

Queuing System

Application of Jackson Network Queue Model on Visitor Queue at Population and Civil Registration Service of Batubara District

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A B S T R A K

Queues are a common problem in society, queues can occur because the level of service demand is greater than the level of facility capacity to provide services. Jackson network queue is a queue model used to describe a queue system that consists of several interconnected locations or servers, where customers move between locations based on certain rules. Jackson network queue refers to the application of queues to model a service system consisting of several interconnected service stages or locations to increase efficiency and reduce customer waiting time. Data collection was conducted at the Population and Civil Registration Office of Batubara Regency for ten days, the counters studied were the registration counter and the recording counter. The initial queue model was Single Channel-Multi Phase with 1 registration counter and 5 recording counters. The results obtained after applying the Jackson network queue method were that the queue model changed to Multi Channel-Multi Phase by adding workstations and the number of employees at each workstation, for 2 registration workstations, 5 general/regular recording workstations, and 1 special recording workstation for visitors who do not have complete files. The results obtained were that the waiting time for visitors at the registration counter and recording counter was 9 minutes, shorter than before using the Jackson network queue system with a total of 23 minutes. These results can be used as a reference to speed up the waiting time for visitors at the Population and Civil Registration Office of Batubara Regency.

INTRODUCTION

Data collection was conducted at the Population and Civil Registration Office of Batubara Regency for ten days, the counters studied were the registration counter and the recording counter. The initial queue model was Single Channel-Multi Phase with 1 registration counter and 5 recording counters. The results obtained after applying the Jackson network queue method were that the queue model changed to Multi Channel-Multi Phase by adding workstations and the number of employees at each workstation, for 2 registration workstations, 5 general/regular recording workstations, and 1 special recording workstation for visitors who do not have complete files. The results obtained were that the waiting time for visitors at the registration counter and recording counter was 9 minutes, shorter than before using the Jackson network queue system with a total of 23 minutes. These results can be used as a reference to speed up the waiting time for visitors at the Population and Civil Registration Office of Batubara Regency.

Public service is an activity carried out by a person or group of people based on material factors through certain systems, procedures, and methods in an effort to fulfill the interests of others according to their rights. Thus, public service is any form of service provided by the government or public agencies to the community to fulfill their basic needs and rights. This service covers various sectors, such as health, education, administration, licensing, and so on, which aims to improve public welfare and ensure that the service is fair, efficient, and easily accessible to all levels of society. The public service office of this research object is at the Population and Civil Registration Office of Batubara Regency located on Jl. Lintas

Sumatera, Tanah Merah, Kec. Air Putih, Kab. Batu Bara, Indrapura, North Sumatra, Indonesia 21256. with operational hours starting at 08.00 - 15.00 WIB.

The queue system at the Population and Civil Registration Office of Batubara Regency uses a Single channel-Multi phase queue structure. People who come will register at the registration counter and get a queue number. After getting a queue number, visitors will wait a few minutes until they are called according to their queue number. When the queue number has been mentioned by the officer, visitors enter the registration counter to provide the form and requirements for managing the Family Card and ID Card that have been prepared from home. Then the officer will verify and check the forms and requirements. If these requirements have been met, the issuance of the Family Card and ID Card can be carried out, but if all the requirements are not met, visitors are asked to complete the requirements for the management first. Visitors who have met these requirements will wait for the files to be received and can pick them up at another time by bringing the requirements for collecting the files that have been given by the officer previously.

A queue network is a group of workstations where customers or goods can queue and move from one workstation to another (Owoloko et al., 2015). Because the Jackson queue network at each workstation is basically continuous and each queue is independent of each other, unlike the Multi-channel - Multi-phase queue system which does not use the probability of visitors moving from one workstation to another. In the Multi-channel - Multi-phase queue system, only queue system performance measurements can be used, such as determining the probability, or average value, of the absence of visitors in the system when visitors move from one workplace to another, the number of visitors expected to wait in a queue, the average number of visitors expected to wait in a queue system, the average visitor waiting time expected in a queue, the average visitor time expected in a queue system [1,2,3].

Based on the background above and several previous studies, it can be seen that by implementing the Jackson queuing network, it can minimize the waiting time for visitors to be served in a queue network. Therefore, the author is interested in giving the title of this paper, namely "Application of the Jackson Network Queue Model to Visitor Queues at the Population and Civil Registration Service of Batubara Regency".

METHOD

Queue System

A queue system is a collection of customers, waiters (counters) and a rule that regulates customer arrivals and queue service problem processing which is characterized by five components, namely: arrival patterns, service patterns, number of services, customer facility capacity, and rules in serving customers [4,5,6]. There are several components in the queue system, namely:

1. Arrival

In general, the arrival process occurs randomly and cannot be predicted when the visitor will come. With the arrival of visitors who are uncertain, the probability used is the Poisson probability distribution.

2. Queue

Queues have a length limit that can be limited or unlimited. An example is the queue at a barbershop which is included in the category of limited queue length due to limited space.

3. Service facilities

Service facilities have several characteristics, namely the physical layout of the queue system, queue discipline, and service time.

Jackson Queuing Network

The queuing network has developed with the contribution of the Jackson queuing network model in 1957, known as the Jackson queuing network model [7,8]. The Jackson queuing network is a queue where visitors can move from one workstation to another before leaving the system. The Jackson queuing network consists of open and closed Jackson networks. In this model, the arrival of visitors to the workstation forms a Poisson distribution that has a First Come First Serve (FCFS) queuing discipline and the service time of a workstation forms an exponential distribution. The movement of visitors is in the form of the probability of moving to the next workstation after completion of being served at the previous workstation with a certain service.

Data Analysis Method

Data analysis method is a series of techniques and approaches used to understand, interpret and obtain information from the collected data.

The steps for data analysis in this study are as follows:

1. Searching for literature or library studies on the topic and research methods, namely queuing theory and Jackson's queuing network method.
2. Collecting visitor arrival data for the Population and Civil Registration Office of Batubara Regency at the registration and recording counters. In this case, the data taken is the time data between the arrivals of service users at each counter, then recapitulating the number of arrivals in one system.
3. The data obtained must meet the steady state ($\rho = \lambda / \mu < 1$).
4. Conducting a distribution test for the number of arrivals of Population and Civil Registration Office users on the issuance of KTP and KK. If the hypothesis for the arrival distribution is accepted, the distribution used is the Poisson distribution and if the service time distribution is accepted, the distribution used is the exponential distribution.
5. Analysis of the queue model at the Population and Civil Registration Service at the registration counter and filing counter.
6. Calculating the performance measures of the queue system consisting of the average length of time visitors wait to be served, the average length of time visitors are in the queue system, the average number of visitors queuing, the average number of visitors in the queue and the probability of there being no visitors in the queue.
7. Calculation of the Jackson queue network method

RESULTS AND DISCUSSION

Arrival Rate and Service Level

Data were collected through direct observation for ten working days (two weeks) from Monday to Friday. Visitors who come to the Population and Civil Registration Office of Batubara Regency will first register, which is open from 08.00 WIB to 15.00 WIB. There is a break time at the Population and Civil Registration Office of Batubara Regency from 12.30 WIB to 13.30 WIB. Visitors who have registered between 08.00 WIB and 15.00 WIB will be served. Meanwhile, visitors who pass the registration hours from 08.00 to 15.00 WIB will not be served.

Researchers will conduct the analysis for ten consecutive days (two weeks), on January 8 to 12, 2024 for the first week and January 15 to 19, 2024 for the second week. In the first week from Monday, January 8 to Friday, January 12, 2024, there were a total of 300 visitors who processed their KTP and KK with a large number of daily visitors on Monday 64 people, Tuesday 61 people, Wednesday 63 people, Thursday 58 people, and Friday 54 people, then in the second week from Monday, January 15 to Friday, January 19, 2024, there were a total of 321 visitors who processed their KTP and KK with a large number of daily visitors on Monday 70 people, Tuesday 66 people, Wednesday 67 people, Thursday 60 people, and Friday 58 people, so that the total number of visitors on January 8 to 12, 2024 for the first week and January 15 to 19, 2024 for the second week was 621 people. The following is a summary graph of the number of visitors to the Population and Civil Registration Office of Batubara Regency for two consecutive weeks:

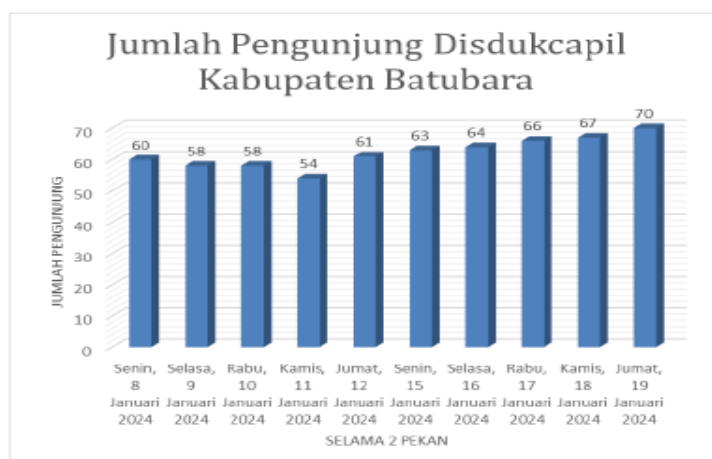


Figure 1. Number of visitors to the Population and Civil Registry Office of Batubara Regency

The arrival rate (λ) used for further calculations is the average arrival rate per minute (person/minute) for 10 working days.

Steady State Condition

A steady state condition is a system condition that does not depend on the initial event or the time that has passed. If there are n customers in the system at time t that does not depend on time. This steady state condition is useful for knowing whether a condition has a constant value or not after running for a certain period, to calculate the Steady State the researcher needs the value of the arrival rate (λ) and service level (μ) that have been obtained previously. At this stage, it is checked whether the queuing system is in a steady state condition or not at the registration counter and recording counter workstations.

By using the equation above, the value of ρ is obtained for the steady state condition of the queue at the registration counter workstation and the recording counter as follows.

Table 1. ρ Value

| No | Workstation | Server (K) | ρ |
|----|--------------|------------|--------|
| 1 | Registration | 1 | 0,2381 |
| 2 | Recording | 5 | 0,5414 |

Based on the calculation results in Table 1, all workstations have a value of ρ less than 1. So that all queues in the queue network at the Population and Civil Registration Office of Batubara Regency are in a steady state or constant value after running for a certain period.

Arrival Distribution Test

The arrival distribution test is conducted to determine the model of the queue system that occurs. Visitor arrivals at the registration counter and recording counter are assumed to be Poisson distributed. Testing the arrival distribution at the registration counter and recording counter at the Population and Civil Registration Office of Batubara Regency uses the Kolmogorov-Smirnov table. The following is a calculation to find the value of (x) or the value of the cumulative distribution function of the sample data and the value of $F(x)$ or the cumulative distribution function of the hypothesized distribution to find the value of D before conducting a hypothesis test.

1. Calculating the number of customers in the system after the i -th arrival or $S(X_i)$
In a queuing system, $S(X_i)$ is often used to state the system status (number of customers in the queue/system) after the i -th arrival.
For example, if the i -th customer arrives, $S(X_i)$ can describe the number of customers in the system (both being served and those waiting) at that time. The following is an explanation of the formula for calculating the number of customers in the i -th arrival system.
2. Calculating the Z _score
The Z _score formula in the Jackson queue is used to calculate how far a value is from the mean in a queue system. In general, Z _score is a measure in statistics that shows how many standard deviations a value is from the mean. Z _score is usually calculated for the distribution of waiting times or queue lengths. For waiting times, Z _score can be calculated using the standard normal distribution formula if the waiting time data follows a normal distribution.
3. Calculating the value of $F(X_i)$
To calculate the value of $F(X_i)$ in a queuing system, we look at the cumulative distribution of the interarrival time or service time in the queuing system. In this case, the value of $F(X_i)$ represents the cumulative distribution function (CDF) of the random variable X_i , which describes the interarrival time or service time in the queue. Then $F(X_i)$ is the probability that the value of X_i is less than or equal to that value in the standard normal distribution value. So it can be calculated by using the cumulative distribution function (CDF) for the standard normal distribution.

The following are the results of the arrival distribution test to find the D value for the registration counter and the registration counter.

Table 2. Arrival Distribution Test to Find the D Value for the Registration Counter

| Number of Arrivals | Frequency | Freqqum | S(Xi) | Z_Score | F(Xi) | S(Xi)-F(Xi) |
|--------------------|-----------|---------|-------|---------|-------|-------------|
| 60 | 1 | 1 | 0.1 | 0.434 | 0.332 | 0.232 |
| 58 | 1 | 2 | 0.2 | 0.847 | 0.199 | 0.001 |
| 58 | 1 | 3 | 0.3 | 0.847 | 0.199 | 0.101 |
| 54 | 1 | 4 | 0.4 | 1.673 | 0.047 | 0.353 |
| 61 | 1 | 5 | 0.5 | 0.227 | 0.410 | 0.090 |
| 63 | 1 | 6 | 0.6 | 0.186 | 0.574 | 0.026 |
| 64 | 1 | 7 | 0.7 | 0.392 | 0.653 | 0.047 |
| 66 | 1 | 8 | 0.8 | 0.806 | 0.790 | 0.010 |
| 67 | 1 | 9 | 0.9 | 1.012 | 0.844 | 0.056 |
| 70 | 1 | 10 | 1 | 1.632 | 0.949 | 0.051 |

Table 3. Arrival Distribution Test Finding the D Value for the Registration Counter

| Number of Arrivals | Frequency | Freqqum | S(Xi) | Z_Score | F(Xi) | S(Xi)-F(Xi) |
|--------------------|-----------|---------|-------|---------|-------|-------------|
| 60 | 1 | 1 | 0.1 | 0.434 | 0.332 | 0.232 |
| 58 | 1 | 2 | 0.2 | 0.847 | 0.199 | 0.001 |
| 58 | 1 | 3 | 0.3 | 0.847 | 0.199 | 0.101 |
| 54 | 1 | 4 | 0.4 | 1.673 | 0.047 | 0.353 |
| 61 | 1 | 5 | 0.5 | 0.227 | 0.410 | 0.090 |
| 63 | 1 | 6 | 0.6 | 0.186 | 0.574 | 0.026 |
| 64 | 1 | 7 | 0.7 | 0.392 | 0.653 | 0.047 |
| 66 | 1 | 8 | 0.8 | 0.806 | 0.790 | 0.010 |
| 67 | 1 | 9 | 0.9 | 1.012 | 0.844 | 0.056 |
| 70 | 1 | 10 | 1 | 1.632 | 0.949 | 0.051 |

Based on Table 2 and Table 3, the researcher takes the highest value from $|(x)-F0(x)|$ which is called the D value. Then the D^* value at the significance level $\alpha = 0.05$ from the Kolmogorov-Smirnov table is found to be 0.409 is the value used to compare with the calculated D value. The D value in the calculation of the arrival distribution test for the registration and recording counter is 0.353 which will be compared with the D^* value of 0.409. Because the D value in the arrival distribution test at the registration and recording counter is 0.353, which is smaller than D^* in the Kolmogorov-Smirnov table 0.409, the result is accepted H_0 . In this case, the null hypothesis (H_0) explains that the distribution of arrivals at both counters (registration and recording) follows the Poisson distribution.

Test Statistics

This hypothesis test aims to determine whether the visitor arrival data at the registration counter or the registration counter is in accordance with the expected Poisson distribution. If the D value $> D^*$ (α) then reject H_0 and if the test results show that $D \leq D^*$ then H_0 is accepted, which means that the visitor arrival data at the registration counter or the registration counter is distributed Poisson. If the null hypothesis (H_0) is rejected and the alternative hypothesis (H_1) is accepted, it means that the visitor arrivals at the registration counter or the registration counter are not distributed Poisson, so it is necessary to analyze the causes of the Poisson distribution not being met, such as checking the data to see patterns that might affect the arrival distribution. For example, there are external factors, namely peak times or variations in arrival patterns, seasonal factors, certain days, or certain times that make the arrival distribution deviate from the Poisson distribution.

Table 4. Arrival Distribution Test

| Workstation | D | D^* (α) | Decision | Conclusion |
|--------------|-------|--------------------|----------------|---------------------------|
| Registration | 0.353 | 0.409 | H_0 Accepted | Poisson Distribution Data |
| Recording | 0.353 | 0.409 | H_0 Accepted | Poisson Distribution Data |

Service Distribution Test

Next, the researcher will analyze the distribution of visitor service time at the registration counter and the registration counter which is assumed to be exponentially distributed. The service distribution test is a statistical method or procedure used to determine the probability distribution that is most suitable to describe the pattern of service time or the length of service time in a queuing system or service process. The purpose of the service distribution test is to understand how service time is distributed, for example whether it is normally distributed, exponentially distributed, Poisson, or other types of distribution. Testing the service distribution at the registration counter and registration counter at the Population and Civil Registration Office of Batubara Regency uses the Kolmogorov-Smirnov table. The following is a calculation to find the value of $S(x)$ or the value of the cumulative distribution function of the sample data and the value of $F_0(x)$ or the cumulative distribution function of the hypothesized distribution to find the D value before conducting the hypothesis test.

Comparison of Initial Queue System Performance Analysis with Jackson Queue

Based on the calculation of the queue system performance of the two methods, the initial queue system performance with a single channel-multi phase structure obtained a result of 0.389 hours or 23 minutes. While the Jackson queue system performance with a single channel-multi phase structure was 0.146 hours or 9 minutes. This means that the Jackson queue method effectively reduces visitor waiting time in the queue system and optimizes the process by dividing the queue load at each workstation, which leads to a reduction in overall waiting time.

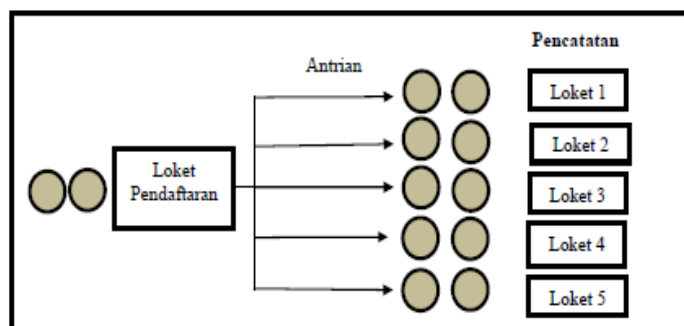


Figure 2. Jackson Queuing Pattern Simulation with Single Channel-Multi Phase

Figure 2 is a simulation of the Jackson queuing system pattern at the Population and Civil Registration Office of Batubara Regency using a single channel-multi phase structure. Where in this queuing system all visitors who come queue at one registration counter. At this registration counter, officers will process initial information, check documents, then be given a queue number to go to the registration counter. After passing the registration counter, visitors are directed to one of the five registration counters. Visitors are called based on the counter queue number and then allocated to one of the registration counters based on the queue number. Each registration counter can work in parallel and each visitor is served only once at one of the five registration counters. In this queuing model, it is expected that all visitors have completed all the files needed to make an ID card and family card, if there are visitors whose files are not fulfilled, they will be served at another time.

CONCLUSIONS

The conclusions that can be drawn based on the results of the analysis and discussion at the Population and Civil Registration Office of Batubara Regency using the Jackson network queue method are: The initial queue system conditions, namely the average time at the registration counter used by officers to serve visitors is 2 minutes/person. Then the average time at the registration counter used by officers to serve visitors is 21 minutes/person. The average visitor arrival rate at the registration and registration counters is the same, namely 8 people/hour, while the average level of visitor service at the registration counter that can be served is 33 people/hour and the registration counter is 3 people/hour. By applying the Jackson network queue structure at the registration counter and the recording counter with the Single channel-Multi phase structure, the average time spent by visitors to make KTP and KK is 9 minutes. Meanwhile, at the registration counter and the recording counter with the Multi channel-Multi phase structure, the average time spent by visitors to make KTP and KK is 8 minutes, slightly shorter than using the Single channel-Multi phase structure because in the Single channel-Multi phase structure model, all visitors who come queue at one registration counter only. Trials

with the application of the Jackson network queue structure using Multi Channel-Multi Phase found that by adding workstations, where there are 2 registration workstations. Then there are 5 general/regular recording workstations and 1 special recording workstation for visitors who do not have complete files. By adding 1 special registration and recording workstation, visitors with incomplete files can be processed in parallel without adding to the burden on the general or regular counters.

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