Traffic Congestion in a Hill City of North East India and Its Consequences

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Abstract

The complexity of traffic congestion in a hill city is more than in a plain city in its nature and dimensions. The congestion adverselyaffects the speed, travel time, fuel expenditure, business and many other activities. This paper examines incidence of traffic congestion at some major traffic intersections in a hill city of North Eastern region of India, Shillong through which majority of the traffic movements occur. Further, major factors behind regular traffic congestion in the city have been analysed. Traffic volume in peak hours has been measured by using Volume-Capacity Ratio and major factors responsible for traffic congestion is explained by Principal Component Analysis. Results show that locational misdistribution of various government offices and institutions, badly located filling stations, driving behaviour are some important factors leading to severe congestion. Results also show that there are significantadverse effects on the individual performances including a decline in productivity and earning opportunity of the taxi drivers due to traffic congestion.

Keywords*: Traffic Congestion, Level of Service, Causes of Traffic Congestion, Congestion Externality*

1. Introduction

Traffic congestion occurs when the demand for road space exceeds supply. The congestion is reflected in the rising travel time, fuel expenditure, and delay for some activities, loss of opportunities and business activities, anxiety and so on.With rapid increase in population and several other socio-economic changes, vehicular pressure on road has been increasing exponentially and the negative impacts of congestion sometimes surpass the beneficial effects of transportation.In thecontemporary lifestyle, a great transformation is observed where majority of families in city owns a private vehicleand prefer to travel in their own car even for a shortest distance. It appears to be a sign of progressof the city people. In the present situation, people have hardly any time to wait and everybody is in a rush. It is preferred to drop children in their own private cars rather than school buses or pooled cars. Given the limited road infrastructure and improper location of various institutions, an increase in the problem of traffic congestion has been noticed in several cities.

Traffic congestion in the hill city, Shillongin North East India has become one of the severe problems that every individual has been facing. Prolonged hours in traffic jam adversely affects workers' productivity, business and other activities in daily life along with the emotional state of commuters. Traffic congestion is observed throughout the day in all major road intersections. The rush hours vary across locations depending on the economic and other activities. With schools and colleges resuming, traffic congestion is at its worst, making it difficult for people to reach their destination on time. The city roads in every nook and corner are packed with cars. Besides traffic congestions witnessed all over the city, it is more pronounced around educational institutions, business establishments and government offices. Therefore, it is pertinent to examine the spatio-temporal pattern of traffic congestion and its intensity to find out the major causes that can be addressed for a possible solution.

2. Review of Literature

Factors of Traffic Congestion

A number of studies have been undertaken to understand the issues of social cost imposed due to traffic congestion. Rapid growth in passenger vehicles due to increase in income and the development of low-cost cars into the market is one of the prime causes of traffic congestion(Azeem Uddin, 2009). Ukpata and Etika (2012) examined the causes of traffic congestion with the help of primary data collected from the participants of the Annual General Meeting and National Congress of the Nigerian Society of Engineers. Participants included planning experts in transportation, engineers, students, wives of engineers, drivers, etc. Poor driving habits, poor road networks, inadequate road capacity and lack of parking facilities are found to constitute the major cause of traffic congestion. Poor road traffic management, lack of adequate town planning, lack of space for expansion of road infrastructure, etc. were also identified as the reasons behind traffic congestion in the developing nations (Jain et al, 2012). To detect the traffic congestion in the critical areas, they used a simple image processing algorithm to analyse CCTV video feeds from traffic cameras. With the help of this algorithm they tried to show evidence of actual congestion in Sao Paulo, Brazil and Nairobi in Kenya. The reasons for traffic congestion as identified include unplanned cities, poor discipline of drivers, alternate traffic means, tighter budget, etc. Study showed high congestion in Brazil during 4:30 p.m. to 8:30 p.m. In Kenya it was highly erratic and busy schedule is stretched from 10 a.m. to 2 p.m. Inadequacy of traffic police, narrow roads, illegal parking, increasing population, higher purchasing power of the public, improper city development planning development are also cited to be some important reasons for traffic congestion in the city places (Rahane and Saharkar, 2014; Bhatt and Gandhi, 2014).

Impacts of Traffic Congestion

Singh and Sarkar (2009) has shown how with growing urban population and economic activities, the travel demand has increased in Delhi. In the study, costs associated with roads were classified as private cost in terms of fuel and time lost, wear and tear of vehicles, etc. Commuting costs associated with traffic congestion were in terms of noise, fumes, and dangers of accidents and loss of amenity. Here, two approaches - engineering

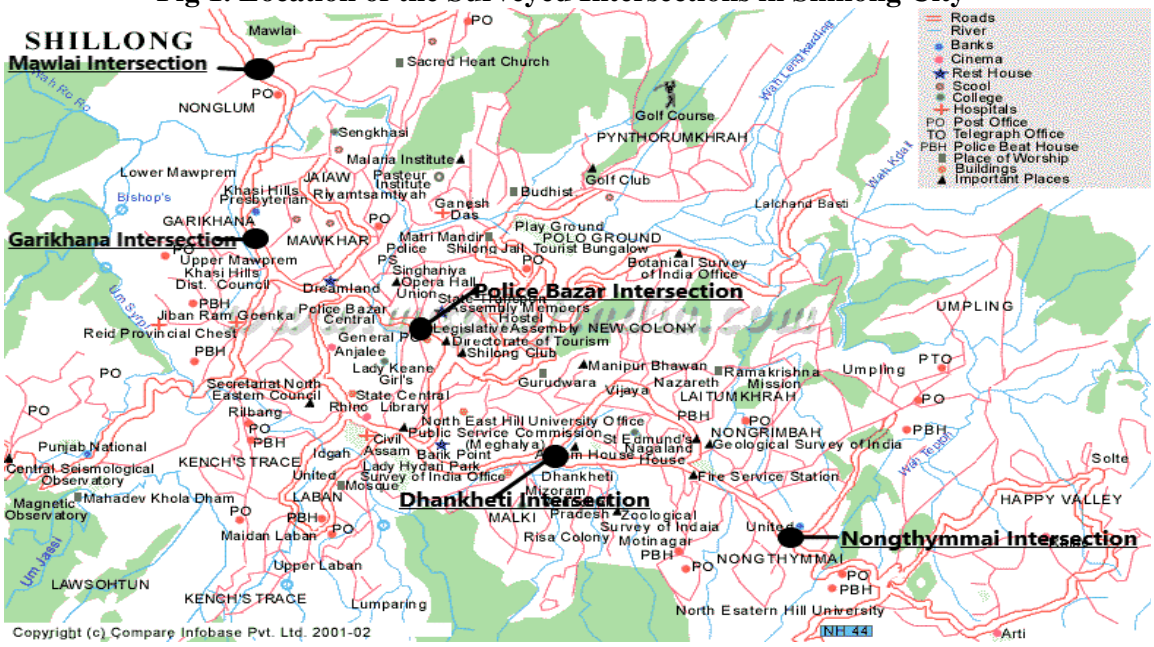
and economic approach were mentioned by the authors for the analyses of traffic congestion costs. By engineering approach, time lost is measured by pricing time lost at average income levels and under economic approach an optimum traffic level is a function of the demand for road use. Here optimum speed was further linked to willingness to pay by the road users. It is found that major traffic flow was observed between 9 AM to 9 PM. Average vehicular speed during peak and off-peak hour varies between 10 and 35 Km/Hr. Harriet *et. al.* (2013) attempted to examine the extent to which traffic congestion negatively affects worker productivity in Kumasi Metropolis, Ghana. The magnitude of loss in earning of the drivers in terms of productivity loss was estimated at 14.3% of the whole expected activity.Khan and Islam (2013) analysed the travel time costs, vehicle operating costs and externality costs due to delay and environmental damages. They estimated the cost of traffic congestion in monetary terms through travel time cost and vehicle operating cost in Dhaka city, Bangladesh. It was stated that the time spent on travelling has an opportunity cost which includes Total Time Variability loses (Rahane and Saharkar, 2014).

Data and Methodology

The broad area of study is considered to be Shillong Urban Agglomeration in Meghalaya. The town is well connected by a road-network within the state and with all important cities in the neighbouring states through National Highway 44.

In order to examine the traffic congestion,the first step is to select the zones or intersections. A structured questionnaire was distributed among 600 randomly selected individuals in the city (200 private individuals who own car and daily commuters, taxi drivers andbusinessmen other than taxi drivers). Respondents were asked to rank in order 5 major traffic congested intersections in Shillong and finally five major intersections have been chosen for study based on their overall ranking in the frequency distribution table (De and Rajbongshi, 2020). Out of the 16 major road intersections in the city, 5 major intersections namely Mawlai point, Garikhana, Police Bazar intersection, Dhankheti intersection and Nongthymmai intersection covering the major portion of the cityare chosen for the present analysis (Fig. 1).

Fig 1. Location of the Surveyed Intersections in Shillong City



Source: Mappery, Accesed from: http://www.mappery.com/Shillong-City-Mapon 20th April 2019.

At these five locations, manual vehicle traffic count has been made on each working day during July to September 2018. Vehicle count has been conducted for 12 hours in a day from 7:00 a.m. to 7:00 p.m. The traffic volume starts increasing after around 7.00 a.m. in the morning and starts declining after 7.00 p.m. in the evening and under normal circumstances there is no traffic congestion after 7.00 p.m. till 7.00 a.m. For examining traffic congestion Volume/Capacity (V/C) Ratio has been employed(Guidelines for Capacity of Urban Roads in Plain Areas, Indian Road Congress, 1990). Level of Service (LOS)of any road intersection gives information about both the amount of traffic and the quality of traffic flow (Eddington, 2006). Traffic volume in peak hours is used to compute Volume/Capacity Ratio. V/C varies between 0 (a car enjoys free flow) and 1 (heavily congested or maximum number of cars are there in a particular point/junction at a given time).

Principal Component Analysis (PCA) has been used for dimension reduction and to find the major factors responsible for traffic congestion in the selected road intersections. There are several possible factors with close correlations and it is very difficult to include all of them to examine their individual effects efficiently.PCA helps in identifying the prime components by using the Eigen values of greater than one. A total of 20 possible variables (obtained from review of literature and personal experience) classified under four major dimensions viz. physical factors, land use factors, human factors and technical factorshave been considered.

Here, each respondent was requested to weight the potential variables affecting traffic congestion in accordance with 3 - point Likert Scale (as per their strength in different locations). Weighting of variables is one of the statistical techniques used to identify significant variables in empirical studies (Chibuzor, 2011). Each questionnaire contains

20 variables organised into four main factors suspected to be responsible for traffic congestion.

1. **Physical Factors**: Under this first broad category of reasons for traffic congestion includes: (a) Inadequate road capacity, (b) Increase in traffic volume, (c) Poor road condition, (d) Lack of footpaths, (e) So many cross junctions that causes traffic congestion.

2. **Land use Factors**: This second category includes: (a) Encroachment by hawkers, (b) Dumping of refuse or construction materials on road ways, (c) Badly located filling stations, (d) Unplanned building of houses, (e) Improper locations of Schools, Colleges and Government institutions.

3. **Human Factors**: This category includes factors as: (a) Vehicle drivers are impatient and intolerant, (b) Unskilled drivers, (c) Drivers avoiding bumps, (d) Road users disregard traffic regulations (e) Absence of traffic police.

4. **Technical Factors**: The fourth category includes: (a) Vehicle breakdown, (b) Bus stops at inappropriate places, (b) Accidents on the road ways, (c) Illegal motor parking on roadways, (d) Too many road curvatures, (e) Slow moving of the front vehicle/unequal speed of simultaneously moving vehicles.

Using the responses,a **Severity Index (SI)**is computed for each factor by the formula,

$$\frac{\frac{\sum_{i=0}^{3} a_i x_i}{\sum_{i=0}^{3} a_i} * 100}{3}$$

Where a_i = constant expressing the weight given to i^{th}response.

a_i = 0, 1, 2 and 3 for i = 0, 1, 2 and 3 respectively

a_0 = 0 is equivalent to **"does not affect"**

a_1 = 1 is equivalent to **"slightly affects"**

a_2 = 2 is equivalent to **"moderately affects"**

a_3 = 3 is equivalent to **"strongly affects"**

X_i is the variable expressing percentage (%) of degree of importance of each factor.

X_0 = 0, i.e., % of persons telling it**"does not affect"**

X_1 = 1, i.e., % of persons telling it**"slightly affects**"

X_2 = 2, i.e., % of persons telling it**"moderately affects"**

X_3 = 3, i.e., % of persons telling it**"strongly affects"**

The 20 potential causes identified as factors responsible for traffic congestion is ranked in order of severity index.

3. Observation and Analysis:

Traffic Congestion Scenario in Shillong

Shillong being the state capital of Meghalaya is the busiest administrative centres of the state. It is one of the main commercial and institutional centres of the state. It is an important centre of education, administration and tourism. Shillong urban agglomeration consists of 7 urban units i.e., Shillong Municipality, Shillong Cantonment, Mawlai, Nongthymmai, Pynthorumkhrah, Madanrting and Nongmynsong. Continuous and rapid increase in the number of registered vehicles in Shillong with rising affordability of the people has resulted in chaotic traffic situation. Majority of the road corridors suffer from several inadequacies like capacity constraints in the road networks, poor definition of

road hierarchy, on street parking, mixed traffic, poor traffic management, slow journey speeds, poor safety situations, inadequacy enforcement of traffic rules, lack of pedestrian facilities and other street furniture. Further, passing of two National Highways i.e., NH-40 & NH-44 through the heart of the city has aggravated the problem. Also, the construction of activity centres and shopping centres along already congested road are putting additional pressure on these congested roads.

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. This has further lead to the problem of traffic congestion in Shillong. The traffic points that have been taken for the study and their geometric characteristics are shown in Table 1. In Table 2 the traffic volume count of five major locations have been presented.

Table 1: Major Road Intersections in Shillong

Zone	Intersections	Types	Associated Issues
1	Mawlai Point	4- Legged	Four arm intersection, traffic due to regional trucks, rush during school and office hours, on street parking, etc.
2	Garikhana	3- Legged	Major intersection, on street parking of tourist buses and taxis for dropping and picking up passengers.
3	Dhankheti	4- Legged	Poor geometrics, traffic due to school and offices in the morning and after peak hours due regional trucks traffic, Improper channelizes.
4	Police Bazaar	4- Legged	High pedestrianized traffic, 7 roads meet together
5	Nongthymmai	3- Legged	Major traffic of local taxis due to school and offices.

Source: City Development Plan, Shillong (2009).

Table 2: Traffic Flow Data of Mawlai, Garikhana, Dhankheti, Police Bazar and Nongthymmai

Time(Hr)	*Mawlai*	*Garikhana*	*Dhankheti*	*Police Bazar*	*Nongthymmai*
07:00-08:00	568	766	522	534	402
08:00-09:00	1238	2050	2434	1076	1308
09:00-10:00	3112	2824	4594	1766	2420
10:00-11:00	4016	2314	3352	2518	1208
11:00-12:00	3778	2098	2274	4082	1194
12:00-13:00	2762	3072	2360	4002	1106
13:00-14:00	1708	2666	1542	3362	1418
14:00-15:00	1894	2456	3498	2774	2110
15:00-16:00	2258	3326	4270	2810	2318
16:00-17:00	3068	3386	3764	3518	2084
17:00-18:00	3268	3626	2612	3768	1946
18:00-19:00	2608	2288	2600	3910	1848

Source: Field Survey, conducted during July to September, 2018.

The traffic volume in peak hours has been measured by using Volume/Capacity Ratio. V/C varies between 0(free flow) and >1(heavily congested). LOS gives information about both the amount of traffic and the quality of traffic flow (Eddington, 2006).
The Level of Service at any intersection on a highway has a significant effect on the overall performance of that highway. It denotes a range of operating conditions which occur on a transportation facility when it accommodates a range of traffic volumes.It divides the quality of traffic into six levels ranging from Level A to Level F (Table 3) (Kadiyali, 2015).

Table 3: Levels of Service (LOS)

LOS	V/C	Detailed Description
A	0.00-0.35	Represents the best operating conditions and is considered free flow. Individual users are virtually unaffected by the presence of others in the traffic stream.
B	0.35-0.58	Represents reasonably free-flowing conditions but with some influence by others.
C	0.58-0.75	Represents a constrained constant flow below speed limits, with additional attention required by the drivers to maintain safe operations. Comfort and convenience levels of the driver decline noticeably.
D	0.75-0.90	Represents traffic operations approaching unstable flow with high passing demand and passing capacity near zero, characterised by drivers being severely restricted in manoeuvrability.
E	0.90-1.00	Represents unstable flow near capacity. LOS E often changes to LOS F very quickly because of disturbances (road conditions, accidents, etc.) in traffic flow.
F	>1.00	Represents the worst conditions with heavily congested flow and traffic demand exceeding capacity, characterised by stop and go waves, poor travel time, low comfort and convenience and increased accident exposure.

Source: Hartgen, D.T. (2006) Building Roads to Reduce Traffic Congestion in America's City. Reasons Foundation. Appendix B.

For various intersections on road the highway capacity manual measures congestion in terms of average delay per vehicle and similarly LOS are defined based on the average amount of delay.

LOS A------<10 Secs
LOS B------11-20 Secs
LOS C------21-35 Secs
LOS D------36-55 Secs
LOS E-------56-80 Secs
LOS F--------> 80 Secs

Table 4: Volume/ Capacity Ratio of Mawlai, Garikhana, Dhankheti, Police Bazar and Nongthymmai

Time(Hr)	*Mawlai*	*Garikhana*	*Dhankheti*	*Police Bazar*	*Nongthymmai*
07:00-08:00	0.47	0.51	0.35	0.36	0.34
08:00-09:00	1.03	1.15	1.62	0.72	1.09
09:00-10:00	2.59	1.88	3.06	1.18	2.02
10:00-11:00	3.35	1.54	2.23	1.68	1.01

11:00-12:00	3.15	1.40	1.52	2.72	1.00
12:00-13:00	2.30	2.05	1.57	2.67	0.92
13:00-14:00	1.42	1.78	1.03	2.24	1.18
14:00-15:00	1.58	1.64	2.33	1.85	1.76
15:00-16:00	1.88	2.22	2.85	1.87	1.93
16:00-17:00	2.56	2.26	2.51	2.35	1.74
17:00-18:00	2.72	2.42	1.74	2.51	1.62
18:00-19:00	2.17	1.53	1.73	2.61	1.54
Source: Field Survey, conducted during July to September, 2018.					

Table 4 describes the Volume/Capacity ratio of the major road intersections in Shillong. It revealed that the ratio exceeds 1 during most of the interval hours of the day and the intensity is more during school and office hours.This clearly represents the worst conditions of traffic flowwith heavy congestion and traffic demand exceedsdrastically the existing road capacity. The hourly traffic volume of locations presented in Table 2 has been divided by the standard road capacities as shown in Table 5 and the results has been presented in Table 4.

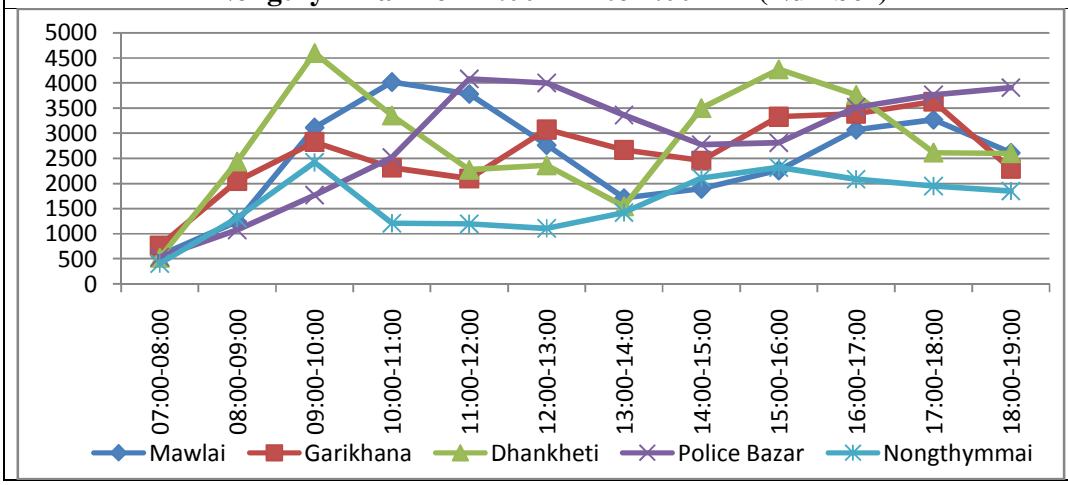
Table 5: Recommended Design Service Capacity for Urban Roads

			Total Capacity per hour for Various Traffic Condition (PCU/hour)		
Sl. No	***Width of Carriageway***	***Traffic Flow***	***Roads with no frontage access, no standing vehicles, very little cross traffic***	***Roads with frontage access, no standing vehicles, high traffic intersections***	***Roads with free frontage access, parked vehicles and heavy traffic***
1	2-Lane * (3.5-4.0 m)	Two way	NA	1200	NA
2	2-Lane (7-7.5 m)	One way	2400	1500	1200
		Two Way	1500	1200	750
3	3-Lane (10.5 m)	One way	3600	2500	2000
4	4-Lane 14m	One way	4800	3000	2400
		Two Way	4000	2500	2000
5	6-Lane 21m	One way	3600	2500	2200
		Two Way	6000	4200	3600

Source: Guidelines for Capacity of Urban Roads in Plain Areas, Indian Road Congress, 1990.
Note: * Calculated by the authorsby using the proportion of road width as it is not given for the 3.5-4 metre width road category. NA means not available and also not applicable in case of Shillong urban area.

Traffic volume count data, collected through manual count conducted for 12 hours duration (7:00 AM to 7:00 PM) reveal that traffic flow characteristics of zones surrounded by educational offices and institutions are more or less identical (Fig 2). Flow pattern in Mawlai junction, the entry point to the City traffic congestion remains very high between 9.00 AM to 1.00 PM and again during 4.00 PM to 5.00 PM.

Fig 2: Traffic Flow Data of Mawlai, Garikhana, Dhankheti, Police Bazar and Nongthymmai from 7.00 AM to 7.00 PM (Number)



The highest level of congestion is observed in the Dhankheti junction point, especially from 8.00 AM to 9.00 AM and then again it reaches a peak around 3.00 PM. This junction caters to the flow of traffic for the major educational institutions located in the surrounding. This point is also located at the heart of the city and it links many other alternative routes to various locations. 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 numberthrough both the Mawlai and Dhankheti points and thus the points remain congestedmore during office and school hours (10:00 AM to 11:00 PM & 5:00 PM to 6:00 PM) (Fig 2).

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. It is 2.5 km away from Garikhana junction and its traffic flow depends on the traffic flow in Garikhana. If there is traffic jam in Grikhana, its effect spreads to other road stretches connecting Garikhana, thereby affect Mawlai intersection.

Similar traffic behaviour is found in Garikhana and Nongthymmai but with less intensity. Peak hour traffic in Garikhanais witnessed in the morning office hours from 9:00 AM to 10:00 AM, and again around 12.00 Noon due to heavy business activity. During evening hours,the congestion occurs from 5:00 PM to 6:00 PM. 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 Bazar. Many loadings and unloading of luggagetake place in Garikhanasince the sumo and bus stands are located just in the intersection.Despite having similar pattern of movement, traffic flow in Nongthymmai remains comparatively lower than the other points.

The Police Bazarpoint 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 AM and reaches its peak during 11:00 AM to 12:00 Noon and after a lean patches traffic volume grows after 4:00 PM till 7.00 PM 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 PM for a while.

Table 6: Level of Service of Mawlai, Garikhana, Dhankheti, Police Bazar and Nongthymmai

Time(Hr)	Mawlai	Garikhana	Dhankheti	Police Bazar	Nongthymmai
07:00-08:00	B	B	A	B	A
08:00-09:00	F	F	F	C	F
09:00-10:00	F	F	F	F	F
10:00-11:00	F	F	F	F	F
11:00-12:00	F	F	F	F	F
12:00-13:00	F	F	F	F	E
13:00-14:00	F	F	F	F	F
14:00-15:00	F	F	F	F	F
15:00-16:00	F	F	F	F	F
16:00-17:00	F	F	F	F	F
17:00-18:00	F	F	F	F	F
18:00-19:00	F	F	F	F	F

Source: Primary survey.
Note: Authors' calculation by using volume capacity ratio.

Table 6 presents the LOS in five major locations within the city. It clearly shows that except for some early morning hours, throughout the day the level of service reaches F that is it exceeds the maximum capacity and thereby leads to severe traffic congestion.

Application of Principal Component Analysis to Extract the Important Factors Leading to Traffic Congestion

Principal Component Analysis (PCA)has been used to examine the factors responsible for traffic congestion in Shillong among 3 categories of individuals (Private Individuals, Taxi drivers & Businessmen). Prior to running PCA, Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy Test has been conducted to check the adequacy of the data. KMO values close to 1 means that sample is adequate. Factors were extracted by computing and choosing those corresponding to Eigen values greater than 1. The results of the PCA analysis have been discussed for 3 categories of respondents respectively.

Case of Private Individuals:

In respect of private individuals owing car and almost daily commuters, the computed KMO valueis 0.61, which shows that sample is adequate and PCA analysis can be carried out for extraction of components. The Bartlett's test of sphericity also found to be statistically significant ($p<0.001$) with 190 degrees of freedom (Table 7). Seven components have been extracted of which,in case of individuals owing cars, land-use factors such as locational misdistribution of government offices and institutions, dumping of refuse is found to be the primary factors responsible for traffic congestion. Also, Physical factors such as multiple cross junctions and poor road conditions have been listed in the first component.

The city has been characterized by multiple cross junctions with severe turnings leading to huge flow of traffic from various road stretches, and that is one of the important factors. Also, locational misdistribution or skewed distribution of government offices and institutions has been referred by the individuals as another important factor. As in cases of Dhankheti and Don Bosco point in the vicinity, it is clearly evident that the flow of traffic goes beyond capacity for being the area to be hub of large number of educational

institutions. The respondents opine that if the institutions are relocatedsuitably in various other areas within the city, the situation would have been under control to a great extent (Table 8).

Under second component include human factors like disobey of traffic regulation, drivers avoiding bumps and occasionally absence of traffic police.

Table 7: KMO and Bartlett's Test (Pvt Ind)

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.611
Bartlett's Test of Sphericity	Approx. Chi-Square	1929.06
	df	190
	Sig.	0.000

Table 8: Component Matrix[a]forPvt Individuals Owning Car and Daily Commuters

	Components						
	1	2	3	4	5	6	7
Multiple_Intersection	-.862						
Bad_Rd_Condtn	.807						
Dumping_refuse	.766						
locational_misdistribution	-.762						
badly_locatedFillingStn.	.762						
Impatient_veh_drivers	.636						
Disobey_trf_regu		.861					
avoiding_rd_bumps		.822					
Veh_breakdown		.674					
Rd_curvature		.663					
Absence_trf_police		.617					
Illegal_parking			.113				
Lack_Footpath			.793				
Unskilled_drivers				.389			
Unplanned_building				.123			
SlowMoving_front_veh				-.700			
Inapp_busStops					.595		
Encroachment_hawkers						-.200	
Rd_Space						.157	
Trfc_Vol							.239
Extraction Method: Principal Component Analysis.							
a. 7 Components Extracted.							

Case of Taxi Drivers:

The computed value of KMO is 0.63 in case of taxi drivers which fulfils the sample adequacycriteria. The Bartlett's test of sphericity is also found to be statistically significant ($p<0.001$) with 190 degrees of freedom (Table 9). Taxi drivers suggest that human factors are the prime cause of traffic congestion in Shillong. Also, land use factors are listed in the first component. Taxi drivers experience great disturbances with the encroachment of hawkers near the locations like Police Bazar and Barabazar. Further, in their opinion, locational misdistributions of various institutions, dumping refuse on road sides of the arterial roads and locations of petrol pumps at improper places aggravate the situation of traffic on city roadsin addition to the former two factors (Table 10).

Table 9: KMO and Bartlett's Test (Taxi drivers)		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.629
Bartlett's Test of Sphericity	Approx. Chi-Square	2297.81
	df	190
	Sig.	0.000

Table 10: Component Matrix[a] in Case of Taxi Drivers						
	Component					
	1	2	3	4	5	6
Impatient_veh_drivers	-.918					
Dumping_refuse	.797					
Bad_Rd_Condtn	.787					
Unskilled_drivers	.773					
Encroachment_hawkers	.759					
locational_misdistribution	.533					
badly_locatedFillingStn.		-.751				
Lack_Footpath		.731				
Multiple_Intersection		-.637				
Rd_Space		.620				
SlowMoving_front_veh		.527				
Illegal_parking			-.727			
avoiding_rd_bumps			.693			
Rd_curvature			.666			
Absence_trf_police			.590			
Unplanned_building				.795		
Trfc_Vol				-.646		
Inapp_busStops					.589	
Disobey_trf_regu					.509	
Veh_breakdown						.757
Extraction Method: Principal Component Analysis.						
a. 6 Components Extracted.						

Case of Businessmen:

The generated KMO value in case of businessmenis 0.57 and the Bartlett's test of sphericity also found to be statistically significant ($p<0.001$) with 190 degrees of freedom (Table 11).Businessmen express that physical factors and land use factors mainly responsible for affecting the normal traffic flow within the city. Due to multiple intersections and heavy traffic volume the flow of traffic is choked. Also, landuse factors such as badly located filling stations and locational misdistribution of institutions adversely affect the flow or speed of vehicles on the city roads (Table 12).

Table 11: KMO and Bartlett's Test (Businessmen)		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.571
Bartlett's Test of Sphericity	Approx. Chi-Square	1615.95
	df	190
	Sig.	.000

Table 12: Component Matrix[a] in Case of Businessmen							
	Component						
	1	2	3	4	5	6	7
Multiple_Intersection	.875						
Impatient_veh_drivers	-.786						
badly_locatedFillingStn.	-.771						
locational_misdistribution	.596						
Trfc_Vol	.484						
Disobey_trf_regu		.849					
avoiding_rd_bumps		.826					
Veh_breakdown		.657					
Rd_curvature		.587					
Absence_trf_police		.557					
Encroachment_hawkers			.754				
SlowMoving_front_veh			-.714				
Bad_Rd_Condtn			-.552				
Lack_Footpath			-.546				
Unplanned_building			.190				
Dumping_refuse			.442				
Unskilled_drivers				-.107			
Rd_Space					.529		
Inapp_busStops						.796	
Illegal_parking							.539
Extraction Method: Principal Component Analysis.							
a. 7 Components Extracted.							

Incidence of Traffic Congestion

Here incidence of traffic congestion is examined through the analysis of Severity Index.Severity Index in the range 75 to 100 is regarded as the indication of highly severe traffic congestion. If the Index lies between 45 and 75, it is regarded as the indicator of moderate trafficcongestion and a value ranging 25 to 50 is regarded as no congestion.

Traffic volume, locational misdistribution of government offices and institutions, narrow road space, inappropriate bus stoppage, illegal parking, lack of foot path, multiple intersection, encroachment by hawkers and impatient vehicle drivers have been identified as the highly severe factors leading to traffic congestion in Shillong (Table 13).

Table 13: Description of Causes for Traffic Congestion in Shillong, Severity Index and their Respective Ranking						
	Private Individuals and Commuters		***Taxi Drivers***		***Businessmen***	
Description of Causes for traffic congestion in Shillong	**Severity Index**	**Ranking**	**Severity Index**	**Ranking**	**Severity Index**	**Ranking**
Rd_Space	***97.33***	***3***	***99.17***	***1***	***95.83***	***3***
Trfc_Vol	***99.17***	***1***	***86.67***	***5***	***96.67***	***2***
Bad_Rd_Condtn	***65.67***	***7***	***60.33***	***11***	***59.33***	***9***
Lack_Footpath	***61.67***	***9***	***46.67***	***17***	***69.83***	***6***
Multiple_Intersection	***97.17***	***3***	***66.67***	***8***	***83.67***	***4***
Encroachment_hawkers	***32.50***	***15***	***59.33***	***12***	***81.17***	***5***
Dumping_refuse	***60.00***	***10***	***58.17***	***13***	***49.00***	***14***
badly_locatedFillingStn	***69.83***	***5***	***62.33***	***9***	***63.50***	***8***

Unplanned_building	***51.17***	***11***	***54.00***	***14***	***43.83***	***15***
locational_misdistribution	***98.00***	***2***	***95.83***	***3***	***98.33***	***1***
Impatient_veh_drivers	***72.33***	***4***	***53.50***	***15***	***65.00***	***7***
Unskilled_drivers	***62.00***	***8***	***61.50***	***10***	***53.33***	***12***
avoiding_rd_bumps	***60.50***	***10***	***49.33***	***16***	***53.33***	***12***
Disobey_trf_regu	***38.50***	***13***	***66.00***	***8***	***60.33***	***10***
Absence_trf_police	***22.67***	***16***	***66.17***	***8***	***49.67***	***13***
Veh_breakdown_A	***37.17***	***14***	***72.00***	***6***	***58.17***	***11***
Inapp_busStops	***98.50***	***2***	***97.00***	***2***	***96.17***	***2***
Illegal_parking	***98.00***	***2***	***94.33***	***4***	***98.00***	***1***
Rd_curvature	***66.00***	***6***	***69.00***	***7***	***61.83***	***9***
SlowMoving_front_veh	**46.67**	***12***	**35.00**	***18***	***50.00***	***13***
Source: Primary Survey.						

Among moderately affecting factors include lack of footpath, dumping refuse, badly located filling stations, unplanned buildings, unskilled drivers, drivers avoiding bumps, vehicle breakdown, etc.Though Encroachment of hawkers is moderately significant in case of taxi drivers and businessmen, it does not match with the opinion of car owners.

Impacts of Traffic Congestion on Daily Commuters (Private car owner, Taxi Drivers and Businessmen)

Here we also tried to estimate the impacts of traffic congestion by using t-test with respect to indicators like extra time spent on traffic jam, increasing fuel expenditure and decline in productivity of the commuters (Private car owner, Taxi Drivers and Businessmen). Apart from this, decline in frequency of trips of the taxi drivers in Shillong city due to traffic jam is estimated. Traffic congestion not only affects the taxi drivers adversely but also the businessmen who had to incur significant opportunity costs for being unable to start or operate their businesses timely due to traffic congestion.

The proposed hypothesis to test is that, there is significant difference in number of trips, time spent, fuel expenditure and net profit of the taxi drivers with changes in traffic congestion. The t- test is used for the said hypothesis at 5 per cent level of significance. Here the decision rule is that if $|\square| > 1.645$ we reject the null hypothesis and accept that there is significant variation in those target variables due to variation in traffic congestion.The results in case of Private Car Owners, Taxi drivers cum owners and Businessmen are presented in Table 14.

Here, the t values are found to be significant at one per cent level of significance and wereject null hypotheses of no significant variation in those target variables due to variation in traffic congestion.Results of the T-test showed thatthere is significant reduction in the number of trips, increase in travel time for identical distance, rise in fuel expenditure and reduction in the net profit of the taxi drivers when compared those values of the days of traffic jam with those of the days without traffic jam.

Table 14: Test for Effects of Traffic Congestion on Number of Trips, Time Spent, Fuel Expenditure and Net Profit						
Private Car Owners						
Indicators	**Mean**	**Std. Deviation**	**Std. Error Mean**	**t**	**df**	**Sig. (2-tailed)**
Time Spent on Traff_jam_days-vs-less traffic_Day	-26.80	16.062	1.136	-23.60	199	.000
Net_profit_freeway- net_profit_jam	104.75	356.159	25.184	4.159	199	.000047
Fuel_exp_school_freeway-vs-fuel_exp_school_jam	-36.775	45.927	3.248	-11.32	199	.000
Fuel_exp_office_freeway-vs-fuel_exp_office_jam	-70.809	104.242	7.390	-9.59	199	.000
Fuel_exp_marketing_freeway-vs-fuel_exp_marketing_jam	-49.95	58.499	4.136	-12.08	199	.000
Taxi Drivers Cum Owners						
Within Trip_with_TrafficCongestion andTrip_Without Traffic Congestion	-5.145	2.706	.191	-26.89	199	.000
Within TimeLoss on less Congested day and Time Loss on severely Congested day	-16.895	11.194	.792	-21.34	199	.000
Within Fuel Expenditure on Less Traffic dayand Fuel Expenditure on Severely Congested day	-188.0	105.768	7.479	-25.14	199	.000
Within Net Profit on Less Congested Days and Net Profit on More Congested Days	281.75	233.887	16.538	17.04	199	.000
Businessmen						
Time_Watage_on_less_traffic_day -vs-Time_Wastage_on_congested_day	-38.275	15.430	1.091	-35.08	199	.000
net_profit_freeway–vs-net_profit_jam	704.50	544.068	38.471	18.31	199	.000
Fuel_exp_school_freeway –vs–fuel_exp_school_jam	-38.95	32.145	2.273	-17.14	199	.000
Fuel_exp_office_freeway-vs fuel_exp_office_jam	-49.075	48.128	3.403	-14.42	199	.000
Source: Calculated by the authors using the primary data collected.						

Time loss due to traffic congestion is one of the direct impacts. Respondents revealed that most of the time they are not able to forecast their travel time due to severe congestion. Fuel wastage due to traffic congestion is another direct impact of it. Respondents have revealed that costs on fuel increased along with the increase in intensity of traffic jam. The taxi drivers have also particularly revealed that there is significant reduction in the number of trips made by them in a day due to traffic congestion. This further affects their daily income as their earnings are heavily dependent on the number of trips that they can make. Similarly, business activities are also greatly affected due to this. Starting business activities on time is very important for its healthy performance for the businessmen. Many of the businessmen have revealed that they are unable to start their business on time due to traffic congestion. As a result of this, it has a negative impact on their profits (Table 14). Therefore, to reduce its impacts in future, strict measures should be undertaken to check the problem of traffic jam in the city. The measures to reduce traffic congestion have been discussed below.

4. Measures for Controlling Traffic Congestion

Traffic congestion in urban centres is a worldwide problem and is not concentrated to a particular region or a country. Day by day the severity of traffic congestion in cities is increasing and it is such a problem which cannot be cured totally. The problem is acute in case of densely populated hill towns where widening of road is very difficult due to geographical texture. The city of Shillong is also gradually experiencing the negative effects of traffic congestion for example increase in longer travel time, unable to reach work place or schools on time, energy wastage. Therefore, it has become a necessity to immediately put a check on the problem before it's too late. But through the application of various techniques and rules its impact can be reduced to a certain extent.

The measures to prevent traffic congestion can be classified into demand side measures as well as supply side measures. Some of the supply side measures include better road network and infrastructure, building of more flyovers. Under demand side measures include availability of public transportation, implementation of institutional buses and vehicles, strict action against illegal parking, proper traffic management, carpooling.

Respondents have revealed a number of valuable suggestions which is analysed by assigning codes to each of the suggestions. The results of the frequency of suggestions provided by all the respondents have been listed in Table 15.

Table 15: Frequency Distribution of Remedial Measures for Traffic Congestion and their Ranks Respectively for Private Vehicle Owners/Commuters, Taxi drivers and Businessmen

		Private Vehicle Owners and Commuters		Taxi Drivers		Businessmen	
Sl.No.	Suggestions	Frequency	Rank	Frequency	Rank	Frequency	Rank
1	Better road network	8	10	8	7	7	10
2	Proper location of schools and offices, widening of roads and public transport	26	2	31	2	23	3
3	Expansion of road, better road infrastructure	16	6	28	3	16	5
4	Build flyovers	17	5	9	6	11	8
5	Shifting of institutions and government offices in the outskirts of the city	1	14	1	11	2	13
6	Expansion of road and building of flyovers	13	7	53	1	13	7
7	Construction of 4-Lane, flyovers and discourage road side parking	11	8	23	4	20	4
8	Construction of more bypass road	2	13	1	11	5	11
9	Well Planned city	3	12	1	11	4	12
10	Expansion of road, better road infrastructure by construction of more bypass	1	14	1		2	13
11	Proper Traffic Management and strict penalty for overtaking vehicles within the city	25	3	8	7	30	1
12	Strict penalty for illegal parking	30	1	2	10	14	6
13	Implementation of institutional buses so as to reduce concentration of private vehicle on city road and carpooling	10	9	13	5	11	8

14	Traffic diversion from highly congested to underutilised roads	8	10	7	8	10	9
15	ITS and tracking congestion through android cell phones	22	4	8	7	25	2
16	Strict traffic rules, implementation of awareness programme	7	11	6	9	7	10
	Total	200		200		200	

Majority of the respondents have suggested for the imposition of strict penalty for illegal parking and for overtaking vehicles within the city, proper traffic management and plan for appropriate location of schools and offices, widening of roads wherever possible and increasing use of public transport, construction of 4-Lane, flyovers and discourage road side parking, expansion of road, better road infrastructure, ITS and tracking of congestion through GPS system in order to control traffic congestion in Shillong (Table 15).

5. Conclusion:

In this paper, an attempt has been made to examine the traffic congestion scenario in Shillong city. Results showed that the road stretches remain congested for most of the hours during day time but peak hours have been identified during office as well as school opening and closing hours in those intersections which are located near the educational institutions and offices. Roads near business centres face heavy congestion immediately after office hours or after 10.00 AM.Also, Volume/Capacity ratio was calculated to understand the level of service.Except for early morning i.e., from 7:00 am – 8:00 am, throughout the day the ratio exceeds 1.

Principle Component Analysis hasrevealed that land use factors like locational misdistribution of various government offices and institutions, badly located filling stations, and physical factors like increase in traffic volume over time are some important factors leading to severe congestion.

There is significantadverse impact of traffic congestion on the productivity ofcar drivers vide fuel expenditure, number of trips made and overall time loss. Also, analysis of opinion on incidence of traffic congestion reveals that traffic volume, locational misdistribution of government offices and institutions, narrow road space, inappropriate bus stoppage, illegal parking, lack of foot path, multiple intersection, encroachment by hawkers and impatient vehicle drivers have been associated with severe traffic congestion in Shillong.

Theanalysis suggests for the proper traffic management and imposition of penalty for illegal parking, overtaking vehicles in narrow road space within the city, appropriate planning for relocation of schools and offices, widening of roads and construction of flyovers wherever possible and encouragement for increasing use of public transport and use of GPS tracking to divert congestion for maintaining smooth flow of traffic. Further, human factors like rush driving, improper roadside parking and dumping of refuse and encroachment on the narrow footpath or roadside need attention.

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