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Optimization of traffic congestion at signalized points in Agartala: A smart city project of North-East India

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Abstract
A smart city is one that uses technology for optimal utilization of resources to make it efficient, sustainable and people-oriented. Efficient traffic management system is a first and foremost parameter of a smart city. Vehicular traffic congestion is a severe problem in many major cities across the world and it has become a nightmare for the commuters in this city also. Traffic congestion is a growing problem in many metropolitan cities as it increases travel time, air pollution, carbon-di-oxide (CO_2) emissions and fuel use because vehicles cannot run smoothly. Inadequate infrastructure, flexibility in law enforcement and poor traffic management has leads to traffic congestion. One of the major problems with Indian cities is that the existing infrastructure cannot be expanded as per requirements in most cases, and thus the options available are implementation of better management and strict law enforcement.
In an aim to upgrade traffic management system, the Government of Tripura has taken the decision to improve some intersection points of Agartala with the help of electronic traffic signal system. This paper seeks to analyze the vehicular traffic flow and explore how vehicular traffic congestion could be minimized using mathematical models in order to reduce the delays on roads in these electronic signalized points of Agartala city.

Keywords: Queuing theory, forecasting, traffic management

1. Introduction
In the last two decades, urban infrastructure in many Indian cities has been developed with the introduction of modern airports, flyovers and expressways, modern bus stand and rail station, bridges etc. Overcrowding has led to a space crunch, which is aggravated due to lack of efficient and scientific utilization of urban spaces. The growing urban population exerts unbearably high pressure on the environment which contributes to deterioration in the quality of lives of most citizens. The next transformation in urban India would involve placing the concerns of citizens at the centre of any urbanization strategy–something which smart cities aim to achieve in the next few years.
A smart city is characterized by smartness along with multiple parameters, where smart governance playing a vital role in enabling each of them. Smart governance has five parameter and these are smart economy, smart people, smart living, smart environment and smart mobility.
Mobility is an indispensable activity of our daily lives and road transport is one popular approach of mobility. However, road congestion occurrence can be irritating and costly. Traffic congestion on road networks is nothing but slower speeds, increased trip time and increased queuing of the vehicles. When the number of vehicles exceeds the capacity of the road, traffic congestion occurs. In the metropolitan cities of India, traffic congestion is a major problem. Traffic congestion is caused when the demand exceeds the available road capacity. Individual incidents like accidents or sudden breaking of a vehicle in a smooth flow of heavy traffic have rippling effects and cause traffic jams. There are even severe security problems in traffic system due to anti-social elements which also leads to stagnation of traffic at one place.
Being the capital of Tripura, a small state of north-east India, socio-economic factors in Agartala are influencing rapid growth in vehicular population. Human population growth in the capital coupled with increased road vehicle ownership is the main factor fuelling vehicular population increases. As per Unique Identification Authority of India (as on 2020), the human

population growth in the city is 13.50% higher than the national average (13.26%) and presently road vehicle ownership is increasing at 23.03% (as on 2018) per annum. Agartala is one of the most populous city in the north-eastern part of the country and the levels of road vehicular traffic congestion now observed in many intersection points (locally known as 'Chowmohani') at the city.

In an aim to ease the traffic congestion system and part of smart city project, Agartala Municipal Corporation (AMC) with the direction of Urban Development Department (UDD), Government of Tripura an auto-electronic traffic signal system has been introduced step by step in different intersection points at capital town of Agartala. Among the different intersection points we have taken 7 intersection points on the basis of judgment sampling. The points are - North Gate, Gurkhabosti, Paradise Chowmuhani, Ganaraj Chowmuhani, IGM Chowmuhani, Math Chowmuhani and Orient Chowmuhani.

This research work calculate the traffic intensity, mean number vehicles in queue and mean waiting time in queue at these 7 intersection points at the city by queuing theory. The paper also tries to find out moderately high and low traffic intensity at these 7 intersection points by applying Correspondence Analysis (CA) technique. The regression approach is used here to describe the prediction of the Motor vehicles under Transport Department, Government of Tripura up to 2030 and at the 7 intersection point as an insight into road vehicular congestion there and give some recommendations how such congestion occurrence can be efficiently managed.

Not many research articles are available in this field. However some of the important works are highlighted in this paper.

Works on the research paper in Queuing Models for Uninterrupted Traffic flows. Whereas, M. Anokye *et al*. (2013) [6] studied Application of Queuing Theory to Vehicular Traffic at Signalized Intersection in Kumasi-Ashanti Region, Ghana and suggest that the public transport system should be introduced in Ghana.

Studied Intelligent Traffic Management System where he proposed the concept of synchronizing the CCTV camera with traffic light. On the other hand, Xavier studied on A Comparative Study on road Traffic Management Systems. In research paper Predicting Traffic Congestion: A Queuing Perspective (2014), J. D. Lartey gives insight into possible undesirable levels of vehicular traffic congestion and optimize waiting time at the intersection points.

On the other hand, Mala and S.P. Varma (2016) studied on Minimization of Traffic Congestion by Using Queuing Theory and they expect their studies will be a helping tool for the designers of the forthcoming 'Smart City' project of Muzaffarpur, India.

2. Objectives

The objective of the study are therefore is to investigate the problem of vehicular congestion on the 7 intersection points and subsequently build upon this research work to develop some technical observations of predicting and providing scientific information on vehicular traffic flow. These are:

1. How to minimize the traffic congestion in those 7 intersection points at three different schedules.
2. To check whether these 7 intersection points are necessary and sufficient to introduce automatic signal system or not.
3. The present scenario or status of the vehicles under the MVI - west Tripura of Transport Department, Government of Tripura.
4. Prediction of vehicles under the MVI-west Tripura, Transport Department, Government of Tripura up to 2030.

3. Data Sources

This paper uses primary data recorded in these 7 intersection points at three different sessions i.e. Morning Session: 10.15 AM – 10.35 AM, Afternoon Session: 01.30 PM - 02.00 PM and Evening Session: 05.20 PM - 06.00 P.M. collected by Students of Statistics department, M.B.B. College, Agartala, Tripura (west).

4. Methodology of the Study

Operational Research (OR) is a scientific approach to analyze problems and making powerful decision. In operational research, queuing theory is a mathematical technique to minimize the waiting time of a particular queuing system. Whenever, the problem of congestion arises in the area of traffic management, the queuing theory and its application always comes into picture.

This research work is based on the following assumptions:

a. The arrival of vehicles follows Poisson arrival process and the service time follows negative exponential distribution.
b. The queuing discipline is general i.e. the first vehicles goes to the server which is ready for the service.
c. The number of customers in the system is very large.
d. All vehicles are independent i.e. their decision to use the system are independent of other users.

Hence this research activity is based on the most popular and widely used queueing model (M/M/1):(∞/FIFO).

Some Notions and Definitions used in this research paper

Traffic Intensity: The average number of customers being served is the ratio of arrival and service rate, i.e., $\rho = \frac{\lambda}{\pi}$

For a stable system, $\rho \leq 1$.

Average Waiting Time in Queue

The average waiting time in queue is the average time a customer waits in queue for getting service and it is calculated by

$$W_q = \frac{\lambda}{\mu(\mu-\lambda)}$$

Average Number of Vehicles in Queue

It can be viewed as average queue length that is, the average number of vehicles who are waiting in the queue. It is defined as

$$L_q = \frac{\lambda^2}{\mu(\mu-\lambda)}\pi r^2$$

5. Data Analysis

Table 1: Calculation of Traffic Intensity

Sl. No.	Location	Road Direction	Session	Arrival Rate	Service Rate	Traffic Intensity
1	North Gate	Bodhjung-Colonel	Morning	30	23	1.30
		Radhanagar - Colonel	Morning	26	22	1.18
		Bodhjung - Colonel	Afternoon	12	14	0.86
		Radhanagar - Colonel	Afternoon	11	10	1.10
		Bodhjung - Colonel	Evening	20	27	0.74
		Radhanagar - Colonel	Evening	26	19	1.37
2	Orient Chowmuhani	Rabindra Bhavan – Sakuntala Rd	Morning	17	22	0.77
		Lanin Sarani-R.M.S.	Morning	8	12	0.67
		Rabindra Bhavan - Sakuntala Rd	Afternoon	11	12	0.92
		Lanin Sarani- R.M.S	Afternoon	10	12	0.83
		Rabindra Bhavan - Sakuntala Rd	Evening	25	22	1.14
		Lanin Sarani- R.M.S	Evening	19	17	1.12
3	Math Chowmuhani	Math Chowmuhani – Motor Stand	Morning	13	9	1.44
		College Road - Jail Road	Morning	8	6	1.33
		Math Chowmuhani - Motor Stand	Afternoon	10	8	1.25
		College Road - Jail Road	Afternoon	9	7	1.29
		Math Chowmuhani - Motor Stand	Evening	22	29	0.76
		College Road - Jail Road	Evening	13	9	1.44
4	Ganaraj Chowmuhani	L.N. Bari Road - Purbasha	Morning	19	14	1.36
		Motor Stand - Lal Bahadur	Morning	21	12	1.75
		L.N. Bari Road - Purbasha	Afternoon	18	15	1.20
		Motor Stand - Lal Bahadur	Afternoon	18	14	1.29
		L.N. Bari Road - Purbasha	Evening	23	17	1.35
		Motor Stand – Lal Bahadur	Evening	15	10	1.50
5	Paradise Chowmuhani	Post Office -Battala	Morning	19	24	0.79
		IGM - Gangail Road	Morning	29	18	1.61
		Post Office - Battala	Afternoon	22	23	0.96
		IGM - Gangail Road	Afternoon	24	19	1.26
		Post Office - Battala	Evening	14	24	0.58
		IGM - Gangail Road	Evening	25	21	1.19
6	IGM Chowmuhani	Paradise - TRTC	Morning	27	21	1.29
		RMS - Fire Service	Morning	34	25	1.36
		Paradise - TRTC	Afternoon	29	23	1.26
		RMS - Fire Service	Afternoon	35	23	1.52
		Paradise - TRTC	Evening	26	26	1.00
		RMS - Fire Service	Evening	36	25	1.44
7	Gurkha Bosti	Assam Rifle - Bhulagiri	Morning	36	29	1.24
		Assam Rifle - Bhulagiri	Afternoon	18	20	0.90
		Assam Rifle - Bhulagiri	Evening	16	18	0.89

Morning: 10.15 AM – 10.35 AM, Afternoon: 01.30 PM - 02.00 PM, Evening: 05.20 PM - 06.00 P.M.

Table 2: Calculation of Mean No. Vehicles and Mean waiting time in queue

Location	Road Direction	Session	Arrival Rate	Service Rate	Traffic Intensity	Status of Traffic Intensity	Mean number of vehicles in queue	Mean waiting time of vehicles in queue
Ganaraj Chowmohani	Motor Stand – Lal Bahadur	Morning	21	12	1.75	High	Large	Large
Paradise Chowmohani	IGM - Gangail Road	Morning	29	18	1.61	High	Large	Large
IGM Chowmohani	RMS - Fire Service	Afternoon	35	23	1.52	High	Large	Large
Ganaraj Chowmohani	Motor Stand - Lal Bahadur	Evening	15	10	1.50	High	Large	Large
Math Chowmohani	Math Chowmuhani - Motor Stand	Morning	13	9	1.44	High	Large	Large
Math Chowmohani	College Road - Jail Road	Evening	13	9	1.44	High	Large	Large
IGM Chowmohani	RMS - Fire Service	Evening	36	25	1.44	High	Large	Large
North Gate	Radhanagar - Colonel	Evening	26	19	1.37	High	Large	Large
IGM Chowmohani	RMS - Fire Service	Morning	34	25	1.36	Medium	Large	Large
Ganaraj Chowmohani	L.N. Bari Road - Purbasha	Morning	19	14	1.36	Medium	Large	Large
Ganaraj Chowmohani	L.N. Bari Road - Purbasha	Evening	23	17	1.35	Medium	Large	Large
Math Chowmohani	College Road - Jail Road	Morning	8	6	1.33	Medium	Large	Large
North Gate	Bodhjung-Colonel	Morning	30	23	1.30	Medium	Large	Large
Math Chowmohani	College Road - Jail Road	Afternoon	9	7	1.29	Medium	Large	Large
Ganaraj Chowmohani	Motor Stand - Lal Bahadur	Afternoon	18	14	1.29	Medium	Large	Large
IGM Chowmohani	Paradise - TRTC	Morning	27	21	1.29	Medium	Large	Large
Paradise Chowmohani	IGM - Gangail Road	Afternoon	24	19	1.26	Medium	Large	Large
IGM Chowmohani	Paradise - TRTC	Afternoon	29	23	1.26	Medium	Large	Large
Math Chowmohani	Math Chowmuhani - Motor Stand	Afternoon	10	8	1.25	Medium	Large	Large
Gurkha Bosti	Assam rifle - Bhulagiri	Morning	36	29	1.24	Medium	Large	Large
Ganaraj Chowmohani	L.N. Bari Road - Purbasha	Afternoon	18	15	1.20	Medium	Large	Large

Paradise Chowmohani	IGM - Gangail Road	Evening	25	21	1.19	Medium	Large	Large
North Gate	Radhanagar - Colonel	Morning	26	22	1.18	Medium	Large	Large
Orient Chowmohani	Rabindra Bhavan - Sakuntala Rd	Evening	25	22	1.14	Medium	Large	Large
Orient Chowmohani	Lanin Sarani- R.M.S	Evening	19	17	1.12	Medium	Large	Large
North Gate	Radhanagar - Colonel	Afternoon	11	10	1.10	Medium	Large	Large
IGM Chowmohani	Paradise - TRTC	Evening	26	26	1.00	Medium	Large	Large
Paradise Chowmohani	Post Office - Battala	Afternoon	22	23	0.96	Low	21	0.957
Orient Chowmohani	Rabindra Bhavan - Sakuntala Rd	Afternoon	11	12	0.92	Low	10	0.917
Gurkha Bosti	Assam rifle - Bhulagiri	Afternoon	18	20	0.90	Low	8	0.450
Gurkha Bosti	Assam rifle - Bhulagiri	Evening	16	18	0.89	Low	7	0.444
North Gate	Bodhjung-Colonel	Afternoon	12	14	0.86	Low	5	0.429
Orient Chowmohani	Lanin Sarani- R.M.S	Afternoon	10	12	0.83	Low	4	0.417
Paradise Chowmohani	Post Office - Battala	Morning	19	24	0.79	Low	3	0.158
Orient Chowmohani	Rabindra Bhavan - Sakuntala Rd	Morning	17	22	0.77	Low	3	0.155
Math Chowmohani	Math Chowmuhani - Motor Stand	Evening	22	29	0.76	Low	2	0.108
North Gate	Bodhjung-Colonel	Evening	20	27	0.74	Low	2	0.106
Orient Chowmohani	Lanin Sarani- R.M.S	Morning	8	12	0.67	Low	1	0.167
Paradise Chowmohani	Post Office - Battala	Evening	14	24	0.58	LOW	1	0.058

Table 3: Total Number of Vehicles under MVI of west Tripura District

Year	New Entry	Total
1992	2261	2261
1993	2131	4392
1994	2577	6969
1995	1811	8780
1996	2207	10987
1997	2433	13420
1998	2360	15780
1999	2964	18744
2000	3660	22404
2001	5252	27656
2002	5937	33593
2003	6520	40113
2004	6620	46733
2005	6733	53466
2006	6982	60448
2007	6806	67254
2008	6889	74143
2009	9999	84142
2010	14490	98632
2011	15918	114550
2012	16890	131440
2013	17087	148527
2014	15673	164200
2015	15070	179270
2016	16704	195974
2017	19862	215836
2018	24438	240274
2019	20645	260919
2020	17753	278672

Table 4: Mode Fit for Quadratic Equation

n	R	R-Square	Adjusted R-Square	SE of estimate	F	df	P-value
29	0.999***	0.998	0.997	4337.54	5407.634	2, 26	0.000

*** (Significant at 1 % level)

Table 5: Regression Equation & related Tests

Total Registration = 13982.8 -3289.44 (Year-1991) + 426.065 (Year-1991)^2

Predictor	Coefficient	SE	t	P-value
Intercept	13982.8***	2593.169	5.392	0.000
Year - 1991	-3289.44***	398.439	-8.256	0.000
(Year - 1991)^2	426.065***	12.888	33.06	0.000

*** (Significant at 1 % level)

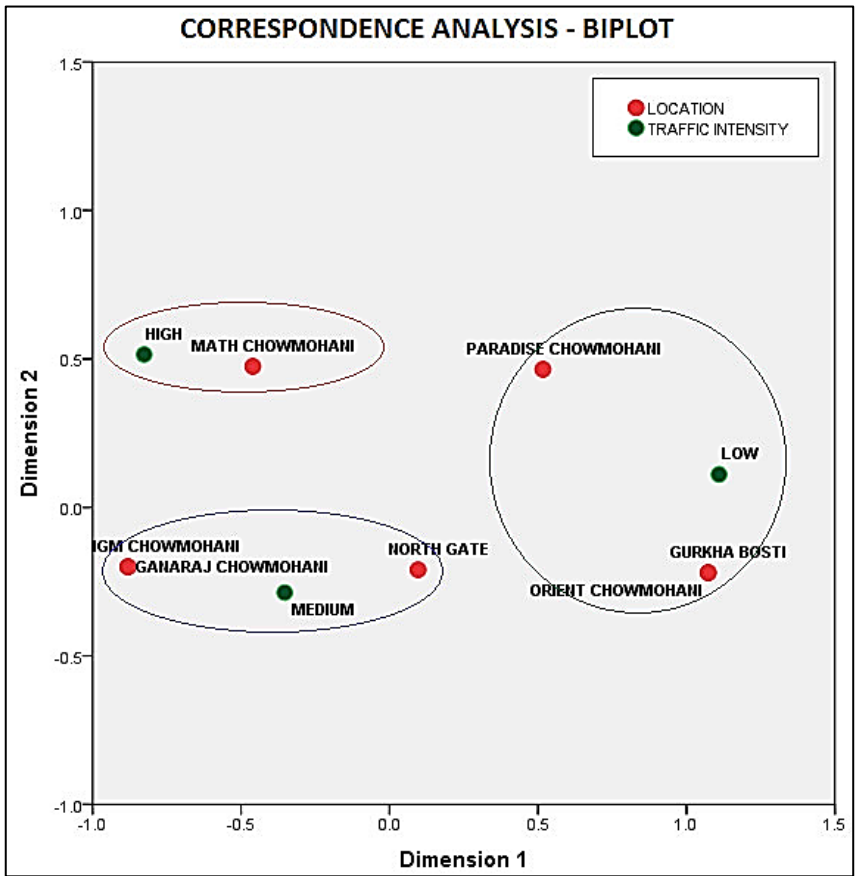

Fig 1: Correspondence Analysis between Location and Traffic intensity

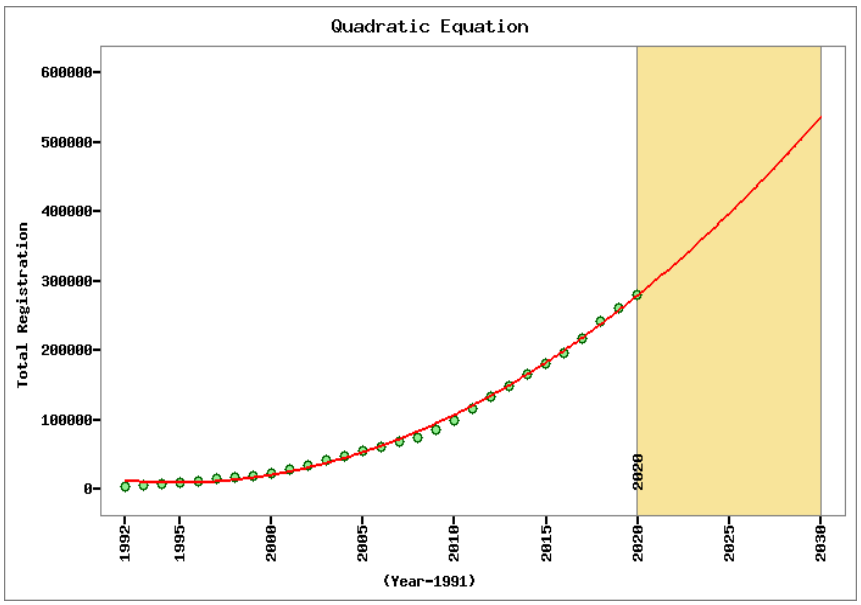

Fig 2: Prediction of Vehicles up to 2030 under MVI, west Tripura District

Table 6: Estimated Total Registration

Year	Total Registration
2021	298758
2022	321458
2023	345011
2024	369416
2025	394673
2026	420782
2027	447743
2028	475556
2029	504222
2030	533739

5. Conclusion

The queuing theory or models is more ubiquitous in our progressively congested traffic flow of urbanized society. Also it is an effective mathematical technique for solving various problems of any systems. As queuing theory applies on the traffic management situation by using different mathematical terms and formulae, its application cover a wide range including the traffic congestion also. City planning and urban design practices can have a huge impact on levels of future traffic congestion.

The present research work is based upon the analysis of primary data of traffic flow at various locations (locally called ”chowmuhani”) in 3 different times at Agartala City. The

application of the queuing theory is exploited to minimize the traffic congestion leading to a well-known situation "*Traffic Jam*" at 3 different times. The study will be a helping tool for the planners or designers of the forthcoming project "Smart City – Agartala" which is a dream project of the people of Agartala, Tripura with a hope of "Jam free traffic".

6. Some Recommendations

1. For smooth traffic flow we can construct some island type points instead of electronic signal system setup.
2. Also we may include other intersection points like Kasari patty –Shantipara crossing, Ker chowmuhani etc. on the basis of our observation for the same.
3. Some roads can be turn as one way road.
4. Avoid right turn in any intersection point.
5. Strictly follow law enforcement.
6. Improve infrastructure facility.
7. Increase public vehicles like double-decker bus, trolley bus, jeep etc. for reducing non-commercial private vehicles.
8. Remove paddle Rickshow/ Meter Rickshow/ e-Rickshow from all main roads.
9. Remove all temporary shops from the pavement
10. Maintain parking zone properly
11. May apply the odd-even system process (like Delhi Govt.) near future.
12. May hike the registration fee, road tax, insurance and pollution charge for maintaining the quality of smart living system (like Singapur).

7. Acknowledgements

We are grateful to our students who helped us to gather primary data from the traffic intersection.

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