ORIGINAL ARTICLE

Simulation of Multi Server Queue System With Non Poisson Distribution of Antigen Rapid Test in Terminal I Juanda Surabaya Airport Area

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ABSTRACT

Introduction: The lack of perception in determining service distribution of the queue system cause inefficiency of service. Therefore, this study aims to analyze and simulate the queue system of antigen rapid test in Terminal I Juanda Surabaya Airport area. **Methods:** This study used an observational design on antigen rapid test customers. It was conducted for three days consecutively in a week namely Saturday, Sunday, and Monday, while the data collected include customer arrival time and duration for each service. Furthermore, a total of eight variables were analyzed using Minitab and Matlab software. **Results:** The applied queue model was FIFO and the highest customer arrival rate was found in the registration and sample-taking services with 30 customers per hour. The highest means of service and waiting durations, as well as customer queue and average time spent for a service, was observed in the result-taking service with values of 19.26 minutes per customer, 9.27 minutes per customer, 167 customers per hour, and 28.53 minutes per customer. The highest idle service probability was found in the registration service with 0.76% per hour, while the highest chance of one customer being on the queue was observed in the result-taking service with 57.18% per hour, and the overall waiting time for service was 38.01 minutes. **Conclusion:** Simulation of queue system was suitably obtained with real-life conditions, the management needs to add channel at the result-taking service to minimize the waiting time. Each addition of one channel will decrease waiting time by 6.13 minutes.

Keywords: Antigen rapid test, COVID-19, Health service, Queue system, Service management

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INTRODUCTION

SARS-CoV-2 transmission has been reported massively since it was first found in 2019 at Wuhan City, China. The rapid transmission globally in a short time prompted the World Health Organization (WHO) to declare the increase of SARS-CoV-2 infection as COVID-19 pandemic in March, 2020 (1). As of July 7th, 2021, approximately 175,000,000 global citizens have been infected by COVID-19 with a confirmed increase of 2,000,000 citizens (2). To date, the slowdown in the disease transmission can not be predicted, therefore, impacted areas are recommended to enforce effective means to decrease the outspread and prevent the amount of loss caused by the pandemic including health, education, economic, and social (3).

Indonesia is one of the countries that was heavily affected by the COVID-19 pandemic with the transportation sector reporting a decrease in the citizen's mobility. This is caused by the concern that they can get infected and due to the government regulations in most areas (4). Besides, the Indonesian Government also required every citizen to attach a negative result of COVID-19 RT-PCR test, antigen rapid test, or GeNose each time when traveling locally or abroad to prevent the spread through public transportation (5,6).

Terminal I Juanda Surabaya Airport is one of the domestic public transportation services that provide the antigen rapid and GeNose COVID-19 test services to support government policy. Compared to GeNose, some people prefer the antigen rapid test because it has a better level of results accuracy. However, this accuracy is lower compared to that of RT-PCR. Antigen rapid test is known to have a sensitivity and specificity of approximately 80% and 98.9% on patients with symptoms. Meanwhile, the sensitivity and specificity on patients without symptoms is only 41.2% and 98.4% respectively (7). Although both values are higher in RT-PCR, the antigen rapid test is most preferred because the results are released more quickly (8).

The management team of the antigen rapid test in Terminal I Juanda Surabaya Airport area stated that the average number of customers examined per day is up to 500. Besides, the customer arrival rate can rise exponentially when there is an increase in Covid-19 cases. The estimated waiting duration is 30 minutes, from the time the customer enters the registration service until the collection of results. This prolonged waiting time is caused by the operational standard procedure as the examination tools have time limit accuracy for reading the result. Moreover, the use of the handwritten or manual method to fill the registration form also leads to crowding of customers. The waiting time tends to be longer particularly at busy flying hours such as in the morning, beginning and end of the week, as well as during long holidays.

Misperception often occurs when service providers assume that the customers are all satisfied with their services. Meanwhile, there is an imbalance between the expectation and the service received by the customer in reality. Consequently, regular analysis is needed to check the queue system of antigen rapid test in Terminal I Juanda Surabaya Airport area, to achieve a clear perspective on the customers' waiting time. The health service queue system analysis consists of waiting time and the benefit of each provided service (9). It can be used as a basis to find a balance between service and demand (10). Furthermore, the queue system analysis is expected to determine the optimal waiting time, service efficiency, and system improvement to upgrade customer satisfaction (11). Therefore, this study aims to analyze and simulate the queue system of antigen rapid test in Terminal I Juanda Surabaya Airport area.

MATERIALS AND METHODS

Research design

This study used an observational design and was conducted in June 2021 on the antigen rapid test services in Terminal I Juanda Surabaya Airport area that has 4 types of services including registration, cashier, sample-taking, and result collection. Meanwhile, the participants used were antigen rapid test customers in the study area.

Data collection methods

The study was conducted for three days consecutively from Saturday, Sunday, and Monday beginning from when the service was open until closing namely 04.00 am – 04.00 pm. The data collected include the customers' arrival time and duration for each service. Furthermore, a total of 8 variables were analyzed including the mean of customer arrival and service rate, service duration, estimated numbers of customers on the queue, waiting duration before receiving the service, how long a person receives a service, as well as the chance of idle service, and emerging on the queue in each service.

Statistical analysis

The data were analyzed in two steps, first, the distribution test was carried out on customer arrival data and service duration in each service using the Minitab 19 software. Second, queue simulation was performed by Matrix Laboratory 2013 software.

ETHICAL CLEARANCE

This study was approved by the Health Research Ethics Committee, Faculty of Public Health, Universitas Airlangga No. 34/EA/KEPK/2021.

RESULT

Identification of the queueing model

The antigen rapid test service in Terminal I Juanda Surabaya Airport area applies the FIFO (First In First Out) queue model. This service included in the multiserver category has three series servers namely registration service, cashier, and result, as well as one parallel server consisting of four channels including sample-taking service. The flow of antigen rapid test service in Terminal I Juanda Surabaya Airport area is shown in Figure 1.

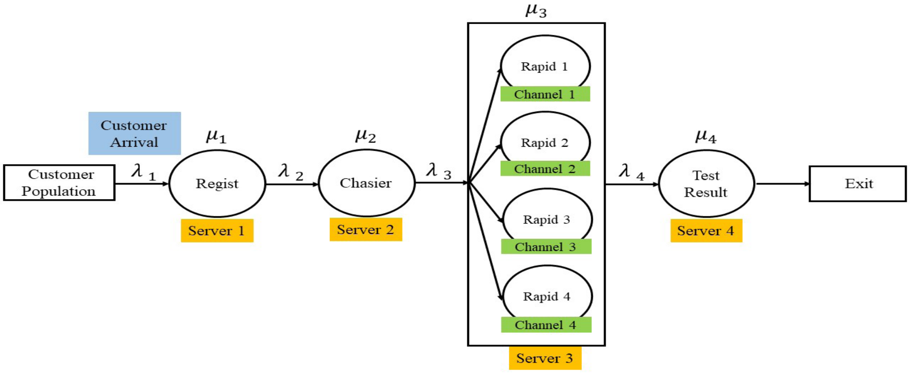

Figure 1: Flow of Antigen Service. The flow of antigen rapid test service in Terminal I Juanda Surabaya Airport started with the customer coming to the registration table to fill the form, followed by payment at the cashier. Afterward, the customer goes to the sample-taking table and then queues to wait for the result. Finally, the customer can leave the examination service after collecting the antigen rapid test result.

The customer arrival rate in each service is symbolized with λ, service rate μ, registration λ_1, cashier λ_2, sample-taking λ_3, and result λ_4. Furthermore, the service rate in the registration section is symbolized with μ_1, cashier μ_2, sample-taking μ_3, and result μ_4. The test results of customer arrival distribution patterns in each service are shown in Table I.

Table I: Customer Arrival Distribution Pattern in Each Service

Service	Distribution	Parameter	
		Mean	Standard deviation
Registration	Weibull	2	1
Cashier	Eksponensial	3	-
Sample taking	Weibull	2	1
Result taking	Weibull	3	1

Source: Primary Data, 2021

The test results of the arrival distribution pattern in each antigen rapid test service showed that almost all customers followed the Weibull distribution, while the arrival in cashier service followed an Exponential distribution. The standard deviation showed a value of 1 which means that data spread ±1 from the average. The pattern distribution test results of service duration are shown in Table II.

Table II: Pattern Distribution Test Result of Service Duration in Each Service

Service	Distribution	Parameter	
		Mean	Standard deviation
Registration	Weibull	4	2
Cashier	Weibull	2	1
Sample Taking	Gamma	2	1
Result Taking	Weibull	20	4

Source: Primary Data, 2021

The pattern distribution results of duration in each service of antigen rapid test showed that almost all services followed the Weibull distribution, while the sample-taking service followed the Gamma distribution. Standard deviation in cashier and sample-taking services showed a value of 1 indicating that data spread ±1 from the average. Meanwhile, the standard deviation in the registration and test result services showed a value of 2 and 4 which means data spread ±2 and ±4 from the average respectively.

Simulation of queueing system

The test results on the distribution pattern were further used as a basis of the queue system model using the software, Matrix Laboratory 2013. The queue simulation was set to assess the means of customer arrival and service rates, service duration, the estimated customer population in the queue, waiting duration before receiving the service, as well as the chance of idle service and customers crowding in each service, the results are shown in Table III.

Table III: Result of Queue Service Simulation of Antigen Rapid Test

	Registration	Cashier	Sample taking	Result
Means of arrival rate (people per hour)	30	22	30	19
Means of service rate (people per hour)	17	33	30	4
Means of service duration (minutes per customer)	3,49	2,05	2,01	19,26
Estimation of customer pupulation in queue (people per hour)	51	19	29	167
Means of waiting duration before receive the service (minutes per customer)	2,01	0,29	1,38	9,27
Means of total duration to examine one customer (minutes per customer)	5,50	2,24	3,39	28,53
Chance of idle service (%)	0,76	0,35	0,04	0,04
Chance of queueing (%)	18,46	0,95	0,01	57,18
Means of overall process (minutes per customer)	38,01			

Queue service simulation of antigen rapid test in Terminal I Juanda Surabaya Airport area was carried out with the estimate that there are 500 customers per day according to the service management. Table III shows that with 500 customers a day, each will spend 38.01 minutes waiting for the process starting from the registration to the result collection.

As demonstrated in Tabel III, the queue simulation in the registration service showed that in one hour, 30 customers were counted. Meanwhile, the registration service can only serve 17 customers in an hour with an average of 3.49 minutes each. The number of waiting customers in an hour was estimated to be 51, while the means of waiting duration before receiving the registration service was 2.01 minutes. Furthermore, the customers averagely spent 5.50 minutes during the entire registration service process. The chance of idle service was 0.76% which means that the registration service is busy, while the chance of one customer having to queue in the registration service was 18.46%.

Queue simulation in cashier service based on Table III showed that in one hour, 22 customers arrived but the service can serve up to 33 customers per hour. The average duration spent in the cashier service for one customer was 2.05 minutes, while the number of customers on the queue in an hour was estimated to be

19. Furthermore, the average waiting duration for each customer before the cashier service was 0.29 minutes which means that the customers did not wait for long, and an average of 2.24 minutes was spent during the service. The probability of idle service was 0.35% which means cashier service was busy. Also, the chance of one customer having to queue was 0.95% which indicates that the customers probably do not need to wait for the service.

Based on Table III, the queue simulation of the sample-taking service showed that 30 customers arrived in an hour, coincidentally, the service can examine 30 customers every hour. The average time taken in the sample-taking service from one customer was 2.01 minutes, while a total of 29 were estimated to queue in an hour. Furthermore, the average waiting duration for one customer before they receive sample-taking service was 1.38 minutes and the duration for the entire service was 3.39 minutes. The probability of idle service was 0.04% which means that the sample-taking service was busy. In the sample-taking service, every customer has the chance to be on queue for 0.01% which implies that the customer probably does not need to wait.

Queue simulation of the result collection service on Table III shows that 19 customers arrived in one hour. Meanwhile, this service can only cater for 4 customers every hour. The average duration of the result collection service for one customer was 19.26 minutes, while a total of 167 were estimated to queue in one hour. Furthermore, the average waiting duration for each customer before receiving the test result was 9.27 minutes and the duration for the entire service was 28.53 minutes. The probability of idle service was approximately 0.04% which indicates the result collection service was busy. In the test result service, each customer has a 57.18% chance to be in the queue.

Reduce the waiting time

As an effort to minimalize the time spent by one customer to finish one examination, a simulation was carried out to add one officer to the test result service and remove one from the sample-taking service, the results are presented in Table IV.

The result showed that there was no significant difference after removing one officer from the sample-taking service compared to the previous condition. The simulation showed that in one hour, 30 customers arrived. Meanwhile, the sample taking service can serve up to 30 customers every hour. Averagely, each officer in the sample-taking service used 2.03 minutes to take care of one customer and the queue population was estimated to be 31 in one hour. The average waiting duration was 1.39 minutes for one customer, and the entire duration for the received service was 3.42 minutes. The probability for the service to be idle was 0.04% which shows the sample-taking service was busy. Each customer had a 0.01% chance to be on the queue, implying that the customer probably does not need to queue.

A significant difference was found in the simulation result after adding one officer to the test result service. The result showed that 19 customers arrive every hour but the test result service can only serve 8. Averagely, the duration for one customer was 15.60 minutes and the queue population was 148 customers in one hour. Furthermore, the waiting duration before the collection of results was 6.80 minutes, while the duration for the entire service was 22.40 minutes. Idle service probability was 0.03% which means that the result-taking service was busy, each customer has a 50.0% chance of queuing for the service.

Table IV: Simulation in Sample and Result Taking Service to Reduce Waiting Time

	Sample Taking		Result Taking	
	Before	After	Before	After
Means of arrival rate (people per hour)	30	30	19	19
Means of service rate (people per hour)	30	30	4	8
Means of service duration (minutes per customer)	2,01	2,03	19,26	15,60
Customer amount estimation in queue (people per hour)	29	31	167	148
Means of waiting duration before receiving service (minutes per customer)	1,38	1,39	9,27	6,80
Means of overall time spent to get one service (minutes per customer)	3,39	3,42	28,53	22,40
Probability of idle service (%)	0,04	0,04	0,04	0,03
Probability of queue (%)	0,01	0,01	57,18	50,00

DISCUSSION

The queue system simulation of antigen rapid test aims to analyze the time required for one customer to get a service. Simulation is a method that occasionally imitates a specific situation that resembles a real-life condition (12). Although various experts have tried to develop simulation as a way to solve daily life problems, there are still some errors including treating model and simulation as the same concept. Model is defined as a method to counterfeit a system, while a simulation is an expansion from a model and occasionally focuses on the pattern of a system (13).

In recent years, the waiting period has become quite an interesting topic in health since it relates to customers satisfaction and service efficiency. Customers who feel satisfied will reutilize a health service (14). Although customers' satisfaction and service efficiency are not the only benefits for service providers, they also contribute toward the health degree of society. Bleustein et al. stated the patients' perception about health worker's ability in handling complaint tend to decrease with the long waiting period of a health service (15).

To achieve customers' satisfaction and service efficiency, much effort must be maximized from the time of arrival to the departure (16). Queue simulation is often conducted to determine the waiting duration in a service (17). There are seven vital components in the queue simulation system including customer arrival and service duration distribution, service design and model, queue measurement, summoning source, as well as behavior (18).

The queue model used for the antigen rapid test service is First In First Out (FIFO) or First Come First Served (FCFS). This model explains that the order of service to customers is based on early arrival (19). Queue measurement describes the ability of a system to serve customers and consists of two components namely finite and infinite (18,20). In the antigen rapid test service, queue measurement is in the infinite category, indicating that service management can serve customers infinitely or unpredictably every day. However, queue management with infinite size needs caution since customers' arrival is unpredictable. A high rate of patient arrival causes a long duration of service, thereby decreasing customers' satisfaction (21).

Summoning source means the estimated number of customers that will be in the system (18,20). In this study, the summoning source was included in the infinite category, hence, the management can not predict the customers' arrival rate. Human behavior in the queue system is categorized as mobility, rejection, and cancellation. In the antigen rapid test service, human behavior did not fulfill the three categories since the customers were willing to wait from the beginning of the service until they collect their results. Human behavior is defined as the customers' reaction when they enter a queue system (18).

With an estimated number of 500 customers daily from the queue simulation of the antigen rapid test service, the overall waiting duration will be 38.01 minutes since the customers wait at the registration line until they take their results. This result is consistent with actual field conditions. Pandit et al. showed that in this era, health service facilities are often marked with long queues where patients might stay for 30-60 minutes (22). Other studies recommended that service provider attends to patients within 30 minutes from the arrival time (21,23). Based on the results, the order of longest duration contributor in the antigen rapid test service is result-taking, registration, sample-taking, and cashier. The length of the waiting period in the registration service was influenced by age, gender, customers awareness, and experience of previous antigen rapid test checkup. Therefore, some customers require further explanation before conducting the check-up procedure (21).
Based on the operational standard procedure, the antigen rapid test result can be maximally well interpreted in 15 minutes after sample-taking, but must not be read after 20 minutes. The result-taking service analysis showed that the data had the biggest standard deviation indicating a significant variant compared to other services data. Higher variation based on real-life observation is caused by minimum human resource in the result-taking service. This increases the number of customers queuing to collect results. Furthermore, the duration was longer compared to conditions when the service is slack indicating that service is far from the average.

The average time needed by one person in the result-taking service was 28.53 minutes. This condition is inverse compared to the sample-taking service which has four channels thereby reducing the time needed by the customers to 3.39 minutes. To minimize the waiting duration in the test result-taking service, the simulation was carried out by removing one channel from the sample-taking service and adding it to the result-taking service. The simulation result showed that removing one channel in the sample-taking service showed no significant difference in the waiting duration. Meanwhile, adding one channel to the result-taking line decreased the service duration up to 3.66 minutes and waiting time up to 2.47 minutes. The overall time spent by one customer in the result-taking service is 22.40 minutes. A previous study stated that the waiting duration is an important indicator to evaluate service management performance (24). Longer waiting durations among customers can cause a significant decrease in satisfaction (24,25).

Satisfacton is obtained when there is conformity in the customers' perspective about the service given in a real situation (26). Although the waiting duration can not be definitely measured, it influences satisfaction standards for customers during health service (21,27). A study mentioned that there are three main aspects that can build customers satisfaction namely interaction between the service provider and patient, special treatment toward the patient, and waiting period during the service (28). A decrease in the waiting period up to 20 minutes at result pickup service tends to increase the patients' satisfaction. Howard et al. stated that customers who wait for 20 minutes and below to get a service showed good appreciation (29). Furthermore, customers satisfaction in health tends to affect the treatment result, recovery rate, trust in utilizing health services, as well as reduce the risk of patient retention, and skepticism on malpractice (30).

This study has certain limitations, first, it only showed the time needed by one customer to get one antigen rapid test. Second, this study did not mention the causes or factors of long-duration service in the system. Therefore, further studies are recommended to carry out factor analysis. Third, this study was conducted only on weekends, hence, it was unable to determine the conditions on weekdays.

CONCLUSION

The queue system simulation of the antigen rapid test in Terminal I Juanda Surabaya Airport area was obtained in line with the real situation at the location. The overall waiting period for customers during one checkup session was 38.01 minutes. Furthermore, the simulation to achieve service efficiency and increase customers satisfaction was performed by reducing one channel in the sample-taking service and adding to the result-taking service. The addition of one channel to the result pickup service reduced the waiting period up to 6.13 minutes, hence, the overall waiting period for customers during one checkup session for the antigen rapid test service starting from registration to the result pickup was ±30 minutes.

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