International Journal of Advanced Scientific Research and Management, Special Issue II, Oct 2018
www.ijasrm.com
ISSN 2455-6378

A Case Study of CNG Pump Using Simulation Modelling Approach

Prachi Jain[1], Rashid Ali[2]

[1] Department of Applied Sciences, Vishveshwarya Institute of Engineering & Technology, Greater Noida - 203207, Uttar Pradesh, India

[2] Department of Applied Sciences, Krishna Engineering College, Ghaziabad -201007, Uttar Pradesh, India

Abstract

A model is presented in this paper 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 in India. Studying this situation in many CNG pumps I realized that people are ready to switch from other pollution increasing fuels to CNG but the long queues at CNG pumps demotivates them. As per the latest survey of Times of India, it was observed that long queues of vehicles waiting outside CNG pump stations led to traffic congestion on service lanes or even main roads. It was also observed that haphazardly parked cars and autos can also lead to accidents. For each CNG centre it is a challenge to decrease the waiting time for environment friendly fuel 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 broader problem, the relationship between resources and waiting times, and to provide a method for understanding and providing a better solution to face the daily crisis at CNG pumps.

Keywords : *CNG pump; Fuel; Servers; Queuing Theory; Waiting time.*

1. Introduction

There is regular heavy traffic block outside the CNG filling station in every area on the nearby roads. The whole road is occupied by vehicles waiting for filling fuel. They queue up in 2-3 rows which take away a major portion of the road. Besides, there are other traffic also near the CNG station and it is a nightmare to drive through these roads many times.
Heavy rush at CNG stations is a major problem in our country in current scenario as this is the best fuel for having pollution free transportation. The demand of fuel at CNG pumps is increasing day by day but the capacity of CNG pump is not in the same ratio. Delays in the availability of fuels may cause drastic outcomes for customers as well as for surroundings. 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 queues 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 r or 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.

Simulation has been practiced to numerous segments including services, manufacturing, healthcare, defense and public services by Quesnel G et al., Robinson S et al., Tako AA et al. and Gul M et al.. It is known as one of the most proper commonly used approaches in the field of operations management. The appropriateness, suitability and relevance of simulation methods is a significant issue to study in applied real-world applications, chiefly as there is a rising necessity to address the difficulties of the entire enterprise. In any service organization, managers are mostly concerned about the customers and their profit simultaneously as shown by Li M et al., Abbasian-Hosseini SA et al. and Nikakhtar A et al.. The important structures of a standard queuing system contain line structure, demand group, entrance and service procedures, and queue discipline as used by Xiaobing P et al., Cha J-H et al. . The majority of existing studies in service industry focus on maximizing the customer satisfaction. The type and quality of demand or quantity of customers, serving priority, the tolerable queue length, the bearable waiting time are the major factors which can affect customer satisfaction.

Different approaches have been applied to progress service quality and subsequently customer satisfaction in various service industry. Previously, Cornillier, Boctor developed an exact algorithm and Moazzami et al. Yasara O., focused on simulation, modeling and analysis of a petrol station where a petrol station behavior was simulated as one of the most significant sections of service industry. This Research paper show that the Queuing Theory can be used efficiently for evaluating the performance of CNG pump stations. Masoud Rahiminezhad Galankashi, Ehsan Fallahiarezoudar, Anoosh Moazzami, Noordin Mohd Yusof, Syed Ahmad Helmi contributed in the study of petrol station queuing system. Lakshmi C, Sivakumar Appa Iyer reviews the contributions and applications of the queuing theory in the field of health care management problems. Samuel Fomundam and Jaffrey Herrmann (Fomundam & Herrmann, 2007) summarize a range of queuing theory results in the following areas: waiting time and utilization analysis, system design and appointment system. McClain (McClain, 1976) reviews research on models for evaluating the impact of bed assignment policies on utilization, waiting times and the probability of turning away patients. Seshaiah and Thiagaraj (Seshaiah & Thiagaraj, 2011) using a queuing model, they obtained a relationship between the percentage of reneged patients and the reneging parameter in addition to finding the wait time distribution. Albin et al. (Albin, Barett, D.Ito, & Muller, 1990) use the QNA software, which calculates server utilization. De Vericourt and Jennings (Vaericourt & Jennings, 2011) present a queuing model to determine efficient nurse staffing policies. Mayhew and Smith to visualize and interpret the 4- hours Government target in a simple way. Worthington (D.J.Worthington, 1991) suggests that increasing service capacity has little effect on queue length. Hoot and Aronsky (N.R.Hoot & Aronsky, 2008) conducted a systematic review with the main objective to describe the scientific literature on Emergency Department crowding from the perspective of causes, effects, and solutions. Vass and Szabo (Hajnal Vass, Zsuzsanna K. Szabo, 2015) offer a solution to plan the capacity of Emergency Department to manage the patients flow.

In this paper, We proposed our analysis, to use queuing models with simulation modeling at CNG pump stations to provide an accurate evaluations of the system's performance in present scenario, to make appropriate capacity plan in order to maintain optimal uses of resources.

2.Case Study - Conceptual Model for Customer's flow at CNG pump station

The case study is located in Patparganj, New Delhi, India. It consists of two main platforms. Each of these platforms comprises two fuel dispenser. There is regular heavy traffic block outside the CNG filling station in Patparganj on the road that goes to Max Hospital. The whole road is occupied by vehicles waiting for filling fuel. They queue up in 2-3 rows which takes away a major portion of the road. Besides, there are two schools near this CNG station and it is a nightmare to drive through this road in the morning and afternoon. A Metro station is also situated here and with all those e-rickshaws and cycle rickshaws that gather around the metro station add to the misery. So this is a challenge for authorities to take necessary steps to help smooth flow of traffic under the given financial constraints.

The CNG station layout consists of two pumps having separate area to enter and exit. The process commences with vehicle arrival to the CNG station and goes to the desired pump among 4 available options. Their selection would be influenced by the least quantity of vehicles in the queue and distance to the counters if they cannot find an empty queue. Refueling process starts once the drivers pay for the fuel at the selected pump . Afterward, the pump in-charge will fill the fuel cylinder equal to payment. Once the fuel filling process ended, pump in-charge put the nozzle back and vehicle leave the system.

Following assumptions are considered in simulation modeling:

- All customers have 4 choices to select from, on the basis of queue length
- No customer leaves the system after entering the Queue until the CNG gas is not finished.
- There is no jockeying in the system (changing the Queue lines).
- The observation process (data collection) was completed in numerous days of the week and different hours of the day.

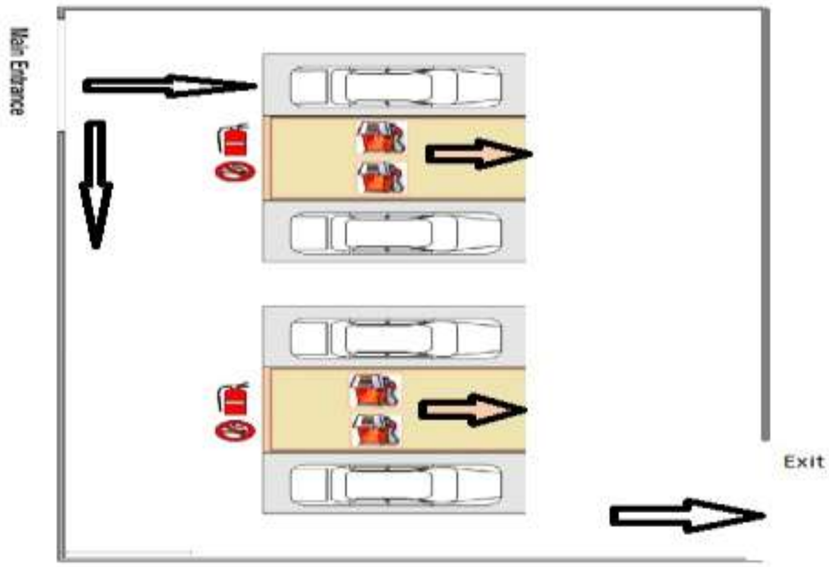

Figure 1. CNG pump station layout

It is common for CNG station management to project requirement of fuel, physical infrastructure and manpower planning. They must consider five typical measures when evaluating the existing or proposed CNG station. These measures are:

- Capacity utilization;
- Waiting time in the system(in minutes) to get fuel
- No. of lost customers due to long waiting queue
- Gain due to sale of CNG(in Rupees) at various fuel points(server)
- Loss due to the customers who don't enter in the server on because of long waiting time and queues(in Rupees)

The system utilization measure reflects the extent to which the servers are busy rather than idle. On the surface, it might seem that CNG management would seek over utilization of severs and long waiting queues with long waiting time.. Here, optimization is used to provide an efficacious management of occupancy of sever and resources utilization, enabling thus the CNG Management to balance the number of servers and finance against the cost of long waiting time to avail service and lost customers.

3.Simulation Model of CNG pump station

A CNG Pump receive customers throughout the day, with the rate of arrival varying hour by hour. The arrivals are modeled by Poisson process. Service providers attend complaints on a first-come-first-served basis from the queue and their time to process a customer is modeled as exponentially distributed. The only possible outcome after the completion of service is that customer gets his or her fuel tank filled and exit from the pump. The only cases when customer exits without fuel are : fuel is finished at CNG station or the waiting queue is very long.

The working process in the CNG station: firstly the customer arrives at CNG pump and join anyone of the 4 pumps as per his choice, when he reaches at the position near to pump, customer-personnel interaction occurs at that area, where a representative asks about his requirement and collect money. Then the representative fills the fuel tank of that customer's vehicle and customer leave the CNG station passing through exit. If all the servers are busy in parallel with any customer then the new arrived customer has to wait in the queue for getting service.

Building on the customer flow we will use the queuing theory to estimate the necessary number of CNG pumps, to estimate the average waiting time. The results are important for the management of the CNG Station in order to make optimal decisions, to organize in optimal way the workflow and to manage traffic near CNG station.

After studying the current situation at the mentioned CNG station and visiting other CNG station, We obtained that average arrival rate of customers is very high in morning and evening hours. Hence our focus for study the rate of customer's flow is high rush time. In these hours arrival of customers in every 36 seconds, thus the complaints are arriving at a rate of 100/hour and stay in anyone of the four queues. And the service time taken to serve one customer is approximately 4 minutes i.e. average service rate is 15/hour when there are 4 severs working in parallel. Since the arrival rate of customer is high as compared to service rate of 4 parallel servers, so queue formation takes place at each server. All data were collected in 4 h periods (from 6:00 A.M. to 10:00 A.M.) during 4 weeks. This long-term period was helpful to consider the rush hours (weekends, holidays and etc.) Here, we create a Event based simulation model to understand this network of queues and run simulation many times for 4 hours, starting at morning from 6:00 AM to 10:00 AM under the similar situations and record following observations.

3.1 The State of the System after 1 hr. from the start of simulation

Table 1: Statistics at 7:00 AM

Statistics	**Value**	**Time Duration**
Maximum Server utilization	0.975	1:00:00
Maximum Waiting time in the system(in minutes) to get fuel	14.29887	1:00:00
No. of lost customers	44	1:00:00
Gain due to sale of CNG(in Rupees)	77800	1:00:00
Loss due to long queues(in Rupees)	66200	1:00:00

3.2 The State of the System after 2 hrs from the start of simulation

Table 2: Statistics at 8:00 AM

Statistics	**Value**	**Time Duration**
Maximum Server utilization	0.9875	2:00:00
Maximum Waiting time in the system(in minutes) to get fuel	27.90492	2:00:00
No. of lost customers	74	2:00:00
Gain due to sale of CNG(in Rupees)	174200	2:00:00
Loss due to long queues(in Rupees)	113800	2:00:00

3.3 The State of the System after 3 hrs from the start of simulation

Table 3: Statistics at 9:00 AM

Statistics	**Value**	**Time Duration**
Maximum Server utilization	0.9916	3:00:00
Maximum Waiting time in the system(in minutes) to get fuel	38.35365	3:00:00
No. of lost customers	104	3:00:00
Gain due to sale of CNG(in Rupees)	275000	3:00:00
Loss due to long queues(in Rupees)	157000	3:00:00

IJASRM

International Journal of Advanced Scientific Research and Management, Special Issue II, Oct 2018

www.ijasrm.com

ISSN 2455-6378

3.4 The State of The System at the end of simulation

Table 4: Statistics at 10:00 AM

Statistics	Value	Time Duration
Maximum Server utilization	0.9937	4:00:00
Maximum Waiting time in the system(in minutes) to get fuel	47.7476	4:00:00
No. of lost customers	150	4:00:00
Gain due to sale of CNG(in Rupees)	360000	4:00:00
Loss due to long queues(in Rupees)	216000	4:00:00

For the total period of 4 hours, the graphical representation of number of customers in the queue waiting for availing services and sever utilization under the current scenario (when server are 4) are shown in Fig 2 and Fig 3.

It is clear from above figure that waiting queue is very long during the peak of the day and keep on increasing as the day passes through, which will result in customer dissatisfaction and loss of goodwill, under the present conditions. As the sever utilization is also very high, so there is no scope for improving service time. Hence only solution to improve service time is expanding server capacity i.e. to increase number of servers, so that loss of revenue as well as intangible assets can be controlled.

Figure 2: Representation of Number of Customers waiting in the Queue

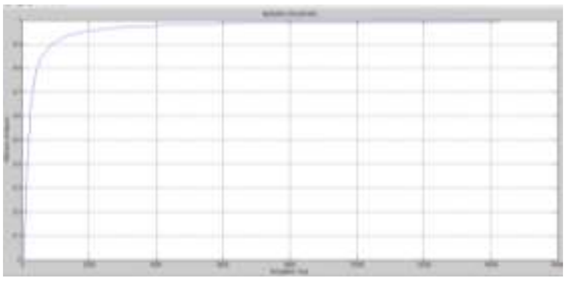

Figure 3: Representation of Server Utilization (When No. of Severs are 4)

It is clear from above figure that waiting queue is very long during the peak of the day and keep on increasing as the day passes through, which will result in customer dissatisfaction and loss of goodwill, under the present conditions. As the sever utilization is also very high, so there is no scope for improving service time. Hence only solution to improve service time is expanding server capacity i.e. to increase number of servers, so that loss of revenue as well as intangible assets can be controlled.

4.Conclusions

Now after doing the analysis of current system, we observed that there are long queue formation at all CNG filling points i.e. servers (4 servers working in parallel) due to the high demand of CNG by CNG vehicles like autos, cars, buses etc. Since, we want to provide quick service to customer, so we need to eliminate the waiting line of customers because it gives rise to traffic problems on the roads near CNG pump station and financial as well as goodwill loss, as after observing long waiting queue or long waiting time some customer move to any other option, as dissatisfied customers. Hence we should make this system balanced as it is necessary to turn dissatisfied customers into satisfied customers for maintaining goodwill in the market and gaining more revenue. In this regard we can increase number of servers under the financial constraints, so that no server will be idle for long duration and queue size will also be decreased with improved waiting time. Since each CNG port has two CNG nozzles till now, so by installing one port we can increase two servers at a time or we can increase one server. Using the data of many plans of CNG installation at various locations in India, we come to know that the expenses of installing one server setup with all equipments, in an old setup is 1,50,00,000 approximately. The proposed solutions are:

4.1 Case 1: Increase in Number of servers by 1 (n=5)

Increase in number of servers by one results is decrease in Server Utilization by 0.382%, decrease in waiting time by 44% and the sale is also increased by 24.27%. The cost incurred due to increase of one sever and due to less server utilization is very low as compared to increase in sale and Goodwill due to quick service. The State of The System at the end of simulation in this case is mentioned in Table 5

Table 5: Statistics at 10:00 AM when total No. of servers are 5

Statistics	**Value**	**Time Duration**
Maximum Server utilization	0.9899	4:00:00
Maximum Waiting time in the system(in minutes) to get fuel	26.7189	4:00:00
No. of lost customers	89	4:00:00
Gain due to sale of CNG(in Rupees)	447400	4:00:00
Loss due to long queues(in Rupees)	128600	4:00:00

The graphical representation of the results obtained in the proposed model is shown in Fig 4 and Fig 5.

Figure 4: Representation of Number of Customers waiting in the Queue (When No. of Severs are 5)

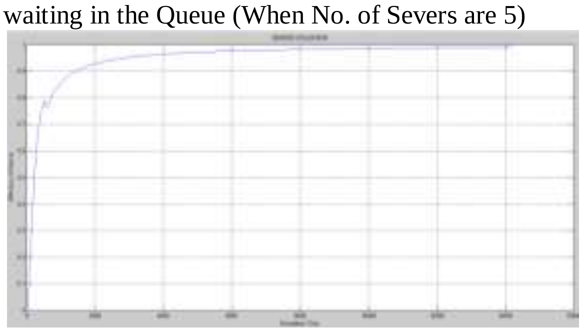

Figure 5: Representation of Server Utilization (When No. of Severs are 5)

The cost incurred in installing one server is Rs. 1,50,00,000.00 while the increase in sale due to one more server installation is Rs. 87,400.00 per day. Which means the expenses in installing one more server will be covered only in 172 days or in nearly 6 months.

4.2 Case 2 : Increase in Number of servers by 2 (n=6)

Increase in number of servers by 2 results in decrease in Server Utilization by 2.12%, decrease in waiting time by 80.88% which is very much higher than that of in the case of n =5 and increase in sale by 55.97%. The State of The System at the end of simulation in this case is mentioned in Table 6

Table 6: Statistics at 10:00 AM when total No. of servers are 6

Statistics	**Value**	**Time Duration**
Maximum Server utilization	0.9717	4:00:00
Maximum Waiting time in the system(in minutes) to get fuel	9.1297	4:00:00
No. of lost customers	9	4:00:00
Gain due to sale of CNG(in Rupees)	561500	4:00:00
Loss due to long queues(in Rupees)	13400	4:00:00

The graphical representation of the results obtained in proposed model is shown in Fig 6 and Fig 7.

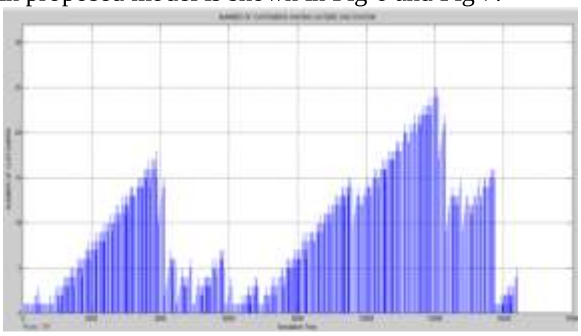

Figure 6: Representation of Number of Customers Waiting in the Queue (When No. of Severs are 6)

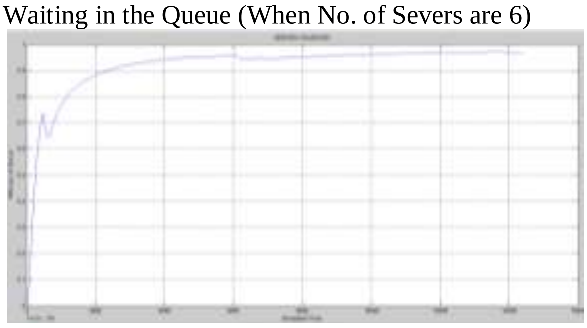

Figure 7: Representation of Server Utilization (When No. of Severs are 6)

The cost incurred in installing two more servers is Rs. 3,00,00,000.00 while the increase in sale due to two more servers installation is Rs. 2,01,500.00 per day. Which means the expenses in installing two servers will be covered only in 149 days or in nearly 5 months. The cost incurred due to increase of servers has a balance with gain in tangible and Intangible costs, goodwill . So the management must carefully decide according to financial constraints for the proposed solutions.

References

[1] McClain, J Bed planning using queuing theory models of hospital occupancy: a sensitivity analysis. Inquiry 13 , 167-176. (1976)

[2] McQuarrie, D. Hospital utilization levels. The application of queuing theory to a controversial medical economic problem. Minesota Medicine 66 , 679-686. (1983)

[3] Albin, S., Barett, J., D.Ito, & Muller, j.. A queuing network analysis of a health center. Queuing systems 7 , 51-61. (1990)

[4] D.J.Worthington. Hospital waiting list management models. Journal of Operational Research Society 42 , 833-843. (1991).

[5] Fomundam, S., & Herrmann, J. A survey of Queuing Theory Applications in healthcare. ISR Technical Report 24 . (2007).

[6] Mayhew, L., & Smith, D. Using queuing theory to analyse the government's 4-h completion time target in accident and emergency departments. Health Care management Science 11 , 11-21. (2008).

[7] N.R.Hoot, & Aronsky, D. Systematic Review of Emergency Department Crowding: Causes, Effects, and Solutions. Annals of Emergency Medicine 52 , 126-136. (2008).

[8] Xiaobing P. An application of OR and IE technology in bank service system improvement, in: Proceedings of the IEEE international conference on industrial engineering and engineering management, 2008. IEEM 2008; (2008).

[9] Yasara, O. Queuing Models and Capacity Planning. In O. Yasara, Queuing Methods in Health care management (pp. 348-356). San Francisco: Jossey-Bass. (2009)

[10] Quesnel G, Duboz R, É Ramat. The virtual laboratory environment–an operational framework for multi-modelling, simulation and analysis of complex dynamical systems. Simul Model Pract Theory; 17(4):641–53. (2009)

[11] Cha J-H, Roh M-I. Combined discrete event and discrete time simulation framework and its application to the block erection process in shipbuilding. Adv Eng Software; 41(4):656–65. (2010)

[12] Seshaiah, C., & Thiagaraj, H.. A queuing network congestion model in hospitals. European Journal of Scientific Research 63 ,419-427. (2011)

[13] Vaericourt, f. D., & Jennings, O. Nurse staffing in medical units: a queuing perspective. Operation Researche 59 , 1320-1331. (2011).

[14] Robinson S, Radnor Z J, Burgess N, Worthington C. SimLean: utilising simulation in the implementation of lean in healthcare. Eur J Oper Res ;219(1):188–97. (2012).

[15] Tako AA, Robinson S. The application of discrete event simulation and system dynamics in the logistics and supply chain context. Decis Support Syst ;52(4):802–15. (2012)

[16] Li M, Yang F, Wan H, Fowler JW. Simulation-based experimental design and statistical modeling for lead time quotation. J Manuf Syst ; doi:10.1016/j.jmsy. 2014.07.012 (2014)

[17] Abbasian-Hosseini SA, Nikakhtar A, Ghoddousi P. Verification of lean construction benefits through simulation modeling: a case study of bricklaying process. KSCE J Civil Eng ;18(5):1248–60. (2014)

[18] Nikakhtar A, Hsiang SM. Incorporating the dynamics of epidemics in simulation models of healthcare systems. Simul Model Pract Theory ;43:67–78. (2014)

[19] Gul M, Guneri AF. A comprehensive review of emergency department simulation applications for normal and disaster conditions. Comput Indus Eng ;83(0):327–44. (2015)

[20] Shannon, Robert E. *Systems Simulation – The Art and Science*, Prentice-Hall. (1975)