Spatio-Temporal Analysis of Vehicle, Road Facilities and Distribution of Traffic Movement in the Hill City Shillong

Dr. Gitumoni Rajbongshi
School of Economics Management and Information Sciences
North Eastern Hill University, Shillong Campus – 793022
Email: gitueco23@gmail.com, Ph. No.: +91- 8787448383

Abstract: Shillong, the capital city of Meghalaya has undergone substantial change both in structure and character. Over the years, there has been a gradual increase in the population of Shillong from about 223366 in 1991 to over 267662 in 2001 and further to 354759 in 2011 (Census Reports 1991, 2001 and 2011). Number of vehicles registered per year has also shown an increasing trend. The road density of Shillong is also very low compared to other cities of the country, which thereby leading to the problem of traffic congestion. Unplanned growth of educational institutions and administrative centres across places within the town further aggravate the existing traffic congestion problem during school or office opening and closing hours. Thus, this paper tried to examine the spatio-temporal analysis of vehicles to understand the nature and pattern of traffic flow and also to capture the major classification of vehicles in the city. Results showed that spatio-temporal analysis of traffic congestion across five selected locations revealed that congestion is highest in Dhankheti intersection, followed by Mawlai and Garikhana. In terms of composition of vehicles across all locations, four-wheeler cars are found to dominate the scenario, which is followed by 2- wheelers and buses.

Keywords: Traffic congestion, spatio-temporal analysis, road density, traffic volume, composition of vehicles

1. INTRODUCTION

Social and economic well-being of the citizens is the aim of every nation. Apart from food, cloth and housing transport and communication system is one of the basic necessities that come into focus while discussing economic and social development. Without proper transport and communication system, no society can imagine the maintenance of speed of development at all. Even for arranging food, cloth and shelter everybody realises the need for transport and its means. If we look at the progress of civilization, development of system and means of transport has been found to keep the pace of activities required, facilitate reaching required items and human being themselves to their destinations in time, reduce cost of transportation, save time which is more crucial in a growing busy schedule. Finally, it facilitates connectivity between societies and exchange of ideas and goods.

Arasan (2012) has defined transportation as an activity of life processes that seeks to provide access to various activities satisfying mobility needs to humankind. According to Eddington (2006), an effective transportation system is important for economic growth in contemporary economies as it provides linkages between different parts of the country and the global world. Thus, an advanced transportation system is not only the key to national growth but serves as a driving force for overall economic development of a country.

3. TOPOGRAPHICAL CHARACTERISTICS OF THE STUDY AREA

Shillong, the capital city of Meghalaya has undergone substantial change both in structure and character. Over the years, there has been a gradual increase in the population of Shillong from about 223366 in 1991 to over 267662 in 2001 and further to 354759 in 2011 (Census Reports 1991, 2001 and 2011). Number of vehicles registered per year has also shown an increasing trend. According to the record of District Transport Office in Shillong, number of registered vehicles during 1990-91 was only 30456 and increased to 40645 during 2000-01 that further increased to 278010 in 2015-16 (Govt. of Meghalaya, 2018). The figures indicate that there is an accelerated growth of registered vehicles in Shillong and its surrounding areas. Further, the road density of Shillong is also very low compared to other cities of the country, which thereby leading to the problem of traffic congestion. Unplanned growth of educational institutions and administrative centres across places within the town further aggravate the existing traffic congestion problem during school or office opening and closing hours. Thus, it has become pertinent to study in depth the nature and flow of traffic congestion the city.

2. OBJECTIVES OF THE STUDY:

i). To examine the spatio-temporal nature of traffic congestion in the city

ii). To examine major composition of vehicle in the city.

3.1. Overview of Population Structure

Over the years, we observed unbalanced growth of transport system and means of transport across the cities and rural areas in any country. Cities and traffic have developed hand in hand since the earliest large human settlements. However, the population growth in the urban centres for various socio-economic reasons and their habit towards luxuries in the form of having individual transport vehicles (single or multiple) have led to the disproportionate growth of road communications and number of vehicles on road.

Along with economic growth, population size is an important determinant of vehicle requirement and thus its growth over time. Looking at the vehicle population growth along with the road infrastructure one can identify the changes in stress on road over time. Population in Greater Shillong Planning Area (GSPA) has almost doubled in last four decades with figures from 155600 in 1971 to 397883 in 2011. It is expected to reach 914261 by 2041. Consequently, the number of towns in SUA has also increased significantly from 2 census towns (Nongthymmai and Mawlai) in 1971 to 10 census towns in 2011 along with two statutory towns (Shillong Municipality and Shillong Cantonment), which have been there since 1971.

Table 1: Population of Greater Shillong Planning Area

Sl.	GSPA Component	Population				
		1971	**1981**	**1991**	**2001**	**2011**
1	Shillong Municipality	87659	109244	131719	132867	143229
2	Shillong Cantonment	4730	6520	11076	12396	11930
3	Nongthymmai	16103	21558	26938	34292	38004
4	Mawlai	14260	20405	30964	38303	55012
5	Madanrting	NA	6165	8987	16318	29194
6	Pynthorumkhrah	NA	10711	13682	22115	27219
7	Nongmynsong	NA	NA	NA	11371	15017
8	Mawpat	NA	NA	NA	4663	6184
9	Umpling	NA	NA	NA	9796	8529
10	Nongkseh	NA	NA	NA	4931	4846
11	Umlyngka	NA	NA	NA	4696	7381
12	Lawsohtun	NA	NA	NA	6386	8214
	Shillong Urban Agglomeration	**122752**	**174703**	**223366**	**298134**	**354759**
13	**Surrounding Villages Total**	**32848**	**42571**	**47747**	**63711**	**76474**
	GSPA	**155600**	**217274**	**271113**	**331373**	**397883**

Source: Department of Urban Affairs, Government of Meghalaya, *City Development Plan*, 2009.

Table 2 Population Density of Greater Shillong Planning Area

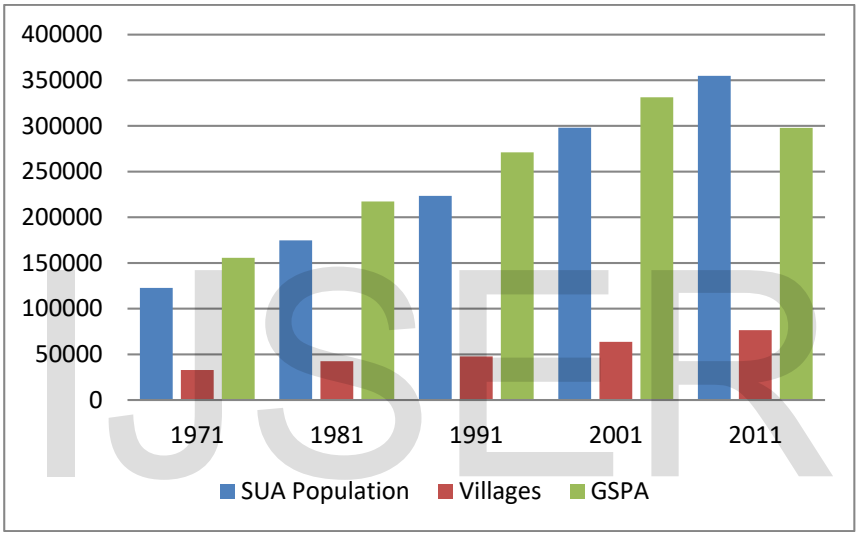
Sl.	Component of GSPA	Population Density (per Sq.Km.)					Growth (%)
		1971	**1981**	**1991**	**2001**	**2011**	**1971-2011**
1	Shillong Municipality	8461	10545	12714	12825	13825	63.39
2	Shillong Cantonment	2570	3543	6019	6737	6025	134.43
3	Nongthymmai	5496	7358	9194	11704	10984	99.85
4	Mawlai	2322	3323	5043	6238	8960	285.87
5	Madanrting	NA	3051	4449	8078	12975	NA
6	Pynthorumkhrah	NA	5076	6484	10481	11583	NA
7	Nongmynsong	NA	NA	NA	5686	10078	NA
8	Mawpat	NA	NA	NA	565	750	NA
9	Umpling	NA	NA	NA	389	347	NA
10	Nongkseh	NA	NA	NA	398	392	NA
11	Umlyngka	NA	NA	NA	673	1059	NA
12	Lawsohtun	NA	NA	NA	674	866	NA
	SUA	**4832**	**6878**	**9794**	**11728**	**12999**	169.01

13	Villages	220	286	320	428	513	133.18
	GSPA	**894**	**1248**	**1558**	**1904**	**2289**	156.0403

Source: Department of Urban Affairs, Government of Meghalaya, *City Development Plan*, 2009.

Table 1 shows how the population over the years have been increasing in all the peripheral urban areas along with the population of villages included in the GSPA. Number of villages in GSPA as per 2011 census is 32. Significant growth in the village population is observed over the years. Table 2 reveals that the density of population in Shillong Municipality is the highest among all the GSPA Component areas, which is followed by Madanrting (second) and Pynthorumkhrah (third) (2011 census). Fig 1 below represents the composition of population in urban and rural areas from 1971 to 2011. It is found that the composition of population have been higher in urban areas throughout the years.

Figure 1 Population Trend of SUA, Villages and GSPA from 1971 to 2011



3.2 Road Network in Shillong

3.2.1 Trend of Road Network and its Characteristics

Table 3 depicts the trend of road length, number of vehicles registered and road density in the East Khasi Hills (EKH) District of Meghalaya. It is revealed that over the years, vehicle density has been increasing at a much higher rate (6.12 per cent annual exponential rate) as compared to the annual exponential rate of growth of road density (1.5 per cent) (Table 4). These growth rates have been estimated by running regression of the type $LnY_t = \infty + \beta.t + U_t$, where Y_t is the value of dependent variable (road length, number of vehicles registered, road density and vehicle density) at time t, ∞ and β are two parameters, t is time in year and U_t is random disturbance term with all classical regression properties. Here β represents the annual exponential rate of growth of the respective dependent variable. Faster rise in vehicle number and vehicle density in comparison to the growth of road length and road density is a matter of grave concern as there has been increase in the pressure of vehicles on this narrow hilly road thereby causing traffic congestion at different point of time.

Table 3 Road Length, Vehicle Registered, Road Density and Vehicle Density of East Khasi Hills District from 2000-2015

Year	*Road Length of*	*Vehicle Registered in*	*Road Density*	*Vehicle Density of*

	East Khasi Hills (EKH)	*East Khasi Hills (EKH)*	*(EKH) per 100sq.km *100*	*East Khasi Hills*
2000	1696	34996	0.62	20.63
2001	1707	40711	0.62	23.84
2002	1718	43069	0.63	25.06
2003	1729	46344	0.63	26.80
2004	1740	53843	0.63	30.94
2005	1751	61009	0.64	34.84
2006	1762	62304	0.64	35.36
2007	1773	65133	0.65	36.73
2008	1784	74033	0.65	41.49
2009	1788	65985	0.65	36.90
2010	2008	80510	0.73	40.09
2011	2040	89103	0.74	43.68
2012	2030	89119	0.70	43.90
2013	1933	93520	0.76	48.38
2014	2075	98021	0.75	47.24
2015	2050	137753	0.75	67.20

Source: Directorate of Economics and Statistics. Government of Meghalaya, *Statistical Handbook of Meghalaya*, (2001, 2011, 2018).

Table 4 Regression Results of LN Road Length, LN Registered Vehicles, Ln Road Density and Ln Vehicle Density on Time (t)

Ln Road Length = 7.40+ 0.0147 t (434.05) (8.322)	Adj R^2 = 0.82
Ln Registered Vehicles = 10.46 + 0.076 t (252.70) (17.726)	Adj R^2 = 0.954
Ln Road Density = -0.52 + 0.015 t (-31.016) (8.562)	Adj R^2 = 0.828
Ln Vehicle Density= 3.066 + 0.0612 t (66.797) (12.90)	Adj R^2 = 0.9169
Source: Calculated by the author.	

3.2.2 Type of Roads

Classification of the types of roads in the GSPA has been presented in Table 5. Of the total road length in GSPA, majority are black topped (93.12 per cent) and 9.1 per cent is gravelled, while 15.1 per cent of the roads in GSPA is still kutcha. Of the total road lengths of GSPA 356 kms, about 70 per cent have width of 3.75 mts. Around 16 per cent are of Intermediate Lane having width 3.75-6.9 meters and Double lane is only of 13 per cent with width 7 meters and above, which is relatively very small (Table 6). It thus reveals that more than two-third of the city roads (over 70 per cent of urban road) have very narrow space. However, a large number of people are found to drive large luxurious vehicles owing to the affluence. Narrowness of the roads without multiple lanes during the peak hours of the day (especially on working day) cause traffic congestion. If the state could make provision for wider road infrastructure, the problem of traffic congestion would have been comparatively less as compared to the present situation.

Table 5 Classification of Roads in Greater Shillong Planning Area

Classification	Black top	Cement concrete	Gravel	Kutcha	Total
National Highway	33	0	0	0	33
State Highway	0	0	0	0	0
Other District Roads	59.4	0	9.1	7.5	76
Village Road	37.4	0	0	7.6	45
Urban road	198.7	0.3	0	0	199
Total Road Length	**331.5**	**0.3**	**9.1**	**15.1**	**356**
Percentage	**93.12**	**0.08**	**2.56**	**4.24**	**100**

Source: Department of Urban Affairs, Government of Meghalaya, (2009), City Development Plan.

Table 6 Road Width in Greater Shillong Planning Area in 2009 (Meters)

Classification of Road	Single Lane	Intermediate Lane	Double Lane	Total
	Upto 3.75 mts	3.75-6.9 mts	Above 7 mts	
National Highway			33 (100)	33 (100)
State Highway	0 (00)	0 (00)	0 (00)	0 (100)
Other district roads	66 (86.84)	10 (13.16)	0 (00)	76 (100)
Village Road	45 (100)	0 (00)	0 (00)	45 (100)
Urban road	140 (70.35)	35 (17.59)	24 (12.06)	199 (100)
Total Road length	**251 (70.51)**	**58 (16.29)**	**47 (13.20)**	**356**

Source: City Development Plan, Department of Urban Affairs, Government of Meghalaya, 2009.
Note: Figures in the parentheses represent percentage to total of each horizontal category.

3.2.3 Pattern of Vehicle Growth in Shillong

Table 7 depicts the number of various categories of vehicles registered in East Khasi Hills District. It is evident that number two wheelers registered were the highest, which is as usual shows the dominant position of middle and lower middle-income groups with highest demand for the same. It is noticeable that the number of two wheelers were 11346 as against 8955 cars in 2001. However, number of cars reached 51344 in 2015 as against 37017 two wheelers. It indicates that while two-wheelers reached about three times in 15 years, four-wheelers increased to six times during the same period. This reveal increases in the purchasing power of people that led them to use their own private vehicles for meeting daily mobility needs. It is also a positive sign for the state where the material well-being of the people has been improving day by day. But for the smooth functioning of the economic activity and its growth it is very important to have well developed transport and communication infrastructure in tune with growing transport needs of the people. Without provision of better road infrastructure and facilities, aim of development cannot be attained due to the problems of transport obstacles like narrow and insufficient road space and traffic congestion. Here, it is clearly observed that road infrastructure development has not been keeping pace with vehicular growth over time. Table 8 revealed the annual exponential growth rate percentage of vehicles in the East Khasi Hills District Meghalaya.

Table 7: Number of Vehicles Registered in East Khasi Hills

Year	Truck	Buses	*Cars*	Jeeps	Tractors	Trailors	*Two Wheelers*	Three Wheelers	*Taxis*	Others

2001	6954	1484	***8955***	6057	255	1983	***11346***	213	***3196***	268
2002	7506	1521	***8964***	6402	263	2012	***11961***	293	***3773***	374
2003	7516	1609	***11029***	6651	269	1933	***12703***	398	***3813***	423
2004	8320	1784	***13223***	7352	280	2126	***14044***	832	***5265***	617
2005	8704	1876	***16418***	7910	293	2163	***15757***	961	***6181***	746
2006	8720	1891	***17174***	7965	295	2179	***15886***	1023	***6354***	817
2007	8883	1917	***18099***	8299	301	2163	***16598***	1128	***6837***	908
2008	9226	2079	***22460***	9131	314	2211	***18407***	1347	***7824***	1034
2009	8883	1917	***18099***	8299	301	2163	***16598***	1128	***7988***	609
2010	9616	2150	***25570***	9565	324	2234	***19861***	1441	***8596***	1153
2011	10623	2201	***33787***	10570	342	2281	***24118***	1645	***13290***	4510
2012	11012	2407	***37920***	11788	NA	NA	***26821***	1700	***11461***	4672
2013	11351	2449	***42348***	12537	NA	NA	***29829***	1724	***12497***	5199
2014	11443	2547	***46316***	13629	NA	NA	***33201***	1731	***13191***	5252
2015	11925	2696	***51344***	13790	NA	NA	***37017***	1742	***14116***	5283

Source: Directorate of Economics and Statistics. Government of Meghalaya, Statistical Handbook of Meghalaya, (2001, 2011, 2018).

Table 8: Exponential Growth Rate of the Various Classification of Vehicles

Categories	*Annual Exponential Growth Rate (%)*
Truck	3.6
Buses	4
Cars	12.8
Jeeps	5.9
Tractors	2.6
Trailors	1.4
Two wheelers	8
Three-Wheelers	13.5
Taxis	10.7
Others	22.5

Source: Calculated by the author.

4. NATURE AND PATTERN OF TRAFFIC CONGESTION

4.1 Measures of Traffic Congestion

For the assessment of traffic congestion, the first step is the selection of zones or road intersections. On the selected intersections, manual traffic volume count has been conducted to capture the number of vehicles passing through these points during each fifteen minutes interval from either direction. Respondents were asked to rank in order 5 major road intersections with traffic flow and congestion in Shillong and those five major intersections have been chosen based on their order of ranking from top in the frequency distribution table. Out of the 16 major road intersections recorded by the respondents in the city, top 5 major intersections namely Mawlai point, Garikhana, Police Bazar intersection, Dhankheti intersection and Nongthymmai intersection are chosen for the present study (Table 9).

Table 9 Frequency Distribution of Five Most Congested Intersections in Shillong

	First	*Second*	*Third*	*Fourth*	*Fifth*

Locations	*Freq*	*%*	*Freq*	*%*	*Freq*	*%*	*Freq*	*%*	*Freq*	*%*
Laitumkhrah	85	14.2	47	7.8	39	6.5	0	0	24	4.0
Garikhana	107	17.8	**173**	**28.8**	48	8.0	73	12.2	60	10.0
PB	66	11.0	21	3.5	**168**	**28.0**	99	16.5	5	.8
Anjalee Point	3	.5	0	0	130	21.7	81	13.5	0	0
Mawlai	67	11.2	10	1.7	0	0	15	2.5	**130**	**21.7**
Dhankheti	**137**	**22.8**	111	18.5	2	.3	51	8.5	119	19.8
Civil	0	0	101	16.8	92	15.3	1	.2	81	13.5
Bara-bazar	3	.5	31	5.2	64	10.7	61	10.2	106	17.7
Mawkhar	0	0	17	2.8	0	0	0	0	0	0
Rhino Point	0	0	9	1.5	4	.7	0	0	27	4.5
Barik Point	107	17.8	0	0	0	0	6	1.0	11	1.8
Nongthymmai	0	0	50	8.3	0	0	**166**	**27.7**	0	0
Don Bosco	0	0	8	1.3	46	7.7	1	.2	0	0
Malki Point	9	1.5	0	0	0	0	0	0	0	0
Polo Crossing	10	1.7	22	3.7	0	0	37	6.2	0	0
Rilbong	6	1.0	0	0	7	1.2	2	.3	1	.2
Mawiong	0	0	0	0	0	0	7	1.2	0	0
Lachummeire	0	0	0	0	0	0	0	0	11	1.8
IGP	0	0	0	0	0	0	0	0	25	4.2
Total	**600**	**100.0**	**600**	**100.0**	**600**	**100.0**	**600**	**100.0**	**600**	**100.0**

Source: Calculated by the author using primary survey conducted during July-September, 2018.

4.2 Method of Manual Traffic Volume Count

Traffic volume counts have been conducted to approximate the number of vehicle movement through a particular point and classification of roadway vehicles at various intersections has also been done for the purpose of present study. These data help to identify flow of vehicles during various slots of the time period of the day, from where critical flow time periods, i.e., higher concentration and flow of vehicles (peak) time slot of the day is understood. Manual count with 15-minutes intervals have been used to collect data on vehicles count.

Usually for the accurate results, all the 7 days count of the week is important. But due to economic and time constraint the count has been done for three days in a week, two working days and one holiday. The experiment has been undertaken in the same manner for three months (July to September, 2018). The traffic count in each intersection has been conducted at two different week days (by rotation) and alternately on holiday for arriving at the best possible results. The traffic volume counts have been made from 7:00 A.M. to 7:00 P.M. It is done because, before 7.00 A.M. there is hardly any congestion and after 7:00 P.M. there is almost freeway, if there is no exception. The vehicles have been counted in categories as cars, two wheelers, three-wheelers, trucks, buses and others. The characteristics of the five major intersections are described below.

4. 3 Description of the selected Study Intersections

4. 3.1 Mawlai Intersection

The 3-Legged intersection of Mawlai has been shown in the figure below (Map 1). The urban centres of Shillong are affected by urban sprawl which thereby imposes severe demand on road transportation that further leads to the problem of traffic congestion. Mawlai junction being the main entry point to the Shillong city, remains congested throughout the day. Throughout the year the city witnesses traffic congestion but it is observed that it becomes severe mainly during the month of July. This is because during this month the city attracts a large number of tourists as it is the month of summer vacation for most of the nearby surrounding states like Assam, etc.

Map 1 Map View of Mawlai Intersection

4.3.2 Garikhana Intersection

The 3-legged intersections of Shillong have been presented in the map below. This intersection is being surrounded by business shops, educational institutions, temples and sumo and bus stands. Also, it is surrounded by people's residence side by side. This intersection is always seen crowded with vehicles and people, further it is also the main centre for wholesale marketing and there are adjacent points for boarding taxis by the people who commute almost daily from their workplace to their respective homes in Barapani, Umsing, Nongpoh, etc. Also, as mentioned above, the biggest market place Barabazar is located very near to this intersection. Therefore, the concentration of people is also heavy along with the movements of vehicles and loading and unloading of trucks and buses in Garikhana.

Map 2 Map View of Garikhana Intersection

4.3.3 Police Bazar Intersection

Police Bazar is a highly commercialized area and the intersection being surrounded by many shops, hotels, banks, Government offices, educational institutions etc., there is heavy movement of varieties of vehicles throughout the day. Unlike the other locations, this centre faces severe traffic jam as the office and business hours starts i.e., after 10 A.M. and the congestion starts mostly after 11.00 A.M. and remains moderate throughout the day. But it becomes severe in the afternoon for the visitors go for marketing after office hours, especially on Friday and Saturday.

Map 3 Map View of Police Bazar Intersection

4.3.4 Dhankheti Intersection

Dhankheti intersection is at the heart of the city and most congested intersection in the city. The severity of the congestion has been faced mainly by the school and college students as well as teachers. This is because this intersection is surrounded by many schools and colleges. Throughout the day the centre remains congested but main peak hours of congestion are during school opening and closing hours. Even during off-peak hours also, it takes sometimes 7-8 minutes from 250 metres just to reach the main intersection for vehicles coming from the Malki approach.

Map 4 Map View of Dhankheti Intersection

4.3.5 Nongthymmai Intersection

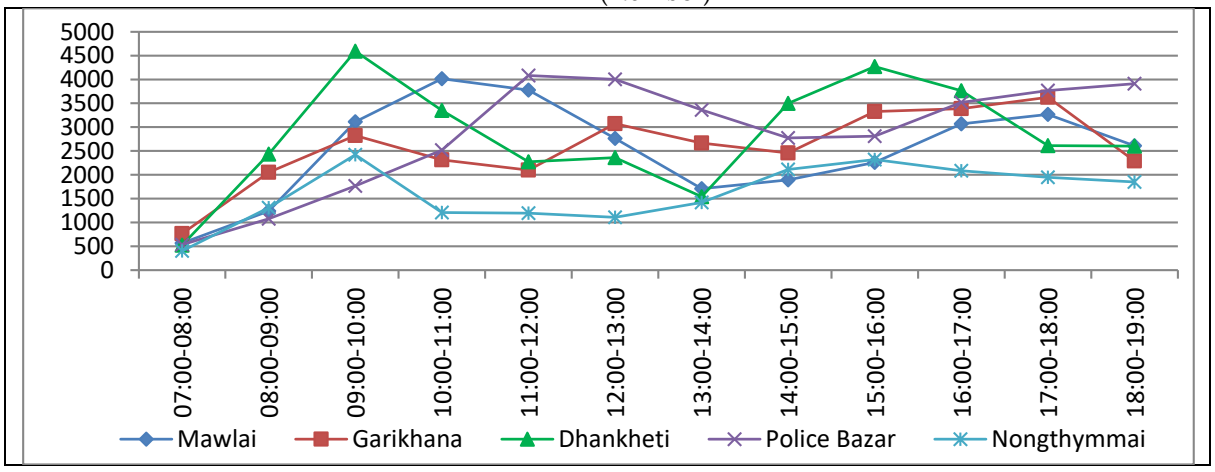
Nongthymmai intersection is one of the most congested intersection in Shillong. It is characterised by its peculiar geometric design of the road infrastructure, along with very narrow road of width 3.5 metres only. The severe ups and downs in the slope of the road thereby force the commuters to drive at an average speed of 35-45 Km/Hr even during off peak hours or empty road (Primary Survey). The slower speeds and longer travel time with long queue on the existing road network are observed in middle of the day and afternoon, when the offices are over. Further this location adds multiple intersections to the main road which further adds to the pressure on the already congested road.

Map 5 Map View of Nongthymmai Intersection

5. SPATIO-TEMPORAL VARIATION IN TRAFFIC CONGESTION IN SHILLONG

The spatio – temporal analysis of vehicles revealed that, highest level of congestion is observed in the Dhankheti junction point, especially from 8.00 A.M. to 9.00 A.M. and then again it reaches a peak around 3.00 P.M. This junction however is the hub of educational institutions therefore most the commuters that travel nearby this junction are due to educational purpose. This junction remains congested throughout the day, thus, most of those commuters have to pass through this intersection and face congestion at major part of the day. Apart from local taxis and cars; tourists' vehicles are also observed to pass in greater number through both the Mawlai and Dhankheti points and thus the points remain congested more during office and school hours (10:00 A.M. to 11:00 A.M. and 5:00 P.M. to 6:00 P.M.) (Fig 2).

Figure 2 Traffic Flow Data of Mawlai, Garikhana, Dhankheti, Police Bazar and Nongthymmai from 7:00 AM to 7:00 PM (Number)



Mawlai junction which is just 2.5 km away from Garikhana junction, its traffic flow depends on the traffic flow in Garikhana. If there is traffic jam in Garikhana, its effect spreads to other road stretches connecting Garikhana, thereby affect Mawlai intersection. Through the Mawlai junction also a crossing is there for the entry to North Eastern Hill University (NEHU), Shillong Campus, and Umshing area and thereby Institute buses cross that junction during most of the time of the day along with other public transportation buses.

The traffic flow characteristics of Garikhana and Nongthymmai are however similar and less intense. Peak

hour traffic in Garikhana has been witnessed in the morning office hours from 9:00 A.M. to 10:00 A.M., and again around 12.00 Noon due to heavy business activity. During evening hours, it is observed to be congested from 5:00 P.M. to 6:00 P.M. It is one of the main points of vehicle stoppage as it is very near to the commercial market Barabazar that is extended to Police Bazaar. Many loadings and unloading of luggage take place in Garikhana since the sumo and bus stands are located just in the intersection.

The Police Bazar point is the centre of not only official institutions but also hub of commercial activities, so traffic flows here has been found to increase after 9.00 A.M. and reaches its peak during 11:00 A.M. to 12:00 Noon and after a lean patches traffic volume grows after 4:00 P.M. till 7:00 P.M. due to increasing business activities, and flow of office people who moves there after their offices are closed for the day and sometimes the congestion continues beyond 7.00 P.M. for a while.

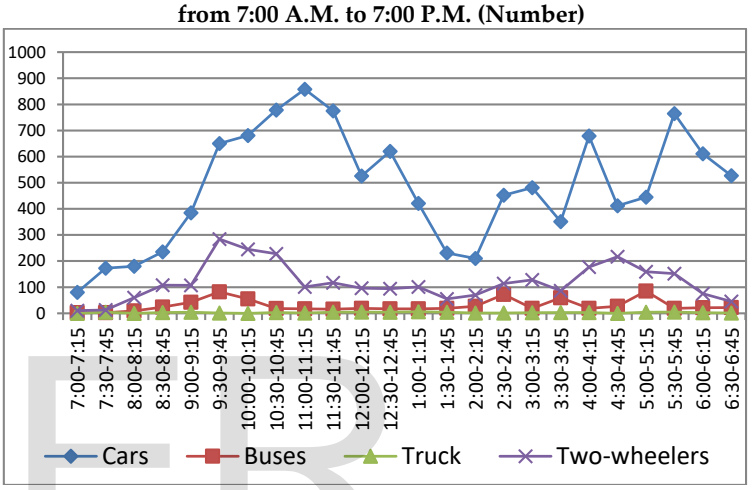
6. COMPOSITION OF TRAFFIC AT FIVE INTERSECTIONS IN SHILLONG

Traffic composition in Shillong mainly comprises of cars, buses, trucks and 2- wheelers.[1]Average composition of traffic has been presented for each location individually. In general, data revealed that the highest composition of traffic is for cars followed by 2-wheelers like scotty and bikes at Mawlai intersection. The composition of trucks and buses are comparatively low as compared to the number of cars on road in the city. It has been found Shillong being the hilly region and mostly rainy, plying of 2-wheelers is comparatively less as compared to other places. Yet on sunny days people prefer to ride two-wheelers to avoid traffic jam and reach destination on time. The composition is more or less same for all the intersections. Fig 3 reflects the traffic composition of Mawlai intersection.

Fig 4 reflects the traffic composition of Garikhana intersection. It shows that the traffic flow remained high throughout the day. Among the vehicles, the highest flow is observed in case of cars, which is followed by 2-wheelers and thereafter trucks. In Dhankheti intersection, traffic flow is more in case of cars and then 2-wheelers (Fig. 5). Similar is the case of Police Bazaar intersection (Fig. 6). Results showed that the flow of buses in this intersection is high as compared to other intersections in Shillong. In some other cities, two-wheelers are prevalent. But in Shillong, despite severe traffic congestion and some peoples' desire to ride two-wheelers (as opined by several respondents) people mostly drive car in order to avoid rain at odd times. It also reveals peoples' rising capability to afford for luxurious vehicles in the study area.

The traffic composition of Nongthymmai intersections is however erratic though overall it has more or less similar traffic characteristics like other intersections. The traffic composition of cars is the highest and again followed by 2-wheelers and buses (Fig 7).

Figure 3: Average Composition of Traffic in Mawlai Intersection from 7:00 A.M. to 7:00 P.M. (Number)



[1]It was difficult to count three and four-wheeler vehicles on the road for speedy movement of multiple vehicles and thus three and four wheelers have been taken together and presented as four-wheeler cars in the present study.

Figure 4: Average Composition of Traffic in Garikhana Intersection from 7:00 A.M. to 7:00 P.M. (Number)

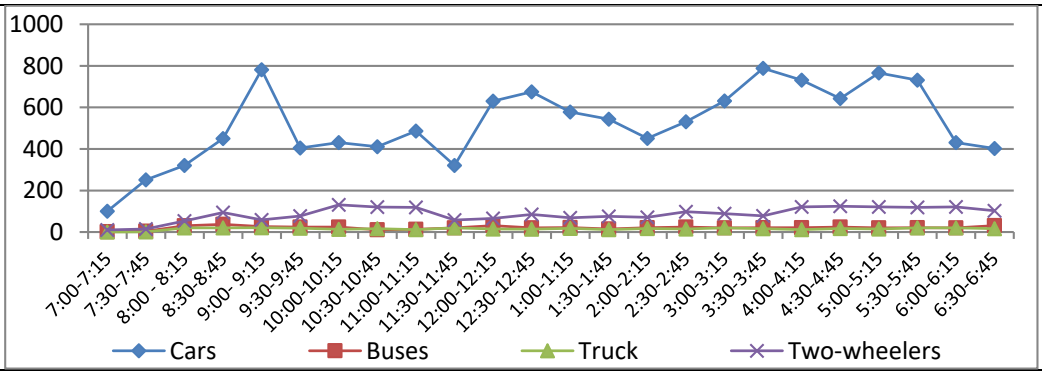


Figure 5: Average Composition of Traffic in Dhankheti Intersection from 7:00 A.M. to 7:00 P.M. (Number)

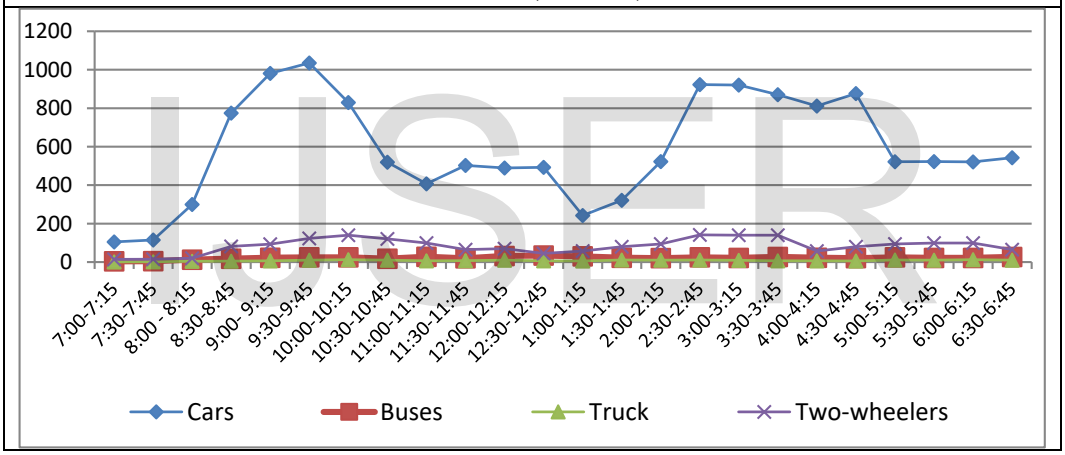


Figure 6: Average Composition of Traffic in Police Bazaar Intersection from 7:00 A.M. to 7:00 P.M. (Number)

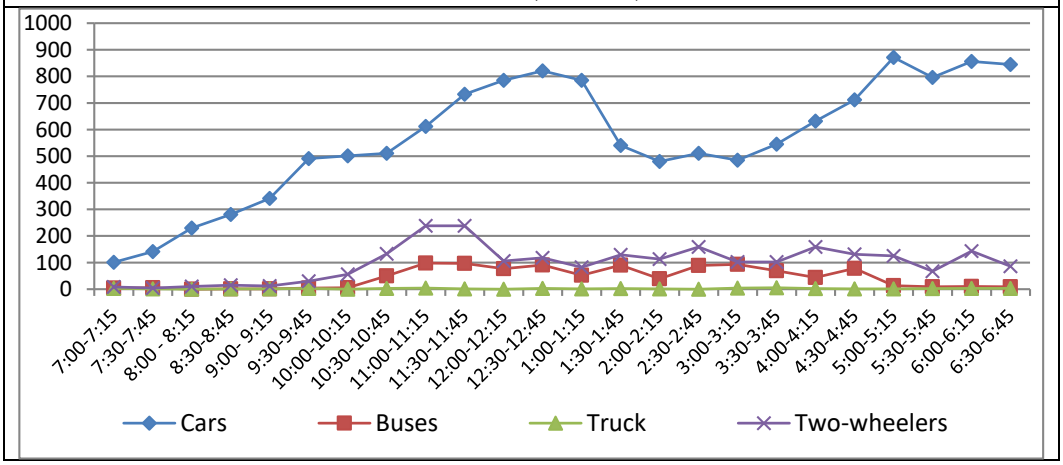
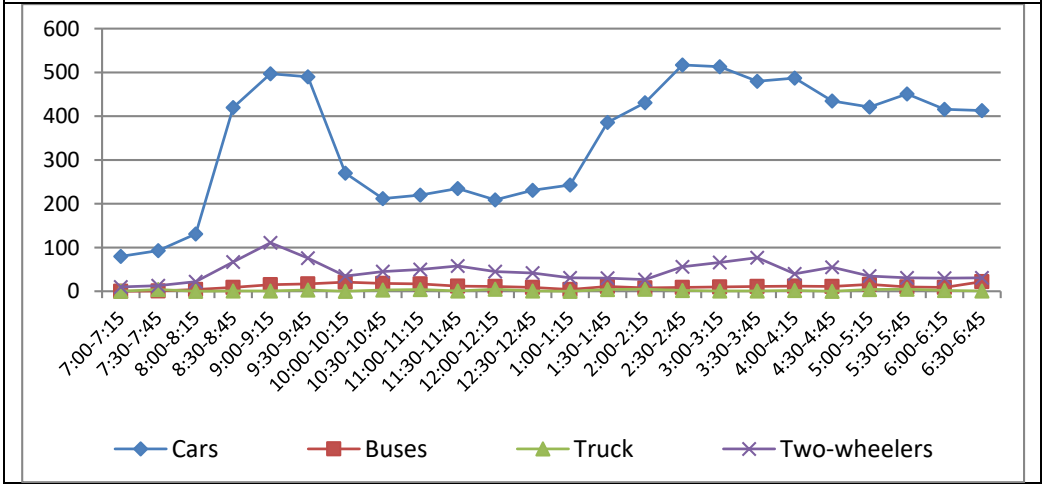


Figure 7: Average Composition of Traffic in Nongthymmai Intersection from 7:00 A.M. to 7:00 P.M. (Number)



6. CONCLUSION:

The study gives rise to the following conclusions: It has been found that road infrastructural facilities in Shillong have not kept pace with the rapid growth of vehicle population in the area. This however is one of the reasons of increasing pressure of vehicles on road leading to the problem of traffic congestion within the city. Capacity of road to bear the burden of rising cars also depend on the geographical texture of the streets, smoothness of roads, management of traffic system etc. Spatio-temporal analysis of traffic congestion across five selected locations revealed that congestion is highest in Dhankheti intersection, followed by Mawlai and Garikhana. It is observed that the intersections remain congested almost throughout the day but peak hours of congestion for places like Mawlai, Dhankheti and Nongthymmai is during office and school going hours, whereas for places like Garikhana and Police Bazaar, congestion occurs after office opening hours, i.e., after 10 A.M. In terms of composition of vehicles across all locations, four-wheeler cars are found to dominate the scenario, which is followed by 2- wheelers and buses.

References:

[1]Census of Meghalaya (2011). *District Census Handbook East Khasi Hills*. Directorate of Census Operation, Meghalaya.

[2]Directorate of Economics and Statistics. Government of Meghalaya, *Statistical Handbook of Meghalaya* (1981, 1991, 2001, 2011, 2018). Shillong.

[3]DPR for Procurement of Buses Shillong (2009). Urban Affairs Department Government of Meghalaya. Available at http://www.asrtu.org/wpcontent/uploads/2016/06/DPR_For_Procurement_Of_Buses_Shillong.pdf (Accesses 20/03/2017)

[4]Government of Meghalaya (2009). *City Development Plan Report*. Department of Urban Affairs.