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Retraction

Retraction: Application of queuing theory to reduce waiting period at ATM using a simulated approach (*IOP Conf. Ser.: Mater. Sci. Eng.* **1145** 012041)

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This article (and all articles in the proceedings volume relating to the same conference) has been retracted by IOP Publishing following an extensive investigation in line with the COPE guidelines. This investigation has uncovered evidence of systematic manipulation of the publication process and considerable citation manipulation.

IOP Publishing respectfully requests that readers consider all work within this volume potentially unreliable, as the volume has not been through a credible peer review process.

IOP Publishing regrets that our usual quality checks did not identify these issues before publication, and have since put additional measures in place to try to prevent these issues from reoccurring. IOP Publishing wishes to credit anonymous whistleblowers and the Problematic Paper Screener [1] for bringing some of the above issues to our attention, prompting us to investigate further.

[1] Cabanac G, Labbé C and Magazinov A 2021 arXiv:2107.06751v1

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Application of queuing theory to reduce waiting period at ATM using a simulated approach

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Abstract. Queuing theory is the mathematical study of waiting lines, or queues. A queuing model is constructed so that queue lengths and waiting time can be predicted. A basic queuing system consists of an arrival process (how customers arrive at the queue, how many customers are present in total), the queue itself, and the service process for attending to those customers, and departures from the system.This paper investigates the Automated Teller Machine (ATM) service optimization in the banking industry using queuing modelling approach. Data were collected over a week and calculations are done on an average. Measurements were taken about arrival time and service time of customers who arrived at the bank within the period of investigation. In ATM, bank customers arrive randomly and the service time is also random. We use Little’s theorem and M/M/1 queuing model to derive the arrival rate, service rate, utilization rate, waiting time in the queue.

Key Words: Arrival rate, Service rate, Queue, Poisson distribution, Exponential distribution.

1. Introduction

Queue is a common word that implies a holding up line or the demonstration of joining a line. Here are a few factors that decides the holding up season of an individual in a queue. By constructing a queueing model, we can predict the length and waiting time of a queue. With the help of queuing theory, the waiting time of a person in a queue can be reduced.

Queuing theory wasfrom the start proposed by Agner Krarup Erlang. He made models to depict the arrangement of Copenhagen Telephone Exchange Company. He displayed the quantity of telephone calls arriving at an exchange by a Poisson process. Queuinghypothesis is by and large considered as a part of operations research. The hypothesis has applications including telecom, traffic planning, figuring and, particularly in modern designing, in the plan of plants, shops, office and centers, just as in project the executives. Here we consider the queue formed in an ATM counter. The purpose of this paper is to check that the M/M/1 model is a best fit model for the queuing system that can be used to reducethe holding up time of customers.

2. Methodology

By utilizing queuing theory, we can streamline the waiting line, utilizing respective measures of performance, as average queue length, average waiting time in queue and utilization factor. In this paper data from an ATM is collected and detailed analysis is done utilizing Little's hypothesis and M/M/1 queuing model, and we are doing a comparison between simulated data and collected data.

By using queueing theory, we can inferthe expected holding up time in the queue, the average time in the system, the expected queue length as well as the states of the system, such as empty or full. Six fundamental attributes of a Queuingmeasures are, [1] Arrival pattern of clients[2] Service pattern of servers [3] Queue discipline [4] Systemcapacity [5] Number of administration channels [6] Number of administration stages. For the most part queuing models might be totally indicated in the symbol form (a/b/c): (d/e), where

a = Probability law for the appearance time

b = Probability law as indicated by which the clients are being served

c = Number of service stations

d = The Maximum number permitted in the system

e = Queue Discipline

The above notation is called Kendal's Notation.

The arrival and departure of customers occur randomly and independently so the number of clients appeared and served per unit time will be a Poisson distribution and the process are called Poisson process. The interarrival time follows an exponential distribution. The Poisson probabilities are calculated using Eq. (1) as follows:

$$f(x) = \frac{e^{-\lambda}\lambda^{x}}{x!}, \forall x \geq 0, \lambda \geq 0 \qquad (1)$$

Where

x = number of customers arrived per unit time.

λ = average customers arrival rate.

3. The Models Used

A wide assortment of queuing models might be applied in operations research. Here we utilize Little's hypothesis and M/M/1 queuing model to analyse the appearance rate, administration rate, utilization rate, holding up time in the queue with the assistance of Observed data.

3.1.Little's theorem

Little's theorem portrays the association between appearance&administration rate, cycle time and work in process (i.e. number of clients in the framework). The theorem expresses that the expected number of clients (N) for a system in consistent state can be resolved utilizing the accompanying equation:

$$L = \lambda W \qquad (2)$$

Here, λ is the average client appearance rate and W is the average administration time for a client.

3.2. The Single Server Poisson Queue Model (M/M/1): (FIFO/∞)

The M/M/1 is a Markovian model, where a solitary server is taken into concern. This model is the most rudimentary of queuing models. In this model we assume that appearance follow a Poisson distribution and administration times have an exponential distribution. In this model we assume the appearance rate is λ and administration rate is μ. Discipline followed here is first in first out that is there is no need arrangement for an appearance on help. There is no limit to the number of users, the

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service provider works at their full capacity and the service rate is independent of the line length [7-11].The M/M/1 model is viewed as steady just if λ<μ. On the off chance that on an average arrival happens quicker than service completions the queue will develop uncertainly long and the framework won't have a stationary distribution.

For the analysis of the queuing model, the accompanying factors will be explored.

λ: The mean client's appearance rate

μ: The mean service rate

$\rho = \frac{\lambda}{\mu}$: Utilization factor

- The average number of clients in the framework

$$Ls = \frac{\lambda}{\mu-\lambda}$$

- The average number of clients in the line

$$Lq = \rho\ L = \frac{\lambda^2}{\mu(\mu-\lambda)}$$

- The average time spent holding up in the framework

$$Ws = \frac{1}{\mu-\lambda}$$

- The average time spent holding up in the line

$$Wq = \rho\ W = \frac{\lambda}{\mu(\mu-\lambda)}$$

- The Probability of zero clients in the framework

$$Po = 1-\rho$$

- The Probability of n clients in the framework

$$Pn = (1-\rho)\rho^n$$

4. Data Analysis

All the data for the analysis was collected from a bank side ATM through direct observation and interview with an employee of the bank. The number of visitors on an average was obtained through an interview with an employee. The arrival time and service time was obtained through direct observation. The whole transactions were done through a single ATM counter. It was found that an average of 500 customers come to the ATM counter per day. Arrival and departure of customers for over 3 hours from 10.00 am to 01.00 pm were given in Table 1.

Table 1. Arrivals and departures of customers

Intervals	Arrivals/30min	Departure/30min

10.00 – 10.30	16	10
10.30 – 11.00	26	20
11.00 – 11.30	25	19
11.30 – 12.00	14	18
12.00 – 12.30	9	16
12.30 – 01.00	5	12

Starting from 10.00 am to 01.00 pm about 95 customers used the server for over 3 hours. This number of customers are taken as our sample for the analysis.Now the collected data was used to calculate the performance measure of the M/M/1 model. Table 2. shows the execution proportion of the model.

Table 2. Execution proportion of M/M/1 model

Attributes	Symbol	Value
Total sample taken into concern	n	95 customers
Average number of clients served per unit time	μ	1.95 customers per minute
Average number of clients arrived per unit time	λ	1.84 customers per minute
Average holding up time in line	Wq	8.5781 minute
Average holding up time in the system	Ws	9.0909 minute
Average number of clients in line	Lq	15.7837 customers
Average number of clients in system	Ls	16.7273 customers

4.1 Simulated Model

By assuming the following parameters

- The customers' arrival rate is random
- The customer's arrival time is infinite customers are served on FCFS basis the arrival rate is independent of each other and follows Poisson distribution and the interarrival time follows an exponential distribution
- Service times vary from one customer to another and it follows an exponential distribution.

And with the help of Random numbers and M/ M/1 model is drafted using Excel which is given in Table 3.

Table 3. Simulated Model

Sl. No	Arrival time	Random Number	Interarrival time	Service begin	Random number	Service time	Service ends	Wq	Ws
1	0	0.4334	0.3088	0	0.7768	0.7692	0.7692	0	0.5128
2	0.3088	0.2452	0.1529	0.7692	0.9595	1.6445	2.4138	0.4604	0.9732
3	0.4617	0.5632	0.4502	2.4138	0.4553	0.3116	2.7254	1.9520	2.4648

4	0.9120	0.8311	0.9668	2.7254	0.3844	0.2488	2.9742	1.8134	2.3262
5	1.8788	0.4020	0.2794	2.9742	0.3635	0.2316	3.2059	1.0954	1.6082
6	2.1583	0.7437	0.7399	3.2059	0.0367	0.0191	3.2251	1.0475	1.5604
7	2.8983	0.3693	0.2505	3.2251	0.48174	0.3370	3.5622	0.32628	0.8396
8	3.1488	0.2796	0.1782	3.5622	0.39093	0.2542	3.8164	0.4133	0.9262
9	3.3271	0.6963	0.6477	3.8164	0.4401	0.2974	4.1139	0.4893	1.0021
10	3.9748	0.4920	0.3681	4.1139	0.5540	0.4140	4.5280	0.1390	0.6519
11	4.3430	0.7387	0.7295	4.5280	0.7276	0.6670	5.1950	0.1850	0.6978
12	5.0725	0.0484	0.0270	5.1950	0.8413	0.9441	6.1391	0.1224	0.6353
13	5.0995	0.8750	1.1303	6.1391	0.2019	0.1156	6.2548	1.0395	1.5524
14	6.2299	0.6279	0.5373	6.2548	0.2439	0.1433	6.3982	0.0249	0.5377
15	6.7673	0.9862	2.3286	6.7673	0.62404	0.5016	7.2689	0	0.5128
16	9.0959	0.0640	0.0359	9.0959	0.58242	0.4478	9.5438	0	0.5128
17	9.1319	0.3621	0.2443	9.5438	0.27688	0.1662	9.7100	0.4118	0.9247
18	9.3763	0.6478	0.5672	9.7100	0.5353	0.3930	10.1030	0.3337	0.8465
19	9.9435	0.2839	0.1815	10.103	0.9077	1.2220	11.3251	0.1594	0.6723
20	10.1250	0.8270	0.9535	11.325	0.9730	1.8525	13.1776	1.2000	1.7128

5. Result and Discussion

From the result (Table 2) it is clear that the service rate is higher than the appearance rate, so the utilization factor will be less than 1 so the queue is stable. A total of 95 customers got served during the observed time interval and the average arrival rate is $\lambda = 1.84$ customers per minute and the average service rate is $\mu = 1.95$ customers per minute. Table 4 shows a comparison between simulated value and theoretical value. From this it is clear that the model is sufficient.

Table 4. Comparison between Simulated Value and Theoretical Value

	Wq	Ws	Lq	Ls
Simulated Value	7.822	8.335	14.393	15.337
Theoretical Value	8.5780	9.090	15.783	16.727

A simulation is an approximate imitation of the system. From Table 4 it is clear that there is no significant difference between simulated values and the theoretical values.

6. Conclusion

This examination paper talk about the use of queueing theory to an ATM counter. Utilization will be low if the service rate is high ,so the probability of the customers going away diminishes. From the analysis it is observed that the utilization factor is less than 1 so the queue isstable.From the comparision between simulated value and theoritical value it shows that the M/M/1 model is sufficient. On account of above discussion it is clear that, now the queue is stable so an increase in the number of servers is not needed as it will affect the coustomers demand and the profit of the bank.

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