Sensitivity Analysis of a Single-Server Fuel Queue System Using the M/M/1 Model: A Case Study of a Pertamini Station

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Article Info

ABSTRACT

The rapid growth of motorcycle ownership in Indonesia has significantly increased the demand for fuel, particularly for daily transportation activities. This condition has encouraged the development of micro-scale refueling services, commonly known as Pertamini, which provide easier and more accessible fuel services for local communities. However, Pertamini stations generally operate with limited facilities and a single service channel, which may lead to queue formation, especially during peak hours. Long waiting times can reduce service efficiency and customer satisfaction, making queue system evaluation essential to support operational improvements. Therefore, this study aims to analyze the performance of the Pertamini service queue system using the M/M/1 queue model. This research applies a quantitative approach through direct field observation to collect data on customer arrival rates and fuel service times during a specified observation period. The collected data are used to determine the arrival rate (λ) and service rate (μ) as the main parameters in modeling the queue system. System stability is evaluated by comparing these parameters to ensure that service capacity can accommodate customer demand. Several performance indicators are analyzed, including system utilization, the average number of customers in the queue and in the system, and the average waiting time experienced by customers. The results indicate that under normal operational conditions, the queue system operates in a stable condition where the service rate exceeds the arrival rate. However, sensitivity analysis shows that an increase in arrival rate or a decrease in service rate significantly increases waiting time. Therefore, improving service efficiency is necessary to maintain system stability and reduce customer waiting time.

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1. INTRODUCTION

The growth of motorcycle use in Indonesia continues to increase because of the mobility of the population in urban and suburban areas. The need for fast and easily accessible refueling services is one of the important aspects to support this mobility. In addition to large-scale public refueling stations (SPBU), micro-scale refueling services such as Pertamini are increasingly an option, especially in residential environments and local routes that have not been optimally served by conventional petrol stations [1]

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This research focuses on Pertamini's services operating on Jl. Kalimulya RT 01 RW 04, Kalimulya Village, Cilodong District, which serves customers every day during operational hours from 05.00 to 22.30 WIB. The characteristics of long operations and the high intensity of customer arrivals, especially during peak hours, make this service vulnerable to the formation of long queues. Therefore, this kind of service is a relevant object of analysis to evaluate the performance of the service system based on queue theory.

The queue problem not only arises due to the high arrival rate but also due to the limitation of service facilities which usually only involve one line and one officer. Circumstances like this can lead to increased customer waiting times, service inconvenience, and potential for an overall decrease in service quality. The queue theory approach provides a mathematical framework to measure and evaluate the performance of the service system in terms of facility utilization, average waiting time, and queue length [2]. Various previous studies have used queue theory to analyze the public service system in Indonesia. For example, optimizing petrol station services by adding service lines has been proven to significantly reduce average waiting times and customer queue lengths [3]. In addition, research on petrol stations in Pontianak shows that queues can affect customer comfort and operational efficiency if not managed properly [3], [4]. Although these studies provide an overview of queuing behavior in fuel services, the focus is on large-scale services such as petrol stations. Research on micro-scale refueling services, such as Pertamini, is still relatively limited in the local literature.

One of the approaches often used in the study of queuing systems is the M/M/1 model, which is suitable for service systems with a single server and random customer arrivals (Poisson), as well as variable service times (exponential) [1], [5], [6]. The application of the model enables evaluation of system performance based on parameters such as utilization rate, average wait time, and queue length, thereby aiding operational decision-making. The novelty value of this study lies in applying the queue model to Pertamini's services wich have not been widely discussed in the literature, and in analyzing sensitivity to changes in the system's main parameters. This research is expected to make a scientific contribution to the development of a micro-scale public service queuing system study and provide practical recommendations for Pertamini managers in to improve service efficiency and reduce customer waiting times.

2. METHOD

2.1 Design and Research Approach

This study employs a descriptive quantitative approach using the Operations Research method, specifically the M/M/1 queuing model, to analyze the performance of the Pertamini refueling service system. The quantitative approach was selected because queue systems can be mathematically modeled, allowing objective evaluation of system performance through measurable indicators such as queue length, customer waiting time, and service facility utilization rate [1], [7]. The M/M/1 model is considered appropriate since the Pertamini service system operates with a single service channel and one server, where customer arrivals occur randomly and service times vary. These characteristics are consistent with the fundamental assumptions of the M/M/1 model, which include a Poisson distribution for customer arrivals and an exponential distribution for service times [2], [8]. Furthermore, this model has been widely applied in studies of fuel station services and other public service systems in Indonesia due to its simplicity, analytical efficiency, and capability to adequately represent real operational conditions [9]

2.2 Research Object and Scope

The object of the research is the motorcycle refueling queue system at one Pertamini unit located in a residential environment. The service system consists of one filling pump and one operator who serves customers alternately. The scope of this research includes several main aspects: (1) analysis of the vehicle arrival rate (λ), (2) analysis of the service rate (μ), (3) calculation of the queue system performance measures, (4) sensitivity analysis of changes in system parameters, and (5) formulation of managerial recommendations based on the analysis results.

2.3 Data Collection Techniques and Sources

The data in this study were obtained through direct observation of service activities at a Pertamini. Observation is carried out by recording the time and number of vehicles that come and the length of the refueling service. In detail, the data collected includes (1) time between vehicle arrivals, (2) service time of each vehicle, (3) the number of vehicles in the queue at any given time. Data collection is carried out during normal operational conditions and peak hours to obtain a comprehensive picture of system performance. Direct observation techniques were chosen because they were able to produce actual data that reflected the real condition of the service system [10]. In addition to primary data, this study also uses secondary data in the form of national journals and Research Operational literature as a theoretical foundation and analysis support.

2.4 Research Variables and Parameters

These parameters are used to evaluate the performance of service systems quantitatively and have been widely used in public service queue research [1], [2], [10].

Table 1. Variables of research parameters

Yes	Emblem	Remarks
1	n	Number of customers in the system
2	c	Number of servers (c = 1)
3	λ (lambda)	Average customer arrival rate (vehicles/hour)
4	μ (MIU)	Average service level (vehicles/hour)
5	ρ (rho)	System utilization rate
6	Lq	Average number of customers in a queue
7	Ls	Average number of customers in the system
8	Wq	Average wait time in a queue
9	Ws	Average customer time in the system
10	P_o	Probability of no customers in the system

2.5 Research Model Assumptions

In applying the M/M/1 queue model, this study establishes several basic assumptions to simplify the real service system and represent it mathematically without eliminating the main characteristics of Pertamini's services. These assumptions are necessary to ensure the theoretical consistency of the model and the validity of the analysis results.

The assumptions used in this study are as follows:

1. Customer arrival follows the Poisson distribution, which means customers come randomly and independently of each other in each unit of time. This assumption is considered relevant because the pattern of motorcycle arrival at Pertamini is influenced by community activities and does not have a fixed arrival schedule.

2. Service time follows an exponential distribution, which reflects the variation in service duration between customers. In practice, the refueling time at Pertamini varies depending on the amount of fuel purchased, the speed of the operator, and the condition of the equipment.

3. The system has one server (single server), because the Pertamini service analyzed only uses one filling pump and is operated by one officer, so customers are served alternately.

4. The queue discipline uses the principle of First in First out (FIFO), where customers who come first will be served first. This principle reflects the actual service conditions at Pertamini and is the most used queue discipline in the public service system.

5. The queue capacity is considered unlimited, meaning that the system is assumed to be able to accommodate all customers who come without a limit on the number. This assumption is used to facilitate mathematical analysis and is commonly applied in queue theory research.

6. The system is in a stable state when the arrival rate is smaller than the service level ($\lambda < \mu$). This stability condition is important so that the system does not experience uncontrolled queue growth and the calculation of the size of the system's performance can be done validly.

7. These assumptions are in accordance with the operational characteristics of Pertamini's services and have been widely used in various studies on the petrol station and microservice queue systems in Indonesia.

With the application of this assumption, the M/M/1 model is expected to be able to provide a representative picture of the performance of the refueling service system analyzed [10], [11], [12].

2.6 Research Methodology Procedures and Flows

The research methodology flowchart systematically describes the workflow for analyzing Pertamini's service queue system using the M/M/1 model, from the initial stage through to the conclusions. The process starts with identifying queue-related problems by observing the accumulation of two-wheeled vehicles in Pertamini's refueling services, particularly at specific times, to determine the focus and relevance of the research issue. Observation and data collection are then conducted by recording the number of vehicle arrivals and the refueling service times within a defined observation period, producing quantitative data that serve as the basis for queue system analysis. The arrival rate (λ) and service rate (μ) are subsequently calculated to

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obtain the average values of the main parameters used in modeling the M/M/1 queue system. A system stability test is performed by comparing λ and μ, where the system is considered stable if $\lambda < \mu$, allowing performance analysis to proceed; otherwise, evaluation and improvement of service capacity or speed are required. For a stable system, performance measures such as system utilization rate, the average number of customers in the queue and in the system, and the average customer waiting time are calculated to assess service efficiency and quality. Sensitivity analysis is then conducted by simulating changes in system parameters, including increased arrival rates or decreased service rates, to evaluate the system's responsiveness to operational changes. Finally, the results are interpreted to understand their operational and managerial implications, and conclusions along with recommendations are formulated, summarizing the main findings and providing practical suggestions for Pertamini managers to enhance service efficiency and reduce customer waiting times.
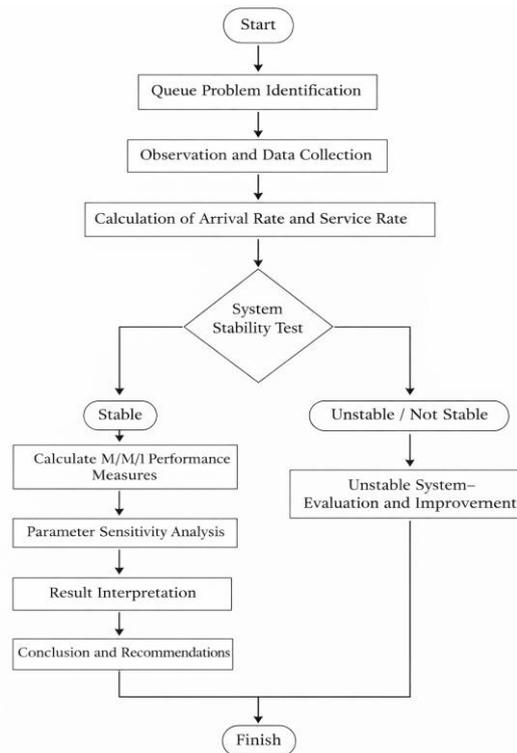

Figure 1. Research flowchart

3.   RESULTS AND DISCUSSION

3.1. Operational Characteristics of Pertamini's Queue System

Table 2 presents the main characteristics of Pertamini's queue system, which form the basis for selecting the appropriate queuing model in this study. The system is classified as an M/M/1 queue model, indicating that customer arrivals follow a Markovian (random) process, service times are also Markovian in nature, and the system operates with a single service facility. This classification reflects the actual operational condition of Pertamini, where fuel dispensing is handled through one service channel. The table also shows that the number of servers consists of one operator, meaning that all arriving customers must wait for service from a single attendant. The arrival pattern is categorized as random, implying that customers arrive independently and unpredictably over time, consistent with a Poisson arrival distribution. Meanwhile, the service pattern follows an exponential distribution, indicating that service duration varies depending on factors such as fuel volume requested and payment processing time. The queue discipline applied is First In First Out (FIFO), where customers are served in the same order as their arrival, ensuring fairness in service delivery. Overall, these characteristics confirm that Pertamini's operational system aligns with the assumptions required for applying the M/M/1 queuing model in performance analysis. Understanding these system characteristics is essential for accurately evaluating queue performance and identifying potential operational inefficiencies. The information provided in the table also supports further analysis in determining system stability, service effectiveness, and customer waiting time under different operational conditions. Consequently, the model can be used as a reliable basis for proposing improvements to enhance service efficiency at Pertamini stations.

Table 2. Characteristics of Pertamini's Queue System

System Components	Remarks
System type	M/M/1
Number of servers	1 Operator
Arrival Patterns	Random
Service pattern	Exponential
Discipline of Queue	FIFO

3.2. Queue System Performance under Normal Operational Conditions

The calculation of the performance size of the system is carried out using the parameters of Arrival Level and Service Level obtained from the results of field observations.

- λVehicle arrival rate (λ) = 30 vehicles/hour
- Service level (μ) = 40 vehicles/hour

Table 3. Normal Condition Queuing System Performance

Performance Indicators	Symbols	Calculation	Value
System usability level	ρ	$\rho = \dfrac{\lambda}{\mu} = \dfrac{30}{40} = 0.75$	0.75 or 75%
Average amount Customers in the queue	Lq	$Lq = \dfrac{\lambda^2}{\mu\,(\mu-\lambda)} = \dfrac{30^2}{40\,(40-30)} = \dfrac{900}{400} = 2{,}25$	2 Vehicles
Average amount customers in the system	Ls	$Ls = \dfrac{\lambda}{(\mu-\lambda)} = \dfrac{30}{(40-30)} = 3$	3 Vehicles
Average time Wait	Wq	$Wq = \dfrac{\lambda}{\mu\,(\mu-\lambda)} = \dfrac{30}{40\,(40-30)} = \dfrac{30}{40.10} = 0{,}075\ hours$	4.5 Minutes
Average time in System	Ws	$Ws = \dfrac{1}{(\mu-\lambda)} = \dfrac{1}{(40-30)} = \dfrac{1}{10} = 0{,}1\ hours$	6 Minutes
Probability is not There are customers in the system	P_0	$P_0 = 1 - 0.75 = 0.25$	0.25 or 25%

The system utilization value of 0.75 indicates that the service facility is used for 75% of the operational time. This value is still below the saturation limit, so the system is relatively stable. The average customer waiting time of 4.5 minutes shows that the service is still relatively efficient and does not cause long queues under normal conditions.

3.3. System Utilization and Stability Levels

To ensure that the system is in a stable condition, an evaluation of the system utilization value is carried out.

Table 4. Interpretation of System Utilization Rate

Value ρ	System conditions	Remarks
r < 1	Stable	The system is able to serve arrivals
$\rho = 0.75$	Stable	The system is not yet saturated
r -> 1	Critical	Queues have the potential to increase

The utilization value obtained is 0.75 and shows that Pertamini's service system still has spare capacity. However, an increase in arrival rate or a decrease in service speed can cause the system to approach a saturated state.

3.4. Analysis of Changes in Operational Conditions

To determine the sensitivity of the system to parameter changes, a simple calculation was made of the Arrival Level and Service Level.

Table 5. Comparison of System Performance in Various Conditions

Conditions	λ (vehicle/hour)	μ (fame/hour)	Wq (minutes)
Normal	30	40	4,5
Peak Hours	35	40	10,5
Services Decline	30	35	10,26

The results of this table show that the increase in the arrival rate and the decrease in the service level cause a significant increase in the waiting time for services. This indicates that the queue system is quite sensitive to changes in operational conditions.

3.5. Sensitivity Analysis to Changes in Arrival Rates

To find out the impact of changes in vehicle arrival rates on system performance. In certain peak hour conditions such as morning and evening, the level of security increases to:

Table 6. Vehicle arrival rate sensitivity analysis

Performance Indicators	Simbol	Calculation	Value
System utilization	ρ	$\rho = \frac{\lambda}{\mu} = \frac{35}{40} = 0{,}875$	0.875 or 87.5%
Average time in the system	Ws	$Ws = \frac{1}{(\mu - \lambda)} = \frac{1}{(40-35)} = 0{,}2 \, hours$	0.2 hours or 12 minutes
Average time Wait	Wq	$Wq = \frac{\lambda}{\mu\,(\mu - \lambda)} = \frac{30}{40\,(40-35)} = 0{,}175 \, hours$	0.175 hours or 10.5 minutes

The results of this table show that an increase in the arrival rate of 16.7 % resulted which caused the wait time to increase more than twofold. This indicates that the two-wheeled petrol station queue system is very sensitive to an increase in the number of vehicles which has the potential to lead to long queues and greater customer inconvenience

3.6. Sensitivity Analysis to Changes in Service Levels

It is suspected that there has been a decrease in service speed due to operational disruptions so that the level of service decreases to:

Table 7. Sensitivity analysis to service changes

Performance Indicators	Simbol	Calculation	Value
System utilization	ρ	$\rho = \frac{\lambda}{\mu} = \frac{30}{35} = 0{,}86$	0.86 or 86%
Average time in the system	Ws	$Ws = \frac{1}{(\mu - \lambda)} = \frac{1}{(35-30)} = 0{,}2 \, jam$	0.2 hours or 12 minutes
Average time Wait	Wq	$Wq = \frac{\lambda}{\mu\,(\mu - \lambda)} = \frac{30}{35\,(35-30)} = 0{,}171 \, jam$	0.171 hours or 10.3 minutes

Table 7 shows that a relatively small decrease in service levels is proven by having a significant impact on system performance. Waiting times have more than doubled compared to normal conditions. Based on the results of the sensitivity analysis of Pertamini's refueling queue system, changes in customer arrival rate (λ) and service level (μ) have a significant impact on system performance, especially on customer waiting time and service facility utilization rate. These findings have important managerial implications for micro-scale refueling service managers.

3.7. Pre-Change Conditions (Normal Operating Conditions)

Under normal conditions, the system has an arrival rate of 30 vehicles per hour and a service rate of 40 vehicles per hour. With this condition, the system utilization rate is at 0.75, which indicates that the service facilities have not reached a saturated condition. The average waiting time for customers in the queue is 4.5 minutes and the average time customers are in the system is 6 minutes. This condition reflects a service system that is relatively efficient, stable, and able to provide a level of comfort that can still be accepted by customers.

3.8. Conditions After Change (Peak Hours and Service Decrease)

In rush hour conditions, when the arrival rate increases to 35 vehicles per hour while the service level is fixed, the system utilization rate increases to 0.875. This increase caused the average customer's waiting time to increase significantly to 10.5 minutes. A similar thing happened when the service level decreased to 35 vehicles per hour with a fixed arrival rate, where the waiting time increased to more than 10 minutes. This condition shows that the system is approaching the saturation point and has the potential to cause long queues and a decrease in service quality.

3.9. Managerial Implications

Managerially, these results show that Pertamini's queue system is very sensitive to small changes in operational parameters. An increase in the number of customers or a decrease in the speed of service, even if

relatively small, can have a big impact on waiting times and customer convenience. Therefore, managers need to proactively manage service capacity, especially during peak hours. Reduced In addition, managers can also consider adding temporary service facilities during peak hours to prevent the system from reaching saturation. By understanding the managerial significance of these changes, managers can make data-driven decisions to maintain system stability, minimize waiting times, and improve customer satisfaction on an ongoing basis. By understanding the managerial significance of these changes, managers can make data-driven decisions to maintain system stability, minimize waiting times, and improve customer satisfaction on an ongoing basis.

3.10. Recommended Improvements

Based on these conclusions, several practical recommendations relevant to daily life can be given to micro-scale refuelling service managers, namely:

a) Setting peak hours, by preparing more optimal services in the morning and evening, for example through increasing operator readiness or vehicle flow arrangements.
b) Improved service efficiency, such as speeding up the refueling process and ensuring equipment is functioning properly to reduce service time per customer.
c) Regular maintenance of equipment, to prevent a decrease in service speed that can prolong waiting time.
d) Consider adding temporary facilities, such as additional pumps or operator assistance during peak hours, so that queues do not accumulate.
e) Educate customers, for example by providing information on relatively quiet service times so that customers can adjust the refuelling time.

By implementing these recommendations, it is hoped that the queuing system can remain stable, customer waiting time can be minimized, and the quality of Pertamini's services in daily life can continue to be improved.

4. CONCLUSION

Based on the results of the analysis and discussion of the Pertalite refueling queue system for two-wheeled vehicles at petrol stations using the M/M/1 queue model, it shows that the two-wheeled fuel filling queue system at petrol stations can be modeled well because it has one service line, one officer, random arrival patterns, and varied service times. With the average number of vehicles in the system and the waiting time generated under normal conditions it is still relatively reasonable and acceptable. Under normal conditions with an arrival rate of 30 vehicles/hour and a service level of 40 vehicle/hour, the system is in a stable condition with a utilization rate of 0.75. However, the results of the sensitivity analysis indicate that the queue system is highly sensitive to changes in arrival and service rates. An increase in arrival rates or a decrease in service levels leads to a significant increase in waiting times. Thus, improvement efforts such as increasing service efficiency, regular equipment maintenance, and adding service facilities at certain times are strategic steps to maintain system stability, reduce waiting times, and increase customer satisfaction.

REFERENCES

[1] Hasan, M., Aisha Putri Lubis, S., Izzati Sarah, S., Purba, diyah, & Salamah Br Ginting, S. (2026). Kajian Teori Antrian Model M/M/1 dan Implementasinya pada Berbagai Sistem Pelayanan. *Jejak Digital: Jurnal Ilmiah Multidisiplin*, *2*(1), 1409–1418. https://doi.org/10.63822/31ahp913
[2] Mangga, S., Sahdani, M., Hasibuan, R., Fiter, A., Reza, V., Fahri Irawan, M., Wira Yudha, H., Ritonga, I., Informasi, S., Sains, F., & Teknologi, D. (2025). Analisis Model Antrian Single Channel Single Phase Pada Pelayanan Publik SPBU. *Journal of Computer Science and Information Systems*, *1*, 45–52. https://jurnal.ulb.ac.id/index.php/JCoInS/article/download/6883/pdf
[3] Hans, Y., Manurung, A., Roma, P., Manik, S., Manurung, D. P., & Situngkir, E. Y. (2025). Analisis Antrian Pada Stasiun Bahan Bakar Umum (SPBU) 2536307 Sungai Bahar Unit V. *Terapan Informatika Nusantara*, *5*(8), 496–503. https://doi.org/10.47065/tin.v5i8.6020
[4] Angraini, W., & Yundari, Y. (2025). Analisis Kinerja Sistem Antrian Di SPBU Jalan Jenderal Ahmad Yani Kota Pontianak. Buletin Ilmiah Math. Stat. Dan Terapannya (Bimaster), 14(4), 520–529. https://jurnal.untan.ac.id/index.php/jbmstr/article/view/99126/75676606823

[5]   Devi Octaviany, C., Bagus, C., Dwi Maharani, Z., & Hary Yadi, Y. (2024). Analisis Teori Antrian Pada Loket Masuk Ramayana Cilegon. *Journal of Systems Engineering and Management*, *03*(02), xx–xx. https://doi.org/10.62870/joseam.vxix.30019

[6]   Tyas, G. R., Ardelia, A., Artamevia, K. S., Padmantyo, S., Manajemen, J., Ekonomi, F., & Bisnis, D. (2023). Analisis Penerapan Teori Antrian Pada Mie Gacoan Cabang Surakarta. *Prosiding Management Business   Innovation Conference (MBIC)*,   6. https://jurnal.untan.ac.id/index.php/MBIC/article/view/67595

[7]   Emanuel Necko, & Bagas Arjuna. (2025). Optimasi Antrean Layanan Pengumpulan Formulir Samsat Tandes Surabaya Barat Berbasis Simulasi. *JURAL RISET RUMPUN ILMU TEKNIK*, *4*(1), 611–627. https://doi.org/10.55606/jurritek.v4i1.5231

[8]   Prasetyo, B. A., Paskaria, E., Tarigan, L., & Zetli, S. (2023). Pemodelan Simulasi untuk Mengurangi Antrian pada Fasilitas Layanan Kesehatan. *Jurnal Surya Teknika*, *10*(2), 912–916. https://doi.org/https://doi.org/10.37859/jst.v10i2.6611

[9]   Ibrahim, N., K. Nasib, S., Nuha, A. R., Katili, M. R., Nurwan Nurwan, & Wungguli, D. (2025). Analisis Sistem Antrian dengan Model M/M/C dalam Meningkatkan Efektivitas Kinerja Sistem. *Algoritma : Jurnal Matematika, Ilmu Pengetahuan Alam, Kebumian Dan Angkasa*, *3*(2), 20–34. https://doi.org/10.62383/algoritma.v3i2.431

[10] Hidayat, N., Firmansyah, S., Novriza, D., & Dwi Amanda, Z. (2024). Analisa Teori Antrian Pada Sistem Pelayanan Di Rt Shop Kota Tarakan Menggunakan Software Pom-Qm. *Jurnal Ilmiah Kajian Multidisipliner*, *8*(3), 2118–7302.

[11] Oktarini, D. (2025). Optimasi Jumlah Pit Servis Bengkel Sepeda Motor Dengan Pendekatan Teori Antrian. *Jurnal Desiminasi Teknologi*, *13*(1).

[12] Sugioko, A., Hidayat, T., Chabella, C., Wenlicia, F., Khrisna Cahya Gulo, G., Hardianto, G., & Jeremiah, M. (2024). Optimasi waktu tunggu dengan simulasi sistem antrian pada gerai F&B. *Jurnal Teknik Industri Dan Manajemen Rekayasa*, *2*(2), 81–93. https://doi.org/10.24002/jtimr.v2i2.9854