A Project Report On,

"A Study on The Queue at CNG Station in Nashik City"

In the partial fulfilment of M.Sc. degree in Statistics 2021-2022

Submitted to

SAVITRIBAI PHULE PUNE UNIVERSITY, PUNE

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CERTIFICATE

This is to certify that, Miss. Dhikale Shubhangi Kailas, Miss. Gaikar Kajal and Miss. Gawali Manasi have successfully completed the project *entitled "A Study on The Queue at CNG Station in Nashik City*" under my guidance and supervision during the academic year 2021-2022.

Dr. K.P. Amrutkar
(Project Guide)

Head,
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Date: 27-06-2022

Place: Nashik

DECLARATION

We hereby declare that project entitled A Statistical Study on " The Queue at CNG Stations ", submitted by us, for the partial fulfilment of our M.Sc. degree in Statistics during 2021-2022 is our original work.

We further declare that the analysis has been carried out based on primary data collected from CNG stations at Nashik city in Maharashtra. We have given our best and hope that our project work may be helpful for people to reduce heavy rush at CNG stations.

ACKNOWLEDGEMENT

The success and final outcome of this project required a lot of guidance from many people. All that we have done is only due to such direction and we would not forget to thank them.

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ABSTRACT

Background: A statistical survey is carried out to study a queue at CNG stations among the Nashik. We have collected primary data through direct observation from CNG stations. Primarily we have selected 3 stations for data which are situated at three different locations.

Objectives: To review queuing Theory and its empirical analysis based on the observed data of CNG stations. To briefly overview the queue at CNG stations and to simulate a queue-server model to reduce waiting time. Also, to estimate average waiting time, service time to give statistical support to CNG filling slot booking web application.

Method: We have use queueing analysis, simulation model for queue theory.

Results: The waiting time can be decrease if we increase service unit (number of serves)

Keywords: Queue at CNG stations, servers, queue theory, utilization factor, waiting time.

MOTIVATION

A model is presented in this paper is for CNG pumps. The model was developed under the assumption that there are many customers having requirement of fuel for uninterrupted working of their vehicles and limited number of gas outlets in working conditions at every CNG pump (service providers) which provide gas to fill the cylinders of vehicles. The heavy rush at CNG pumps motivates the people to move for other fuels like petrol, diesel, etc which increases the level of pollution in the atmosphere. Studying this situation in many CNG pumps we realized that people are ready to switch from other pollution increasing fuels to CNG but the long queue at CNG pumps demotivates them. **As per the latest survey of Times of India, it was observed that long queue of vehicles waiting outside CNG pump stations led to traffic congestion on service lanes or even main roads.** For each CNG center it is a challenge to decrease the waiting time and to improve the customer's satisfaction. Long waiting times is the most important problem in customer's satisfaction. We have discussed many customers and the most frequent issues are about the waiting time which is too long and the number of less outlets. To manage these situations, we will use queuing models which can provide reasonably accurate evaluations of our system's performance. The results of this study can help us to understand the situation and the relationship between resources and waiting times, and to provide a method for understanding and providing a better solution to face the daily rush at CNG pumps.

INTRODUCTION

There is regular heavy traffic outside the CNG filling station in every area on the nearby roads. The whole road is occupied by vehicles waiting for filling fuel. There is other traffic also near the CNG station and it gets difficult to drive through these roads many times. Heavy rush at CNG stations is a major problem in our city in current scenario. The demand of fuel at CNG pumps is increasing day by day but the capacity of CNG pump is not in the same ratio.

CNG Pump's performance in terms of customers flow and of the available resources can be studied using the Queuing Theory. CNG stations can be regarded as a network of queue and servers where customers with their requirements of fuel in respective vehicle arrive, wait for a service, get the fuel tank i.e., gas cylinder filled and then leave the station. The length of queue, utilization of pumps and waiting time evaluations are effective tools to support management decisions about capacity planning of their CNG stations as per the arrival and service rate of customers. These problems could be solved from the results of the proposed model. In this project, we proposed our analysis, to use queuing models with simulation modeling at CNG pump stations to provide an accurate evaluation of the system's performance in present situation, to make appropriate capacity plan in order to maintain uses of resources.

We have chosen 3 different locations of CNG stations. The data used for this study is collected from the number of arrivals and departures from direct observation of customers that come to purchase CNG for weekdays and weekends at three different locations, between peak hours. During data collection, data were collected based on the arrival rate and departure rate of customers at the fuel station for particular server that were serving customers. Also, formal and informal interviews at an individual level of discussions were held to obtain clarification about other variables that can influence the development of the queueing model for customers satisfaction. The interview conducted with the CNG Pump Operators and Manager by us revealed that an average of 1200kg CNG arrive at stations. He also revealed that the waiting time of customers in the system increases during the peak hours and that the service discipline was on First Come First Serve (FCFS) basis.

Technical Problem

- To measure the expected queue length in each service unit (server) and the service rate provided to the Passenger.
- To study the nature of arrival and service rate.
- To determine whether the system is working good if not then what changes should be made for better performance (to reduce waiting time) in other words to give insight view of the steady-state behavior of queuing processes and running the simulation experiments to obtain the required statistical results.

Conversion of technical problems into statistical problems

- The arrival and service rate distributions of customers have been checked as it is main assumption of queueing theory.
- Selected appropriate queue model and checked its performance.
- Queue analysis have been conducted and appropriate model have been suggested for better service.

Theoretical Background

At the CNG stations, it is a situation where the customers arrive from a calling population and joins a queue of customers to be served available on a first-come, first served (FCFS) basis. There is no limit on customers joining this particular queue, and the calling source is infinite. The primary data collection from direct observations shows that there was complete randomness in arrival pattern as well as service pattern. Therefore, M/M/c: FCFS/∞/∞ queueing model has been proposed for the queue. Where c is the number of servers. M/M/c: FCFS/∞/∞ queueing system is a multi-server queueing system with Poisson input, exponential departure distribution, first come first served service discipline, unlimited number of calling population and waiting positions. This model was structured to accommodate the main characteristics of the queueing system the CNG station.

- **Assumptions for Queuing Model:**

1. The system is assumed to be in a steady state.
2. Arrivals at the system of passenger follows poisson distribution.
3. Service time is exponentially distributed.
4. The capacity of the queue is infinite (any number of customers can join the queue), and only one line comes up.
5. The queue discipline is First-Come, First-Served (FCFS) basis by any of the servers. There is no preference classification for any arrival.
6. The mean arrival rate is constant. This rate is independent of the number of customers already serviced, queue length or any other random property of the line.
7. The servers here represent only the CNG pumps but not pumps for other products.

8. The service providers are working to their full capacity.
9. The mean service rate μ is constant. This rate is independent in the sense that server won't speed up when the line is longer.
10. Both the arrival and departure rates are state dependent, meaning that they depend on the number of customers in the service facility.
11. No customer leaves the system after entering the Queue until the CNG gas is not finished.
12. There is no jockeying in the system (changing the Queue lines).

- **Determination of Performance Measures M/M/c: FCFS/∞/∞ Queueing Model:**

Service demanded by customers is greater than the capability of servers, and so a queue is formed, that is, $n \geq c$ (the number of customers in the system at a time is greater than or equal to the number of servers). Therefore, all servers will be busy, and the maximum number of customers in the queue will be n-c.

Where,

n = Number of customers in the system,

λ= Arrival rate,

μ = Service rate

- **The utilization factor ρ:** For the whole system is the ratio between the mean arrival rate λ and the maximum possible rate of service of all the channels;

Hence,

$$\rho = \lambda / c\mu$$

- The probability of having no customers (empty or idle facility)

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

- The mean length of waiting line

$$L_q = \frac{\lambda\mu \left(\frac{\lambda}{\mu}\right)^c}{(c-1)!\,(c\mu - \lambda)^2} \; P_0$$

- The average number of customers in system

$$L_s = L_q + \frac{\lambda}{\mu}$$

- The average time customer spends in system

$$W_s = \frac{L_s}{\lambda}$$

- The average time customer spends in the queue

$$W_q = \frac{L_q}{\lambda}$$

- Average waiting time for an arrival not immediately served

$$W_q = \frac{1}{(c\mu - \lambda)}$$

- **Determination of the Acceptable Utilization Factor**: The mean for the servers' utilization factor is to be determined. The model with the least squared deviation from this calculated mean is the minimum acceptable utilization factor for the policy making in this system, and it is also known to be the optimal utilization factor and the corresponding number of servers is required to provide the optimal service level. Any value below this value is at this moment rejected because utilization factor below the acceptable factor causes an increment of idle time, and decrease in service rate.

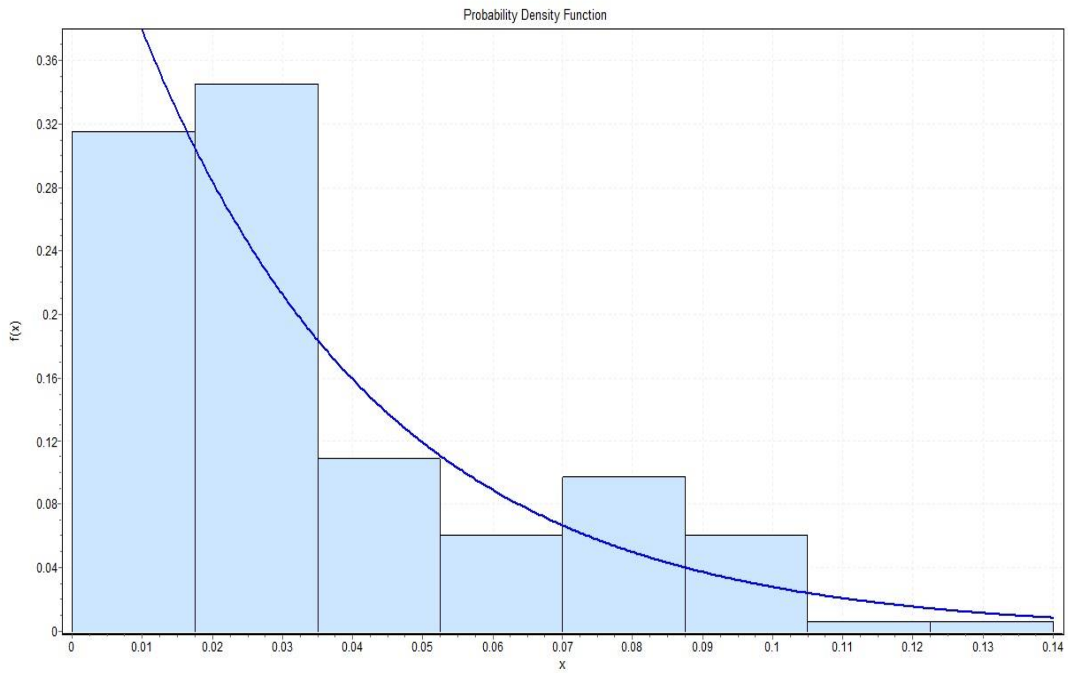
Analysis of The Data

First, we have checked assumptions for queue model at CNG stations:

One of the advantages of availability of software packages is to handle the data to get a solution for effective decision making of followed distributions types. EasyFit is used for checking the distribution types followed by arrival rate and service rate.

e.g.

Service Rate Follows Exponential Distribution



This graph is for the service rate distribution of Station 3.

Similarly, distribution of arrival and service time have been checked for all the stations.

Assumption followed by stations:

a. Arrival time follows Poisson process.
b. Service rate is exponentially distributed.
c. Identical service facilities.
d. No passenger leaves the queue without being served.
e. Infinite number of passengers in queuing system. (i.e. No limit for queue capacity)
f. FIFO (first in first out) or FCFS (first come first serve)
g. Server working at their full capacity.

❖ **Station 1** (Deshmane Petrol Pump, Pimpalgaon Baswant):

Analysis of current situation:

Arrival rate: λ: 0.2057 customer/min

Service rate: µ: 0.2188 customer/min

System utilization: ρ:0.9545

The mean length of waiting line: Lq:20

The average time customer spends in system: Ws:100mins

Here, system works with **single queue single server.**

Waiting time is too high.

So, we expected to do changes that, like What if service unit(servers) will increase?

The result is as follows

Comparative Analysis

scenario	c	λ	µ	ρ	p_0	Ls	Lq	Ws	Wq
1	1	0.21	0.22	0.9545	0.0454	21.00	20.044	100	95.45
2	2	0.21	0.22	0.7234	0.3538	12.36	10.98	48.96	47.23
3	3	0.21	0.22	0.5772	0.3812	1.2361	0.2815	5.8862	1.3408
4	4	0.21	0.22	0.3181	0.3845	0.9923	0.0378	4.7255	0.1801

Discussion of results:

i. The arrival rate follows a Poisson distribution and the service rate follows an exponential distribution
ii. The existing queueing model is that of M/M/1: FCFS/∞/∞
iii. The ρ = 57.72% obtained from the 3-servers model is closest to the mean utilization factor 61.83 % as it has the least squared deviation from the average value for all models and hence selected as the minimum acceptable utilization factor for the system with this model, a customer spends an average duration of 5.87 minutes in the station and just 1.34 minute in the queue.
iv. The application of this model, however, implies the addition of two more servers will leads to the less waiting time.

❖ **Station 2** (Adhav petrol pump,Nandur Naka,Nashik):

Analysis of current situation:

Arrival rate: λ: 0.2242 customer/min

Service rate: µ: 0.2421 customer/min

System utilization: ρ:0.9166

The mean length of waiting line: Lq:10.0833 customers

The average time customer spends in system: Ws:50 mins

Here, system works with **single queue single server**.

The comparative analysis result is as follow

Comparative Analysis

scenario	c	λ	µ	ρ	p_0	Ls	Lq	Ws	Wq
1	1	0.22	0.24	0.9166	0.0833	11	10.0833	50.00	45.833
2	2	0.22	0.24	0.4583	0.3714	1.16	0.2437	5.2747	1.1080
3	3	0.22	0.24	0.3055	0.3965	0.9489	0.0322	4.3132	0.1466
4	4	0.22	0.24	0.2291	0.3994	0.9212	0.0045	4.1872	0.0206

Discussion of results:

i. The arrival rate follows a Poisson distribution and the service rate follows an exponential distribution
ii. The existing queueing model is that of M/M/1: FCFS/∞/∞
iii. The ρ =45.83% obtained from the 2-servers model is closest to the mean utilization factor 47.73 % as it has the least squared deviation from the average value for all models and hence selected as the minimum acceptable utilization factor for the system with this model, a customer spends an average duration of 5.2747 minutes in the station and just 1.34 minute in the queue.
iv. The application of this model, however, implies the addition of one more server leads to the less waiting time.

- **Station 3** (Bharat petrol pump, CBS, Nashik):

Analysis of current situation:

Arrival rate: λ: 0.23 customer/min

Service rate: µ: 0.33 customer/min

System utilization: ρ:0.6969

The mean length of waiting line: Lq :1 customer

The average time customer spends in system: Ws:6 mins

Here, system works with **single queue two server.**

The comparative analysis result is as follow

Comparative Analysis

scenario	c	λ	µ	ρ	p_0	Ls	Lq	Ws	Wq
1	2	0.23	0.33	0.6969	0.4359	1.2941	0.7300	5.8823	3.3182
2	3	0.23	0.33	0.3484	0.5600	0.6128	0.0487	2.7857	0.2216

Discussion of results:

Existing model is already working well. Because its utilization rate is moderate. We don't think that we should make changes in it as waiting time is already good.

Conclusion

Following the analysis, observations and lots of formal and informal interviews carried out in this research work, the following recommendations are made:

i. The Management should open more servers for less waiting time. It will lead to better performance.
ii. Waiting time drastically changes as the service unit increases.
iii. Incentives can be given to creating over time; which will increase the utilization factor of the suggested number of servers.
iv. To improve customer satisfaction, loyalty, and goodwill leading to an improved state of the facility since there is still 27.66% of the time that all the 3-servers are not busy for station 1 and so on.
v. Any utilization value below the minimum acceptable utilization rate of the proposed model is not encouraged as there will be an increment of idle time leading to less productive time.
vi. The proposed model provides a tool to assist management of the service station and same service stations to take decisions more precisely as compared to decisions based on intuition and judgment about the number of facilities to be provided for efficient service delivery.

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In [4]:
```
n=int(input("Enter the number of customers in the system:"))
lambda1=float(input("Enter the arrival rate:"))
mu=float(input("Enter the Service rate:"))
c=int(input("Enter the number of server:"))
print(lambda1)
print(mu)
print(c)
utilization_factor=lambda1/(c*mu)



from math import factorial
po = 0
for n in range(c):
    po += ((((lambda1/mu)**n)/factorial(n))+((((lambda1/mu)**c)/factorial(c))*((c

Po = 1/po
Po

lq = ((lambda1*mu)*(lambda1/mu)**c)/((factorial(c-1))*(c*mu-lambda1)**2)*Po
lq

Ls=lq+(lambda1/mu)
Ls

Ws=Ls/(lambda1)
Ws

Wq=1/(c*mu-lambda1)
Wq

print('utilization factor is:',utilization_factor)
print('probability of having no custome:r',Po)
print('mean length of waiting line:',lq)
print('average number pf customer in the system:',Ls)
print('average time customer spend in the system:',Ws)
print('average time customer spend in queue:',Wq)
```

```
Enter the number of customers in the system:50
Enter the arrival rate:0.222
Enter the Service rate:0.24
Enter the number of server:1
0.222
0.24
1
utilization factor is 0.925
probability of having no customer 0.07499999999999996
mean length of waiting line 11.408333333333342
average number pf customer in the system 12.333333333333343
average time customer spend in the system 55.5555555555556
average time customer spend in queue 55.55555555555559
```

In [6]:
```
from datetime import datetime,time,timedelta
now = datetime.now() # current date and time
t1 = now.strftime("%H:%M:%S")
print(f"You are booking your slot at {t1}" )
timeList = ['1:40:00', t1]
mysum =timedelta()
for i in timeList:
    (h, m, s) = i.split(':')
    d = timedelta(hours=int(h), minutes=int(m), seconds=int(s))
    mysum += d
print(f'You will be serverd at {str(mysum)}.')
```

```
You are booking your slot at 10:35:06
You will be serverd at 12:15:06.
```