average (mean) of 4.63 minutes. The most frequently occurring time between patient arrivals (mode) was 1 minute. Meanwhile, the patient service duration ranged from 20 minutes to 73 minutes, with mode of 30 minutes and mean of 44.22 minutes.

Table 2. Time between patient arrivals and the patient service duration in Tuesday

No	Time between patient arrivals (minute)	Service duration (minute)	No	Time between patient arrivals (minute)	Service duration (minute)
(1)	(2)	(3)	(1)	(2)	(3)
1	0	28	20	1	28
2	2	28	21	2	27
3	3	28	22	1	61
4	6	28	23	1	29
5	4	71	24	15	41
6	2	74	25	4	42
7	9	73	26	1	44
8	1	73	27	2	42
9	2	62	28	2	57
10	2	107	29	2	36
11	2	59	30	4	37

No	Time between patient arrivals (minute)	Service duration (minute)
12	6	113
13	7	112
14	2	53
15	1	69
16	10	95
17	17	83
18	11	62
19	13	27

No	Time between patient arrivals (minute)	Service duration (minute)
31	8	45
32	17	30
33	5	37
34	6	32
35	9	40
36	3	45
37	4	48
38	3	57
\bar{x}	5	53.237

Table 2 shows that the time between patient arrivals on Tuesday ranged from 0 minutes to 17 minutes with a mode of 2 minutes, and a mean of 5 minutes. Meanwhile, the duration of patient service ranges from 27 minutes to 113 minutes. The most frequently occurring duration was 28 minutes and the average duration of service was 53.23 minutes.

Table 3. Time between patient arrivals and the patient service duration in Wednesday

No	Time between patient arrivals (minute)	Service duration (minute)
(1)	(2)	(3)
1	0	73
2	3	72
3	1	66
4	1	77
5	2	93
6	4	46
7	2	68
8	1	67
9	4	37
10	3	65
11	6	41
12	3	56
13	1	74
14	3	63
15	0	53

No	Time between patient arrivals (minute)	Service duration (minute)
(1)	(2)	(3)
22	1	58
23	4	61
24	4	57
25	4	62
26	2	81
27	1	63
28	6	85
29	2	58
30	9	55
31	2	57
32	2	56
33	0	40
34	9	46
35	3	51
36	27	17

No	Time between patient arrivals (minute)	Service duration (minute)
16	8	59
17	4	45
18	1	45
19	13	50
20	1	96
21	0	73

No	Time between patient arrivals (minute)	Service duration (minute)
37	9	17
38	17	23
39	15	14
40	5	30
41	10	25
42	5	30
\bar{x}	4.714	54.881

Table 3 shows that the time between patient arrivals on Wednesday ranged from 0 minutes to 27 minutes with a mode of 2 minutes, and a mean of 4.71 minutes. While the duration of patient service ranged from 14 minutes to 85 minutes with a mode of 50 minutes and a mean is 54.88 minutes.

Table 4. Time between patient arrivals and the patient service duration in Thursday

No	Time between patient arrivals (minute)	Service duration (minute)
(1)	(2)	(3)
1	0	25
2	4	51
3	1	58
4	1	45
5	4	50
6	14	46
7	9	38
8	1	57
9	6	39
10	3	48
11	15	35
12	2	34
13	2	32
14	1	20
15	1	28
16	4	22

No	Time between patient arrivals (minute)	Service duration (minute)
(1)	(2)	(3)
17	4	48
18	3	80
19	7	45
20	5	57
21	9	40
22	7	33
23	9	29
24	10	29
25	13	20
26	3	37
27	7	35
28	7	33
29	1	42
30	9	38
\bar{x}	5.4	39.8

Table 4 shows that the time between patient arrivals on Thursday ranged from 0 minutes to 19 minutes with a mode of 1 minute and an average of 5.4 minutes. Meanwhile, the duration of patient care ranged from 20 minutes to 80 minutes with a mode of 30 minutes and an average of 39.8 minutes.

Table 5. Time between patient arrivals and the patient service duration in Friday

No	Time between patient arrivals (minute)	Service duration (minute)	No	Time between patient arrivals (minute)	Service duration (minute)
(1)	(2)	(3)	(1)	(2)	(3)
1	0	66	12	5	48
2	9	61	13	15	33
3	1	55	14	3	35
4	9	54	15	7	31
5	4	52	16	7	28
6	6	71	17	16	36
7	4	57	18	3	48
8	10	59	19	10	43
9	9	57	20	8	75
10	0	60	21	10	90
11	8	55	\bar{x}	6.857	53.048

Table 5 shows that the time between patient arrivals on Friday ranged from 0 minutes to 16 minutes with a mode of 1 minute and an average of 6.85 minutes. While the duration of patient care was recorded to range from 28 minutes to 90 minutes with a mode of 30 minutes and an average of 53.04 minutes.

Table 6. Time between patient arrivals and the patient service duration in Saturday

No	Time between patient arrivals (minute)	Service duration (minute)	No	Time between patient arrivals (minute)	Service duration (minute)
(1)	(2)	(3)	(1)	(2)	(3)
1	0	41	16	2	34
2	13	42	17	2	37
3	8	29	18	17	84

No	Time between patient arrivals (minute)	Service duration (minute)	No	Time between patient arrivals (minute)	Service duration (minute)
4	3	23	19	5	97
5	2	38	20	6	35
6	8	30	21	7	29
7	5	29	22	8	31
8	2	27	23	2	33
9	1	29	24	6	18
10	2	27	25	2	28
11	2	30	26	1	43
12	2	27	27	2	32
13	2	24	28	2	31
14	1	29	29	3	55
15	1	37	30	9	30
			\bar{x}	4.2	35.967

Table 6 shows that the time between patient arrivals on Saturday ranged from 0 minutes to 17 minutes with a mode of 1 minute and an average of 4.2 minutes. Meanwhile, the duration of patient care ranged from 18 minutes to 97 minutes with a mode of 30 minutes and an average of 35.96 minutes

2. Test on distribution of the time between patient arrivals and the duration of patient service

a. Test on time distribution in Monday

The number of patients who came on Monday was 48 people, as listed in Appendix 1. The time between patient arrivals on Monday can be grouped into several 2-minute data intervals as shown in Table 7 below.:

Table 7. Grouped time between patient arrivals on Monday

No	Time between arrivals (minutes)	Frequency (f_i)	x_i	$f_i x_i$
1	0-2	17	1	17
2	3-5	16	4	64
3	6-8	5	7	35
4	9-11	6	10	60
5	12-14	1	13	13
6	15-17	2	16	32
Total		47		222

From these data, it was obtained the average time between patient arrivals, denoted by $\frac{1}{\lambda} = \frac{222}{47} = 4.7$ minutes/person. The tests to determine whether the data follows the exponential distribution are listed in Appendix 4, with the results of which are summarized in Table 8 below .

Table 8. Test on the time between patient intervals

Day/date	Exponential parameter (a, b)	N	Asymptotic significance (2-tailed)
Monday/5 February 2018	13,43	7	0,914
Tuesday/6 February 2018	10,57	7	0,954
Wednesday/7 February 2018	13,67	7	0,068
Thursday/8 February 2018	9,67	6	0,998
Friday/9 February 2018	6,67	7	0,274
Saturday/10 February 2018	8,29	7	0,491

Table 8 shows that criteria used for the test are Asymptotic Significances (2-tailed). For Monday, the value of Asymp.Sig (2-tailed) is calculated to be 0.914, which is above 0.05. Therefore, it is concluded that the null hypothesis, H_0 , is accepted. In other words, the time between patient arrivals in Monday follows an exponential distribution. Furthermore, testing if the data on the duration of patient service on Monday is exponential distributed, with the same technique, started with grouping the data into several 8-minute intervals as listed in Table 9 below:

Table 9. Grouped duration of patient service on Monday

No	Service duration (minutes)	Frequency (f_i)	x_i	$f_i x_i$
1	20-28	5	24	120
2	29-37	15	33	495
3	38-46	10	42	420
4	47-55	4	51	204
5	56-64	6	60	360
6	65-73	8	69	552
Total		48		2151

The average of service duration is calculated to be $\frac{1}{\mu} = \frac{2151}{48} = 44.8$ minutes per person. Furthermore, the parameters used in the test to determine if the data on service duration in Monday follows an exponential distribution are listed in the following Table 10:

Table 10. Test on the duration of patient service

Day/date	Exponential parameter (a, b)	N	Asymptotic significance (2-tailed)
Monday/5 February 2018	8,00	6	0,311

Tuesday/6 February 2018	5,43	7	0,985
Wednesday/7 February 2018	7,00	6	0,460
Thursday/8 February 2018	10,00	7	0,519
Friday/9 February 2018	7,00	6	0,852
Saturday/10 February 2018	10,00	6	0,576

The Asymp.Sig (2-tailed) value in Table 10 is the test criteria used to determine whether the data is exponentially distributed. The Asymp.Sig (2-tailed) value for Monday is calculated at 0.311, which is above 0.05 ($0.311 > 0.05$) thus the null hypothesis H_0 is accepted and it can be concluded that the duration of patient care on Monday follows an exponential distribution.

b. Test on time distribution in Tuesday

Table 11. Grouped time of patient arrivals on Tuesday

No	Service duration (minutes)	Frequency (f_i)	x_i	$f_i x_i$
1	0-2	16	1	17
2	3-5	8	4	32
3	6-8	5	7	35
4	9-11	4	10	40
5	12-14	1	13	13
6	15-17	3	16	48
Total		37		185

The average of the time of patient arrivals is calculated to be $\frac{1}{\mu} = \frac{185}{37} = 5$ minutes per person. Furthermore, the parameters used in the test to determine if the data on the time of patient arrivals in Tuesday follows an exponential distribution are listed previously mentioned Table 8.

As shown in Table 8, for Tuesday, the value of Asymp.Sig (2-tailed) is calculated to be 0.954, which is above 0.05. Therefore, it is concluded

that the null hypothesis, H_0 , is accepted. In other words, the time between patient arrivals in Tuesday follows an exponential distribution as also found for Monday. Furthermore, testing if the data on the duration of patient service on Tuesday is exponential distributed, with the same technique, started with grouping the data into several 12-minute intervals as listed in Table 12 below:

Table 12. Grouped duration of patient service on Tuesday

No	Service duration (minutes)	Frequency (f_i)	x_i	$f_i x_i$
1	27-39	13	33	429
2	40-52	8	46	368
3	53-65	7	60	420
4	66-78	5	72	360
5	79-91	1	85	85
6	92-104	1	98	98
7	105-117	3	111	333
Total		38		2093

The average of service duration is calculated to be $\frac{1}{\mu} = \frac{2093}{38} = 55$ minutes per person. Furthermore, the parameters used in the test to determine if the data on the service duration in Tuesday follows an exponential distribution are listed previously mentioned Table 10.

As shown in Table 10, for Tuesday, the value of Asymp.Sig (2-tailed) is calculated to be 0.985, which is above 0.05. Therefore, it is concluded that the null hypothesis, H_0 , is accepted. In other words, the patient service duration in Tuesday follows an exponential distribution as also found for Monday.

c. Test on time distribution in Wednesday

Table 13. Grouped time of patient arrivals on Wednesday

No	Service duration (minutes)	Frequency (f_i)	x_i	$f_i x_i$
1	0-4	28	2	58
2	5-9	8	7	56
3	10-14	2	12	24
4	15-19	2	17	34
5	20-24	0	22	0
6	25-29	1	27	27
Jumlah		41		199

The average of the time of patient arrivals is calculated to be $\frac{1}{\mu} = \frac{199}{41} = 4.85$ minutes per person. Furthermore, the parameters used in the test to determine if the data on the time of patient arrivals in Wednesday follows an exponential distribution are listed previously mentioned Table 8.

As shown in Table 8, for Wednesday, the value of Asymp.Sig (2-tailed) is calculated to be 0.068, which is above 0.05. Therefore, it is concluded that the null hypothesis, H_0 , is accepted. In other words, the time between patient arrivals in Wednesday follows an exponential distribution as also found for Monday and Tuesday. Furthermore, testing if the data on the duration of patient service on Wednesday is exponential distributed, with the same technique, started with grouping the data into several 11-minute intervals as listed in Table 14 below:

Table 14. Grouped duration of patient service on Wednesday

No	Service duration (minutes)	Frequency (f_i)	x_i	$f_i x_i$
1	14-25	5	19,5	97,5

2	26-37	3	31,5	94,5
3	38-49	6	43,5	261
4	50-61	12	55,5	666
5	62-73	10	67,5	675
6	74-85	6	79,5	477
Total		42		2271

The average of service duration is calculated to be $\frac{1}{\mu} = \frac{2271}{42} = 54$ minutes per person. Furthermore, the parameters used in the test to determine if the data on the service duration in Wednesday follows an exponential distribution are listed previously mentioned Table 10.

As shown in Table 10, for Wednesday, the value of Asymp.Sig (2-tailed) is calculated to be 0.460, which is above 0.05. Therefore, it is concluded that the null hypothesis, H_0 , is accepted. In other words, the patient service duration in Wednesday follows an exponential distribution as also found for Monday and Tuesday.

d. Test on time distribution in Thursday

Table 15. Grouped time of patient arrivals on Thursday

No	Service duration (minutes)	Frequency (f_i)	x_i	$f_i x_i$
1	0-3	11	1,5	18
2	4-7	10	5,5	55
3	8-11	4	9,5	38
4	12-15	3	13,5	40,5
5	16-19	1	17,5	17,5
Total		29		111

The average of the time of patient arrivals is calculated to be $\frac{1}{\mu} = \frac{111}{29} = 3.82$ minutes per person. Furthermore, the parameters used in the test to

determine if the data on the time of patient arrivals in Thursday follows an exponential distribution are listed previously mentioned Table 8.

As shown in Table 8, for Thursday, the value of Asymp.Sig (2-tailed) is calculated to be 0.998, which is above 0.05. Therefore, it is concluded that the null hypothesis, H_0 , is accepted. In other words, the time between patient arrivals in Thursday follows an exponential distribution. Furthermore, testing if the data on the duration of patient service on Thursday is exponential distributed, with the same technique, started with grouping the data into several 10-minute intervals as listed in Table 16 below:

Table 16. Grouped duration of patient service on Thursday

No	Service duration (minutes)	Frequency (f_i)	x_i	$f_i x_i$
1	20-30	7	25	175
2	31-41	11	36	396
3	42-52	8	47	376
4	53-63	3	58	174
5	64-74	0	69	0
6	75-85	1	80	80
Total		30		1201

The average of service duration is calculated to be $\frac{1}{\mu} = \frac{1201}{30} = 40$ minutes per person. Furthermore, the parameters used in the test to determine if the data on the service duration in Thursday follows an exponential distribution are listed previously mentioned Table 10.

As shown in Table 10, for Thursday, the value of Asymp.Sig (2-tailed) is calculated to be 0.519, which is above 0.05. Therefore, it is concluded that

the null hypothesis, H_0 , is accepted. In other words, the patient service duration in Thursday follows an exponential distribution.

- e. Test on time distribution in Friday

Table 17. Grouped time of patient arrivals on Friday

No	Service duration (minutes)	Frequency (f_i)	x_i	$f_i x_i$
1	0-2	2	1	3
2	3-5	5	4	20
3	6-8	5	7	35
4	9-11	6	10	60
5	12-14	0	13	0
6	15-17	2	16	32
Total		20		150

The average of the time of patient arrivals is calculated to be $\frac{1}{\mu} = \frac{150}{20} = 7.5$

minutes per person. Furthermore, the parameters used in the test to determine if the data on the time of patient arrivals in Friday follows an exponential distribution are listed previously mentioned Table 8.

As shown in Table 8, for Friday, the value of Asymp.Sig (2-tailed) is calculated to be 0.274, which is above 0.05. Therefore, it is concluded that the null hypothesis, H_0 , is accepted. In other words, the time between patient arrivals in Friday follows an exponential distribution. Furthermore, testing if the data on the duration of patient service on Friday is exponential distributed, with the same technique, started with grouping the data into several 10-minute intervals as listed in Table 18 below:

Table 18. Grouped duration of patient service on Friday

No	Service duration (minutes)	Frequency (f_i)	x_i	$f_i x_i$
1	28-38	5	33	165
2	39-49	3	44	132
3	50-60	8	55	440
4	61-71	3	66	198
5	81-91	2	86	172
Total		21		1107

The average of service duration is calculated to be $\frac{1}{\mu} = \frac{1107}{21} = 52.7$ minutes per person. Furthermore, the parameters used in the test to determine if the data on the service duration in Friday follows an exponential distribution are listed previously mentioned Table 10.

As shown in Table 10, for Friday, the value of Asymp.Sig (2-tailed) is calculated to be 0.852, which is above 0.05. Therefore, it is concluded that the null hypothesis, H_0 , is accepted. In other words, the patient service duration in Friday follows an exponential distribution.

- f. Test on time distribution in Saturday

Table 17. Grouped time of patient arrivals on Saturday

No	Service duration (minutes)	Frequency (f_i)	x_i	$f_i x_i$
1	0-2	16	1	17
2	3-5	4	4	16
3	6-8	6	7	42
4	9-11	1	10	10
5	12-14	1	13	13
6	15-17	1	16	16
Total		29		114

The average of the time of patient arrivals is calculated to be $\frac{1}{\mu} = \frac{114}{29} = 3.93$ minutes per person. Furthermore, the parameters used in the test to determine if the data on the time of patient arrivals in Saturday follows an exponential distribution are listed previously mentioned Table 8.

As shown in Table 8, for Saturday, the value of Asymp.Sig (2-tailed) is calculated to be 0.491, which is above 0.05. Therefore, it is concluded that the null hypothesis, H_0 , is accepted. In other words, the time between patient arrivals in Saturday follows an exponential distribution. Furthermore, testing if the data on the duration of patient service on Saturday is exponential distributed, with the same technique, started with grouping the data into several 15-minute intervals as listed in Table 18 below:

Table 20. Grouped duration of patient service on Saturday

No	Service duration (minutes)	Frequency (f_i)	x_i	$f_i x_i$
1	18-33	18	25	450
2	34-49	8	41	328
3	50-65	1	57	57
4	66-81	1	73	73
5	82-97	2	86	178
Total		30		1086

The average of service duration is calculated to be $\frac{1}{\mu} = \frac{1086}{30} = 36.2$ minutes per person. Furthermore, the parameters used in the test to determine if the data on the service duration in Saturday follows an exponential distribution are listed previously mentioned Table 10.

As shown in Table 10, for Saturday, the value of Asymp.Sig (2-tailed) is calculated to be 0.576, which is above 0.05. Therefore, it is concluded that

the null hypothesis, H_0 , is accepted. In other words, the patient service duration in Saturday follows an exponential distribution.

3. Problem solving in the registration section and general clinic

From the observation and analysis of the observed data, the queuing characteristics in the HCLB are obtained as follows:

- a. The time between patient arrivals for the 6 days follows an exponential distribution.
- b. The patient service duration for the 6 days follows an exponential distribution
- c. There are 8 employees ($c = 8$) to serve patients, 2 people handle the registration section, 2 people handle the patient's status, 1 person is in charge of measuring the patient's weight and blood pressure, 1 person is in charge of calling the patient to enter the doctor's room, and 2 doctors to perform medical procedures
- d. The service rule is that patients who come first will be served first
- e. The attendance of the patient is unlimited.

By considering the characteristics described above, the queuing model applied in HCLB is classified as a dual service queue model with an unlimited population (M/M/C): (GD/ ∞/∞). However, this model can be simulated for a more stable system that satisfies $\frac{\lambda}{c\mu} < 1$. Therefore, it is necessary to investigate whether the current system is in a stable condition or not, using $c = 8$.

a. Solution for Monday case

Based on the test on distribution of time between patient arrivals and duration of patient service on Monday, it is obtained:

$$\frac{1}{\lambda} = \frac{222}{47} = 4.7 \text{ minutes/person} \rightarrow \lambda = \frac{1}{\frac{4.7}{60}} = 13 \text{ persons/hour}$$

$$\frac{1}{\mu} = \frac{2151}{48} = 44.8 \text{ minutes/person} \rightarrow \mu = \frac{1}{\frac{44.8}{60}} = \frac{1}{0.746} = 1 \text{ person/hour}$$

and

$$\frac{\lambda}{c\mu} = \frac{13}{(8)(1)} = 1.6$$

The results above show that the number of arriving patients (λ) is 13 persons/hour and the number of patients who can be served (μ) is 1 person/hour. Since the steady state condition, $\frac{\lambda}{c\mu} < 1$, is not fulfilled, the solution can be obtained by increasing c . This means that the number of employees in service must be increased, especially during peak hours. Let c be increased to 14, obtained

$$\frac{\lambda}{c\mu} = \frac{13}{(14)(1)} = 0.92$$

which satisfies the steady state condition. The analysis result for queuing model (M/M/14): (CD/ ∞ / ∞) is listed in Appendix 6, contains the following information:

- 1) The average patient waiting in the queue is calculated using equation (4) to obtain $L_q = 9.28 \approx 10$

- 2) The average patient waiting in the system is calculated using equation (5) to obtain $L_s = 22.28 \approx 23$
- 3) The average time spent in the system is calculated using equation (6) to obtain $W_s = 102.83$ minutes ≈ 103 minutes
- 4) The average time spent in the queue is calculated using equation (6) to obtain $W_q = 42.83$ minutes ≈ 43 minutes

Table 21 below lists the basic queue measures by simulating some increases in the number of serving employees.

Table 21. Basic queue measures by simulating increases in the number of serving employees on Monday

Basic queue measures	$c = 14$	$c = 15$	$c = 16$
Average number of patients in the system (person)	23	17	15
Average number of patients in the queue (person)	10	4	2
Average time spent by patients in the system (minute)	102.83	74.87	66.69
Average time spent by patients in the queue (minute)	42.83	14.87	6.69

Table 22 below shows the improvement of the average waiting time in the system and the percentage employee's idle time (X) when the number of employees is increased. The value of X is calculated using equation (9).

Table 22. Improvement in average waiting time in the system and the percentage of employee's idle time as a response to increasing number of serving employees in Monday

Number of employees (person)	14	15	16
Average waiting time in the system (minute)	102.83	74.87	66.69
Percentage of idle time	7%	13%	19%

b. Solution for Tuesday case

Based on the test on distribution of time between patient arrivals and duration of patient service on Tuesday, it is obtained:

$$\frac{1}{\lambda} = \frac{185}{37} = 5 \text{ minutes/person} \rightarrow \lambda = \frac{1}{\frac{5}{60}} = 12 \text{ persons/hour}$$

$$\frac{1}{\mu} = \frac{2093}{38} = 55 \text{ minutes/person} \rightarrow \mu = \frac{1}{\frac{55}{60}} = 1 \text{ person/hour}$$

and

$$\frac{\lambda}{c\mu} = \frac{12}{(8)(1)} = 1.5$$

The results above show that the number of arriving patients (λ) is 12 persons/hour and the number of patients who can be served (μ) is 1 person/hour. Since the steady state condition, $\frac{\lambda}{c\mu} < 1$, is not fulfilled, the solution can be obtained by increasing c . This means that the number of employees in service must be increased, especially during peak hours. Let c be increased to 13, obtained

$$\frac{\lambda}{c\mu} = \frac{12}{(13)(1)} = 0.92$$

which now satisfies the steady state condition. The analysis result for queuing model (M/M/14): (CD/ ∞ / ∞) is listed in Appendix 6, contains the following information:

- 1) The average patient waiting in the queue is calculated using equation (4) to obtain $L_q = 8.45 \approx 9$

- 2) The average patient waiting in the system is calculated using equation (5) to obtain $L_s = 20.45 \approx 21$
- 3) The average time spent in the system is calculated using equation (6) to obtain $W_s = 102.26$ minutes ≈ 103 minutes
- 4) The average time spent in the queue is calculated using equation (6) to obtain $W_q = 42.26$ minutes ≈ 43 minutes

Table 23 below lists the basic queue measures by simulating some increases in the number of serving employees.

Table 23. Basic queue measures by simulating increases in the number of serving employees on Tuesday

Basic queue measures	$c = 13$	$c = 14$	$c = 15$
Average number of patients in the system (person)	21	15	14
Average number of patients in the queue (person)	9	3	2
Average time spent by patients in the system (minute)	103	75	67
Average time spent by patients in the queue (minute)	43	15	7

Table 24 below shows the improvement of the average waiting time in the system and the percentage employee's idle time (X) when the number of employees is increased. The value of X is calculated using equation (9).

Table 24. Improvement in average waiting time in the system and the percentage of employee's idle time as a response to increasing number of serving employees in Tuesday

Number of employees (person)	13	14	15
Average waiting time in the system (minute)	102.26	74.45	66.38
Percentage of idle time	8%	14%	20%

c. Solution for Wednesday case

Based on the test on distribution of time between patient arrivals and duration of patient service on Wednesday, it is obtained:

$$\frac{1}{\lambda} = \frac{199}{41} = 4.85 \text{ minutes/person} \rightarrow \lambda = \frac{1}{\frac{4.85}{60}} = 13 \text{ persons/hour}$$

$$\frac{1}{\mu} = \frac{2271}{42} = 54 \text{ minutes/person} \rightarrow \mu = \frac{1}{\frac{54}{60}} = 1 \text{ person/hour}$$

and

$$\frac{\lambda}{c\mu} = \frac{13}{(8)(1)} = 1.5$$

The results above show that the number of arriving patients (λ) is 13 persons/hour and the number of patients who can be served (μ) is 1 person/hour. Since the steady state condition, $\frac{\lambda}{c\mu} < 1$, is not fulfilled, the solution can be obtained by increasing c . This means that the number of employees in service must be increased, especially during peak hours. Let c be increased to 14, obtained

$$\frac{\lambda}{c\mu} = \frac{13}{(14)(1)} = 0.92$$

which now satisfies the steady state condition. The analysis result for queuing model (M/M/14): (CD/ ∞ / ∞) is listed in Appendix 6, contains the following information:

- 1) The average patient waiting in the queue is calculated using equation (4) to obtain $L_q = 9.28 \approx 10$

- 2) The average patient waiting in the system is calculated using equation (5) to obtain $L_s = 22.28 \approx 23$
- 3) The average time spent in the system is calculated using equation (6) to obtain $W_s = 102.83$ minutes ≈ 103 minutes
- 4) The average time spent in the queue is calculated using equation (6) to obtain $W_q = 42.83$ minutes ≈ 43 minutes

Table 25 below lists the basic queue measures by simulating some increases in the number of serving employees.

Table 25. Basic queue measures by simulating increases in the number of serving employees on Wednesday

Basic queue measures	$c = 14$	$c = 15$	$c = 16$
Average number of patients in the system (person)	23	17	15
Average number of patients in the queue (person)	10	4	2
Average time spent by patients in the system (minute)	103	75	67
Average time spent by patients in the queue (minute)	43	15	7

Table 26 below shows the improvement of the average waiting time in the system and the percentage employee's idle time (X) when the number of employees is increased. The value of X is calculated using equation (9).

Table 26. Improvement in average waiting time in the system and the percentage of employee's idle time as a response to increasing number of serving employees in Wednesday

Number of employees (person)	14	15	16
Average waiting time in the system (minute)	102.83	74.87	66.69
Percentage of idle time	7%	13%	19%

d. Solution for Thursday case

Based on the test on distribution of time between patient arrivals and duration of patient service on Thursday, it is obtained:

$$\frac{1}{\lambda} = \frac{111}{29} = 3.82 \text{ minutes/person} \rightarrow \lambda = \frac{1}{\frac{3.82}{60}} = 16 \text{ persons/hour}$$

$$\frac{1}{\mu} = \frac{1201}{30} = 40 \text{ minutes/person} \rightarrow \mu = \frac{1}{\frac{40}{60}} = 2 \text{ person/hour}$$

and

$$\frac{\lambda}{c\mu} = \frac{16}{(8)(2)} = 1$$

The results above show that the number of arriving patients (λ) is 16 persons/hour and the number of patients who can be served (μ) is 2 person/hour. Since the steady state condition, $\frac{\lambda}{c\mu} < 1$, is not fulfilled, the solution can be obtained by increasing c . This means that the number of employees in service must be increased, especially during peak hours. Let c be increased from 8 to 9, obtained

$$\frac{\lambda}{c\mu} = \frac{16}{(9)(2)} = 0.89$$

which now satisfies the steady state condition. The analysis result for queuing model (M/M/14): (CD/ ∞ / ∞) is listed in Appendix 6, contains the following information:

- 1) The average patient waiting in the queue is calculated using equation (4) to obtain $L_q = 5.23 \approx 16$

- 2) The average patient waiting in the system is calculated using equation (5) to obtain $L_s = 13.23 \approx 14$
- 3) The average time spent in the system is calculated using equation (6) to obtain $W_s = 49.6$ minutes ≈ 50 minutes
- 4) The average time spent in the queue is calculated using equation (6) to obtain $W_q = 19.6$ minutes ≈ 20 minutes

Table 27 below lists the basic queue measures by simulating some increases in the number of serving employees.

Table 27. Basic queue measures by simulating increases in the number of serving employees on Thursday

Basic queue measures	$c = 9$	$c = 10$	$c = 11$
Average number of patients in the system (person)	14	10	9
Average number of patients in the queue (person)	6	2	1
Average time spent by patients in the system (minute)	49.6	36.14	32.45
Average time spent by patients in the queue (minute)	19.6	6.14	2.45

Table 28 below shows the improvement of the average waiting time in the system and the percentage employee's idle time (X) when the number of employees is increased. The value of X is calculated using equation (9).

Table 28. Improvement in average waiting time in the system and the percentage of employee's idle time as a response to increasing number of serving employees in Thursday

Number of employees (person)	9	10	11
Average waiting time in the system (minute)	49.6	36.14	32.45
Percentage of idle time	11%	20%	27%

e. Solution for Friday case

Based on the test on distribution of time between patient arrivals and duration of patient service on Friday, it is obtained:

$$\frac{1}{\lambda} = \frac{150}{20} = 7.5 \text{ minutes/person} \rightarrow \lambda = \frac{1}{\frac{7.5}{60}} = 8 \text{ persons/hour}$$

$$\frac{1}{\mu} = \frac{1107}{21} = 52.7 \text{ minutes/person} \rightarrow \mu = \frac{1}{\frac{52.7}{60}} = 1 \text{ person/hour}$$

and

$$\frac{\lambda}{c\mu} = \frac{8}{(8)(1)} = 1$$

The results above show that the number of arriving patients (λ) is 8 persons/hour and the number of patients who can be served (μ) is 1 person/hour. Since the steady state condition, $\frac{\lambda}{c\mu} < 1$, is not fulfilled, the solution can be obtained by increasing c . This means that the number of employees in service must be increased, especially during peak hours. Let c be increased from 8 to 9, obtained

$$\frac{\lambda}{c\mu} = \frac{8}{(9)(1)} = 0,89$$

which now satisfies the steady state condition. The analysis result for queuing model (M/M/14): (CD/ ∞ / ∞) is listed in Appendix 6, contains the following information:

- 1) The average patient waiting in the queue is calculated using equation (4) to obtain $L_q = 5.23 \approx 16$

- 2) The average patient waiting in the system is calculated using equation (5) to obtain $L_s = 13.23 \approx 14$
- 3) The average time spent in the system is calculated using equation (6) to obtain $W_s = 99.2$ minutes ≈ 100 minutes
- 4) The average time spent in the queue is calculated using equation (6) to obtain $W_q = 39.2$ minutes ≈ 40 minutes

Table 29 below lists the basic queue measures by simulating some increases in the number of serving employees.

Table 29. Basic queue measures by simulating increases in the number of serving employees on Friday

Basic queue measures	$c = 9$	$c = 10$	$c = 11$
Average number of patients in the system (person)	14	10	9
Average number of patients in the queue (person)	6	2	1
Average time spent by patients in the system (minute)	99.2	72.28	64.9
Average time spent by patients in the queue (minute)	39.2	12.28	4.9

Table 30 below shows the improvement of the average waiting time in the system and the percentage employee's idle time (X) when the number of employees increases. The value of X is calculated using equation (9).

Table 30. Improvement in average waiting time in the system and the percentage of employee's idle time as a response to increasing number of serving employees in Friday

Number of employees (person)	9	10	11
Average waiting time in the system (minute)	99.2	72.28	64.9
Percentage of idle time	11%	20%	27%

f. Solution for Saturday case

Based on the test on distribution of time between patient arrivals and duration of patient service on Saturday, it is obtained:

$$\frac{1}{\lambda} = \frac{114}{29} = 3.93 \text{ minutes/person} \rightarrow \lambda = \frac{1}{\frac{3.93}{60}} = 15 \text{ persons/hour}$$

$$\frac{1}{\mu} = \frac{1086}{30} = 36.2 \text{ minutes/person} \rightarrow \mu = \frac{1}{\frac{36.2}{60}} = 2 \text{ person/hour}$$

and

$$\frac{\lambda}{c\mu} = \frac{15}{(8)(2)} = 1$$

The results above show that the number of arriving patients (λ) is 15 persons/hour and the number of patients who can be served (μ) is 2 person/hour. Since the steady state condition, $\frac{\lambda}{c\mu} < 1$, is not fulfilled, the solution can be obtained by increasing c . This means that the number of employees in service must be increased, especially during peak hours. Let c be increased from 8 to 9, obtained

$$\frac{\lambda}{c\mu} = \frac{15}{(9)(2)} = 0,83$$

which now satisfies the steady state condition. The analysis result for queuing model (M/M/14): (CD/ ∞ / ∞) is listed in Appendix 6, contains the following information:

- 5) The average patient waiting in the queue is calculated using equation (4) to obtain $L_q = 12.11 \approx 13$

- 6) The average patient waiting in the system is calculated using equation (5) to obtain $L_s = 19.61 \approx 20$
- 7) The average time spent in the system is calculated using equation (6) to obtain $W_s = 78.44$ minutes ≈ 79 minutes
- 8) The average time spent in the queue is calculated using equation (6) to obtain $W_q = 48.44$ minutes ≈ 49 minutes

Table 31 below lists the basic queue measures by simulating some increases in the number of serving employees.

Table 31. Basic queue measures by simulating increases in the number of serving employees on Saturday

Basic queue measures	$c = 8$	$c = 9$	$c = 10$
Average number of patients in the system (person)	20	11	9
Average number of patients in the queue (person)	13	3	1
Average time spent by patients in the system (minute)	78.44	40.16	33.68
Average time spent by patients in the queue (minute)	48.44	10.18	3.68

Table 32 below shows the improvement of the average waiting time in the system and the percentage employee's idle time (X) when the number of employees increases. The value of X is calculated using equation (9).

Table 32. Improvement in average waiting time in the system and the percentage of employee's idle time as a response to increasing number of serving employees in Saturday

Number of employees (person)	9	10	11
Average waiting time in the system (minute)	78.44	40.16	33.68
Percentage of idle time	6%	17%	25%

B. Discussion

Based on the results of the analysis, from the data on the time between arrivals and the duration of patient service at the registration section and general clinic for six days, the criteria for testing $\text{Asymp.Sig (2-tailed)} > \alpha = 0.05$ were obtained. Therefore, the time between arrivals and the duration of patient service follows the exponential distribution. The results also reveal that on Monday, Tuesday, Wednesday, Thursday, Friday and Saturday with 8 employees serving, the steady state requirement $\frac{\lambda}{c\mu} < 1$, in which the percentage of employee unemployment time and the average time waiting for patients in the system is taken into account, is not satisfied. As a consequence, the number of service employees must be increased.

For Monday's case it was found that if the number of employees was increased to 14 people, then the percentage of employees' idle time would be 7% of their working time and the average waiting time for patients in the system would be 102.83 minutes. If the number of employees is 15 persons, the percentage of employees' idle time becomes 13% of the working time and the average waiting time for patients in the system decreases to 74.87 minutes. Furthermore, if the employee is increased to 16 people, the percentage of employees' idle time increases to 19% of their working time and the average waiting time for patients in the system decreases to 66.69 minutes.

For Tuesday's case it was found that if the number of employees was increased to 13 people, then the percentage of employees' idle time would be 8% of their working time and the average waiting time for patients in the system would

be 102.26 minutes. If the number of employees is 14 persons, the percentage of employees' idle time becomes 14% of the working time and the average waiting time for patients in the system decreases to 74.45 minutes. Furthermore, if the employee is increased to 15 people, the percentage of employees' idle time increases to 20% of their working time and the average waiting time for patients in the system decreases to 66.38 minutes.

For Wednesday's case it was found that if the number of employees was increased to 13 people, then the percentage of employees' idle time would be 7% of their working time and the average waiting time for patients in the system would be 102.83 minutes. If the number of employees is 14 persons, the percentage of employees' idle time becomes 13% of the working time and the average waiting time for patients in the system decreases to 74.87 minutes. Furthermore, if the employee is increased to 15 people, the percentage of employees' idle time increases to 19% of their working time and the average waiting time for patients in the system decreases to 66.69 minutes.

For Thursday's case it was found that if the number of employees was increased to 9 people, then the percentage of employees' idle time would be 11% of their working time and the average waiting time for patients in the system would be 49.6 minutes. If the number of employees is 10 persons, the percentage of employees' idle time becomes 20% of the working time and the average waiting time for patients in the system decreases to 36.14 minutes. Furthermore, if the employee is increased to 11 people, the percentage of employees' idle time

increases to 27% of their working time and the average waiting time for patients in the system decreases to 32.45 minutes.

For Friday's case it was found that if the number of employees was increased to 9 people, then the percentage of employees' idle time would be 11% of their working time and the average waiting time for patients in the system would be 99.2 minutes. If the number of employees is 10 persons, the percentage of employees' idle time becomes 20% of the working time and the average waiting time for patients in the system decreases to 72.28 minutes. Furthermore, if the employee is increased to 11 people, the percentage of employees' idle time increases to 27% of their working time and the average waiting time for patients in the system decreases to 64.9 minutes.

For Saturday's case it was found that if the number of employees was increased to 9 people, then the percentage of employees' idle time would be 6% of their working time and the average waiting time for patients in the system would be 78.44 minutes. If the number of employees is 10 persons, the percentage of employees' idle time becomes 17% of the working time and the average waiting time for patients in the system decreases to 40.16 minutes. Furthermore, if the employee is increased to 11 people, the percentage of employees' idle time increases to 25% of their working time and the average waiting time for patients in the system decreases to 33.68 minutes.

Optimization of the system at the registration and general clinic can be determined using the aspiration rate where the employee's idle time is not allowed

to exceed 20% of their working time and the average patient waiting time in the system is not more than 10 minutes.

Based on the analysis results, it was found that employees' idle time in all days had met the condition set in the aspiration rate, namely 6%, 7%, 8%, and 11%, 13%, 14%, 17% and 20%. Meanwhile, the patient's average waiting time in the system has not been able to meet the predetermined number in the aspiration rate. The most optimal condition that can be obtained from this queuing model is that the percentage of employees' idle time is 20% of their working time with an average patient waiting time in the system of 58.26 minutes. This unsatisfactory result can be related to the characteristics of the health service itself where services in the registration section until before the patient is examined by a doctor in the general clinic can be accelerated, but not with the case for doctor's examination that requires high accuracy and possibly longer time. Therefore, the other patients still have to wait until the current patient complete receiving medical treatment considering his/her situation. So, in order for the queuing system to run as effectively as possible, additional employees are needed, especially on Mondays, Tuesdays and Wednesdays.

CHAPTER V

SUMMARY

A. Conclusion

Based on the results of analysis presented in previous chapter, the following conclusions are drawn:

1. The queuing system at the registration and general clinic division is not yet effective if handled by eight employees. In order to obtain an effective queuing system, additional employees are required especially for Monday, Tuesday and Wednesday.
2. The most optimum aspiration rate used for the system determines the average waiting time in the system of 58.26 minutes with the percentage of employees' idle time of 20%.

B. Recommendation

To further improve service to patients, it is suggested that the HCLB to recruit more employees, especially for Monday, Tuesday and Wednesday, in which peak or busy hours may occur. More employees needed at those days for handling registration section who are in charge of finding patient files.

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APPENDICES

Appendix 1. Data on patient arrival time, patient being served, and patient complete being served

a. Monday, 5 February 2018

No.	Registration			General clinic					
	Arrival	Receiving service	Complete Service	Arrival	Receiving service	Complete Service	Receiving doctor's treatment	Complete doctor's service	Service duration (hour)
1	8.06	8.07	8.07	8.08	8.25	8.28	8.29	8.33	0.27
2	8.07	8.08	8.08	8.09	8.28	8.30	8.31	8.37	0.30
3	8.12	8.15	8.16	8.16	8.32	8.35	8.35	8.42	0.30
4	8.15	8.18	8.19	8.19	8.40	8.44	8.45	8.52	0.37
5	8.16	8.22	8.22	8.23	8.43	8.47	8.47	8.50	0.34
6	8.20	8.23	8.24	8.24	8.38	8.40	8.41	8.56	0.36
7	8.23	8.25	8.26	8.26	8.42	8.44	8.44	8.53	0.30
8	8.24	8.27	8.27	8.28	8.43	8.52	8.53	8.59	0.35
9	8.26	8.30	8.31	8.31	8.47	8.50	8.51	8.55	0.29
10	8.29	8.31	8.31	8.32	8.53	8.58	8.59	9.02	0.73
11	8.32	8.40	8.41	8.41	8.57	8.59	8.59	9.05	0.73
12	8.37	8.43	8.43	8.44	9.08	9.12	9.13	9.20	0.83
13	8.45	8.46	8.47	8.47	9.13	9.15	9.22	9.29	0.84
14	8.52	8.58	8.58	8.59	9.20	9.22	9.29	9.35	0.83
15	8.59	9.00	9.02	9.03	9.35	9.38	9.38	9.43	0.84
16	9.10	9.16	9.16	9.17	9.37	9.39	9.39	9.44	0.34
17	9.15	9.22	9.23	9.23	9.45	9.47	9.47	9.50	0.35
18	9.16	9.24	9.24	9.25	9.48	9.50	9.50	10.01	0.85

19	9.25	9.29	9.29	9.30	10.00	10.03	10.03	10.12	0.87
20	9.28	9.33	9.34	9.34	10.20	10.22	10.22	10.27	0.99
21	9.32	9.35	9.35	9.36	10.23	10.26	10.26	10.31	0.99
22	9.47	9.49	9.50	9.50	10.27	10.30	10.30	10.38	0.91
23	9.56	10.02	10.03	10.03	10.30	10.32	10.32	10.40	0.84
24	10.02	10.03	10.04	10.04	10.33	10.35	10.35	10.41	0.39
25	10.17	10.19	10.19	10.20	10.38	10.40	10.40	10.45	0.28
26	10.26	10.28	10.28	10.29	10.47	10.50	10.50	10.58	0.32
27	10.37	10.38	10.38	10.39	10.51	10.54	10.54	11.00	0.63
28	10.49	10.52	10.53	10.53	10.55	10.58	10.58	11.09	0.60
29	10.50	10.55	10.55	10.56	11.09	11.13	11.13	11.20	0.70
30	10.55	10.57	10.58	10.58	11.11	11.15	11.15	11.26	0.71
31	10.57	10.59	10.59	10.59	11.16	11.20	11.20	11.25	0.68
32	10.59	11.00	11.01	11.01	11.27	11.31	11.31	11.40	0.81
33	11.03	11.15	11.15	11.16	11.32	11.35	11.35	11.42	0.39
34	11.03	11.16	11.16	11.17	11.48	11.51	11.51	11.59	0.56
35	11.07	11.25	11.26	11.26	11.52	11.54	11.54	12.00	0.93
36	11.08	11.27	11.27	11.28	11.55	11.58	11.58	12.01	0.93
37	11.10	11.30	11.30	11.31	12.15	12.18	12.18	12.22	1.12
38	11.16	11.32	11.33	11.33	12.03	12.06	12.06	12.10	0.94
39	11.20	11.37	11.37	11.38	12.07	12.14	12.15	12.21	1.01
40	11.30	11.38	11.39	11.39	12.15	12.18	12.18	12.26	0.96
41	11.31	11.39	11.40	11.40	12.25	12.27	12.27	12.32	1.01
42	11.33	11.40	11.41	11.41	12.27	12.31	12.31	12.42	1.09
43	11.38	11.42	11.42	11.42	12.32	12.34	12.35	12.44	1.06

44	11.40	11.43	11.43	11.44	12.35	12.38	12.38	12.49	1.09
45	11.45	11.47	11.48	11.48	12.45	12.48	12.48	12.53	1.08
46	11.46	11.48	11.49	11.49	12.48	12.50	12.51	12.59	1.13
47	11.48	11.49	11.50	11.50	12.50	12.53	12.53	12.57	1.09
48	11.49	11.50	11.51	11.51	12.53	12.56	12.57	12.59	1.10

b. Tuesday, 6 February 2018

No .	Registration			General clinic					
	Arrival	Receiving service	Complete Service	Arrival	Receiving service	Complete Service	Receiving doctor's treatment	Complete doctor's service	Service duration (hour)
1	8.07	8.08	8.08	8.09	8.21	8.24	8.25	8.35	0.28
2	8.09	8.09	8.1	8.1	8.24	8.27	8.27	8.39	0.3
3	8.12	8.15	8.16	8.16	8.28	8.3	8.3	8.4	0.28
4	8.18	8.19	8.19	8.19	8.32	8.38	8.39	8.46	0.28
5	8.2	8.33	8.34	8.35	9.25	9.26	9.28	9.31	1.11
6	8.22	8.38	8.39	8.41	9.26	9.27	9.28	9.36	1.14
7	8.31	8.44	8.44	8.44	9.38	9.39	9.4	9.44	1.13
8	8.32	8.45	8.46	8.46	9.39	9.4	9.41	9.45	1.13
9	8.34	8.46	8.47	8.47	9.29	9.29	9.31	9.36	1.02
10	8.36	8.51	8.51	8.52	10.15	10.17	10.2	10.23	1.87
11	8.38	8.48	8.49	8.49	9.35	9.37	9.37	9.37	0.99
12	8.44	8.54	8.55	8.56	10.24	10.25	10.28	10.37	1.93
13	8.51	8.59	9	9	10.25	10.26	10.37	10.43	1.92
14	8.53	8.57	8.57	8.58	9.4	9.42	9.44	9.46	0.93

15	8.54	8.58	9	9.01	9.42	9.43	10.01	10.03	1.49
16	9.04	9.07	9.07	9.08	10.25	10.26	10.37	10.39	1.35
17	9.21	9.28	9.28	9.29	10.26	10.27	10.4	10.44	1.23
18	9.32	9.47	9.48	9.48	10.02	10.03	10.21	10.34	1.02
19	9.45	9.48	9.49	9.49	10.04	10.06	10.07	10.12	0.67
20	9.46	9.49	9.5	9.5	10.03	10.04	10.06	10.14	0.68
21	9.48	9.51	9.52	9.52	10.06	10.09	10.12	10.15	0.67
22	9.49	10.05	10.05	10.12	10.27	10.28	10.43	10.5	1.01
23	9.5	9.52	9.53	9.53	10.1	10.11	10.16	10.19	0.69
24	10.05	10.08	10.11	10.11	10.28	10.29	10.44	10.46	0.41
25	10.09	10.13	10.13	10.13	10.29	10.32	10.45	10.51	0.42
26	10.1	10.15	10.15	10.16	10.36	10.37	10.5	10.54	0.44
27	10.12	10.17	10.18	10.18	10.38	10.4	10.53	10.54	0.42
28	10.14	10.18	10.18	10.19	10.42	10.43	10.57	11.11	0.97
29	10.16	10.26	10.26	10.26	10.45	10.46	10.5	10.52	0.36
30	10.2	10.35	10.36	10.36	10.4	10.42	10.53	10.57	0.37
31	10.28	10.4	10.41	10.41	10.47	10.48	11.11	11.13	0.85
32	10.45	10.47	10.45	10.46	10.48	10.51	11.11	11.15	0.7
33	10.5	10.51	10.52	10.52	11.06	11.07	11.12	11.27	0.77
34	10.56	10.57	10.58	10.58	11.09	11.12	11.23	11.28	0.72
35	11.05	11.12	11.12	11.13	11.35	11.37	11.38	11.45	0.4
36	11.08	11.14	11.14	11.15	11.42	11.44	11.44	11.53	0.45
37	11.12	11.15	11.16	11.16	11.45	11.49	11.49	12	0.88
38	11.15	11.16	11.17	11.17	11.5	11.55	11.56	12.12	0.97

c. **Wednesday, 7 February 2018**

No.	Registration			General clinic					
	Arrival	Receiving service	Complete Service	Arrival	Receiving service	Complete Service	Receiving doctor's treatment	Complete doctor's service	Service duration (hour)
1	8.05	8.15	8.16	8.16	8.43	8.44	9.15	9.18	1.13
2	8.08	8.16	8.16	8.17	8.45	8.48	9.16	9.2	1.12
3	8.09	8.17	8.18	8.18	8.49	8.53	8.54	9.15	1.06
4	8.1	8.19	8.2	8.2	8.47	8.48	9.22	9.27	1.17
5	8.12	8.21	8.22	8.22	9.08	9.1	9.41	9.45	1.33
6	8.16	8.28	8.28	9.29	8.4	8.41	9	9.02	0.86
7	8.18	8.29	8.29	8.3	8.48	8.5	9.22	9.26	1.08
8	8.19	8.3	8.3	8.31	8.5	8.51	9.24	9.26	1.07
9	8.23	8.3	8.31	8.32	8.51	8.52	9.26	10	1.77
10	8.26	8.32	8.33	8.33	8.52	8.54	9.28	9.31	1.05
11	8.32	8.33	8.35	8.35	8.41	8.42	9.02	9.13	0.81
12	8.35	8.41	8.42	8.42	9.03	9.03	9.28	9.31	0.96
13	8.36	8.43	8.44	8.44	9.11	9.12	9.48	9.5	1.14
14	8.39	8.47	8.47	8.48	9.07	9.08	9.38	9.42	1.03
15	8.39	8.46	8.47	8.48	9.05	9.07	9.32	9.32	0.93
16	8.47	8.49	8.5	8.5	9.1	9.11	9.45	9.46	0.99
17	8.51	8.52	9	9	9.03	9.04	9.31	9.36	0.85
18	8.52	8.53	9.01	9.01	9.04	9.05	9.29	9.37	0.85
19	9.05	9.12	9.12	9.13	9.33	9.35	9.51	9.55	0.5
20	9.06	9.07	9.08	9.08	10.11	10.11	10.31	10.41	1.35

21	9.06	9.14	9.18	9.18	9.41	9.42	10.17	10.19	1.13
22	9.07	9.19	9.2	9.2	9.35	9.37	9.5	10.05	0.98
23	9.11	9.26	9.27	9.27	9.38	9.39	10.09	10.12	1.01
24	9.15	9.28	9.29	9.29	9.4	9.4	10.11	10.12	0.97
25	9.19	9.29	9.3	9.3	9.4	9.42	10.17	10.21	1.02
26	9.21	9.31	9.32	9.32	9.57	9.57	10.2	10.42	1.21
27	9.22	9.33	9.33	9.34	9.53	9.54	10.19	10.25	1.03
28	9.28	9.32	9.45	9.45	10.16	10.18	10.49	10.53	1.25
29	9.3	9.46	9.46	9.5	10.1	10.11	10.24	10.28	0.98
30	9.39	9.4	9.41	9.41	10.16	10.16	10.31	10.34	0.95
31	9.41	9.56	9.57	9.57	10.15	10.15	10.29	10.38	0.97
32	9.43	9.59	10.01	10.02	10.18	10.19	10.35	10.39	0.96
33	9.43	9.57	9.58	9.59	10.12	10.13	10.21	10.23	0.8
34	9.52	10.04	10.04	10.05	10.19	10.19	10.34	10.38	0.86
35	9.55	10.04	10.05	10.05	10.2	10.22	10.41	10.46	0.91
36	10.28	10.06	10.07	10.07	10.13	10.15	10.28	10.45	0.17
37	10.37	10.1	10.11	10.11	10.21	10.23	10.52	10.54	0.17
38	10.4	10.52	10.53	10.53	10.54	10.55	10.57	11.03	0.63
39	10.55	10.57	10.58	10.58	10.59	11.02	11.06	11.09	0.54
40	11	11.02	11.03	11.03	11.2	11.21	11.22	11.3	0.3
41	11.1	11.12	11.12	11.13	11.25	11.26	11.26	11.35	0.25
42	11.15	11.16	11.17	11.17	11.28	11.32	11.34	11.45	0.3

d. **Thursday, 8 February 2018**

No .	Registration			General clinic					
	Arrival	Receiving service	Complete Service	Arrival	Receiving service	Complete Service	Receiving doctor's treatment	Complete doctor's service	Service duration (hour)
1	8.1	8.17	8.18	8.18	8.26	8.29	8.33	8.35	0.25
2	8.14	8.24	8.25	8.26	9.02	9.03	9.05	9.05	0.91
3	8.15	8.27	8.27	8.28	9.03	9.04	9.07	9.13	0.98
4	8.16	8.28	8.28	8.29	8.56	8.58	8.59	9.01	0.85
5	8.2	8.29	8.3	8.31	9.05	9.08	9.09	9.1	0.9
6	8.34	8.4	8.4	8.41	9.15	9.16	9.18	9.2	0.86
7	8.43	8.52	8.52	8.53	9.14	9.18	9.2	9.21	0.78
8	8.44	8.53	8.53	8.54	9.25	9.26	9.28	9.31	0.87
9	8.5	8.55	8.55	8.56	9.22	9.24	9.26	9.29	0.79
10	8.53	8.57	8.57	8.58	9.08	9.29	9.4	9.41	0.88
11	9.08	9.11	9.12	9.12	9.36	9.37	9.41	9.43	0.35
12	9.1	9.16	9.17	9.17	9.37	9.38	9.43	9.44	0.34
13	9.22	9.26	9.27	9.27	9.42	9.48	9.5	9.54	0.32
14	9.23	9.29	9.29	9.3	9.36	9.37	9.41	9.43	0.2
15	9.24	9.3	9.3	9.31	9.47	9.48	9.49	9.52	0.28
16	9.28	9.28	9.31	9.32	9.46	9.47	9.48	9.5	0.22
17	9.32	9.36	9.36	9.37	10.07	10.08	10.13	10.2	0.88
18	9.35	10.37	10.38	10.38	10.45	10.48	10.49	10.55	1.2
19	9.42	9.42	9.43	9.43	10.09	10.09	10.22	10.27	0.85

20	9.47	9.52	9.52	9.53	10.25	10.27	10.28	10.44	0.97
21	9.56	9.59	9.59	10	10.27	10.28	10.33	10.36	0.8
22	10.03	10.04	10.05	10.05	10.28	10.29	10.34	10.36	0.33
23	10.22	10.23	10.24	10.24	10.33	10.34	10.36	10.41	0.19
24	10.22	10.25	10.25	10.26	10.34	10.35	10.41	10.51	0.29
25	10.35	10.37	10.38	10.38	10.45	10.48	10.49	10.55	0.2
26	10.38	10.39	10.4	10.4	11.02	11.04	11.05	11.15	0.77
27	10.4	10.42	10.42	10.43	11.05	11.07	11.1	11.2	0.8
28	10.52	10.53	10.53	10.54	11.08	11.1	11.15	11.25	0.73
29	10.53	10.55	10.56	10.56	11.15	11.17	11.26	11.35	0.82
30	11.02	11.04	11.05	11.05	11.18	11.22	11.23	11.4	0.38

e. **Friday,9 February 2018**

Registration				General Clinic					
No.	Arrival	Receiving service	Complete Service	Arrival	Receiving service	Complete Service	Receiving doctor's treatment	Complete doctor's service	Service duration (hour)
1	8	8.09	8.09	8.1	8.33	8.33	8.58	9.06	1.06
2	8.09	8.12	8.13	8.14	8.34	8.34	8.59	9.1	1.01
3	8.1	8.13	8.13	8.14	8.35	8.35	9.04	9.05	0.95
4	8.19	8.21	8.21	8.22	8.42	8.43	9.08	9.13	0.94
5	8.23	8.23	8.24	8.24	8.43	8.44	9.13	9.15	0.92
6	8.29	8.32	8.33	8.33	8.52	8.54	9.25	9.4	1.11
7	8.33	8.35	8.36	8.36	8.48	8.51	9.23	9.3	0.97
8	8.43	8.44	8.44	8.45	8.55	8.56	9.4	9.42	0.99
9	8.52	8.56	8.56	8.57	8.58	9	9.43	9.49	0.97
10	8.52	8.58	8.59	8.59	9.1	9.1	9.43	9.52	1
11	9	9.04	9.04	9.06	9.1	9.12	9.52	9.55	0.55
12	9.05	9.06	9.07	9.08	9.12	9.3	9.46	9.53	0.48
13	9.2	9.21	9.21	9.22	9.24	9.26	9.48	9.53	0.33
14	9.23	9.24	9.24	9.25	9.32	9.33	9.55	9.58	0.35
15	9.3	9.31	9.31	9.32	9.33	9.34	9.58	10.01	0.71
16	9.33	9.34	9.34	9.35	9.48	9.48	9.59	10.01	0.68
17	9.49	9.5	9.5	9.52	10.1	10.14	10.19	10.25	0.76
18	9.52	9.53	9.54	9.56	10.15	10.18	10.24	10.4	0.88
19	10.02	10.09	10.09	10.11	10.32	10.37	10.38	10.45	0.43
20	10.1	10.13	10.13	10.15	10.2	10.54	11.16	11.25	1.15

21	11.2	11.23	11.24	11.35	11.36	11.37	11.49	11.5	0.3
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f. **Saturday, 10 February 2018**

Registration				General clinic					
No.	Arrival	Receiving service	Complete Service	Arrival	Receiving service	Complete Service	Receiving doctor's treatment	Complete doctor's service	Service duration (hour)
1	8.01	8.04	8.05	8.05	8.17	8.2	8.21	8.43	0.42
2	8.14	8.24	8.24	8.25	8.47	8.49	8.51	8.55	0.41
3	8.22	8.33	8.34	8.35	8.41	8.41	8.42	8.51	0.29
4	8.25	8.35	8.35	8.36	8.45	8.46	8.48	8.48	0.23
5	8.27	8.4	8.4	8.41	8.49	8.51	8.57	9.01	0.74
6	8.35	8.4	8.41	8.41	8.52	8.54	9.02	9.05	0.7
7	8.4	8.43	8.43	8.44	8.53	8.55	8.56	8.59	0.19
8	8.42	8.45	8.46	8.47	8.56	8.59	9.05	9.09	0.67
9	8.43	8.48	8.48	8.49	9.06	9.07	9.09	9.12	0.69
10	8.45	9.49	8.49	8.52	9.08	9.09	9.1	9.12	0.67
11	8.47	8.55	8.56	8.57	9.06	9.09	9.1	9.17	0.7
12	8.49	9.53	8.54	8.58	9.09	9.1	9.12	9.16	0.67
13	8.51	8.57	8.58	8.59	9.1	9.1	9.12	9.15	0.64
14	8.52	8.58	8.58	8.59	9.1	9.11	9.14	9.21	0.69
15	8.53	8.59	9	9	9.23	9.24	9.25	9.3	0.77
16	8.55	9.09	9.09	9.1	9.24	9.24	9.25	9.29	0.74
17	8.57	9.14	9.14	9.15	9.25	9.26	9.31	9.34	0.77
18	9.14	9.21	9.21	9.22	9.26	9.27	9.29	9.38	0.24

19	9.19	9.28	9.28	9.29	9.49	9.51	9.51	9.56	0.37
20	9.25	9.37	9.37	9.38	9.51	9.52	9.53	10	0.75
21	9.32	9.44	9.44	9.45	9.53	9.55	10	10.1	0.78
22	9.4	9.45	9.45	9.46	9.58	9.59	10	10.11	0.71
23	9.42	9.49	9.51	9.51	10	10.02	10.04	10.15	0.73
24	9.48	9.51	9.51	9.52	10.03	10.04	10.05	10.06	0.58
25	9.5	9.54	9.55	9.55	10.11	10.14	10.14	10.18	0.68
26	9.51	9.56	9.57	9.57	10.14	10.16	10.17	10.34	0.83
27	9.53	9.57	9.58	9.59	10.17	10.18	10.2	10.25	0.72
28	9.55	10	10.01	10.02	10.19	10.21	10.23	10.26	0.71
29	9.58	10.09	10.1	10.1	10.28	10.29	10.4	10.53	0.95
30	10.07	10.14	10.14	10.15	10.3	10.31	10.35	10.37	0.3

Appendix 2. Calculation on f(b)

$$\lambda = 8, \mu = 1, c = 9 \text{ obtained } \rho = \frac{\lambda}{\mu} = \frac{13}{1} = 13$$

$$p_0 = \frac{1}{\sum_{n=0}^{c-1} \frac{\rho^n}{n!} + \frac{\rho^c}{c! \left(1 - \frac{\rho}{c}\right)}}$$

$$p_0 = \frac{1}{\left(\frac{8^0}{0!} + \frac{8^1}{1!} + \frac{8^2}{2!} + \frac{8^3}{3!} + \frac{8^4}{4!} + \frac{8^5}{5!} + \frac{8^6}{6!} + \frac{8^7}{7!} + \frac{8^8}{8!}\right) + \frac{8^9}{9! \left(1 - \frac{8}{9}\right)}}$$

$$p_0 = 0,000196$$

then,

$$f(b) = \frac{\rho^c}{c! \left(1 - \frac{\rho}{c}\right)} p_0$$

$$f(b) = \frac{8^9}{9! \left(1 - \frac{8}{9}\right)} (0,000196)$$

$$f(b) = 0,653327$$

Appendix 3. Calculation on L_s , L_q , W_s , dan W_q

Rata-rata pasien dalam sistem (L_s)

Dengan menggunakan persamaan (5) diperoleh

$$L_s = (0,653327) \left(\frac{16}{(9(2) - 16)} \right) + \frac{16}{2}$$

= 13,23 \approx 14 orang

Rata-rata yang menunggu dalam antrian (L_q)

Dengan demikian persamaan (4) diperoleh

$$L_q = (0,653327) \left(\frac{16}{(9(2) - 16)} \right)$$

= 5,23 \approx 6 orang

Waktu rata-rata pasien dalam sistem (W_s)

Dengan demikian persamaan (6) diperoleh

$$w_s = (0,653327) \left(\frac{1}{(9(2) - 16)} \right) + \frac{1}{2}$$

= 0,8267 jam \approx 49,6 menit

Waktu rata-rata pasien menunggu dalam antrian (W_q)

Dengan demikian persamaan (7) diperoleh

$$w_q = (0,653327) \left(\frac{1}{(9(2) - 16)} \right)$$

= 0,3267 jam \approx 19,6 menit

Appendix 4. SPSS output on Kolmogorov-Smirnov's test on arrival time between patients

One-Sample Kolmogorov-Smirnov Test

	Waktu Antar Kedatangan Senin
N	7
Exponential parameter. ^{a,b} Mean	13.43
Most Extreme Absolute	.211
Differences Positive	.211
Negative	-.125
Kolmogorov-Smirnov Z	.559
Asymp. Sig. (2-tailed)	.914

a. Test Distribution is Exponential.

b. Calculated from data

One-Sample Kolmogorov-Smirnov Test

	Waktu Antar Kedatangan Selasa
N	7
Exponential parameter. ^{a,b} Mean	10.57
Most Extreme Absolute	.195
Differences Positive	.195
Negative	-.113
Kolmogorov-Smirnov Z	.515
Asymp. Sig. (2-tailed)	.954

a. Test Distribution is Exponential.

b. Calculated from data

One-Sample Kolmogorov-Smirnov Test

	Waktu Antar Kedatangan Rabu
N	7 ^a
Exponential parameter. ^{b,c} Mean	13.67
Most Extreme Absolute	.531
Differences Positive	.531
Negative	-.038
Kolmogorov-Smirnov Z	1.300
Asymp. Sig. (2-tailed)	.068

a. There is 1 value outside the specified distribution range. This value is skipped.

b. Test Distribution is Exponential.

c. Calculated from data

One-Sample Kolmogorov-Smirnov Test

	Waktu Antar Kedatangan Kamis
N	6
Exponential parameter. ^{a,b} Mean	9.67
Most Extreme Absolute	.161
Differences Positive	.161
Negative	-.145
Kolmogorov-Smirnov Z	.395
Asymp. Sig. (2-tailed)	.998

- a. Test Distribution is Exponential.
b. Calculated from data.

One-Sample Kolmogorov-Smirnov Test

	Waktu Antar Kedatangan Jumat
N	7 ^a
Exponential parameter. ^{b,c} Mean	6.67
Most Extreme Absolute	.407
Differences Positive	.407
Negative	-.093
Kolmogorov-Smirnov Z	.996
Asymp. Sig. (2-tailed)	.274

- a. There is 1 value outside the specified distribution range. This value is skipped.
b. Test Distribution is Exponential.
c. Calculated from data.

One-Sample Kolmogorov-Smirnov Test

	Waktu Antar Kedatangan Sabtu
N	7
Exponential parameter. ^{a,b} Mean	8.29
Most Extreme Absolute	.315
Differences Positive	.315
Negative	-.141
Kolmogorov-Smirnov Z	.833
Asymp. Sig. (2-tailed)	.491

- a. Test Distribution is Exponential
b. Calculated from data.

Lampiran 5. Output SPSS Uji Kolmogorov Smirnov untuk Waktu Pelayanan

One-Sample Kolmogorov-Smirnov Test

	Senin
N	6
Exponential parameter. ^{a,b} Mean	8.00
Most Extreme Absolute Differences	.393
Positive	.153
Negative	-.393
Kolmogorov-Smirnov Z	.964
Asymp. Sig. (2-tailed)	.311

- a. Test Distribution is Exponential
b. Calculated from data.

One-Sample Kolmogorov-Smirnov Test

	SENIN
N	7
Exponential parameter. ^{a,b} Mean	13.43
Most Extreme Absolute Differences	.211
Positive	.211
Negative	-.125
Kolmogorov-Smirnov Z	.559
Asymp. Sig. (2-tailed)	.914

- a. Test Distribution is Exponential
b. Calculated from data.

One-Sample Kolmogorov-Smirnov Test

	SELASA
N	7
Exponential parameter. ^{a,b} Mean	10.57
Most Extreme Absolute Differences	.195
Positive	.195
Negative	-.113
Kolmogorov-Smirnov Z	.515
Asymp. Sig. (2-tailed)	.954

- a. Test Distribution is Exponential
b. Calculated from data.

One-Sample Kolmogorov-Smirnov Test

	RABU
N	7 ^a
Exponential parameter. ^{b,c} Mean	13.67
Most Extreme Absolute	.531
Differences Positive	.531
Negative	-.038
Kolmogorov-Smirnov Z	1.300
Asymp. Sig. (2-tailed)	.068

- There is 1 value outside the specified distribution range. This value is skipped.
- Test Distribution is Exponential.
- Calculated from data

One-Sample Kolmogorov-Smirnov Test

	KAMIS
N	6
Exponential parameter. ^{a,b} Mean	9.67
Most Extreme Absolute	.161
Differences Positive	.161
Negative	-.145
Kolmogorov-Smirnov Z	.395
Asymp. Sig. (2-tailed)	.998

- Test Distribution is Exponential
- Calculated from data.

One-Sample Kolmogorov-Smirnov Test

	JUMAT
N	7 ^a
Exponential parameter. ^{b,c} Mean	6.67
Most Extreme Absolute	.407
Differences Positive	.407
Negative	-.093
Kolmogorov-Smirnov Z	.996
Asymp. Sig. (2-tailed)	.274

- There is 1 value outside the specified distribution range. This value is skipped
- Test Distribution is Exponential
- Calculated from data.

One-Sample Kolmogorov-Smirnov Test

	SABTU
N	7
Exponential parameter. ^{a,b} Mean	8.29
Most Extreme Absolute	.315
Differences Positive	.315
Negative	-.141
Kolmogorov-Smirnov Z	.833
Asymp. Sig. (2-tailed)	.491

- a. Test Distribution is Exponential
- b. Calculated from data.

Appendix 6. Output for Pom For Windows

a. Monday

Waiting Lines Results					
puskesmas solution					
Parameter	Value	Parameter	Value	Minutes	Seconds
Multiple-Server Model		Average server utilization	.93		
Arrival rate(λ)	13	Average number in the line(L_q)	9.28		
Service rate(μ)	1	Average number in the system(L)	22.28		
Number of servers	14	Average time in the line(W_q)	.71	42.83	2569.68
		Average time in the system(W)	1.71	102.83	6169.68

Waiting Lines Results					
puskesmas solution					
Parameter	Value	Parameter	Value	Minutes	Seconds
Multiple-Server Model		Average server utilization	.87		
Arrival rate(λ)	13	Average number in the line(L_q)	3.22		
Service rate(μ)	1	Average number in the system(L)	16.22		
Number of servers	15	Average time in the line(W_q)	.25	14.87	892.22
		Average time in the system(W)	1.25	74.87	4492.22

Waiting Lines Results					
puskesmas solu					
Parameter	Value	Parameter	Value	Minutes	Seconds
Multiple-Server Model		Average server utilization	.81		
Arrival rate(λ)	13	Average number in the line(L_q)	1.45		
Service rate(μ)	1	Average number in the system(L)	14.45		
Number of servers	16	Average time in the line(W_q)	.11	6.69	401.11
		Average time in the system(W)	1.11	66.69	4001.11

b. Tuesday

Waiting Lines Results					
puskesmas sol					
Parameter	Value	Parameter	Value	Minutes	Seconds
Multiple-Server Model		Average server utilization	.92		
Arrival rate(λ)	12	Average number in the line(L_q)	8.45		
Service rate(μ)	1	Average number in the system(L)	20.45		
Number of servers	13	Average time in the line(W_q)	.7	42.26	2535.8
		Average time in the system(W)	1.7	102.26	6135.8

Waiting Lines Results					
puskesmas sol					
Parameter	Value	Parameter	Value	Minutes	Seconds
Multiple-Server Model		Average server utilization	.86		
Arrival rate(λ)	12	Average number in the line(L_q)	2.89		
Service rate(μ)	1	Average number in the system(L)	14.89		
Number of servers	14	Average time in the line(W_q)	.24	14.45	867.07
		Average time in the system(W)	1.24	74.45	4467.07

Waiting Lines Results					
puskesmas sol					
Parameter	Value	Parameter	Value	Minutes	Seconds
Multiple-Server Model		Average server utilization	.8		
Arrival rate(λ)	12	Average number in the line(L_q)	1.28		
Service rate(μ)	1	Average number in the system(L)	13.28		
Number of servers	15	Average time in the line(W_q)	.11	6.38	383.03
		Average time in the system(W)	1.11	66.38	3983.03

c. Wednesday

Waiting Lines Results					
puskesmas solut					
Parameter	Value	Parameter	Value	Minutes	Seconds
Multiple-Server Model		Average server utilization	.93		
Arrival rate(λ)	13	Average number in the line(L_q)	9.28		
Service rate(μ)	1	Average number in the system(L)	22.28		
Number of servers	14	Average time in the line(W_q)	.71	42.83	2569.68
		Average time in the system(W)	1.71	102.83	6169.68

Waiting Lines Results					
puskesmas solut					
Parameter	Value	Parameter	Value	Minutes	Seconds
Multiple-Server Model		Average server utilization	.87		
Arrival rate(λ)	13	Average number in the line(L_q)	3.22		
Service rate(μ)	1	Average number in the system(L)	16.22		
Number of servers	15	Average time in the line(W_q)	.25	14.87	892.22
		Average time in the system(W)	1.25	74.87	4492.22

Waiting Lines Results					
puskesmas so					
Parameter	Value	Parameter	Value	Minutes	Seconds
Multiple-Server Model		Average server utilization	.81		
Arrival rate(λ)	13	Average number in the line(L_q)	1.45		
Service rate(μ)	1	Average number in the system(L)	14.45		
Number of servers	16	Average time in the line(W_q)	.11	6.69	401.11
		Average time in the system(W)	1.11	66.69	4001.11

d. Thursday

Waiting Lines Results					
puskesmas sol					
Parameter	Value	Parameter	Value	Minutes	Seconds
Multiple-Server Model		Average server utilization	.89		
Arrival rate(λ)	16	Average number in the line(L_q)	5.23		
Service rate(μ)	2	Average number in the system(L)	13.23		
Number of servers	9	Average time in the line(W_q)	.33	19.6	1175.99
		Average time in the system(W)	.83	49.6	2975.99

Waiting Lines Results					
puskesmas sol					
Parameter	Value	Parameter	Value	Minutes	Seconds
Multiple-Server Model		Average server utilization	.8		
Arrival rate(λ)	16	Average number in the line(L_q)	1.64		
Service rate(μ)	2	Average number in the system(L)	9.64		
Number of servers	10	Average time in the line(W_q)	.1	6.14	368.26
		Average time in the system(W)	.6	36.14	2168.26

Waiting Lines Results					
Puskesmas Solution					
Parameter	Value	Parameter	Value	Minutes	Seconds
Multiple-Server Model		Average server utilization	.73		
Arrival rate(λ)	16	Average number in the line(L_q)	.65		
Service rate(μ)	2	Average number in the system(L)	8.65		
Number of servers	11	Average time in the line(W_q)	.04	2.45	146.97
		Average time in the system(W)	.54	32.45	1946.98

e. Friday

Waiting Lines Results					
puskesmas sol					
Parameter	Value	Parameter	Value	Minutes	Seconds
Multiple-Server Model		Average server utilization	.89		
Arrival rate(λ)	8	Average number in the line(L_q)	5.23		
Service rate(μ)	1	Average number in the system(L)	13.23		
Number of servers	9	Average time in the line(W_q)	.65	39.2	2351.98
		Average time in the system(W)	1.65	99.2	5951.98

Waiting Lines Results					
puskesmas sol					
Parameter	Value	Parameter	Value	Minutes	Seconds
Multiple-Server Model		Average server utilization	.8		
Arrival rate(λ)	8	Average number in the line(L_q)	1.64		
Service rate(μ)	1	Average number in the system(L)	9.64		
Number of servers	10	Average time in the line(W_q)	.2	12.28	736.52
		Average time in the system(W)	1.2	72.28	4336.52

Waiting Lines Results					
puskesmas sol					
Parameter	Value	Parameter	Value	Minutes	Seconds
Multiple-Server Model		Average server utilization	.73		
Arrival rate(λ)	8	Average number in the line(L_q)	.65		
Service rate(μ)	1	Average number in the system(L)	8.65		
Number of servers	11	Average time in the line(W_q)	.08	4.9	293.95
		Average time in the system(W)	1.08	64.9	3893.95

f. Saturday

Waiting Lines Results					
puskesmas sol					
Parameter	Value	Parameter	Value	Minutes	Seconds
Multiple-Server Model		Average server utilization	.94		
Arrival rate(λ)	15	Average number in the line(L_q)	12.11		
Service rate(μ)	2	Average number in the system(L)	19.61		
Number of servers	8	Average time in the line(W_q)	.81	48.44	2906.11
		Average time in the system(W)	1.31	78.44	4706.11

Waiting Lines Results					
puskesmas sol					
Parameter	Value	Parameter	Value	Minutes	Seconds
Multiple-Server Model		Average server utilization	.83		
Arrival rate(λ)	15	Average number in the line(L_q)	2.55		
Service rate(μ)	2	Average number in the system(L)	10.05		
Number of servers	9	Average time in the line(W_q)	.17	10.18	610.98
		Average time in the system(W)	.67	40.18	2410.98

Waiting Lines Results					
puskesmas sol					
Parameter	Value	Parameter	Value	Minutes	Seconds
Multiple-Server Model		Average server utilization	.75		
Arrival rate(λ)	15	Average number in the line(L_q)	.92		
Service rate(μ)	2	Average number in the system(L)	8.42		
Number of servers	10	Average time in the line(W_q)	.06	3.68	220.76
		Average time in the system(W)	.56	33.68	2020.76

Appendix 7. Calculation for Kolmogorov-Smirnov's test

a. Monday

No.	Observed	Expected	Relative frequency		Cumulative relative frequency		D
			Observed	expected	Observed	expected	
1	17	7.83333333	0.361702	0.16666667	0.36170213	0.166666667	-0.19504
2	16	8	0.340426	0.16666667	0.70212766	0.333333333	-0.36879
3	5	8	0.106383	0.16666667	0.80851064	0.5	-0.30851
4	6	8	0.12766	0.16666667	0.93617021	0.666666667	-0.2695
5	1	8	0.021277	0.16666667	0.95744681	0.833333333	-0.12411
6	2	8	0.042553	0.16666667	1	1	0
total	47	47.8333333	1	1			

b. Tuesday

No.	Observed	Expected	Relative frequency		Cumulative relative frequency		D
			Observed	expected	Observed	expected	
1	16	6.16666667	0.432432	0.16666667	0.43243243	0.166666667	-0.26577
2	8	6.16666667	0.216216	0.16666667	0.64864865	0.333333333	-0.31532
3	5	6.16666667	0.135135	0.16666667	0.78378378	0.5	-0.28378
4	4	6.16666667	0.108108	0.16666667	0.89189189	0.666666667	-0.22523
5	1	6.16666667	0.027027	0.16666667	0.91891892	0.833333333	-0.08559
6	3	6.16666667	0.081081	0.16666667	1	1	0
total	37	37	1	1			

c. Wednesday

No.	Observed	Expected	Relative frequency		Cumulative relative frequency		D
			Observed	expected	Observed	expected	
1	28	6.83333333	0.682927	0.1666667	0.682926829	0.1666667	-0.51626
2	8	7	0.195122	0.1666667	0.87804878	0.3333333	-0.54472
3	2	7	0.04878	0.1666667	0.926829268	0.5	-0.42683
4	2	7	0.04878	0.1666667	0.975609756	0.6666667	-0.30894
5	0	7	0	0.1666667	0.975609756	0.8333333	-0.14228
6	1	7	0.02439	0.1666667	1	1	0
Total	41	41.8333333	1	1			

d. Thursday

No.	Observed	Expected	Relative frequency		Cumulative relative frequency		D
			Observed	expected	Observed	expected	
1	11	5.8	0.37931	0.2	0.366666667	0.2	-0.16667
2	10	5.8	0.344828	0.2	0.7	0.4	-0.3
3	4	5.8	0.137931	0.2	0.833333333	0.6	-0.23333
4	3	5.8	0.103448	0.2	0.933333333	0.8	-0.13333
5	1	5.8	0.034483	0.2	0.966666667	1	0.033333
total	29	29	1	1			

e. Friday

No.	Observed	Expected	Relative frequency		Cumulative relative frequency		D
			Observed	expected	Observed	Expected	
1	2	3.33333333	0.1	0.16666667	0.0952381	0.16666667	0.071429
2	5	3.33333333	0.25	0.16666667	0.33333333	0.33333333	0
3	5	3.33333333	0.25	0.16666667	0.57142857	0.5	-0.07143
4	6	3.33333333	0.3	0.16666667	0.85714286	0.66666667	-0.19048
5	0	3.33333333	0	0.16666667	0.85714286	0.83333333	-0.02381
6	2	3.33333333	0.1	0.16666667	0.95238095	1	0.047619
Total	20	20	1	1			

f. Saturday

No.	Observed	Expected	Relative frequency		Cumulative relative frequency		D
			Observed	expected	Observed	Expected	
1	16	4.83333333	0.551724	0.1666667	0.53333333	0.1666667	-0.36667
2	4	4.83333333	0.137931	0.1666667	0.66666667	0.3333333	-0.33333
3	6	4.83333333	0.206897	0.1666667	0.86666667	0.5	-0.36667
4	1	4.83333333	0.034483	0.1666667	0.9	0.6666667	-0.23333
5	1	4.83333333	0.034483	0.1666667	0.93333333	0.8333333	-0.1
6	1	4.83333333	0.034483	0.1666667	0.96666667	1	0.033333
Total	29	30	1	1			