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Modelling Customer's Satisfaction at Portofino Eatery Ado-Ekiti Using Queuing Theory

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Abstract
This study evaluated the queuing system in Portofino Eatery- Bread section with a view to determine its operating characteristics and to improve customers' satisfaction during waiting time using the lens of queuing theory. The model of operation was detected to be M/M/s model while the arrival rate, service rate, utilization rate and waiting time in the queue were derived. Data was collected by direct observation at the Portofino Eatery service facility, Ado – Ekiti. The arrival rate (λ) at Portofino Eatery- Bread section was about 43 customers per hour, while the service rate was about 40 customers per hour for each server. The system includes four different servers. The average number of customers in the system in an hour window was 43 customers with a utilization rate of 0.722. This research work concludes with a discussion on the benefits of performing queuing analysis to a restaurant. In order to avoid congestion and reduce customer's waiting time, increase patronage and boost customer's confidence in Portofino eatery service delivery.
Keywords: *Queuing theory, Restaurants, Portofino, Arrival rate, Service rate.*

INTRODUCTION

Queuing theory is the mathematical study of the congestion and delays of waiting in line. Queuing theory examines every component of waiting in line to be served, including the arrival process, service process, number of system places and number of customers (which might be people, data packets, cars, etc.). Queues happen when resources are limited. At its most elementary level, queuing theory involves the analysis of arrivals at a facility, such as a bank or a fast-food restaurant, then the service requirements of that facility, e.g., tellers or attendants. By applying queuing theory, a business can develop more efficient queuing systems, processes, pricing mechanisms, staffing solutions and arrival management strategies to reduce customer waiting times and increase the number of customers that can be served.(www. Jiwaji.edu.com)

Queuing theory otherwise known as waiting line causes not only inconvenience but is also discouraging and frustrate people's daily lives such as waiting at a hospital ward to see a doctor, waiting on hold for a telephone operator to pick up calls, queuing at a filling station to get fuel, waiting to get served by a cashier at a bank, sitting at an amusementpark to go on the newest ride among others are all queuing phenomena encountered in human daily activities. Thus, unmanaged queues are detrimental to the gainful operation of service systems and result in a lot of other managerial problems. In order to reduce the frustrations of customers, managers try to adopt certain measures like multiple lines, multiple checkout systems. In queuing theory, a queue does not refer simply to a neat row that is always first come, first served. This is one example of a queue, but not the only kind. A mob trying to rush for the door on Black Friday is considered as a queue, as is a group of job applicants waiting for interviews who are picked randomly, one by one, to be interviewed.

Queues formed in any service facility is for the purpose of quick and easy rendering of service to customers. Customers are served as they arrive based on the server discipline operated by the system so that limited time is spent by the customers in the system. Various queuing models have been developed in order to describe a different scenario of queues and to derive performance measures to determine how effective the system is in delivering its services in time. One area of such is the service rendered at eateries and food restaurants.

Reneging by customers due to long queues in Restaurants has become a frequent occurrence in many restaurants today. Most restaurants provide waiting chairs for their customers to seat and feel relaxed while waiting to be served. However, waiting for chairs alone would not solve a problem when customers withdraw and go to the competitor's door; the service time surely needs to be improved. This shows the necessity for a numerical investigation of the system and for the restaurant management to understand the exact situation better. As a result, statistical models such as queueing models are employed to determine the performance of the system. This work aims to show that queuing theory satisfies the model when tested with a real-case scenario. This study investigates the queuing system at the Portofino Eatery- Bread section in Ado Ekiti. Portofino eatery is a fast-food company that is into continental dishes, pastries, bakery and African dishes. It is located at Adebayo area of Ado-Ekiti, Ekiti State, Nigeria.

Queuing theory also known as random system theory is the body of knowledge about waiting lines and is now an entire discipline within the field of operation research and also it has become a valuable tool for operations managers.(www. Investopedia.com)

Different types of Queues and Services

- First In First Out or First Come First Served is fairly the most common service pattern in many places such as in banks, restaurants, malls etc. It is the type of queue you get when you have people politely lined up, waiting for their turn. Last In First Out is the opposite scheme; whoever has been waiting for the shortest time is served first. This type of queue management is common in asset management, where assets produced or acquiredlast are the ones used or disposed of first. For example: the most recent employees are often the ones laid off first.

- Balking is when a customer decides not to wait for service because the waiting time threatens to be too long. Reneging on the other hand is when a customer who has waited for a while decides to leave because they have wasted too much time. Jockeying is when a customer alternates between queues in a tandem/parallel queue system, trying to orchestrate the shortest wait possible to service.

Priority is where customers are served based on their level of importance or preference, these levels could be based on status, task urgency, or some other criteria. Shortest Job First is when whoever needs the shortest amount of service gets taken care of first. Processor Sharing is when everyone gets served, or half-served, at the same time; service capacity is distributed evenly among everyone waiting. There may be a single server, where a line of people or items must go through a single bottleneck, or parallel servers, where the same line is served by several servers. Or there may be a tandem queue, where each of multiple servers has their own queue or line (Chowdhurry, S. R. 2013).

Relevant Literatures on queuing theory were reviewed. Queuing has been reviewed by some to be process of people waiting in line to get served in commercial outfits like checkout counters, banks, super markets, fast food restaurants etc. Queuing theory according to Dharmawirya and Adi (2011) was particularly suitable to be applied in a fast food or restaurant settings, since it has an associated queue or waiting line where customers who cannot be served immediately have to queue for service.An arriving customer may find that he has to wait in a line, on entering the restaurant, if he finds another customer on line being served. If the customers arrive, then waiting line develops. Queuing theory or waiting line theory, aquantitative tool, was developed to examine and solve the associated problem. Hence, queuing theory is defined as properly matching of the service pattern to the rate of arrival of customers (Chowdhurry, 2013).

Queuing theory in relation to restaurants involves various factors, such as when large numbers of customers can typically be expected to arrive, the amount of time customers usually spend in the restaurant and the number of parties expected to loiter at their table long after they finish eating. Other facilities must address psychological issues associated with queuing theory to ensure customer satisfaction (Brann and Kulick, 2002). Queuing theory is the brainchild of A.K. Erlang. Its evolution could be traced back to the research he conducted in 1908, while studyingthe telephone traffic congestion with the objective of meeting uncertain demand for services at the Copenhagen telephone system and within ten years he had derived a method to solve the problem. The outcome of it is what is today termed as Queuing or waiting line theory (Cooper, 1990).

In any Eatery of this kind, unmanaged queues and long waiting time are detrimental to the gainful operation of service systems, which often results in a lot of other managerial problem, the issue this research study tends to looks into.

METHODOLOGY

The method employed in the data collection was direct observation. The data collected recorded the arrival time, waiting time, departure time and number of customers in the queue at Portofino Eatery (Bread section) for a period of 9 days (Three weekends) with a time frame of three-hour window intervals from 4pm–7pm daily. Based on observation (the number of servers which is noted by c), it is concluded that the model that best illustrates the operation of Portofino Eatery (Bread section) is *M/M/4*. The restaurant system consists of only four servers. However, the data obtained shows that customer's arrival time pattern is random and follows a Poisson distribution.

Model specification

1. Expected (average) number of customers in the system:

$$L_s = \frac{\lambda\mu\left(\frac{\lambda}{\mu}\right)^c}{(c-1)!(c\mu-\lambda)^2} P_0 + \frac{\lambda}{\mu} \quad \text{...... Equation 1}$$

2. Expected (average) number of customers in the queue:

$$L_q = L_S - \frac{\lambda}{\mu} \quad \text{...... Equation 2}$$

3. Average time a customer spends in the system:

$$W_S = \frac{\mu\left(\frac{\lambda}{\mu}\right)^C}{(C-1)!(C\mu-\lambda)^2} P_0 + \frac{1}{\mu} \quad \text{...... Equation 3}$$

4. Average waiting time of a customer in the queue:

$$W_q = W_S - \frac{1}{\mu} \quad \text{...... Equation 4}$$

5. Traffic intensity:

$$\rho = \frac{\lambda}{\mu} \quad \text{...... Equation 5}$$

6. The fraction of time each server is busy is given below

$$\rho = \frac{\lambda}{c\mu} \quad \text{...... Equation 6}$$

To determine the Probability distribution (p_n) for the number of customers Portofino Eatery (Bread section), use (p_n) to compute values in terms of (p_o). Therefore,

$$P_0 = \frac{1}{\left[\sum_{n=0}^{c-1} \frac{1}{n!}\left(\frac{\lambda}{\mu}\right)^n\right] + \frac{1}{c!}\left(\frac{\lambda}{\mu}\right)^c \frac{c\mu}{c\mu-\lambda}} \quad \text{...... Equation 7}$$

To obtain the Probability distribution (p_n) for the number of customers in the Portofino Eatery (Bread section), we use (p_n) to compute values in terms of (p_o). Sum the values of (p_n), set the sum equal to one since

$\sum_{n=0}^{N} P_n = 1$, and then determine the value of (p_o).

Note: we know the value of (p_n) if the value of (p_o) is known.

Results and Discussion

This study made use of data recorded between the hours of 04:00 pm to 07:00 pm at Portofino restaurant (Bread section), Adebayo, Ado Ekiti, Ekiti State, Nigeria.

The analysis was carried out on the 1,170 customers collected over 3 weekends (Friday, Saturday and Sunday) for 3 hours daily.

Table 1.0: Data on Number of Customers' arrival per hour.

	4:00 – 5:00	**5:00 – 6:00**	**6:00 – 7:00**	**TOTAL**
Friday	34	32	34	100
Saturday	57	69	14	140
Sunday	73	54	23	150
Friday	25	23	52	100
Saturday	50	66	24	140
Sunday	61	61	28	150
Friday	33	32	35	100
Saturday	51	56	33	140
Sunday	91	49	10	150
Total	**475**	**442**	**253**	**1170**

Customer's Average arrival rate (λ) =

$$\frac{Total \quad number \quad of \quad customers \quad Arrival}{Total \quad Time \quad Taken}$$

$$= \frac{1170 customers}{9 days}$$

= 130 per 3 hours

= 43.33 customers every hour

To obtain the value per 1 minute = $\frac{43.33}{60}$

= 0.722 Approximately 1 customer per minute

From the data in Table 1 aboove, it can be deduced that 4:00 – 7:00 on Sundays with the highest number of arrivals, is the busiest period during the weekends and the busiest day. This is understandable because Ekiti state being a state that its citizenry are majorly civil servants, most of the customers are always busy during the week. They only go out on weekends. Bread purchase on Sunday was on an increasing rate compared to others because some always like to have bread at home and because children love to have it before heading to work the following day.

Table 2.0: Data on Number of Customers served per hour

	4.00 – 5.00	5.00 – 6.00	6.00 – 7.00	TOTAL
Friday	2	38	27	67
Saturday	54	64	22	140
Sunday	47	56	47	150
Friday	14	30	29	73
Saturday	34	38	68	140
Sunday	36	74	40	150
Friday	27	26	28	81
Saturday	7	75	50	132
Sunday	50	38	62	150
Total	**271**	**439**	**373**	**1083**

Customer's Average Service rate = $\frac{\text{Total number of customers served}}{\text{Total Time Taken}}$

= 1083 customers served / 9 days

= 120.3 per 3 hours

= 40.1 customer served every 1 hour

To obtain the value per 1 minute = $\frac{40.1}{60}$

= 0.669 Approximately 1 customer per minute

Analysis

Using multi- channel queuing system (M/M/c).

$\lambda = 0.722$
$\mu = 0.669$
$C = 4$

System intensity (mean number in queue)

$$\rho = \frac{\lambda}{\mu}$$

$$\rho = \frac{0.722}{0.669}$$

$$= 1.079$$

The fraction of time each server is busy and given below

$$\rho = \frac{\lambda}{c\mu}$$

$$= \frac{0.722}{4(0.669)}$$

$$= 0.27$$

$$= 27\%$$

The probability that there are zero customers in the system is:

$$P_0 = \frac{1}{\left[\sum_{n=0}^{c-1} \frac{1}{n!}\left(\frac{\lambda}{\mu}\right)^n\right] + \frac{1}{c!}\left(\frac{\lambda}{\mu}\right)^c \frac{c\mu}{c\mu - \lambda}} \quad \text{for } c\mu \succ \lambda$$

$$= \frac{1}{\sum_{n=0}^{4-1} \frac{1}{n!}\left(\frac{0.722}{0.669}\right)^n + \frac{1}{4!}\left(\frac{0.722}{0.669}\right)^4 \frac{4(0.669)}{4(0.669) - 0.722}}$$

$$= \frac{1}{(2.8705) + 0.0774}$$

$$= \frac{1}{2.9479}$$

$$= 0.3392$$

The average number of customers in the system is calculated by the formula:

$$L_s = \frac{\lambda\mu\left(\frac{\lambda}{\mu}\right)^c}{(c-1)!(c\mu-\lambda)^2}P_0 + \frac{\lambda}{\mu}$$

$$= \frac{0.722(0.669)\left(\frac{0.722}{0.669}\right)^4}{(4-1)!(4(0.669)-0.722)^2}0.3392 + \frac{0.722}{0.669}$$
$$= 0.0286(0.3392) + 1.079$$
$$= 1.0887$$

The average time a customer spends in the waiting line and being serviced (namely in the system) is

$$W_S = \frac{\mu\left(\frac{\lambda}{\mu}\right)^C}{(C-1)!(C\mu-\lambda)^2}P_0 + \frac{1}{\mu}$$

$$= \frac{0.669\left(\frac{0.722}{0.669}\right)^4}{2\ .9086}(0.3392) + \frac{1}{0.669}$$
$$= 0.0134 + 1.4948$$
$$= 1.508$$

OR

$$= \frac{L_S}{\lambda}$$
$$= \frac{1.0887}{0.722}$$
$$= 1.508$$

The average number of customers on the queue, waiting to be served (attended to) at any time is:

$$L_q = L_S - \frac{\lambda}{\mu}$$
$$= 1.0887 - \frac{0.722}{0.669}$$
$$= 1.0887 - 1.079$$
$$= 0.0097$$

The average time a Customer spends in the queue waiting for service

$$W_q = W_S - \frac{1}{\mu}$$

$$= 1.508 - \frac{1}{0.669}$$
$$= 1.508 - 1.4948$$
$$= 0.013$$

OR

$$\frac{L_q}{\lambda}$$
$$= \frac{0.0097}{0.722}$$
$$= 0.013$$

The probability that a customer must wait for service

$$P_W = \frac{1}{C!}\left(\frac{\lambda}{\mu}\right)^C\left[\frac{1}{1-\frac{\lambda}{C\mu}}\right]P_0$$

$$= \frac{1}{4!}\left(\frac{0.722}{0.669}\right)^4\left[\frac{1}{1-\frac{0.722}{4(0.669)}}\right]0.3392$$
$$= 0.042(1.3566)(1.3695)(0.3392)$$
$$= 0.05653(1.3695)0.3392$$
$$= 0.026$$

Suppose, we are interested in knowing what percent of Customers in this system waits for a threshold time of 2 minutes or less before they are attended to, we run the function

QTPMMS_ServiceLevel (Threshold time, Arrival Rate, Service Rate, Servers)

Threshold Time = 2 minutes

Arrival Rate = 0.722

Service rate = 0.669

Servers=4

QTPMMS_ServiceLevel (2,0.722,0.669,4) =0.9995

=99.95%

If 99.95% of the customers waits 2 minutes or less before they are attended to, it means that

100 % - 99.95% = 0.05 % waits longer.

However, using the same threshold time of 2 minutes, if we so desire to know the number of servers needed to achieve a service level of say 99.95% i.e. how many servers do we need to ensure that 99.95% of the customers spends less than or equal to 2 minutes before they are attended to,

We run the function;

QTPMMS_MinServers (Threshold time,Service level, ArrivalRate, Service Rate)

QTPMMS_MinServers (2,99.95%,0.722,0.669) = 5

This means that if we want 99.95% of the arriving customers to spend a maximum of 2 minutes before being attended to, we would need to have 5 servers attending to the customers.

Below in Figure 1.0 is the graph showing the Different desired service levels and the minimum number of the servers needed to achieve them

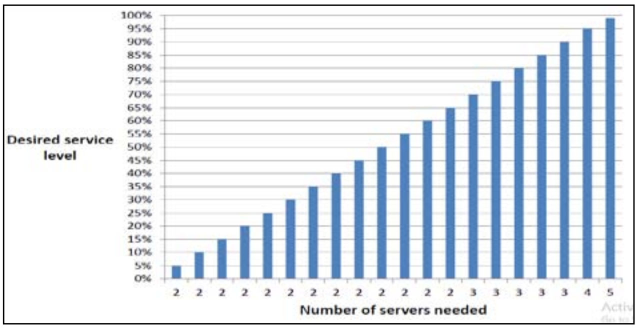

Fig 1: Chart showing the desired service levels against the minimum number of servers

If weare also interested in calculating the state probabilities. The state of a queuing system (at least for so-called markovianqueuing systems) is the number of customers in the system state probability is the probability that an observer arriving at random sees customer in the system.

Using the function QTPMMS_PrState (state, Arrival rate, service rate, servers)

The table of the state probabilities is shown in table 3

Table 3: Table showing the states and the respective state probabilities

Number of customers (State)	0	1	2	3	4	5	6	7	8	9	10
Probability	**34%**	**37%**	**20%**	**7%**	**2%**	**1%**	**0%**	**0%**	**0%**	**0%**	**0%**

Table 3 depicts that;

i. The state probabilities add up to exactly to 100%.

ii. The probability of the system being in state 0 is the same as the probability of the system being empty i.e. the probability that there are zero customers in the system from (i) is equal to the probability of the system being in state 0

iii. The sum of the probabilities of the system being in state 4 or higher equals the probability that an arriving customer has to wait for service. The chart of the probabilities is displayed in Figure 2 below

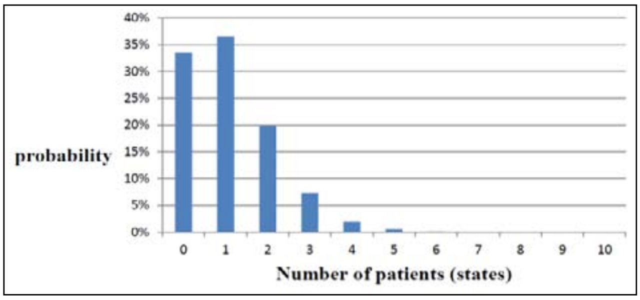

Fig 2: Chart of the showing the states and their respective state probabilities

CONCLUSION

From the calculations of the queuing parameters, the fraction of time each server is busy is gotten as ρ = 0.27 (i.e. this shows that each server will be 27% busy) and while the system intensity is 1.079 (i.e. it is greater than 1 which reveals there is a queue). The probability that there will be zero customers in the system when a customer comes in, is P0= 0.3392 which is uncertain because the probability for it to be certain is 1.The average number of customers in the system is gotten as Ls= 1.0887, while the average number a customer spends in the waiting line and being serviced is 1.508 which implies that a customer has to wait an average time of Ws= 1.508 before he/she can be served. The average number of customers on the queue waiting to be served is Lq= 0.0097 while the average time a customer spends in the queue waiting for service is Wq= 0.013, that is a customer has to wait an average time of 0.013 on the queue. The probability that a customer has to wait for service is Pw= 0.026 which implies the probability that a customer will wait for the service without leaving the queue is 0.026 which is uncertain because it falls below 1. It is shown that the performance of the servers is sufficiently good with the addition of the fifth server. It can be seen that the probability of the servers being busy was 0.9998 which was 99.98%. The proposed system which is the multiple-line, multi-server system reduces the waiting time of customers in the queue. This implies that a customer needs to wait longer in the queue of the existing system compared to in the proposed system. We can say that this work has shown that the single queue design will improve the efficiency and the quality of services in the Portofino eatery (Bread section).

Referring to the proposed system, the interpretation from the analysis shows that there should make a transformation of their queuing system. We can clearly see that the proposed system has an advantage over the existing system design. The customers' waiting time is shortened by applying the proposed system design. As the waiting time of customers is reduced, this will increase the customers' satisfaction and can help improve the quality of service at Portofino eatery (Bread section). The result of this research work may serve as a reference to analyze the current system and improve the next system. However, the restaurant can now estimate how many customers will wait in the queue and how many will walk away each day. By anticipating the number of customers coming and going in a day, the restaurant can set a target profit that should be achieved daily depending on the purchases each customer makes. This research work recommends the following to the eatery. The results from this project work should be used to improve customer service and optimize the business' efficiency. Improvement on customer's relation. Use of pre-order (this allows customers to pre-order their meals). Taking note of customers in system to know when there is the need for expansion. There should be Improvement on quantity and quality of foods. There should be constant staff training on how to relate with customers. They should adopt multi system queue in place of single line server. There should be more additional server when the system is busy to have more efficient service.

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