ANALYSIS OF ROAD TRAFFIC FLOW BY USING M/M/1: ∞/FCFS QUEUING MODEL

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Abstract:

In applied mathematics and civil engineering, traffic flow is the study of interactions between vehicles, drivers, and with the aim of research and developing an optimal road network with efficient movement of traffic and to minimise traffic congestion problems. Overcrowd traffic is a challenging task of highly increased separation of traffic movement in Indian cities, with increasing vehicles on the road, overcrowd traffic is quickly increasing. Much has been written about the Queuing Theory technique and its strong and effective application. The present paper deals analysis of road traffic flow by using M/M/1: ∞/FCFS queuing model with respect to over crowd traffic. In order to analysis the same, the few squares (intersection point) of Raipur city, Chhattisgarh has been selected. The paper summarized various queuing theory performance parameters such as traffic intensity, Average number of customers in the system, System Design, Waiting Time and Utilization Analysis.

Key words: *Queuing Theory, M/M/1: ∞/FCFS Model, Road Traffic Flow,*

1. Introduction

There are various applications of the queuing theory in the literature of probability theory, operations research, engineering and other related areas. The main work in the field of queuing theory has been developed by Erlang (1909). Fry (1928) in his book on "Probability and its engineering uses" throws further important observations on the queue related problem. Later on, the networks of queues were developed by Jackson (1957).

Now, Gaver (1959) made a successful attempt to solve queuing problem using imbedded Markov chain technique assuming time space to be continuous. In operation research, queuing theory is a mathematical technique to minimize the waiting time of a particular queuing system. We are well aware about queuing right from beginning to end of life “i.e. Before takes birth place to till the immersion of bones after the death” a person follows queuing (lining) system. Whenever the problems of over crowd arise in the field of traffic management, the queuing theory and its application always comes in to the picture. The Queuing theory is an effective mathematical technique for solving various critical problems of any organization or system. As queuing theory focuses on representation of traffic situation by using mathematical terms and formulas. City planning and urban designing can have good impact on future traffic management.

As we are aware that, Road traffic jams continue to remain a major problem in most of the cities around the world, especially in developing regions resulting in massive delays, increased fuel wastage and monetary losses. Because of the poorly planned road networks, a common outcome in many developing regions is the presence of small critical areas which are common hot-spots for congestion; poor traffic management around these hotspots potentially results in elongated traffic jams. Shuguo Yang and Xiaoyan Yang (2014) pointed out that it is practically significant to perform the research to the traffic flow of intersection because the capacity of intersection affects the efficiency of highway network directly. They further explained that the result shows that queuing theory is applied in the study of intersection traffic flow and it can provide references for the other similar designs

There are many reasons of over crowd: narrow road, slower speed, longer trip times and increased vehicular queuing. Over crowd also take place due to non-recurring highway incidents, such as a crash or road works, which may reduce the capacity of road below normal level. Therefore the over crowd roads can be seen as an example of the tragedy of common. When vehicles are fully stopped for a certain period of time then this situation is called “traffic jam”. There are number of sudden activities which makes worse overcrowd; most of them reduce the capacity of a road at a given points or over a certain length, or increase the number of vehicles required for a given volume of goods or people. Only high population or increasing of vehicle or sudden activities cannot blame for jam occurrence by traffic researcher. The poor correlation of theoretical model to actual observed traffic flow, transportation planners and highway engineers applied their future assumption using experimental models. Most preferable working traffic models use a combination of macro-micro mesoscopic .Babicheva (2015) studied that Methods of queuing theory helped to obtain detailed solutions of the problem of minimizing delays at signal-controlled road intersection. Recently, Mala, and Verma (2016) remarked that, In India with rapid increasing vehicles on the road, traffic congestion is quickly increasing. Consequently, it is important to study the road traffic flow using queuing theory approaches. Some of references in the proposed fields are Immers, L. H. and Logghe S. (2003), Ho Woo Lee (1989),Denis Jacquet (2008), Rajat Jain and MarGragor J. (1997),Shanmugasundaram and Umarani (2010), Vipin Jain et al. (2012), Transportation Research Board (1996).Isaac Kwasi Adu et. al (2014), and Namdeo V. Kalyankar (2009),

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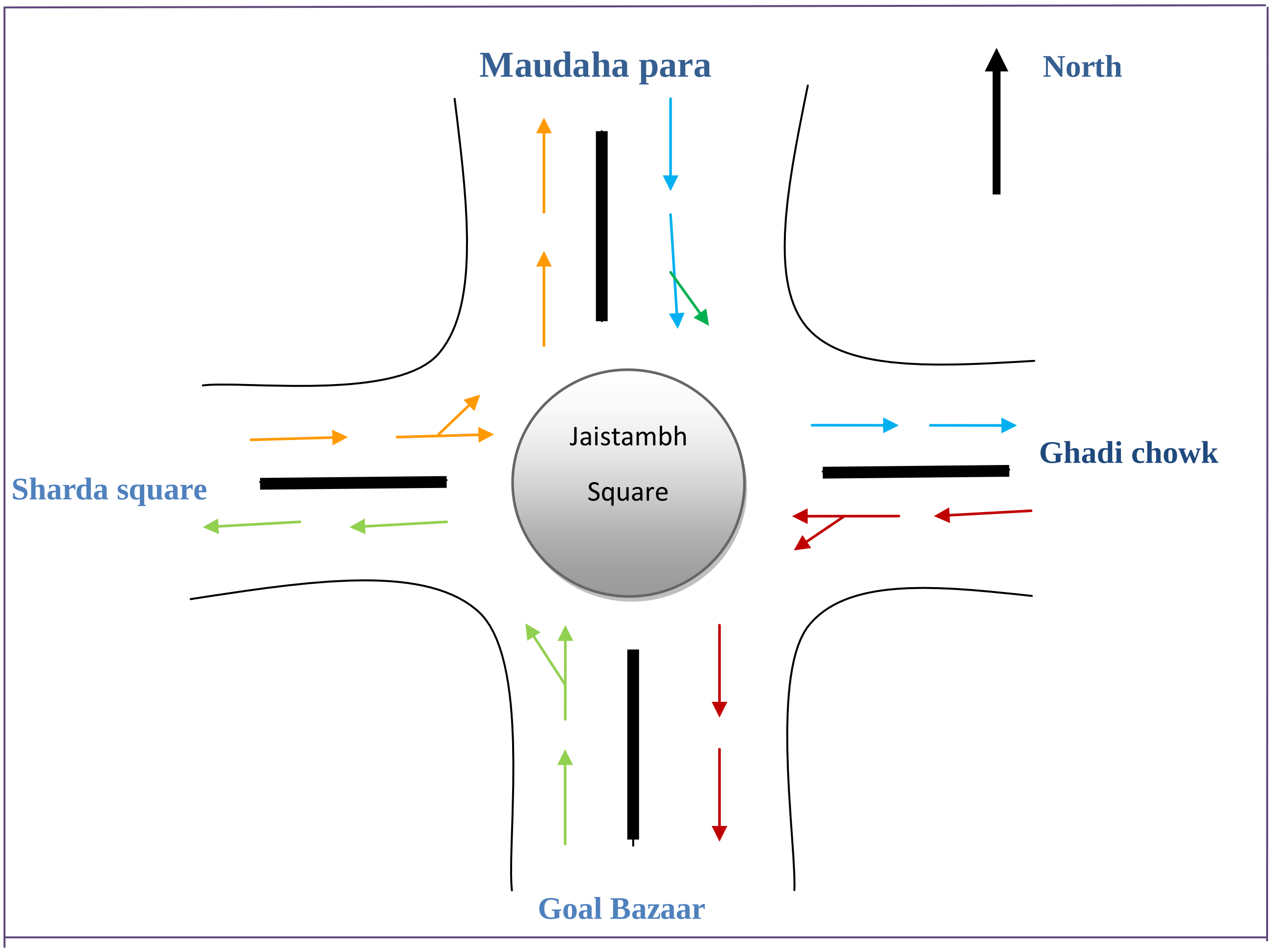
2. Some important Impact of Traffic Jam on Road Traffic Flow:

There are some important Impact of overcrowd or traffic jam on Road Traffic Flow. The waiting times spent by the drivers and passengers road traffic flow are most important impact of traffic jam. Wastes of fuel (diesel or petrol) in the air in the form air population carbon, carbon dioxide, carbon monoxide which leads to nd pollution increased because of the traffic jam. Moreover, the Ambulance, VIP vehicles and other important road transport means affected by the traffic Jam. On the other hand, in the general way traffic Jam also affects the local people to reach their destination to perform their routine job.

3. Road Traffic flow Diagram of Jai stambh Square of Raipur C. G.



in the above traffic diagram, round shape in the middle represent the jai stambh and arrows represents the flow of vehicles.

4. Description and Notations(M/M/I): (1 / FIFO)

In this paper, the queuing model using M/M/1: ∞/FCFS has been considered. Here the arrival process follows the Poisson with arrival rate λ. The service time for vehicles are negative exponentially distributed with service rateμ . The following assumptions have been considered:

- The arrival follows Poisson distribution with mean arrival rate
- The service time has exponential distribution with average service rate
- There is only a single service station.
- Arrivals are from infinite population.
- The customers or vehicles are served on FCFS basis.

Notations:

The following notions have been considered based on Hira and Gupta (2009) for the proposed queuing model:

n = Number of customers/vehicles in the system (waiting line + service facility) at time t.

λ = Mean arrival rate. (Number of arrivals per unit if time).

μ = Mean service rate per busy server (number of customers served per unit of time).

ρ = Utilization factor (Traffic intensity) for the service system.

L_s = Expected (Average) number of customers in the system (waiting + being served).

L_q = Expected (Average) number of customers in the queue

W_s = Expected (Average) time a customer spends in the system.

W_q = Expected (Average) waiting time for per customer in a queue

c = Number of service channels.

P_n= Steady rate probability of exactly n customers in the system.

L_n = Expected number of customers waiting in line (excluding those time when the line is empty)

W_n= Expected time a customer waits in line if he has to wait at

5. Determination data and Parameter of the proposed model:

The following measurements of the model M/M/1: ∞/FCFS has been considered:

Traffic Intensity $\rho = \lambda / \mu$

Average Number of Customer in the System $Ls = \frac{\lambda}{(\mu-\lambda)}$

Average Number of Customer in Queue $Lq = \frac{\lambda^2}{\mu(\mu-\lambda)}$

Average Time Spent in the System $Ws = \frac{1}{(\mu-\lambda)}$

Average Waiting Time in Queue $Wq = \frac{\lambda}{\mu(\mu-\lambda)}$

Now, table 5.1 shows that Tabular Representation of the View of the Traffic Situation at the Jai Stambh square Raipur on the line of Mala and Verma (2016)

Location	**session**	**Arrival**		**Service**		**Arrival**	**Service**	**Traffic**
		Vehicle	**Min**	**Vehicle**	**Min**	**Rate**	**Rate**	**Intensity**
Sharda square to jaistambh	Morning	27	1.23	31	1.01	22	31	0.7097
	Afternoon	19	2.11	18	1.15	9	16	0.5625
	Evening	45	1.72	36	1.03	26	35	0.7429
ghari chowk to Jaistambh	Morning	29	2.35	21	1.43	12	15	0.8000
	Afternoon	19	1.09	23	1.02	10	23	0.4457
	Evening	42	2.13	32	1.0	19.72	32	0.6163
Goal bazaar to jaistambh	Morning	18	2.01	19	1.07	9	18	0.500
	Afternoon	27	1.87	21	1.11	14.43	18.92	0.7632
	Evening	58	3.84	29	1.52	15	19	0.7917
Moudaha para to jaistambh	Morning	17	1.83	21	1.01	9	21	0.4285
	Afternoons	25	2.3	23	1.18	11	19	0.5789
	Evening	37	4.53	41	2.31	8	18	0.4444

The data collection of vehicles at Jaistambh Square. While collecting data morning session considered between 8 .00 am to 10.30 am afternoon session considered between 1.00 pm to 3.00 pm and evening session considered between 5.30 pm to 7.00 pm.

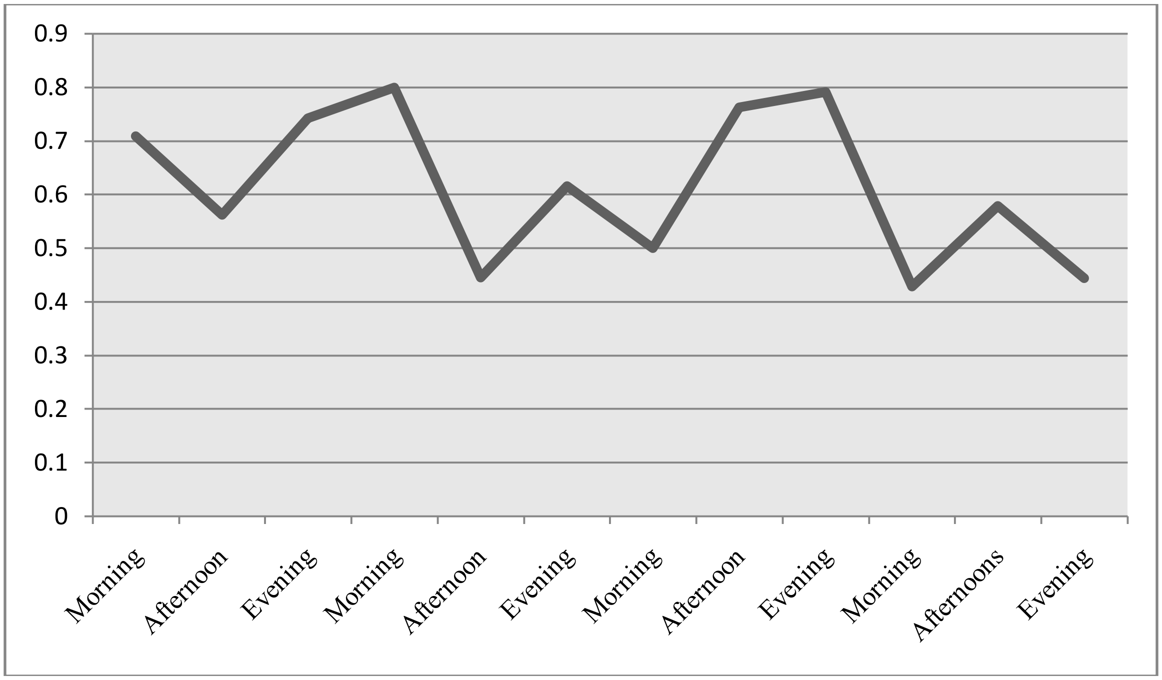


Figure 1: Graphical Representation of Traffic Intensity at Jaistambh square Junction

While following the data of this table it is observed that traffic in junctions leading to Jaistambh square from Sharda square and Ghari chowk during peak hour of morning and evening but Goal Bazar after noon. The traffic intensity is approaching towards higher side i.e. nearer to 1.

Table– 2 Tabular Representation of the View of the Traffic Situation at the JaiStambh square Raipur

Location Or Joining point	session	Arrival Rate	Service Rate	Traffic Intensity	Mean no. of vehicles waiting in the system	Mean no. of vehicles waiting in the queue	Mean time spent in the system	Mean time spent in the system
		λ	**μ**	**ρ**	L_s	L_q	W_s	W_q
Sharda square to jai stambh	Morning	22	31	0.7097	2.4444	1.7347	0.1111	0.0788
	Afternoon	9	16	0.5625	1.2857	0.7232	0.1429	0.0804
	Evening	26	35	0.7429	2.8888	2.1460	0.1111	0.0825
ghari chowk to Jaistambh	Morning	12	15	0.8	4	3.2	0.3333	0.2667
	Afternoon	10	23	0.4457	0.7692	0.3344	0.10	0.0334
	Evening	19.72	32	0.6163	1.6058	0.9896	0.0814	0.0502
Goal bazaar to jaistambh	Morning	9	18	0.5	1	0.5	0.1111	0.0555
	Afternoon	14.4385	18.9189	0.7632	3.2229	2.4594	0.2231	0.1703
	Evening	15	19	0.7917	3.75	2.96	0.25	0.1974
Moudaha para to jaistambh	Morning	9	21	0.4285	0.75	0.3214	0.0833	0.0357
	Afternoons	11	19	0.5789	0.75	0.7960	0.125	0.0724
	Evening	8	18	0.4444	0.8	0.3556	0.1	0.0444

This aforesaid table represents the traffic flow model of queuing theory in mathematical terms using queuing approaches. The brief explanation (session wise) is given in para 12.

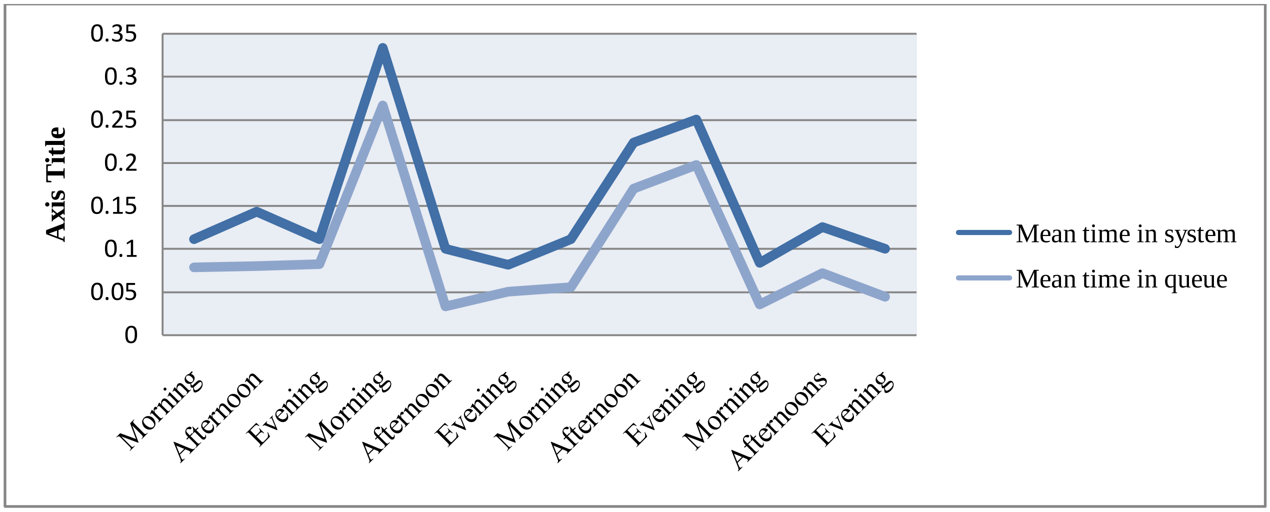


Figure 2. Graphical representation of average time spent in the Queue at Jaistambh square Junction

The discussions of the Morning session are as below:

- (Sharda square to Jaistambh square)the arrival rate and service rate were 22 and 31 according to collected data therefore the traffic intensity becomes 0.7097 which is not good and smooth traffic flow.
- (Ghari Chowk To Jaistambh) The arrival rate and service rate were 12 and 15 respectively according to collected data therefore the traffic intensity becomes 0.8 which is more nearer to 1, this is too **much horrible** and creates unhealthy and critical situation on traffic flow.
- Goal Bazaar To Jaistambh: The arrival rate and service rate were 9 and 18 respectively according to collected data therefore the traffic intensity becomes 0.5 which represents a better and **comfortable traffic** flow.
- Moudaha Para To Jaistambh: The arrival rate and service rate were 9 and 21 respectively according to collected data therefore the traffic intensity becomes 0.4285 which shows very good and fairly Stabled traffic flow. Similarly, the parameters can be discussed for the Afternoon session **a**nd evening session.

6. Result And Conclusion

Actual analysis of the collected data at Jaistambh square Raipur exhibits more closely to a under perfect system. It is observed that in some of the junction focal towards the intersection, the arrival rate reached closer to the respective service rate i.e. traffic intensity is approaching to 1. During morning session Ghadi chowk, during afternoon session Goal bazaar chowk but evening both Goal bazaar and sharda square intersections are over crowded. Lack of footpath and hawkers are also one of the reasons for traffic crowd. The Dust, smoke and noise pollution crossed the red line towards the danger zone. Thus to make Raipur as neat, clean and smart city pollution control is now mandatory.

In this paper, data of actual survey of traffic flow at different time at one of the busiest four one way junctions (Jaistambh square) of Raipur, capital of Chhattisgarh. In order to minimize the traffic overcrowd some possible conclusion may be recommended such as
Construction of foot path, Separate place for the hawkers, Development of parking area, and Signal time should according to vehicle density. The proposed solution may be valuable to traffic or civil engineers and city planners.

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