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Modeling of Queues At 3 Kg Lpg Filling and Transportation Stations (Sppbe) With Optimization of Promotional Service Stations

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Abstract

Queues are a common problem that often arises from an imbalance between the arrival rate and the service capacity or facilities. Queues occur because customers (users) arrive at a service facility when the available service capacity is insufficient to handle the incoming demand. Queues often occur in the Single Channel - Single Phase queue system, which is observed at SPPBE (Filling and Transportation Stations for Bulk LPG). In the Single Channel - Multi Phase queue structure, queues also occur due to the accumulation of waiting time required for each service stage. Therefore, this research aims to explain the model and analyze the queue system that occurs at SPPBE, provide an explanation of the analysis results of the Single Channel - Single Phase queue model for two service locations, and use the Kolmogorov-Smirnov method for data conformity testing. The SPSS program was used to analyze the Single Channel - Single Phase queue model for two service locations and to use the Multi Channel - Multi Phase queue model for the two service locations.

Keywords: Queue system, Single Channel - Multi Phase, Multi Channel - Multi Phase, Bulk Filling and Transportation Station (SPPBE), Service system optimization, Kolmogorov-Smirnov test, Poisson distribution, Queue model analysis, Service efficiency, Service desk performance, Queue structure analysis.

1. Introduction

Currently, technological advancements have had an impact on increasing human needs for natural resources and energy. These needs have become very important in supporting human activities, both in daily life and for other purposes. One of the energy sources that is widely used by humans, especially for household needs, is LPG (Liquefied Petroleum Gas) (Arifin, 2021). LPG is a basic material derived from natural gas and can be liquefied. As a product derived from natural gas, LPG has several advantages such as being clean-burning, producing minimal smoke, and being easily stored (Kurniati, I., et al., 2016).

The Bulk LPG Filling and Transportation Station (SPPBE) of PT. Hakamindo Petro Chem is one of the LPG filling service locations for 3 kg cylinders that serves several agent-owned filling stations. The queue at SPPBE initially occurs because of the limited number of filling stations. Furthermore, the queue process at the agent filling stations also contributes to the overall queue. Therefore, efforts to manage the LPG filling, LPG transportation, and agent filling stations return to the SPPBE at predetermined times (Meutia, 2021). The SPPBE of PT. Hakamindo Petro Chem has only one service window, which causes queues. This research uses a Single-Channel Multi-Phase queue system, where there are several service stages that must be passed sequentially by each vehicle before it can be served completely. The application of the Single-Channel Multi-Phase queue system is implemented at the Filling and Transportation Station for Bulk LPG (SPPBE) of PT. Hakamindo Petro Chem.

The application of probability theory is crucial for modeling the stochastic nature of arrivals and service times in queueing systems, as detailed by Asmussen (2003). While focused on manufacturing, the principles of flow and queueing discussed in Factory Physics (Hopp & Spearman, 2011) offer valuable insights applicable to service systems aiming to improve efficiency and reduce waiting times. The source of the queue is the arrival of trucks and the subsequent service process. Generally, in this complex system, the analysis focuses on the queue theory (Okunade, 2024). In the queue model, the arrival rate, service rate, and waiting time are stated in a probability distribution formula. This is often referred to as the distribution of arrival and service times. The queue system for 3 kg LPG filling service at the SPPBE of PT. Hakamindo Petro Chem consists of 4 stages or service phases. The standard service time for one truck is 20 minutes, while the average actual queue time at the SPPBE is explained in Table 1:

Table 1: Average Time at Each Stage

Stage	Column A (t)	Column B (T)
1	Registration	5 minutes
2	Unloading	8 minutes
3	Filling	17 minutes
4	Weighing and Sealing	10 minutes
	Total Time	40 minutes

Based on the table above, it can be seen that the total average time a truck spends in the service process is 40 minutes, or twice the standard service time set by the company. Therefore, observations on the queue system at the SPPBE need to be carried out to identify critical points in the service, analyze the potential for bottlenecks, and provide simulation of the queue system that occurs.

Discrete-event simulation is a powerful technique for analyzing complex systems where events occur at specific points in time, allowing for the evaluation of different scenarios and system configurations (Fishman, 2001). Software tools like Arena facilitate the development and analysis of simulation models, enabling practitioners to evaluate system performance and identify areas for improvement (Rossetti, 2010). To analyze the queue, simulation is carried out using a multi-method approach, by modeling mathematical models and simulation models (Ostrowski, 2021; Prakarsa et al., 2021). Understanding the principles of discrete-event system simulation is essential for accurately modeling and analyzing dynamic systems with inherent variability (Banks, 1999). In this study, simulation modeling is used as a tool to solve problems that are quite complex if solved using mathematical models. Thus, the simulation model is a solution for solving these mathematical phenomena. This is important to detail and deeply analyze the existing phenomena. Currently, the use of simulation is inseparable from technology and computers because both tools are useful for facilitating the identification of problems, processing data, and producing information. This research focuses on the use of technology and computer software that is used to solve existing problems using the ProModel software.

2. Literature Review

2.1.1. Simulation Technique

Simulation is a process of imitation or replication of the actual system along with its related environment (Banks et al., 2004; Law, 2015). Simulation is a vital and important tool in planning and managing complex systems, such as logistics and manufacturing systems (Swain, 2018). According to Schmidt (2018), along with increasing demand and costs within a system, simulation is needed to carry out more effective and efficient planning.

2.1.2. Queue

A queue is a process where customers wait to be served by a service facility (server) that is busy (Gross et al., 2018). Queueing theory provides a mathematical framework for understanding and analyzing waiting lines, which are prevalent in various service and operational systems (Cooper, 1981)." This foundational text offers a comprehensive introduction to the mathematical principles underlying queueing phenomena. As one of the seminal works in the field, Kleinrock's (1975) Queueing Systems lays the theoretical groundwork for analyzing the behavior of queues and their impact on system performance. After the customer receives service from the facility, they then leave the service facility (Harchol-Balter, 2013; Longo and Zanin, 2020). The queue system is a sequence of service processes that are interdependent and involves customer arrivals in a queue and subsequently receiving service from one or more servers (Tijms, 2012; Gross, et al., 2018).

According to Fitzsimmons, J. A., & Fitzsimmons, M. J. (2013), there are three components in a queue system, namely:

1) Arrival Characteristics (Kedatangan Masukan Sistem)
   Arrivals have characteristics such as population size, behavior, and a statistical distribution.
2) Queue Discipline (Disiplin Antrian)
   Queue discipline includes whether the queue length is limited or unlimited and the order in which customers are served (e.g., first-come, first-served).
3) Service Facility (Fasilitas Pelayanan)
   Service facility characteristics include design and the statistical distribution of service time.

The queue model helps in making decisions to balance service costs with the costs of waiting lines. The queue model analysis involves the following:

1) Average time spent by a customer in the queue (Wq)
   a) Model Single Server (M/M/1):

$$Wq = \frac{\lambda}{\mu(\mu - \lambda)} \tag{1}$$

   b) Model Multi Server (M/M/c):

$$Wq = \frac{Lq}{\lambda} \tag{2}$$

2) Average queue length (Lq)
   c) Model Single Server (M/M/1):

$$Lq = \frac{\lambda^2}{\mu\,(\mu - \lambda)} \tag{3}$$

   d) Model Multi Server (M/M/c):

$$Lq = Ls - \frac{\lambda}{\mu} \tag{4}$$

3) Average time spent by a customer in the system (Ws)
   e) Model Single Server (M/M/1):

$$Ws = \frac{1}{\mu - \lambda} \tag{5}$$

   f) Model Multi Server (M/M/c):

$$Ws = \frac{Ls}{\lambda} \tag{6}$$

4) Average number of customers in the system (Ls)
   g) Model Single Server (M/M/1):

$$Ls = \frac{\lambda}{\mu - \lambda} \tag{7}$$

   h) Model Multi Server (M/M/c):

$$Ls = \frac{\lambda.\mu \frac{\lambda}{\mu}^{M}}{M - 1!\,(M\mu - \lambda)^2} P0 + \frac{\lambda}{\mu} \tag{8}$$

5) Probability that the service facility will be idle (P0)
   i) Model Single Server (M/M/1):

$$P0 = 1 - \frac{\lambda}{\mu} \tag{9}$$

   j) Model Multi Server (M/M/c):

$$P0 = \frac{1}{\sum_{n=0}^{M-1} \frac{(\frac{\lambda}{\mu})^n}{(n)!} + (\frac{(\frac{\lambda}{\mu})^M}{M!}) \frac{1}{1 - \frac{\lambda}{M.\mu}}} \tag{10}$$

Notation:
λ : average arrival rate of LPG agent trucks in the queue
μ : average service rate of trucks at one service point
M : number of parallel service channels

2.1.3. Basic Structure of Queue Models

The queue process is generally grouped into four basic queue model structures, according to the number of service facilities and the sequence of service stages that must be passed (Fitzsimmons, J. A., & Fitzsimmons, M. J., 2013; Purnawan, et al., 2023):

1) Single Channel - Single Phase
   Single Channel - Single Phase is a queue structure where there is only one queue and one service facility, as shown in the following Figure 1:

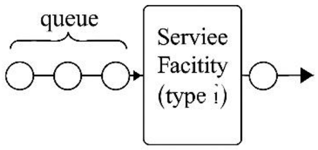


Figure 1: Single Channel-Single Phase Queue Structure

2) Single Channel - Multi Phase
   Single Channel - Multi Phase is a queue structure where there is only one queue and two or more service facilities that are passed sequentially, as shown in Figure 2 below:

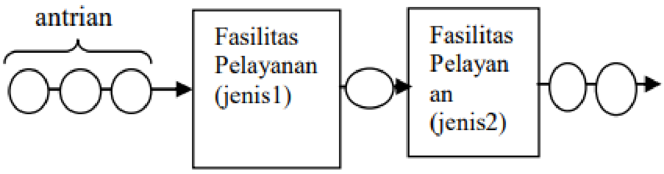


Figure 2: Single Channel-Multi Phase Queue Structure

3) Multi Channel-Single Phase
Multi Channel-Single Phase is a queue structure where there are two or more parallel service facilities and only one queue, as shown in the following Figure 3:

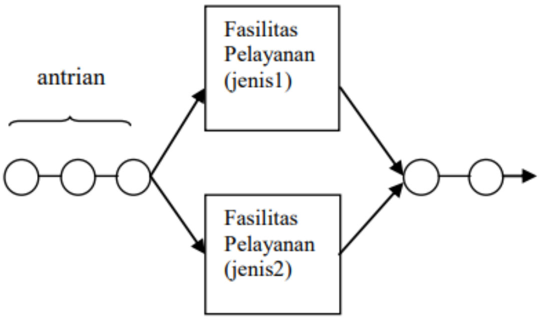


Figure 3: Multi Channel-Single Phase Queue Structure

4) Multi Channel-Multi Phase
Multi Channel-Multi Phase is a queue structure that has two or more queues and/or service facilities, as seen in Figure 4 below:

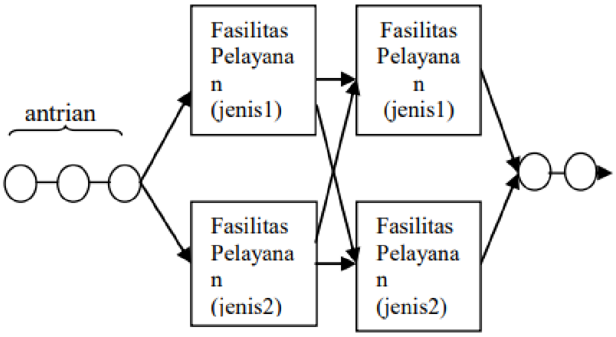


Figure 4: Multi Channel-Multi Phase Queue Structure

2.1.4. Queue Discipline

Effective management of service operations often requires the application of queueing analysis to optimize capacity and minimize customer waiting (Nahmias & Olsen, 2015). Queue discipline refers to the rule used to select customers from the queue for service. According to Heizer and Render (2005), there are several forms of queue discipline commonly used, namely:

1. FCFS (First Come First Served) or FIFO (First in First out), meaning that the earliest arrival (first in) is served first (first out). For example, queuing at a movie ticket counter.
2. LCFS (Last Come First Served) or LIFO (Last in First out), meaning that the latest arrival is served first. For example, the queue in an elevator for the same floor.
3. SIRO (Service in Random Order), meaning that customers are called for service randomly, without regard to who arrived earlier or later.
4. PS (Priority Service), meaning that service is given to customers with higher priority compared to customers with lower priority, even though the latter may have arrived earlier. For example, someone in a state of illness is prioritized over others in a doctor's waiting room.

2.1.5. Utilization

Utilization rate measures the extent to which a server or service facility is busy. The higher the utilization rate, the more likely a bottleneck will occur and the longer the potential queue (Kazak, 2009). For example, SPPBE service hours are from 08.00 to 16.00, meaning the total operating time is 9 hours, but if the break time for SPPBE employees is 12.00 - 13.00, which is 1 hour, then the effective operating time of SPPBE is 8 hours. The utilization rate of the SPPBE service is 8/9 x 100% = 88.89%.

2.1.6. ProModel

ProModel is a powerful and flexible simulation software for manufacturing and logistics systems. ProModel can be used to evaluate systems to become better, provide alternatives, and analyze design plans before they are implemented (Peter, et al., 2021). ProModel is a simulation tool in the form of software that can model various manufacturing or service systems and perform process animation and analysis of the models created (Bhagya, 2022), (Septiani, 2020).

3. Materials and Methods

The Queue System Simulation is designed and developed using the methodological framework shown in Figure 5 below:

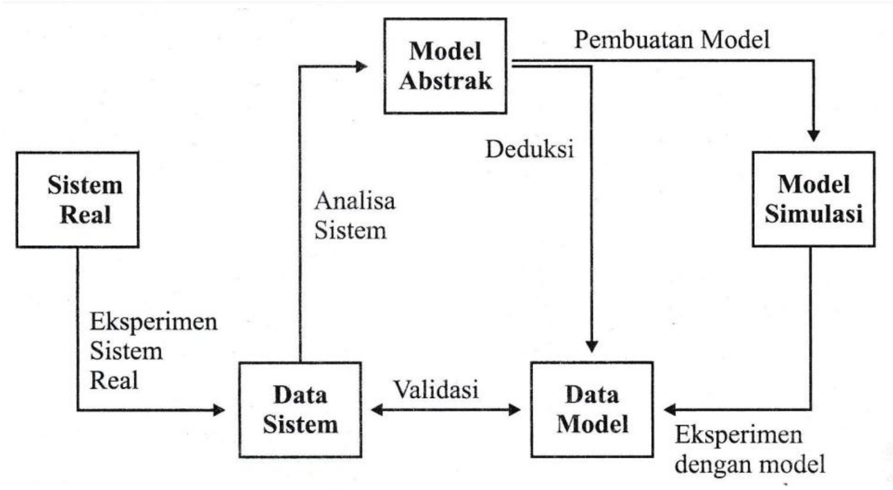


Figure 5: Five Stages of Modeling

3.1. Real System

The real system analyzed in this research is the queue system for LPG Filling and Transportation Stations (SPPBE) for 3 kg cylinders owned by PT. Hakamindo Petro Chem. This system consists of several main elements:

1) Source, the trucks arriving at the SPPBE location.
2) Service Stations, the LPG filling areas equipped with filling machines.
3) Destination, the vehicles leaving the location after being served.

3.2. System Data

In the system data, attention is paid to the queue variables and several indicators such as the average customer arrival rate, average service rate, number of servers, average waiting time, and the service efficiency variables that support the calculation of waiting costs and service costs.

3.3. Abstract Model

Representation of a simplified real system. This model includes the main elements that influence the queue system at the SPPBE of PT. Hakamindo Petro Chem. The determination of these elements is intended to help in building an abstract model that can predict and analyze the performance of the LPG filling service system.

3.3.1. Abstract Single Channel Model

The queue system is designed with a single-channel approach where all arriving vehicles are directed to one service window to begin the administrative process. Furthermore, upon arrival at the location, vehicles that have not yet been served will directly enter the Queue. Once their turn arrives, the vehicles will be served by the officer at the service window, as shown in Figure 6 below:

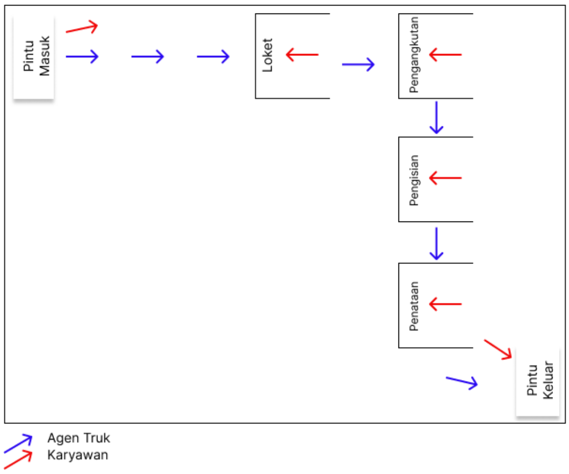


Figure 6: Single Channel Abstract Model

After the service process at the window is complete, the vehicles continue their journey to the LPG filling station. Next, the vehicles leave the system after the entire filling process is complete, designated as Destination. However, because there is only one service window, the potential for accumulation occurs in the Queue, especially if the arrival rate (Source) is higher than the service capacity (Service) at that point.

3.3.2. Abstract Multi Channel Model

In this model, arriving vehicles are directed to one of the available service windows. With two service windows, vehicles have the option to choose a shorter queue, so the queue can be more evenly distributed between the two lanes. At each service window, vehicles will be served by the officer to handle the administrative process. After being served at the window, the vehicles proceed to the LPG filling station. The LPG filling process is carried out in parallel for all vehicles that have passed through the service windows. Vehicles that have finished being served leave the system through the Destination, as shown in Figure 7 below:

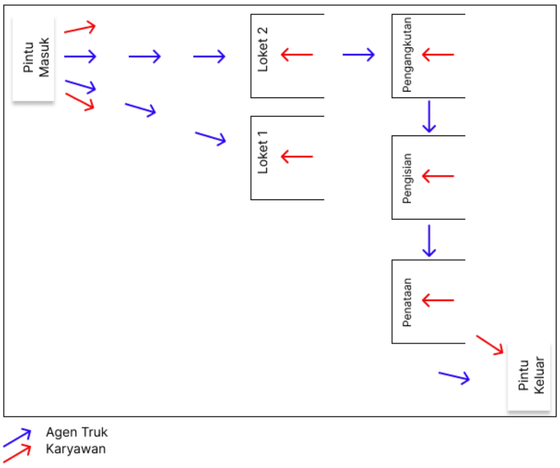


Figure 7: Multi Channel Abstract Model

The Multi Channel model is considered more optimal than the first model because with two service windows, the average waiting time of vehicles in the queue is shorter. This results in faster service and reduces the potential for congestion, especially when the number of arriving vehicles is high.

3.4. Simulation Model

The implementation of the abstract model is carried out in the ProModel simulator which allows for virtual experiments. This simulation program is expected to save time and cost in analyzing and programming variables that significantly affect the performance of the queue system without disrupting the real system. The creation of the model is carried out in several stages, namely:

3.4.1. Designing the Model

Several components are used to create the simulation model with ProModel, which are as follows:

1) Location (Lokasi), represents a place within the system where entities do not move but undergo processes, such as storage areas or other activity locations.

2) Entities (entity), are all objects that become the focus of the model. Included in this are documents, people, raw materials, and others.
3) Arrivals (kedatangan), states the entry of entities from outside the observed system for the first time.
4) Processings (proses), represents all processes that occur within a location and the movement of entities between locations.

3.4.2. Creating Control Statements

Control Statements used in the modeling and simulation process are as follows:
1) Wait, holds entities for a certain period of time at a location.
2) Move For, moves entities from one location to another specified location.

3.5. Experiments with the Model

The simulation model run on ProModel is used to analyze average waiting times, service capacity, and service efficiency at the SPPBE of PT. Hakamindo Petro Chem to reach conclusions.

3.6. Validation Process

Ensuring the suitability of input data with actual data from the system. The validation process is as follows:
1) Entity Trace, validating the route taken by each truck according to the model simulation.
2) Output Analyzer and Status Monitoring, continuously monitoring the simulation execution and verifying various metrics such as waiting time, queue length, and server utilization.
3) Simulation Output Report, containing statistical data from the simulation results, where the report helps in validating whether the output is appropriate based on manual calculations or actual data.

4. Results and Discussion

4.1. System Data

The design of the service system at the SPPBE of PT. Hakamindo Petro Chem can be seen in Figure 8 below:

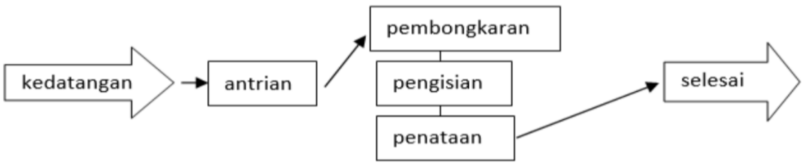


Figure 8: System Model

Customers enter the service area and form a queue at the available service facilities. They wait in the queue to receive service at these facilities, and the waiting time in the system is calculated. After the service processes are complete, customers leave the service area or system. The service facilities require different service times, which causes queues to occur.

The SPPBE of PT. Hakamindo Petro Chem, located on Jl. Surabaya-Krakasaan KM 112, Desa Bulang, Kabupaten Probolinggo, uses a simple queue system with a Single Channel - Multi Phase model. This model has one queue line with several sequential service windows. After the administrative process, LPG agent customers with 3 kg cylinders queue to become agents. At the SPPBE, the queue is quite long, causing LPG agent customers to wait long enough. The process begins when the LPG agent truck arrives and goes to the registration window. Next, the truck queues for LPG unloading, followed by the 3 kg LPG filling process, weighing, and finally waiting for all service processes to be completed as shown in Table 2 below:

Table 2: Truck Arrival Data for February 6-28, 2023

Day / Date	Number of Trucks	Number of Trucks Served
Monday, February 6, 2023	30	26
Tuesday, February 7, 2023	30	27
Wednesday, February 8, 2023	30	28
Thursday, February 9, 2023	30	27
Friday, February 10, 2023	30	27
Saturday, February 11, 2023	30	26
Sunday, February 12, 2023	30	27
Monday, February 13, 2023	30	27
Tuesday, February 14, 2023	30	28

Wednesday, February 15, 2023	30	27
Thursday, February 16, 2023	30	27
Friday, February 17, 2023	30	27
Saturday, February 18, 2023	30	26
Sunday, February 19, 2023	30	27
Monday, February 20, 2023	30	26
Tuesday, February 21, 2023	30	26
Wednesday, February 22, 2023	30	27
Thursday, February 23, 2023	30	28
Friday, February 24, 2023	30	26
Saturday, February 25, 2023	30	27
Sunday, February 26, 2023	30	28
Monday, February 27, 2023	30	26
Tuesday, February 28, 2023	30	26
Total	690	638

From the table above, the average arrival and service rates at the SPPBE of PT. Hakamindo Petro Chem are calculated as follows:

$$\lambda = \frac{\text{total number of arrivals}}{\text{total observation time}} = \frac{690}{20 \text{ days} \times 8 \text{ hours/day}} = 160690 = 4.3125 \text{ trucks per hour}$$

$$\mu = \frac{\text{total number served}}{\text{total observation time}} = \frac{638}{(20 \text{ days} \times 8 \text{ hours/day})} = 160638 = 3.9875 \text{ trucks per hour}$$

4.2. Model of the SPPBE Service Queue System Conducted by PT. Hakamindo Petro Chem

The characteristics of the queue system at the SPPBE of PT. Hakamindo Petro Chem in the 3 kg LPG filling and transportation service are as follows:

1) Arrival or Input Characteristics
   k) Population Size, where the LPG agent truck population is assumed to follow a Poisson distribution, originating from a finite but large population, and entering the queue system at the SPPBE for LPG filling and transportation.
   l) Arrival Pattern, where each LPG agent truck arrives independently, with an arrival rate that varies and cannot be predicted with certainty during the service process for 3 kg LPG.
   m) Arrival Behavior, where every arriving truck will directly proceed to the registration window. After registration, the truck queues for LPG unloading, continues with the cylinder filling, and ends with weighing before returning.
2) Queue Discipline
   LPG agent trucks that arrive earlier will be served earlier or based on the first in, first out (FIFO) rule in the 3 kg LPG filling and transportation service at the SPPBE of PT. Hakamindo Petro Chem.
3) Arrival or Input Characteristics
   n) The queue system design uses a Single Channel - Multi Phase configuration, which means there is only one service window that serves several sequential stages in the 3 kg LPG filling and transportation process.
   o) The service time distribution starts when the truck registers at the available service window. After registration, the truck waits its turn for the LPG unloading process, continues with filling, and ends with weighing before returning.

4.3. Queue Model at PT. Hakamindo Petro Chem Before Service Improvement

To optimize the queue system at the SPPBE of PT. Hakamindo Petro Chem, it is necessary to calculate the costs incurred. The goal is to minimize the total cost.

1) Service Cost: The salary cost of officers is IDR 2,750,000 per month. Assuming 26 working days and 9 working hours per day, the hourly salary cost is IDR 11,700.
2) Waiting Cost: The waiting cost is based on the truck's waiting time in the system. Based on the Regional Minimum Wage (UMR) of Probolinggo Regency, which is IDR 2,750,000 per month (720 hours), the hourly cost of one truck is IDR 4,000.

The following is a calculation using the Single Channel - Multi Phase queue system model:

M = 1 service window

λ=4 trucks/hour

μ=3 trucks/hour

plProbability of an empty system:

$$P_0 = 1 - \frac{\lambda}{\mu}$$

$$P_0 = 1 - \frac{4}{3}$$

$$P_0 = 1 - 1{,}33 = -0{,}33$$

Average number of trucks in the system:

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

$$Ls = \frac{4}{3 - 4}$$

$$Ls = \frac{4}{-1} = -4$$

Average time spent by a truck in the system:

$$Ws = \frac{1}{\mu - \lambda}$$

$$Ws = \frac{1}{3 - 4}$$

$$Ws = \frac{1}{-1} = -1\ jam$$

Average number of trucks waiting in the queue:

$$Lq = \frac{\lambda^2}{\mu\ (\mu - \lambda)}$$

$$Lq = \frac{4^2}{3\ (3 - 4)} = -5{,}33$$

Average time spent by a truck waiting in the queue:

$$Wq = \frac{\lambda}{\mu\ (\mu - \lambda)}$$

$$Wq = \frac{4}{3\ (3 - 4)} = -1{,}33\ jam = 79{,}8\ menit$$

Measuring the trade-off between the two costs is as follows:

a) Total Expected Cost of Service per period (E(Cs)):
   E(Cs) = S x Cs
   E(Cs) = 1 x IDR 11,700
   E(Cs) = IDR 11,700
b) Total Expected Waiting Cost per period (E(Cw)):
   E(Cw) = N x Cw
   E(Cw) = 4 x IDR 4,000
   E(Cw) = IDR 16,000
c) Total Expected Cost per period (E(Ct)):
   E(Ct) = E(Cs) + E(Cw)
   E(Ct) = IDR 11,700 + IDR 16,000
   E(Ct) = IDR 27,700

4.4. Queue Model at PT. Hakamindo Petro Chem After Service Improvement

The following is the calculation using the multi-channel queue system model (Multi Channel - Multi Phase):

Two Service Windows

M = 2 service windows
λ =4 trucks/hour
μ =3 trucks/hour

Probability of an empty system:

$$P_0 = \frac{1}{\sum_{n=0}^{M-1} \frac{\left(\frac{\lambda}{\mu}\right)^n}{(n)!} + \left(\frac{\left(\frac{\lambda}{\mu}\right)^M}{M!}\right) \frac{1}{1 - \frac{\lambda}{M.\mu}}}$$

$$P0 = \frac{1}{\sum_{n=0}^{2-1}\frac{\left(\frac{4}{3}\right)^n}{(n)!} + \left(\frac{\left(\frac{4}{3}\right)^2}{2!}\right)\frac{1}{1-\frac{4}{2.3}}}$$

$$P0 = \frac{1}{\left(\frac{\left(\frac{4}{3}\right)^0}{(0)!} + \frac{\left(\frac{4}{3}\right)^1}{(1)!}\right) + \left(\frac{\left(\frac{4}{3}\right)^2}{(2)!}\right)\frac{1}{1-\frac{4}{2.3}}}$$

$$P0 = \frac{1}{\left(1+\frac{4}{3}\right) + \left(\frac{\left(\frac{4}{3}\right)^2}{2}\right)\frac{1}{1-\frac{4}{6}}}$$

$$P_0 = \frac{1}{5} = 0.20$$

Average number of trucks in the system:

$$Ls = \frac{\lambda\mu\frac{\lambda}{\mu}^M}{M-1!\,(M\mu-\lambda)^2}P0 + \frac{\lambda}{\mu}$$

$$Ls = \frac{4.3\frac{4}{3}^2}{2-1!\,(2.3-4)^2}0{,}20 + \frac{4}{3}$$

$$Ls = 1.33$$

Average time spent by a truck in the system:

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

$$Ws = \frac{1.86}{4}$$

$$Ws = 0.465\,JAM = 27.9\,menit$$

Average number of trucks waiting in the queue:

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

$$Lq = 1.86 - \frac{4}{3}$$

$$Lq = 1.86 - 1.33 = 0.53$$

Average time spent by a truck waiting in the queue:

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

$$Wq = \frac{0.53}{4}$$

$$Wq = 0.1325\,JAM = 7.95\,menit$$

Measuring the trade-off between the two costs is as follows:

d) Total Expected Cost of Service per period (E(Cs)):
 E (Cs) = S X Cs
 E (Cs) = 2 X Rp 11,700
 E (Cs) = Rp 23,700

e) Total Expected Waiting Cost per period (E(Cw)):
 E (Cw) = nt X cw
 E (Cw) = 1.86 X Rp 4,000
 E (Cw) = Rp 7,440

f) Total Expected Cost per period (E(Ct)):
 E (Ct) = E (Cs) + E (Cw)
 E (Ct) = Rp 23,700 + Rp 7,440
 E (Ct) = Rp 31,140

Two Service Windows

M = 3 service windows
λ = 4 trucks/hour

μ = 3 trucks/hour

Probability of an empty system:

$$P0 = \frac{1}{\sum_{n=0}^{M-1} \frac{(\frac{\lambda}{\mu})^n}{(n)!} + (\frac{(\frac{\lambda}{\mu})^M}{M!}) \frac{1}{1 - \frac{\lambda}{M.\mu}}}$$

$$P0 = \frac{1}{\sum_{n=0}^{2-1} \frac{(\frac{4}{3})^n}{(n)!} + (\frac{(\frac{4}{3})^2}{2!}) \frac{1}{1 - \frac{4}{3.3}}}$$

$$P0 = \frac{1}{\left(\frac{\left(\frac{4}{3}\right)^0}{(0)!} + \frac{\left(\frac{4}{3}\right)^1}{(1)!}\right) + \left(\frac{\left(\frac{4}{3}\right)^2}{(2)!}\right) + \left(\frac{\left(\frac{4}{3}\right)^3}{(3)!}\right) \frac{1}{1 - \frac{4}{3.3}}}$$

$$P0 = \frac{1}{\left(1 + \frac{4}{3}\right) + \left(\frac{\left(\frac{4}{3}\right)^2}{2}\right) + \left(\frac{\left(\frac{4}{3}\right)^3}{6}\right) \frac{1}{1 - \frac{4}{9}}}$$

$$P0 = \frac{1}{3.91} = 0.25$$

Average number of trucks in the system:

$$Ls = \frac{\lambda\mu \frac{\lambda}{\mu}^M}{M - 1!\,(M\mu - \lambda)^2} P0 + \frac{\lambda}{\mu}$$

$$Ls = \frac{4.3 \frac{4}{3}^3}{3 - 1!\,(3.3 - 4)^2} 0.25 + \frac{4}{3}$$

$$Ls = \frac{0,14}{1.33} = 1.47$$

Average time spent by a truck in the system:

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

$$Ws = \frac{1.47}{4}$$

$$Ws = 0.3675\, jam = 22.05\, menit$$

Average number of trucks waiting in the queue:

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

$$Lq = 1,47 - \frac{4}{3}$$

$$Lq = 1.47 - 1.33 = 0.14$$

Average time spent by a truck waiting in the queue:

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

$$Wq = \frac{0.14}{4} = 0.035\, jam = 2.1\, menit$$

Measuring the trade-off between the two costs is as follows:

g) Total Expected Cost of Service per period (E(Cs)):
   E (Cs) = S X Cs
   E (Cs) = 3 X Rp 11,700
   E (Cs) = Rp 35,100

h) Total Expected Waiting Cost per period (E(Cw)):
   E (Cw) = nt X cw
   E (Cw) = 1.47 X Rp 5,900
   E (Cw) = Rp 5,880

i) Total Expected Cost per period (E(Ct)):
   E (Ct) = E (Cs) + E (Cw)
   E (Ct) = Rp 35,100 + Rp 5,900
   E (Ct) = Rp 41,000

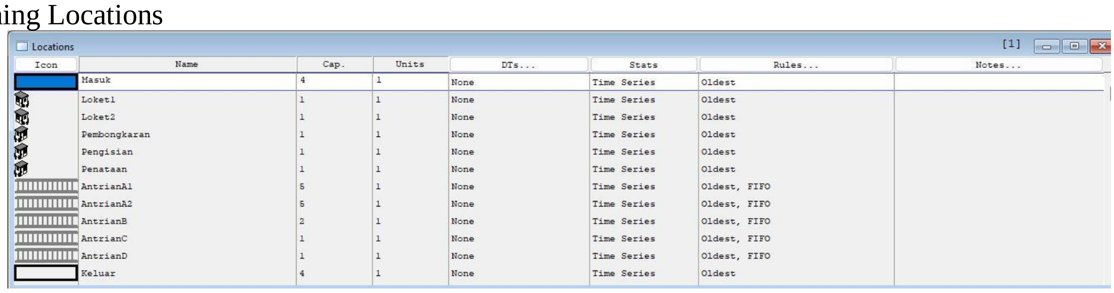
Table 3: Summary of Results for Each Service Window

Queue Characteristic	Window 1	Window 2	Window 3
P0	-0.33	0.20	0.25
Ls	-4	1.86	1.47
Ws	60 menit	27.9 menit	2.05 menit
Lq	-5.33	0.53	0.14
Wq	79.8 menit	7.95 menit	2.1 menit
E (Cs)	Rp 11,700	Rp 23,700	Rp 35,100
E (Cw)	Rp 16,000	Rp 7,440	Rp 5,900
E (Ct)	Rp 27,700	Rp 31,140	Rp 41,000
P0	-0.33	0.20	0.25

4.5. Model Implementation

The queue simulation model at the SPPBE of PT. Hakamindo Petro Chem uses ProModel. Several main components used are Locations, which are used for define the LPG filling stations as the places where the service process takes place. Entities represent the vehicles or trucks that arrive to fill LPG. Arrivals describe the entry of vehicles into the system at predetermined times, and Processings describe the LPG filling process carried out at the defined locations. Furthermore, several Control Statements are used in the simulation, including Wait to hold entities in a process for a certain period until a certain condition is met, and Move For to move entities from one location to another location at a certain time. The implementation of the simulation model on the queue system at the SPPBE of PT. Hakamindo Petro Chem is shown in Figures 9, 10, and 11 below:

1) Defining Locations



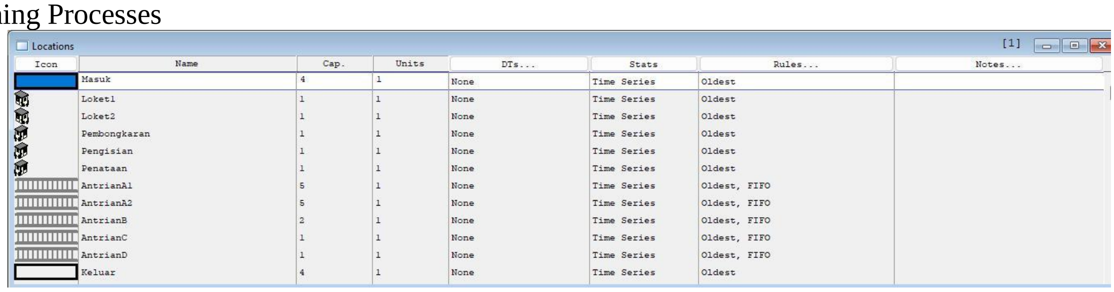
Locations

Icon	Name	Cap.	Units	DTs...	Stats	Rules...	Notes...
	Masuk	4	1	None	Time Series	Oldest	
	Loket1	1	1	None	Time Series	Oldest	
	Loket2	1	1	None	Time Series	Oldest	
	Pembongkaran	1	1	None	Time Series	Oldest	
	Pengisian	1	1	None	Time Series	Oldest	
	Penataan	1	1	None	Time Series	Oldest	
	AntrianA1	5	1	None	Time Series	Oldest, FIFO	
	AntrianA2	5	1	None	Time Series	Oldest, FIFO	
	AntrianB	2	1	None	Time Series	Oldest, FIFO	
	AntrianC	1	1	None	Time Series	Oldest, FIFO	
	AntrianD	1	1	None	Time Series	Oldest, FIFO	
	Keluar	4	1	None	Time Series	Oldest	

Figure 9: ProModel Layout

a) AntrianA, AntrianB, AntrianC, AntrianD are locations where vehicles wait before entering the service station. Using the FIFO rule with varying capacities, recording the waiting time of vehicles.
b) Pembongkaran (Unloading) is the initial location for the administrative and preparation process. Capacity 1, only serves one vehicle at a time, with service time recorded using Time Series.
c) Pengisian (Filling) is the service location for LPG filling. Capacity 1, serves one vehicle at a time, and records the processing time.
d) Penataan (Weighing) is the service location for arrangement after the filling process. Capacity 1 with process time recording to ensure the vehicle is ready to leave the location.
e) Masuk (Entry) serves as the initial entry point for vehicles into the service system. Capacity 4 with recording of vehicle arrival times.
f) Keluar (Exit) serves as the final exit point of the system, the location where vehicles leave after all processes are complete with a capacity of 4.

2) Defining Processes



Locations

Icon	Name	Cap.	Units	DTs...	Stats	Rules...	Notes...
	Masuk	4	1	None	Time Series	Oldest	
	Loket1	1	1	None	Time Series	Oldest	
	Loket2	1	1	None	Time Series	Oldest	
	Pembongkaran	1	1	None	Time Series	Oldest	
	Pengisian	1	1	None	Time Series	Oldest	
	Penataan	1	1	None	Time Series	Oldest	
	AntrianA1	5	1	None	Time Series	Oldest, FIFO	
	AntrianA2	5	1	None	Time Series	Oldest, FIFO	
	AntrianB	2	1	None	Time Series	Oldest, FIFO	
	AntrianC	1	1	None	Time Series	Oldest, FIFO	
	AntrianD	1	1	None	Time Series	Oldest, FIFO	
	Keluar	4	1	None	Time Series	Oldest	

Figure 10: ProModel Process Layout

Vehicles enter the system through Masuk (Entry) without waiting time, then proceed to AntrianA before Loket (Window) (waiting time 5 minutes). After that, to AntrianB before Pembongkaran (Unloading) (8 minutes). Next, vehicles go to AntrianC for the Pengisian (Filling) process (17 minutes), then to AntrianD before Penataan (Weighing) (10 minutes). After completion, vehicles exit through Keluar (Exit) (10 seconds).

3) Queue Simulation in ProModel

Locations [1]

Icon	Name	Cap.	Units	DTs...	Stats	Rules...	Notes...
	Masuk	4	1	None	Time Series	Oldest	
	Loket1	1	1	None	Time Series	Oldest	
	Loket2	1	1	None	Time Series	Oldest	
	Pembongkaran	1	1	None	Time Series	Oldest	
	Pengisian	1	1	None	Time Series	Oldest	
	Penataan	1	1	None	Time Series	Oldest	
	AntrianA1	5	1	None	Time Series	Oldest, FIFO	
	AntrianA2	5	1	None	Time Series	Oldest, FIFO	
	AntrianB	2	1	None	Time Series	Oldest, FIFO	
	AntrianC	1	1	None	Time Series	Oldest, FIFO	
	AntrianD	1	1	None	Time Series	Oldest, FIFO	
	Keluar	4	1	None	Time Series	Oldest	

Figure 11: ProModel Simulation Layout

The ProModel simulation represents the queue system at the SPPBE of PT. Hakamindo Petro Chem, including areas such as Masuk (Entry), Antrian (Queue), Loket (Window), Pembongkaran (Unloading), Pengisian (Filling), Penataan (Weighing), and Keluar (Exit). This simulation is used to determine and analyze the flow efficiency and queues at the SPPBE of PT. Hakamindo Petro Chem. With ProModel, simulations are carried out to identify problems and design improvements to the system.

5. Conclussion

From the queue analysis results, it can be concluded that queues occur because the arrival rate is higher than the service rate. Using 2 open service windows is able to increase service efficiency at the SPPBE. Meanwhile, increasing the number of windows to 3 can indeed further increase efficiency, but the additional costs required are not proportional to the increase obtained. The suggestions that can be given are as follows.

a) The service time for each stage (phase) needs to be recorded in detail to facilitate the determination of critical stages in the service.
b) Recording when service times deviate significantly from the average, because service is carried out by humans, so service is certainly not free from errors (human error).

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