International Journal of Academic and Applied Research (IJAAR)
ISSN: 2643-9603
Vol. 9 Issue 6 June - 2025, Pages: 147-153

Simulation Analysis of the M/M/c Queueing Model in the Service System of Indomaret Fresh Dharmahusada Surabaya Indonesia

Doni Muhammad Fauzi[1], Nathania Fauziah[2], Adelia Sukma Dwiyanto[3], Galang Mahardika Candra Pratama[4], Toha Saifudin[5]

[1,2,3,4,5]Statistics Study Program, Department of Mathematics, Faculty of Science and Technology
Airlangga University
Surabaya, Indonesia
Corresponding author: tohasaifudin@fst.unair.ac.id

Abstract: *Indomaret has become one of the most frequently visited places by people every day to meet their household needs. When shopping at such popular places, customers often have to wait in line before making their payment. Long queues often result in customers having to wait for a considerable amount of time. Therefore, a queue simulation study was conducted to analyze the service system at Indomaret Fresh Dharmahusada Surabaya. The data used in this study were obtained through direct observation on May 26, 2025, between 15:31 and 16:39 WIB. The data collected include the time intervals between customer arrivals and the duration of transactions at the cashier. The study utilized both R software and manual calculations to analyze the observed data. Based on the results, it can be concluded that the queuing system at Indomaret Fresh Dharmahusada Surabaya follows the (M/M/2):(FCFS/∞/∞) model, with an average interarrival time of 0.5983 and an average service time of 0.7371. The probability of zero customers in the queue is 0.425616, the average number of customers in the system is 0.97284, the expected time in the system is 1.735218, and the server utilization rate is 40.58%. The results of this analysis are expected to provide concrete recommendations to improve the efficiency and quality of service at the local Indomaret store.*

Keywords—Indomaret, FCFS, M/M/c, Queue Simulation

1. INTRODUCTION

In daily life, shopping activities have become an inseparable part of people's routines. Minimarkets such as Indomaret Fresh, which are spread across various corners of the city, have emerged as a practical solution to meet consumer needs quickly and conveniently [1]. Kehadiran minimarket tidak hanya menawarkan kenyamanan The presence of minimarkets not only offers convenience but also reflects the fast-paced and efficient lifestyle of urban communities. However, as public mobility increases and daily activities become more hectic, customer service challenges have become more complex, particularly in terms of queue management.

Long queues that are not properly managed often cause discomfort for customers [2]. Extended waiting times at the cashier, especially during peak hours or weekends, can lead to frustration that affects customer satisfaction and loyalty. In this context, service efficiency is no longer merely an added value but a crucial requirement for businesses to remain competitive and appealing.

Indomaret Fresh in Dharmahusada, Surabaya, is one of the most frequently visited branches due to its strategic location and wide variety of products offered. However, the high number of visitors can lead to crowding and long queues at the cashier area [3]. This phenomenon is worth further investigation, as effective queue management not only enhances customer comfort but also reflects the quality of operational management in a retail business.

A previous study on queue simulation was conducted at Indomaret Darmo, Surabaya, by [4], which found that the service duration ranged from 4.48 to 5.128 minutes, and the average waiting time ranged from 3.974 to 5.505 minutes. In addition, the analysis showed that the average, median, mode, and standard deviation of idle time were all zero (less than one minute). This indicates that there was virtually no idle time in the service process at Indomaret Darmo, Surabaya. This study focused only on a single cashier, despite the presence of multiple cashiers, and therefore used a single channel single phase system

Furthermore, another study by [5] examined customer satisfaction with Indomaret's service using the Servqual method and Importance Performance Analysis (IPA). The study found an overall satisfaction level of 85.77 percent, which falls into the very satisfied category. However, this research was solely based on customer perceptions and opinions collected through questionnaires, and did not evaluate the system's performance quantitatively or operationally, such as wait time or service time.

Therefore, this study offers a novelty by employing an M/M/c queue system simulation at Indomaret Fresh

Dharmahusada, Surabaya. The M/M/c queue model is used to analyze the service system by considering the number of available servers [6]. Through this simulation, the study aims to evaluate waiting time and the number of customers in the queue. The results of the analysis are expected to provide concrete recommendations to improve efficiency and service quality, especially in high-traffic locations such as Indomaret Fresh Dharmahusada, Surabaya.

2. LITERATURE REVIEW

2.1 Indomaret Fresh

Indomaret Fresh is an expansion of the Indomaret retail network that offers a wide range of daily necessities, including food, beverages, household supplies, as well as fresh products such as fruits, vegetables, and ready-to-eat meals [7]. Therefore, Indomaret Fresh provides a more comprehensive selection compared to regular minimarkets. By the end of 2023, PT Indomarco Prismatama had recorded more than 1,000 Indomaret Fresh outlets across major cities in Indonesia, particularly in densely populated areas [8]. Indomaret, including Indomaret Fresh, has captured 36.1 percent of the modern retail market share in Indonesia, making it the market leader in the convenience store category in the country [9].

2.2 Queuing Theory

A queueing system is a mechanism that consists of customers, servers, and a set of rules that govern the arrival and service processes. Its three main elements include customers as the recipients of service, servers as the providers of service, and the rules that determine the order and method of service delivery [10]. The purpose of queueing theory is to understand queue formation, resource utilization, and ways to improve system performance [11]. Through this theory, it is possible to analyze waiting times, determine the required number of servers, design optimal systems, and enhance both efficiency and customer satisfaction. In the context of modern retail such as minimarkets, the application of queueing theory helps management understand customer arrival patterns, service durations, and factors that affect operational efficiency [12]. Effective queue management not only improves customer comfort and satisfaction, but also has a direct impact on the productivity and smooth operation of the minimarket as a whole.

2.3 M/M/c Simulation

The M/M/c queueing system, also known as a multi-server queueing model, is a system in which two or more service channels or service stations are available to handle incoming customers [13]. In this system, customers form a single queue and are served by the first available service station. Customer arrivals follow a Poisson distribution, which means the interarrival times are random and follow a negative exponential distribution. Similarly, service times are assumed to follow a negative exponential distribution, reflecting the randomness in service duration. The optimization of the M/M/c queueing system aims to improve service efficiency, minimize waiting times, and ultimately enhance customer satisfaction. The calculations involved in the M/M/c queueing system are explained as follows:

1. Average arrival rate per time unit

$$\lambda = \frac{\text{Number of Arrivals}}{\text{Observation Time}} \quad (1)$$

2. Average number of customers served per time unit

$$\frac{1}{\mu} = \frac{\text{Service Time}}{\text{Number of Customers Served}} \quad (2)$$

3. Probability of idle time(P_0)

   Idle time is an indicator that shows the opportunity when there are no customers in the system, or when all cashiers are not serving transactions. This value is important to evaluate how efficiently the cashier is utilized in store operations.

$$P_o = \left(\sum_{k=0}^{c-1} \frac{(\lambda/\mu)^k}{k!} + \frac{(\lambda/\mu)^c}{c!\,(1-\rho)}\right)^{-1} \quad (3)$$

   Where c is the number of cashiers.

4. Expected number of customers in the queue (L_q)

$$L_q = \frac{\rho_0 \left(\frac{\lambda}{\mu}\right)^2 \rho}{c!\,(1-\rho)^2} \quad (4)$$

   L_q states the average number of customers waiting in the queue.

5. Customer’s expected time while waiting in queue (W_q)

$$W_q = \frac{L_q}{\lambda} \quad (5)$$

   W_q represents the average time a customer spends waiting before being served.

6. Time expected by customers in the system (W_s)

$$W_s = W_q + \frac{1}{\mu} \quad (6)$$

   W_s combines waiting time and service time to show how long the average customer is in the system.

7. The average number of customers expected in the system (L)

$$L = L_q + \frac{\lambda}{\mu} \tag{7}$$

L states how many customers are in the system on average, either being served or waiting

8. System utilization rate (ρ)

$$\rho = \frac{\lambda}{c.\mu} \tag{8}$$

Utilization shows how much system capacity (cashiers) is used to serve customers. This value is important to measure operational efficiency.

2.4 Exponential Distribution

The exponential probability distribution is one type of continuous distribution that is often used because of its ease of estimation. This distribution only requires information on the population mean as the main parameter, because the value of the standard deviation is equal to the mean value [14]. A continuous random variable X is said to follow an exponential distribution with parameter $\theta > 0$ if it has a cumulative distribution function of the following form.

$$f(x;\theta) = \begin{cases} \frac{1}{\theta} e^{-\frac{x}{\theta}} & ; x > 0 \\ 0 & ; other \end{cases} \tag{9}$$

With θ being the scale parameter. The cumulative distribution function is as follows.

$$F(x;\theta) = \begin{cases} 1 - e^{-\frac{x}{\theta}} & ; x > 0 \\ 0 & ; other \end{cases} \tag{10}$$

3. RESEARCH METHODOLOGY

3.1 Data and Data Source

In this study, the data used was primary data obtained directly from observations in the field at Indomaret Fresh Dharmahusada Surabaya. The observation was conducted on May 26, 2025, for 1 hour, from 3:31 PM to 4:39 PM and 41 data points were obtained. Based on the assumption that customer service time follows an exponential distribution, a distribution test will be conducted using the Kolmogorov-Smirnov test.

3.2 Research Stages and Algorithms

The research stages used are as follows.

1. Conducting a literature review related to the research topic, both in terms of case studies and the methods used.
2. Conducting direct observations to collect data on interarrival times and service times at the Indomaret Fresh Dharmahusada Minimarket in Surabaya.
3. Analyzing data using the M/M/c queueing simulation method with 2 servers.

The following is the algorithm used in the program for queue simulation at the Indomaret Fresh Dharmahusada Surabaya minimarket:

1. The **simulate_MMc** function was created using the R programming language and serves to simulate a queueing system with an M/M/c model, which is a system with arrivals and service following an exponential distribution and involving more than one server. This function accepts three main parameters: **num_servers**, which represents the number of available servers; **interarrival_time**, which is a vector of the time between customer arrivals; and **service_time**, which is a vector of the service time for each customer.
2. The number of customers n is determined based on the length of the **interarrival_time** vector, then a data frame named **data** is created containing the initial information for each customer, such as customer sequence number (**cust**), inter-arrival time (**int_arr**), service time (**serv_time**), actual arrival time (**arrival**) calculated by the cumulative sum of **interarrival_time**, and empty columns for **inserver, start_serv, end_serv, wait**, and **sys_time** that will be filled during the simulation process.
3. Two vectors are initialized: **server_available_time**, which indicates when each server will become available again, and **server_busy_time**, which stores the total time each server is used to serve customers. Both vectors are initially set to zero for all servers.
4. The simulation is performed by iterating from index **1** to **n**, where each customer is processed one by one. In each iteration, the arrival time of customer i is taken from the data, then the fastest available server is found using the **which.min(server_available_time)** function. The customer is then assigned to the relevant server.
5. The start of service time is calculated as the maximum value between the customer arrival time and the server availability time. Based on the start of service time and the service duration, the end of service time (**end_serv**), the customer wait time in the queue (**wait**), and the total time the customer spends in the system (**sys_time**) are calculated. After that, the server availability and workload information is updated.
6. After all customers have been processed, the total simulation time is calculated as the last service completion time of all customers, i.e., the maximum value from the **end_serv** column in the data frame.
7. Various queue system performance parameters are then calculated, including the average customer service time

(**rata.wt**), average waiting time in the queue (**rata.wa**), and average time the customer spends in the system (**rata.ws**). Additionally, the average number of customers being served (**rata.custinser**), the average number of customers in the queue (**rata.custqing**), the average number of customers in the system (**rata.custinsys**), and the occupancy rate of each server are also calculated.

8. All calculation results and simulation data are then stored in a list named **summary**, which includes the simulation results data frame along with the previously calculated system performance parameter values.

4. RESULTS AND DISCUSSION

4.1 Description of Observation Data

The data used in this study is primary data observed directly by researchers at Indomaret Fresh Dharmahusada Surabaya. Observations were made on May 26, 2025 for 68 minutes, namely from 15.31 to 16.39 WIB and 41 data were obtained. The research data is presented in Table 1.

Table 1: Research Data

Interarrival Time	*Service Time*
0,00	1,02
0,62	1,12
1,47	0,42
⋮	⋮
0,53	1,08

4.2 Interarrival Exponential Distribution Suitability Test

This research was conducted using the exponential distribution test to determine the performance of the queuing system applied to cashiers at Indomaret Fresh Surabaya. To find out whether the Interarrival data is exponentially distributed or not, a suitability test is carried out using the Kolmogorov-Smirnov test with the following hypothesis formulation.

H_0 : interarrival data is exponentially distributed

H_1 : interarrival data is not exponentially distributed

After conducting the Kolmogorov-Smirnov test, the result shows that the p-value is 0.9980578 which is greather than the significance level ($\alpha = 0.05$) with a decision to fail to reject H_0 so it is concluded that the interarrival data is exponentially distributed with λ of 0.59827. The following histogram of the Interarrival time data is presented in Figure 1.

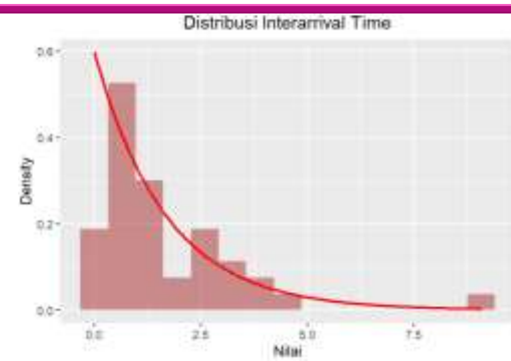

Fig. 1. *Interarrival Data Histogram*

4.3 Test Distribution Suitability of Transaction Length

The transaction length at the Indomaret Fresh Surabaya cashier is assumed to be exponentially distributed. To test buyer service, the Kolmogorov-Smirnov test is carried out with the following hypothesis formulation.

H_0 : length of transaction data is exponentially distributed

H_1 :length of transaction data is not exponentially distributed

After conducting the Kolmogorov-Smirnov test, result shows that the p-value is 0.06051 which is greather than the significance level ($\alpha = 0.05$) with a decision to fail to reject H_0 so that it is concluded that the transaction length data is exponentially distributed with μ of 0.7371. The following histogram of service time data is presented in Figure 2.

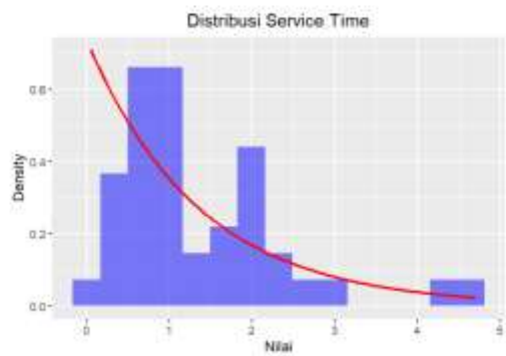

Fig. 2. *Histogram of Transaction Length Data*

4.4 Steady State Testing

Steady state has a measure where the system busyness level $= \lambda\ \mu < 1$. If $\lambda < \mu$ which means $\rho < 1$ indicates the arrival rate is smaller than the service rate, this steady state has been met. However, if $\rho > 1$ or $\rho = 1$ it is necessary to increase the number of servers or speed up service. The following analyzes the average number of arrivals, average service time, and load ratio to determine the steady state condition.

The average number of buyer arrivals at Indomaret Fresh Dharmahusada is as follows.

$$\lambda = \frac{number\ of\ arrivals}{length\ of\ observation\ time}$$

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$\lambda = \frac{41}{68,53}$

$\lambda = 0,5983$ customers per minute

The average length of service time at Indomaret Fresh Dharmahusada is as follows.

$\frac{1}{\mu} = \frac{length\ of\ service\ time}{number\ of\ customers\ served}$

$\frac{1}{\mu} = \frac{55,62}{41}$

$\frac{1}{\mu} = 1,3566$ minutes per customer

The queue load ratio value at Indomaret Fresh Dharmahusada is as follows.

$\rho = \frac{\lambda}{c\,\mu}$

$\rho = \frac{0,59827}{2} \times 1,3566$

$\rho = 0,4058$

Based on the results of these calculations, the ρ value of 0.4058 is obtained, which means that the ratio between the arrival rate and the system service capacity or system utility is 40.58%. Since the value of $\rho < 1$, it can be concluded that the arrival rate and service time reach a steady state condition.

4.5 Indomaret Fresh Queue Model and Simulation

Based on the results of the exponential distribution fit test on the interarrival time and service time, the queue model that has been observed can be determined. The queuing system model used at Indomaret Point Dharmahusada follows the Multi Channel Single Phase form with the number of service facilities (servers) as many as 2 cashiers. The queue used is First Come First Served (FCFS), which means that customers who queue first will be served first. In this study, it is assumed that the system capacity and call sources are infinite. Thus, the queuing system model formed at Indomaret Fresh Dharmahusada Surabaya is the (M/M/2) queuing model : (FCFS/∞/∞). The following Table 2 simulation results of the queue model at Indomaret Fresh Dharmahusada Surabaya with a case study of 41 visitors.

Table 2: Queue Simulation Results of Observed Data

cust	int_arr	serv_time	arrival	inserver	mulai_serv	end_serv	wait	sys_time
1	0.00	1.02	0.00	1	0.00	1.02	0.00	1.02
2	0.62	1.12	0.62	2	0.62	1.74	0.00	1.12
3	1.47	0.42	2.09	1	2.09	2.51	0.00	0.42
4	0.80	1.03	2.89	2	2.89	3.92	0.00	1.03
5	0.78	2.05	3.67	1	3.67	5.72	0.00	2.05
6	0.27	0.05	3.94	2	3.94	3.99	0.00	0.05
7	0.33	0.53	4.27	2	4.27	4.80	0.00	0.53
8	0.55	1.68	4.82	2	4.82	6.50	0.00	1.68
9	1.42	0.62	6.24	1	6.24	6.86	0.00	0.62
10	2.70	0.55	8.94	2	8.94	9.49	0.00	0.55
11	0.17	1.05	9.11	1	9.11	10.16	0.00	1.05
12	2.23	1.52	11.34	2	11.34	12.86	0.00	1.52
13	3.52	0.85	14.86	1	14.86	15.71	0.00	0.85
14	3.47	1.93	18.33	2	18.33	20.26	0.00	1.93
15	0.63	0.73	18.96	1	18.96	19.69	0.00	0.73
16	2.47	0.47	21.43	1	21.43	21.90	0.00	0.47
17	3.85	1.08	25.28	2	25.28	26.36	0.00	1.08
18	9.08	1.17	34.36	1	34.36	35.53	0.00	1.17
19	0.35	2.12	34.71	2	34.71	36.83	0.00	2.12
20	1.98	0.52	36.69	1	36.69	37.21	0.00	0.52
21	1.50	1.73	38.19	2	38.19	39.92	0.00	1.73
22	0.58	1.85	38.77	1	38.77	40.62	0.00	1.85
23	2.32	0.33	41.09	2	41.09	41.42	0.00	0.33
24	0.00	0.52	41.09	1	41.09	41.61	0.00	0.52
25	1.40	4.70	42.49	2	42.49	47.19	0.00	4.70
26	1.62	0.73	44.11	1	44.11	44.84	0.00	0.73
27	2.72	0.70	46.83	1	46.83	47.53	0.00	0.70
28	0.17	2.17	47.00	2	47.19	49.36	0.19	2.36
29	4.53	1.15	51.53	1	51.53	52.68	0.00	1.15
30	2.92	4.42	54.45	2	54.45	58.87	0.00	4.42
31	0.73	0.53	55.18	1	55.18	55.71	0.00	0.53
32	3.77	3.01	58.95	1	58.95	61.96	0.00	3.01
33	0.90	1.97	59.85	2	59.85	61.82	0.00	1.97

cust	int_arr	serv_time	arrival	inserver	mulai_serv	end_serv	wait	sys_time
34	0.40	0.45	60.25	2	61.82	62.27	1.57	2.02
35	0.45	2.32	60.70	1	61.96	64.28	1.26	3.58
36	0.50	1.43	61.20	2	62.27	63.70	1.07	2.50
37	1.33	1.00	62.53	2	63.70	64.70	1.17	2.17
38	2.62	2.74	65.15	1	65.15	67.89	0.00	2.74
39	1.23	1.89	66.38	2	66.38	68.27	0.00	1.89
40	1.62	0.40	68.00	1	68.00	68.40	0.00	0.40
41	0.53	1.08	68.53	2	68.53	69.61	0.00	1.08

From the results of the observed data queue simulation process, visually the number of customers in the system over time is presented in Figure 3. below.

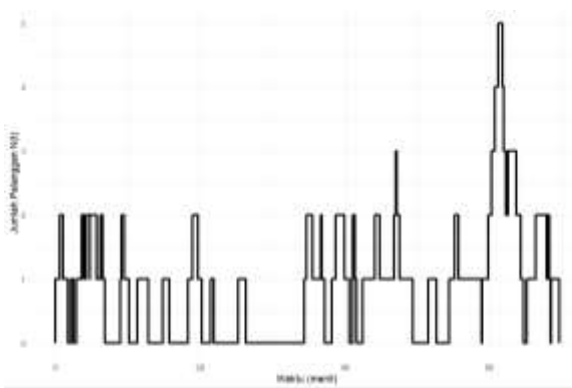

Fig. 3. *Number of Customers in the System Over Time*

4.6 Indomaret Fresh Queue Model Calculation Analysis

1. The chances of there being no customers in the system are as follows.

$$P_o = \left(\sum_{k=0}^{c-1} \frac{(\lambda/\mu)^k}{k!} + \frac{(\lambda/\mu)^c}{c!\,(1-\rho)}\right)^{-1}$$

$$P_o = \left(\sum_{k=0}^{2-1} \frac{(0{,}5983/0{,}7371)^k}{k!} + \frac{(0{,}5983/0{,}7371)^2}{2!\,(1-0{,}4058)}\right)^{-1}$$

$$P_0 = (1{,}81169 + 0{,}537845)^{-1}$$

$$P_0 = 0{,}425616$$

This means that there is a 42.56% chance that there are no customers at all in the system, either in the queue or being served.

2. Expected number of customers in queue (L_q)

$$L_q = \frac{P_0 \left(\frac{\lambda}{\mu}\right)^2 \rho}{c!\,(1-\rho)^2}$$

$$L_q = \frac{(0{,}425616)\left(\frac{0{,}5983}{0{,}7371}\right)^2 (0{,}4058)}{2!\,(1-0{,}4058)^2}$$

$$L_q = 0{,}161146$$

This means that on average, there are about 0.16 customers waiting in the queue.

3. Expected waiting time in queue (W_q)

$$W_q = \frac{L_q}{\lambda} = \frac{0{,}161146}{0{,}425616} = 0{,}378618$$

This means that the average customer only has to wait about 0.38 minutes before being served.

4. Expected number of customers in the system (L)

$$L = L_q + \frac{\lambda}{\mu} = 0{,}161146 + \frac{0{,}5983}{0{,}7371} = 0{,}97284$$

The average number of customers in the system (both waiting and being served) is about 0.97, meaning that there is rarely more than one customer in the system at a time.

5. Expected time in system (W_s)

$$W_s = W_q + \frac{1}{\mu} = 0{,}378618 + 1{,}3566 = 1{,}735218$$

A customer will spend an average of about 1.74 units of time in the system, which includes waiting time and service time. Where based on the results of the waiting time calculation, most of the time in this system is spent on the service process itself.

6. Percentage of server utilization

$$\rho = 0{,}4058 \times 100\% = 40{,}58\%$$

This means that each server is only used about 40.58% of the total operating time, indicating that the server still has a large enough capacity to serve additional customers without causing long queues. The system is still in a stable condition because $\rho < 1$ so there will be no queues that continue to grow indefinitely.

5. CONCLUSION

Based on the analysis that has been done, it is concluded that the interarrival and transaction duration are exponentially distributed with λ of 0.5983 and μ of 1.3566. Thus, the queue model is obtained (M/M/2):(FCFS/∞/∞) with a chance that there are no customers of 0.425616, the expected number of customers in the queue is 0.161146, the expected waiting time in the queue is 0.378618, the expected number of customers in the system is 0.97284, the expected time in the system is 1.735218, and the percentage of server utilization is 40.58% which shows the system is in a stable condition because $\rho < 1$ so that there will be no queue that continues to grow indefinitely. The queue model used in this study is the (M/M/2) model: (FCFS/∞/∞) model. For researchers who want to try to apply the Multi Channel Single Phase queuing structure, they can apply it with a different model. The data used in the study is data that has reached a stable condition. For researchers with the same queuing model can use data that has not been stabilized (has not reached steady-state).

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