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Analysis of Gas Station Queue System; Case Study of Gas Station 13.201.101 on Jalan Jamin Ginting, Medan Baru District, Medan City

Johana Sihol Marito Purba[1] , Roberta Simarmata[2], Mayono Suko Marbinoto[3]

[1,2,3]Institut Sains & Teknologi TD. Pardede (ISTP Medan). Indonesia.

Corespodence: johanasima@gmail.com[1]

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ABSTRACT

Public Fuel Filling Stations (SPBU) are essential facilities that support transportation by ensuring the availability of fuel for motorized vehicles. However, long queues, particularly during peak hours, often cause traffic congestion, wasted time, and reduced customer satisfaction. These inefficiencies are generally linked to limited service capacity and uneven workload distribution among fuel pumps. This study aims to analyze the queuing system at Gas Station 13.201.101, Jalan Jamin Ginting, Medan, using the M/M/s queuing model and simulation with Arena software. Data were collected through direct observation of vehicle arrivals and service times for motorcycles and cars. Statistical tests, including chi-square and Kolmogorov-Smirnov, were applied to determine the best fit for inter-arrival and service time distributions, which followed exponential and beta distributions, respectively. The results indicate that motorcycles had an average inter-arrival time of 3.8 minutes and a service time of 3.3 minutes, while cars averaged 5.5 minutes between arrivals with 5.9 minutes of service. The theoretical M/M/s analysis showed relatively efficient performance, with less than one minute of waiting time and pump utilization ranging between 32% and 70%. In contrast, Arena simulation reflected real operational conditions more accurately, showing no waiting lines but revealing uneven distribution of workload among pumps, with some exceeding 70% utilization while others remained low. These findings highlight that while the system is generally efficient, improvements in vehicle routing and pump allocation are necessary. Recommendations include optimizing station layout, operator training, and adopting automated distribution systems to enhance efficiency and customer satisfaction.

Keyword: Queuing System, Arena Simulation, Service Performance

INTRODUCTION

Public Fuel Filling Stations (SPBUs) are vital facilities that play a central role in sustaining mobility and ensuring the smooth operation of transportation systems. Beyond merely providing fuel for motorized vehicles, SPBUs are an integral part of public service infrastructure that supports both economic and social activities. The increasing number of vehicles, especially in densely populated urban areas, has significantly raised the demand for fuel services. This situation often creates operational challenges, most notably long queues at SPBUs, particularly during peak hours, which disrupt service efficiency and reduce customer satisfaction (Nasir & Andesta, 2024; Teimoury et al., 2011; Qamari & Trizula, 2022).

Vehicle queues at fuel stations are not only associated with prolonged waiting times but also have wider implications, such as traffic congestion around the station, wasted time, and customer dissatisfaction. The imbalance between service capacity and fluctuating demand has been identified as one of the primary causes of this inefficiency (Pellondou et al., 2021; Galankashi & Fallahiarezoudar, 2015). In addition, previous research has shown that queuing inefficiencies can significantly affect customer perceptions and evaluations of service, making effective management of waiting lines critical to sustaining user satisfaction (Taylor, 1994; Katz et al., 1991). Consequently, analyzing queuing systems is an essential approach to identify the sources of inefficiency, quantify performance, and propose solutions supported by empirical evidence (Little, 1961; Kendall, 1953; Jackson, 1957).

The urgency of addressing queuing issues at SPBUs is reinforced by the high dependency of Indonesian society on motorized vehicles, both two-wheeled and four-wheeled. In cities such as Medan, the demand for fuel services often exceeds the available capacity, resulting in service bottlenecks. This mismatch not only reduces the quality of public services but also poses significant challenges for maintaining transportation efficiency and customer satisfaction, which are critical indicators of modern service delivery (Farhan et al., 2013; Li et al., 2017). Moreover, international studies demonstrate that simulation and queuing models can effectively optimize layout, allocate resources, and improve flow management in service facilities, including petrol stations (Amjath, 2024; Jones et al., 2025).

In academic literature, queuing theory has been widely applied to analyze public services, including banking, healthcare, transportation, and fuel distribution systems. Mathematical models such as M/M/1 and M/M/s are commonly employed to measure the performance of queuing systems, particularly in contexts where arrival rates follow a Poisson distribution and service times are exponentially distributed (Manalu & Palandeng, 2019; Helbing, 1998; Li & Lui, 2014). However, many of these studies remain generalized and fail to capture the complexities of operational realities at urban fuel stations with mixed traffic characteristics. To overcome these limitations, simulation-based approaches, such as Arena, have been increasingly used to complement theoretical models and provide a more realistic representation of operational performance (Fuad & Putra, 2020; Tavafoghi et al., 2019).

Previous research on fuel station queuing systems has demonstrated diverse methodological approaches. For example, some studies applied simulation to evaluate queuing performance at SPBUs in Serang, while others examined queuing in motorcycle lanes at SPBUs in Oebobo. Nevertheless, few studies have integrated theoretical queuing models with simulation-based approaches to compare mathematical predictions with actual operational performance, highlighting the need for empirical studies that provide context-specific insights and practical recommendations for fuel station management (Hanggara & Putra, 2020; Pellondou et al., 2021).

This article addresses the issue by focusing on Gas Station 13.201.101, located on Jalan Jamin Ginting, Medan Baru District, Medan. The site was chosen due to its strategic location, serving both local residents and intercity traffic, which results in consistently high demand. Field observations show irregular vehicle arrival patterns and varying service times, leading to congestion and queues during peak periods. Such conditions demonstrate the importance of evaluating the queuing system to improve efficiency and reduce negative externalities (Fuad & Putra, 2020; Galankashi & Fallahiarezoudar, 2015).

The urgency of this research also stems from the need to design more effective operational strategies for SPBUs. By understanding empirical patterns of vehicle arrivals and service durations, managers can implement improvements such as adding fuel dispensers, reorganizing service lanes, or enhancing staff training to optimize vehicle distribution across pumps. Data-driven analysis thus plays a crucial role in identifying practical interventions to improve customer experience and system efficiency (Nasir & Andesta, 2024; Li et al., 2017).

The approach adopted in this study combines the theoretical M/M/s queuing model with simulation using Arena software. The M/M/s model provides a mathematical framework to evaluate key performance indicators such as waiting times, queue lengths, and pump utilization. Meanwhile, Arena simulation enables a more realistic representation of operational dynamics, accounting for variability in arrival and service processes, and allows testing of alternative scenarios for improvement (Farhan et al., 2013; Teimoury et al., 2011). Integrating these two approaches provides a more comprehensive understanding of the system's performance. The mathematical model offers analytical clarity, while simulation provides practical insights into operational challenges such as uneven workload distribution across pumps. This dual approach is particularly useful for comparing theoretical assumptions with actual outcomes, thereby ensuring the robustness of findings and the applicability of recommendations (Manalu & Palandeng, 2019; Qamari & Trizula, 2022).

Research contributes to filling the gap in the literature on fuel station queuing systems in medium-sized urban areas while also offering practical solutions for improving service delivery. By combining theoretical modeling and simulation, this study not only strengthens the academic discourse on queuing theory but also provides actionable insights for SPBU managers. Ultimately, the findings are expected to enhance service efficiency, increase customer satisfaction, and reduce traffic congestion around SPBUs, thereby supporting broader goals of effective urban transportation management (Pellondou et al., 2021; Jones et al., 2025).

METHODOLOGY

The Research Method section of this study outlines the systematic approach adopted to analyze the queuing system at Gas Station 13.201.101, located on Jalan Jamin Ginting, Medan Baru District, Medan City. This research employs a quantitative descriptive design, focusing on the application of the M/M/s queuing model and simulation techniques to explore patterns of vehicle arrivals, service durations, and overall system efficiency. The target population of the study consisted of motorized vehicle users both motorcycles and cars who accessed the gas station during peak hours. From this population, a purposive sampling approach was applied, and observational data were recorded for a sample size of 104 vehicles, comprising 64 motorcycles and 40 cars, in order to ensure sufficient variability for statistical analysis.

Data collection relied on direct observation, conducted systematically over a five-hour period between 10:00 and 15:00 WIB. The procedures involved recording arrival times, inter-arrival intervals, service start and completion times, and vehicle types. These data were compiled into structured observation sheets specifically designed for this study, ensuring consistency and reliability of the recorded information. Ethical safeguards were implemented, including anonymization of data, ensuring that no personal identifiers of vehicle users were collected during the observation process.

For data analysis, the study employed two complementary approaches. First, mathematical analysis was conducted using the M/M/s queuing model, where inter-arrival times and service times were tested for goodness-of-fit to theoretical distributions. Statistical tests, including the Chi-Square test and the Kolmogorov-Smirnov test, were applied to validate whether the data followed exponential and beta distributions, respectively. Second, the study utilized Arena simulation software, which enabled a more dynamic representation of real-world operations and allowed testing of alternative scenarios for system optimization.

The use of Arena simulation strengthened the research by providing insights into performance indicators such as average waiting time, queue length, pump utilization, and workload distribution across service stations. This dual approach allowed comparison between theoretical predictions and simulated outcomes, enhancing the validity of the findings. Ethical considerations were respected throughout the research process, including transparency in data handling and adherence to institutional research standards.

RESULTS AND DISCUSSION

1. Motorcycle Arrival Analysis

The observation of motorcycle arrivals at the gas station provides a detailed picture of how interarrival times fluctuate during peak operational hours. Table 1 illustrates the chronological sequence of motorcycles arriving, being served, and completing their fueling process. The arrival intervals range between three and four minutes, with some variations that reflect the irregular nature of customer demand. When analyzing the raw data, it becomes evident that motorcycles arrive in relatively consistent waves, yet small deviations highlight the randomness of customer behavior. This phenomenon is crucial for understanding how queues form and dissipate, particularly under limited pump capacity.

Table 1. Motorcycle Arrival and Service Data

No	Arrival Time	Arrival Difference (minutes)	Served	Finished	Service Duration (minutes)
1	10:00:00	-	10:00:30	10:04:00	3.5
2	10:04:00	4	10:04:30	10:08:00	3.5
3	10:07:00	3	10:08:30	10:11:30	3.0
4	10:11:00	4	10:12:00	10:15:30	3.5
5	10:15:00	4	10:16:00	10:19:30	3.5
6	10:18:00	3	10:20:00	10:23:00	3.0
7	10:22:00	4	10:23:30	10:27:00	3.5
8	10:26:00	4	10:27:30	10:31:00	3.5
9	10:29:00	3	10:31:30	10:34:30	3.0
10	10:33:00	4	10:35:00	10:38:30	3.5
11	10:37:00	4	10:39:00	10:42:30	3.5
12	10:40:00	3	10:43:00	10:45:00	3.0
13	10:44:00	4	10:45:30	10:49:00	3.5

No	Arrival Time	Arrival Difference (minutes)	Served	Finished	Service Duration (minutes)
14	10:48:00	4	10:49:30	10:53:00	3.5
15	10:51:00	3	10:53:30	10:56:30	3.0
16	10:55:00	4	10:57:00	11:00:30	3.5
17	10:59:00	4	11:01:00	11:04:30	3.5
18	11:02:00	3	11:05:00	11:08:00	3.0
19	11:06:00	4	11:08:30	11:12:00	3.5
20	11:10:00	4	11:12:30	11:16:00	3.5
21	11:13:00	3	11:16:30	11:19:30	3.0
22	11:17:00	4	11:20:00	11:23:30	3.5
23	11:21:00	4	11:24:00	11:27:30	3.5
24	11:24:00	3	11:28:00	11:31:00	3.0
25	11:28:00	4	11:31:30	11:35:00	3.5
26	11:32:00	4	11:35:30	11:39:00	3.5
27	11:35:00	3	11:39:30	11:42:30	3.0
28	11:39:00	4	11:43:00	11:46:30	3.5
29	11:43:00	4	11:47:00	11:50:30	3.5
30	11:46:00	3	11:51:00	11:54:00	3.0
31	11:50:00	4	11:54:30	11:58:00	3.5
32	11:54:00	4	11:58:30	12:02:00	3.5
33	11:57:00	3	12:02:30	12:05:30	3.0
34	12:01:00	4	12:06:00	12:09:30	3.5
35	12:05:00	4	12:10:00	12:13:30	3.5
36	12:08:00	3	12:14:00	12:17:00	3.0
37	12:12:00	4	12:17:30	12:21:00	3.5
38	12:16:00	4	12:21:30	12:25:00	3.5
39	12:19:00	3	12:25:30	12:28:30	3.0
40	12:23:00	4	12:29:00	12:32:30	3.5
41	12:27:00	4	12:33:00	12:36:30	3.5
42	12:30:00	3	12:37:00	12:40:00	3.0
43	12:34:00	4	12:40:30	12:44:00	3.5
44	12:38:00	4	12:44:30	12:48:00	3.5
45	12:41:00	3	12:48:30	12:51:30	3.0
46	12:45:00	4	12:52:00	12:55:30	3.5
47	12:49:00	4	12:56:00	12:59:30	3.5
48	12:52:00	3	13:00:00	13:03:00	3.0
49	12:56:00	4	13:03:30	13:07:00	3.5
50	13:00:00	4	13:07:30	13:13:00	3.5
51	13:03:00	3	13:13:30	13:14:30	3.0
52	13:07:00	4	13:15:00	13:18:30	3.5
53	13:13:00	4	13:19:00	13:22:30	3.5
54	13:14:00	3	13:23:00	13:26:00	3.0
55	13:18:00	4	13:26:30	13:30:00	3.5
56	13:22:00	4	13:30:30	13:34:00	3.5

No	Arrival Time	Arrival Difference (minutes)	Served	Finished	Service Duration (minutes)
57	13:25:00	3	13:34:30	13:37:30	3.0
58	13:29:00	4	13:38:00	13:41:30	3.5
59	13:33:00	4	13:42:00	13:44:30	3.5
60	13:36:00	3	13:45:00	13:48:00	3.0
61	13:40:00	4	13:48:30	13:52:00	3.5
62	13:44:00	4	13:52:30	13:56:00	3.5
63	13:47:00	3	13:56:30	13:59:30	3.0
64	13:51:00	4	14:00:00	14:04:30	3.5
65	13:55:00	4	14:04:00	14:08:30	3.5

Source: Author, 2025

When the data was processed using the Arena Input Analyzer, the results indicated that motorcycle arrival times follow an exponential distribution with a mean of 3.8 minutes. The exponential distribution is often applied in queuing system studies because it accurately represents the probability of random events occurring at a constant average rate. In this case, the goodness-of-fit test supported the suitability of the exponential model. The chi-square test produced a p-value of 0.905, which is well above the 0.05 threshold, meaning there is no statistical reason to reject the exponential assumption.

The exponential distribution implies that shorter interarrival times are more common, while longer intervals occur less frequently. This characteristic is important for simulating the queuing system because it determines the likelihood of multiple motorcycles arriving in quick succession. In practice, this reflects real-world observations where short bursts of motorcycles often arrive together, especially during high-traffic periods. Such clustering events contribute to temporary queues and affect pump utilization.

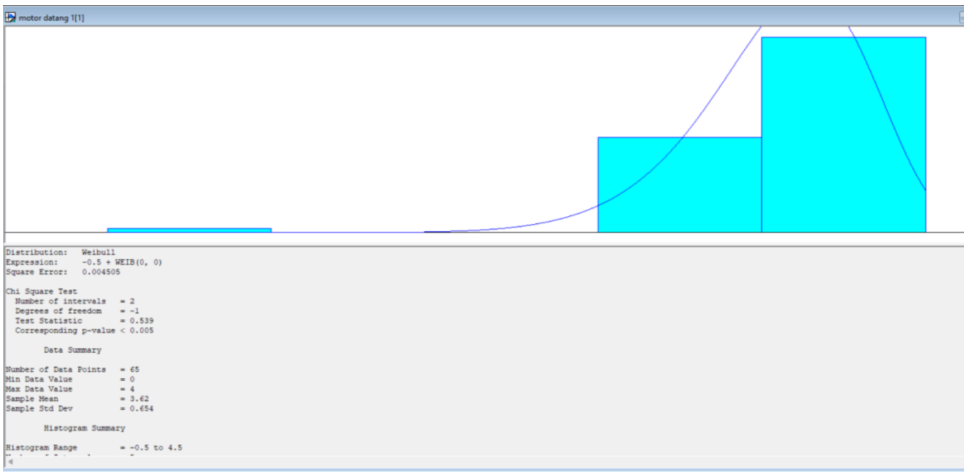

Figure 1. Arena Input Analyzer Output for Motorcycle Arrivals
Source: Author, 2025

The histogram presented in Figure 1 further confirms that the data distribution aligns closely with the exponential curve. The bars of the histogram show a high frequency of short arrival intervals and a gradually declining frequency as the intervals grow longer. This matches theoretical expectations and validates the choice of the exponential distribution for modeling. Therefore, the motorcycle arrival pattern provides a reliable foundation for constructing an accurate simulation of the queuing system.

2. Motorcycle Service Time Analysis

The analysis of motorcycle service times reveals additional insights into how efficiently pumps handle two-wheeled vehicles. Table 1 already provides a clear breakdown of start and completion times, which were then processed to determine statistical distribution. Service durations for motorcycles consistently ranged between three and three and a half minutes. Although the intervals appear relatively short, even small delays in this range can significantly impact system congestion when aggregated across dozens of motorcycles.

Arena Input Analyzer identified the beta distribution as the most suitable model for motorcycle service times, with parameters (3, 0.551, 3, 3.5). This choice makes sense because the beta distribution is appropriate for bounded continuous data, where values are restricted between specific minimum and maximum limits. In this case, the lower and upper limits of three and 3.5 minutes capture the real operational boundaries observed during fieldwork. The shape parameters produce a curve that concentrates values at both ends, reflecting the tendency of service durations to cluster around the extremes.

However, the statistical goodness-of-fit tests suggest only a marginal match between the data and the beta distribution. The chi-square test yielded a p-value of 0.005, which falls below the 0.05 threshold, indicating that the fit is statistically weak. Similarly, the Kolmogorov-Smirnov test produced a p-value of 0.01, reinforcing the observation that the distribution is only borderline acceptable. Despite these results, the beta distribution was retained for simulation because it best represented the observed limits and patterns. This practical compromise ensures that the simulation remains realistic even if the statistical rigor is not perfect.

Figure 2. Arena Input Analyzer Output for Motorcycle Service Times
Source: Author, 2025

The histogram presented in Figure 2 illustrates the distribution of service times, with two distinct peaks near the minimum and maximum limits. This suggests that operators often complete refueling tasks either as quickly as possible or closer to the maximum observed duration. Such a bimodal pattern reflects human and operational variability, where different attendants may work at slightly different speeds or where situational factors (such as payment delays) affect the total service duration. Overall, the analysis of motorcycle service times highlights both the efficiency and variability inherent in real-world operations.

3. Car Arrival Analysis

The arrival patterns of cars at the gas station show a different rhythm compared to motorcycles. As recorded in Table 2, the interarrival times of cars ranged from five to seven minutes, with occasional shorter intervals. This slower frequency reflects the smaller proportion of cars relative to motorcycles in the total customer base. Nevertheless, the impact of cars on the queuing system is disproportionately large due to their longer service times. As a result, understanding their arrival patterns is vital for predicting congestion during peak hours.

When the arrival data was processed using the Arena Input Analyzer, the results suggested that car arrivals followed an exponential distribution with a mean of 5.5 minutes. This distribution aligns with the general assumption that arrivals at service facilities occur randomly over time. The chi-square test, however, indicated a weaker statistical fit with a p-value of 0.005. While this would typically raise concerns, the visual alignment of the histogram with the exponential curve suggested that the model was still practically acceptable for simulation purposes.

Table 2. Car Arrival and Service Data

No	Arrival Time	Arrival Difference (minutes)	Served	Finished	Service Duration (minutes)
1	10:00:00	-	10:00:00	10:05:00	5
2	10:05:00	5	10:06:00	10:11:00	5
3	10:11:00	6	10:12:00	10:19:00	7
4	10:16:00	5	10:20:00	10:25:00	5
5	10:21:00	5	10:26:00	10:31:00	5
6	10:27:00	6	10:32:00	10:39:00	7
7	10:32:00	5	10:40:00	10:45:00	5
8	10:37:00	5	10:46:00	10:51:00	5
9	10:43:00	6	10:52:00	10:59:00	7
10	10:48:00	5	11:00:00	11:05:00	5
11	10:53:00	5	11:06:00	11:11:00	5
12	10:59:00	6	11:12:00	11:19:00	7
13	11:04:00	5	11:20:00	11:25:00	5
14	11:09:00	5	11:26:00	11:31:00	5
15	11:15:00	6	11:32:00	11:39:00	7
16	11:20:00	5	11:40:00	11:45:00	5
17	11:25:00	5	11:46:00	11:51:00	5
18	11:31:00	6	11:52:00	11:59:00	7
19	11:36:00	5	12:00:00	12:05:00	5
20	11:41:00	5	12:06:00	12:11:00	5
21	11:47:00	6	12:12:00	12:19:00	7
22	11:52:00	5	12:20:00	12:25:00	5

23	11:57:00	5	12:26:00	12:31:00	5
24	12:03:00	6	12:32:00	12:39:00	7
25	12:08:00	5	12:40:00	12:45:00	5
26	12:13:00	5	12:46:00	12:51:00	5
27	12:29:00	6	12:52:00	12:59:00	7
28	12:35:00	5	13:00:00	13:05:00	5
29	12:40:00	5	13:06:00	13:11:00	5
30	12:46:00	6	13:12:00	13:19:00	7
31	12:51:00	5	13:20:00	13:25:00	5
32	12:56:00	5	13:26:00	13:31:00	5
33	13:02:00	6	13:32:00	13:39:00	7
34	13:07:00	5	13:40:00	13:45:00	5
35	13:12:00	5	13:46:00	13:51:00	5
36	13:18:00	6	13:52:00	13:59:00	7
37	13:23:00	5	14:00:00	14:05:00	5
38	13:28:00	5	14:06:00	14:11:00	5
39	13:34:00	6	14:12:00	14:19:00	7
40	13:39:00	5	14:20:00	14:25:00	5
41	13:44:00	5	14:26:00	14:31:00	5

Source: Author, 2025

The exponential mean of 5.5 minutes corresponds to an arrival rate (λ) of approximately 0.182 cars per minute. This low arrival rate may give the impression that cars contribute less to queuing problems. However, because cars require more time to complete refueling, their presence often prolongs the occupation of pumps, thereby indirectly contributing to delays for subsequent arrivals. This interplay between arrival frequency and service duration explains why even a modest stream of cars can strain the system.

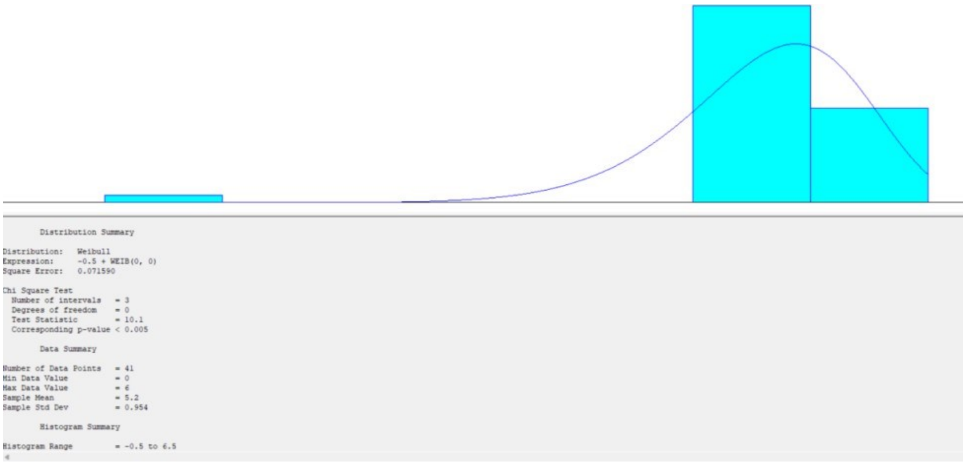

Figure 3. Arena Input Analyzer Output for Car Arrivals
Source: Author, 2025

Figure 3 displays the histogram of car arrival times compared with the exponential curve. The graphical alignment shows that most arrival intervals cluster around five to six minutes, reinforcing the statistical conclusion. While occasional shorter intervals exist, they are rare and consistent with exponential probability patterns. Overall, the analysis of car arrivals demonstrates that although less frequent, cars exert significant influence on the queuing dynamics due to their time-intensive service requirements.

4. Car Service Time Analysis

The service times for cars highlight one of the main sources of delay in the gas station's operations. As shown in Table 2, car refueling consistently takes between five and seven minutes, which is significantly longer than motorcycle service times. This extended duration is due to larger fuel tank capacities, different types of fuel used, and sometimes longer payment interactions. The effect of these service times is amplified during peak hours, where even slight increases in processing time lead to visible queues.

Statistical analysis using Arena Input Analyzer identified the beta distribution as the best fit for car service times, with parameters (1.45, 3, 5, 7). The beta distribution once again proves suitable because it accommodates bounded data within a clear range. In this case, the parameters generate a curve that heavily weights shorter service durations near the lower limit of five minutes, gradually tapering off towards the upper limit of seven minutes. This reflects the observed reality where most refueling processes finish closer to five minutes, but occasional outliers extend to seven.

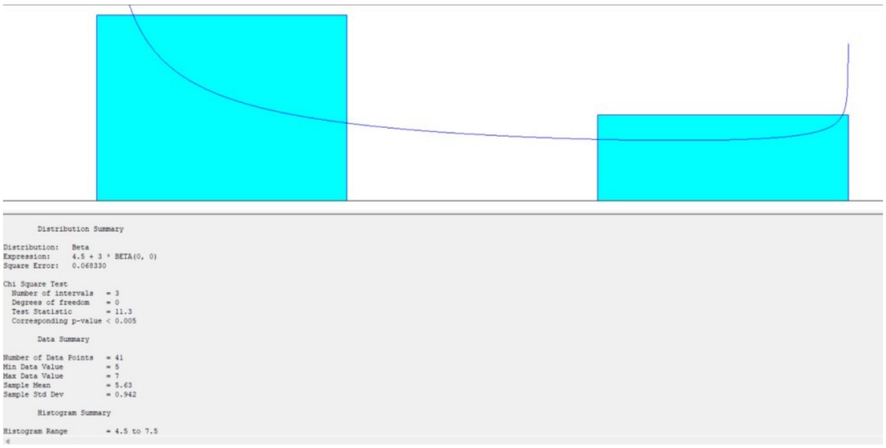

Figure 4. Arena Input Analyzer Output for Car Service Times
Source: Author, 2025

The chi-square test, however, revealed a poor statistical fit with a p-value of 0.005. While this indicates that the beta distribution is not an ideal representation of the data, it remains the most practical option for simulation because it respects the natural boundaries of the observed values. In practice, this ensures that simulated service times do not fall outside the realistic operational range. As with motorcycles, simulation accuracy relies more on practical realism than on perfect statistical conformity.

The histogram shown in Figure 4 highlights that most service durations cluster around the five-minute mark, with smaller peaks near seven minutes. This confirms the shape predicted by the beta distribution and underscores the fact that car services, although less frequent, tend to occupy pumps for longer durations. Consequently, cars create bottlenecks that can ripple through the queuing system, particularly when multiple cars arrive in quick succession.

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5. System Performance: M/M/s Model vs Simulation

The theoretical analysis of the gas station's performance using the M/M/s model provided initial insights into system efficiency. Under average conditions, the model estimated that the average waiting time for vehicles was less than one minute and the average number of vehicles in the queue was also less than one. Pump utilization varied between 32% and 70%, depending on the type and frequency of arriving vehicles. These results suggest that, in theory, the gas station is capable of handling its demand with minimal queuing.

However, the Arena simulation revealed a more nuanced picture. During the observation period, 40 cars and 64 motorcycles were processed, and all exited the system without significant delays. The simulation reported waiting times of zero minutes, no vehicles in the queue, and pump utilization levels that varied dramatically across the four pumps. Pump 1 showed the highest utilization at 70.01%, while Pump 2 recorded only 18.14%. Pumps 3 and 4 were moderately used at 58.37% and 32.12%, respectively.

Entity

Other

Number In	Average	Half Width	Minimum Average	Maximum Average
MOBIL	40.0000	0,00	40.0000	40.0000
MOTOR	64.0000	0,00	64.0000	64.0000

Figure 5. Arena Simulation Output – Vehicle Throughput
Source: Author, 2025

This uneven distribution of workload highlights a major operational issue. While the overall system may appear efficient, the imbalance in pump utilization means that some pumps are overloaded while others are underused. This discrepancy stems from how vehicles are directed to pumps, often leaving some lanes congested while others remain relatively free. Such inefficiencies cannot be captured by the M/M/s model, which assumes equal load distribution across all service channels.

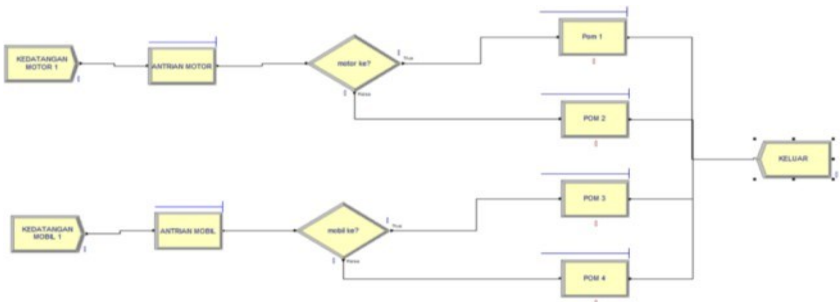

Figure 6. Arena Simulation Output – Pump Utilization
Source: Author, 2025

Figures 5 and 6 present the output of the Arena simulation, showing the throughput of vehicles and the utilization of pumps. The results emphasize the importance of simulation for capturing real-world irregularities that theoretical models overlook. By highlighting the uneven workload, the simulation provides a valuable tool for redesigning operations and improving service equity across pumps.

6. Interpretation and Implications

The findings of this study carry important implications for both daily operations and long-term service planning. The current queuing system is relatively efficient in preventing excessive delays, but the uneven pump utilization undermines overall service quality. In particular, the overloading of Pump 1 contrasts sharply with the underuse of Pump 2, revealing a structural imbalance in how customers select or are directed to fueling points. This suggests that improvements should not focus solely on adding capacity but on redistributing demand more effectively.

One potential solution involves implementing an automatic vehicle routing system that guides customers to the least utilized pump. Such a system could be based on digital signage or lane management technologies that balance demand across all pumps in real time. Another strategy involves training attendants to actively direct vehicles to underused pumps, ensuring a more equitable distribution of workload. Both measures could significantly reduce waiting times during peak hours, even without expanding physical capacity.

Redesigning the layout of the gas station may also help alleviate imbalances. By creating clearer entry and exit paths, or by reconfiguring lanes to improve visibility of underutilized pumps, customers may naturally distribute themselves more evenly. These physical interventions, combined with behavioral and technological strategies, can transform the efficiency of the station without major capital investment. It is important to acknowledge the limitations of this study. Data collection was limited to a five-hour observation window on a single day, which may not capture variations across different times or days. Additionally, the simulation did not account for differences in fuel types, weather conditions, or technical malfunctions, all of which could influence service times. Future studies should expand the observation period and incorporate these factors for a more comprehensive analysis.

CONCLUSION

This study aimed to analyze the queuing system at Gas Station 13.201.101, Jalan Jamin Ginting, Medan, using the M/M/s model and Arena simulation. The findings show that motorcycle arrivals follow an exponential distribution with an average inter-arrival time of 3.8 minutes and a service time of 3.3 minutes, while cars arrive every 5.5 minutes on average with service times ranging between 5–7 minutes. The theoretical M/M/s model indicated that the system is relatively efficient, with waiting times of less than one minute and pump utilization rates between 32% and 70%. However, the Arena simulation provided a more realistic picture, revealing uneven workload distribution, where some pumps exceeded 70% utilization while others remained underused.

These results highlight that although the system overall prevents excessive delays, operational inefficiencies remain due to unbalanced pump usage. The study emphasizes the need for managerial strategies to optimize vehicle distribution across pumps. Practical solutions may include implementing automated routing systems, improving station layout, or providing attendants with training to guide vehicles to less-utilized pumps. Such measures can enhance service efficiency, reduce congestion, and improve customer satisfaction without necessarily increasing physical capacity.

Nevertheless, this research has several limitations. Data collection was restricted to a five-hour observation period on a single day, which may not reflect variations across different days or peak conditions. Additionally, the simulation did not account for external factors such as different fuel types, weather conditions, or technical issues that could affect service time. Future studies should extend the observation period, incorporate additional variables, and test alternative scenarios to provide more comprehensive recommendations. By addressing these limitations, further research can strengthen the applicability of findings and support more effective management of fuel station operations in urban areas.

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