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Application of Queuing Theory of a Toll Plaza-A-Case Study

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***Abstract*— Due to ever increasing traffic, the road capacity has to be increased to accommodate different configuration vehicular dimensions. Toll roads need huge financing to construct a safe, effective, durable road network. Toll financing is one of the technique in which revenue collected from the road users for the service provided by them. This in turn results in development in queues at particular junction where in the toll booths are erected. Long queue could lead to increase in travel time which is drawback of road user. Hence toll should be designed and planned in such a way that minimum time would be wasted in the queuing area. The toll booths are planned on the basis of queuing area. Queuing theory involves parameters such as arrival, number of lanes, service time, waiting time, merging area. In present study road inventory, traffic volume, space mean speed, arrival rate, time headway and service rate are analyzed.**

Keywords—Arrival rate, Service rate, Space mean speed, Time headway

CHAPTER 1
INTRODUCTION

1.1 General

A queue is simply a waiting line. Therefore systems that involve waiting lines are called queuing systems and mathematical descriptions of queuing systems are known as queuing models. Transportation systems often involve queues. Queuing or waiting-line, phenomena are everyday occurrences Queuing systems are characterized by an arrival pattern, a service facility and a queue discipline. Toll financing has been used throughout the history of civilization to make the building of long-distance roads possible. Beginning in the 1940's, America's first modern freeways were financed with tolls. Today developing nations such as China are building their own networks of superhighways, and they too turning to the tollbooth for expenditure. Tolls are being used successfully in places such as Singapore and London not just to finance road construction, but to limit the flow of vehicles into the urban core, increasing transit usage and unclogging the crowded streets [7].

Despite its many advantages, there is also disadvantage associated with tolling. When traffic is thick, vehicles backup in line to get to tollbooths, and after paying their tolls, drivers lose time scrambling for position as the many lanes exiting the toll plaza merge together, returning the road to its original width. A study conducted at the New Jersey Institute of Technology estimates that a travel time savings of 2 minutes, or over 10 percent, could be affected by the removal of two toll plazas along 14- mile section of the Garden State Parkway [10]. Modern toll facilities, such as Highway 407 near Toronto and the SR-91 Express lanes in Orange County, California, require all payment to be made by means of electronic transponder, so that vehicles do not have to slow down in order to pay the toll [7]. But on many older toll ways moving to all-electronic payment is not an option, while mounting congestion means that planners are faced with the problem of configuring their existence infrastructure to provide the best possible service.

1.2 Background

Highway toll plazas constitute a unique type of transportation system that requires special analysis when trying to understand their operation and their interaction with other roadway components. On the one hand, these facilities are one of the most effective means of collecting user fees for roadways. The object of a toll highway should be to minimize average travel time of all drivers on that road. On the other hand, toll plazas adversely affect the throughput or capacity of the facilities they serve. The adverse effect of toll plazas is particularly evident during hours when traffic is usually heavy. Thus highway toll experience lengthy vehicular queues and long delays when demand is near or exceeds processing capacity. Efficient sizing of toll plazas becomes critical in minimizing the space requirements and capital expense of collecting user fees. Hence keeping all these in view an effort has been made to study the performance of an existing toll on National highway-75 near Kadaballi between Bangalore to Mangalore stretch by applying the queuing theory.

1.3 Scope of Study

Toll plazas have become means for collecting revenue in order to build network of roadways which in turn improve safety, comfort, reduce average travel time and improve the capacity of roads. The study of queuing is important to find out new design methods in arranging the toll plazas and means of operating the toll plazas which in turn improve the service rate at the toll booth and the capacity of the tollbooth otherwise would have created long queues. In the present study an attempt has been made in understanding how the toll booth works which is being designed on queuing theory. The study involves collecting the geometric attributes of the toll plaza, the arrival pattern of vehicles to the queuing area, the service provided by the system.

1.4 Study Area

The site selected for the project lies near Kadaballi between Bangalore to Mangalore highway. The stretch of road length is considered to be 500m away from the toll plaza. This provides clear view of the place selected for case study of

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queuing theory. Ten service booths fixed by the company called L&T Devihalli-Hassan pvt.ltd. There are some irrigated land farms agricultural lands around the toll gates. The selected road is a divided four lane National Highway (NH-75). This site has been selected for the study purpose of queuing theory because there are no intersections near toll plaza. The length of each toll booth is 4.2m and width 1.9m. The length of each lane is 3.6m.

Figure 1.1: Toll plaza of the Study Area.

1.5 Methodology

The major steps involved in the present study are

- Road inventory of the selected road section
- Traffic volume count as per IRC:9-1972 "Traffic Census on Non-Urban Roads"
- To find out the velocity of approaching vehicles by Space mean speed.
- To find out the inter-arrival rate of vehicles by taking time headway.
- To find out the Service rate provided by the serving system at the toll booth.
- To analyze the performance of toll booth from the collected data.

CHAPTER 2

LITERATURE REVIEW

2.1 General

A primary objective in operational problems involving flow is to ensure that the average capacity can handle the average flow, so that persistent traffic jams do not occur. Queuing theory was developed in order to describe the behaviour of a system providing services for randomly arising demands. The fundamental idea of the theory is that delay in a system is caused by an interruption in the flow pattern. Queuing theory is almost exclusively used to describe the traffic behaviour at signalized and un-signalized intersections [10].

2.2 Characteristics Of Queuing System

The analysis of queuing systems and its variables has been the focus of many studies and researchers for many decades. The solution to a queuing problem entails the assessment of a system's performance, which in turn is described by a set of measures of performance (MOP) [2]. The inputs include

1. The input function (Arrival rate)
2. The input source (Finite/Infinite)
3. The queue discipline (FIFO/LIFO)
4. The channel configuration (Number and Arrangement)
5. The delay time (Service rate)

The basic component or main parameters of a queuing system is shown by the figure 2.1

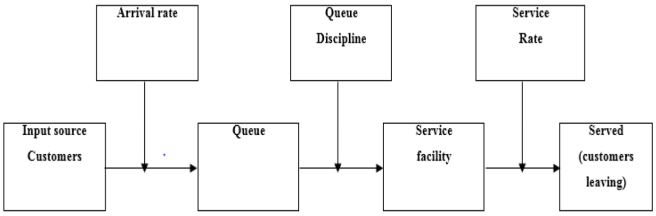

Figure 2.1: Components of a basic queuing system.

- Mean Arrival Rate: It is rate at which customers arrive at a service facility. It is expressed in flow (Vehicles/hour) or time headway (Seconds/vehicles). If inter arrival time that is time headway (h) is known the arrival rate can be found out from the equation.

$$\lambda = \frac{3600}{h}$$

- Queue Discipline: queue discipline is a parameter that explains how the customers arrive at a service facility. The various types of queue disciplines are

1. First in first out [FIFO]
2. First in last out [FILO]
3. Serviced in Random order [SIRO]
4. Priority Scheduling

First in first out: If the customers are served in the order of their arrival, then this is known as the first-come, first served (FCFS) service discipline.

First in last out: Sometimes, the customers are serviced in the reverse order of their entry so that the ones who join the last are served first.

Served in Random order: Under this rule customers are selected for service at random irrespective of their arrivals in the service system. In this every customer in the queue is equally likely to be selected. The time of arrival of the customers is, therefore of no relevance in such a case.

Priority service: Under this rule customers are grouped in priority classes on the basis of some attributes such as service time or urgency or according to some identifiable characteristics and FIFO rule is used within each class to provide service.

- Numbers of servers: The number of servers that are being utilized should be specified and in the manner they work that is they work as "Parallel" servers or "Series" servers has to be specified.
- Mean service rate: It is the rate at which customers depart from a transportation facility. It is expressed in flow (vehicles/hour) or time headway (seconds/vehicle). If inter-service time that is time headway (h) is known, the service rate can be found out from the equation.

$$\mu = \frac{3600}{h}$$

2.3 Structuring Of Queuing Model

Traditionally, traffic flows are modelled empirically, using origin-destination matrices [9]. One of the most important equations in traffic flow theory is that relating between traffic flow (q), traffic density (k) and traffic speed (s) which is given as

$$q = k \times s$$

These fundamental parameters of a traffic flow can be used as inputs in developing appropriate queuing models. Queuing models are often referred to using the Kendall notation, consisting of several symbols e.g. M/G/1 [9]. The first symbol describes the arrival rate of traffic into a system, the second for the service rate provided by the system to the vehicles while the third indicates the number of servers in the system.

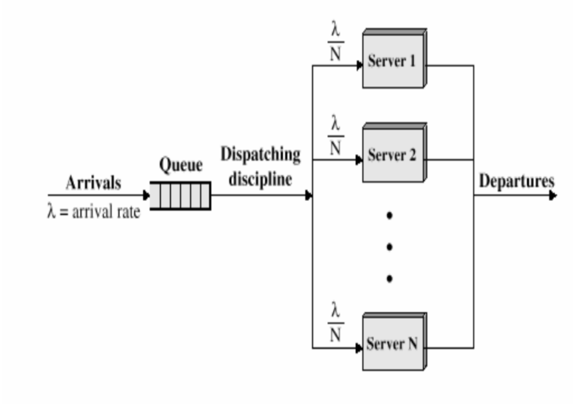

Figure 2.2: A simple model of a multi-server queuing system.

2.4 Theory Applied In Queuing Model

Poisson distribution

- The experiment results in outcomes that can be classified as successes or failures.
- The average number of successes that occurs in a specified reason is known.
- The probability that a success will occur is propositional to the size of the region.
- The probability that a success will occur in an extremely small region is virtually zero.

2.5 The Toll plaza

Tolls are systems (or sometimes called as barriers) constructed on roads which are meant to provide facilities to road users by reducing their average travel time, increased speed, safety and improve the capacity of the road sections. Tolls have become a means of generating revenue in building expressways and National highways there by reducing the problem of congestion on many of the existing road networks.

There are two types of toll collection systems available. These are

1. Open toll system
2. Closed toll system

Open toll system: In an open toll system, not all patrons are charged a toll. In such a system, the toll plaza is generally located at the edge of the urban area.

Figure 2.3: Showing the Open Toll System.

Closed toll system: In a closed toll system, patrons pay the toll based on miles of travel on the facility and category of vehicle. In a closed toll system, plazas are located at all the entry and exit points, with the patron receiving a ticket upon the entering the system. Upon exiting, patron surrenders the ticket to the collector and is charged a prescribed fee based on category of vehicle and distance travelled [3].

Figure 2.4: Showing the Closed Toll System.

2.5.1 Approaching the Toll Plaza

The highway is generally assumed to be free flowing on either side of toll plaza. This assumption allows congestion resulting from the toll plaza design to be isolated from general congestion on the highway. Generally the toll plaza is designed in such a way that traffic flow levels through them will be less than the capacity of the highway. Since most of the toll plazas particularly in India are cash –collecting, at

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some point most vehicles must stop either because the vehicle in front of them has stopped or they have reached a toll booth. This in turn leads to building up of queue lengths particularly when the instantaneous demand exceeds the service. So it is necessary to find out the queuing area which is essential in fixing the number of servers in a toll plaza.

Merging: After the toll booths, the roadway must narrow back from a number of lanes equal to the number of tollbooths, to its normal width, a section will called as "merging area". Sometimes the extra lanes end almost immediately, forcing a sharp merge at a relatively low speed. There are three different merging patterns are used when lanes begin and end are,

- ❖ With several lanes merging into one, all of the merging could occur at a single point, but this means that as many vehicles as there are lanes could interfere with each other at that point.
- ❖ One common choice is to always merge out the rightmost (or leftmost) lane until the desired number of lanes is reached.
- ❖ Another possibility is a "balanced" pattern where pairs of adjacent lanes all across the roadway merge repeatedly until the desired roadway width has been attained.

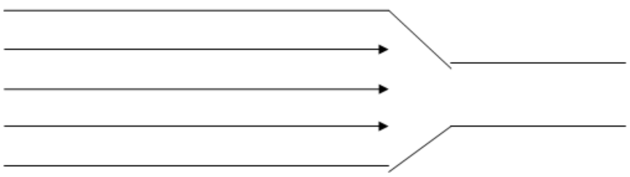

Figure 2.5: Showing Four lanes Merging to 1 Single Point.

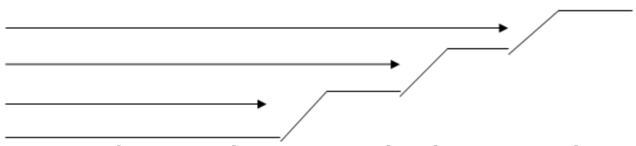

Figure 2.6: Showing Four lanes Merging with Rightmost Lane Ending.

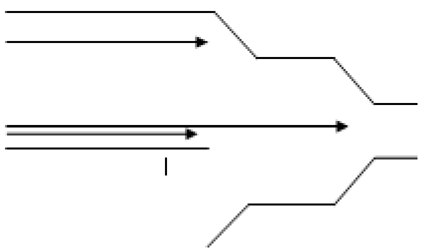

Figure 2.7: Showing Four lanes merging in a Balanced Pattern.

Gustavo ceballos et.al, in "Queue Analysis at Toll and Parking Exit plazas: A Comparison between Multi-server Queuing Models and Traffic simulation." have shown that the simple analytical models can be used for initial understanding of the queuing system but warn that good judgement must be employed while using the analytical models, as their results may differ significantly from real-life plaza operation. They insist the analytical models to be avoided when trying to analyse toll plaza operation under high levels of demand (0.90< v/c ratios< 1.0) given their asymptotic behaviour within this range. The traffic simulation provides a more comprehensive understanding of the toll plaza operation allowing for a more in-depth analysis of its performance. According to them simulation should be used for advance planning, design, operation and management of toll and exit plazas facilities.

Abdul aziz, A.R., et.al, in "Application of queuing theory to vehicular traffic at signalized intersection in Kumasi-Ashanti region, Ghana" has shown that queuing theory can be applied in modelling the vehicular traffic flow and minimize vehicular traffic in order to reduce delays on roads of Kumasi-Ashanti region. The analysis of the data collected at Oforikrom intersections revealed that a smooth flow of traffic is seen when the server at each channel is able to serve more than cars in waiting queue. But in evening there is restriction to flow due to the restraints caused by the commercial vehicle drivers. They have suggested that use of public transport by the government of Ghana would help in reducing congestion on the roads, which in turn boost the productivity.

NicoVandaele.,et.al, in "A Queuing Based Traffic Flow Model" have shown that queuing models can be applied in assessing the traffic flow parameters compared to traditional empirical methods, which lack in terms of predictive power and the possibility of sensitivity analysis. Based on queuing theory they analytically constructed the well-known speed-flow-density diagrams. They have shown that the exact shape of the different speed-flow-density diagrams is largely determined by the model parameters so that a good choice of parameters can help to adequately describe reality. They also believe that speeds have a significant influence on vehicle emissions and models can be effectively used to assess the environmental impact of road traffic.

CHAPTER 3
FIELD STUDIES

3.1 General

In order to understand the theory behind queuing a toll plaza has been selected in the present study which is located on NH-75 near Kadaballi. Field studies like road inventory, traffic volume, space mean speed, time headway, arrival rate and service pattern have been carried out.

3.2 Road Inventory

Road inventory reflects the pavement characteristic. Inventory data basically consists of data necessary to identify the project under evaluation. This consists of the geometric details of the project which are collect visually walking along the entire stretch. All of these data will remain constant until the pavement undergoes maintenance or repair. The inventory data of the selected road stretches are listed in table-3.1

Roadway attributes covering the roadway classification, ownership, physical condition, traffic volume, pavement conditions, highway performance monitoring information and more.

Figure 3.1: Showing the Flexible Pavement and rigid pavement near the Toll Plaza.

Table 3.1: Shows the details of Pavement Structure before Toll Plaza.

SI no	Parameters	Collected data
1	Type of pavement	Flexible pavement
2	Divided/undivided	Divided
3	Number of lanes	Four
4	Width of pavement (m)	9
5	Median width (m)	2.5
6	Shoulder width (m)	1.5
7	Type of shoulder	Earthen

Table 3.2: Shows the details of Queuing Area.

Sl No	Parameters	Collected data
1	Type of pavement	Rigid
2	Width of pavement(one side)	30m
3	Length of pavement on arrival side	250m
4	Length of pavement on merging side	250m
5	Number of toll booth on one side	5
6	Length of each toll booth	2.4m
7	Width of each toll booth	1.9m
8	Width between toll booths	3.6m
9	Type of merging	Left most merging

Table 3.3: Showing traffic flow on both the directions of the National Highway 75.

Figure 3.2: Shows the Toll Area having Concrete Road.

3.3 Traffic Volume:

Traffic volume or traffic flow is defined as "the product of the average traffic intensity and the time period of the study". It is measured by the units "vehicle per hour". In the present study the traffic count census is done as per IRC: 9-1972 "Traffic census on Non-Urban Roads". To take into account the randomness, the traffic volume study was carried out in short intervals (1 hour) at different hours of a day and at different days. Traffic flow is usually considered to be roughly constant at any given instant, as changes in flow occurs smoothly and slowly, while measurements employed are over very short time periods.

Figure 3.3: Shows Vehicle Platoon at Toll Plaza.

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Table 3.3: Showing traffic flow on both the directions of the National Highway 75.

SL No	Direction	Time	Traffic flow rate(vehicles/hour)	Average traffic flow rate (vehicles/hour)
1	Hassan to Bangalore	4:00 to 5:00	396	375
		5:00 to 6:00	518	
		9:00 to 10:00	321	
		10:00 to 11:00	262	
2	Bangalore to Hassan	4:00 to 5:00	297	345
		5:00 to 6:00	311	
		9:00 to 10:00	354	
		10:00 to 11:00	417	

3.4 Space Mean Speed:

The space-mean speed is "the average speed of vehicles travelling a given segment of roadway during a specified period of time". It is calculated using the average travel time and length for the roadway Segment. In this study the space mean speed is found out as per IRC: 108-1996"Guidelines for Traffic Prediction on Rural Highways". The space-mean speed is then calculated by dividing the distance between Instrumented locations by the average travel time. This is speed that is involved in flow-density relationships. The data of the space mean speed collected in the field is shown from table 3.5

$$\text{Space mean speed}=\frac{\text{Distance in m}}{\text{Average time taken in seconds}}$$

$$V_s=\frac{3.6*d*n}{\sum_{i=1}^{N} Ti}$$

Where VS=Space mean speed km/s

$T_i = t_1+t_2+t_3+t_4+\ldots\ldots\ldots\ldots + t_n$=Average time taken seconds.

Figure 3.4: Collection of Space-mean Speed at the Study Area.

Table 3.4: Showing the Space-mean Speed of Vehicles approaching the Toll Booth Near to Toll.

Duration (hours)	Direction	Average time (s)	Distance in (m)	Number of Vehicles	Average velocity near the toll booth (km/hr)
4	Hassan to Bangalore	0.80	10	453	20.38
4	Bangalore to Hassan	0.96	10	366	13.72

Table 3.5: Showing the Space-mean Speed of Vehicles approaching the Toll Booth Away from Toll.

Duration (hours)	Direction	Average time (s)	Distance in (m)	Number of Vehicles	Average velocity away from toll booth (km/hr)
4	Hassan to Bangalore	0.63	10	598	34.17
4	Bangalore to Hassan	0.76	10	556	26.33

Figure 3.5: Collection of Space-mean Speed data by marking the distance.

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Table 3.6: Showing the Details of the Space Mean Speed (Hassan to Bangalore).

Type of vehicle / Parameters	Four wheelers											Buses		Trucks		
Total vehicles	101											19		22		
Distance	10											10		10		
Time in seconds	.99	.92	.58	.77	.57	.78	.57	.58	.56	.51	.66	.83	1	1.2	1.7	1.2
	.53	.58	.64	.67	.62	.59	.71	.61	.6	.63	.72	1.4	.95	1.78	.92	1.5
	.78	1.1	.57	.66	.58	.83	.60	.72	.84	.52	.74	.87	.97	.8	.57	1.7
	.56	.66	.69	.54	.45	.52	.68	.53	.72	.57	-	1.09	.96	1.02	1.6 5	1.5
	.53	.68	.59	.57	.66	.55	.70	.75	.56	.63	-	.99	.83	1.46	1.8 0	-
	.78	.73	.63	.54	.54	.55	.75	.62	.55	.59	-	1.0	.81	1.25	1.7	-
	.89	.61	.56	.65	.64	.74	.75	.56	.64	.61	-	1.09	.970	1	1.3	-
	.59	.95	.78	.63	.85	.61	.80	.54	.52	.72	-	.93	1	.80	.87	-
	.58	.57	.57	.60	.56	.67	.61	.64	.56	1.6	-	1.9	-	1.41	1.1 9	-
Average time taken	.70											1		.73		
Space mean speed	14.28											10		13.64		

Table 3.7: Showing the Details of the Space Mean Speed (Hassan to Bangalore).

Type of vehicle / Parameters	Four wheelers								Buses			Trucks						
Total vehicles	45								13			38						
Distance	10								10			10						
Time in seconds	.3	.7	.5	.6	.6	.7	.3	.5	.4	.4	.6	.9	1.2	1.8	1.2	2	1.2	.8
	.3	.2	.3	.2	.6	.7	.2	.3	.5	.6	-	1.3	1.1	.9	.9	.6	1.5	.7
	.2	.4	.5	.3	.6	.4	.5	.5	.4	.6	-	.9	.7	.5	.9	.7	.7	
	.3	.4	.6	.3	.3	.6	.6	.4	.7	1	-	1	.8	.4	.7	.5	.6	
	.4	.6	.3	.7	.4	.4	.4		.4	.5	-	.6	.7	.8	.9	.6	.7	
	.3	.4	.3	.3	5.3	.5	.3		.4	.5	-	1	.7	2.5	.7	.8	1.2	
Average time taken	.45								.615			.939						
Space mean speed	22.05								16.25			10.64						

Table 3.8: Showing the Details of the Space Mean Speed (Hassan to Bangalore).

Type of vehicle / Parameters	Four wheelers							Buses			Trucks							
Total vehicles	41							18			40							
Distance	10							10			10							
Time in seconds	.79	2.2	.96	.98	.72	.96	.68	.84	1	1.5	1.3	1.7	1.6	1.7	.78	.96	1.4	1
	.69	.74	.82	.75	.69	.68	.7	.89	1	1	.98	1.4	.92	.76	.86	1.8	2.8	1.1
	.79	.96	.6	.78	.58	.62	.72	.96	.88	.95	.97	.99	1.2	2.5	1	1.4	1	-
	1	2.2	1.9	.65	.59	.76	.54	.95	.95	1.1	1.8	.86	1.0	.97	.74	2.8	.92	-
	.76	.57	.61	.69	.80	.72	.68	.85	.96		1.5	1	1.2	1.7	4	1	1.4	-
	.74	.8	.74	.74	.74	.97		.85	.95		1.1	1.6	1.4	3	1.2	.92	2.3	-
Average time taken	.84							.98			1.41							
Space mean speed	11.90							10.20			7.09							

Table 3.9: Showing the Details of the Space Mean Speed (Bangalore to Hassan).

Type of vehicle / Parameters	Four wheelers										Buses				Trucks				
Total vehicles	58										21				30				
Distance	10										10				10				
Time in seconds	.61	.67	.61	.74	.84	.64	.51	.66	.56	.43	1	1	.91	.92	.87	.96	1.3	1.7	1.7
	.60	.66	.8	.71	.6	.68	.55	.8	.9	.45	1.1	1	.94	.99	1.2	1.3	1.8	1.7	1.4
	.64	.79	.79	.66	.72	.59	.62	.59	.94	1	1	.99	1.1	.92	1.4	1	1.2	1.6	1.1
	.74	.63	.65	67	.68	.66	.71	.76	.75	-	.89	.97	.97	-	.99	1.4	1.5	1.7	1.6
	.62	.63	.66	1.6	.68	.6	.62	.85	.77	-	1	.88	1.2	-	1.6	1.3	2.3	1.2	1.2
	.62	.57	.83	.53	1	.55	.46	.73	.93	-	.83	.92	1	-	.73	1.4	1.7	1.7	1.1
Average time taken	.68										.99				1.38				
Space mean speed	14.7										10.10				7.24				

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Table 3.10: Showing the Details of the Space Mean Speed (Bangalore to Hassan).

Type of vehicle / Parameters	Four wheelers					Buses		Trucks		
Total vehicles	30					7		18		
Distance	10					10		10		
Time in seconds	.75	.56	.74	.91	.8	1.2	1.05	.99	1.5	1.2
	.72	1	.62	.63	.77	.95	-	1.62	1.4	1.8
	.58	1	1	2	.72	1.3	-	1.6	1.3	1.3
	1.38	.56	.62	.77	.64	1.9	-	1.2	1	1.2
	.60	1	.69	.68	.84	.82	-	.91	1	1.6
	.33	.76	.78	.69	.78	1.1	-	1	1.6	1.3
Average time taken	.84					1.18		1.322		
Space mean speed	11.87					8.42		7.55		

Table 3.11: Showing the Details of the Space Mean Speed (Bangalore to Hassan).

Type of vehicle / Parameters	Four wheelers							Buses			Trucks			
Total vehicles	42							17			20			
Distance	10							10			10			
Time in seconds	.93	.81	.61	.6	.7	.88	.69	1.8	.88	.83	1.2	.89	1	.84
	.87	.5	.64	.5	.78	.48	.65	1	.96	1.1	1.5	1.4	1.2	-
	.5	.52	.48	.87	.69	.66	.81	1.2	.86	.9	1.9	1.7	1.5	-
	.67	.56	.64	.62	.53	.7	.76	1	.69	.85	1.7	1.7	.88	-
	.57	.6	.71	.86	.76	.59	.70	.93	.77	-	1.4	1	1.8	-
	.8	.51	.82	.47	.51	.62	.52	1	.86	-	1	1.4	1	-
Average time taken	.65							.98			1.33			
Space mean speed	15.35							10.12			7.46			

Table 3.12: Showing the Details of the Space Mean Speed (Bangalore to Hassan).

Type of vehicle / Parameters	Four wheelers											Buses			Trucks						
Total vehicles	66											17			41						
Distance	10											10			10						
Time in seconds	1.2	.6	.4	.4	.6	.4	.7	.4	.3	.5	.3	1	.6	.5	.8	1.2	1	.5	1	.5	.9
	0.6	.7	.7	.4	.6	.3	.3	.4	.3	.4	.5	.8	.5	.7	.9	.8	1	.4	1.5	.5	1.2
	.7	.4	.3	.8	.3	.3	.4	.4	.7	.3	-	.7	.7	.7	.6	.9	1.2	.7	1.2	1.1	.5
	.7	.4	.5	.4	.3	.8	.7	.5	.5	1	-	.7	.6	.5	.6	1.7	1.2	.7	1.2	1	.5
	.3	.4	.4	.5	.4	.3	.5	.4	.3	.4	-	.5	.8	1	.5	.9	1.4	.6	1.2	1.3	1.1
	.6	.3	.3	.3	.5	.5	.3	.2	.5	.2	-	.8	.7		1	.7	.6	1.9	.7	1.3	-
Average time taken	.56											.7			.949						
Space mean speed	17.74											14.28			10.53						

Table 3.13: Showing the Details of the Space Mean Speed (Hassan to Bangalore).

Type of vehicle / Parameters	Four wheelers									Buses					Trucks					
Total vehicles	54									30					32					
Distance	10									10					10					
Time in seconds	.5	.3	.6	.3	.3	.4	.6	.3	.3	.5	.5	1.1	1	.6	.8	.9	1.4	1.6	1.2	1.2
	.4	.5	.3	.5	.6	.3	.4	.4	.3	.5	.8	.5	.5	.6	.6	.5	.6	.6	.6	.5
	.6	.4	.7	.3	.5	.5	.3	.7	.3	.7	.6	1.2	.5		1.2	1.2	1.4	.7	1.2	-
	.3	.3	.4	.3	.7	.3	.7	.3	-	.7	.5	.7	.5		.7	1.3	.7	.4	.7	-
	.3	.3	.3	.4	.3	.3	.4	.6	-	.5	.7	.5	1		1	.9	1	.8	.6	-
	.7	.3	.3	.3	.3	.3	.4	.3	-	.7	.5	.5	1		.8	1	1.2	1	.6	-
Average time taken	.4									.677					.934					
Space mean speed	25									14.77					10.7					

3.5 Time Headway:

Time headway (H) is the difference between the time the front of a vehicle arrives at a point on the highway and the time the front of the next vehicle arrives at the same point. The time headway is usually expressed in seconds. Time headway is necessary to known the inter arrival rate among the vehicles which is needed to find out the capacity of a highway system.

$$\text{Time headway} = \frac{\textit{Average time in seconds}}{\textit{Number of vehicles}}$$

$$T_h = \frac{\sum_{i=1}^{n} Ti}{V}$$

Figure 3.6: Showing the Time Headway Count.

Table 3.14: showing the Average Time Headway.

Duration(hours)	From	To	Total Number of vehicle	Total time in seconds (s)	Average time in seconds (s)
14	Hassan	Bangalore	2068	21170	10.23
14	Bangalore	Hassan	2370	21179	10.42

Figure 3.7: Observing the Time Headway Count.

Table 3.15: Showing details of Time Headway.

Direction	Hassan to Bangalore									Bangalore to Hassan								
Lane	Lane A					Lane B				Lane C					Lane D			
Parameters	Total vehicles	Time in seconds				Total vehicles	Time in seconds			Total vehicles	Time in seconds				Total vehicles	Time in seconds		
		4	22	5	10		7	25	24		1	37	89	60		31	22	50
		8	8	5	9		4	34	21		22	13	20	30		21	24	58
		6	1	45	33		11	31	4		34	15	30	34		12	18	
		10	4	13	9		13	21	18		17	56	12	17		71	19	
		8	6	16	45		7	10	32		32	6	16	4		11	35	
		9	7	37	9		16	33	24		14	27	6	38		21	9	
		14	5	4	57		35	11	2		22	47	4	30		19	11	
		4	3	47	2		9	3	21		34	14	57	5		21	7	
		1	16	13	10		15	17	14		13	20	16	4		20	79	
		24	3	34	44		53	12			2	17	16	7		77	31	
	164	9	36	20	8	102	14	21		126	7	30	7	11	88	11	3	
		15	24	36	6		73	6			18	11	46	6		10	48	
		12	23	38	10		45	3			14	98	14	65		9	27	
		30	34	6	8		30	17			38	48	19	10		11	73	
		5	14	9	8		20	57			8	26	17	75		12	35	
		61	37	31	18		53	18			5	16	39	66		52	51	
		2	3	10	3		52	5			27	13	16	28		26	17	

Table 3.16: Showing a details of Time Headway.

Direction	Hassan to Bangalore								Bangalore to Hassan								
Lane	Lane A				Lane B				Lane C						Lane D		
Parameters	Total vehicles	Time in seconds			Total vehicles	Time in seconds			Total vehicles	Time in seconds					Total vehicles	Time in seconds	
		61	20	4		17	41	28		44	16	20	11	16		36	15
		62	17	31		25	9			15	32	16	12	21		22	14
		8	5	62		7	10			35	31	12	41	55		68	20
		4	9	12		27	99			19	99	20	31	21		29	19
		4	28	12		8	6			41	78	35	9	6		53	39
		37	43	43		13	48			21	9	21	11	21		98	42
		20	6	14		57	9			29	39	11	99	19		7	21
		10	10	27		19	12			3	16	14	11	31		16	59
		15	24	13		23	35			89	17	10	9	29		57	99
		5	36	16		24	14			13	17	24	19	11		99	18
	108	36	19	15	86	13	10		206	12	19	51	30	8	68	49	59
		4	16	51		86	7			18	20	20	7	6		64	46
		45	13			79	3			4	6	25	24	19		16	31
		23	34			18	62			7	48	37	60	13		7	
		65	19			2	39			9	27	32	7	20		13	
		21	24			22	17			16	9	18	9	3		33	
		29	16			39	13			10	9	2	8	37		71	
		99	8			40	26			3	28	19	19	9		47	
		8	60			52	17			56	29	18	48	28		3	
		5	43			43	51			52	25	13	19			43	
		12	11			31	95			45	21	41	38			96	

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Table 3.17: Showing a details of Time Headway.

Direction	Hassan to Bangalore									Bangalore to Hassan									
Lane	Lane A					Lane B				Lane C						Lane D			
Parameters	Total vehicles	Time in seconds				Total vehicles	Time in seconds			Total vehicles	Time in seconds					Total vehicles	Time in seconds		
	156	40	12	16	4	94	31	85	64	178	31	15	56	16	23	126	1	5	3
		17	9	3	11		38	99	49		18	43	5	76	38		2	3	78
		11	34	26	25		99	12	24		99	21	4	77	12		4	22	15
		19	44	31	11		66	99	65		16	6	19	10	38		6	2	26
		3	5	73	24		5	98	24		25	13	36	64	20		7	4	23
		12	26	54	53		13	3			43	10	40	8			1	2	46
		10	16	3	6		30	7			13	50	23	6			12	60	3
		12	25	35	85		32	10			18	25	37	16			14	6	30
		5	4	9	18		99	1			38	8	20	9			4	94	1
		18	31	22	6		6	53			23	28	60	12			7	10	60
		7	3	12	4		32	99			61	10	16	20			20	18	14
		19	5	19	8		99	85			3	35	12	47			4	5	5
		5	9	9	44		40	92			14	16	14	54			6	9	6
		18	18	32	20		9	99			34	22	17	8			10	18	99
		2	13	19	23		11	98			4	14	13	17			19	8	9
		12	29	11			65	11			13	4	43	38			15	94	12
		3	5	15			21	21			5	9	50	51			31	41	19
		16	16	7			99	36			14	24	12	46			25	14	38
		76	36	15			9	99			195	9	30	8			2	11	99
		11	10	2			17	14			7	26	14	35			1	28	4
		33	25	10			31	33			16	27	8	31			1	31	22

Table 3.18: Showing a details of Time Headway.

Direction	Hassan to Bangalore																					
Lane	Lane A											Lane B										
Parameters	Total vehicles	Time in seconds										Total vehicles	Time in seconds									
	414	11	56	27	9	30	6	32	5	2	14	358	10	8	11	19	10	12	13	1	4	43
		26	18	18	27	20	7	13	16	21	11		13	8	6	13	19	3	35	5	4	9
		31	8	1	40	21	5	19	16	5	89		10	17	11	38	2	30	21	7	1	40
		14	9	4	27	18	12	59	65	4	56		5	21	7	4	13	11	23	19	16	27
		8	17	22	3	30	1	7	54	14	2		65	26	5	11	36	5	21	16	26	3
		97	23	31	14	4	15	4	67	10	43		2	57	72	2	14	11	9	12	13	
		3	18	26	17	4	5	2	7	26	23		51	8	3	14	2	1	10	12	15	
		99	91	15	7	5	4	45	10	62	98		60	4	5	1	35	13	19	3	7	
		18	24	17	33	18	4	41	9	10	16		26	64	7	27	7	8	2	30	10	
		20	35	2	11	20	1	6	33	34			61	6	13	4	2	4	13	11	8	
		30	15	31	1	12	16	7	14	11			56	3	20	16	5	11	36	5	17	
		9	60	28	2	18	16	31	28	5			13	17	6	11	11	2	14	11	13	
		40	33	25	33	11	18	4	30	13			7	10	6	2	2	14	2	1	18	
		20	91	14	10	9	31	28	7	13			37	54	12	26	23	1	35	19	4	
		13	25	30	25	35	38	39	60	15			6	37	16	5	4	27	6	16	7	
		37	20	22	34	30	15	21	22	19			5	10	2	7	30	4	2	12	12	
		19	34	13	13	15	19	22	8	10			4	61	11	13	1	16	5	24	19	
		34	99	4	11	6	28	5	10	22			61	5	17	35	5	11	11	7	30	
		20	16	7	1	26	10	18	18	18			10	3	38	21	7	2	2	28	13	
		11	17	13	34	2	12	9	33	23			35	13	10	21	19	26	23	14	22	
		12	11	43	33	19	10	18	5	15			97	29	24	23	16	4	4	21	4	
		11	13	19	29	2	19	6	49	49			22	3	10	6	12	8	30	24	7	

Table 3.19: Showing a details of Time Headway

Direction	Bangalore to Hassan																				
Lane	Lane C											Lane D									
Parameters	Total vehicles	Time in seconds										Total vehicles	Time in seconds								
	412	14	12	14	13	9	6	2	5	2	19	366	9	22	8	27	8	7	40	32	9
		18	28	4	17	17	8	9	6	4	13		30	2	4	8	6	6	5	3	4
		12	8	6	6	7	8	18	7	8	19		19	6	2	9	7	15	12	6	21
		15	19	8	6	7	10	14	9	9	11		1	2	17	4	22	7	9	24	16
		5	30	8	7	16	15	9	13	44	10		11	3	2	6	34	21	30	1	4
		4	12	1	12	23	2	26	12	4	15		14	6	12	12	9	4	9	4	
		10	20	10	14	13	9	5	35	21	4		2	33	9	3	10	2	7	6	
		7	21	3	39	11	8	21	7	11	15		15	8	2	1	12	14	15	9	
		26	18	11	16	5	10	10	19	3			10	10	24	5	2	7	30	50	
		11	17	17	1	13	17	4	40	5			16	4	6	3	11	15	5	14	
		15	10	15	26	10	1	6	7	6			20	8	2	21	23	16	7	6	
		2	5	6	31	9	3	7	15	7			20	6	22	15	17	6	5	15	
		10	2	21	7	5	13	4	12	9			3	7	37	27	1	13	2	3	
		13	8	4	11	4	11	2	19	13			8	13	7	14	17	1	6	7	
		18	5	5	8	10	14	3	8	12			9	1	2	18	21	7	8	4	
		14	10	5	11	16	12	8	21	35			15	3	8	5	4	38	7	28	
		7	6	8	11	4	2	10	18	7			16	3	11	12	14	5	19	3	
		2	12	15	13	4	3	44	13	19			20	23	7	3	7	28	17	11	
		13	1	13	12	23	5	4	11	40			19	5	18	1	11	8	4	19	
		17	3	3	10	7	31	21	19	7			19	4	1	4	3	4	12	15	
		10	12	12	31	2	5	11	10	15			12	18	20	2	13	7	3	43	
		2	6	4	15	10	9	3	14	12			10	15	10	7	6	7	10	11	

Table 3.20: Showing a details of Time Headway

Direction	Hassan to Bangalore															
Lane	Lane A									Lane B						
Parameters	Total vehicles	Time in seconds								Total vehicles	Time in seconds					
	338	18	20	7	29	12	13	18	24	228	20	36	21	4	6	60
		40	10	9	12	9	21	2	27		4	19	15	99	12	3
		4	4	21	22	10	6	4	15		9	22	132	11	30	24
		6	6	7	5	1	24	2	3		51	34	37	55	8	9
		5	8	9	6	3	39	13	5		37	99	34	80	10	
		44	11	62	3	3	24	18	11		99	23	25	8	10	
		17	8	35	1	4	16	14	18		18	12	4	6	8	
		10	3	17	8	17	4	17	8		15	50	59	70	26	
		14	37	19	9	24	11	6	23		99	14	58	15	27	
		17	18	6	19	15	1	25	5		24	56	10	28	28	
		2	43	27	4	22	5	48	2		11	3	56	6	99	
		24	58	31	5	3	8	7	11		3	12	15	9	10	
		34	23	33	27	11	6	2	4		27	14	24	20	7	
		19	39	9	35	8	18	9	13		56	51	12	23	10	
		69	29	5	1	46	7	25	9		49	5	86	10	15	
		48	5	24	13	9	5	34			34	21	2	19	10	
		19	7	1	15	4	6	5			12	20	3	10	5	
		18	13	2	34	9	2	22			7	20	32	5	9	
		42	13	1	27	7	20	9			36	11	6	5	58	
		17	42	24	1	3	8	5			2	10	11	56	21	
		36	25	58	12	28	11	3			65	20	21	10	20	
		45	29	8	11	7	24	7			7	9		26	5	

Table 3.21: Showing a details of Time Headway.

Direction	Bangalore to Hassan																		
Lane	Lane C										Lane D								
Parameters	Total vehicles	Time in seconds									Total vehicles	Time in seconds							
		13	24	6	4	3	7	11	4	4		10	154	15	35	11	17	16	16
		3	5	12	3	14	8	3	10	21		19	5	10	1	6	2	6	7
		9	4	15	7	20	9	7	3	5		18	12	4	3	8	4	18	32
		5	5	6	4	1	2	13	15	9		1	12	9	3	9	9	13	3
		19	5	4	24	13	3	7	15	7		25	5	1	11	6	12	22	34
		9	4	10	16	12	26	10	11	4		9	6	8	9	32	6	34	5
		19	12	10	3	3	5	1	22	15		7	7	23	3	5	3	21	53
		16	6	2	8	3	12	15	12	10		3	12	3	3	2	21	4	6
	370	19	10	17	10	7	17	9	24	29	336	1	7	20	16	1	29	47	1
		20	7	5	11	6	10	11	4	22		71	13	13	26	1	11	3	66
		19	3	1	24	6	25	13	10	7		5	15	5	20	11	262	16	42
		17	5	4	8	12	14	10	12	2		15	33	12	5	5	1	8	22
		7	9	6	5	7	30	20	22	14		51	46	13	3	22	6	17	6
		11	6	2	10	18	21	8	42	13		3	11	23	2	312	6	8	9
		4	13	10	12	39	36	8	7	7		30	1	9	12	2	29	31	16
		7	6	6	15	2	2	23	4	15		1	15	2	15	2	16	2	19
		12	10	3	19	17	19	8	14	2		28	1	18	4	8	6	16	6
		8	7	5	17	14	9	10	19			2	9	8	14	6	20	29	21
		26	4	8	6	8	2	24	2			5	7	9	20	2	11	4	11
		18	4	7	11	16	7	23	14			16	12	20	17	18	15	17	20
		5	6	20	6	22	7	3	17			18		5	10	11	5	8	31

3.6 Arrival Rate:

Arrival is generally defined as "The simple model assumes that the number of arrivals occurring within a given interval of time follows a Poisson distribution". This parameter is the average number of arrivals in time which is also the variance of the distribution.

Table 3.22: Showing the Average Arrival Rate.

Duration (hours)	From	To	Timings in seconds(s)	Observed vehicles
5	Hassan	Bangalore	18000	1973
5	Bangalore	Hassan	18000	1946

Figure 3.8: Showing Counting of Vehicles for every 30 seconds Time Interval

Table 3.23: showing the observed frequency from Hassan to Bangalore.

Number of vehicles arriving for every 30 second	Observed frequency						Total number of vehicles	probability	Theoretical Frequency
	Day 1	Day 2	Day 3	Day 4	Day 5	Total			
0	6	7	8	2	3	26	0	0.036	21.52
1	11	10	21	13	10	65	65	0.120	71.76
2	21	22	22	32	31	128	256	0.199	119.00
3	19	16	23	35	34	127	381	0.220	131.56
4	24	20	24	20	24	112	448	0.183	109.43
5	16	19	7	9	12	63	315	0.121	72.35
6	13	15	5	6	4	43	258	0.067	40.062
7	3	5	8	3	0	19	133	0.031	18.53
8	2	3	2	0	1	8	64	0.013	7.74
9	2	2	0	0	0	4	36	0.0048	2.87
10	0	1	0	0	0	1	10	0.0016	0.956
11	0	1	0	0	0	1	11	0.00048	0.287
12	1	0	0	0	0	1	12	0.000135	0.08
Above 12	0	0	0	0	0	0	0	0.00013	0.077
Total	598						1989	1.000	597

Table 3.24: showing the observed frequency from Bangalore to Hassan.

Number of vehicles arriving for every 30 second	Observed frequency						Total number of vehicles	probability	Theoretical frequency
	Day 1	Day 2	Day 3	Day 4	Day 5	Total			
0	0	0	12	12	12	36	0	0.02	11.58
1	1	2	14	18	15	50	50	0.078	45.16
2	7	7	25	40	30	109	218	0.153	88.58
3	12	11	21	22	23	89	267	0.199	115.22
4	15	16	20	16	20	87	348	0.195	112.90
5	21	20	10	4	15	70	350	0.152	88.008
6	16	18	5	6	3	48	288	0.099	57.32
7	12	15	2	1	1	31	217	0.055	31.84
8	13	12	0	0	1	26	208	0.027	15.63
9	6	11	0	0	0	17	153	0.011	6.36
10	6	5	0	1	0	12	120	0.0046	2.66
11	1	2	0	0	0	3	33	0.0016	0.926
12	0	1	0	0	0	1	12	0.00053	0.306
Above 12	0	0	0	0	0	0	0	0.00016	0.092
Total	579						2264	1.00	577

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3.7 Service Rate:

The service rate depends upon the type of operation involved in providing service to the customers. Generally cash collecting service takes more time than the automatic way of collection. Service rate denotes the rate at which vehicles are been served in a system. It is the reciprocal of the service time.

$$\text{Service rate}=\frac{\text{Total time in seconds}}{\text{Number of vehicles}}$$

When the vehicle enters the toll plazas, a rational driver selects the counter service by seeing the queue length existing relative to other counters. Once the vehicle is in the queue length it has to follow the queue discipline. The waiting time is the time spend by the vehicle in the queue length and the time spends in providing the amount. The driver must pay the with exact change in order to minimize service time.

Table 3.25: Showing the Average Service Rate.

Duration (hours)	From	To	Number of vehicles	Total time in seconds(s)	Service time in seconds(s)
4	Hassan	Bangalore	315	5660	18.02
4	Bangalore	Hassan	277	4709	17.06

Figure 3.9: Showing the Service Section of Toll Plaza.

Table 3.26: Showing the Details of Service Rating Time.

Type of Vehicles	Service Rating Time												
	Hassan to Bangalore							Bangalore to Hassan					
Four Wheelers	24.6	27.0	19.7	19.4	15.4	26.0	11.9	35.3	07.0	08.0	10.7	12.6	6.95
	22.0	08.7	12.1	09.2	25.2	22.4	22.3	23.3	13.0	11.9	08.0	07.0	13.23
	22.5	15.7	08.5	20.7	17.3	24.8	15.4	08.0	16.5	07.0	08.0	9.56	10.45
	41.0	10.2	13.6	16.6	37.8	17.4		06.0	14.2	10.3	13.3	16.4	10.95
	24.4	22.6	17.3	25.1	27.6	16.5		36.6	08.2	07.0	09.0	08.5	10.13
	52.3	35.4	18.5	20.6	27.0	12.0		27.2	08.3	13.2	12.0	06.0	13.00
	13.0	10.9	08.5	09.0	15.4	20.8		13.0	09.2	15.0	13.3	12.0	07.00
	12.7	21.4	10.9	17.5	18.2	13.3		11.5	11.2	07.0	07.4	06.1	8.92
	07.5	09.4	9.13	23.5	09.9	09.1		10.5	13.8	12.5	13.5	07.0	13.43
Buses	32.3							19.0					
	15.2							13.2					
	37.0							19.0					
	12.1							22.0					
	08.9												
Trucks	27.2	40.6						08.8	27.0				
	35.0	63.7						08.0					
	22.7	93.2						18.2					
	15.2							20.2					
	32.5							18.0					
	25.9							17.6					
	25.6							41.9					
	45.5							14.4					

Table 3.27: Showing the Details of Service Rating Time.

Type of Vehicles	Service Rating Time												
	Hassan to Bangalore							Bangalore to Hassan					
Four Wheelers	10.91	09.13	19.48	07.82	17.48	15.53	13.33	14.47	08.86	13.21	22.59	17.48
	20.08	11.28	08.53	15.49	09.25	18.55	14.41	13.03	20.63	12.65	10.10	18.55
	20.78	07.97	22.63	09.89	09.27	09.98	08.29	41.07	10.91	09.56	19.49	22.36
	10.98	06.23	13.03	12.02	20.63	43.28	16.03	09.13	37.82	23.32	20.78	15.43
	13.47	23.81	25.29	16.53	12.97	11.63	21.21	12.17	52.33	07.13	20.89	11.26
	08.23	16.51	17.38	20.89	08.98	09.28	22.01	24.61	27.01	13.48	22.59	16.78
	10.93	17.48	07.82	24.27	15.23	09.74	10.46	18.55	09.25	09.36	17.51	09.44
	19.46	09.13	12.18	12.17	15.40	18.63	11.28	15.49	07.3	08.92	16.57	
	15.18	44.63										
Buses	38.05	09.23						15.29				
	16.38	33.01						09.62				
	11.41	20.46						11.48				
	15.36	19.27						39.43				
	18.43							13.23				
Trucks	33.46	29.58						38.42				
	19.43	21.33						41.66				
	25.63	27.46						27.30				
	22.89	39.11						18.89				
	40.73	17.28						25.63				
	43.46							25.99				
								63.75				
								21.49				

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CHAPTER 4
ANALYSIS OF FIELD DATA

4.1 General

The delay and waiting time of drivers in toll plaza depends on service time and arrival rate. The quick service time and number of toll booths can reduce the time wasted in the queue. The wasted time can be calculated and minimised by analysis of the observed data. By calculating the wasted time the performance of the servers can be analysed and also the delay in overall travel time can be found out.

4.2 Road Inventory

The road inventory reveals that the number of incoming lanes is two and it diverges into five lanes within the queuing area of the toll plaza. The pavement structure before the toll plaza is divided flexible pavement. The number of lanes is four of width 9m and median width is 2.5m. The type of a shoulder is earthen and shoulder width is 1.5m.

The queuing area is of rigid pavement. The width of the pavement is 30m, and the length of pavement on arrival and merging side is 250m. the number toll booth on each side is 5, length of toll booth is 2.4m and width is 3.6m.

4.3 Traffic Volume

In the present study the traffic count census is done as per IRC: 9-1972 “Traffic census on Non-Urban Roads”. To take into account the randomness, the traffic volume study was carried out in short intervals (4 hour) at different hours of a day and at different days. The average traffic flow rate from Hassan to Bangalore is 375veh/hr and the average traffic flow rate from Bangalore to Hassan is 345 veh/hr.

4.4 Space Mean Speed

In the present study the space mean speed is found out as per IRC: 108-1996 “Guidelines for Traffic Prediction on Rural Highways”. The drivers slow down their vehicle before the toll plaza to judge the lanes and to select the lanes so that they spend less time in the queue. If the traffic flow rate increases the space mean speed decreases. The space mean speed of vehicles approaching the near the toll booth from Hassan to Bangalore is 21 km/hr and from Bangalore to Hassan is 14 km/hr.

The space mean speed of vehicles at a certain distance away from the queuing area on both the directions was found out to be 34km/hr and 26 km/hr respectively.

4.5 Time Headway

Time headway is the difference between the time the front wheel of a vehicle arrives at a point on the highway and the time of the front wheel of the next vehicle arrives at the same point. Time headway can be used to predict the flow rate of vehicles on a section of roadway the field data observed shows that the inter-arrival time between vehicles was found out to be 10.5s (Bangalore to Hassan) and 10.2s (Hassan to Bangalore). Both the directions have equal headway indicating nearly equal flow of vehicles in both the directions. Hence this might be one of reason for having equal number of booths in both the directions (i.e, 5 on each side).

4.6 Arrival Rate

The data obtained from the arrival rate was analysed using Poisson distribution. The observed frequency (598) approximately equal to the theoretical frequency (597) as per the Poisson distribution. Hence vehicles arriving at a section of a highway simply follow Poisson distribution. Hence for any future studies for finding out arrival rate, Poisson distribution can be made use off.

4.7 Service Rate

In the present study, the average service time from Hassan to Bangalore is 18.02 seconds and from Bangalore to Hassan is 17.06 seconds. The observed data reveals the service rate to be almost equal and hence service rate can be considered as general (G).

4.8 Traffic Flow Theroy

One of the most important equation in traffic flow theory is given between traffic flow (q), traffic density (k) and speed (s).

$$q=k*s$$

In the present study, graphs are plotted to show the behaviour of vehicles on the road section. In the present study the queuing theory was modelled on M/G/1. M represents the arrival pattern follows Poisson distribution, G represents service pattern considered general and 1represents a single booth selected for the analysis.

Table 4.1: Shows Speed Density data for M/G/1 Model for One Lane

Density(veh/km)	Effective speed(km/hr)
59	4
72	3
84	2.5
85	2

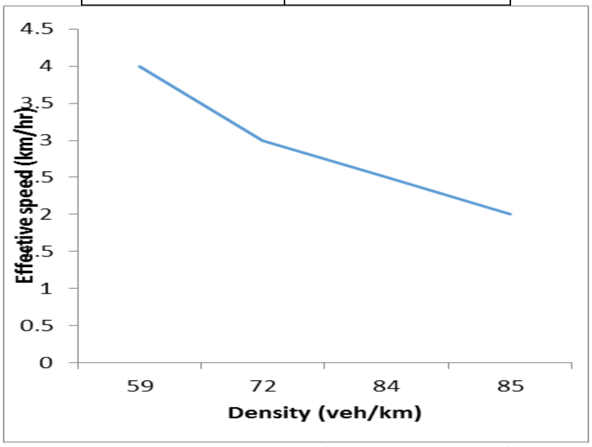

Figure 4.0: The speed density diagram for the M/G/1 model for one lane

Table 4.2: Shows Speed Density data for M/G/1 Model for Both Lanes

Density(veh/km)	Effective speed(veh/km)
18	11.1
26	8.14

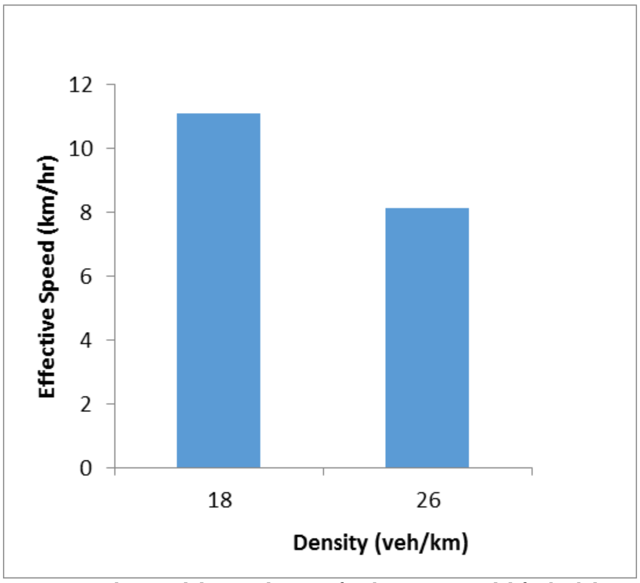

Figure 4.1: The speed density diagram for the M/G/1 model for both lanes

The above figure clearly indicates that as the traffic density increases the effective speed decreases. Hence speed and traffic density varies inversely. The travel time will also increase as density increases. The above bar graph shows that density on (Bangalore- Hassan) is more and the effective speed on that road section is less compared to (Hassan-bangalore) where in the density is less and the effective speed is more.

Table 4.3: Shows the Effective Speed and Traffic Flow data

Traffic flow(veh/hr)	Effective speed(km/hr)
345	8.14
345	11.1

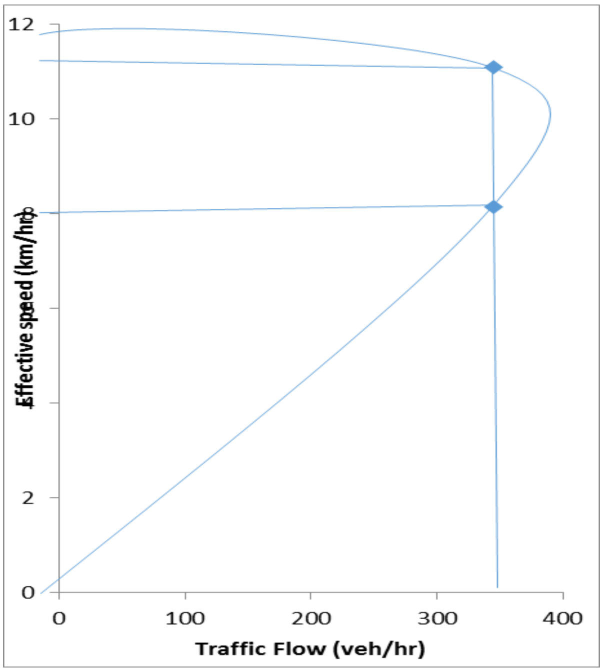

Figure 4.1: The speed flow diagram for the M/G/1

The speed flow figure is envelope of all possible combination of the effective speed and traffic flow. The effective speed decreases with increases traffic flow.

CONCLUSION

A detailed study was carried out to analyse the performance of a tool booth. The following conclusion was drawn from the observed data.

- It was found that flow rate remained constant on both directions 375 and 345 (veh/hr)
- The inter arrival time between two vehicle was found out be 10 seconds on both the directions.
- The waiting time in the queuing area was found out to be 10 seconds as general.
- The flow theory diagram reveals that as the density increases the effective speed decreases on that road section.

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