ANALYSIS AND SIMULATION OF VACCINATION QUEUE SYSTEM AT XYZ PUBLIC HEALTH CENTER

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Abstract

This study discusses the vaccination system at XYZ Public Health Center. Vaccination activities at the site through several stages of service, registration, health check, vaccination, observation with the printing of vaccination cards. The vaccination system at XYZ Public Health Center experienced long lines that caused a crowd that should be avoided, especially on registration servers that were done manually. This research aims to determine the best scenario that can be obtained through the analysis of the results of simulated queue models as an alternative decision in optimizing the UPTD vaccination service system of Puskesmas XYZ. The best-case scenario selection analysis is based on consideration of aspects of average service time that aim to reduce the number of queues on service servers. The queue model at existing conditions has 4 officers on registration, 5 officers on inspection, 5 officers on vaccinations, and 4 officers on observation and printing. Based on the results of the analysis can be concluded that the model of the queue system with the number of 5 officers on registration, 2 officers on health check, 2 officers on vaccination, and 1 officer on observation has the best queue system model. The proposed queue system model is able to minimize the crowd that occurs *on the service server by reducing the service time from existing conditions by 4523.38 seconds to 1401.92 seconds. The proposed improvement with the queue model is also able to increase productivity from 37% to 57% with an increase of 20% from existing conditions, as well as reduce working wages from Rp3,800,000 per day to Rp1,800,000 per day.*

Keywords: Queue, Simulation, Vaccination, Covid-19

Introduction

Corona Virus Disease 2019 (COVID-19) has now been designated as an outbreak of the disease in all regions of the world. Emergency conditions in which community activities and community mobility are restricted, ranging from keeping their distance, wearing masks, imposing curfews, and other policies that reduce contact between individuals. One of the most up-to-date ways to end the COVID-19 pandemic is to gradually accelerate vaccination to all layers and consider the priority scale. Vaccination in Indonesia itself is underway, but the acceleration can still be said to be lacking.

The vaccination system implemented at *Unit Pelayanan Teknis Daerah (UPTD) Puskesmas* XYZ seems to be contrary to policies aimed at reducing contact between individuals and eliminating crowds due to the length of queues that occur. The number of doses provided by *XYZ Public Health Center* in the February-September period amounted to 11,237 doses for 1st doses and 3,050 doses for 2nd doses, while in fact XYZ Regency has a population of 47,657 people. The number of residents who have been vaccinated to date is about 23.5% for 1st doses and 6.4% for 2nd doses of the total population contained in XYZ Regency [1-4].

The imbalance between the number of doses provided with the number and enthusiasm of the population to vaccinate makes the vaccination service system experiencing excessive queues. In addition, technical registration services at the venue are done manually with the number of service desks available causing long lines so that the crowd cannot be avoided. This causes the related system to need to be simulated so that analysis can be done related to the vaccination queue system at *XYZ Public Health Center* which can later be determined a solution to improve the queue system. The simulation approach was chosen as a problem-solving method because experiments on real systems tend to be constrained by resource availability and licensing [5-9].

Analysis of the queue system can be done with a simulation approach, as was done in previous research. According to [10]the suitability of the results of each service simulation is approaching a real system. [11, 12] revealed that through simulation tests can be known the level of service and performance on the queue system is more optimal than some simulated scenarios by analyzing the results of the simulation test.

[13] also states that queue system optimization can be done on health services using a simulation approach. The results of the study stated that the simulation approach to the queue system can optimize service time to reduce the time by 38.9% of the existing system.

Based on previous studies, this study used a simulation approach to analyze and optimize the queue system of *UPTD Puskesmas* Subdistrict XYZ.

Literature Review

Modeling and Simulation

A model is a description or analogy used to help describe something that cannot be observed directly. Modeling and simulation is a test tool to support decision making by obtaining the best alternative in problem solving by utilizing past data [14, 15] Modeling and simulation are developed in various aspects so that the most relevant to the discussion are described in the context of the life cycle of the project or the study of modeling and simulation [16]

Discrete-Event Simulation (DES)

Discrete-Event Simulation is a simulation that discusses the model of a system that is always evolving due to the representation of changes in variables under certain conditions at a given moment. Discrete-Event Simulation can be conceptually done using calculations manually, but because so much data will be processed where storage media is needed for these processes, problem solving using Discrete-Event Simulation is recommended to use computer media [17]

Distribution Match Test

Distribution match tests are used to determine how far the observed sample data aligns or matches the particular model offered. The distribution match test was conducted using the *Kolmogrwov-Smirnov* test. The alignment test is a distribution match test that is useful for evaluating how far a model is able to approach the real situation it describes, in this case the appropriate distribution [12, 18]

Data Adequacy Test

The basis of consideration in determining the size of a sample drawn from a population requires careful thought [19] For this reason, a data adequacy test is carried out to determine the size of the required sample with the following equations:

$$N' = \left(\frac{\frac{k}{s}\sqrt{N\sum x_i^2 - (\sum xi)^2}}{\sum x_i} \right)^2 \quad \text{...} \ (1)$$

Description:
N' : The number of observations that should be made
k : Level of trust in observation
s : Level of thoroughness in observation
N : The number of observations that have been made
x_i : Observational data

Queue

The queue system is the whole process of customers or goods arriving and entering the queue line that in turn requires service as it should apply. The average length of waiting time is very dependent on the average service speed rate *(*rate of services). The main purpose of the queue theory is in view of how long customers have to wait, this is outlined through the average time it takes to wait until getting service and what percentage of the time provided to provide services in idle conditions [11, 20]

Software AnyLogic

AnyLogic software is simulation software used to create virtual prototype environments. AnyLogic supports the design of discrete, continuous, and mixed behavioral simulations of complex systems. In AnyLogic there is a *pallete* menu that provides a list of graphic model elements such as *source, queue, service, resource pool, sink* and so on [21]

Methods

Location and Time of Reseach

This study was conducted on the queue system of vaccination patients at *UPTD Puskesmas* Subdistrict XYZ. Research activities in the form of data collection are carried out in September, October, and November 2021.

Data Collection

This method of data collection is done through 3 ways, observation, interview, and literature studies. Observations were made to find out the number of arrivals and time of vaccination services at *XYZ Public Health Center*. Intervals of observation time to determine the number of arrivals are made every 1 minute. Interviews are conducted to vaccination service personnel to find out the service schedule and the number of personnel who serve in vaccination activities. The literature studies used in research aim as supporting and comparing materials to support research conducted at *XYZ Public Health Center*.

Data Processing

The research stages conducted in the study consist of data adequacy tests, distribution tests, queue system modeling and queue system simulations. The data adequacy test in this study used a level of accuracy of 5% and a confidence rate of 95%. Distribution tests are conducted to determine the suitability of population distribution with the Kolmogrov Smirnov test using SPSS software. The modeling of the queue system is adjusted to the vaccination queue system on the actual circumstances. The queue system simulation is done using AnyLogic software.

Analysis and Conclusions

The analysis was conducted on the queue model and the results of Anylogic software simulations*.* Proposed improvements or optimization of models can be done to improve the efficiency of vaccination queues so as to minimize the buildup of patients. The results of the analysis will be used as a basis in the withdrawal of research results conclusions.

The flow diagram of analysis and simulation of the queue system at *UPTD Puskesmas* Subdistrict XYZ is fully shown in Figure 1.

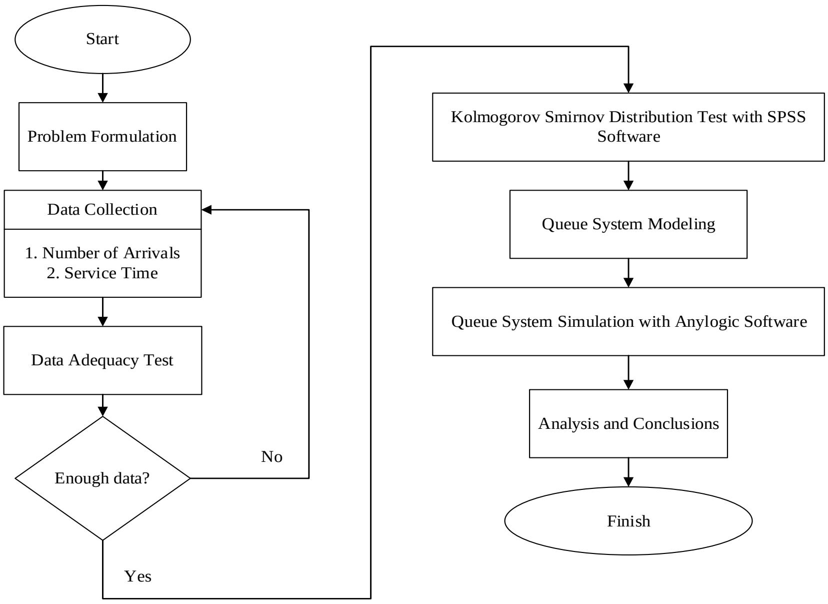

Figure 1 Research Flow Diagram

Result and Discussion

Data Adequacy Test

The data is said to be sufficient and can represent the existing population if it meets the equation $N > N'$. The results of the calculation of the adequacy test data on the number of arrivals, registration service times, health checks, and vaccinations are shown by Table 1.

Table 1

Data Adequacy Test

No.	Data Type	N	Σxi	Σxi^2	$(\Sigma xi)^2$	N'	Decision
1	Coming	100	4378	644	414736	88,978	Enough
2	Registration 1	30	487624	3798	14424804	22,618	Enough
3	Registration 2	30	505546	3874	15007876	16,898	Enough
4	Registration 3	30	470880	3736	13957696	19,339	Enough
5	Registration 4	30	521161	3929	15437041	20,500	Enough
6	Health Check 1	30	78.371	1.529	2337841	9,095	Enough
7	Health Check 2	30	80.499	1.551	2405601	6,231	Enough
8	Health Check 3	30	78.124	1.526	2328676	10,337	Enough
9	Health Check 4	30	74.397	1.491	2223081	6,354	Enough
10	Health Check 5	30	79.674	1.542	2377764	8,382	Enough
11	Vaccination 1	100	105028	3166	10023556	76,499	Enough
12	Vaccination 2	100	102676	3136	9834496	70,463	Enough
13	Vaccination 3	100	100102	3084	9511056	83,969	Enough
14	Vaccination 4	100	99574	3086	9523396	72,916	Enough
15	Vaccination 5	100	100258	3096	9585216	73,544	Enough
16	Observation 1	100	13198	1128	1272384	59,625	Enough
17	Observation 2	100	14096	1166	1359556	58,895	Enough
18	Observation 3	100	12765	1109	1229881	60,648	Enough
19	Observation 4	100	13072	1120	1254400	67,347	Enough

Examples of calculations using data adequacy test equations on arrival number data are as follows:

$$N' = \left(\frac{\frac{k}{s}\sqrt{N \sum x_i^2 - (\sum xi)^2}}{\sum x_i} \right)^2 = \left(\frac{\frac{2}{0{,}05}\sqrt{100 \times 4378 - 414736}}{644} \right)^2 = \left(\frac{\frac{2}{0{,}05}\sqrt{23064}}{644} \right)^2$$

$$= 88{,}978$$

$N > N' \rightarrow 100 > 88{,}978$, data is enough.

Based on Table 1 it is known that the number of arrivals data, as well as service time is said to be sufficient and no need to add data back because it has met the data adequacy test.

Data Distribution Test

The data distribution test of the number of arrivals and service time data is conducted with SPSS software using *the Kolmogorov-smirnov* test. Testing using a α = 5% with the following hypothesis:

H_0: Data has a poisson or exponential distribution

H_1: Data is not poisson or exponential distribution type

If the value of Asymp. Sig. 2-tailed on test results on SPSS software over 5% or 0.05 then H_0 is accepted, vice versa if Asymp. Sig. 2-tailed on test results less than 5% or 0.05 then H_0 is rejected. Based on distribution tests that have been conducted using SPSS software on data on the number of service time arrivals can be compared between the percentage of accuracy of 5% with the value of Asymp Sig 2 tailed*.* The results of the decision on all arrival time and service time data show that H_0 was rejected due to asymp value. Sig (2-tailed) is less than 0.05 so the distribution test results are obtained in Table 2 and Table 3.

Table 2

Distribution Test Results

No.	Data Type	Decision
1	Arrival	Not Distributing Poisson
2	Registration 1	Not Distributing Exponentially
3	Registration 2	Not Distributing Exponentially
4	Registration 3	Not Distributing Exponentially
5	Registration 4	Not Distributing Exponentially
6	Health Check 1	Not Distributing Exponentially
7	Health Check 2	Not Distributing Exponentially
8	Health Check 3	Not Distributing Exponentially
9	Health Check 4	Not Distributing Exponentially
10	Health Check 5	Not Distributing Exponentially
11	Vaccination 1	Not Distributing Exponentially
12	Vaccination 2	Not Distributing Exponentially
13	Vaccination 3	Not Distributing Exponentially
14	Vaccination 4	Not Distributing Exponentially
15	Vaccination 5	Not Distributing Exponentially

Table 3

Distribution Test Results (Continous)

No.	Data Type	Decision
16	Observation and Printing 1	Not Distributing Exponentially
17	Observation and Printing 2	Not Distributing Exponentially
18	Observation and Printing 3	Not Distributing Exponentially
19	Observation and Printing 4	Not Distributing Exponentially

System Modeling

The vaccination queue system has 4 registration service officers, 5 health check officers, 5 vaccination officers, and 4 observation and printing officers, where each observation officer can serve 10 vaccination processes. The results of the modeling of the vaccination queue system can be seen in Figure 2.

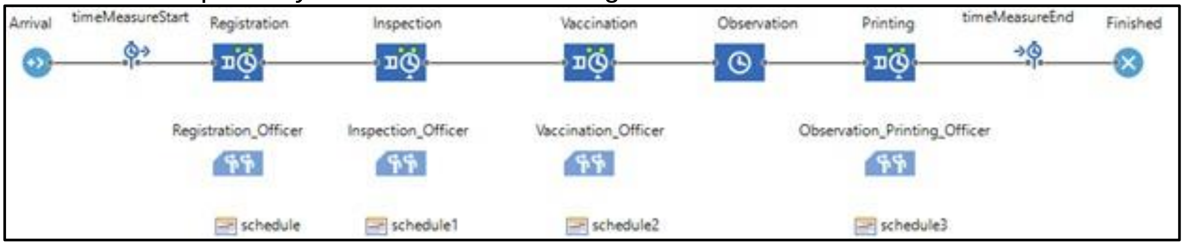

Figure 2 Results of Vaccination Queue System Modeling

Verify Model

Verification of the model is done to find out if the model of the vaccination activity queue system that is built is in accordance with the system running on the real system. Model verification is done using anylogic simulations shown in Figure 3.

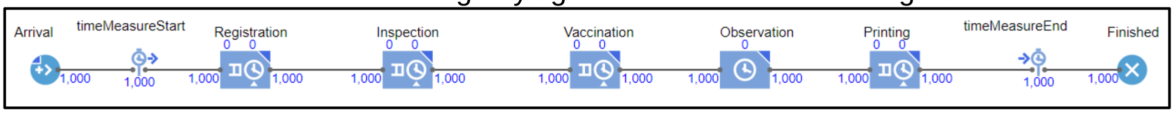

Figure 3 Model Verification Results

The results of the model verification that has been done in Figure 3 show that the simulated system model has been running in accordance with the real system based on the assumptions that have been made. The simulation time has been adjusted through schedule time with service time at *UPTD Puskesmas* Subdistrict XYZ which performs vaccination services from 07.00 to 16.30 with the replacement of officers at 12:30 so that there is no rest time. Simulations of the system showed that the number of arrivals as well as the number of participants who completed vaccination services were in accordance with the availability of 1000 doses of vaccine provided.

Model Simulation

The results of a simulation of the vaccination queue system model in *UPTD Puskesmas* Subdistrict XYZ using Anylogic software are shown in Figure 4.

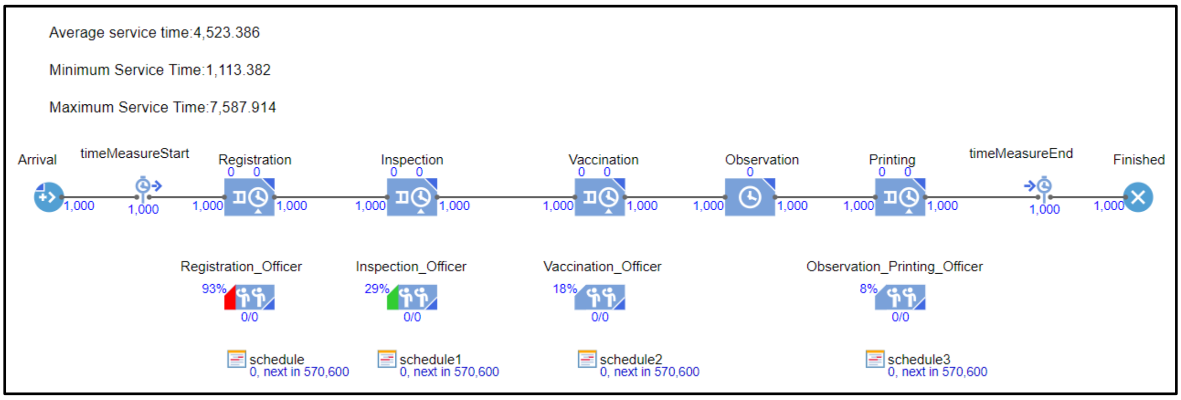

Figure 4 Running Model Results

Figure 4 shows that the average service time for the existing queue system model is 4,523.38 seconds. The greater the average service time, the more queues occur on the service server. The number of registration server queues in the simulation results showed a figure of up to 192 people. The figure can be categorized as a crowd because the available seat capacity is only 50 seats. The productivity percentage of each service from registration, health check, vaccination, and observation showed consecutive figures of 93%, 29%, 18% and 8% with an average productivity of 37%.

Analysis of Queue System Model Simulation Results

Proposed improvements to the *XYZ Public Health Center* vaccination queue system model is done with several scenarios. Table 4 shows the number of workers in existing conditions and the number of workers for each repair scenario.

Table 4

Proposed Improvement Scenario

Scenario	Number of Service Personnel (persons)			
	Registration	Health Check	Vaccination	Observation
Existing	4	5	5	4
Scenario 1	4	4	4	3
Scenario 2	4	3	3	2
Scenario 3	4	2	2	1
Scenario 4	4	2	1	1
Scenario 5	5	2	2	1

Existing conditions indicate that the number of queues that exceed the capacity on the registration server as well as a low percentage of productivity on the service server inspection, vaccination and observation and printing of cards so that simulations are carried out using improvement scenarios by adjusting the number of officers on each service server. A comparison of the average service time on the existing condition queue model and the queue model on each proposed improvement scenario can be seen in Figure 5.

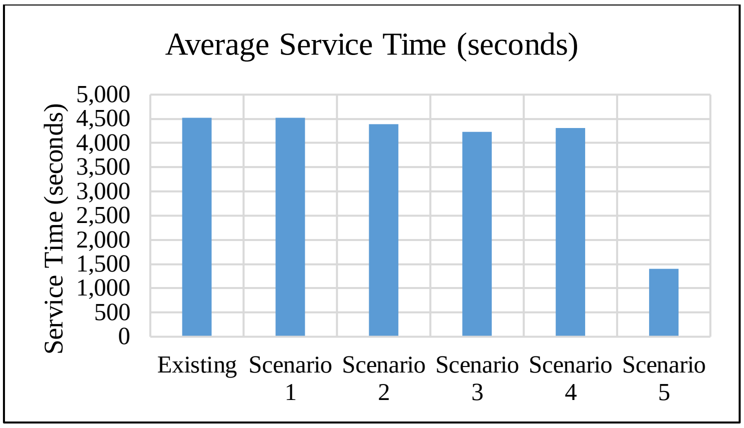

Figure 5 Comparison of Average Service Time

Figure 5 shows the average service timeof the existing condition queue model and the queue model of each repair scenario. The comparison graph shows that scenario 5 is thesmallest average servicetime of 1401.92 seconds or 23.36 minutes. The lower the average service time, the smaller the number of queues that occur on the service server, meaning that scenario 5 has the smallest number of queues compared to the existing condition queue model, scenario 1, scenario 2, scenario 3 and scenario 4.

Economic Analysis

Economic analysis is conducted with the aim of calculating the expected costs incurred due to the number of officers employed in the system. Officers on registration, health check, vaccination, and observation servers each get a wage per day of Rp100,000, Rp300,000, Rp300,000 and Rp100,000 per officer. Here's a calculation to calculate wages for work under real conditions:

$$Wages = \sum_{i=1}^{n} (number\ of\ officers \times empolee's\ wages\ on\ the\ server)$$

$$= (4 \times Rp100.000) + (5 \times Rp300.000) + (5 \times Rp300.000) + (4 \times Rp100.000)$$

$$= Rp400.000 + Rp1.500.000 + Rp1.500.000 + Rp400.000$$

$$= Rp3.800.000$$

Based on the same equation, the calculation of working wages is carried out in each scenario of proposed improvements. Economic analysis based on the number of service personnel on real system conditions and proposed improvements is shown in Table 5.

Table 5

Calculation of Economic Analysis

Scenario	Officer's Wages (per day)				
	Registration	Health Check	Vaccination	Observation	Sum
Existing	Rp400,000	Rp1,500,000	Rp1,500,000	Rp400,000	Rp3,800,000
Scenario 1	Rp400,000	Rp1,200,000	Rp1,200,000	Rp300,000	Rp3.100.000
Scenario 2	Rp400,000	Rp900,000	Rp900,000	Rp200,000	Rp2,400,000
Scenario 3	Rp400,000	Rp600,000	Rp600,000	Rp100,000	Rp1,700,000
Scenario 4	Rp400,000	Rp600,000	Rp300,000	Rp100,000	Rp1,400,000
Scenario 5	Rp500,000	Rp600,000	Rp600,000	Rp100,000	Rp1,800,000

Recommendations for Proposed Improvements

The results of the percentage comparison of productivity, economic analysis and service time in each scenario are seen in Table 6.

Table 5

Comparison of Simulation Results and Economic Analysis

Scenario	Service Time (Seconds)	Percentage Of Productivity	Economic Analysis
Existing	4523,38	37%	Rp3,800,000
Scenario 1	4523,39	41%	Rp3.100.000
Scenario 2	4392,45	47%	Rp2,400,000
Scenario 3	4233,35	61%	Rp1,700,000
Scenario 4	4312,21	73%	Rp1,400,000
Scenario 5	1401,92	57%	Rp1,800,000

Based on consideration of aspects of average service time to reduce the number of queues that occur on service servers, scenario 5 is the most effective proposed improvement to optimize the vaccination queue system, scenario 5 has an average minimum service time of 1401.92 seconds or about 23.4 minutes compared to the average service time in existing conditions, scenario 1, scenario 2, scenario 3, scenario 4, scenario 5 lowers the average service time to 3121.46 seconds or 52.02 minutes. Minimization of average service time can reduce the number of queues that have an impact on the reduced crowd that occurs in the vaccination service process.

The results of the simulation using the queue model in scenario 5 with the number of 5 officers on registration, 2 officers at the health check, 2 officers on vaccinations, and 1 officer on observation can reduce the number of queues that occur on the registration server from the existing condition of 192 people to 26 people. Scenario 5 allows the number of queues on service servers to meet the queue capacity provided, through simulation results it is also known that scenario 5 not only lowers the average service time, but also increases the average percentage of productivity from 37% to 57% and lowers the employment wages of service personnel from Rp3,800,000 to Rp1,800,000 with a decrease of Rp2,000,000.

Conclusion

Conclusions that can be taken based on research that has been done are obtained 5 scenarios proposed improvements. Based on consideration of the average aspect of service time to reduce the number of queues that occur on service servers, scenario 5 is the most effective proposed improvement to optimize the vaccination queue system. Scenario 5 has the number of officers on the registration, inspection, vaccination, and observation servers of 5 officers, 2 officers, 2 officers, and 1 officer, respectively. Scenario 5 was able to reduce the service time from existing conditions by 4523.38 seconds to 1401.92 seconds with a decrease of 3121.46 seconds, in addition scenario 5 managed to increase productivity from 37% to 57%% with an increase of 20%, scenario 5 was also able to reduce employment wages from existing conditions from Rp3,800,000 per day to Rp1,800,000 with a decrease of Rp2,000,000 per day.

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