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Najmeh Madadi
Universiti Teknologi Malaysia

Arousha Haghighian Roudsari
Inha University

Masoud Rahiminezhad Galankashi
Universiti Teknologi Malaysia

Modeling and Simulation of a Bank Queuing System

Najmeh Madadi, Arousha Haghighian Roudsari, Kuan Yew Wong, Masoud Rahiminezhad Galankashi
Department of Manufacturing and Industrial Engineering, Faculty of Mechanical Engineering
Universiti Teknologi Malaysia
Skudai, Johor, Malaysia
E-mail: najmeh.madadi@gmail.com

***Abstract*—One of the major factors influencing the success of organizations in today's competitive world is to increase customer satisfaction through the improvement of service quality. In any service organization, managers are mostly concerned about the time that customers are required to wait for receiving their service. Banks in particular pay special attention to service quality as the most significant core competence. The queue length and waiting time are two significant factors which play important roles in customer perception about the quality of service in banks. Therefore, banks' managers are concerned about providing the optimal service configuration that can satisfy both customers and service providers. Among different approaches which are useful to evaluate different alternatives, simulation has proven its high capability in modeling and evaluating such situations. This study attempts to investigate and suggest the best possible configuration for a bank in Malaysia through constructing computer–based simulation models. As the result of this study, the final suggested configuration shows improvement in terms of average utilization rate of counters and average waiting time that customers have to spend in the queue.**

Keywords-Computer modeling; queue; service time; simulation; bank

I. INTRODUCTION

One of the major factors influencing the success of organizations in today's competitive world is to increase customer satisfaction through the improvement of service quality. Therefore, service organizations have focused on various ways to understand customer perceptions and have planned different strategies in order to provide a greater degree of service to customers [1].

In any service organization, managers are mostly concerned about the time that customers are required to wait for receiving their service. The delays in receiving service which will lead to queuing are the usual problems in industrial environments and even in everyday life situations [2]. The fundamental features of a standard queuing system consist of the structure of the line, groups of demand, arrival and service processes, and discipline of the queue [3]. In on-site service organizations such as governmental agencies, retail stores or banks, the inability to optimize the capability of the service will result in long queues. Hence, the recognition and understanding of customer demand and what the customer prefers is the initial step for the improvement of the service capability [4].

Banks in particular pay special attention to service quality as the most significant core competence [5]. Therefore, different approaches have been applied in order to improve service quality and consequently customer satisfaction in the banking industry. For instance, Shao et al. [4] adopted agent simulation to determine the optimal resource configuration of a bank, in terms of cost and customer satisfaction. In a similar study, Sarkar et al. [1] applied simulation to find the best alternative in terms of reducing the service time of banks' counters considering the utilization rate of counters. However, Sandmann [6], used simulation for studying delays in a set of queues with correlated service time at each node, where service time for each customer at the first node is a random variable and the consecutive service times are correlated with the one at the first node. Hammond and Mahesh [7] also tried to propose a simulation model, in which some bank teller management policies were applied to achieve the desired level of service quality. In other different studies, Jiantong and Liu [8] and Wang and Sun [5], applied the six-sigma methodology with DMAIC steps in banking services, aiming at enhancing service quality. In addition, some other researchers tried to incorporate industrial engineering techniques to improve the service quality of banks. As an example, in the study conducted by Pei [3], motion study was performed in order to reduce the service time of a bank's tellers.

Reviewing the relevant literature reveals that tellers and lobby services are the two important areas through which the productivity of banking operations can be improved. Waiting for a long period of time, will result in customer dissatisfaction. Therefore, banks should have adequate teller stations to be able to provide quick service and at the same time ensure that tellers are not idle and their productive work time is properly used [7]. It should be noted that waiting time relies on several factors such as arrival rate of customers in the system, time of the day, rate at which the service is provided, service type, and efficiency of counters [1].

Customer behavior has a tremendous influence on the effectiveness of service resource utilization. A typical customer's characteristics can be influenced by the following specifications: the type and quality of demand, the priority by which she/he is served, the bearable queue length, the tolerable waiting time, etc. The queue length and waiting

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time are two significant factors which play important roles in customer perception about the quality of service. However, in order to have an optimal service configuration, both the customer perception about the quality of service and the cost of providing the service should be taken into account [4]. Therefore, various options should be tested to achieve the best possible configuration which is acceptable from both the customer's and service provider's points of view.

Among different approaches which are useful to evaluate different alternatives, simulation has proven its high capability in modeling and evaluating such situations. Caring about the aspect of time and having knowledge about the possible ways through which the waiting time can be reduced are necessary even prior to starting a simulation. This knowledge specifically is very useful to create suggestions for possible work layouts or other alternative changes. The altered situations are then tested sequentially and compared using simulation [2].

Taking into account the mentioned advantages of performing simulation in the service industry, this study also applies the simulation approach in order to investigate the optimum configuration by which, better service quality for a bank in Malaysia can be achieved. However, unlike many similar computer-based simulation studies which used ARENA software, this study applies WITNESS software to construct a computer-based simulation model for the bank under study. In addition, the study tries to present an illustrative example of how better service quality in a banking system can be accomplished, taking into account the utilization rate and cost of implementing a new configuration.

This paper consists of different parts. In the next section, a brief description about the bank will be presented. The conceptual framework of the model will be discussed in section III. Sections IV and V give information about the operating conditions of the bank under study and assumptions of the model respectively. Section VI provides information about the collected data. Section VII presents the simulation model which is constructed using WITNESS software. Verification and validation of the simulation model will be discussed in sections VIII and IX respectively. Section X provides a comparison between the current configuration of the bank under study and other suggested alternatives, and finally the conclusion of the study is presented in section XI.

II. A Brief Description about the Bank

The company chosen for this study is one of the banks located in Johor Bahru, Malaysia. The bank works 5 days per week. It has 4 counters and 2 service tables which are exclusively for service information. The bank opens at 9:15 a.m. and closes its entrance door at 4:30 p.m., but still operates until all the customers in the bank are served. Once a customer enters the bank, she/he takes a number from the ticket machine based on the required service. The bank offers five different types of services including:

- A: Deposit/ Withdraw/ Loan payment
- B: Western Union
- C: Customer Service Information
- D: Preferred/ Prime account
- E: Account Opening

Customers are categorized into three groups based on the type of service chosen:

- Customer type 1: A, B and E
- Customer type 2: D
- Customer type 3: C

The number taken represents the position of the customer in the waiting line. The customers will be called according to their numbers based on the queue discipline. Three queues have been considered in the system:

- Q1: the queue for getting a ticket number
- Q2: the queue in which the customers will be served by one of the four counters
- Q3: the queue in which the customers will be served by one of the service tables

The customers arrive at the bank and join Q1 to take a number from the ticket machine. Customer type 1 will be placed in Q2 and will wait to be called based on the first-in first-served discipline by one of the four counters. Customer type 2 has a priority over other customers and will also be served by one of the four counters. However, the situation is different for customer type 3. When a type 3 customer arrives in the system and takes a number, if any of the 2 service table tellers is available, she/he will join Q3; otherwise she/he will join Q2 and will be treated as a type 1 customer in the system. It should be noted that, in the real situation there is a common waiting area in the bank where all types of customers wait together to be served based on their numbers, that is, the mentioned queues are all virtual.

III. Conceptual Framework of the Model

Based on the description in section III and the observation on customer flow in the real system, the conceptual framework of the model can be drawn. Fig. 1 represents the conceptual framework related to the bank under study.

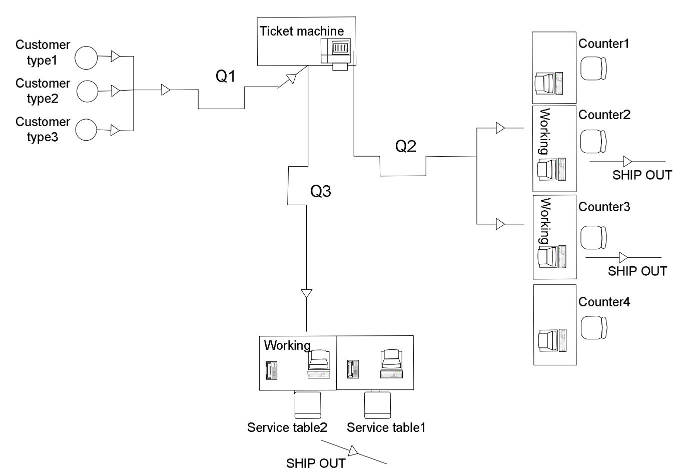

Figure 1. Conceptual framework of the model.

IV. OPERATING CONDITIONS OF THE BANK

In order to construct the simulation model, the operating conditions of the bank should be precisely investigated and taken into account. The following conditions have been considered.

- Bank opens its door at 9:15 a.m.
- Ticket Machine will stop working after 4:30 p.m.
- Only 2 of the four counters and 1 of the two service tables are working.
- One of the two working counters works until 5 p.m., whereas the other one is open until all customers in the system are served.
- Just one of the two available service tables works. Working shift for this service table is three hours per day from 9:15 a.m. to 12:15 p.m.

V. ASSUMPTIONS OF THE SIMULATION MODEL

The following assumptions were considered when the simulation model was constructed:

- The customers remain in the system until they receive the required service.
- The interval between the time a customer is called by a server and the time when a service starts can be neglected.
- There is no interruption in service at the counters.
- Based on the operating conditions of the bank described in the previous section, one of the working counters works after 4:30 p.m. until all customers in the system are served; it is assumed that there is no customer in the system by 7:15 p.m. (i.e. the run length of the system is considered 600 minutes).
- Waiting time is the time when a customer takes a number until she/he is called to be served.
- Breakdown time of 12 minutes and time between failures of 180 minutes have been considered for counter 2.

VI. DATA COLLECTION AND ANALYSIS

Data related to inter arrival time of the customers and service time of the two working counters and one service table were collected during one working day.

The pattern of customer arrival in the system is a basic attribute of a queuing system. In order to have an insight about a service system, the corresponding distribution of inter arrival time must be investigated. In many studies, it has been proven that the time between arrivals of customers follows a negative exponential distribution [3].

Using the chi-squared goodness of fit tests lead to the conclusion that the arrivals of types 1 and 3 customers follow a negative exponential distribution with an average of 3.89 minutes and 29.62 minutes respectively. However, data analysis shows a uniform inter arrival time of 34 ± 5 minutes for type 2 customers. In addition, the goodness of fit tests for data related to service time of counters 2 and 3 demonstrate conformity with a negative exponential distribution with an average of 6.7 minutes and 7.14 minutes respectively. On the other hand, the service time corresponding to the service table follows a uniform distribution with an average of 10 minutes and a tolerance level of 1 minute (10 ± 0.5).

Table I is an illustration of the chi-squared goodness of fit test which was implemented for inter arrival time of customer type 1. The procedures for other attributes are the same.

- H0 (Null hypothesis): data follow a negative exponential distribution with an average of 3.89.
- H1 (Alternative hypothesis): data do not follow a negative exponential distribution with an average of 3.89.

TABLE I. CHI-SQUARED GOODNESS OF FIT TEST

Class	Test Details				
	Cum. Prob.	***Cell Prob.***	***Expected***	***Observed***	***Chi-squared value***
0-1	0.226	0.226	24.915	26	0.047
1-2	0.402	0.175	19.272	11	3.550
2-3	0.537	0.136	14.907	18	0.642
3-4	0.642	0.105	11.530	12	0.019
4-5	0.723	0.081	8.919	11	0.486
5-6	0.786	0.063	6.899	9	0.640
6-7	0.834	0.049	5.336	10	4.076
>7	1	0.166	18.223	13	1.497
Total chi-squared value= 10.958					
DF= 8 (number of classes) - 2= 6					

Considering a significance level of 0.05, the corresponding chi-squared critical value equals to 12.59 which is greater than the obtained total chi-squared value namely 10.958 (Table I). This result confirms that there is no evidence for rejecting the null hypothesis and it can be concluded that the inter arrival time of customer type 1 follows a negative exponential distribution with an average of 3.89 minutes.

VII. SIMULATION MODELING

In the modeling phase, the constructed conceptual model is converted into a computer-based simulation model. Computer simulation is a useful technique to analyze complex systems which are expensive to be changed through real experimentation. This approach allows investigation of different service configurations without any physical alteration, leading to the selection of the best solution while spending significantly lower cost.

This study uses WITNESS software to convert the conceptual model into a simulation model. The WITNESS simulation package is capable of modeling a variety of discrete (e.g., part-based) and continuous (e.g., fluids and high-volume fast moving goods) elements [9]. The following section gives information about the simulation flow and presents the interface of the WITNESS simulation model for the current configuration of the bank.

A. Flow and Interface of the Model

Considering the operating conditions as well as the assumptions of the model (refer to sections IV and V), the flowchart shown in Fig. 2 was followed when constructing the simulation model. It should be noted that type 2 customers have priority over other types of customers and they do not follow the queue discipline.

Fig. 3 shows the WITNESS interface for the constructed simulation model.

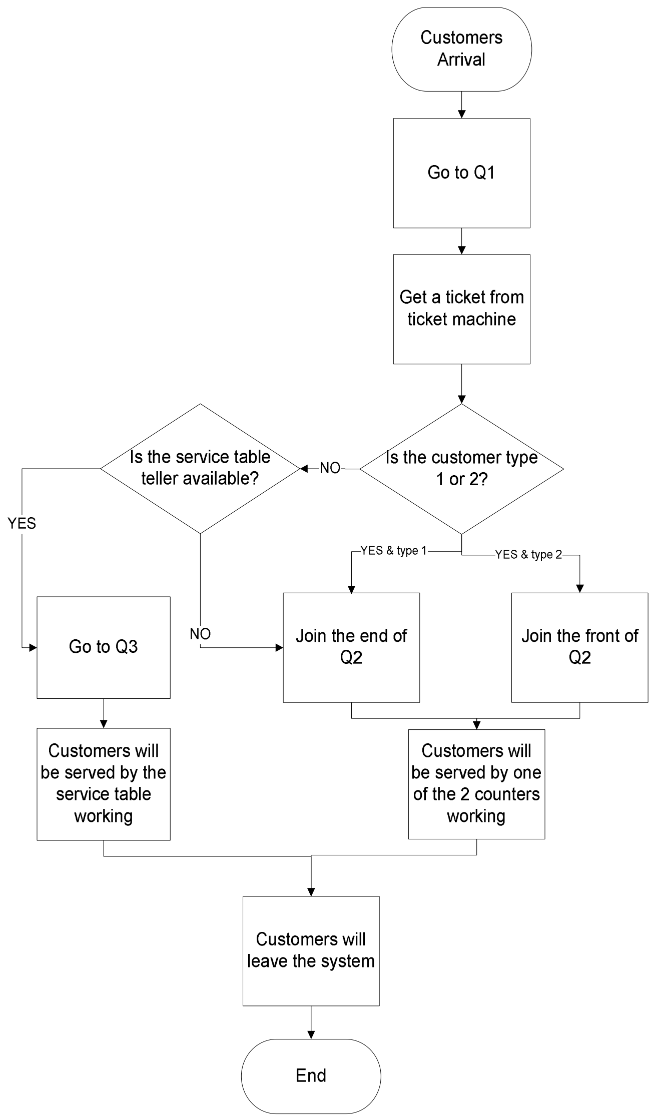

Figure 2. Flowchart of the simulation model.

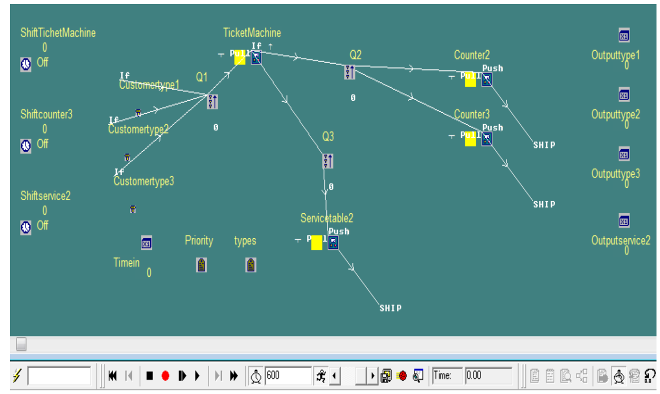

Figure 3. Inter face of WITNESS software for the simulation model.

VIII. Verification of the Model

Verification aims at testing the computer-based model against the conceptual model [10]. Verification is performed to show that all parts of the model are able to work correctly. The model was verified through taking small steps, one at a time and making sure that the completed step was working well before continuing with the next step.

IX. Validation of the Model

The validation process was conducted to examine the accuracy of the model as compared to the real system. To do so, the average number of customers was selected as the measure of model validity. In this respect, the actual average number of customers arrived at system during 5 working days (134 customers) was compared to the average number of customers obtained in 5 iterations of the simulation model (129 customers). The traditional comparison between these two values shows an acceptable difference (3.7%) which establishes the validity of the simulated model.

X. Finding the Best Configuration

Table II presents the results obtained from simulating the current configuration of the bank under study. The manager of the bank believes that the current average waiting time of 39.47 minutes that customers have to spend in the queue to be served by one of the two counters is unacceptable. Therefore this value could be decreased by investigating different alternatives. However, from the manager's point of view, other factors such as the cost of implementing changes and the utilization of counters should also be taken into account. To do so, different configurations have been suggested and simulated. The output results are presented in the following section.

TABLE II. OUTPUTS RESULTING FROM SIMULATION OF CURRENT CONFIGURATION

Counter/Service table	Outputs	
	Idle time (%)	*Busy time (%)*
Counter2	16.35	77.22
Counter3	16.49	83.51
Service table2	56.21	43.79
Queue	***Avg. waiting time***	***Avg. queue size***
Q2	39.47	8.75
Q3	3.03	0.04

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A. *Suggesting Different Configuration Alternatives*

This section introduces different configurations that may result in better outputs including average utilization rate and average waiting time.

1) Alternative I: Improving the service rate through training the employees

Any reduction in service time leads to a decline in the average time that customers have to spend in the queue. Training is one of the effective ways that leads to the reduction in service time of the counters. Based on manager's opinion, training the associated tellers can reduce the service time of counters 2 and 3 at least to 6.2 and 6.5 minutes respectively which will decrease the average waiting time in Q2 by 13.11 minutes.

The effect of training on other factors is presented in Table III.

TABLE III. OUTPUTS RESULTING FROM ALTERNATIVE I

Counter/Service table	Outputs	
	Idle time (%)	*Busy time (%)*
Counter2	26.13	67.44
Counter3	18.62	81.38
Service table2	56.21	43.79
Queue	***Avg. waiting time***	***Avg. queue size***
Q2	26.36	6.34

2) Alternative II: Addition of a new counter

As mentioned before, only two of the four counters were working in the current configuration of the bank. However, alternative II suggests opening a new counter (counter1) with working hours from 9:15 a.m. till 5 p.m. The new opened counter serves all types of customers, same as the other two counters. Table IV shows the simulation results related to the configuration of alternative II.

TABLE IV. OUTPUTS RESULTING FROM ALTERNATIVE II

Counter/Service table	Outputs	
	Idle time (%)	*Busy time (%)*
Counter1	40.22	59.78
Counter2	44.55	51.16
Counter3	29.01	70.99
Service table2	56.21	43.79
Queue	***Avg. waiting time***	***Avg. queue size***
Q2	9.07	2.01

3) Alternative III: Addition of a new counter and removing service table 2

In this configuration, service table 2 has been removed and a new counter (counter1) with two different working shifts (one from 9:15-17:00 and the other one from 9:15-13:00) is considered. In the absence of service table 2, type 3 customers are served by any of the three counters. The results of the two mentioned options are shown in Tables V and VI.

a) A new counter with working hours from 9:15-17:00

TABLE V. OUTPUTS RESULTING FROM ALTERNATIVE III- THE FIRST OPTION

Counter	Outputs	
	Idle time (%)	*Busy time (%)*
Counter1	38.89	61.11
Counter2	43.63	52.09
Counter3	24.37	75.63
Queue	***Avg. waiting time***	***Avg. queue size***
Q2	9.89	2.32

b) A new counter with working hours from 9:15-13:00.

TABLE VI. OUTPUTS RESULTING FROM ALTERNATIVE III- THE SECOND OPTION

Counter/Service table	Outputs	
	Idle time (%)	*Busy time (%)*
Counter1	31.07	68.93
Counter2	19.03	74.54
Counter3	20.60	79.40
Queue	*Avg. waiting time*	*Avg. queue size*
Q2	32.07	7.54

4) Alternative IV: Addition of a new counter, removing service table 2 and standardizing the shift of all counters.

In this option, service table 2 has been removed and a new counter has been added. The working shift of all counters is from 9:15 to 17:00. The outputs corresponding to this alternative are presented in Table VII.

TABLE VII. OUTPUTS RESULTING FROM ALTERNATIVE IV

Counter	Outputs	
	Idle time (%)	*Busy time (%)*
Counter1	17.54	82.46
Counter2	25.26	69.09
Counter3	23.28	76.72
Queue	*Avg. waiting time*	*Avg. queue size*
Q2	10.88	3.30

B. *Analysis of output data obtained from suggested alternatives*

As mentioned in the previous section, in order to select the best alternative, some factors including waiting time, utilization rate and cost of implementing a new configuration are the most influential factors which are taken into account by the manager of the bank under study. Figures IV and V respectively, give a comparison of average utilization rate and average waiting time resulted from the simulation of the considered alternatives. It is observed that alternative II has the lowest average waiting time followed by alternatives III.a and IV. As the manager is concerned about having a low average waiting time and a high level of utilization simultaneously, alternative II is less favorable due to its inappropriate level of utilization.

Comparing the waiting time corresponding to alternatives III.a and IV shows a slight difference (nearly about 1 minute) whereas the utilization rate of alternative IV is much higher than alternative III.a. Furthermore, based on management's perspective, the factor of cost should also be taken into account. Comparing the cost of implementing these two alternatives also shows a higher cost for alternative III.a, stems from the higher cost that should be paid due to longer working hours of one of the counters. Therefore, it can be concluded that alternative IV is the most suitable configuration in terms of average utilization rate, average waiting time and cost.

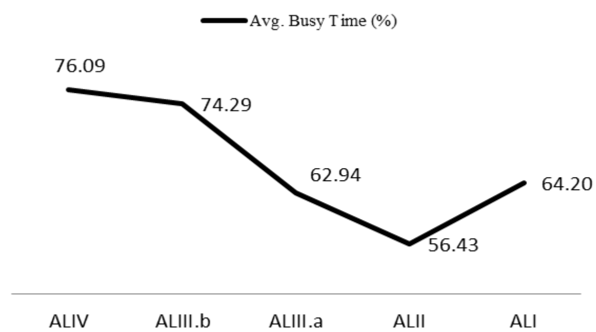

Figure 4. Average utilization percentage obtained from different alternatives

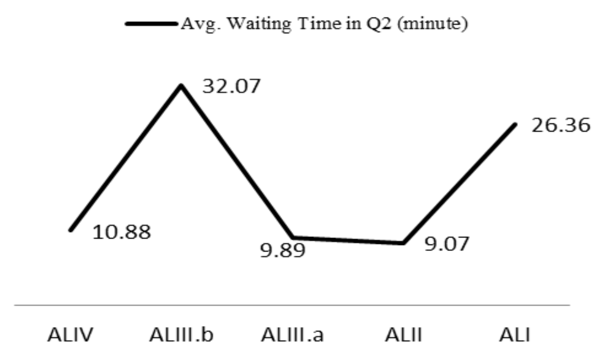

Figure 5. Average waiting time in Q2 related to different alternatives

XI. CONCLUSION

Through this study, an attempt was made to improve the service quality of a branch of a bank by constructing a computer-based simulation model. The simulation model proved its capability in investigating different configuration alternatives without imposing the cost of physical changes. The computer-based simulation model was constructed using WITNESS software based on the data and conceptual model related to the current configuration of the bank under study. After validation and verification of the model, different alternatives were suggested and their output data were compared. The results of comparison show that alternative IV which recommends the addition of a new counter, removing the service table and standardizing the shift of all counters is the most suitable configuration in terms of utilization rate, average waiting time of customers and cost of implementation.

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