

Queue Management and Application in Supermarket

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Abstract: Waiting times and long queues are typical occurrences that have become a serious issue at supermarkets. Time spent waiting for customers to be served, especially if they have to wait for an extended period of time, can affect them in a variety of ways, including tiredness. This study focuses on a queuing simulation of a supermarket using Arena Simulation Software. The goal of this research is to learn more about Arena Simulation Software and to examine the supermarket's queuing problem. Throughout this study, three factors were examined: Average Waiting Time of Customer, Average Number of Waiting Customers, and Instantaneous Utilization. The simulation model result shows that the Average Waiting Time of Customer is 13.84 minutes, the Average Number of Waiting Customers is 3 customers, and the Instantaneous Utilization is 89%. These conditions are considered to be well utilized. We also try to simulate the outcome if the supermarket adds another server. From the analysis, it was found that the Average Waiting Time of Customer is 8.74 minutes, the Average Number of Waiting Customer is approximately 1 customer, and Instantaneous Utilization is 45%. Although Average Waiting Time of Customer and Average Number of Waiting Customers show well improved results, however we found that the Instantaneous Utilization is below the utilization capacity. Thus, we suggest the supermarket use just one cashier to serve customers, and we anticipate that scenario 1 where another cashier will be hired only during peak hours in the store.

Keywords: Queuing, Supermarket, Arena Simulation Software

1. Introduction

In today's dynamic market environment, modern society is rapidly evolving into a service-oriented one. Consumer satisfaction and customer service capabilities have been shown to provide a company with a competitive advantage in the marketplace, and as a result, service operation management is becoming increasingly important. Queuing theory is a discipline within operations management that studies the systematic study of standing in line [1]. Agner Krarup Erlang began researching queuing

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theory. The first pioneer of queuing theory for the telecommunications industry was Erlang. Erlang dealt with market trends and changes in telephone and traffic and later published a report discussing the delays and costs of automatic dialing devices. In 1909, he published “Probability Theory and Telephone Conversations.” He was also expanded to more general issues and market implementations of waiting lines. Erlang discovered that majority of telephone systems had either a single channel, several channels (servers) or input Poisson, exponential holding (service) times, and constant holding times [2].

Company owners, such as supermarkets, have worked on measuring and monitoring line ups and customers waiting times for many years [3]. Despite these efforts, today’s retail shoppers are often dissatisfied with their experience of shopping. The frustrating experience of standing in line may have a negative impact on the remainder of a customer’s supermarket visit. The amount of time spent waiting in line at the supermarket causes queues. Consumers dislike lengthy waits, and establishment management dislikes them because disgruntled customers might cost them money [4]. The objectives of the research are to analyse the queue at the supermarket using appropriate queuing analysis tools, simulate queuing situations at the supermarket by using Arena Simulation Software, and suggest a suitable improvement policy for resolving the queue problem at the supermarket.

The scope of this study is Arena Simulation Software will be used to simulate supermarket queueing because this software provides suitable queuing analysing tool. Since the supermarket can deliver service to customers at the checkout counter, the supermarket model is based on a single-server model. The project’s results will be analysed in terms of the total number of waiting customers, the average waiting time of customers to be served, facility usage, and customer satisfaction with the intention of reducing customer waiting time at the supermarket so that some solution to enhance the system can be recommended.

2. Methodology

The simulation aims to ensure effective scheduling while also maximising process performance using real-time data [5]. The simulation aims to ensure effective scheduling while also maximising process performance using real-time data. Legal advantages, increased accuracy, and the importance of the training are all provided by simulation. It is also a cutting-edge error management method and safety protocol since this model can be simulated on a laptop. The application of queuing theory attempts to reduce costs and wait time by reducing inefficiencies and delays in processes [6].

2.1 Derivation of M/M/1 Queuing Model

The arrival and service time is exponentially distributed in the M/M/1 queuing model (Poisson process). The following factors will be explored for the cash transaction counter M/M/1 queuing model analysis:

n = Total number of customers in the system (in queue plus in-service)

c = Number of parallel servers (Checkout sales operation units in ICA)

λ = The mean customers’ arrival rate (1 / (average number of customers arriving in each queue in a system in one hour))

μ = Mean serving rate (1 / (average number of customers being served at a server per hour))

The assumptions that define the M/M/1 model are as follows:

- Based on a Poisson process, jobs will arrive with parameter λt , or equivalently, the time between arrivals, t , will have an exponential distribution with parameter λ , i.e., for $t \geq 0$, the probability density function is

$$f(t) = \lambda e^{-\lambda t} \qquad \text{Eq. 1}$$

- There is just one server
- The buffer is infinitely large
- The number of possible jobs is limitless.

State-dependent departure and arrival rates are in a steady-state (equilibrium between events) situation. Hence, the notations and descriptions for the single queue and parallel multiple server models, assuming the device is in a steady state.

2.2 M/M/s Queuing Model

We have an M/M/s queuing system when we have a single queue with more than one parallel server. The following factors will be explored for the cash transaction counter M/M/s queuing model analysis:

Let,

- λ The mean of customer's arrival rate,
- μ The mean of service rate,
- ρ Utilization factor.

Then,

L_q The average number of customers in the queue:

$$L_q = \frac{\rho^2}{1-\rho} = \frac{\lambda^2}{\mu[\mu-\lambda]} \quad \text{Eq. 2}$$

W_q The average waiting time in the line (queue):

$$W_q = \frac{\lambda}{\mu[\mu-\lambda]} \quad \text{Eq. 3}$$

L_s The average number of customers in the supermarket:

$$L_s = L_q + \frac{\lambda}{\mu} \quad \text{Eq. 4}$$

By definition, the difference between the average number in the system, L_s , and the average number in queue, L_q must equal the average number of busy servers, \bar{c} . Therefore, we have,

$$\bar{c} = L_s - L_q = \frac{\lambda}{\mu} \quad \text{Eq. 5}$$

It follows that,

$$\text{Instantaneous Utilization} = \frac{\bar{c}}{c} \quad \text{Eq. 6}$$

For networks of queues, such as several queues, there are no predefined formulas. The fundamental explanation for this is the complexity of the models. As a result, for a single queue with parallel servers, we use notations and formulas. We can use simulation to measure estimates for multiple queues and multiple servers.

2.3 Data

Data were used from previous study entitled of modelling of queuing system at sales checkout [7]. We followed the data distribution reported in Table 2.1 for the server because our study was primarily focused on simulation approach rather than data observation. The expression for the arrival time at counter 1 and service time counter 1 are gained by using the Arena software's Input Analyzer to determine the distributions of the various interarrival times and service times. The data was loaded as a raw text file, which was afterwards fitted to a suitable distribution.

Table 2.1: Data distribution by Arena Input Analyzer

DATA DISTRIBUTION	
NAME	EXPRESSION
Arrival time at counter 1	$-0.5+12*BETA(1.04,1.36)$
Service time counter 1	$1.5+LOGN(2.96,2.74)$

2.4 Create Pop-Up Box

The first step in every simulation is to create. The simulation will produce the arrival of the entities. To run the simulation, fill in all necessary details in the Create pop-up box and then double-click the Create button to open the Create pop-up box. Double-click the Create button to bring up the Create pop-up window. As shown in Figure 2.1, the Create pop-up box will appear. The pop-up box has seven fields that must be completed.

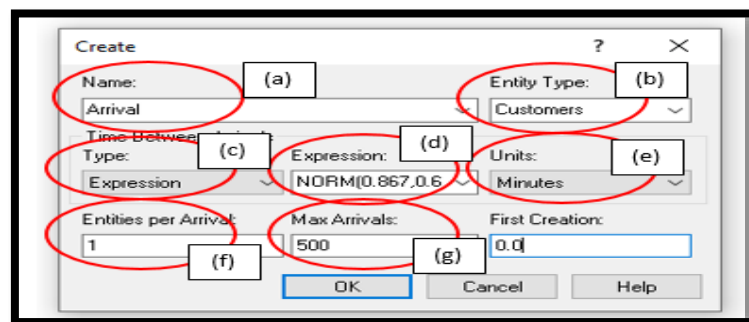


Figure 2.1: Create Pop-Up Box

- (a) **Name Field:** Type any name in this field to refer to a customer’s arrival. As a result, it will be known as ‘Customer Arrival’ in this study.
- (b) **Entity Type Field:** This field has three choices to choose from: ‘Entity, Customers, and Items.’ The entity is a general newcomer who joins the queue. Meanwhile, the second and third options appear, since ‘Customers’ and ‘Item’ would be defined in the entity sector. If the option ‘Customers’ is selected, the system will only allow customers to join the queuing system. As a result, this area will be set to ‘Customers.’
- (c) **Type field:** There are three options of the time between arrivals: type, value, and units. There are four types of form to choose from (i) Random (expo), (ii) Schedule, (iii) Constant, and (iv) Expression. Select Expression.
- (d) **Value Text Box:** The value text box indicates the average time between arrivals. This value field will be filled in according to the expression in Table 2.1 in this analysis.
- (e) **Units Field:** There are three choices for units, including hours, minutes, and seconds. The Value field will be set in minutes in this study.

- (f) **Entities per Arrival Field:** The number of customers who arrive at each arrival is defined in this field. Entities per arrival will be set in this study to make analyzing the results simpler.
- (g) **Maximum Arrivals:** The Max Arrivals field indicates the total number of customers expected to join the system. It means that the number of customers who will be admitted to the scheme can be predetermined. The Max Arrival will be set to 50 in this study, which means only 50 customers will enter and exit the system. After finished filling in the details, click OK to save it.

2.5 Process Pop-Up Box

It is essential for us to fill out the Process pop-up box and enter the required details. To open the Process pop-up box, double-click on the Process button. The Process pop-up box appears as shown in Figure 2.2. The Process pop-up box has many fields that must be filled out. We have one Process buttons corresponding to one resource in this study. The one Process button represents one cashier, calculated using the data distribution obtained from the input analyzer.

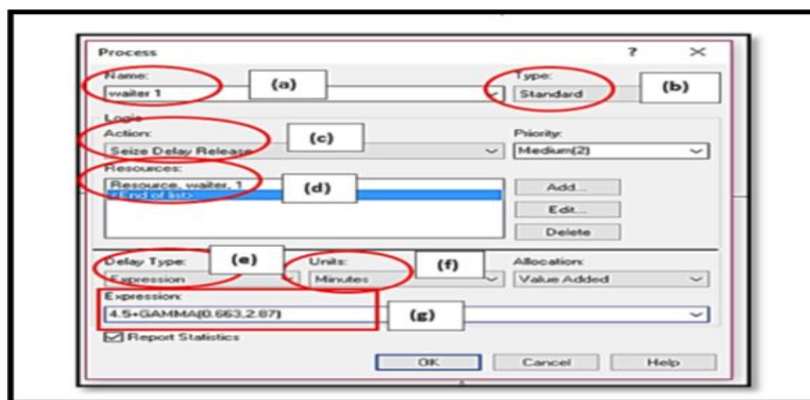


Figure 2.2: Process Pop-Up box

- (a) **Name field:** Type any name in this field to name the simulation. It will be known as Counter 1 in this study. Customers are using the system to pay for their items.
- (b) **Type field:** Submodel and Standard are the two choices in the form area. When several models are linked together, a sub-model is used. Standard was chosen because standard queuing can only be used in this simulation’s framework.
- (c) **Action field:** There are four options in this field and Seize Delay Release will be selected. Consider the following scenario: customers will join the supermarket system, wait for the cashier to scan their item, and pay for their items at the counter, and only be released after the customers have completed their services.
- (d) **Area of Resources:** If the Seize Delay Release option is selected in the action field, this field will appear. Instead, except for the Resource name area, leave the other fields blank. Since they are the ones that offer the services to the customers, the resource area will be called Counter 1.
- (e) **Delay type:** There are five options in this field: Triangular, Constant, Normal, Uniform, and Expression. Once we have keyed in the data, we will get the delay from the input analyzer’s output.
- (f) **Units field:** The time units that will be used in the simulation are defined in this region. To get the result in minutes, set this field to Minutes.
- (g) **Expression field:** This field follows the data distribution obtained from the input analyzer and results from the Delay form field. Then the OK button will be pressed to save the data and move on to the next level.

2.6 Dispose of Pop-Up Box

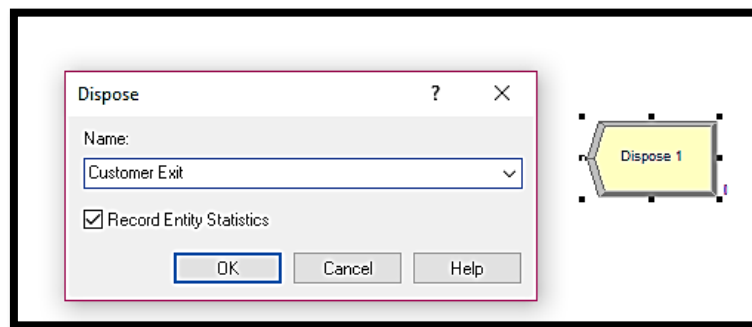


Figure 2.3: Dispose Pop-Up Box

Dispose of means to get rid of the whole thing (removed from the program). This is the final simulation, in which the customer leaves the machine after receiving their services. The Dispose is the number of customer exits written as Customer Exit in the Arena Simulation Software in this study, as shown in Figure 2.3 above. Customers will leave the store after they have completed their purchases at the checkout counter.

We only allowed 50 customers to enter the system during this study because a previous study just to observe 50 customers that came to the supermarket. Because the observation is 4 hours a day, the system's replication length is 4 [7].

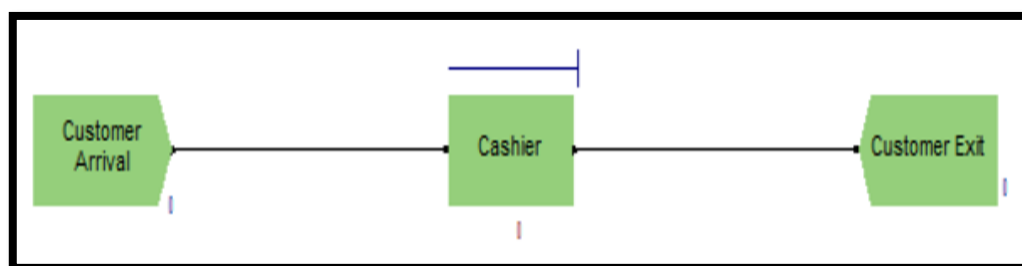


Figure 2.4: Base Model of supermarket in Arena Simulation Software

Figure 2.4 depicts the basic supermarket model that we simulate in the Arena Simulation Software. In this model, there is one arrival of customer, one server (cashier) that will serve the customers and one customer exit in this simulation.

In this research, there are one scenario proposed in order to analyze the changes in term of Average Waiting Time (W_q), Average Number of Waiting Customer (L_q), and Instantaneous Utilization ($\frac{\bar{c}}{c}$) was conducted. Based on the Arena Output Result, all of these variables are collected and analyzed.

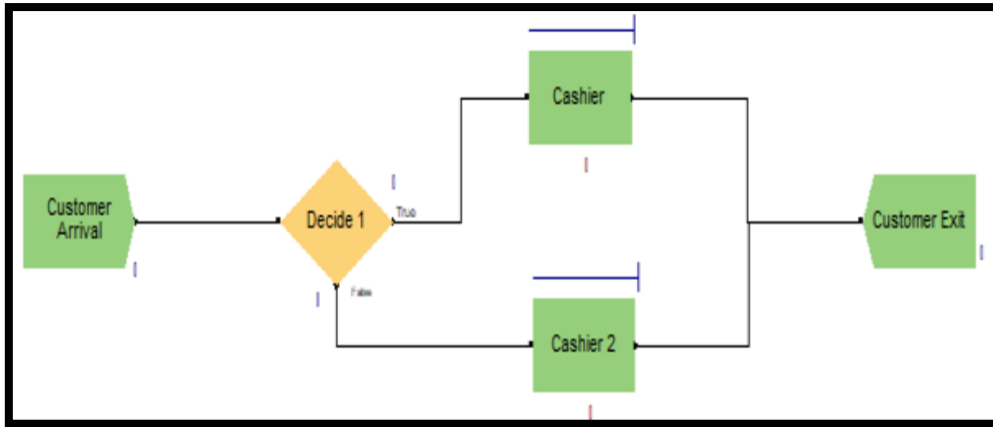


Figure 2.5: Arena Simulation Model for Scenario 1

The scenario 1 is added a server or Cashier 2, to the supermarket operation. We thought adding one cashier might reduce customer wait time in that supermarket. We suppose that Cashier 2's distribution is $1.5 + \text{LOGN}(2.96, 2.74)$, which is the same as Cashier 1 from the base model, because the result from the base model shows that Cashier 1 has the lowest average customer waiting time.

3. Results and Discussion

A simulation will be thoroughly modelled to determine and understand the queue's difficulties. As a result, some sort of remedy can be introduced in the system to alleviate the problems.

3.1 Results Output

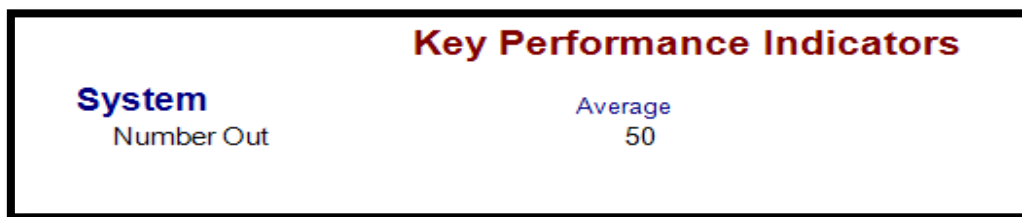


Figure 3.1: Key Performance Indicator of System

Figure 3.1 depicts the number of customers who enter and then exit the system during the simulation. In this figure, 50 customers leave the system after receiving service at the supermarket. This result is obtained when the Maximum Arrival is set to 50 arrivals.

Table 3.1: The Base Model Analysis Result

Performance Measurement	Result of Base Model
Total Average Time Waiting (Minutes)	13.84
Total Average Number Waiting (Person)	2.94
Instantaneous Utilization (%)	89

Table 3.1 shows the results after simulating the queuing using Arena Simulation Software. Base Model is consisting of one customer arrival, one server (cashier) and one customer exit. From this model, the customers will enter the queue to get served by the cashier and leave once they receive the

service. The overall Average Waiting Time (W_q) is 13.84 minutes. This shows that the W_q need to be reduced in order to serve more customers for a sufficient waiting time of the customer to be served. The Total Average Number of Waiting Customers (L_q) is 2.94, which is roughly equivalent to 3 customers queuing to receive service from the cashier in the supermarket. We need to reduce the L_q to reduce the customers' tiredness during waiting in the queue. Next, the cashier has an 89% for Instantaneous Utilization ($\frac{\bar{c}}{c}$). Thus, the cashier is well utilized, with less than 11% idle time. This idleness is required for the worker to take a short break during a busy period. As a result of these findings, we can conclude that the Base Model needs improvement in order to reduce the waiting time of customers, the number of waiting customers, and the instantaneous utilization to increase customers' satisfaction.

3.2 Analysis of Improvement System

Table 3.2: Arena Simulation Software Result of Cashiers for Scenario 1

Performance Measurement	Average Waiting Time (Minutes)	Average Number Waiting (People)	Instantaneous Utilization (%)
Cashier 1	8.55	0.86	45
Cashier 2	8.92	0.76	45
Total	17.47	1.62	90
Average	8.74	0.81	45

We assume that scenario 1, with a total waiting time of 8.74 minutes and a total number of waiting customers of one, would be the most effective scenario for reducing waiting time at the busy supermarket. We calculate the percentage for each performance. It show that 5.29 minutes which is about 38.22% can be reduced in W_q while for L_q is about 33.33% can be reduced. In this scenario, cashiers' instantaneous utilisation has decreased slightly by about 45%. However, the cashier appears to be idler than in the first Base Model simulation because they have 55% idleness to have a break in the servers. As a result, we can assume that the cashiers will be able to serve more customers during peak hours.

3.3 Comparison Between the Base Model and Scenario 1

Table 3.3: Comparison of Scenario 1 with the Base Model Analysis Result

Performance Measurement	Base Model	Scenario 1
Total Average Waiting Time (Minutes)	13.84	8.74
Total Average Number Waiting (Person)	2.94	0.81
Instantaneous Utilization (%)	89	45

There are significantly decrease for the W_q and L_q the $\frac{\bar{c}}{c}$ in Scenario 1 than Base Model. Unfortunately, the $\frac{\bar{c}}{c}$ in scenario 1 is not a good indicator where the cashier is not fully utilized with more than 50% idleness. This will cause management to pay a huge salary for a cashier who is not fully employed. Thus, the results indicate that Base Model is the optimum option to implement in this circumstance. The improvement of scenario 1 is substantially greater than Base Model but it is underutilized in the server. Thus, scenario 1 maybe can be implemented during peak hours as it very

helps the management to provide good service to customer in order to maintain the satisfaction of the customers' experience during shopping at the supermarket.

4. Conclusion

Base Model is the most effective queuing system. We calculated that the overall Average Waiting Time (W_q), is 13.84 minutes, the total Average Number of Waiting Customers (L_q) is 3 and the cashier has an 89% for Instantaneous Utilization ($\frac{\bar{c}}{c}$). This suggests that cashiers are well utilized, with less than 11% idleness throughout the operation hour. As a result, we suggest the supermarket just use one cashier and we anticipate that scenario 1 where another cashier will be hired only during peak hours in the store, hence lowering the worker's labour cost while maintaining the satisfaction of the customers.

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