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Improving Customer Service at Gas Stations Using Discrete Event Simulation Approach

N.N. Hawari*, W.L.H. Mat Desa, N. Nordin and N.H. Mohd Zaki

School of Quantitative Sciences, Universiti Utara Malaysia

The aim of this research is to create a simulation model for a gas station in Changlun, Kedah. This model is intended to identify bottlenecks and propose alternative solutions to enhance system performance and improve customer satisfaction. The study uses the discrete event simulation (DES) approach to develop and analyse the operational system of a specific gas station in Changlun. Performance metrics considered in this model include average and maximum queue waiting times, average and maximum total system times, average and maximum queue lengths, and utilisation rates. The simulation model is developed using Arena software, and the resulting data is analysed. Based on the findings, three potential solutions are proposed: designating pumps exclusively for motorcycles, expanding parking space, and combining both approaches.

Keywords: gas station simulation; discrete event simulation (DES); service performance; queue management; operational efficiency

I. INTRODUCTION

A gas station, also known as a filling station, fuelling station, service station, or petrol station, is a facility that sells fuel and lubricants for motor vehicles. Most of the gas stations are built in a similar design, and they have a similar function which with most of the fuelling installation underground, pump machines in the forecourt and a point of service inside a building. Based on statistics (www.statista.com), the number of gas stations in Malaysia until the year 2017 is more than 3000 stations from various brands such as Petronas, Shell, Chevron Caltex, BH Petrol, Petron, and Buraq Oil. Petronas recorded the highest number of stations, which is 1065 stations, followed by Shell gas station, which has 570 stations. Petron and Chevron Caltex stations recorded 570 and 420 stations, respectively. BHP has 360 stations and a total of 335 stations from various brands.

Specifically, in Malaysia, there are three types of fuel, which are RON 95, RON 97 and diesel. The most common fuels sold are petrol RON 95 and diesel fuel. It is essential and important to find a strategic location where the traffic is high so there is a significant volume of fuel purchased every day. The gas stations not only help drivers solve the problem of fuel shortage but also supply a short-term rest area for road users such as car drivers. Not only that, but most gas stations also provide various facilities such as toilets, squeegees and paper towels for customers to clean their vehicle's windows, as well as an air compressor to inflate tyres and a hose to add water to vehicle radiators. Furthermore, there are also convenience stores found in gas stations, which typically sell candy, soft drinks and snacks intended to facilitate road users.

Many people can get services from gas stations daily. The selected gas station in this study is located in Changlun, which is known as NW Gas Station, in the further discussion in this paper. The NW Gas Station, Changlun, is strategically located in the middle of the highway between Jitra to Bukit Kayu Hitam. Most of its customers are highway users from Changlun, Bukit Kayu Hitam, Universiti Utara Malaysia and even those from Perlis. Usually, the NW Gas Station will be busier during peak hour, which is in the evening, as road users will be back from work and will stop by to refuel. Since the quality and price are commonly comparable in the markets, speed service and queue length can be considered the most influential factors in customer satisfaction.

*Corresponding author's e-mail: nnazihah@uum.edu.my

Although queue length is a common issue in almost every place, such as supermarkets, post offices, banks, and not excepted gas stations, too long of a waiting time or queue length can cause many problems and lead to ineffectiveness and inefficiency issues. Developing, simulating and analysing the NW Gas Station system will help the management of the NW Gas Station to improve its operations and services using a discrete event simulation approach.

There are two main research questions in this study: What is the current system performance for customer service at the NW Gas Station, and what are the best solutions to achieve a good satisfaction level of customer service at the gas station? Thus, the main research objective of this study is to develop a simulation model of the NW Gas Station at Changlun. Next, the sub-objective of this study is to identify the bottleneck and later to provide alternative solutions for better system performance for customers' satisfaction.

This research is conducted at NW Gas Station in Changlun. Some important data is collected during peak hours which is from 5 pm to 7 pm. This data collection process has taken place during the weekend as it is common for road users to come out at that time. The collected data consist of arrival time, service time, waiting time, and how many fuel dispensers were available during that time, as well as a way of payment, either in cash or by credit card. From this research, the bottleneck problems at the gas stations during peak hours will be identified. The developed simulation model of system performance can provide management of the gas station to improve its services, which will result in a higher level of customer satisfaction.

II. LITERATURE REVIEW

Existing literature related to long queues, the number of increasing customers, striving for an excellent operational performance, operational costs analysis, inventory management, and layout design are among the common issues that have been studied by the researchers. There are many approaches that have been used to solve that problem, including using the discrete event simulation (DES) approach. Previous research proved that the DES approach provides better management of system performance. It has also been discussed in several research areas such as road traffic congestion (Jalal *et al*., 2019), healthcare (Sharif *et al*., 2016), manufacturing (Desa *et al*., 2012), and services (Tan *et al*., 2016; Hawari *et al*., 2021). On the other hand, findings from the simulation study also help the researcher to understand the significant factors and optimise and evaluate the system performance using suitable software (Galankashi *et al*., 2016; Aqil, 2016). Developing a simulation model of system performance under study can help to improve the utilisation rates and reduce the number of queues and time in the system (Anthony *et al*., 2012). Discrete event simulation also prevents catastrophic failures in the actual system performance due to the impact of a change. Most of the previous research stressed that customer satisfaction will decrease when they need to wait in a long queue. The long waiting times in the queue will cause inconvenience and frustrate the customers, which results in reducing the satisfaction level of customer service (Abel & Ekabua Obeten, 2015; Gumus *et al*., 2017; Tan *et al*., 2016). Decreasing customer satisfaction levels will cause a higher customer loss rate (Md. Al-Amin Molla, 2017). According to He and Hu (2018), service-oriented enterprises need to improve services to maintain the survival and development of the company. Increases in the number of customers will affect the performance of operations (Kanyan *et al*., 2016). Li and Jiang (2016) solve the problem of how to arrange the transportation plan when the supply is insufficient to minimise the cost using a simulation approach. In 2014, Zhou, Bu and Feng studied the problem of the unreasonable layout problem and the excessive number of gas stations in some regions of China. Hence, several issues in simulation studies that are discussed from this section are summarised in Figure 1.

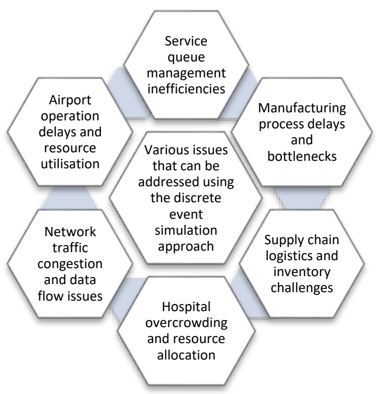

Figure 1. Summary of various issues that can be addressed using the discrete event simulation approach

From several previous studies, there are four common methods to analyse the queuing research problem such as discrete event simulation (DES), system dynamics (SD), heuristic approach and mixed integer programming model. Rani *et al.* (2014) and Desa *et al.* (2012) developed the DES model using specific software in the production line for performance evaluation, such as the number and waiting time in the queues at workstations. On the other hand, Moazzami *et al.* (2013) simulated the behaviour of a petrol station performance system using WITNESS software, while Abel, Eric, and Enda, in 2014, simulated the queue at Pertamina Alam Gas Station using Promodel software. One of the advantages of using the DES and SD approach as the trial and error process is that it is used to evaluate a complex system and able to look at the variables individually (Anthony *et al.*, 2003; Desa *et al.*, 2015; Rahim *et al.*, 2017; Hawari *et al.*, 2023). DES approach provides the researcher with a proper understanding and optimisation of the system performance under study by using simulation software (Fallahiarezoudar *et al.*, 2016; Aqil, 2016; Tan *et al.*, 2016). Whilst another approach to analysing the gas station issue is referred to by Zhou, Bu and Feng (2014), where multi-agent simulation has been used to find the main factors that influence the layout design of the gas station. Besides that, Li and Jiang (2016) used mixed integer programming to find the minimum cost when the total volume of supply is insufficient in the research of petrol distribution. Figure 2 summarises some methods related to the discussion based on this paper topic.

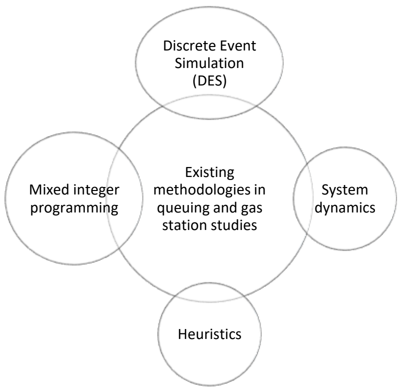

Figure 2. Overview of current methodologies in queuing and gas station studies

III. MATERIALS AND METHODS

This research applied a discrete event simulation approach to analyse the queuing problem at NW Gas Station in Changlun. The simulation model is developed using Arena software version 15.1. This research uses primary data. The data is collected by observation regarding the behaviour of customers, such as the number of customers arriving on time, the number of lost customers that leave the system before joining the queue (baulking), customers leaving the system, and the number of customers paying using a card or cash. The data on arrival, waiting, and service times is collected from 5 pm to 7 pm on weekends. The collected data is analysed using an input analyser which is embedded in Arena software. There are two input variables that have been analysed, which are inter-arrival rate and service rate. The output random variables are the average time in the system, the number of customers to be served, the number of vehicles in the queue, the waiting time in the queue, and the maximum number of vehicles in the queue.

From the analysis, the inter-arrival rate for customers who drive a car with a side dispenser follows the Poisson distribution with the expression 1.17 minutes (Figure 3). Customers who drive a car with a side dispenser follow the Lognormal distribution with the expression 0.5+LOGN(1.53,1.37) (Figure 4), and customers who ride a motorcycle follow the Lognormal distribution with the expression -0.5+LOGN(2.23.2.22) (Figure 5). However, six pumps provide the same services, such as pump 1, pump 2, pump 3, pump 4, pump 5 and pump 19, and pump 6 and pump 20. Each counter has one resource, but pump 5 and pump 19, and pump 6 and pump 20 have two resources. The distribution for service rate is different and the expression values for the data collected for each pump are summarised in Table 1. Figure 12 to Figure 17 shows the model logic of the developed model. The base time unit for these inter-arrival and service rates is in minutes.

Table 1. The expression value for each pump at NW gas station

Pump No.	Distribution	Expression
1	Weibull	0.5 + WEIB (1.81,1.6)
2	Poisson	POIS (3.18)
3	Weibull	0.5 + WEIB (2.77,1.61)
4	Normal	NORM (2.64,0.947)
5 and 19	Weibull	0.5 + WEIB (1.97,1.51)
6 and 20	Beta	0.5 + 13*BETA (0.751,2.62)

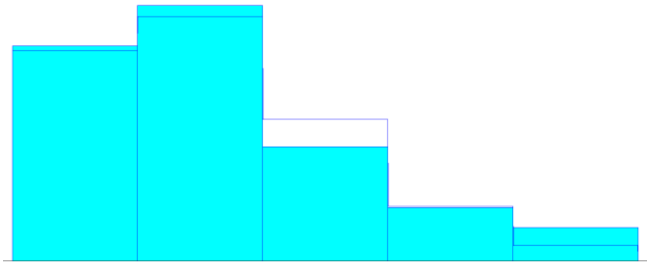

Figure 3. Distribution of inter-arrival time for a customer who drives a car with a right-side dispenser

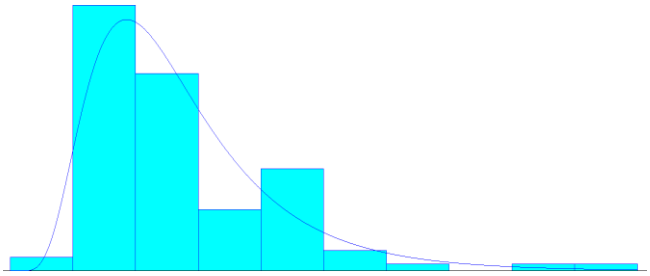

Figure 4. Distribution of inter-arrival time for a customer who drives a car with a left-side dispenser

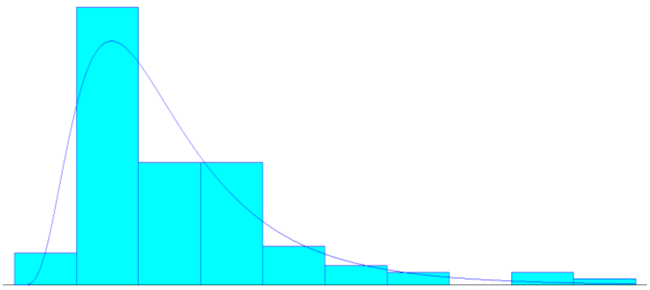

Figure 5. Distribution of inter-arrival time for customer who rides a motorcycle.

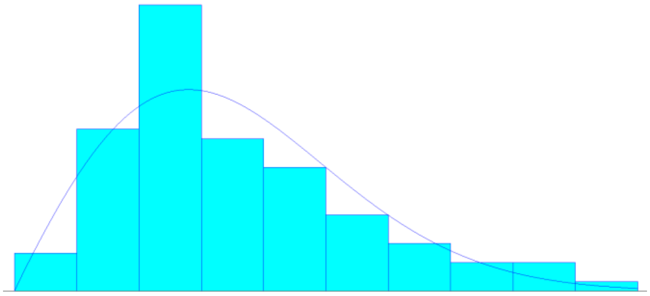

Figure 6. Distribution of service time of pump 1

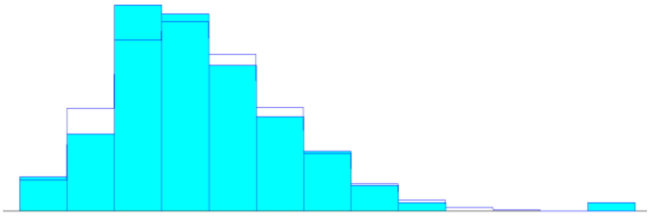

Figure 7. Distribution of service time of pump 2

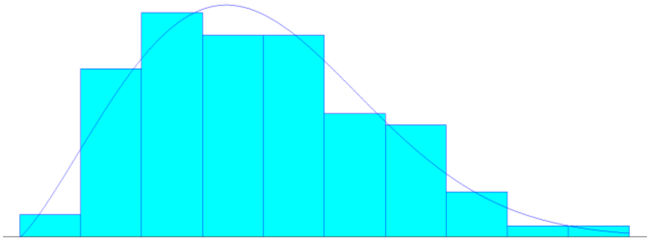

Figure 8. Distribution of service time of pump 3

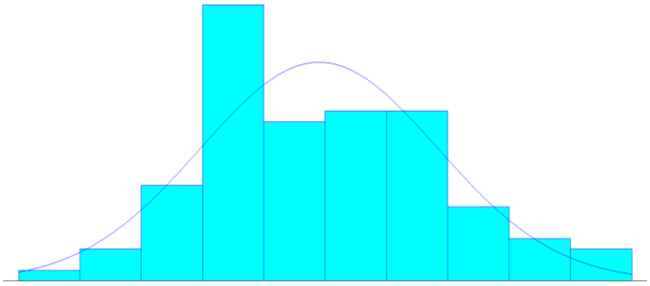

Figure 9. Distribution of service time of pump 4

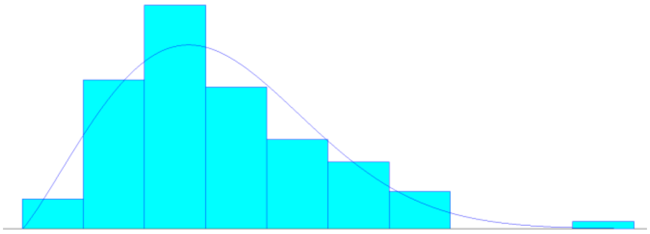

Figure 10. Distribution of service time of pump 5 and pump 19

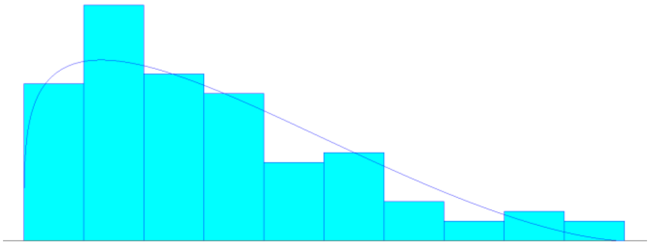

Figure 11. Distribution of service time of pump 6 and pump 20

There are three types of entities for this model, which are customers driving a car with right and left side dispensers and motorcycles. Figure 12 shows the model logic of the customers arriving at the system and baulking. When the entities arrive in the system, customers must decide whether they want to join the queue or leave the system. Figure 13 is the model logic of customer identification. The customers are differentiated based on the type of vehicle, either the customer who drives a car with a right-side dispenser, the customer who drives a car with a left-side dispenser, or the customer who rides a motorcycle. The pump is differentiated by the type of customers. If the customer drives a car with the right-side dispenser, they will go to pump 1, pump 3, pump 5, and pump 19. If the customer drives a car with a left-side dispenser, they will go to pump 2, pump 4, pump 6, and pump 20. The arriving customer will join the queue of certain pumps based on the lowest number of vehicles in the queue. Whereas a customer who rides a motorcycle can enter any available pump that has the shortest queue. Later, they will leave the system after getting served. The model was developed based on several assumptions, which were:

- The customers, focusing on the arrival of cars and motorcycles only.
- Simulation run time is two hours with no break time.
- Travel time between all processes is assumed to be constant.

IV. MODEL VERIFICATION AND VALIDATION

This section identifies model verification and validation as two important steps in a simulation study. Model verification ensures that the model behaves as it has been planned. Therefore, tracing a single entity method has been chosen for verifying the developed model. Meanwhile, the model validation is referred to in formula (1) by calculating and comparing an average simulation output with the actual data, which is known as the validity level. The validity level must be obtained around ±10% to declare the developed model valid (Law, 2006; Altiok & Melamed, 2007; Rosetti, 2010). Five replications have been run to fulfil the validation steps requirement. Tables 2 and 3 show the output analysis of the performance measure of total customers served at NW Gas Station. The validity level obtained was 5.567%, and it is shown that the developed model is valid and represents a real system.

Validity Level:

$$\frac{\text{simulation output-actual data}}{\text{actual data}} \times 100\% \qquad (1)$$

Table 2. Simulated total customers served in 5 replications

Performance Measure	Replications					Avg
	1	2	3	4	5	
Total customers served	253	259	245	259	273	257.8

Table 3. The validity level of total customers served

Performance Measure	Average Simulated Output	Actual Data	Difference (%)
Total customers served	257.80	273.00	5.56

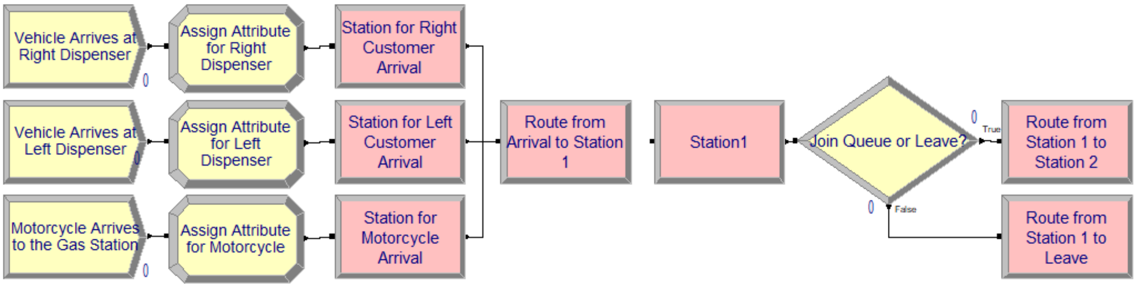

Figure 12. Model logic of customer arrival to the gas station and balking

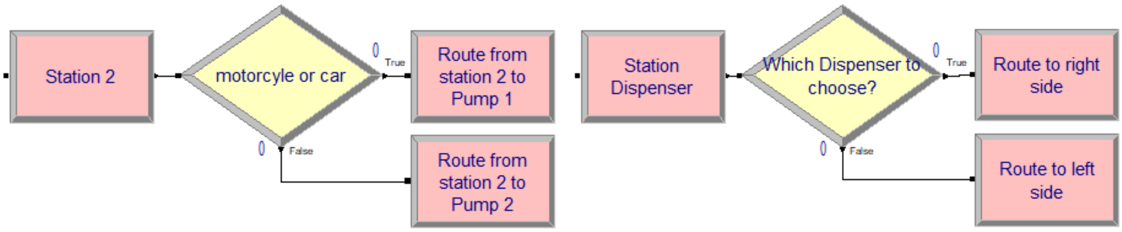

Figure 13. Model logic of customer identification

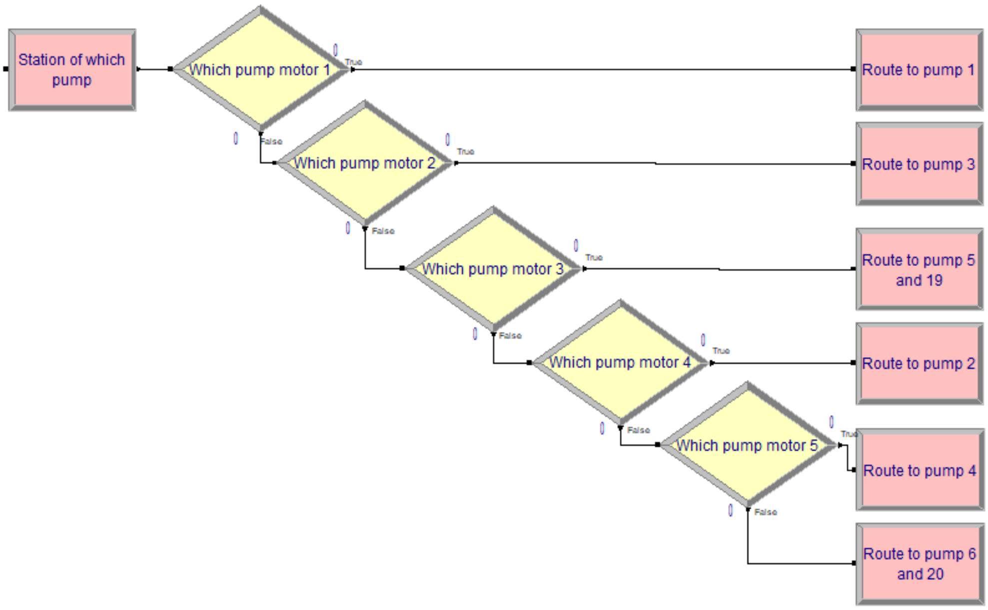

Figure 14. Model logic of the shortest queue to be selected by the customer at a gas station.

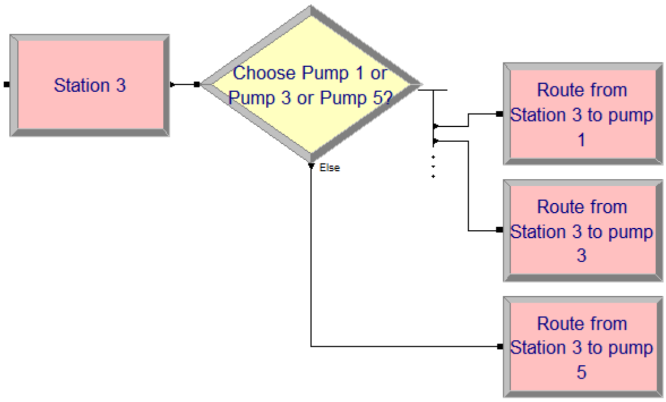

Figure 15. Model logic of the shortest queue for customers driving a car with a right-side dispenser

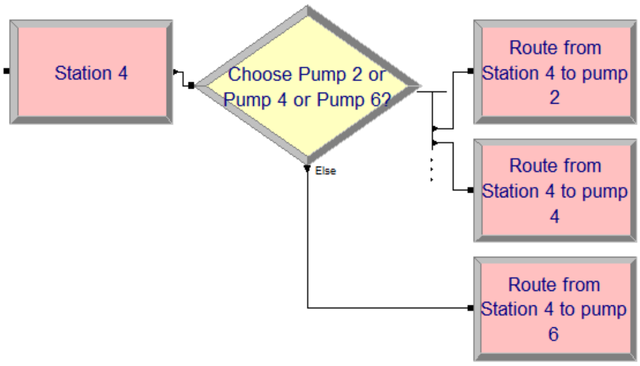

Figure 16. Model logic of the shortest queue for customers driving a car with a left-side dispenser

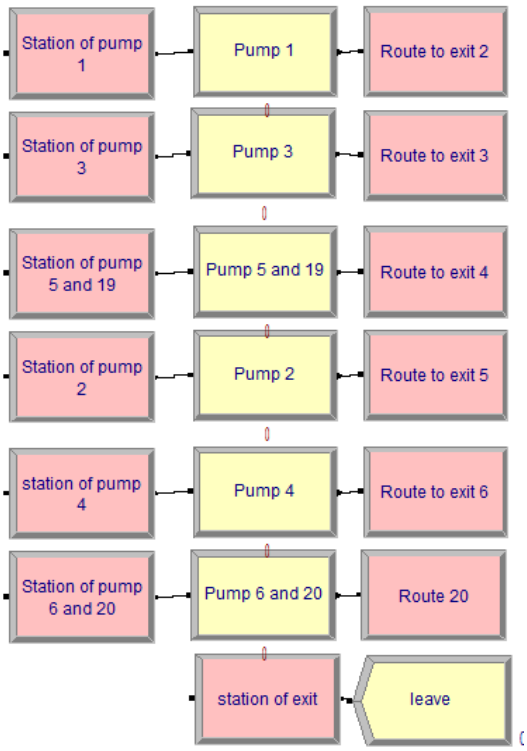

Figure 17. Model logic of resources (gas pump)

V. RESULT AND DISCUSSION

Table 4 below shows the performance measure with 5 replications and its sample mean of each pump and each side of the fuel dispenser. Since the aim of this study is to analyse the current system performance and to improve it to increase customer satisfaction, few findings have been drawn from the result. Firstly, for the average waiting time of the queuing system, pump 6 and 20 have the highest value, which is 11.2297 minutes, while pump 5 and 19 set the lowest value of 5.16116 minutes, resulting in the average maximum waiting time in the queue of 22.5856 minutes and 12.9041 minutes respectively. As for the average total time in the system, the left-fuel dispenser customers spent 12.7754 minutes, the right-fuel dispenser customers spent 8.2367 minutes, and the motorcycle customers spent 7.82512 minutes. For the average number of customers in a queue, only pump 2 has 3 customers, while the other pumps have 2. Next, on the average maximum total of customers in queue, only pump 2 has 7 customers, the other pump has 5 and 6. Lastly, on the percentage of utilisation, all of the pumps are at 89% and above, with pump 1 set at the highest percentage which is 99.87%. Table 4 shows the summary of the model output.

A. Alternative Development

Based on the researcher's observation and supported by the simulation output, most of the customers tend to leave their vehicle at the pump while refuelling and go somewhere else to do other matters, for example, to the convenience store or the toilet. Thus, the service time is longer, not because of the service itself, but because they purposely left their vehicle at the pump unattended. Several what-if experiments have been performed to reduce the waiting time and improve the percentage of utilisation.

- Alternative 1: to set pump 5 and 19 as pumps for motorcycles only.
- Alternative 2: to provide suitable number of parking spaces for customers to go to convenience stores or toilets.
- Alternative 3: to set pump 5 and 19 as pumps for motorcycles only, and to build more parking spaces simultaneously.

The results for each alternative are shown in Table 5 to Table 7. From the result, we can see that alternative 1, which is to set up pump 5 and pump 19 as pumps for motorcycles only, has the better average maximum waiting time and the

Table 4. Simulation output of performance measures with 5 replications

Performance Measure	**Replications**					**Average**
	1	**2**	**3**	**4**	**5**	
Total customers served	253.00	259.00	245.00	259.00	273.00	257.80
Average waiting time in queue (minutes)						
Pump 1	5.87	7.23	3.48	7.65	3.07	5.46
Pump 2	12.29	16.76	10.93	10.87	3.64	10.90
Pump 3	7.43	10.14	3.84	9.60	4.03	7.01
Pump 4	8.52	11.05	7.67	7.44	2.97	7.53
Pump 5 and 19	5.89	7.40	2.34	8.03	2.14	5.16
Pump 6 and 20	13.44	14.42	11.98	12.09	4.22	11.23
Maximum waiting time in queue (minutes)						
Pump 1	18.83	15.10	9.98	15.65	6.84	13.28
Pump 2	21.37	32.14	23.73	17.56	12.64	21.49
Pump 3	19.19	20.92	12.17	18.01	9.67	15.99
Pump 4	14.71	22.23	14.71	15.56	9.00	15.24
Pump 5 and 19	15.55	16.50	8.75	17.23	6.49	12.90
Pump 6 and 20	24.23	25.17	25.93	23.32	14.28	22.59
Average total time in the system (minutes)						
Left fuel dispenser	14.58	17.81	12.60	12.34	6.54	12.77
Right fuel dispenser	8.70	10.60	5.50	11.09	5.31	8.24
Motorcycles	8.09	10.16	6.12	10.27	4.48	7.82
Maximum total time in the system (minutes)						
Left fuel dispenser	27.17	34.14	30.50	26.77	18.20	27.36
Right fuel dispenser	20.94	25.92	13.88	20.26	12.21	18.64
Motorcycles	20.28	21.34	21.56	26.57	18.70	21.69
Time-Average Number of Customers in queue (minutes/customer)						
Pump 1	2.99	3.63	1.61	3.81	1.61	2.73
Pump 2	4.02	4.91	3.19	3.79	1.31	3.44
Pump 3	2.78	3.58	1.38	3.66	1.41	2.56
Pump 4	3.19	4.05	2.56	3.37	1.19	2.87
Pump 5 and 19	2.41	3.11	0.92	3.33	1.02	2.16
Pump 6 and 20	3.47	3.87	2.60	3.28	0.91	2.83
Maximum Total Number of Customers in queue (customers)						
Pump 1	7.00	7.00	4.00	7.00	3.00	5.60
Pump 2	7.00	9.00	7.00	8.00	4.00	7.00
Pump 3	7.00	7.00	4.00	7.00	3.00	5.60
Pump 4	7.00	8.00	6.00	7.00	4.00	6.40
Pump 5 and 19	7.00	7.00	4.00	7.00	3.00	5.60

Pump 6 and 20	7.00	8.00	6.00	7.00	4.00	6.40
Utilisation (%)						
Pump 1	99.99	100.00	99.87	100.00	99.47	99.87
Pump 2	100.00	97.37	85.91	94.17	93.81	94.25
Pump 3	97.13	100.00	96.23	97.96	99.74	98.21
Pump 4	99.53	98.86	84.88	96.76	97.91	95.59
Pump 5	89.14	97.00	74.28	92.45	97.91	90.16
Pump 6	94.99	91.99	90.01	93.03	79.78	89.96
Pump 19	89.14	96.99	74.28	92.45	96.64	89.90
Pump 20	94.90	91.99	90.00	93.03	79.78	89.94

percentage of utilisation. For percentage of utilisation, pumps 5 and 19 have lower a percentage compared to other pumps, which is 67.68%. This is because after setting up pump 5 and pump 19 as a pump for motorcycles only, if there are no motorcycles in service, the pump was left idle, resulting in a lower percentage of utilisation.

Based on the simulation output of these alternatives, Alternative 1 has better results of performance measures and would be the most effective way for the NW Gas Station management to improve their system performance for customer service.

Table 5. Simulation output for alternatives 1

Maximum waiting time in queue (minutes)	**1**	**2**	**3**	**4**	**5**	**Average**
Pump 1	13.02	24.86	77.79	25.44	11.16	30.45
Pump 2	11.18	16.94	18.89	19.37	17.79	16.83
Pump 3	21.19	37.98	8.37	20.21	15.81	20.71
Pump 4	5.06	10.44	4.82	15.17	12.84	9.67
Pump 5 and 19	11.75	4.47	4.82	3.92	4.26	5.84
Pump 6 and 20	7.92	14.00	20.53	16.47	18.29	15.44
Utilisation (%)						
Pump 1	100.00	100.00	97.18	99.17	84.17	96.10
Pump 2	93.57	84.17	84.17	82.86	84.17	85.79
Pump 3	100.00	99.17	89.17	98.33	90.01	95.34
Pump 4	85.88	94.18	82.12	94.43	84.73	88.27
Pump 5	76.01	55.35	64.19	67.91	74.94	67.68
Pump 6	69.70	74.07	78.71	74.23	90.75	77.49
Pump 19	76.01	55.35	64.19	67.91	74.94	67.68
Pump 20	69.70	74.07	78.71	74.23	90.43	77.43

Table 6. Simulation output for alternatives 2

Maximum waiting time in queue (minutes)	**1**	**2**	**3**	**4**	**5**	**Average**
Pump 1	34.59	22.32	18.52	28.29	30.11	26.77
Pump 2	27.79	20.37	16.39	32.99	29.95	25.50
Pump 3	31.23	23.59	18.10	32.37	28.55	26.77
Pump 4	36.53	20.95	15.29	31.24	28.81	26.56
Pump 5 and 19	29.00	19.52	18.69	29.95	31.33	25.70
Pump 6 and 20	33.23	18.49	14.58	30.88	25.07	24.45
Utilisation (%)						
Pump 1	99.80	100.00	100.00	100.00	100.00	99.96
Pump 2	100.00	97.37	98.71	94.47	98.96	97.90
Pump 3	100.00	100.00	100.00	98.33	100.00	99.67
Pump 4	100.00	99.62	100.00	97.16	100.00	99.36
Pump 5	99.60	99.17	99.17	95.00	99.75	98.54
Pump 6	96.12	90.56	97.88	93.99	98.07	95.32
Pump 19	99.60	99.17	99.17	95.00	99.75	98.54
Pump 20	96.12	90.56	97.88	93.99	98.07	95.32

Table 7. Simulation output for alternatives 3

Maximum waiting time in queue (minutes)	1	2	3	4	5	Average
Pump 1	25.44	22.92	26.87	29.40	24.55	25.84
Pump 2	12.62	11.31	12.34	16.78	19.77	14.56
Pump 3	21.52	23.71	26.87	25.66	22.88	24.13
Pump 4	10.12	12.38	11.65	16.19	22.87	14.64
Pump 5 and 19	4.14	3.60	6.36	3.89	10.29	5.66
Pump 6 and 20	10.09	8.24	11.51	16.85	20.07	13.35
Utilisation (%)						
Pump 1	98.85	99.16	100.00	99.17	100.00	99.44
Pump 2	85.55	82.14	84.11	82.01	81.71	83.10
Pump 3	91.98	94.86	99.17	93.06	90.03	93.82
Pump 4	89.91	94.56	94.01	91.26	84.57	90.86
Pump 5	65.80	55.35	67.50	53.47	81.59	64.74
Pump 6	70.24	57.54	68.59	67.63	74.19	67.64
Pump 19	65.80	55.35	67.50	53.47	81.59	64.74
Pump 20	70.24	57.54	68.59	67.63	74.19	67.64

VI. CONCLUSION

This study has employed the discrete event simulation (DES) approach in analysing the system performance at NW Gas Station in Changlun. Currently, there is no specification on whether a pump is designated for four-wheel drive or motorcycles, which makes customers wait in a long queue most of the time, with insufficient parking space provided. By conducting this study, a simulation model is developed, and the findings offer management solutions to reduce the waiting time in queues, which later may improve the customer satisfaction level of the services provided at the gas station. From the analysis, the waiting time at the NW Gas Station has been reduced, resulting in improved service quality. This study has illustrated the development of a simulation model at a gas station. The model built is used to investigate various management issues and conduct what-if experiments in the operation system without disturbing the real operation. These findings also can be considered by other gas stations as their strategy to improve customer satisfaction.

VII. REFERENCES

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