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RESEARCH ARTICLE

APPLICATION OF QUEUING THEORY MODELS FOR OPTIMIZED SERVICE TO AIR LINE PASSENGERS

[*1]Dr. Vaddi Venkata Satanaryana, [2]Dr. Shaik Dawood, A.K., [3]Dr. Karthikeyan, R. and [4]Naseeb Khan

[1]Department of Mechanical Engineering, Vidhya Jothi Institute of Technology, Hyderabad, India
[2]Department of Industrial Engineering, King Khalid University, KSA
[3]Department of Management Studies and Research, Karpagam University, Coimbatore, India
[4]King Khalid University, Department of Industrial Engineering, KSA

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ABSTRACT

A study has been undertaken to investigate the quality of service rendered to airline passengers. The passengers who come to airport would report at the respective counters in the first stage with relevant documents and tickets. It is found that for each flight service three counters are opened and passengers are free to join any of the queues at counters. At those counters the passengers are issued with the boarding passes after verification of documents. In the second stage where immigration cum security pass activity is performed. The system is considered as two stages multiple channels Jackson Queuing model. Data have been recorded for several days at various times in each of the days and at various counters at the stages. The data have been analyzed and the arrival rate of passengers, service rate of passengers, waiting time in the queue system and length of system are computed. The quality control charts are drawn to depict the waiting time of the passengers in the queues before boarding the respective flights. The waiting time was exorbitantly high and hence optimized the serving system with the addition of optimum number of servers. With the proposed addition of optimum servers the total cost is optimized and the waiting time of passengers before boarding the respective flights is reduced greatly and improves the customer's satisfaction.

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INTRODUCTION

Air line passengers are subjected to increasing levels of congestion in airport environments. This congestion is caused by three interrelated problems. The first is fluctuations of demand. Variations of demand occur at various time frames ranging from days to months. Sometimes special events create demand spikes. The second cause of congestion is related to network issues. The third cause of congestion in check-in areas is related to flight scheduling. Here, the congestion is caused by arrangement of scheduled departure times of aircraft. The congestion is caused by overlapping passenger arrival periods of the chosen aircraft. It can be seen that overlapping passenger arrival distributions concept assists in estimation of the period of congestion. (Ervina Ahyudanair *et al.,* 2005) Queuing Theory was developed to provide models to predict behavior of systems that attempt to provide service for randomly arising and not unnaturally demand.

***Corresponding author: Dr. Vaddi Venkata Satanaryana,**
Department of Mechanical Engineering, Vidhya Jothi Institute of Technology, Hyderabad, India.

Analytical Queueing models have frequently been found impractical for many types of real world problems owing chiefly to the inability of queue system to change their parameters in response to fluctuation in traffic intensity. However at the security service in airports it is unvarying and classical models quite well can be applied. (Ronald R. Gillam, 2009) The earliest problems studied were those of telephone traffic congestion and were resolved by queueing theory models (Syski, 1986). Queuing analysis carried out to analyze patient load in outpatient and inpatient services to facilitate more realistic resource planning. Queuing analysis reported in the case study provides a basis for estimating medical staff size and number of beds, which are two very important resources for outpatient and inpatient services in a large hospital, and all other hospital resources in one way or another depend on them (Mital, 2010). A new approach in designing of semiconductor equipment based Queuing Theory to reduce cycle time was applied in calculating optimum batch size for their processing equipment. (Hideaki Takagi, 1993) In production shop floors where the machines that require repair, it is the total down time which includes the queue wait time and repair time that is kept as small as possible. So in this compute waiting delays, queue lengths, in the light of input stream and service procedures. While designing the system balance the customer waiting time against the idle time of servers according to the inherent cost structure. There may be a space cost that should be considered along with customer waiting and idle server costs to obtain optimal system design. (Application of queueing, 2014) The Queuing networks are service facilities where customers must receive service at some of or all these facilities. It is therefore necessary to study the entire network to obtain such information as the expected total waiting time, expected number of customers in the entire system, and so forth. Because of the importance of Queuing networks, this is wide area of network of parallel and distributed computing, research into this area has been very active. To describe a Queuing network, further information must be provided on how the Queuing systems are interconnected, how they interact and how users are assigned to the Queuing systems.

Busy period service delays must occur in case of the services that respond to unpredictable demands whose time and location of occurrence are governed by probabilistic laws. The cost of providing sufficient capacity to avoid all delays under all circumstances would be impossible. The role of the analysis is to design service systems that achieve an acceptable balance between system operating costs and the delays suffered by the users of that system (McGuire, 2010). Jackson's theorem can be used to analyze a network of queues. The theorem is based on three assumptions The Queuing network consists of *m* nodes, each of which provides an independent Exponential service. Items arriving from outside the system to any one of the nodes arrive with a Poisson rate. Once served at a node, an item goes immediately to one of the other nodes with a fixed probability, or out of the system. Jackson's theorem states that in such a network of queues, each node is an independent Queuing system, with a Poisson input determined by the principles of partitioning, merging, and tandem Queuing.

Table 1.

Date 23-2-2015 Stage 1Time 10.00 AMcounter 1

S. No	Customer arrival time	Inter arrival time (minutes)	Service beginning time	Service ending time	Service time(minutes)
1	10.00	0	10.00	10.01	1
2	10.00	0	10.01	10.02	1
3	10.00	0	10.02	10.03	1
4	10.00	0	10.03	10.07	4
5	10.00	0	10.07	10.11	4
6	10.03	3	10.11	10.13	2
7	10.04	1	10.13	10.14	1
8	10.04	1	10.14	10.18	4
9	10.07	3	10.18	10.21	3
10	10.09	2	10.21	10.23	2

Table 2.

Date 25-2-2015 Stage 2 Time 10.20 AM counter 1

S. No	Customer arrival time	Service beginning time	Service ending time	Service time(minutes)
1	10.20	10.25	10.28	3
2	10.20	10.28	10.30	2
3	10.22	10.30	10.33	3
4	10.23	10.33	10.35	2
5	10.26	10.35	10.41	6
6	10.29	10.41	10.43	2
7	10.32	10.43	10.45	2
8	10.35	10.45	10.48	3
9	10.40	10.48	10.51	3
10	10.51	10.51	10.53	2

Table 3. Quality control chart data

Sample No	Average waiting time (minutes)	Range(minutes)
1	6.2	8
2	6.7	8
3	4.5	7
4	5.0	7
5	2.6	9
6	3.3	7
7	4.9	10
8	5.1	12
9	9.0	7
10	8.9	18
11	8.3	17
12	4.6	8

Thus each node may be analyzed separately from the others using the M/M/1 or M/M/C model, and the results may be combined by ordinary statistical methods. Mean delays at each node may be added to derive system delays. (Burke, 1969)

Experimentation

A case study regarding the waiting patterns of passengers and the way of service extended is being taken up for the airline passengers at the airport in Abha, Saudi Arabia. The passengers who come to airport are first enter the stage one where they have been issued with the boarding passes. Then the passengers pass through the next stage where the immigration and security check activities are being conducted; Hence it is considered as two stage serving queuing model and more popularly being called as Jackson models. The data have been recorded at the airport for the information like the time of passengers joining the queue, inter arrival time ,service beginning and end times. A typical sample data collected at both of the stages are presented in Table 1.0 and Table 2.0 The passengers are not distinguished into domestic and international travelers but simply as passengers passing through two stage service system only for the purpose of analysis. The recording is made at various counters and also at different timings for several days to get consistency and randomness.

RESULTS AND DISCUSSION

Arrival and service rates

The air line passengers go to the first stage of system and are free to join any of the three server channels for the boarding pass since presently the air port authorities created three channels for every flight service. The arrival rate of passengers (λ) is computed by finding the average of the recorded data and is equal to 0.708 passengers/minute with an assumption that it is following the Poisson distribution. Similarly the service rate (μ) of passengers are computed for both the stages by averaging the data recorded and is 0.4568passengers /minute at first stage and 0.4174passengers/minute at second stage respectively. It is also assumed that the service time of passengers is following the exponential distribution. For arrival and service rate static, the χ^2 Test is conducted and hypothesis is ascertained for Poisson and exponential distributions.

Waiting time in system (W)

The time spent by every passenger in the two stages is computed separately from the observed data. The waiting time of customers is not unique and varying due to the kind of service extended as per requirement. Hence the quality control charts for the variable waiting time are taken up for the design. The average waiting time and the corresponding range are computed for each of the sample whose size is 10 and the corresponding constant for mean chart is retrieved for constructing the X bar chart. The data is collected for 12 days and the average waiting time and range are presented in Table3.0

The grand mean of waiting time =5.75 minutes and the average of ranges = 9.83 minutes. The upper control limit (UCL) and the lower control limit (LCL) are computed.

UCL=5.75+0.308x9.83=8.77minutes
LCL=5.75-0.308x9.83=2.73 minutes

From this it is found that the process is out of control and the waiting time of passengers is exorbitantly high. Hence it is necessary to optimize the process for holding it in control.

Number of Servers as per efficiency and quality criteria (C*)

It is a controversial issue between customer and server queuing problems are concerned. The customer expects immediate service as and when he arrives while the server idle time is a major concern for the administration .Hence to provide improved quality service and also to have a higher system efficiency optimum number of servers are to be facilitated. The variable 'r' is equal to 1.69 and is computed from the arrival rate to service rate ratio. The desired number of servers for optimal conditions with a designed criteria of 95% service and 5% waiting is computed. Desired number of servers $=C^*=r + K\sqrt{r} = 1.69+1.645\text{x}\sqrt{1.69} =3.825$ say 4

Length of system (l)

The number of passengers in the system is the arithmetic sum of both the stages as per Jackson model theory and is computed separately from the observed data. The stages are of the three server model[M/M/3/FIFO] and computed the number of passengers in system. Total length of system= number of passengers in both stages = 2.173+6.36=8.533

Optimal service rate for minimum cost (μ^*)

The cost per each service per unit time and the imputed cost of unit waiting time per each customer are balanced such that the optimum achievable service rate for the minimum cost can be computed. The creation of optimum number of servers in both the stages can increase the service rate and reduced the waiting time of passenger in the system. Achievable service rate for minimum cost = $\mu^* = (\lambda) + \sqrt{(L.\lambda)} = 1.48$ passengers/ minute

Conclusion

Based on the experimental data and by employing the Jackson Queuing model the following conclusions are drawn. The average waiting time of each passenger before the security check are falling above upper control limit of the quality control charts drawn for waiting time. Hence designed for improved quality and enhanced efficiency of the system by computing the optimum number of servers. With the creation of optimal number of servers ,the service rate of passengers has increased from 0.4568persons/minute to 1.48 persons/minute.

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