Available online at http://www.iorajournal.org/index.php/ijgor/index

International Journal of Global Operations Research

e-ISSN: 2722-1016
p-ISSN: 2723-1739

Vol. 4, No. 3, pp. 146-153, 2023

Performance Analysis of Service System in the Pediatric Clinic Department at Rumah Sakit Umum Daerah (RSUD) Sumedang

Diana Annisa[1*], Sudradjat Supian[2], Julita Nahar[3]

[1]*Mathematics Undergraduate Study Program, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran, Jatinangor, Indonesia*
[2,3]*Department of Mathematics, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran, Jatinangor, Indonesia*

**Corresponding author email: diana19007@mail.unpad.ac.id*

Abstract

A service is considered good if it can provide fast service so that customers are not left waiting for too long. If a service has a long queue, then causing customers to wait for a long time, their satisfaction and trust levels may decrease. Rumah Sakit Umum Daerah (RSUD) Sumedang offers various outpatient services, including a pediatric clinic. Almost every day, a significant number of patients come to the pediatric clinic, resulting in considerable waiting time for patients. The service discipline used is First Come First Serve, and the service system falls under the multi-phase category, where each patient has to go through several stages to receive optimal service. This research will focus on the service system in the pediatric clinic at each stage, starting from registration, examination by the doctor, to medication collection at the pharmacy. The research findings indicate that the workload at the pharmacy counter is very high, while it is significantly low at the registration counter, resulting in suboptimal performance of the service system at these two stages. The performance of the service system can be improved by reducing service facilities at the registration counter and adding resources at the pharmacy counter.

Keywords: Service System, multiphase, hospital.

1. Introduction

Every company, whether it is big or small, will always strive to improve the quality of the company in order to better satisfy customers. A service is considered good if it can provide prompt service so that customers are not kept waiting for too long. Here, service is related to the queueing system. If long queues frequently occur, it will result in customer dissatisfaction and a decrease in trust towards the service. According to Gross et al. (2018), a queueing system is when customers arrive to receive service, wait to be served if the service facilities or servers are still busy, then receive service and leave the system after being served.

Hospitals are one of the service-oriented companies in the healthcare sector. Long waiting times that occur in service centers such as hospitals can lead to increased disease transmission (Bahadori, Mohammadnejhad, Ravangard, & Teymourzadeh, 2014). Service models can generate relatively simple formulas to predict various performance metrics such as mean delay or the probability of waiting more than a given amount of time before being served. This means that queueing models are easier and cheaper to use, and they can be more readily employed to find "optimal" solutions rather than merely estimating system performance for specific scenarios (Green, 2006). The application of queuing theory in hospital service systems can be used to minimize costs by reducing inefficiencies and delays within the system (Mehandiratta, 2011). The number of patients coming to the hospital is also very difficult to predict, as is the case with one hospital, namely Sumedang Regional General Hospital (RSUD), specifically in the pediatric clinic.

The service system structure at Rumah Sakit Umum Daerah (RSUD) Sumedang falls under the category of a multi-phase service system, where patients need to go through several stages of service, including registration, examination, and medication retrieval at the pharmacy. In a multi-phase service system, also known as a tandem service system, each customer has to go through multiple servers before completing a service (Winston, 2003). The input of each queue in the serial service system, except for the first stage of service, is the output from the previous service (Stallings, 2000).

Analysis of multi-phase service systems has been conducted by several previous researchers, including Khayrullin and Myasnikov (2018), who discussed simulation of multi-phase service systems to optimize service resources in the housing sector. Furthermore, Najmudin et al. (2010) analyzed the multi-phase patient flow system in the Obstetrics and Gynecology Department (O&G Department) of a specialized center by developing a simulation model that depicts the actual patient flow in the department. Vikalia (2017), compared the performance of queueing models in THB machine counters that used a multi-channel-multi-phase model with locket service operators that used a single-channel-single-phase model. Next, Aneyeri and Nadar (2018) conducted research on the multi-phase service system at Kerala International Airport, where the queueing model developed in this study was compared using analysis of variance (ANOVA). Siahaan and Manurung (2021) analyzed the queue system in Happy World using single channel multiphase model. Lastly, Hermanto (2023) conducted research on the analysis of a service system for issuing driving licenses at the Sumbawa Besar Police Department, which consists of three stages and one service facility at each stage.

Based on the problem description above and previous research studies, the multi-phase service system can demonstrate the performance level of the service system at each stage. The service system model used can address system issues such as adding or reducing service facilities at each stage of service. Therefore, this research will focus on analyzing the multi-phase service system in the pediatric clinic at Rumah Sakit Umum Daerah (RSUD) Sumedang and implementing an appropriate service model to optimize the service system in the pediatric clinic.

2. The Basic Concept of Service System

2.1. The Definition of Service System

The definition of service can be related to queues. According to Heizer and Render (2016), a queue (waiting line) is a line of people or items waiting to be served. There are three characteristics of a queue system: arrivals, queue discipline, and service facilities. Queueing occurs when the arrival rate is faster than the service rate, causing the demand for service to exceed the service capacity. Service discipline refers to how a server selects the queue members to be served. There are several types of service discipline, including:

1. FCFS (First come, first served): The first customer in the queue is served first.
2. LCFS (Last come, first served): The last customer in the queue is served first.
3. SIRO (Service in random order): Service is provided to customers randomly.
4. GD (General Discipline): This is a general service discipline applied to most queueing systems (if no specific discipline is in place), where the first customer in the queue is served first.

In service system there are several service models, one of which is the multi-phase service system. The multi-phase service system is a service system where customers have to go through several distinct stages to complete the service process. Each stage of the multi-phase service can have one or more service facilities (Hess, S. and Grbčić, A, 2019). In the analysis of the multi-phase model, the service system can use a combination of the [M/M/1] model, the [M/M/c] model, or a combination of both.

2.2. Distribution Test

1) Poisson Distribution

In service systems, Poisson distribution is used to describe the number of events occurring within a specific time interval. These events can be customer arrivals or departures. A random variable X is said to follow a Poisson distribution with parameter λ if it has the following probability density function:

$$f(x) = \begin{cases} \dfrac{\lambda^x e^{-\lambda}}{x!} & , x = 0,1,2,\ldots \\ 0 & , \text{another } x \end{cases} \tag{1}$$

2) Exponential Distribution

In service systems, the relationship between the Poisson distribution and the Exponential distribution is demonstrated by the inter-arrival time of customers and the departure pattern of customers with the customer service time. A random variable X is said to follow an Exponential distribution with parameter λ if it has the following probability density function:

$$f(x) = \begin{cases} \lambda e^{-\lambda x} & , x > 0 \\ 0 & , \text{another } x \end{cases} \tag{2}$$

3) Kolmogorov-smirnov Test

The basic concept of the Kolmogorov-Smirnov test is to compare a distribution (whose normality is being tested) with a standard normal distribution. In the Kolmogorov-Smirnov test, the decision-making process is as follows:

- If the value of Asym-Sig (2-Tailed) < the significance level, then the data is not normally distributed.
- If the value of Asym-Sig (2-Tailed) > the significance level, then the data is normally distributed.

2.3. Service System Model

1) Single Server Model [M/M/1]

This service system model consists of a single service server, where both the inter-arrival time and service time are distributed according to the Poisson/Exponential distribution. The performance measures of this service system model are as follows:

- System utilization rate (ρ)

$$\rho = \frac{\lambda}{\mu} \tag{3}$$

- Probability of no patient in the system (P_0)

$$P_0 = 1 - \rho \tag{4}$$

- Average number of patients in the system(L_s)

$$L_s = \frac{\lambda}{\mu - \lambda} \tag{5}$$

- Average number of patients in the queue (L_q)

$$L_q = \frac{\lambda^2}{\mu(\mu - \lambda)} \tag{6}$$

- Average waiting time of patients in the system (W_s)

$$W_s = \frac{1}{\mu - \lambda} \tag{7}$$

- Average waiting time of patients in the queue (W_q)

$$W_s = \frac{1}{\mu - \lambda} \tag{8}$$

2) Multiple Server Model [M/M/c]

This model consists of a multiple service servers, where both the inter-arrival time and service time are distributed according to the Poisson/Exponential distribution. The performance measures of this service system model are as follows:

- System utilization rate (ρ)

$$\rho = \frac{\lambda}{\mu c} \tag{9}$$

- Probability of no patient in the system (P_0)

$$P_0 = \frac{1}{\sum_{n=0}^{s=1} \frac{\left(\frac{\lambda}{\mu}\right)^n}{n!} + \frac{\left(\frac{\lambda}{\mu}\right)^s}{s!} \frac{1}{1 - \frac{\lambda}{s\mu}}} \tag{10}$$

- Number of patients in the system(L_s)

$$L_s = L_q + \frac{\lambda}{\mu} \tag{11}$$

- Number of patients in the queue (L_q)

$$L_q = \frac{P_0 \left(\frac{\lambda}{\mu}\right)^s \rho}{s!\,(1 - \rho)^2} \tag{12}$$

- Waiting time of patients in the system (W_s)

$$W_s = W_q + \frac{1}{\mu} \tag{13}$$

- Waiting time of patients in the queue (W_q)

$$W_q = \frac{L_q}{\lambda} \tag{14}$$

3. Materials and Methods

3.1. Materials

The research object used is the patients at each stage of service in the pediatric clinic, including registration, examination, and medication retrieval at the pharmacy. This study discusses the multi-phase service system in the pediatric clinic at Sumedang Regional General Hospital (RSUD).

The data used in this research are secondary data on the arrival time and service time of patients at the registration counter and pharmacy counter, as well as primary data on the arrival time and service time of patients in the doctor's room. Data collection started from February 6, 2023, to February 13, 2023. Data processing in this research was aided by IBM SPSS Statistics 26 and Python software.

3.2. Methods

The steps undertaken in this research are as follows:

1. Identifying the research problem and conducting a literature review on multi-phase service systems from various sources such as books, journals, and previous studies.
2. Collecting data on patient arrival times and service times at each stage of the service system in the Pediatric Clinic of Sumedang General Hospital.
3. Analyzing the collected data by using software such as IBM SPSS Statistics 26. This includes testing the distribution of arrival times and service times at each stage, employing methods like the Kolmogorov-Smirnov test.
4. Determining the multi-phase service model. Based on the analysis of the data, the appropriate service model is derived for each stage of the system.
5. Calculating the values of λ and μ, which represent the arrival rate and service rate, respectively, at each stage of the service system.
6. Evaluating the performance measures of the service system at each stage. This involves assessing various performance indicators to gauge the effectiveness and efficiency of the system.
7. Analyzing the performance level of the service system at each stage. This step involves assessing whether the existing number of service facilities at each stage is optimal or if adjustments need to be made.
8. Conducting testing on the facilities at each stage by considering additions or reductions in the number of facilities to assess their impact on the overall performance of the system.
9. Drawing conclusions based on the findings of the research, which summarize the outcomes and implications of the study.

4. Results and Discussion

4.1. The Result of Distribution Test

4.1.1. The Arrival Distribution Test

The results of the arrival distribution test at each service stage in the pediatric clinic of RSUD Sumedang are presented in the Table 1.

Table 1: Result of Arrival Distribution Test

One-Sample Kolmogorov-Smirnov Test 2				
		Registration _Counter	Pediatric_ Clinic	Pharmacy_C ounter
N		5	5	5
Poisson Parameter[a,b]	*Mean*	251.00	105.20	141.20
Most Extreme Differences	*Absolute*	.492	.316	.280
	Positive	.492	.307	.280
	Negative	-.367	-.316	-.190
Kolmogorov-Smirnov Z		1.100	.707	.627
Asymp. Sig. (2-tailed)		.178	.967	1.000

Based on Table 1, it can be observed that the "Asymp.Sig/Asymptotic significance" values for the services at the registration counter, doctor's room, and pharmacy counter are bigger than 0.05. Therefore, H_0 is accepted, and it can be concluded that the inter-arrival time of patients in the doctor's room follows a Poisson distribution.

4.1.2. The Service Time Distribution Test

The results of the service time distribution test at each service stage in the pediatric clinic of RSUD Sumedang are presented in the Table 2.

Table 2: Result of Service Time Distribution Test

One-Sample Kolmogorov-Smirnov Test 2				
		Registratio_ Counter	Pediatric_ Clinic	Pharmacy_C ounter
N		5	5	5
Poisson Parameter[a,b]	*Mean*	232.00	16.40	73.40
Most Extreme Differences	*Absolute*	.593	.519	.582
	Positive	.345	.295	.318
	Negative	-.593	-.519	-.582
Kolmogorov-Smirnov Z		1.327	1.160	1.301
Asymp. Sig. (2-tailed)		.059	.135	0.068

Based on Table 1, it can be observed that the "Asymp.Sig/Asymptotic significance" values for the services at the registration counter, doctor's room, and pharmacy counter are greater than 0.05. Therefore, H_0 is accepted, and it can be concluded that the inter-arrival time of patients in the doctor's room follows a Exponential distribution.

4.2. Service System Analysis

Number of patients arrival in the registration counter are shown in the Table 3.

Table 3: Number of Patients Arrival in The Pediatric Clinic.

Date	Time	Amount (patient)
6 February 2023	7:00-7:59	203
	8:00-8:59	14
	9:00-10.00	20
7 February 2023	7:00-7:59	207
	8:00-8:59	19
	9:00-10.00	20
8 February 2023	7:00-7:59	178
	8:00-8:59	24
	9:00-10.00	7
9 February 2023	7:00-7:59	187
	8:00-8:59	9
	9:00-10.00	26
13 February 2023	7:00-7:59	203
	8:00-8:59	28
	9:00-10.00	16
Total		1161

Number of patient arrival in the doctor’s room are shown in the Table 4.

Table 4: Number of Patients Arrival in The Pediatric Clinic and The Pharmacy Counter

Date	Time	Number of Patients in The Pediatric Clinic	Number of Patients in The Pharmacy Counter
6 February 2023	9:00-9:59	3	12
	10:00-10:59	9	38
	11:00-12:00	6	24
7 February 2023	9:00-9:59	11	19
	10:00-10:59	0	31
	11:00-12:00	1	17
8 February 2023	9:00-9:59	8	17
	10:00-10:59	7	24
	11:00-12:00	3	23
9 February 2023	9:00-9:59	9	15

	10:00-10:59	6	26
	11:00-12:00	5	37
13 February 2023	9:00-9:59	7	5
	10:00-10:59	5	32
	11:00-12:00	2	47
Total		82	367

The service time of patients in the regristration counter are shown in the Table 5.

Table 5: The Service Time of Patients in The Pediatric Clinic.

Date	Time	Amount (patient)	Total Time (minute)
6 February 2023	9:00-9:59	3	95
	10:00-10:59	7	
	11:00-12:00	8	
7 February 2023	9:00-9:59	3	69
	10:00-10:59	9	
	11:00-12:00	0	
8 February 2023	9:00-9:59	7	120
	10:00-10:59	7	
	11:00-12:00	4	
9 February 2023	9:00-9:59	6	143
	10:00-10:59	8	
	11:00-12:00	6	
13 February 2023	9:00-9:59	2	99
	10:00-10:59	6	
	11:00-12:00	6	
Total		82	526

The service time of patients in the Pediatric Clinic and the pharmacy counter are shown in the Table 6.

Table 6: The Service Time of Patients in The Regristration Counter

Date	Time	Registration Counter		Pharmacy Counter	
		Amount (patient)	Total Time (minute)	Amount (patient)	Total Time (minute)
6 February 2023	9:00-9:59	9	149	9	149
	10:00-10:59	29		29	
	11:00-12:00	36		36	
7 February 2023	9:00-9:59	17	130	17	130
	10:00-10:59	28		28	
	11:00-12:00	22		22	
8 February 2023	9:00-9:59	15	122	15	122
	10:00-10:59	25		25	
	11:00-12:00	24		24	
9 February 2023	9:00-9:59	10	135	10	135
	10:00-10:59	39		39	
	11:00-12:00	29		29	
13 February 2023	9:00-9:59	5	170	5	170
	10:00-10:59	30		30	
	11:00-12:00	49		49	
Total		82	367	706	706

4.3. Analysis of Service System Performance

The service system in the pediatric clinic at RSUD Sumedang using FCFS (First Come First Serve) discipline service and operates with a single server. Therefore, the service model employed in this system is [M/M/1]:[FCFS/∞/∞]. The performance metrics of the service system are presented in the following Table 7.

Table 7: The performance metrics of the service system in pediactric clinic.

	Pediactric Clinic
Service System Model	$[M/\,M/1]:[FCFS/\infty/\infty]$
$\boldsymbol{\lambda}$	0,091
$\boldsymbol{\mu}$	0,155
$\boldsymbol{\rho}$	58,70 %
$\boldsymbol{P_0}$	41,29 %
$\boldsymbol{L_s}$	1,421875 ≈ 2 patient
$\boldsymbol{L_q}$	0,834778 ≈ 1 patient
$\boldsymbol{W_s}$	15,625 minute
$\boldsymbol{W_q}$	9,173387 minute

The service system at the registration counter and pharmacy in RSUD Sumedang also follows the FCFS (First Come First Serve) service discipline. The registration counter consists of five servers, while the pharmacy has one server. Therefore, the service models used in the registration counter and pharmacy are [M/M/5]:[FCFS/∞/∞] and [M/M/1]:[FCFS/∞/∞], respectively. The performance metrics of the service system at both stages are presented in the following Table 8.

Table 8: The performance metrics of the service system in registration counter and pharmacy counter.

	Registration Counter	Pharmacy Counter
Service System Model	$[M/\,M/5]:[FCFS/\infty/\infty]$	$[M/\,M/1]:[FCFS/\infty/\infty]$
$\boldsymbol{\lambda}$	1.29	0.407
$\boldsymbol{\mu}$	0.925	0.519
$\boldsymbol{\rho}$	27.89 %	78.42 %
$\boldsymbol{P_0}$	75.66 %	21.57 %
$\boldsymbol{L_s}$	1.394598≈2 patient	3.633928≈4 patient
$\boldsymbol{L_q}$	0.000004≈1 patient	2.849728≈3 patient
$\boldsymbol{W_s}$	1.081084 minute	8.928571 minute
$\boldsymbol{W_q}$	0.000003 minute	7.001789 minute

The total values of patients in the system (L_s), the total number of patients in the queue (L_q), the total waiting time of patients in the system (W_s), and the total waiting time of patients in the queue $\left(W_q\right)$ for all stages of service are shown in Table 9.

Table 9: The total values of L_q, L_s, W_s, and W_q for all stages of service.

	Registration Counter	Pediatric Clinic	Pharmacy Counter	Total
$\boldsymbol{L_s}$	1.394598 ≈ 2 patient	1.421875 ≈ 2 patient	3.633928 ≈ 4 patient	8 Patient
$\boldsymbol{L_q}$	0.000004 ≈ 1 patient	0.834778 ≈ 1 patient	2.849728 ≈ 3 patient	5 Patient
$\boldsymbol{W_s}$	1.081084 minute	15.625 minute	8.928571 minute	25.634655 minute
$\boldsymbol{W_q}$	0.000003 minute	9.173387 minute	7.001789 minute	16.175179 minute

4.4. Evaluation of Service System Performance

Based on the previous calculation of the performance metrics, it can be determined that the server utilization rate in the service system at the pediatric clinic in RSUD Sumedang is 58.70%, indicating that the system has a significant amount of idle time. However, since the number of servers is already single, no additional or reduction of service facilities can be made at this stage. Therefore, the service model [M/M/1]:[FCFS/∞/∞] is already the most optimal for this stage.

5. Conclussion

The conclusions drawn based on the analysis and discussion in this research are as follows:

1. The optimal service system model used in the pediatric clinic at RSUD Sumedang [M/M/1]:[FCFS/∞/∞].
2. The calculated performance metrics for the optimal service system in the pediatric clinic at RSUD Sumedang are as follows, the system utilization rate is 58.70%, the number of patients waiting in the system is 2, the number of patients waiting in the queue is 1, the average waiting time for patients in the system is 15.625 minutes. the average waiting time for patients in the queue is 9.173387 minutes.

References

Aniyeri, R., & Nadar, R. (2018). Passengers queue analysis in international airports terminals in Kerala using multiphase queuing system. *International Journal of Mathematics in Operational Research*, *12*(1), 1-30.

Bahadori , M., Mohammadnejhad, S. M., Ravangard, R., & Teymourzadeh, E. (2014). Using Queuing Theory and Simulation Model to Optimize Hospital Pharmacy Perfomance. *Iranian Red CRESCENT Medical Journal*, *16*(3).

Green, L. (2006). Queueing analysis in healthcare. *Patient flow: reducing delay in healthcare delivery*, 281-307.

Gross, Donald Harris, Carl M. Shortle, John F. Thompson, J.M. (2018). *Fundamentals of Queueing Theory* (5th ed.). Jhon Wiley & Sons.

Heizer, J., Render, B., & Munson, C. (2016). *Operations Management: Sustainability and Supply Chain Management* (12 ed.). Pearson.

Hermanto, K., Ruskartina, E., Adiasa, I., Hudaningsih, N., & Harizahayu , H. (2023). Evaluation f The Queue System of a Driving License Application at Kepolisian Sumbawa Besar . *Jurnal Ilmu Matematika dan Terapan*, *17*(1),pp.0383-0390.

Hess, S. and Grbčić, A. (2019). The Multiphase Queuing System of Rijeka Airport. *Pomorstvo, 33*(2), 205-209.

Khayrullin, R. and Myasnikov, A. (2018). Application of Methods of The Theory of Multi Phase Queueing Systems to The Problems of Optimizing The Resources of Service Companies in The Field Housing Sector. *In MATEC Web of Conferences*, *196*, 04040.

Mehandiratta, R. (2011). Applications of queuing theory in health care. *International Journal of Computing and Business Research, 2*(2), 2229-6166.

Najmuddin, A., Ibrahim, I., & Ismail, S. (2010). 'A Simulation Approach: Improving Patient Waiting Time for Multiphase Patient Flow of Obstetrics and Gynecology Department (O&G Department) in Local Specialist Centre'. *WSEAS transactions on mathematics, 9(10)*, 778-790.

Stallings, W. (2000). *Queuing Analysis.* WilliamStallings.com/StudentSupport.html..

Siahaan, H. E., & Manurung, J. (2021). Queue System Analysis Happy World Consumers Using Single Chanel Multi-Phase Queue Model. *Journal DISTANCE, 1*(1), 238-245.

Vikaliana , R. (2017). Analysis of Commuter Line Ticket Purchase Queuing System in Bogor Station. *The Management Journal of Binaniaga*, *2*(02), 35-44.

Winston, W. L. (2003). *Operation Research Applications and Algorithms* (4th ed.). Duxbury Press.