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Comparison of the Performance of Inpatient Care for Chemotherapy Patients in RSUP Dr. Hasan Sadikin Bandung West Java Using Queuing Theory

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Abstract

Waiting is the underlying presence of a queue. The queue process is a process associated with the arrival of customers at a care facility, waiting in the queue if the line cannot be served, being served, and eventually left the facility after being served. This article studied the queue models and customer care processes of inpatient chemotherapy in RSUP Dr. HasanSadikin Bandung West Java. The analysis was performed by determining the probability distribution of the arrival and service time using One Sample Kolmogorov-Smirnov test, specify a model queue for each class, and determine the effectiveness of patient care through the calculation of performance measures of queuing model in the class of hospitalization. The queue models which obtained from the analysis are M/G/S model for inpatient class 1, 3, and VIP, and M/M/S model for inpatient class 2. The result shows that the system has been effective in each class based on the values of each performance measurements.

Keywords: chemotherapy, distribution test, inpatient, performance measurements, queue models.

Introduction

It is inevitable that waiting is the most boring job and takes unpredictable time duration. Waiting situation is also part of the circumstances that occurred in a series of operations that are random in a facility [1]. The phenomenon of waiting is that underlying of the existence of a queue to be able to get serviced. Queue theory is a mathematical theory concerns the study of queues or waiting lines [2]. The main actor in a queue situation is the customer and the service provider (server). Also in the service, the service time per customer is being calculated. In queuing models, customer arrival and service time are summarized in the probability distribution that is generally called as the arrival distribution and the service time distribution.

In general, the arrival is assumed as Poisson distributed and the service time is assumed to be exponentially distributed, if both of these assumptions are not met then the distributed queuing model assumed as general (common). There is a notation called Kendall notation to classify different queuing models. Queue discipline commonly applied in daily life is FCFS (First Come First Served), but in some instances, the queue discipline is not always applied because of patient must be service as soon as possible. One example that does not always apply FCFS queuing discipline is the service in the hospital. The applied discipline is PS (Priority Service) discipline. It means more critical patients will be served first without having to pay attention to who comes first. Increasing number of hospitals and health services deals then people will be more selective in determining the place of the treatment, so as to be able to win in the competition then the hospital should improve their service system.

It is devastating for chemotherapy patients because it requires fast service. If there is a solid queue, patient will be wait much longer to get service. If it is going on continuously it will cause a negative impact on the patient and the hospital. The negative impact that may occur on the hospital and the patient is the protest from the patient. If patients out of the queue before getting services, the hospital will lose competition and the more fatal impact is the death of the patient [3].The hospital needs a solution to be able to avoid these negative impacts. Based on the impact and problems that occur in hospitals, the authors make a study entitled "Comparison of the Performance of Inpatient Care for Chemotherapy Patients in RSUP Dr. HasanSadikin Bandung West Java Using Queuing Theory ".

Theoretical Basis

Analysis of the queue was first introduced by A.K. Erlang (1913) who studied the fluctuations in demand for telephone facilities and delays in service. This day, queuing analysis are widely applied in the field of business (banks, supermarkets), industry (automatic machines services), transportation (airports, seaports, postal services) and etc. Characteristics of the queuing system are as follows [4]:

1. Characteristics of Arrival

   There are three main characteristics that must be owned by the arrival of the input source for a customer service system that are the size of the population (source arrival), the behavior of the arrival, arrival pattern.

2. Characteristics of Queue

   Queue line is the second component of the queuing system, it has two main characteristics. First is limited queue or unlimited queues and the second is queuing rules.

3. Characteristics Services

   The system provides service performance for customers using the service system design, and distribution of service time.

From all sort of the queue characteristics above, it can be concluded that the characteristic of the queue is a process starting from the arrival of the population who want to be served until the service is done. There are four discipline characteristics in queue model. The characteristics are given below:

1. First Come First Served (FCFS) or First In First Out (FIFO): is a rule which is the customer to be served is the customer who comes first. For example, a queue at a cashier of a supermarket.

2. Last Come First Served (LCFS) or Last In First Out (LIFO): a queue where that the customer who comes most recently is the earliest to be served. For example, the queue at the pile of goods in warehouse, the goods of the last entry will be pinned on top, so it will be taken first.

3. Service In Random Order (SIRO) or sometimes referred to Random Selection for Service (RSS), means a service or a call based on random probability, is not concerned about whocame first. For examples lottery papers waiting to be awarded, taken at random.

4. Priority Service (PS), meaning that the service priority given to those who have the highest priority compared with those with the lowest priority, even though the latter had already came in the waiting line. An event like this can be caused by several things, such as a person in a state of pain that is heavier than the others in a hospital. PS grouped into two, namely the preemptive and non-preemptive. Discipline preemptive describes the situation where the service providers are serving someone than switch to serve other people who prioritized although they did not finished yet in servingthe patients earlier. Non pre-emptive discipline describes a situation where the service providers will finish their work then switched to serve people who prioritized.

Queuing models help managers to make decisions, with analysis of the queue. The performance of a queue can be measured in several ways. Performance of the queue can be measured by the average time spent by a customer in the queue is the time spent waiting for service. The less is spent, the better the results of performance of the queue, the average time spent by customers in the system (waiting time and service time) is the majority amount of time spent of customers in the system, the number of customers in the system is a number of customers who come to every available system, probability is empty service customers served there, and the system utilization factor is the probability of a busy service in the system.

There are four types of queue model which are very popular among the researchers. The types consist of single server single phase, multi-server single phase, single server multiphase, and multi-server multiphase. In our study, the queue model suitable with the inpatient care for chemotherapy patient is multi-server single phase because there are some rooms in each inpatient care class. There are some models for the types, some of them suitable with the case are M/G/s and M/M/s queue model.

In M/G/s queue model, the first sign (M) indicates that the arrival rate Poisson distribution, general service time distribution, with the number of servers more than one (s> 1). And the model M/M/s, the first sign (M) indicates that Poisson distributed arrival rate, service time is exponentially distributed, with more than one server (s> 1). Queuing system will reach steady-state if [5]:

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

While the performance measurements for each modelis given by Table 1.

Table 1.M/G/s and M/M/s Formula

	M/G/s Queue Model	M/M/s Queue Model
The probability of no patients (P_0)	$P_0 = 1 - \rho$ [5]	$P_0 = \dfrac{1}{\left(\sum_{n=0}^{s-1} \dfrac{\left(\frac{\lambda}{\mu}\right)^n}{n!} + \dfrac{\left(\frac{\lambda}{\mu}\right)^s}{(s-1)!\left(s - \frac{\lambda}{\mu}\right)} \right)}$ [8]
Mean time of customer waiting in the queue (W_q)	$W_q = \dfrac{\lambda^2 \mu^{-2} \left(\frac{\lambda}{\mu}\right)^{s-1}}{2(s-1)!\left(s - \frac{\lambda}{\mu}\right)^2 \left(\sum_{n=0}^{s-1} \dfrac{\left(\frac{\lambda}{\mu}\right)^n}{n!} + \dfrac{\left(\frac{\lambda}{\mu}\right)^s}{(s-1)!\left(s - \frac{\lambda}{\mu}\right)} \right)}$ [6]	$W_q = \dfrac{L_q}{\lambda}$ [8]
Mean time of customer waiting in the system (W)	$W = W_q + \dfrac{1}{\mu}$ [5]	$W = W_q + \dfrac{1}{\mu}$ [8]
Average number of customers in the queue (L_q)	$L_q = \lambda . W_q$ [5]	$L_q = \dfrac{P_0 (\lambda/\mu)^s \rho}{s!(1-p)^2}$ [8]
Average numberof customers in the system (L)	$L = \lambda . W$ [5]	$L = L_q + \dfrac{\lambda}{\mu}$ [8]

It is needed to test the distribution of the arrival and the service time to obtain the suitable model for each class. There are many tests which can be used in testing the distribution of the arrival and service time, one of those is one-sample Kolmogorov Smirnov test. In One-sample Kolmogorov-Smirnov test goodness of fit test, we have to pay attention in the degree of correspondence between the sample distribution of the observations and a particular theoretical distribution. The method used in the one-sample Kolmogorov Smirnov test is establishing the cumulative frequency distribution of the data sample results of observations at a specified interval. One-sample Kolmogorov Smirnov test was selected for testing because it can be used in the very small sample and it does not omit information even if the samples are combined in several categories.

The steps of using the one-sample Kolmogorov Smirnov test are:

Hypothesis:

H_0: Data sample observation results can be ascribed to the Poisson distributed population.

H_1: Data sample observation results cannot be ascribed Poisson distributed population. [7]

Statistic Test: $D = \underset{x}{Sup}\left|_{Fn}(x) - \hat{F}(x)\right|$

Refusal area is D > $d_{n,\alpha/2}$ where the value of $d_{n,\alpha/2}$ is Kolmogorov Smirnov value table, or we reject H_0 if p-value $< \alpha$.

Results and Discussion

Some variables related to queuing system are time duration between the arrival of the patient and the service time for each patient. Descriptive statistics for the variables of time between the patients arrival for each class are shown in Table 2 to Table 5.

Table 2. 1st Class Inpatient Care

Date	**Inter-arrival Time**	**N (patient)**	**Average Length of Inpatient**	**Date**	**Inter-arrival Time**	**N (patient)**	**Average Length of Inpatient**
1-Dec-15	1	2	4	12-Dec-15	1	1	13
2-Dec-15	1	2	8.5	14-Dec-15	2	4	11
3-Dec-15	1	6	8.5	15-Dec-15	1	1	7
4-Dec-15	1	2	11	17-Dec-15	2	3	6.333333
6-Dec-15	2	1	10	18-Dec-15	1	1	3
7-Dec-15	1	3	8.666667	21-Dec-15	3	1	7
8-Dec-15	1	4	11	22-Dec-15	1	1	3
9-Dec-15	1	1	14	23-Dec-15	1	1	9
10-Dec-15	1	1	6	24-Dec-15	1	1	4
11-Dec-15	1	2	7	28-Dec-15	4	2	3.5

In the 1st class inpatient care, most patients entered on December 3rd that is 6 patients, and the average of the shortest inpatient was for 3 days and the longest was 14 days.

Table 3.2nd Class Inpatient Care

Date	Inter-arrival Time	N (patient)	Average Length of Inpatient	Date	Inter-arrival Time	N (patient)	Average Length of Inpatient
1-Dec-15	1	2	10.5	14-Dec-15	2	2	18
2-Dec-15	1	2	7	15-Dec-15	1	1	14
4-Dec-15	2	3	12.33333	16-Dec-15	1	2	9
7-Dec-15	3	1	5	17-Dec-15	1	3	10
8-Dec-15	1	3	15.66667	18-Dec-15	1	1	6
9-Dec-15	1	2	12	22-Dec-15	4	1	6
10-Dec-15	1	2	12.5	23-Dec-15	1	1	9
11-Dec-15	1	1	8	30-Dec-15	7	1	2
12-Dec-15	1	1	4				

In the 2nd class inpatient care, most patients entered on December 4th,8th, and 17th that is 3 patients and the average of the shortest inpatient was 2 days and the longest was 18 days.

Table 4. 3rd Class Inpatient Care

Date	Inter-arrival Time	N (patient)	Average Length of Inpatient	Date	Inter-arrival Time	N (patient)	Average Length of Inpatient
1-Dec-15	1	11	13	14-Dec-15	3	4	11.25
2-Dec-15	1	6	10.66667	15-Dec-15	1	4	10.25
3-Dec-15	1	8	10.125	16-Dec-15	1	10	7.4
4-Dec-15	1	10	9.6	17-Dec-15	1	3	5
5-Dec-15	1	5	11	18-Dec-15	1	5	7.2
6-Dec-15	1	1	11	20-Dec-15	2	2	6.5
7-Dec-15	1	5	13	21-Dec-15	1	2	6
8-Dec-15	1	6	13.16667	22-Dec-15	1	8	7.75
9-Dec-15	1	1	20	23-Dec-15	1	4	8.25
10-Dec-15	1	6	9.333333	28-Dec-15	5	2	3
11-Dec-15	1	4	13.75	29-Dec-15	1	1	2

In 3rd classinpatient care, most patients were entered on the 16th of December that is 10 patients and the average of the shortest inpatient was 2 days and the longest was 13.75 days.

Table 5. VIP Class Inpatient Care

Date	**Inter-arrival Time**	**N (patient)**	**Average Length of Inpatient**	**Date**	**Inter-arrival Time**	**N (patient)**	**Average Length of Inpatient**
1-Dec-15	1	1	6.5	14-Dec-15	3	1	2
2-Dec-15	1	1	9	15-Dec-15	1	2	4
3-Dec-15	1	1	26	17-Dec-15	2	2	5.5
4-Dec-15	1	1	20	18-Dec-15	1	2	7.5
6-Dec-15	2	2	7.5	19-Dec-15	1	1	13
7-Dec-15	1	1	9	20-Dec-15	1	1	8
8-Dec-15	1	3	5	21-Dec-15	1	3	6
10-Dec-15	2	1	7	22-Dec-15	1	1	7
11-Dec-15	1	4	7	26-Dec-15	4	1	5

In the VIP class inpatient care, most patients were entered on the 11th of December that is 4 patients and the average of the shortest inpatient was 2 days and the longest was 26 days.

Furthermore, to fit the queue model for each class, we conduct a test to verify the distribution of the arrival and the service time. The arrival of chemotherapy patients at RSUP Dr. HasanSadikin assumed Poisson distributed.To ascertain the factuality, a Goodness of Fit test with 0.05 level of significance is carried out by using one-sample Kolmogorov-Smirnov test. Data acquired from the research is recapitulated according to visitor arrivals per one day interval. The result of the test is given in Table 6.

Table 6. Output of One-Sample Kolmogorov Smirnov for Testing the Arrival Rate

No.	**Class**	**Asymp. Sig. (2-tailed)**	**Decision**
1.	1st Class	0.176	Do not reject H_0
2.	2nd Class	0.958	Do not reject H_0
3.	3rd Class	0.086	Do not reject H_0
4.	VIP and ICU	0.269	Do not reject H_0

According to the Table 6, it can be observed that the p-value for all classes are greater than 0.05, which means the H_0 is failed to be rejected. It gives the conclusion that the arrival rate of all classesfor chemotherapy patients are Poisson distributed.

Hereafter, we test the service time distribution also using one-sample Kolmogorov Smirnov test. The result of the test is given by Table 7.

Table 7. Output of One-Sample Kolmogorov Smirnov for Testing the Service Time Distribution

No.	Class	Asymp. Sig. (2-tailed)	Decision
1.	1st Class	0.033	Reject H_0
2.	2nd Class	0.108	Do not reject H_0
3.	3rd Class	0.016	Reject H_0
4.	VIP and ICU	0.040	Reject H_0

According to the Table 7, for the 1st class, 3rd class, VIP and ICU we reject H_0 because p-value< α . It implies that the service time for chemotherapy patients in the 1st class, 3rd class, VIP and ICU are not exponentially distributed. While in 2nd class, we failed to reject H_0 because p-value> α which means the service time for chemotherapy patients in the 2nd class is exponentially distributed.

Based on the results of the one-sample Kolmogorov Smirnov which were carried out in chemotherapy inpatients room in RSUP Dr. Hasan Sadikin Bandung, the distribution of the arrival obtained in all classes are confirmed to Poisson. However, in addressing the service time, not all classes are conforming to exponential distribution pattern. In addition, there are 3 rooms available in 1st class and 2nd class, 4 rooms in 3rd class, and 2 rooms in VIP and ICU. According to Kendall's notation, queuing system in inpatient room is obtained as follows:

Table 8. Queue Model for Each Class

Class	Queue Model
1st class	M/G/3
2nd class	M/M/3
3rd class	M/G/4
VIP & ICU	M/G/2

After the model for each class has been obtained, we will compare the service performance in each class by comparing their performance measurement suitable with the model. Table 9 shows the results of the performance measurement for each class.

Table 9. Performance Measurement for Each Class

Class	Level of Activity (ρ)	Probability of No Patients in System (P_0)	Mean Time of Customer Waiting in Queue (W_q) (days)	Mean Time of Customer Waiting in System (W) (days)	Average Number of Customers Waiting in Queue (L_q)	Average Number of Customers Waiting in System (L)
1st class	0.060021	0.93997	2.76036E-05	0.128644967	3.8645E-05	0.180102954
2nd class	0.062112	0.829640618	2.53259E-05	0.10269473	4.45736E-05	0.180742726
3rd class	0.034649	0.965351	1.75258E-06	0.105154224	2.29588E-06	0.137752033
VIP & ICU	0.055914	0.944086	2.05208E-05	0.116164539	2.955E-05	0.167276937

Figure 1 to Figure 3 simplifies the comparison of the performance measurements for each class and shows the correlation between each measure.

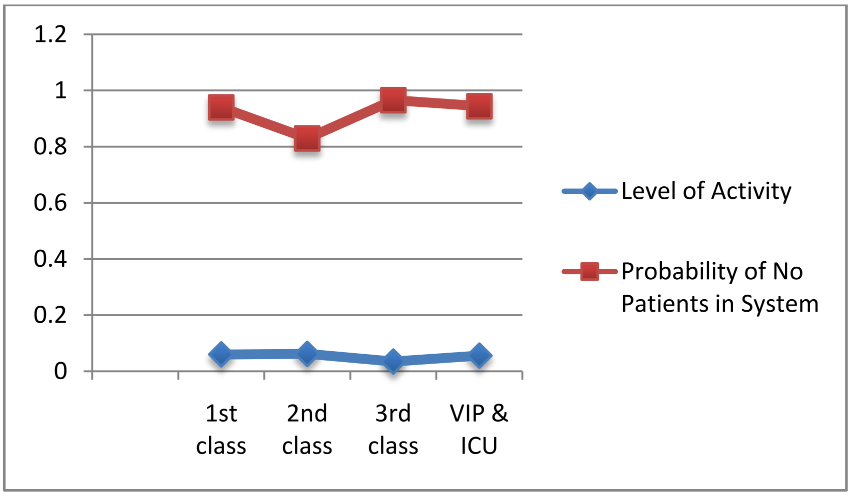

Figure 1. Graphics of Level of Activity and Probability of No Patients in System

Figure 1 shows the level of activity and probability of no patients in the system and its correlation. We can see that the four models are belongs to the effective model because its level of activity is less than 1. A low level of activity shows that there is no accumulated queue in the system. From four classes we can see that the lowest level of activity is in the 3rd class. The lowlevel of activity resulted in the high probability of no patients in the system. These implication is shown by Figure 1 where the lower the level of activity, the higher the probability of no patients in the system, vice versa.

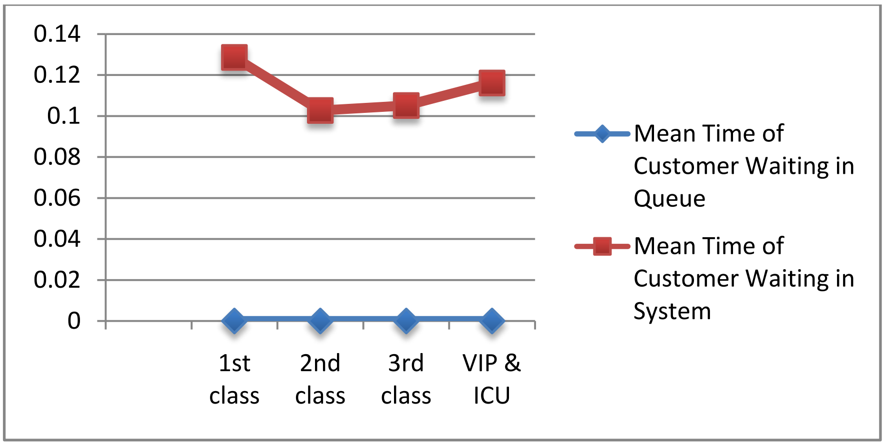

Figure 2. Graphics of Mean Time of a Customer Waiting in Queue and in System

Figure 2 shows the plot of mean time of a customer waiting in queue and in system. We can see that the mean time both in queue and in the system in all of four classes is less than one day. It means that there is no accumulated queue in the system (as shown before) which implies that every customer arrives, they will be directly served.

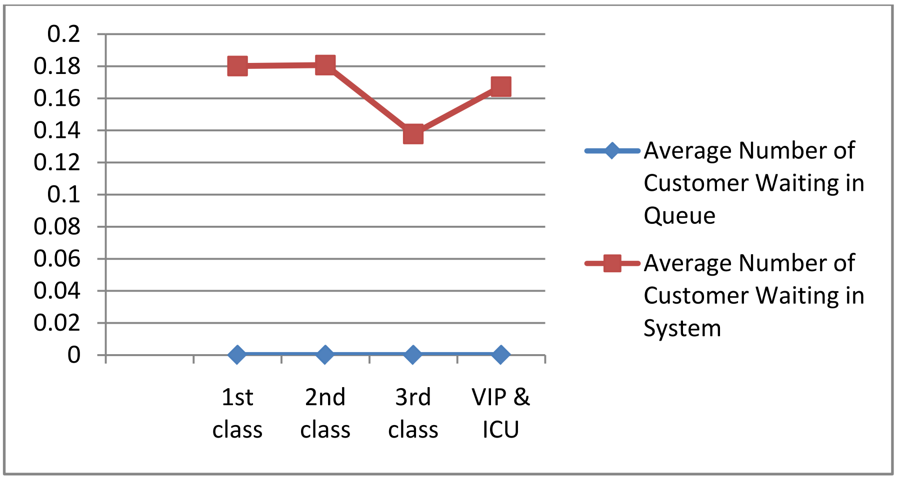

Figure 3. Graphics of Average Number of Customers Waiting in Queue and in System

Figure 3 shows the average number of customers waiting in queue and in system. In all four classes, we can see that there is no customer waiting both in queue and in system. It is quite reasonable, because if the whole room filled with patients and there are other patients who entered into the system, the patient will look for other hospitals that still have vacant rooms, so there will be no queue in the patient's room.

Conclusion

From the analysis, we can draw some conclusions that are:

1. Inpatient queuing model of 1^{st}, 3^{rd}, and VIP class inpatient follow the (M/G/s) model wherethe arrival is Poisson distributed and average general service time distribution. Queuing model of 2^{nd} class follow the (M/M/s) model with an average time of arrival of the Poisson distribution and the average exponentially distributed service time.

2. The shortest level of the patient's arrival in inpatient was 3rd class. It was 1.31(we can say one) patient per day, and the longest was 2nd class. It was 1.76 patients per day. The shortest service time of inpatient was 1st class. It was 7.775 days per patient, and the longest was 3rd class. It was 9.51 days per patient.

3. Based on the results of Performance Measurement for Each Class concluded that almost no queues of patients to receive chemotherapy room. Value of ρ close to 1 means that the queue system has been very effective. The probability there were no patients in the queue is very small, the rooms are always in use and when the room is full does not accept incoming patients.

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