Simulation and Analysis of a Bank Queuing System

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Abstract - **Improving service quality in the banking sector is essential for customer satisfaction. Decision makers are especially concerned about the time that customers wait before receiving their service. To stay competitive, decision makers have to continuously improve their service quality, measured in terms of suitable performance indicators. In this study, we focus on modelling and analysis of bank queuing systems. The study comprises three phases: (i) identify suitable performance indicators that influence customer perception with regards to service quality, (ii) simulate the behavioral performance of bank queuing systems, and (ii) evaluate and improve the service quality of the system. An illustrative case study is presented, showing the utility of proposed simulation approach.**

Keywords - **Simulation modelling, queuing system, bank queues, quality of service, productivity**

I. INTRODUCTION

Increasing customer satisfaction is a major cause for concern in the service sector. Service organizations, particularly banks, strive to find effective ways of improving the quality of service through a thorough understanding of customer perceptions and expectations. To obtain an understanding of customer behavior, it is essential to identify and select a suitable set of performance indices, and formulate appropriate strategies for improved customer satisfaction [1, 2].

In banking operations, the most common measure of customer satisfaction is average waiting time, i.e., the time that customers wait before service. This implies that any time delays before service eventually leads to queuing and customer dissatisfaction [1-4]. In addition to waiting time, some customers may perceive quality of service in terms of average service time, i.e., the time taken to serve the customer. However, since customer satisfaction is also influenced by their perception on queue length, it is worthwhile considering the average queue length as a suitable performance measure. Alongside performance measurement, performance improvement is crucial, leading to higher service quality [5-7].

Various approaches have been implemented to improve service quality and, ultimately customer satisfaction. In particular, a number of approaches have been applied in banks. For instance, Madadi et al. [1] investigated and suggested the best configuration for a bank using a simulation model. The suggested configuration showed a remarkable improvement in terms of average waiting time and server utilization. Shao et al. [6] used a simulation model to investigate the best alternative resource configuration of a bank based on cost and customer satisfaction. In the same vein, Saka et al. [2] presented a simulation model to find the best alternative in terms of service time and utilization rate of bank counters. Related simulation studies considered delays in queues with correlated service times [8], evaluation of bank teller management policies to achieve the desired level of service quality [9], and application of six-sigma principles to improve the service quality of bank operations [10]. A few researchers used work study techniques to improve the service quality of banking systems. For instance, Pei [5] used motion study to reduce the average service times of bank tellers.

Common to most of the studies in the literature is the fact that tellers and lobby services (transactional zone services) are the most important areas through which bank operations productivity can be improved [1]. In this view, it is crucial to provide adequate tellers while ensuring that the tellers and other resources are utilized efficiently [2, 9, 11]. To this end, the purpose of this study is to present an excel-based simulation approach for a bank queuing system. The objectives of the study are as follows:

1. to identify suitable performance indicators that influence customer perception of service quality;
2. to simulate the behavioural performance of bank queuing systems, and;
3. to evaluate and improve the service quality.

We note that average queue length and waiting time are the two most important factors that influence customer perception on service quality. In evaluating several of the available possible system configurations, both quality of service and cost of providing service should be considered

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from the customer and service provider's view point. We use business process re-engineering techniques to simulate and improve a bank queuing systems.

The rest of the paper is structured thus: The next section presents the case study background. Section III provides an excel-based simulation approach. Section IV presents comparative simulation results. Finally, Section V concludes the paper.

II. CASE STUDY BACKGROUND

The selected case study (name withheld) works from 0830 hours to 1530 hours. The bank operations comprise five main services: deposits, withdrawals, account opening, loan processing customer enquiries. However, interviews with the bank revealed that deposits take up over 40% of the total processes done in the bank; therefore, it is the most demanded service. Cash withdrawal experiences the longest waiting time, which may lead to customer dissatisfaction. Cash and check deposits are the most demanded services in the bank.

Customers entering the bank hall seek assistance from the service advisor regarding the queue to join. Currently, there is a single queue for check and cash deposits, cash withdrawal, and money transfer. Four tellers provide service for these customers on a first-in-first-out (FIFO) basis. Queues accumulate during tea and lunch breaks.

II. A. Base System Characteristics

Based on motion time study principles, the service times at the service advisor and at the tellers for deposits and cash withdrawals were measured over 6 days, for a sample of 30 customers for each parameter. In the same manner, the waiting times at the service advisor were measured. For comparison purposes, a brief survey was conducted using a brief questionnaire to investigate customers' perceptions on the waiting times and service times. A total of 30 customers were selected at random for the survey. The aim was to find out the expected waiting and service times. From these measurements and investigations, the average service times for the base case were obtained, as listed in Table I. Table II provides the resultant average waiting and service times associated with service advisor and tellers.

TABLE I
AVERAGE SERVICE TIMES FOR THE BASE CASE PROCESSES

Process	Average service time (sec)
Deposits(Cheque and cash)	128.55
Cash withdrawal <P10 000	224.90
Cash withdrawal >P10 000	319.71
Total processes	224.39

TABLE II
Average waiting and service times (sec) for the base case

Performance Indicator	Service Advisor		Teller	
	Actual	Expected	Actual	Expected
Average waiting time	20.1	15.3	492.0	242.0
Average service time	15.2	12.4	224.4	71.0
Total	35.3	27.7	716.4	313.0

B. Verification and Validation

Before accepting the results of the simulation model, verification and validation of the model were carried out. Verification was done to ensure that the model is correctly describing the system being modelled. This was done through walk through analysis and observations in the banking hall, as well as discussions with staff. This allowed the modeller to have a better understanding of how things worked in the system. Validation was done to ensure that the model is an accurate description of the real world system it is modelling. The average waiting time was selected as the measure of model validity. The average waiting time based on observation of the system for 6 days and a survey of 30 customers to find their perception on waiting times (492 seconds) was compared with the average waiting time obtained from the simulation model (7.73 minutes or 463.8 seconds). The comparison showed an acceptable difference of 5.7% between the actual and simulated results.

III. C. Assumptions

In this simulation approach, we make the following assumptions.

1. There is no customer in the system at the beginning of every working day.
2. The customers wait in the system until they receive the desired service.
3. The time taken by the customer to move from the queue to the teller is negligible.
4. The service at the tellers cannot be interrupted, once started.

Following the above-listed simplifying assumptions, an excel-based simulation methodology was constructed as presented in the next section.

III. EXCEL-BASED SIMULATION METHODOLOGY

Motivated by the above-described case study, we developed a five stage approach for analysing and improving bank queuing systems.

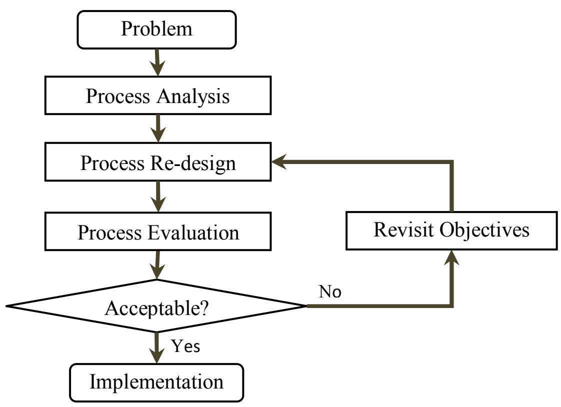


Fig. 1. The simulation-based approach: PADEI

IV. A. *The PADEI Approach*

The proposed five stage approach is a simulation-based methodology, called PADEI. The approach comprises the following:

1. P – Problem identification and formulation
2. A - Analysis of the existing process (base case)
3. D - Re-Design of the process or system
4. E - Evaluation of the re-design
5. I - Implementation

Fig. 1 shows the flow of the PADEI simulation-based approach. The problem identification stage consists of perception of the problem, gathering of relevant data, preliminary formulation of objectives and goals, and formation of project team. This is followed by the fundamental analysis of the existing process, which involves development of the as-is model for the current process, refinement and commitment to the goals and objectives. The design stage follows the analysis stage. Based on a set of performance indicators and the desired objectives, develop process design alternatives with possible improved performance. The evaluation stage consists of the use of simulation-based tools to assess the utility of the design alternatives proposed in the re-design stage. This measures the performance of the redesigned process before the actual implementation of the proposals.

Finally, when acceptable, the implementation stage installs the new design. The performance of the new process is evaluated quantitatively or qualitatively. The next section explains the simulation model.

V. B. *The Excel-based Simulation Model*

The excel-based simulation approach proposed in this study uses the M/M/s queuing model. The model can be used to analyse queuing systems in service systems, particularly in banks. The basic model parameters are defined as in the following notation:

Notation

λ Arrival rate: the number of customer arrivals per hour
s The number of servers available to serve customers
μ Service rate; number of customers served per hour
N Calling population
P_0 Probability of no customers in the system
P_n Probability of n customers in the system
W Average customer waiting time in queue and in service
W_q The waiting time of the customer in the queue
L The number of customers in the queue and in service
L_q The number of customers in the queue

The following performance measures are adopted from queuing theory, specifically the M/M/s model (Hillier and Lieberman, 2010) [12]. Thus, for a multiple server system, with $s > 1$, if $\rho = 1/(s\mu) < 1$, then,

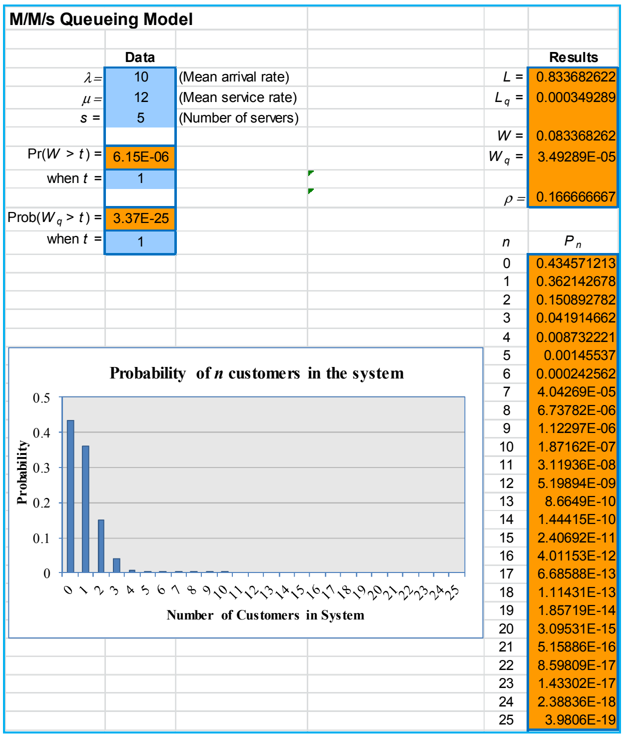


Fig. 2. The excel-based simulation model

$$P_0 = 1 \Big/ \left[\sum_{n=0}^{s-1} \frac{(\lambda/\mu)^n}{n!} + \frac{(\lambda/\mu)^s}{s!} \cdot \frac{1}{1-\lambda/(s\mu)} \right] \quad (1)$$

$$P_n = \begin{cases} \dfrac{(\lambda/\mu)^n}{n!} P_0 & \text{If } 0 \le n \le s \\ \dfrac{(\lambda/\mu)^n}{s!\, s^{n-s}} P_0 & \text{If } n \ge s \end{cases} \quad (2)$$

$$L_q = \frac{P_0 (\lambda/\mu)^s \rho}{s!(1-\rho)^2} \quad (3)$$

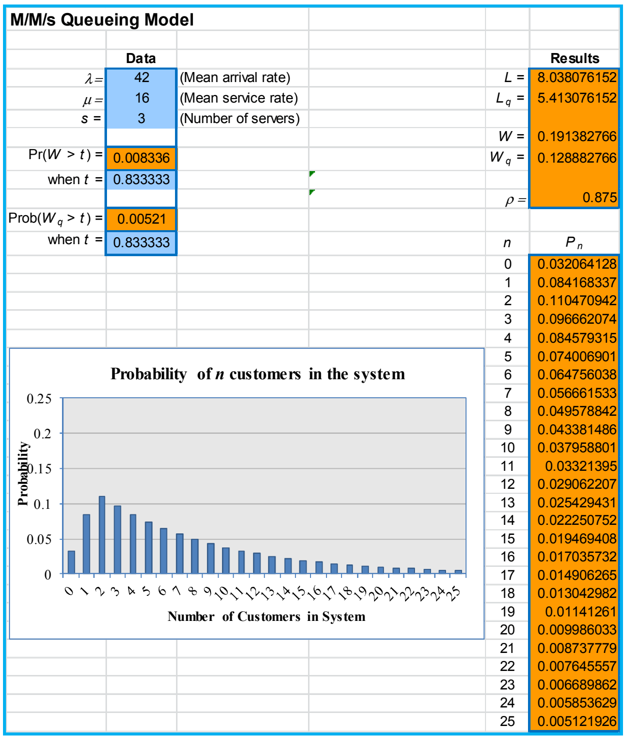
$$W_q = \frac{L_q}{\lambda} \quad (4)$$

$$W = \frac{L}{\lambda} \quad (5)$$

$$L = \lambda \left(W_q + \frac{1}{\mu} \right) = L_q + \frac{\lambda}{\mu} \quad (6)$$

The M/M/s model expressions (1) through (6) were built on an excel platform to evaluate the queuing system.

Fig. 2 shows the excel-based simulation model. The input parameters to the model are the arrival rate ($\lambda = 10$), number of servers ($s = 5$), the service rate ($\mu = 12$), and the time $t = 1$ which expresses the quality of service in


M/M/s Queueing Model

	Data	
$\lambda =$	42	(Mean arrival rate)
$\mu =$	16	(Mean service rate)
$s =$	3	(Number of servers)
$Pr(W > t) =$	0.008336	
when $t =$	0.833333	
$Prob(W_q > t) =$	0.00521	
when $t =$	0.833333	

	Results
$L =$	8.038076152
$L_q =$	5.413076152
$W =$	0.191382766
$W_q =$	0.128882766
$\rho =$	0.875

n	P_n
0	0.032064128
1	0.084168337
2	0.110470942
3	0.096662074
4	0.084579315
5	0.074006901
6	0.064756038
7	0.056661533
8	0.049578842
9	0.043381486
10	0.037958801
11	0.03321395
12	0.029062207
13	0.025429431
14	0.022250752
15	0.019469408
16	0.017035732
17	0.014906265
18	0.013042982
19	0.01141261
20	0.009986033
21	0.008737779
22	0.007645557
23	0.006689862
24	0.005853629
25	0.005121926

Fig.3. The simulated base case performance of the system

terms of the probability of waiting for a given time t. The output measures in the model are W, W_q, L_q, L, and P_n. Correspondingly, a set of output measures are presented alongside the input parameter values.

C. Base Case Performance

On average, the arrival rate of customers for cash deposits, cheque deposits and cash withdrawal was $\lambda = 42$ per hour. All customers then wait in a single queue for service by the next available teller. The mean teller service time for all transactions is $\mu = 3.74$ minutes, as recorded in Table 2. There are four teller cubicles, but oftentimes 3 tellers are available. Surprisingly, there is no defined procedure to determine the number of tellers needed at a particular time. The service advisor uses human judgement to call for available stuff member to help when the queue increases.

Fig. 3 presents the simulation results and the current performance of the system. With three tellers in the system, the average waiting time for customers is W_q = 7.73 minutes, and the average number of customers in the system is L = 8.03. The behavioural performance was validated against the observed performance of the actual system. The next stage of the simulation approach is concerned with re-design of the process in order to improve its performance.

D. Process Re-design and Improvement

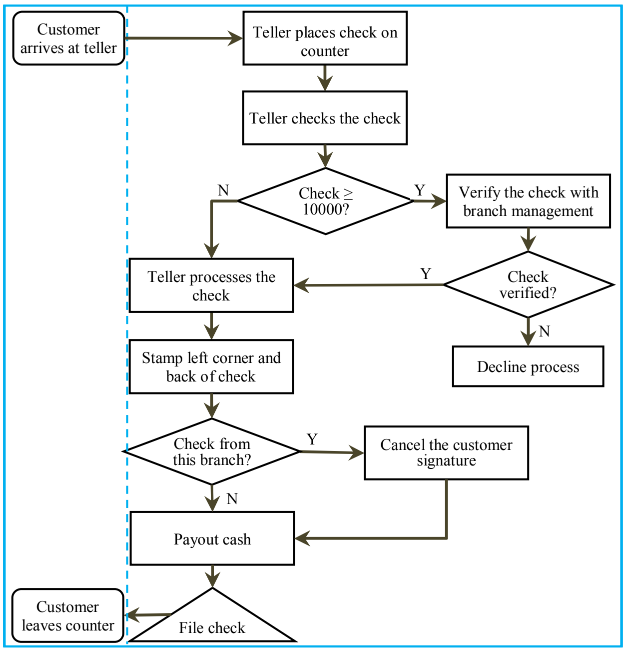


Fig. 4. Cash withdrawal process flow chart

In process re-design, the first step is to represent the process using flowcharting techniques. We present the case of cash withdrawal process in this section.

1) Process Mapping: Fig. 4 shows a flow chart of the cash withdrawal process. A customer with a crossed cheque comes to withdraw cash in a cheque account. There are two types of customers: check with amount less than P10 000 and one with amount P10 000 or above. For the latter case, the cheque has to be verified by management, while the customer waits. The next step involves value added analysis aimed at eliminating or cutting down the impact of activities that do not add value to the desired outcome.

2) Value Added Analysis: In value added analysis, process activities are evaluated from the view point of the customer and the bank. A value added analysis survey was carried out based on 30 randomly selected customers. The questionnaire lists the process steps, and respondents state whether or not each step adds value to the process. The questions were rated as follows:

1. Does the client care whether or not the step is done?
2. Is the step changing the nature of the item being processed?
3. Is the step done right the first time?

The results of the value added analysis procedure is shown in Table III. Non-value adding steps are stamping the check and writing the cash breakdown at the back of the check. These steps were candidates for improvement.

I. Following the above analysis, we measured the time taken by an average experienced worker to carry out the non-value adding steps. From the time study analysis, the steps consumed 17 seconds, thus, the process would be improved by 17 seconds, should these steps be eliminated, The same analysis was done for

TABLE III
VALUE ADDED ANALYSIS FOR CASH WITHDRAWAL

Action	Questions			Value?
	Q1	Q2	Q3	Adding
Place check in front of counter	Yes	Yes	Yes	Yes
Check the check: Date, Payee, Amounts in words and in figures, drawer signature, printers details	Yes		Yes	Yes
Process the check	Yes	Yes	Yes	Yes
CTRL-Backspace to clear account screen	Yes	Yes	Yes	Yes
Click on "Check amount" field on the amount screen. Input check amount	Yes	Yes	Yes	Yes
Make sure the name on the screen agrees with the name on check	Yes	No	Yes	Yes
Stamp the left corner and back of the check	No	Yes	Yes	No
For own branch checks, strike through the customer's signature;	No	Yes	Yes	No
Pay out cash	Yes	Yes	Yes	Yes
Write the breakdown of cash on the back of the check	No	No	No	No
File the check	Yes	Yes	No	Yes

deposits and loan application.

3) Queue Management: For improved queue management, we proposed the use of labels large enough for customers to see where to get the desired service rather than queuing up at the service advisor first. Only customers who need special attention can queue up at the service advisor. Separation of queues was suggested. Due to service time and demand variations across processes, separating queues reduces waiting time variations. The arrival rate for both cash and cheque deposits is 30 customers per hour with an average of 2.143 min service time. For cash withdrawal of less than P10 000, the arrival rate is 7 per hour with an average service time 3.75 min. For cash withdrawal more than P10 000, the arrival rate is 5 per hour with an average service time of 5.33 min. The proposal is:

1. Two tellers for deposits, with a single queue
2. One teller for cash withdrawal less than P10 000
3. One teller for cash withdrawal above P10 000

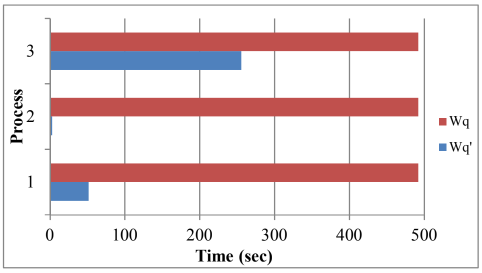


Fig. 5. Simulated performance based on waiting time

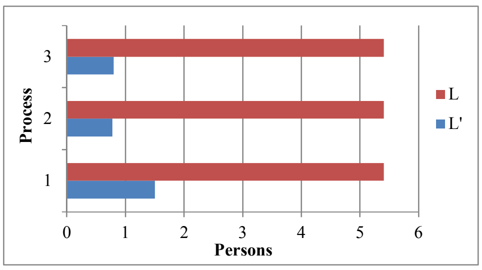


Fig. 6. Simulated performance based on number in system

The final evaluation and analysis of the proposed improvements are presented in the next section.

IV. EVALUATING THE IMPROVED PROCESSES

Value added analysis highlighted the non-value adding steps. Table IV presents the resulting service times due to improvements in the processes.

TABLE IV
IMPROVED PROCESS SERVICE TIMES (sec)

Process	Original	Improved
Cash withdrawal, amount < P10000	66	47
Cash withdrawal, amount ≥ P10000	93	90
Cash deposit process	36	21
Loan application process	1356	936

To evaluate the resulting performance of the improved system, we applied the excel-based queuing analysis. The major performance indicators chosen were average waiting time W_q and average number in system L.

Fig. 5 and Fig. 6 present a comparative analysis of the performance of the original and the improved system. The performance indicators for the improved system are denoted by W_q' and L' and for the original by W_q and L.

From the queuing management proposals, there is an improvement in waiting time. Before the improvement initiatives, the average waiting time is now reduced by the removal of the time waiting for service advisor, the time with the service advisor. The maximum average waiting time is reduced through separation of queues from 463.8 seconds to 255.6 seconds, which is in the cash withdrawal transaction of more than P10 000. As such, the maximum waiting time in the bank in the proposal is 255.6 seconds, an improvement from 499.13 seconds which included time waiting for service advisor, time with service advisor and time waiting for the tellers.

V. CONCLUSIONS

For customer satisfaction and business competitiveness in the banking sector, improving service quality is imperative. Decision makers should especially focus on the time that customers wait before service. To stay competitive, decision makers have to measure and manage the performance of their services in order to improve service quality. This paper presented an excel-based modelling and analysis approach to improving bank queuing systems. The study comprised three phases: (i) identification of suitable performance indicators, (ii) simulation of the system behavioural performance, and (ii) evaluation and improvement of the system service quality. A case study was presented, illustrating the usefulness of the proposed simulation approach.

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