Simulation Model of Arjawinangun Workshop using ProModel 16 and Design of Experiments

Dimas Muhammad Rabigh [1], M. Haykal Firza Himawan [1], Made Ardhia Diva Vikanaswari [1], Ghaida Fatcha Mubiena[2*], Nur Faizatus Sa'idah[2], Sukoyo[2*]
[1] Program Sarjana Teknik Industri, Institut Teknologi Bandung Kampus Cirebon;
[2] Program Studi Teknik Industri, Institut Teknologi Bandung Kampus Cirebon;
ghaidafatcham@itb.ac.id, sukoyo@itb.ac.id

* *Corresponding author*

Abstract
The workshop is a firm that provides equipment maintenance and repair services. The workshop under consideration in this study was authorized repair workshop that offered service areas and replacement components located in Arjawinangun District, Cirebon Regency. The problem identified are the vast number of clients and variations in requests at specific hours that the workshop personnel cannot quickly satisfy. As a result, the goal of this research is to provide optimal policies related to the number of repair slots and the service time of each motorcycle in order to maximize customer satisfaction. To answer the problem, a system simulation model and design of experiments (ANOVA) are used. The stages of the research were as follows: (i) preliminary investigation, (ii) developing the scope, issues, and research objectives; (iii) developing a conceptual model; (iv) gathering data and estimating parameters; and (v) developing and finding solution of the simulation model. The data used are the time between arrivals and the duration of each service procedure. Based on the results by testing the analysis using the response variable (R), the average decrease in consumer time in the system is 11.866 minutes and the average decrease in the number of lost sales is 8.6 people. Meanwhile, based on the simulation results of the existing and proposed conditions, the difference in the average time in the system was 9.19 minutes and the average decrease in the number of lost sales was 7.9 people. The recommended condition simulation findings may be reviewed and applied by the repair workshop management through staff training and the use of 5S in the service process. Furthermore, when implementing the recommended solutions, management must consider both financial and cultural factors.

Keywords*: Simulation, queue, services, after-sales, service time, lost sales.*

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1. Introduction

Arjawinangun is one of the districts in Cirebon Regency, with a population of 11.993 people according to the Central Statistics Agency (Badan Pusat Statistik or BPS) in 2021. Additionally, Kebonturi is a village located in the Arjawinangun district, with a population of

4.631 people according to BPS data in 2021. Kebonturi can be considered a densely populated village, with both native residents and newcomers due to the presence of the Regional General Hospital (Rumah Sakit Umum Daerah or RSUD) Arjawinangun type B. Furthermore, the presence of the Bandung Institute of Technology (Institut Teknologi Bandung or ITB) Cirebon Campus has contributed to the population growth, including students and educational staff. The presence of ITB in the life of Kebonturi's community is expected to stimulate development in the region.

With the influx of newcomers and a significant local population, there is an increase in the number of vehicles to support various activities, including after-sales services such as authorized automotive repair workshop. An authorized repair workshop is a business that provides maintenance and repair services for motor vehicles. The advantages of authorized workshop include quality, warranty, responsive service, extensive networks, and modern and comprehensive equipment. In Cirebon, there are 14 such workshops, and in Arjawinangun, there is one authorized workshop of a specific brand located at By Pass Arjawinangun No. 98, Kebonturi, Arjawinangun District, Cirebon Regency, hereinafter referred to as the Arjawinangun workshop.

Providing excellent service is crucial for any business, including automotive repair workshop, to achieve customer satisfaction (Crosby (1993); Dutka (1994); Vavra (1997, 2002); Hill, dkk. (2004); Hayes (2008)). Bengkel Arjawinangun aims to serve its customers promptly to minimize waiting times and avoid long queues (Wardhani, 2012). Lengthy queues can lead to decreased customer satisfaction as queuing is considered a non-value-added activity. Therefore, addressing queue-related issues becomes essential. Based on preliminary studies, including direct observations and interviews conducted at Bengkel Arjawinangun, it was found that the workshop currently employs nineteen (19) workers, divided into two shifts: the morning shift from 07:00 to 12:00 and the afternoon shift from 13:00 to 17:00. Typically, the same workers handle both shifts, with a break from 12:00 to 13:00. In one shift, the standard configuration includes one worker at the registration service counter, sixteen service personnel distributed across eight service slots (two workers per slot), one worker for final checks, and one worker at the payment counter. Additionally, according to the workshop manager, the workshop experiences higher customer traffic on Mondays and Tuesdays. On a daily basis, eight slots are open for service, with the following layout description.

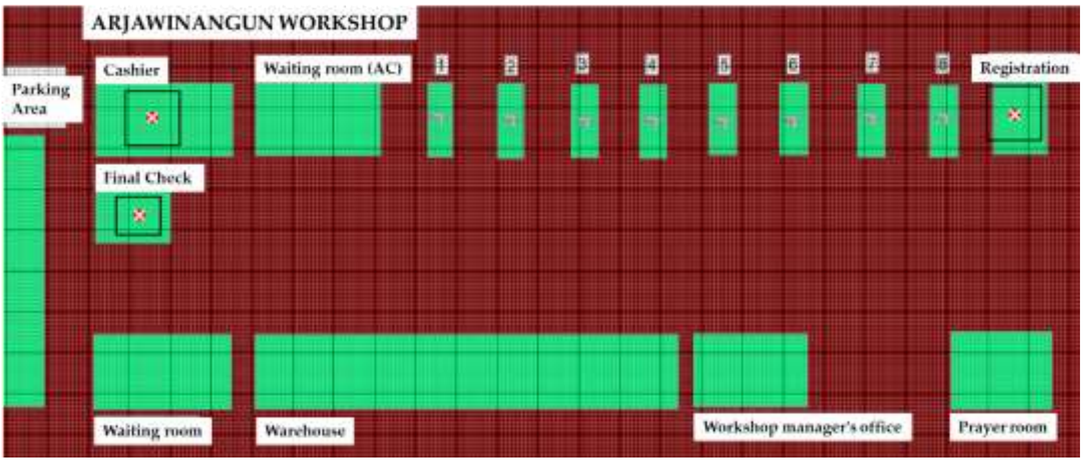

Figure 1. The layout of Bengkel Arjawinangun is as follows:

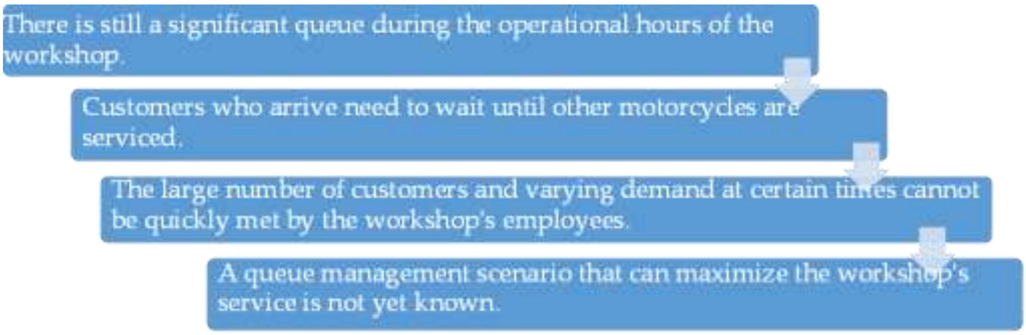

Figure 2. 5 Whys

Within its service process, there is a notable issue: queues form from the registration process until the motorcycles enter the available slots. Congestion occurs due to the high number of motorcycles that need servicing. Based on the identified and described symptoms of this problem, we can pinpoint the root cause using the 5 Whys method, which involves asking "why" to trace the causes of the issue at Bengkel Arjawinangun. As illustrated in Figure 2, it has been determined that the root cause of the queues at Bengkel Arjawinangun is the lack of a defined queue control scenario that can optimize the workshop's service delivery.

2. Methods

The method used to solve the problem is by creating a simulation model of the system and designing design of experiments (ANOVA). The research stages include: (i) preliminary study, (ii) formulating the scope, problems, and research objectives, (iii) creating a conceptual model, (iv) collecting data and estimating parameters, and (v) building and solving the simulation model. The data used consist of inter-arrival times and the duration of each service process.

2.1. Conceptual Model

The development of the conceptual model aims to illustrate the flow of entities, namely customers and motorcycles at Bengkel Arjawinangun, using the entities flow diagram tool, as depicted in Figure 3.

The explanation is as follows. The system begins when customer entities (riders and the motorcycles they bring) enter the workshop area. Upon entering the workshop area, there is a condition that must be checked by the customer related to the workshop's operating hours and availability quota. If the workshop's operating hours are open, the customer will then check the workshop's availability quota. If the workshop's operating hours are closed, the customer will leave the system immediately. Next, when the customer checks the workshop's availability quota and it is sufficient, the customer entity will be divided into two parts: the rider who will go through the registration process and the motorcycle, which will be taken by a worker to the service area. However, if the workshop's availability quota is insufficient, the customer will leave the system directly.

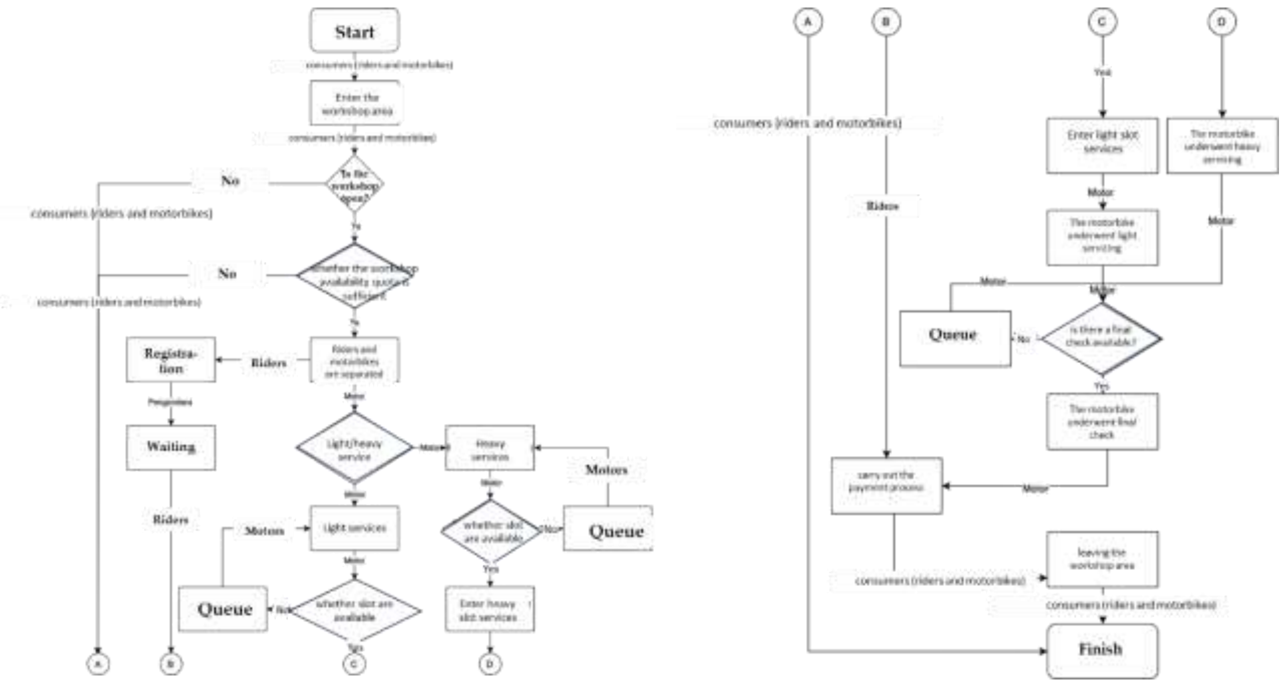

Figure 3. Conceptual Model

In the registration process, the rider will communicate any complaints about their vehicle, and the worker at the registration counter will record these complaints as the corresponding service requests. During the registration process, the desired service type will also be identified and matched with the condition of the vehicle, which is divided into two categories: light service and heavy service. After completing the registration process, the rider will move to the waiting area to await the sequence of service processes.

The motorcycle, along with its categorized service, will enter the queue first. When an appropriate service slot becomes available, the motorcycle will enter that slot, and the worker will proceed with the service. However, if the corresponding service slot is not yet available, or in this case, because another motorcycle is currently being serviced, the motorcycle must wait in the queue. After the service process is completed, the motorcycle will undergo a final check to inspect its condition before being returned to the rider. Similar to the service process, the final check process also depends on the availability of the worker responsible for the final check. If the final check process is available, or in this case, is said to be vacant, the process will proceed. However, if the final check process is not available due to another motorcycle undergoing the same process, the motorcycle must wait. After completing the entire motorcycle service process, the rider, who has been waiting in the waiting area, will proceed to the payment area to settle the payment for the completed service. During this process, the serviced motorcycle will be returned to the rider. Subsequently, the customer will leave the workshop area, concluding their interactions within the system.

2.2. Simulation model

Here is the design of the Arjawinangun Workshop simulation model, which includes layout, location, entities, arrival, variables, resources, and processing.

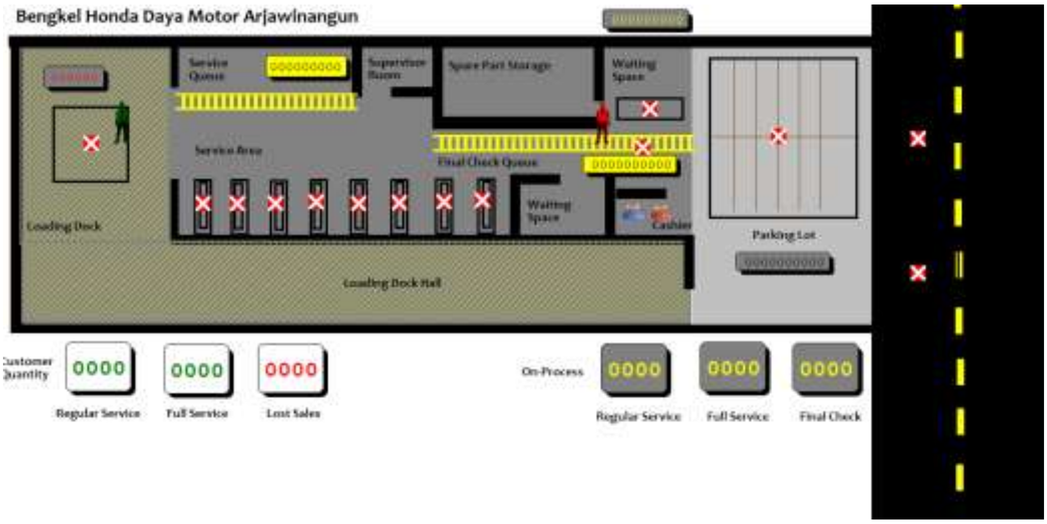

Figure 4. Layout of Arjawinangun Workshop Simulation Model

1) **Layout:** The simulation was conducted using ProModel 2016, see Figure 4.
2) **Location:** In the model, there are processing locations for handling entities, as well as queue locations to temporarily hold entities awaiting processing as seen also in Figure 4.
3) **Entities:** The entities used in the simulation consist of four entities: Motor_Rider (motorcycle ridden by the rider), Pengendara_Only (Rider only), Motor_Only (Motorcycle only), and Motor_Service.
4) **Arrival:** Arrival represents the distribution of entity arrivals at specific locations. The first arrival defined is the arrival of Motor_Rider at the enter location. This arrival has a quantity of 1, occurs first on Monday during the first week at the opening hours of the workshop (08:00 AM), has unlimited occurrences, and follows an exponential arrival frequency with an average of 4,97 minutes.
5) **Variables:** Variables in this simulation model track changes in the number of events. The variables used in this simulation model are Customers_Regular to count the number of customers who choose light service and have been served, Customer_Full to count the number of customers who choose heavy service and have been served, OnProcess_Service1 to see the number of regular service customers currently being served, OnProcess_Service2 to see the number of full service customers currently being served, and Lost_Sales to track the number of lost sales that occur.
6) **Resources:** Resources are used to assist in managing the system. The resource used in the simulation is human resources, including Kang_Transport as employees who transport motorcycles (4 employees), Kang_Final_check as employees who perform the final check (2 employees), and Kang_Service who perform service (8 employees).
7) **Network:** Resources have movement paths within the system. The path network, paths, and resource movement descriptions in the simulation are as follows.
8) **Shifts:** Shifts are used to schedule resource and location availability based on defined shifts. In this simulation, shifts are determined based on the real-world system conditions, where the workshop is open from 08:00 AM to 17:00 PM from Monday to Thursday with a break from 12:00 PM to 13:00 PM. On Friday, the workshop opens from 07:00 AM to 17:00 PM with a break from 11:00 AM to 13:00 PM.

9) **Processing:** The 12 processes considered in the simulation model are based on the previously established conceptual model.

2.3. Model Verification and Validation

The model verification process can be conducted through: (i) watching the animation for correct behavior, which means that if entities move and wait in the correct location sequence until they stop at the right location, the simulation model is considered to pass verification; (ii) checking for reasonable output, which involves testing related outputs. Outputs can be tested by modifying one of the model parameters and observing the resulting changes in output. Refer to Table 1, where from the simulation results of modifying the payment time at the Cashier_Pay location, it can be observed that the faster the payment time, the shorter the average time in the system for Rider_Only. Therefore, the simulation model is considered to pass verification; and (iii) conducting model code reviews using trace and debug feature. Based on these three checks, it can be concluded that the simulation model in this major project has passed the model verification process.

Table 1. Model verification - checking for reasonable output

Changes in time.	
Payment time	**Average time in system (minutes)**
Existing	75,77
Reduced by 1 minute	70,89
Increased by 1 minute	88,36

Validation of the model can also be done by observing the animation and comparing the simulation model results with the actual system. Validation is carried out by comparing the ProModel output with the actual system. The output to be compared is the average service time in the registration section based on observation, which is 2,14 minutes (see Table 2). Using 20 replications, it can be seen that the service time in the registration section simulated by ProModel is not significantly different from the actual system through observation. Furthermore, the ProModel output will be tested in the payment section. Based on observation, the average time spent by customers during payment is 2,46 minutes. Based on the validation test above, the simulation model can be said to represent the real conditions, making this model valid.

Table 2. Model validation based on registration process time

Replication	Average Time per Entry in the Registration process from ProModel (minutes)	Average time in the Registration process from observation (minutes)
1	1,97	
2	2,40	
3	2,20	
4	2,23	
5	2,11	2,14
6	1,99	
7	1,88	
8	2,16	

2.4. Simulation Time and Replication

The simulation conducted in this study is a terminating simulation. This terminating simulation is characterized by several aspects, including the presence of a start and end time in the simulation process – in this case, one replication of the simulation is carried out for 1 week, consisting of 5 working days with the shift arrangement– aiming to find the average values of the corresponding outputs and is not intended to observe the behavior of the system in a steady state. Furthermore, to determine the required number of replications, an initial replication was carried out with a quantity based on the author's intuition, which is ten times. Then, based on the results of these ten replications, the calculation of the required number of replications was performed as follows, with a significance level (α) of 5%. According to the calculation, the required number of replications is ten times. This number of replications will be used in the design of experiments.

2.5. Design of Experiments (ANOVA)

In the design of experiments, we will discuss the factors and responses, and the design of experiments itself.

1) Factors and Respons

Based on the problem statement, to improve the service at Arjawinangun Workshop, the time customers spend in the queue and the time they spend in the system must be reduced with the following alternative solutions.

1. No changes to the initial conditions.
2. Changing the number of employees.
3. Modifying the employee assignment system.
4. Changing the number of motor service slots.
5. Modifying the service speed.
6. Modifying the service speed.
7. Modifying the system layout

From the seven alternatives above, two factors are chosen, each with 2 levels (low level and high level) to perform the design of experiments process. In this case, the responses are: (1) the average time for the Motor_Servis entity within the system, and (2) the number of lost sales that occur. The smaller the response time, the better the alternative is to be implemented. The following is a description of the factors and levels used.

Table 3. The selected factors

	Factor	Low level (-)	High level (+)
1	Service time (i)	L(29.8,6.84) min L(50,6.84) min	L(28.8,5) min L(49,5) min
2	The number of slots (j)	8	10

The first factor, service time, was chosen based on the existing condition obtained from the ProModel simulation, which is the queue at the service area. The second factor, the number of slots, is considered because the service of motorcycles is performed by workers in the slots. Since the longest queue is at the service area, an experiment will be conducted to test the addition of service slots to increase the number of motorcycles that can enter the service slots.

2) Design of Experiment

After determining the factors and their levels, design of experiments was created. The design was developed by combining all possible levels for each factor to find the best alternative based on the interaction between these factors. The number of combinations is determined by the formula 2^k, where k is the number of specified factors.

Table 4. Design of Experiments

Design Point	Factor 1 (i)	Factor 2 (j)
1	+	+
2	+	-
3	-	+
4	-	-

The first design point represents the overall proposed factors, while the fourth design point represents the existing condition. The negative symbol (-) indicates no change in the factor, while the positive symbol (+) indicates a change in that factor. These four designs were then simulated using ProModel to observe the relationship between the factors and responses, as well as the interaction between factor 1 and factor 2.

3. Results and Discussion

3.1. Analysis of the Existing Condition

The motorcycle servicing process at the workshop can be considered quite time-consuming. This is due to the high number of customers seeking motorcycle servicing at the workshop. However, several other factors contribute to the slowdown in the servicing process, such as the time taken for servicing, which can be quite lengthy, and an insufficient number of service slots, among others.. This is primarily attributed to the local population in the Arjawinangun area and the presence of new entities, such as ITB Cirebon Campus. The increasing population, coupled with a rising number of motorized vehicles, demands efficient time management from the workshop. According to the Head of Arjawinangun Workshop, it experiences its peak business on Mondays and Tuesdays.

Based on observations conducted by the author, the workshop has a total of eight motorcycle service slots, with 19 permanent employees distributed across various workstations. Additionally, the workshop accommodates interns from vocational schools (SMK) who gain hands-on experience in the motorcycle servicing process. Furthermore, the author's observations, comprising 37 samples, revealed average durations for specific activities. The average inter-arrival time for customers was 4,97 minutes, the average duration for the initial registration or reception process was 3,14 minutes, the average service duration for motorcycles was 30 minutes, the average duration for the final check process was 4 minutes, and the average duration for the payment process was 3 minutes. In essence, the minimum average time spent by customers within the workshop system, approximately 39,96 or 40 minutes. It is essential to note that in real-world scenarios, the overall process duration for a customer is typically longer due to waiting times during the processes.

3.2. Design of Experiments' Analysis Results and Proposed Improvements

Based on the design of experiments' results, alternative 2 has been selected as the best alternative for reducing the Motor_Service time in the system and decreasing lost sales. This involves accelerating the service time to L(28.8,5) minutes for regular service and L(49,5) minutes for heavy service. Alternative 2 can reduce lost sales by 8 customers per week. Assuming the revenue from one customer is Rp 70,000 (based on the price of regular service, which has more customers), you can calculate the annual savings from alternative 2 (1 year = 52 weeks) as follows.

Table 5. Alternative 2

Alternative	Reduction in time within the system (minutes))	Reduction in Lost Sales (people)	Increase in Revenue in 1 year
2	11,866	8	Rp 29.120.000,00

In the implementation of alternative 2, there must be cooperation between human resources, especially service workers, and management. What can be done is to provide training for permanent employees and prepare and train interns from vocational schools (SMK) to sharpen their skills and prepare them for service tasks. Additionally, management can implement the 5S methodology in the service process, as outlined by Patrianagara & Riandadari (2020).

1) Comparison Analysis of Simulation Results between Existing and Proposed Scenarios

To assess the differences between the existing scenario and the proposed alternative 2, a comparison is conducted for each aspect as follows.

Table 6. Comparison between the Existing and Proposed Systems

Comparison Aspects	Exsisting (a)	Proposed (b)	Difference (b-a)
Average time in system (minutes)	147,81	138,62	-9,19
Average time in waiting (minutes)	43,98	36,04	-7,94
Average time in blocking minutes)	25,628	25,61	-0,018
Average customers	951,1	963,7	12,6
Averge lost sales	196,1	188,20	-7,9
Location Utility			
Service Slot (%)	23,89	24,72	0,83
Resource Utility			
Kang Service (%)	75,84	74,72	-1,12

It can be observed that in terms of time, all time metrics in the proposed system have decreased, leading to increased customer satisfaction. In regards to the number of customers, the proposed system can accommodate more customers. In relation to lost sales, the proposed system reduces lost sales. Regarding the utility of service slots, the proposed system has higher utility.

2) Managerial Implications Analysis

From a financial or economic perspective, scenario 2 can be implemented because reducing service time can be achieved through training and system workflow adjustments, unlike adding slots, which require layout modifications or hiring new personnel. Therefore, scenario 2 is more cost-effective. It requires cooperation from all components of the system to implement and promote the new workflow.

From a cultural perspective, management needs to prepare appropriate training based on the performance and capabilities of the workers, which may involve initial assessments. Management should also establish clear 5S rules and regulations, which could be visually represented through posters to become a part of the workshop's work culture. Additionally, management can consider implementing a reward and punishment system for adherence to the new workflow – rewarding compliance with rules and policies and deducting points for non-compliance. Over time, these rules and the new workflow can become an integral part of the work culture at Arjawinangun Workshop.

This provides a concise and accurate description of the results of the analysis, experiments, and testing in the research. Interpret the findings from the perspective of previous research and existing hypotheses, as indicated by citations to earlier studies for comparison. The research results can either reinforce or correct previous findings. Discuss the implications and new understandings gained, both theoretically and practically. Use figures, graphs, or tables to illustrate important research findings.

4. Conclusion

Based on simulations conducted under existing conditions, the following key findings were obtained: (i) The average customer queue time was 69.608 minutes. (ii) The average customer time inside the system was 147.81 minutes. (iii) The utilization rate of motor service slots and human resources (workers) was 23.89%. (iv) The utilization rate of human resources was 75.84%.

Furthermore, with the optimal policy determined through design of experiments, considering 2 factors with 2 levels each, the following optimal policy was identified: design point 2, which reduced service time without changing the number of service slots. Upon conducting analysis using response variables (R), the following results were obtained: a decrease in the average customer time inside the system by 11.866 minutes, and a reduction in the average number of lost sales by 8.6 individuals. Consequently, the difference or decrease in the average time inside the system was 9.19 minutes, along with a decrease in the average number of lost sales by 7.9 individuals. Moreover, it is recommended to document observations more extensively to accurately depict the system, layout, and workstation situations. Additionally, future research may involve simulations with varying customer traffic levels on specific days, as demonstrated in this case where the workshop experiences higher customer traffic on Saturdays and Mondays.

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