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Discrete-Event Modeling and Simulation of the Mobile Samsat Service Queue System in North Medan

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Abstract

This study discusses the queueing problem at the Medan Utara Mobile Samsat Bus service, which often experiences increased waiting times due to limited resources and variations in service times at each counter. This study aims to analyze the performance of the queueing system and identify bottlenecks in the two-stage service flow using the Discrete-Event Simulation (DES) approach. Interarrival and service time data were obtained through direct observation and used as empirical distributions in the simulation process. The DES model was constructed to represent the sequence of service events from arrival, start of service, to completion of service at Counter 1 and Counter 2. The simulation results showed that Counter 1 had the highest waiting time, with an average waiting time of 50.56 minutes, which was much longer than Counter 2, which was only 0.69 minutes. The average total time customers spent in the system was recorded at 62.27 minutes, which was dominated by the waiting time at Counter 1. Statistical analysis confirmed that service variations at Counter 1 contributed significantly to queue formation compared to Counter 2. This study concludes that the application of DES is effective in realistically describing the dynamics of the Mobile Samsat service queue and can be used as an evaluation tool to formulate recommendations for improvement, such as adjusting the number of officers or improving operational flows to increase service efficiency.

Keywords: Queue System, Discrete-Event Simulation, Mobile Samsat, Waiting Time, Service Modeling

1. Introduction

Public service is one of the main functions of government, which aims to meet the needs of the community in an effective, efficient, and accountable manner. The concept of good governance requires state officials to provide quality, transparent services that are oriented towards public satisfaction. As the level of education and public awareness increases, so do demands for improved quality of public services. The government is required to implement various service innovations in order to create a responsive service system that is oriented towards the public interest [1].

In the context of motor vehicle administration, the One-Stop Integrated Administration System (Samsat) plays a strategic role in supporting orderly administration and optimizing regional revenue. To improve the efficiency and accessibility of services, the government has implemented a one-stop integrated service system as stipulated in Presidential Regulation No. 5 of 2015. This regulation aims to simplify the motor vehicle administration process, including the validation of vehicle registration certificates, payment of motor vehicle taxes, and mandatory traffic accident fund contributions, so that they can be carried out in an integrated, transparent, and accountable manner [2].

As a form of public service development, the government has introduced a Mobile Samsat service that operates in certain locations and moves periodically. This service is designed to reach people who live far from the main Samsat office, especially in suburban areas, with the aim of increasing taxpayer compliance and speeding up the service process. Although it provides ease of access, the Mobile Samsat service has limited resources in terms of the number of officers, counter capacity, and operational space, which has the potential to cause queuing problems [3].

Queuing problems are a common phenomenon in public services that arise when demand for services exceeds available service capacity. An imbalance between the rate of customer arrivals and the system's ability to serve them, variations in service times, and fluctuations in customer arrivals can lead to increased waiting times and queues. This condition not only affects operational efficiency, but also influences the level of public satisfaction with the quality of government services. In the Mobile Samsat service, queue problems become even more complex due to the temporary nature of the service and its operation with limited resources [4].

At the North Medan Samsat Technical Implementation Unit, the Mobile Samsat Bus service implements a two-stage serial queue system. Each taxpayer must go through a document inspection and verification process at Counter 1 before proceeding to the payment and document issuance process at Counter 2. This sequential service structure has the potential to cause congestion if there is an imbalance in the duration of service between counters or high variation in service time at one of the stages. Field observations show that Counter 1 tends to have longer and more varied service times than Counter 2, so it often becomes a bottleneck that increases the overall waiting time for customers.

Various approaches have been developed to analyze and address queueing problems, one of which is through queueing theory. Queueing theory is a branch of applied mathematics that studies the behavior of queueing systems, including arrival processes, service times, and queueing discipline [5], [6]. This approach is widely used to evaluate service system performance through analytical models. However, queueing theory models generally rely on certain assumptions regarding arrival and service time distributions, which in practice are often difficult to fulfill in dynamic public services [7].

In addition to analytical approaches, simulation has been widely used as a tool in planning and decision-making in service systems. Simulation enables the development of representations of real systems in virtual environments so that system behavior can be analyzed without disrupting actual operations [8]. One of the service disciplines commonly applied in public service queuing systems is First Come First Served (FCFS), where customers are served based on their order of arrival. This approach is considered fair and appropriate for administrative services that do not apply special priorities [9].

In queueing system studies, simulation models are used to represent the cause-and-effect relationships between system components, such as customers, service agents, and support facilities. Simulation models enable the testing of various operational scenarios to estimate their impact on system performance [10]. In addition, Little's Law is one of the fundamental principles in queueing theory that links the average number of customers in the system, the arrival rate, and the average time spent by customers in the system. This principle is widely used as the basis for evaluating service system performance, including in multi-stage queueing systems [11].

In recent years, Discrete-Event Simulation (DES) has been increasingly used to analyze complex and dynamic queueing systems. DES models systems as a series of discrete events that occur at specific times, such as customer arrivals, service starts, and service completions. This approach allows for the direct use of empirical data, enabling a more realistic representation of the system's operational conditions compared to classical analytical models [12], [13].

Simulation approaches, particularly Discrete-Event Simulation (DES), are increasingly being used to analyze complex and dynamic service queueing systems. DES enables system modeling based on discrete event sequences such as customer arrivals, service starts, and service completions, thereby representing operational conditions more realistically than classical analytical approaches. Recent studies show that DES is effective in evaluating queueing system performance through key indicators such as average waiting time and queue length, and is capable of identifying bottlenecks at certain service stages and testing various improvement scenarios without disrupting the actual system [14].

In developing simulation models, the system design or modeling stage plays an important role in systematically representing service process flows. The design process translates system requirements into conceptual models that describe activity flows, interactions between components, and service process sequences [15]. This modeling helps ensure that the simulation model built is consistent with actual operational conditions and capable of accurately describing system dynamics.

Although various studies have discussed the application of DES in queueing systems in the service sector, studies that specifically discuss two-stage queueing systems in Mobile Samsat services are still relatively limited. Most studies focus on fixed services or use theoretical assumptions that do not reflect actual operational conditions. Therefore, there is a research gap in the modeling and analysis of Mobile Samsat queueing systems based on empirical data and realistic simulation approaches. Based on this background, this study aims to analyze the performance of the queueing system in the annual tax validation service of the Mobile Samsat Bus of the North Medan Samsat Technical Implementation Unit (UPTD) using a Discrete-Event Simulation approach. This study models a two-stage service flow based on empirical data on arrival times and service times, measures waiting times and the total time customers spend in the system, and identifies potential bottlenecks as a basis for formulating recommendations for improvements to increase the efficiency and quality of public services.

2. Methodology

The methodology section systematically describes the steps applied in this study to model and analyze the annual tax approval service queue system on the Mobile Samsat Bus through the Discrete-Event Simulation (DES) approach. The methodology includes the stages of data collection, system model design, simulation model development, and system performance evaluation process using queue performance indicators.

2.1 Tools and Materials

This study uses hardware in the form of a computer with minimum specifications of an Intel Core i5 or AMD Ryzen 5 equivalent processor and 8 GB of RAM to ensure smooth simulation processes. The software used includes the Python 3.13 programming language as the main platform for developing the Discrete-Event Simulation model, with Jupyter Notebook as the working environment for compiling and executing program code. Empirical data processing and manipulation were performed using the Pandas library, while the simulation results were visualized in the form of histograms and bar charts using Matplotlib. In addition, this study utilized field data in the form of observations of customer arrival times at the Samsat Keliling bus service during operating hours from 08:30 to 15:30, as well as information related to the service process flow as the basis for designing the simulation model.

2.2 Data Collection

Table 1. Raw Data on Mobile Samsat Bus Services

Cust	Arrival Time	Start L1	Finish L1	Start L2	Completed
1	08:30:00	08:30:00	08:34:00	08:34:00	08:38:00
2	08:33:28	08:34:00	08:40:00	08:40	08:47:00

3	8:36:19	8:40:00	8:48:00	8:48:00	08:55:00
4	8:39:19	8:48:00	8:56:00	8:56:00	09:02:00
5	8:42:37	8:56:00	09:02:00	9:02:00	09:09:00
6	8:45:48	9:02:00	09:10:00	9:10:00	09:14:00
7	8:51:29	9:10:00	09:17:00	9:17:00	09:20:00
8	9:00:49	9:17:00	09:25:00	9:25:00	09:31:00
9	9:04:31	9:25:00	09:33:00	9:33:00	09:39:00
10	9:10:59	9:33:00	9:40:00	09:40:00	9:46:00
...	...	...	...	...	...
71	14:12:43	15:24:00	15:32:00	15:33:00	15:36:00

2.3 System Planning

The system design aims to represent the actual service flow of the Mobile Samsat Bus at UPTD Samsat Medan Utara using a Discrete-Event Simulation (DES) approach. The service system is modeled as a two-stage serial queue system, where each customer must sequentially pass through two service counters. Counter 1 functions as the registration and verification stage, including document checking and tax assessment, while Counter 2 serves as the payment and document issuance stage. Each counter operates as a single-server system, reflecting the actual operational conditions of the Mobile Samsat service.

The service architecture is strictly sequential, meaning that customers can only proceed to Counter 2 after completing service at Counter 1. This configuration causes the performance of Counter 1 to have a direct impact on the formation of queues at subsequent stages. Based on field observations, service time at Counter 1 exhibits higher variability and longer duration compared to Counter 2, making it a potential bottleneck in the system.

All customers are processed using a First-Come, First-Served (FCFS) discipline without balking, reneging, or jockeying behavior. The logical flow of the system is illustrated in Figure 1, which presents the flowchart of the DES model. The flowchart describes the sequence of events starting from customer arrival, queue formation, service availability checks, service execution at each counter, and the recording of waiting time and total system time. This flowchart serves as the conceptual foundation for building the simulation model and ensures that the DES accurately reflects the real operational process of the Mobile Samsat service.

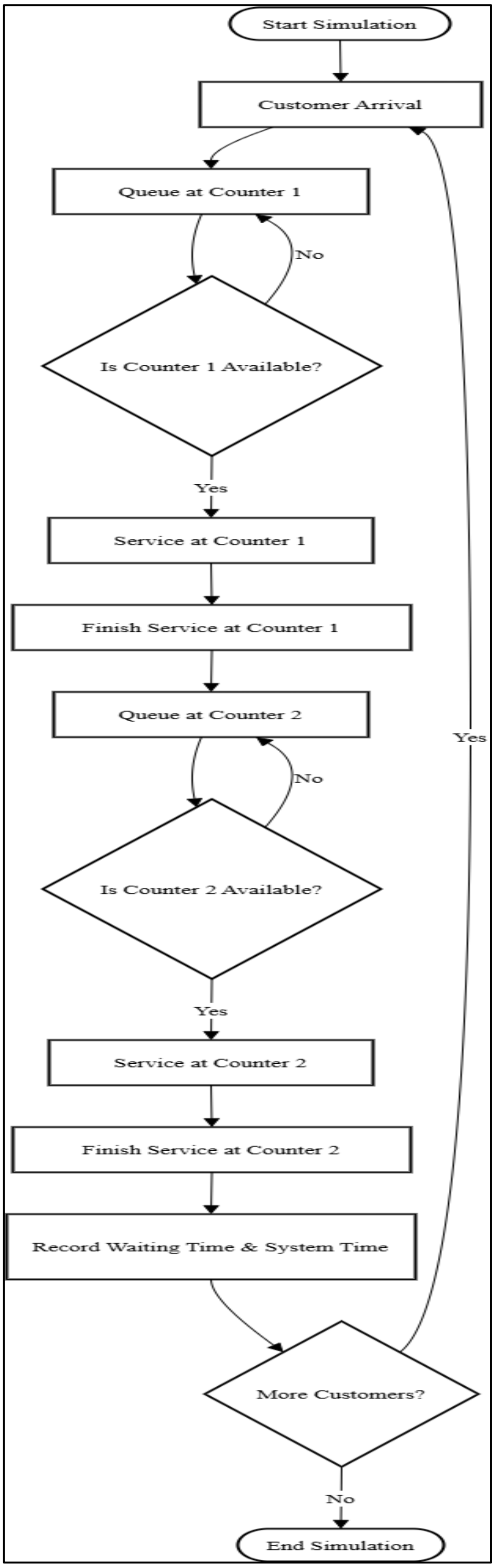

Figure 1. Flowchart of the Discrete-Event Simulation model for the two-stage Mobile Samsat queue system

2.4 Development of DES Simulation Model

The development of the simulation model is carried out by building an event-driven framework that allows any change in the state of the system to be triggered by discrete events, such as the arrival of a customer or the availability of servers. This model was created using the Python programming language, which was chosen for its flexibility in manipulating empirical data, processing events sequentially, and performing precise calculations of service time. The entire simulation process is run chronologically using a simulation clock variable that is always updated every time an event occurs.

The time between arrival and service time data obtained from the observation are entered into the system as an empirical distribution, not a theoretical distribution. Therefore, the sampling process in the simulation is carried out using a random selection method directly from the dataset, so that the variation in service time that occurs in real conditions is maintained. This approach ensures that the simulation does not rely on Poisson assumptions or exponential, but fully reflects the actual behavior of the Mobile Samsat service system.

Each customer is processed by utilizing the list of events that include arrival, service start, and service completion. This mechanism is controlled by two important time variables, namely server availability time and customer event time. When an event is processed, the model determines the next time based on the conditions at the time. The service start time is determined by the server availability schedule through the formula:

$$\text{Start} = \max(\text{Arrival}, \text{ServerFree})$$

Meanwhile, the service completion time is calculated based on the duration of service taken from the empirical sample:

$$\text{Finish} = \text{Start} + \text{ServiceTime}$$

To ensure the stability and reliability of the simulation results, the simulation experiment was conducted using several independent replications. In this study, the simulation was run 30 times, with each replication using the same arrival data but accompanied by random sampling of service times and inter-arrival times from the empirical distribution. This number of replications was chosen to reduce the influence of random variability and obtain a stable estimate of system performance. The Mobile Samsat Bus service system is modeled as a non-terminating system during service operating hours. Therefore, a warm-up period is applied to eliminate bias due to the initial empty system conditions. Data generated during the warm-up period is not included in the system performance calculation, so that the simulation results reflect the conditions of a system that has reached a stable state.

All performance indicators reported in this study, such as average waiting time, service time, and total customer time in the system, are average values from all replications after the warm-up period. With this approach, the developed Discrete-Event Simulation model is able to produce consistent, representative, and reliable system performance estimates that can be used to identify bottlenecks and evaluate the performance of the Mobile Samsat Bus service.

2.5 Model Validation and Evaluation

Model validation was carried out to ensure that the Discrete-Event Simulation (DES) simulation built was able to accurately represent the behavior of the Mobile Samsat Bus service system. The validation process is carried out through two main stages, namely input validation and model logic validation. Input validation was carried out by checking the compatibility of the observed interarrival time and service time data with the data used as the basis for the simulation.

This check ensures that the empirical distributions incorporated into the model reflect real service arrival patterns and durations during service hours.

Model logic validation is carried out by reviewing the event processing flow in the DES, specifically how the system organizes customer arrivals, starts services when servers are available, and processes service completions sequentially. The validation results showed that the event mechanism ran according to the principle of First-Come, First-Served (FCFS) and followed the actual service flow from Counter 1 to Counter 2 without deviations from operational rules, such as queue shifts or queue cancellations (reneging). This is proof that the logical structure of the model has been consistent with real service conditions.

The model evaluation was carried out by analyzing the simulation output in the form of average waiting time, service time, total time customers were in the system, as well as queue parameters such as arrival rate (λ), number of customers in the system (L), and number of customers in queue (Lq) based on Little's Law. The simulation results show that Counter 1 is a bottleneck, as shown by the high waiting time compared to Counter 2. The consistency of this queue pattern with the results of field observations provides evidence that the DES model developed has met the aspects of accuracy and representativeness (face validity). Thus, the model is considered valid and reliable to be used in performance analysis and the formulation of recommendations for improving service systems.

3. Results and Discussion

This section presents the results of modeling and simulation of the Samsat Keliling bus service queue system using the Discrete Event Simulation (DES) approach. The simulation was conducted based on empirical data from field observations, which were processed into distributions of inter-arrival times and service times at each counter. The simulation model was run using 30 independent replications, and the reported system performance values are the average of all simulation results, thereby representing stable system conditions and reducing the influence of random variations. The simulation results cover dynamic queue characteristics, including customer arrival time, service start time, waiting time, service time, and total customer time in the system. The analysis focuses on evaluating system performance and identifying service bottlenecks. The results are presented in the form of simulation output tables, statistical summaries, and distribution graphs to provide a comprehensive overview of the performance of the Mobile Samsat Bus service.

3.1 Event-Based Simulation Results

Table 2. Simulation Results for Counter 1

Cust	Arrival	Start L1	Finish L1	Wait L1	Service L1
1	08:30:00	08:30:00	08:34:00	0	4
2	08:33:28	08:34:00	08:40:00	0.53	6
3	08:36:19	08:40:00	08:48:00	3.68	8
4	08:39:19	08:48:00	08:56:00	8.67	8
5	08:42:37	08:48:00	09:02:00	13.37	6
6	08:45:48	08:56:00	09:10:00	16.19	8
7	08:51:29	09:02:00	09:17:00	18.51	7
8	09:00:49	09:10:00	09:25:00	16.17	8
9	09:04:31	09:25:00	09:33:00	20.47	8
10	09:10:59	09:33:00	09:40:00	22.01	7
...	...	...	...	...	...

71	14:12:43	15:24:00	15:32:00	71.28	8

Table 2 presents the simulation results of the service process at Counter 1, from arrival time to completion time. The results indicate that customer wait times at Counter 1 tend to increase as the number of customers entering the system increases. For initial customers, wait times are relatively low because the server is still available. However, as variations in service times accumulate, queues begin to form, causing significant increases in wait times, particularly between the 40th and 60th customers. This situation indicates that Counter 1 acts as a bottleneck in the service system. Variations in service duration during the document verification and confirmation stages create an imbalance between arrival rates and service capacity, resulting in increasing queues and directly impacting customer wait times.

Table 3. Simulation Results for Counter 2

Cust	Start L2	Finish L2	Wait L2	Service L2	Total Time
1	08:34:00	08:38:00	0	4	8
2	08:40:00	08:47:00	0	7	13.53
3	08:48:00	08:55:00	0	7	18.68
4	08:56:00	09:02:00	0	6	22.67
5	09:02:00	09:09:00	0	7	26.37
6	09:02:00	09:14:00	0	4	28.19
7	09:10:00	09:20:00	0	3	28.51
8	09:17:00	09:31:00	0	6	30.17
9	09:25:00	09:39:00	0	6	34.47
10	09:33:00	09:46:00	0	6	31.01
...	...	...	...	...	...
71	15:33:00	15:36:00	1	3	83.28

Table 3 displays the results of the service simulation at Counter 2. Unlike Counter 1, waiting times at Counter 2 were almost entirely zero. This occurs because customers can only enter Counter 2 after completing service at Counter 1, thus maintaining a more controlled customer flow. Furthermore, service times at Counter 2 were relatively shorter and more consistent, preventing significant queue buildup. Therefore, Counter 2 was not a major source of delays in the system.

3.2 System Performance Statistics

Table 4. Simulation Results Statistics

Parameter	Nilai
Jumlah Pelanggan	71
Rata-rata Waiting L1 (min)	50.56
Rata-rata Waiting L2 (min)	0.69
Rata-rata Service L1 (min)	5.94
Rata-rata Service L2 (min)	5.1
Rata-rata Total Time (min)	62.27
λ (cust/min)	0.16
L (Little)	10.38
Lq (Little)	8.43

The system performance statistics table presents a summary of the main parameters generated from the discrete event-simulation for the queue system on the Mobile Samsat Bus. Based on simulations of 71 customers, it was obtained that the average waiting time at Counter 1 reached 50.56 minutes, which was much higher compared to the waiting time at Counter 2 which was only 0.69 minutes. This very significant difference indicates that Counter 1 acts as a bottleneck point in the service flow. Meanwhile, the average service time at Counter 1 was 5.94 minutes and at Counter 2 was 5.07 minutes, which was relatively balanced and did not cause accumulation in the second service phase.

The average total time experienced by customers in the system (from arrival to completion of the entire service process) is 62.27 minutes, which indicates that most of this duration is spent waiting at Counter 1, not for the service process itself. This is reinforced by a λ value (arrival rate) of 0.1667 subscribers per minute, which is obtained through the calculation:

$$\lambda = \frac{n}{T}$$

with customers and simulated operational time minutes λ =71 T=390.
Furthermore, to evaluate the average number of customers in the system and in the queue, Little's Law is used, which is expressed as:

$$L = \lambda \times W$$
$$L_q = \lambda \times W_q$$

Based on this calculation, a value of L = 10.38 customers was obtained, which indicates that on average there are about 10 customers in the system at any one time. Meanwhile, the value of Lq = 8.43 customers indicates that out of the total system load, about 8 customers spend waiting time in Counter 1 queue. This value further reinforces that the long queue is concentrated entirely at Counter 1 and not at the next phase of service. Overall, this statistical table provides quantitative evidence that the main bottleneck lies in Counter 1, so service system improvements should be focused on capacity building, workflow adjustments, or queue management strategies in the first phase.

3.3 Graph of Queue Sysem Simulation Results

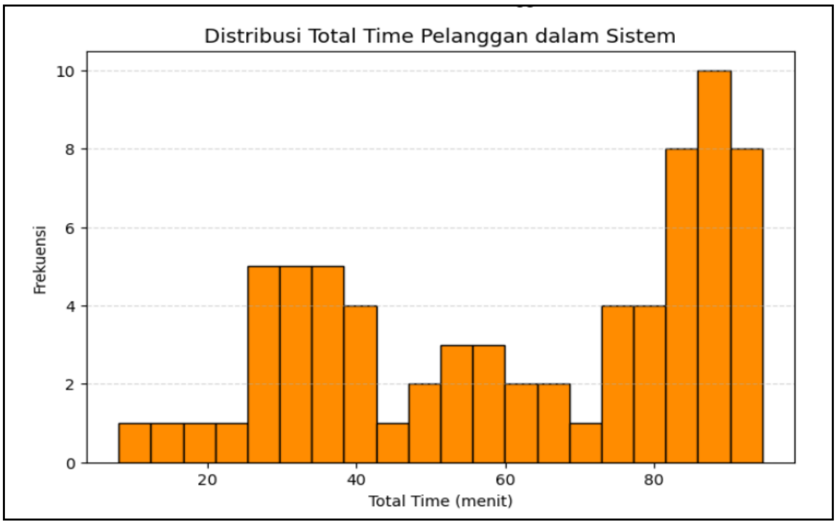

Figure 2. Distribution of the total time of the customer in the system

Figure 2 shows the distribution of total time spent by customers in the system, from arrival to completion of the entire service process. The graph shows a fairly broad time distribution with a multimodal pattern, reflecting the queue dynamics during the Mobile Samsat Bus service's operating hours. Customers arriving during a relatively smooth service period can complete the process in approximately 20–40 minutes. Conversely, customers arriving during periods of queue congestion, particularly at Counter 1, require significantly longer wait times, reaching 60–90 minutes. This variation indicates that queue fluctuations are significantly influenced by differences in arrival rates and variations in service times during the initial phase of service.

These results confirm that Counter 1 acts as a major bottleneck in the system. Therefore, the distribution of total customer time provides a comprehensive overview of system performance and serves as an important basis for formulating strategies to increase capacity or improve operational flow during the initial service phase.

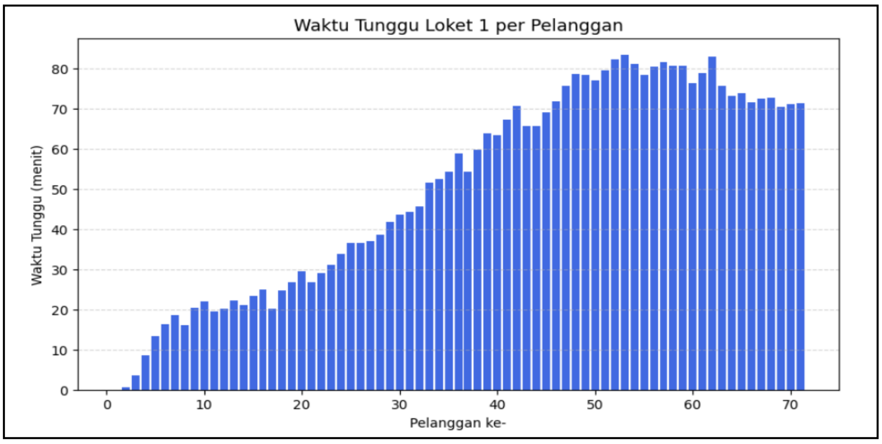

Figure 3. Waiting time of 1 counter per customer

Figure 3 illustrates the pattern of customer waiting times at Counter 1 based on Discrete-Event Simulation (DES) results. The horizontal axis represents the order of customer arrivals, while the vertical axis shows the wait time in minutes. The graph shows a tendency for wait times to increase as the number of customers increases, reflecting the formation of queues due to service capacity limitations in a single-server system.

In the initial phase, wait times are relatively low because the system load is still light. However, variations in service times for subsequent customers cause queue accumulation and a gradual increase in wait times. The most significant increase occurs between the 50th and 60th customers, indicating a bottleneck condition where the arrival rate exceeds service capacity. After reaching the peak, wait times show a downward trend as the system load decreases. Overall, this graph confirms that Counter 1 is a critical component of the Mobile Samsat service system's performance, and therefore, improvement efforts should focus on increasing capacity or operational efficiency at this service stage.

The results of this study have direct implications for the management of Mobile Samsat services. Identifying Counter 1 as a bottleneck suggests that efforts to improve system performance should focus on the document verification and approval stages. Possible improvements include adding staff to Counter 1, implementing document pre-verification, or simplifying administrative procedures to reduce service time variations. This finding aligns with previous studies that suggest that a two-stage queuing system with one server at each stage is highly susceptible to congestion if there is an imbalance in service duration between stages. Compared to classical analytical approaches, the use of Discrete Event Simulation in this study has proven to more accurately represent real-world operational conditions and provides a strong quantitative basis for formulating policies to improve the quality of public services.

4. Conclusion

This study concludes that the modeling and simulation of Discrete-Event Simulation (DES) is able to accurately represent the queue dynamics in the North Medan Mobile Samsat Bus service. Based on the results of modeling using empirical data, the queue system shows an imbalance in workload between two service counters. Counter 1, which acts as the registration and determination stage, is the main bottleneck point due to the higher variation in service time compared to Counter 2. This condition results in increased wait times and extends the total time the customer is in the system.

The simulation showed that the wait time, total time, and other queue parameters were consistent with the queue patterns observed in the field, thus validating the reliability of the developed model. These findings confirm that the DES approach is effective in providing a realistic picture of service performance and in identifying the components that most affect system efficiency.

Thus, the results of this study provide an analytical basis for efforts to improve the quality of Mobile Samsat Bus services. Recommendations that can be considered include restructuring the service flow or adding resources at critical stages to reduce wait times and increase overall service capacity. Further research can extend the model by considering variations in the number of officers, different service hour scenarios, or the integration of optimization methods to support the decision-making process.

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