Performance of Vehicle Arrival Traffic Data at Fuel Station using Queuing System

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Abstract: Vehicle arrival is a main criterion in the delay assessment of different fuel stations. In this paper, pragmatic studies are carried out to investigate the congestion traffic flow at fuel stations. The complications at fueling points have been measured and also found the length of the queue, waiting time of the customers. The results confirmed that the vehicle arrival pattern of arterial road near the fuel station exhibit traffic congestion this finding is helpful to model the fuel station in terms of planning and designing.

1. Introduction

The Traffic congestion is a state of increased disturbance of the motion of traffic. India, escorted by growing many vehicles on the road, consequently traffic congestion may quickly increase. In such cases, traffic is still cannot thoroughly estimate under which condition Traffic Jam may shortly occur. Many techniques have been developed and written about the queuing theory and its applications. A.K Erlang [1] introduced Queuing theory in the basis of telephone services. It is broadly utilized in industrial, management sectors and falls under the view of engineering and decision sciences [2]. The most significant issue in waiting line difficulties is to adopt the finest level of service the organization should offer. Providing too much service would include extreme cost instead insufficient service capacity would affect in waiting lines which result in disappointment of customers or sometimes loss of customers. Therefore, the definitive goal is to reach an economic balance among the service cost and the cost associated with waiting for service [3]. The queuing theory provides a huge number of models for describing and solving mathematical problems. Its efforts to solve problems constructed on a scientific understanding of the difficulties and solving them in optimum manner so that the facilities are entirely utilized and waiting time is reduced to minimum possible [4]. Most of the real-world queuing problems are complex state and difficult to use queuing system technique, even then uncertainty will remain [5]. In the model M/M/S, M stands for the Markovian implying exponential distribution of inter-arrival or service time distributions. Thus, M stands for Poisson and negative exponential distributions. Kendall [6] published his notations for queuing theory, and these notations are still in use today. They are most widely used throughout the queuing literature. This research tries to have a balance of Mean Queue Length and waiting time distribution for M/M/S Queuing systems. The structure of the queuing system is defined as input or arrival distribution, service distribution,
service channels, maximum number of customers in the system, population size or calling source, service discipline. The basic concept and effects are involved to the understanding of queuing theory and is outlined in figure 1.

**Figure 1. The basic queuing processes**

2. **Experimental Study**

2.1. **Data Collection and Area of Study**

The present study focuses on measuring the self-similarity for which we have undertaken G.T Auto lines Filling Station Karimnagar, India. This is one of the biggest fuel stations in Karimnagar, India. It is the center of the city adjacent to the Alphores School of Gen. Next. Due to the only one fuel station in the town, long queues can easily be finding in the service zone. Fuel outlet deals in supply of diesel, petrol, Xtra Premium, lubricants and turbojet from Bharat petroleum. The station has eight refueling pumps, four for four wheelers and four for two wheelers and heavy vehicles of four wheelers. Twelve service executives are working at filling station, eight collection executives, one supervisor and 1 accountant employed under the possession of G.T Autolines. The difficulty of queues at various fueling points have been studied and identified the main reasons which effect in queues. We made several visits to the fueling station and interviewed the working staff about the nature of difficulties they were facing in queue handling. The key data regarding the arrival of vehicular and their service pattern was collected and format the data as follows in table 1.

| Period      | Day 1 Arrival Rate | Day 1 Service Rate | Day 2 Arrival Rate | Day 2 Service Rate | Day 3 Arrival Rate | Day 3 Service Rate | Day 4 Arrival Rate | Day 4 Service Rate | Day 5 Arrival Rate | Day 5 Service Rate | Arrival Rate |
|-------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|---------------|
| 8am-9am     | 68                 | 99                 | 85                 | 93                 | 89                 | 98                 | 104                |
| 9am-10am    | 89                 | 92                 | 92                 | 100                | 99                 | 107                | 98                 |
| 10am-11am   | 88                 | 95                 | 99                 | 108                | 98                 | 108                | 108                |
| 11am-12pm   | 99                 | 105                | 106                | 116                | 104                | 111                | 111                |
| 12am-1pm    | 98                 | 109                | 110                | 123                | 112                | 119                | 119                | 102                |
| 1pm-2pm     | 87                 | 93                 | 96                 | 102                | 94                 | 98                 | 99                 |
| 2pm-3pm     | 97                 | 104                | 91                 | 98                 | 92                 | 97                 | 97                 |
| 3pm-4pm     | 95                 | 103                | 87                 | 94                 | 89                 | 94                 | 97                 |
| 4pm-5pm     | 83                 | 92                 | 92                 | 99                 | 90                 | 96                 | 98                 |
| 5pm-6pm     | 90                 | 98                 | 104                | 109                | 103                | 109                | 100                |
| 6pm-7pm     | 94                 | 102                | 96                 | 102                | 92                 | 99                 | 98                 |
| 7pm-8pm     | 92                 | 97                 | 90                 | 96                 | 91                 | 97                 | 91                 |

3. **Experimental Procedure**

3.1. **Queuing Analysis of Traffic Data- Queue Length Distribution**

This investigation was conducted by two stages. In stage-I investigations, the research works was
conducted to develop quaternary blended concrete with 25% fly ash and 10% GP, based on the preliminary investigation conducted for developing the ternary blended concrete, by varying Nano-silica from 0 to 2% of cementitious content. M35 grade of concrete was considered and designed as per the guidelines of IS 10262:2019 [26]. The mix proportioning of quaternary blended concrete is shown in table 2. The stage-II was conducted with coir fiber varying at 0.25, 0.5, 0.75, 1.0, and 1.25% by volume of concrete for developing the fiber reinforced quaternary blended concrete and mix proportioning is shown in table 3.

3.1.1. M/M/S Queuing System

Queues or waiting lines are the most extensive phenomenon in our everyday life. Queuing system is one of the main segments of an Operations Research. It is a scientific and systematic method to analyze and solve the complicated problems also for making better decisions [7]. The Researchers have given unique importance to the development and the use of techniques like queuing theory. [8] Queuing theory is used to solve problems concerned with traffic congestion in bank counters, ration shop, railway reservation counters, toll plazas, doctor’s clinic, and automobile service etc., its main reason is to predict the congestion situations of a precise urban transportation network and suggest improvements in the traffic Areas. The ultimate idea is to offer a better optimization of the traffic communications. Those optimizations are supposed to conclude into a decrease of pollution, travelling times and fuel consumption. In this paper we introduce markov processes that play a central role in the analysis of all the basic queuing systems. Queuing theory is a complicated and highly practical field of mathematical study it has huge applications in performance evaluation [9].

3.1.2. Description of M/M/S Queuing Model

Multi-channel queuing theory is applicable when there are several servers in the service facility to provide the service. The servers are arranged in parallel and each unit in the waiting line can be served by any one of the servers. [6, 11] The M/M/S model represents the queue length in a system having multiple servers where arrivals are determined by a Poisson process and service times have an exponential distribution. In this model the rate of arrival and the service depend on the length of the line. The arrivals are handled on FCFS (first come first service) basis and service is provided to the customers according to FCFS rules. Arrivals form a single queue, with multiple servers in the service facility. When arrivals do not get influenced by the length of the queue then leave the system only after receiving the service. The Poisson and the exponential distributions are related to each other, both of them are denoted by the same letter “M” is used due to markovian property of exponential process.

The multichannel queuing model is applicable when there are several servers in the service facility to provide the service. The servers are arranged in parallel and each customer in the waiting line can be served by any one of the servers and the service rate is same for each server. [10] The exponential distribution is used to describe the inter arrival time in the pure birth model means arrivals only allowed and the inter departure time in the pure death model means departures only can takes place is to show the close relationship between the exponential and the Poisson distributions. The mean service rate is higher than the mean arrival rate (i.e. \( \mu > \lambda \)). When \( \mu > \lambda \), no queue will be formed and the arriving customers will not have to wait. when \( \mu = \lambda \), in this case, if the initial queue length was zero then new arrival will not have to wait, and in case the initial queue length was not zero, then every person arriving in the system will have to join the queue i.e. the length of the queue would remain constant. When \( \mu < \lambda \), in this case, the length will increase indefinitely and this will not be a steady system. The average arrival rate is less than the combined average service rate of all servers i.e., \( \lambda < S \mu \), where s is the number of servers. The ratio \( \lambda / \mu \) is known as the utilization factor. Fig 2 shows the multiple channels and customers are served at more than one server.
3.2. Mean Performance Metrics

- The average number of customers in queue (i.e queue length)

\[ L_q = \frac{(\lambda/\mu)(\lambda/\mu)^s}{(s-1)(\lambda/\mu)} + P_0 + \frac{\lambda}{\mu} \]

(1)

- The average number of customers in the system.
  This is the number of customers in the queue plus the number of Customers being served and is denoted by

\[ L_s = \frac{(\lambda/\mu)(\lambda/\mu)^s}{(s-1)(\lambda/\mu)} + P_0 \]

(2)

- Average waiting time in the queue system.
  It is the time that a customer spends waiting in queue plus the time it takes for servicing the customer.

\[ W_s = \frac{L_s}{\lambda} \]

(3)

- The average waiting time in the queue.

\[ W_q = \frac{L_q}{\lambda} \]

(4)

- Traffic intensity \( \rho = (\text{mean arrival rate}) \lambda / (\text{mean service rate})S\mu \).
  ‘S’ is the number of servers

(5)

4. Results and Discussion

This study assumes the First Come First Served (FCFS) method, according to their time vehicles are made up queue and being served as per their turn. In the table 1. We presented the Poisson arrival rates and their service rates for 5 days from G.T Autolines filling station during the time interval. The calculated results for Traffic intensity for multiple servers available in the system, mean queue length and system length of the customers, mean waiting time of the customers in the queue and system are presented in table 2. It is also shown that there is a congestion traffic during the morning and evening session, also the forming of queues on weekends is always differ from the other weekdays.

| S.No. | Traffic Intensity \( \rho \) | \( L_s \) | \( W_s \) | \( L_q \) | \( W_q \) | MAE  |
|-------|-----------------|-----|-----|-----|-----|-----|
| 1     | 0.6868          | 6   | 0.6061 | 5   | 0.5692 | 64112.5062 |
| 2     | 0.5452          | 3   | 0.3638 | 2   | 0.2911 | 63991.8400 |
From the computed results figure 3 illustrates that as per the number of servers available in the system traffic intensity represents below curve graphically. Mean number of customers in the queue (Lq) in X-axis and average number of customers in the system (Ls) in Y-axis represents the graph for expected length of customers in the figure 4 Also, average waiting time of the customers in the Queue as per the multiple servers available to do service in the queue (Wq) in x-axis and mean waiting time in the system in y-axis represents the graph as shown in Figure 5. This shows that traffic is not represents the smooth flow but it is constant flow rate. Calculated vales of (Lq), (Ls), (Wq), (Ws) support the traffic situation at fuel station. Traffic intensity generally below the unity (ρ<1) in all sessions. This investigation focused on the managing the traffic flow based on queuing theory.

|     |     |     |     |     |
|-----|-----|-----|-----|-----|
| 3   | 0.9634 | 6   | 0.6491 | 5   | 0.5853 |
| 4   | 0.9598 | 13  | 0.878  | 11  | 0.8219 |
| 5   | 0.7542 | 12  | 0.9897 | 11  | 0.9291 |
| 6   | 0.6912 | 8   | 0.8618 | 7   | 0.7998 |
| 7   | 0.5947 | 3   | 0.6512 | 2   | 0.6416 |
| 8   | 0.2214 | 8   | 0.2387 | 7   | 0.3098 |
| 9   | 0.6585 | 6   | 0.1986 | 5   | 0.0998 |
| 10  | 0.3019 | 4   | 0.6754 | 3   | 0.5971 |
| 11  | 0.4184 | 3   | 0.5982 | 2   | 0.6021 |
| 12  | 0.5021 | 6   | 0.1988 | 5   | 0.2017 |

**Figure 3.** Graphical representation of Traffic Intensity ρ

**Figure 4.** Graphical Representation of Expected Queue Length

**Figure 5.** Graphical Representation of Mean Waiting Time

5. **Conclusion**
Queuing models are more ubiquitous in our progressively congested traffic flow of urbanised society. The outcomes from this study reveals that traffic intensity for each day of the fuelling station is less than one (\( \rho < 1 \)), it was observed that servers are accordingly attends their customers. As per the utilization factor from the graphs we expect that the traffic flow is unstable and not smooth flow. It was recommended to the fuelling points to continuously endeavour to custom their service at peak times to avoid the queues at such fuelling stations.

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