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Analysis of Toll Plaza using Queueing Theory

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***Abstract*—When a toll plaza is designed, choosing the right equipment and technology is a critical issue. In this paper , we try to compare manual collection and ETC(electronic toll collection) by creating a model for traffic in a toll plaza. We apply Queuing Theory to each stage, modelling each stage as a queuing system. We use probability distribution to calculate the average waiting time in terms of number of incoming lanes, traffic flow, and number of tollbooths. The average waiting time is the portion of the travel time that is dependent on the parameters of the system. Using this formula we compute the average waiting time for a broad range of lane counts, traffic levels, and tollbooth numbers, from which queue length and waiting time for each configuration were found and are displayed in tabular form. We recommend RF ID (Radio Frequency Identification) . We considered two scenarios of manual toll collection at Nanakaramguda Toll Plaza for 3 days during peak hours and RF ID performance at Choutuppal Toll plaza for one day. We concluded that service rate performance for RF ID is more efficient than manual service rate.**

***Index Terms*— ETC(electronic toll collection) , queue length , queueing theory , service rate, RF ID (Radio Frequency Identification).**

I. INTRODUCTION

The study of queues comes under a discipline of Operations Research called Queueing Theory and is a primary methodological framework for evaluating resource performance besides simulation. Queueing theory is the mathematical study of waiting lines, or queues. A queueing model is constructed so that queue lengths and waiting time can be predicted.

II. LITERATURE REVIEW

Queuing theory embodies models covering all perceivable systems which incorporate characteristics of a queue. Queuing theory, as such, was developed to provide mathematical models to predict behaviour of systems that attempt to provide service for randomly arising demands and can trace its origins back to a pioneer investigator. Work continued in the area of telephone applications, and although the early work in queuing theory picked up momentum rather slowly, the trend began to change in the 1950s when the pace quickened and the application areas broadened well beyond telephone systems. Zarrilo et al (1998) , Al Deek et al (1996) , Pietryzk (1994) are few notables who developed models on toll plaza to estimate the rush hour delays, queue line traffic and illustrated the impact of ETC(Electronic Toll Collection).

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III. METHODOLOGY

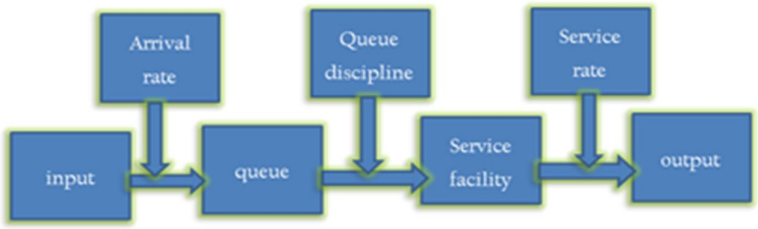


Figure 1 showing parameters in flowchart on analysis of toll plaza

IV. ANALYSIS USING POISSON DISTRIBUTION

Multiple single servers model is adopted for modelling of toll plaza with arrival rate and service rate following exponential distribution. In this model identical independent parallel servers receive vehicles from same source but in different parallel queues.

The main results observed in this model are :

1. Average no. of vehicles in the system $=\frac{\rho}{1-\rho}$
2. Average no. of vehicles in the queue $=\frac{\rho*\rho}{1-\rho}$
3. Expected waiting time in the system $=\frac{1}{\mu-\lambda}$
4. Expected waiting time in the queue $=\frac{\lambda}{\mu(\mu-\lambda)}$

Where ρ = utilization coefficient or traffic intensity

μ = service rate

λ = arrival rate

V. ASSUMPTIONS OF POISSON DISTRIBUTION

1. The system is in steady state (assumption is valid when the uniform arrival patterns are sustained for long duration).
2. Traffic intensity that is (rate of arrival /rate of service) should be always less than 1
3. Number of costumers is discrete.
4. The arrivals are random in nature, hence Poisson distribution is applied.
5. There will be no simultaneous arrivals.
6. Queue is single and is of infinite capacity.
7. There will be single service channel. Separate modification of approach is available for multiple channels.
8. Order of service is first in first out.
9. Service times vary and follow an exponential distribution.

In this paper the data , details of study area of observed toll plaza locations , formulas assumed for analysing toll plaza in Nanakaramguda and choutuppal are represented in tables below.

TABLE I. DETAILS SHOWING NANAKARAMGUDA TOLL PLAZA

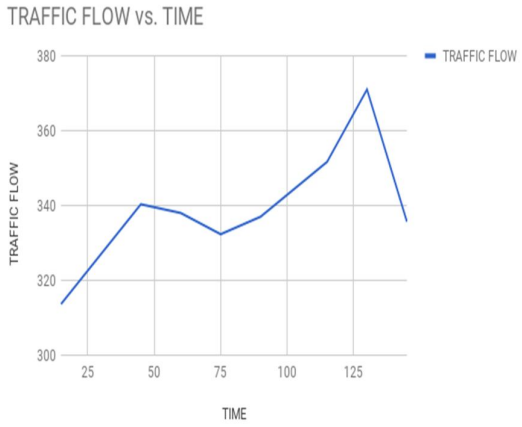
S.NO	PARAMETERS	COLLECTED DATA
1	Total No.of toll booths	12
2	Type of Pavement	Rigid
3	Width of pavement	40m
4	Length of each toll booth	2.5m
5	Width of each toll booth	2m
6	Type of merging	Merging at one point
7	Type of Transaction	Manual

TABLE II. SHOWING DETAILS OF CHOUTUPPAL TOLL PLAZA

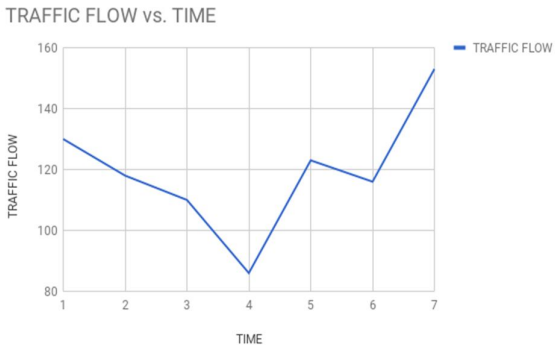
S.NO	PARAMETERS	COLLECTED DATA
1	Total No .of toll booths	16
2	No .of RF ID Toll booths	2
3	Type of pavement	Rigid
4	Width of pavement	41m
5	Length of each toll booth	2.5m
6	Width of each toll booth	2m
7	Type of merging	Merging at one point
8	Type of Transaction	Electronic

TABLE III. SHOWING SUMMARY TABLE FOR NANAKARAMGUDA TOLL PLAZA AND CHOUTUPPAL TOLL PLAZA

LOCATION	ARRIVAL RATE (PCU/Hour)	SERVICE RATE (PCU/Hour)	NO .OF LANES OBSERVED	AVG. NO.OF VEHICLES IN QUEUE	EXPECTED WAITING TIME (secs)
Nanakaramguda	1446	300	6	4	50
Choutuppal	200	1800	1	0	0.25



Graph 1 showing graph of traffic flow vs time for Nanakaramguda Toll plaza(time in mins)



Graph 2 showing graph of traffic flow vs time for choutupal Toll plaza(time in mins)

VI. Conclusion and Recommendations

From observations made at Nanakaramguda Toll plaza, Gachibowli , Hydearabad , we can conclude that though the toll booths are meeting the demand of vehicles serving at 12 seconds per vehicle for peak hour duration , there is chance of increase in demand in later years. From observations made at Choutuppal Toll plaza, , use of dedicated RF ID (Radio Frequency Identification) lane is very advantageous as the expected waiting time for vehicles in queue is minimum. Hence now HMDA(Hyderabad Metropolitan Development Authority) has planned to use RFID(Radio Frequency Identification) tags on all 19 interchanges on Outer Ring Road of Hyderabad to reduce delays caused due to inefficient service rate

By comparing both toll plazas there is a difference of 10 seconds in transaction time and 60 seconds in waiting for vehicles in queue. Hence based on our observations we recommend that with advance of technology, toll collection is made easy with help of RF ID (Radio Frequency Identification) tags saving huge time in waiting and in monetary terms at toll plaza. RF ID(Radio Frequency Identification) can be used as one of the solutions where necessity to meet peak hour demands like queue length and service rate issues at toll reduces for vehicles that merge at merging point.

Reference

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