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Decision of Queuing Models and Layout Design at a Gas Station

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ABSTRACT

Objectives: *This study aims to analyze the accuracy of the queuing models and the application of layout design at the gas station in Ngasinan Wonosobo, Indonesia. Fuel service providers are encouraged to optimize service space as the number of motorized vehicle customers grows. The focus of attention in gas station management is not only on the queuing model, but also on the layout design that is acceptable and adequate for customers, particularly motorcycle riders who use Pertalite. This study will look at how to simulate a realistic gas station queue and provide a user-friendly layout design for anyone interested in gas stations.*
Methodology: *The object of this study was a motorcyclist who was doing Pertalite refueling. The types of data used are quantitative and qualitative data, so this study is classified as mixed methods. Purposive sampling was utilized as the sampling method in this study, which is a non-probability sampling strategy. The analytical method used is descriptive analysis and analysis of the Multi-channel-Single phase (M/M/S) queuing model.*
Finding: *The findings of this study indicate that long queues can interfere with the activities of other facility users for other customers at the gas station. This study identifies the need for a neat layout design for motorcycle queues by utilizing the service-scape gas station.*
Conclusion: *Although the queue system performs well in the afternoon, the results of the queuing analysis show that the total length of vehicles in the system does not exceed the length of the line, ensuring that the queue does not obstruct other vehicle paths. Recommendations and study findings are explored as a queuing model and layout design in the future.*

Keywords: *Queue Model; Layout Design; Gas Station; Multi Channel-Single Phase.*

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INTRODUCTION

Currently, all activities must be carried out quickly in response to demands and with precision in service. This is due to the increasing number of people in the world. Technological developments are also taking place rapidly. Service companies or manufacturing companies must provide good service and fast service (Ginting, 2014). There are several leading sectors in the Indonesian economy, namely the trade and service sectors (Indriani, L. & Mukhyi, A.M., 2013). One of the service companies is a gas station. Gas stations, often called Fuel Gas, is a business unit to business activities that distribute and sell fuel oil to the community to meet vehicle fuel needs. The increase in the number of motorized vehicles in Indonesia is seen in Table 1. This number will certainly have an impact on increasing the number of gas stations in Indonesia (bps.go.id., 2022)

Table 1. Increasing the Number of Motorized Vehicles in Indonesia

Type of Motorized Vehicle	Growth in Number of Motorized Vehicles by Type (Units) 2018	2019	2020
Motorcycle	106 657 952	112 771 136	115 023 039
Car	14 830 698	15 592 419	15 797 746
Bus	222 872	231 569	233 261
Freight Cars	4 797 254	5 021 888	5 083 405
Total	126 508 776	133 617 012	136 137 451

Every year, the Indonesian population grows, causing an increase in the purchase of motorized vehicles. As a result, market demand for car gasoline has increased. The Indonesian Ministry of Transportation reports in 2022 stated that the number of people who own a motor vehicle is extremely high. After the United States and Turkiye, Indonesia is one of the three countries with the biggest motorcycle ownership in the world. The increasing consumer demand for fuel has an impact on the provision of facilities and the increase in the number of gas stations. Each gas station must be able to make improvements and increase the effectiveness of its performance by adding fueling facilities. During peak hours that cause long queues, it is necessary to optimize reliable human resources to manage the service system that must be adjusted.

With the increasing number of consumers, increasing facilities and creating ease and speed in service are necessary. Gas stations must provide good quality service to consumers. The level of service quality can be assessed from the suitability of consumer expectations with what is provided by the company or organization (Ramseook-Munhurrun, P. et al., 2010). The best service is the main thing that producers must provide to consumers in meeting their needs so that consumers feel satisfied (customer satisfaction). The services provided by gas station employees to consumers, such as distributing fuel to vehicles and directing them to use the facilities at the gas station, can provide convenience and comfort for consumers while at the Gas stations.

Gas stations are one of the public places that can cause long queues for motor vehicles. Consumers who need service simultaneously will form a queue (Bahar, S. et al., 2018). A queue is one or more customers waiting in a system to get service (Krajewski, Lee J., et al., 2010). The occurrence of queues is one form of an example of poor service. The phenomenon of long

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queues at gas stations can be overcome by implementing a queuing system. The queuing system is a collection of customers, waiters, and a rule that regulates customer arrival. In the gas stations business, long queues can be reduced by adding a refueling channel pump or a gas station served by two employees and separating for two-wheeler riders and four wheels.

The accuracy of the layout also influences the queuing model at gas stations. The layout is a physical structure in equipment and supplies from a component based on a production process. An arrangement of the facility lies in the production process that will regulate the flow of material, productivity, and relationships between people. Preparation of a good layout ensures safety and worker satisfaction. This happens because the work process is well structured to carry out activities more economically (Putri & Ismanto, 2019). Good facility layout planning can determine the efficiency and effectiveness of operational activities and determine a company's success. Many gas stations provide outstanding service under normal circumstances. However, there are instances when there is an extremely long line, particularly when people return home from work or under certain situations. As a result of these circumstances, crisis management is required to manage queues and vehicle layout (Nouri, J., Omidvari, M., & Tehrani, S. M., 2010). Gas stations must design a suitable layout to improve their services (Casban, C., & Nelfiyanti, N., 2019). This study fills the gap in the phenomenon of queuing vehicles at a gas station. This article aims to examine how to model the proper queue in a gas station service and develop a convenient layout design for everyone interested in gas stations.

LITERATURE REVIEW

Queuing System

Queues can form any place when there is a high demand for customer service and restricted the number of servers available. In such a case, it is critical to building a queuing model that considers that customer traffic in gas stations has a significant impact on customer convenience. As a result, queuing system theory offers much potential in this sector (Stojčić, M. et al., 2018). Lyu, X. et. al. (2021) explain Queuing Theory is a theory with mathematical methods to study the phenomenon of random dispersion of systems and the work process of random service systems. This is covered in the field of operations research. Through statistical research on the arrival and service times of service objects, statistical laws will be obtained from these quantitative indicators (waiting time, queue length, busy period, etc.) A vehicle queue at a gas station is a way of operating vehicle services described as a queuing system. Incoming characteristics consist of vehicle flow as a stochastic process, service intensity, maximum allowed queue length, and the number of service units determined. Queue theory is a helpful science for manufacturing companies or services to learn a queue that often occurs in the company (Grozev D. et al., 2020). The problem of a waiting line occurs when the need for service facilities is greater than the available service capacity.

The system is a series of interconnected components that interact to achieve a goal, where the system is divided into sub-systems that support a more extensive system (Romney, M.B., & Steinbart, 2015). The queue is one or more customers who are waiting in a system to obtain service. Based on the understanding of the system and queues described above, it can be concluded that the queuing system is a series of activities that occur in rows waiting for the service to provide a solution to solve the problem in the queue row, so it does not happen in a long queue.

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The queuing system is a collection of customers, waiters, and a rule that regulates the arrival of customers. Several factors affect the queuing system: a) Queue Discipline; b) Calling population; c) Arrival Rate; d) Service Rate.

Queuing Theory

Queuing theory has a long history and is used to solve problems in various fields, including gas stations, airports, repair workshops, transportation, manufacturing, service industry, communications, inventory control, and other common everyday examples. A queuing model is made up of three components: (1) arrivals or system inputs (also known as the caller population), (2) the queue (or the line itself), and (3) the service facility. Queues need to be appropriately managed so that queues can be identified and services can be well received by customers (Nacy, N. G., & Ibrahim, S. T., 2019). The time between two successive arrivals and the service time is commonly considered to follow a given probability distribution in queuing theory (Fazlollahtabar, H., & Gholizadeh, H., 2019).

There are four queuing structure models commonly used in queuing systems, namely: a) Single Channel-Single Phase is a queuing system that has one service line where the line only has one service station; b) Single Channel-Multi Phase is a queuing structure model that has one service line but gets service more than once in a row; c) Multi Channel-Single Phase is a queuing model that has more than one service facility with a single queue flow; d) Multi Channel-Multi Phase is a queuing model that has several service facilities in each stage so that several customers can be served at the same time. Each company provides a queuing model depending on the existing space facilities and funds to provide service equipment. When customers can be served efficiently, queue effectiveness occurs.

Layout Design

The layout design is a physical structure in the form of equipment and supplies for a work component, based on a production process and an arrangement of the facility in the production process that will manage material flow, productivity, and interpersonal interactions. Distance, time, and cost are all key factors to consider when designing the facility's layout. A lengthy distance of product transfer will result in a long enough period that the expenditures incurred will also be considered due to the length of the process. The layout process determines the arrangement of goods that have low production volumes and high production variations by similar grouping goods (Hong, C. et. al., 2018).

From some definition or understanding stated above, it can be concluded that the layout is crucial for the survival and the achievement of organizational goals or the company. By structuring the appropriate facility layout, the operational processes of a company can run smoothly and precisely. The work area is arranged in good order and according to the production flow to improve their work performance and get comfortable while working.

Conceptual Framework of Queuing Model and Layout Design

The queuing model and layout of the gas station is a concept developed in this study. In the concept of the queuing model, many authors have discussed it, as well as about layout theory (Itoh, E., & Mitici, M., 2020; Zeng, J., & Wan, R., 2018). How queuing and layout models are

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implemented in business is a study that presents novelty to the body of knowledge in the field of service management. The decision of a queuing model and layout design is a responsibility carried out by gas station managers.

In real life, the queue problem is often criticized by customers. All customers hope to find a smooth queue phenomenon. How can queuing issues be properly addressed? When it's quiet, the queuing system is not a problem. But when the situation is crowded, people put forward the theory of queuing. Queuing theory, also known as random service theory, is a theory and method in operations management for studying queuing systems. In particular, based on studying the probabilistic regularities of various queuing systems, the optimal design and optimal operation of queuing systems can be solved. The service queuing process can be described as follows: first, it starts from the customer source, queues to receive the service before arriving at the service agent, and leaves after the service is completed (Gongshan, C. et.al, 2015). Figure 1 depicts the service system model of queuing theory.

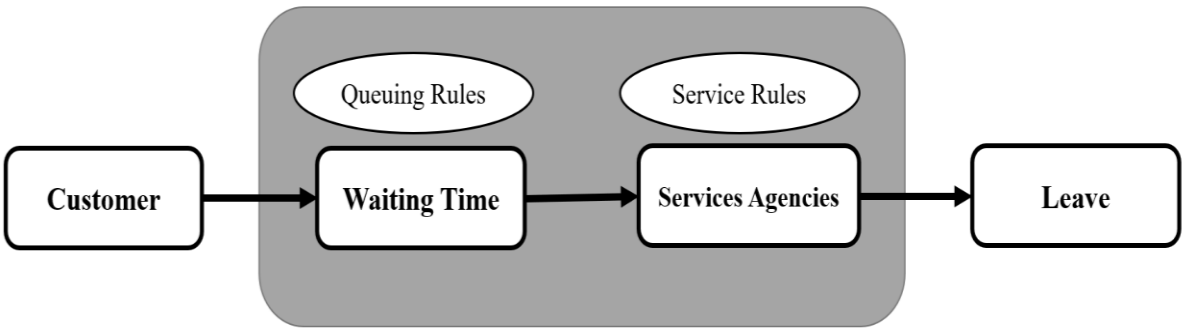

Figure 1. Model of A Queuing Service System

In a gas station, there are certain times when there is a very large number of motorbike arrivals. This of course will greatly disrupt the traffic in the gas station. In addition, the arrival of motorcycles seems less aesthetic, so it is necessary to make a flexible layout that does not interfere with vehicle traffic around the gas station.

The layout in a gas station can also be referred to as the servicescape which is a predictor of perceived service quality. However, the theoretical implications are still few studies that discuss. Therefore, there needs to be a study that constructs the layout and that the evaluation of the service-scape should precede the perception of service quality because these service elements are evident to customers (Hooper, D. et. al, 2013). In addition, customers can use the layout or servicescape to form their perception of the personalized service they will receive in terms of layout as a primary expectation. As a result, the study of queuing models and layout design should be based on a gas station's quality of service.

RESEARCH METHODS

This study was carried out at the gas station in Ngasinan Wonosobo, Indonesia, for three days in mid-November 2020 between 06.00-08.00 am and 03.00-05.00 pm. This period was chosen as the observation time because it is time for people to go to work and begin their daily activities

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in the morning, while in the afternoon, it is time for people to go home from work. There are generally long lines at both times. The workflow process in the research method is carried out in several stages (Shanmugasundaram, S., & Banumathi, P., 2017): 1) Review the queuing process at the gas station, 2) Identify the facilities at the gas station, 3) Determine the model of the gas station queuing system, 4) Presenting the gas station layout design in an illustration picture.

The participants in this study were all riding motorcycles in the queueing system of one of the pertalite fuel pump lines. This research employs mix methods. Purposive sampling is a non-probability sampling approach that was utilized. The data collection method by observation is by observing and measuring the average number of consumer arrivals (λ) and the average number of consumers served (μ) in the period (hours) on the gas station queue system. Then conduct interviews with managers of gas stations to obtain company data such as organizational structure, operational management, and others. The data analysis technique used in this research is descriptive analysis and queuing model analysis, namely Multi-Channel Single Phase.

Descriptive analysis is used in analyzing the layout design to describe the layout arrangement in the gas station. This analysis explains the suitability of the layout arrangement with the queuing model of motorized vehicles in the refueling service system. The service system at the gas station uses the Multi-Channel-Single Phase queuing model. Customer arrivals were analyzed using Kolmogorov Smirnov to check that the data were Poisson distributed. Poisson distribution is used to calculate the probability according to the unit of time, space, or content and area and the binomial distribution if n-major ($n \geq 30$) and a relatively small p ($p < 0.1$).

Having proven the Poisson distributed, followed by optimizing the service process using the calculation model B or double-track queue model (M/M/S) with the following formula:

a. The probability is 0 units in the system (empty service units)

$$Po = \frac{1}{[\sum_{n=0}^{M-1} \frac{1}{n!}(\frac{\lambda}{\mu})^n] + \frac{1}{M!}(\frac{\lambda}{\mu})^M \frac{M\mu}{M\lambda - \mu}}$$

b. The average number of customers in the system

$$Cs = \frac{\lambda \mu (\frac{\lambda}{\mu})^M}{(M-1)!(M\mu - \lambda)^2} Po + \frac{\lambda}{\mu}$$

c. The average time spent in the system (waiting time plus service time)

$$Ts = \frac{Ls}{\lambda}$$

d. The average number of customers waiting in a queue

$$Cq = Ls - \frac{\lambda}{\mu}$$

e. The average time customers spend waiting inline

$$Tq = \frac{Lq}{\lambda}$$

RESULTS AND DISCUSSION

Descriptive Analysis

Observation of this research for 4 hours, 2 hours at 06.00-08.00 am and 2 hours at 03.00-05.00 pm for three days. Observations were made on one of the pertalite gas station lines; the number of motorcycles filling up with fuel was 1360. Then from samples taken at the study showed the average number of customer arrivals (λ) of 340 motorcycles per hour, and the average number of customers served (μ) is 95 motorcycles per hour.

Queue Model Result

The queuing system analysis uses the Multi-Channel-Single Phase (M/M/S) model with two refueling lines in a certain period. The results of the queuing system analysis can be seen in Table 1. It shows that the hours of 03.00-04.00 pm are busy hours of service on the pertalite fueling line for a motorcycle where the average consumer in the service system at that hour is 3,584 people, or it can be said that four motorcycles. Many consumers in the system result in a high level of service so consumers spend a long time waiting for service. The average time for consumers to wait for service at the busiest hour is 0,99 minutes (Tq in the period 03.00-04.00 pm)

Table 2. Queue System Performance Results (in Minutes)

Period	Po Probability 0 unit	Cs Customer in system	Ts Time spent in system	Cq Customer in queue	Tq Time spent in queue
06.00-07.00 am	0,347	1,030	0,750	0,170	0,120
07.00-08.00 am	0,365	0,615	0,660	0,035	0,038
03.00-04.00 pm	0,286	3,584	1,620	2,184	0,990
04.00-05.00 pm	0,313	1,851	1,010	0,690	0,380

The results in Table 2 shows that 07.00-08.00 am has a low level of service where the average number of consumers who are in the service system for that hour is less than other hours is 0.615 or 1 motorcycle (Cs in the period 07.00-08.00 am). The average time of consumers in the queue to get services at 07.00-08.00 am is the shortest time than other hours, which is 0,038 minutes (Tq in the period 07.00-08.00 am).

Layout Design Result

The existence of a layout design for the Ngasinan Wonosobo gas station with a queuing system on the petalite refueling line for motorcycle lanes is illustrated in Figure 1. Several factors can influence the vehicle's capacity that will refill to avoid interfering with the comfort of other customers. The convenience of customers in the vicinity of the gas station must be considered, and the facilities must be well-organized. The vast area of the gas station makes it easier to install facilities and plan the layout. It can be set up neatly and adequately so that it does not obstruct the convenience of other refueling customers.

Samples were taken from the average number of customers in the hourly queue system on channels1, petalite fueling lines for motorcycles. Vehicles that will be refueling Pertalite are directed to enter channels1. If one of the channels is filled, the vehicle will be directed to an empty channel or a lane with a looser queue. The line used for refueling petalite motorcycles has 2 servers or 2 channels with the same type of service and only goes through one service stage, so using the Multi-Channel-Single Phase model.

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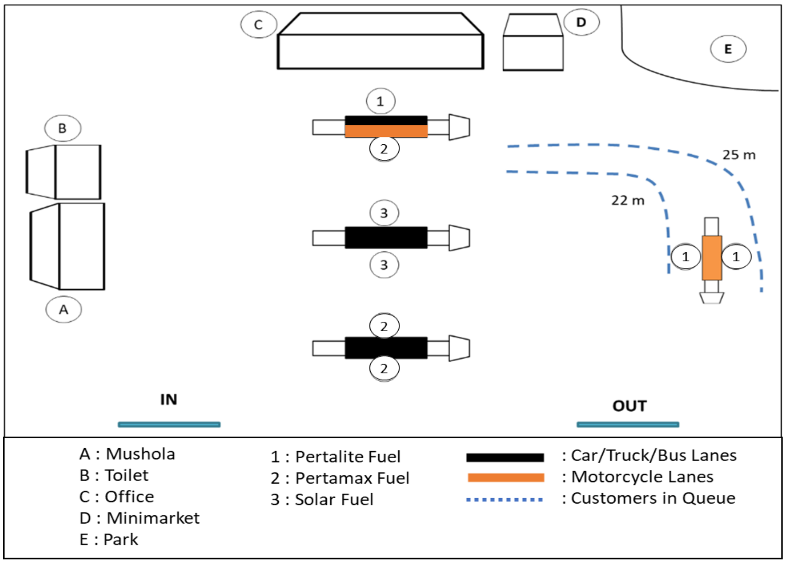

Figure 2. Visualization Of Gas Station Service Facilities

Figure 2 has several parameters based on measurements in the field as follows:
• The queuing system length of track (LT) on channels 1 are 22 m and 25 m
• Assuming the average length of a motorcycle is 2 m.
• Assuming the distance between vehicles in the queue is 0.5 m.
With these parameters it can be seen that the total length of a vehicle:
Total length per vehicle= Leverage + Distance between vehicles
= 2 + 0,5 m
= 2,5 m
From the calculation above, the vehicle's total length in the queuing system can be seen based on the analysis of queuing models every hour. The formula for calculating the total length of vehicles in the queuing system is:

The total length of vehicles in the system (LV)= Ls x total length of vehicles
= Ls x 2,5 m

The results of the study presented in Table 3 mean that there is a difference in the length of the overall vehicle in the queue system every hour. At 06.00-07.00 am, the average number of vehicles in the system is 2 motorcycles with a total length of vehicles in the system 5 m. Furthermore, at 07.00-08.00 am, the average number of vehicles in the system is 1 motorcycle with a total length of 2.5 m. This means that at 07.00-08.00 am. The queue is already looser than the queue at 06.00-07.00 am.

At 03.00-04.00 pm, the average number of vehicles in the system is 4 motorcycles with a total length of vehicles in the system of 10 m. Meanwhile, at 04.00-05.00 pm, the average number of vehicles in the system is 2 motorcycles, with a total length of vehicles in the system being 5 m. This means that the queue that forms at 03.00-04.00 pm is longer than the queue that forms at 04.00-05.00 pm.

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Table 3. Length Of Track and Length of Vehicle

Period (Hours)	Length of Track (LT)		Total Length of Vehicle (LV)	Evidence
	Channel 5	Channel 6		
06.00-07.00 am	22 m	25 m	5 m	Feasible (LV < LT)
07.00-08.00 am			2,5 m	Feasible (LV < LT)
03.00-04.00 pm			10 m	Feasible (LV < LT)
04.00-05.00 pm			5 m	Feasible (LV < LT)

Based on the calculation above, it can be seen that the total length of the vehicle in the system does not exceed the length of the queue line on channel 5 and channel 6 (LV < LT, then the layout at Ngasinan Gas Station is declared eligible and no risk of resulting in the vehicle lane on another channel disturbed.

Discussion

This study differs from previous study carried out by Teimoury, E. et. al. (2021) which stipulates scenario management in gas station management. In this study, it was explained that many gas stations management needed to improve the performance of the non-standard queuing system. As a result, this study proposes that additional attention be paid during rush hour, which might be a critical time that requires immediate attention. The refueling service at the gas station, the conditions and situations faced change every day. The number of consumers who come to meet their daily fuel needs varies, so the queues that occur in the service system have different lengths. This queuing problem can be overcome by implementing a well-managed queuing system. Queuing system calculations can be used to determine the queue length according to the layout design of each gas station.

The calculation results with the multiple-lane queuing model show that the queuing system's performance on the motorbike refueling line at the Ngasinan Wonosobo gas station is effective. This can be seen from the queuing model's calculation results, which shows that in the period 06.00-08.00 am and 03.00-05.00 pm, the average number of consumers in the queue system is 1-4 motorcycles.

This amount still includes the number of standard queues that occur in a service system. The results of the performance of the queuing system on the motorcycle refueling line at the Ngasinan Wonosobo Gas Station also have an efficient time for consumers to use in the queuing system. This is evidenced by the results showing consumers' time in the queuing system, the lowest is 0.038 minutes, and the highest is 0.99 minutes. The time still includes the standard time used in the service system.

The results of the performance of the queuing system show that the layout of the Ngasinan Wonosobo Gas Station is feasible and does not risk disturbing the path of other vehicles passing through the gas station area. The analysis results can prove this on system performance and the total length of vehicles in the queuing system for 2-wheeled vehicles. The results obtained are

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that the total length of vehicles in the queuing system does not exceed the length of the queue line. The queuing system at the Ngasinan Wonosobo gas station with a layout design is adequate. This can be seen from the queues in the period from 03.00 – 04.00 pm. Even though at 03.00-04.00 pm, the queue at the Pertalite gas station for motorbikes has the longest queue compared to other hour periods, which is 10 m. However, this is still considered normal, even though it causes queues of vehicles that reach the outer limits of the gas station area so that it can interfere with the activities of other consumers outside the gas station area.

CONCLUSION

This paper proposes a new approach in queuing-based modeling and layout design for service management in a gas station. Vehicle traffic entering the gas station area allows vehicle traffic disturbances (especially during peak hours) so there is a need to have good service management. The findings and analyses have been considered, and the following conclusions can be presented which the decisions made thus far in terms of queuing models have been appropriate. According to research conducted in the morning (07.00-09.00 am) and afternoon (03.00-05.00 pm), customers find lineups to be very acceptable. With the queue analysis result, it can be seen that the total length of vehicles in the system does not exceed the length of the queue line so that the queuing system does not interfere with another vehicle lane. The queuing system at 03.00-04.00 pm has adequate performance.

The results of the queuing analysis prove that the total length of the vehicle in the system does not exceed the length of the queue so that the queuing system does not interfere with other vehicle lanes. When there are too many vehicles entering the gas station area, a key decision must be made to reduce the length of the vehicle line by appointing someone who can control the vehicle's arrival. This necessitates immediate response in order to appropriately manage queues and vehicle layouts.

This study was conducted during regular times. The study results' recommendation shows the gas station's performance, which is in a state of sufficient fuel, the country's economy is in good condition, and the monetary situation is stable. Future studies need to consider crisis management for gas station managers, aesthetics in layout design, and other service factors that allow convenience in gas station service decisions.

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