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Evaluation of Traffic Congestion in a Hill City of North-East India

Traffic congestion is a menace to the city commuters, particularly during peak business hours. The problem of a hill city assumes an additional dimension because of the peculiar geographical surface than the plain cities. This paper analyses the cost involved in traffic congestion that arises in various ways. Travel time and cost analysis have been followed using primary data surveyed at different road intersections within the city limit. The findings reveal substantial direct and indirect costs imposed by traffic congestion daily that varies across road intersections and individuals of varied occupations who travel for different purposes to their respective destinations.

Keywords: Traffic Congestion, Cost of Congestion, Opportunity loss, North-East India

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Introduction

Traffic congestion is mostly related to urban transport across the countries, affecting people's movement towards various destinations in their daily or occasional activities. Traffic congestion has been increasing over the years that assume a different dimension in the hill cities like Shillong. The congestion causes a delay in reaching a destination, thus add to the time and fuel cost to the daily commuters. Also, traffic jam adds to the anxiety, irritation, probability of an accident. Costs associated with traffic congestion can be categorised as economic, social, and environmental costs. Several studies, however, classified the effects of traffic congestion into health, environmental and economic effects. Wastage of time and fuel, delay in the movement of vehicles, increasing air pollution, wear and tear of vehicles, stress, and frustrations of road users, perishing of agri-products, and the loss of customers for business are some of the major specific effects of traffic congestions (Raheem *et al*., 2015; He *et al*., 2016).

Over the years, we observed the unbalanced growth of the transport system and transport across the cities and rural areas in any country. Growing population in the urban centres for various socio-economic reasons and habit for possessing luxuries individual cars has led to severe traffic congestion. It is therefore important to identify various impacts and costs associated with traffic congestion in the City.

Shillong, the capital city of Meghalaya, has seen a gradual increase in population from 223366 in 1991 to 354759 in 2011 (Census Reports 1991, 2011). The number of vehicles registered increased sharply, from merely 30456 in 1990-91 to 40645 in 2000-01 and further to 278010 in 2015-16 (Govt. of Meghalaya, 2018). Apart from an increase in the number of registered vehicles in Shillong, the majority of the road corridors suffer from capacity constraints in the road networks, poor definition of road hierarchy, on-street parking, poor traffic management, and safety situations, slow journey speeds, inadequate enforcement

of traffic rules, lack of pedestrian facilities and other street furniture. Further, the passing of National Highways NH-40 and NH-44 through the city has compounded the problem. Also, construction activity and shopping centres along the already congested road create further pressure on these roads. Not only vehicle growth but also the unplanned spatial establishment of educational institutions and offices across the town aggravate traffic congestion problems along some specific stretches of roads during the opening and closing hours of the day. Apart from those, narrow curving roads, people's bad driving behaviour, and parking of vehicles at odd locations add to the problem. The congestion affects the time, fuel, opportunity costs of the vehicle owners or taxi drivers and affects the commuters who use hired vehicles.

Therefore, it is pertinent to examine and estimate various costs imposed by congestion on the people to understand the gravity of the problem and suggest policy measures regarding the city's traffic congestion problem. An attempt has been made in this paper to examine the impacts and costs (direct and indirect) associated with traffic congestion along with the evaluation of total costs of traffic congestion in Shillong city. The specific objectives here are

a) To estimate the direct economic cost of traffic congestion in Shillong city.
b) To examine the indirect social cost of traffic congestion in Shillong city.
c) To estimate the overall annual cost of traffic congestion.

Growing direct costs due to traffic congestion have been due to rising travel time and vehicle operating costs (Centre for International Economics, Australia 2006). Increase in travel costs, logistics and scheduling costs, reduction in the market areas for the workers, loss in productivity, costs of additional drivers, fall in the number of customers, and incoming and outgoing deliveries have been identified as the business costs due to traffic congestion. Indirect costs due to traffic congestion include accident costs, costs due to pollution, and reduced amenity (Choudhury, 2015). Rising vehicle population leads to expensive road building and maintenance, clogged and congested roads, high level of energy consumption

along with various economic and environmental costs, worsening air and noise pollution, traffic accidents, and social inequalities in Delhi (Dewan and Ahmed, 2007; Singh and Sarkar, 2009). The study was descriptive and did not adopt any proper methodology to evaluate the impacts of traffic congestion. However, the authors suggested carpooling and proper traffic management as an important strategy to reduce traffic congestion.

Congestion externalities are, in general, increasing travel time, air pollution and fuel consumption, and excessive inflow of vehicles, long queues, and lack of parking places were identified as the reasons for congestion (Lee *et al.* 2008). Also, traffic congestion leads to a fall in land value in areas prone to severe traffic jams. Commuting costs associated with traffic congestion were increasing noise, pollution (fumes), dangers of accidents, and loss of amenity (Chakraborty and Gupta, 2014). Two approaches - engineering and economic were considered to analyse traffic congestion costs by Ye (2012). In the engineering approach, time lost is measured by pricing time loss at average income levels, whereas in the economic approach, traffic level is determined as a function of the demand for road use.

He (2012) defined Extension Traffic Simulation System (ETSS) and identified 5CW problems of traffic congestion to understand road traffic management better, like when, where, how, why, and what change. To better estimate the price of traffic congestion factors like vehicle types, congestion degree, road network situation, and travelers bearing ability needs consideration (Ye, 2012). Thwala *et al*. (2012) identified the most notable urban traffic problem in urban Nigeria like parking difficulties, longer commuting, environmental impacts, energy consumption, and accidents. Chakraborty and Gupta (2014) suggested the improved public transport system, improved traffic management, congestion charging, construction of footpaths to reduce congestion in Kolkata.

Traffic congestion has a negative effect on the nation's growth because it causes loss in workers' productivity, loss in trade opportunities, and delay in delivery (Singh 2014).

Image Mosaicking Techniques for assembling multiple overlapping images of the same scene may help capture traffic flow that may control the same.

With the help of both primary and secondary data (West Bangal Pollution Control Board, 2015), a relationship between vehicle speed and emission of pollution were observed, and results showed that if the vehicle speed is reduced to less than 50 km/hr, CO emission is increased to more than 800 gm/km. Chakraborty and Gupta (2015) identified time losses, pollution, and accidents as negative impacts of traffic congestion. Wastage of time, delay in the movement of vehicles, wastage of fuel, increasing air pollution, wear and tear of vehicles, stress, and frustrations of road users, perishing of agricultural products, etc. were identified as some of the effects of traffic congestions in Oyo, Nigeria (Raheem *et al*., 2015). The study reveals the peak hourly traffic between 7:45 A.M. and 8:30 A.M. and 4:00 P.M. to 4:45 P.M. The road defect like potholes causes significant traffic congestion. Measures suggested reducing traffic congestion were proper parking space arrangements, reduction of encroached shops on the roads, and channelization of traffic control devices at the junctions.

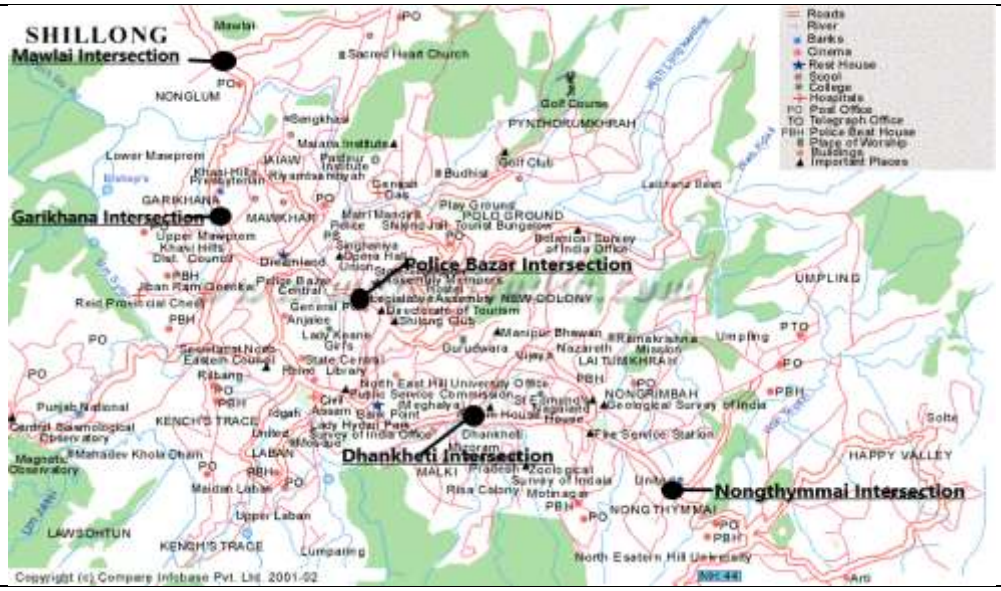
Most of the available studies have found time loss and productivity loss as the severe impacts of traffic congestion. However, very few studies have evaluated rising fuel costs, and it is important to note that time loss with respect to per unit of distance travelled can be used to compare time loss across different stretches of the roads.

Materials and Methods

The Shillong city is well connected by a network of roads within the state and other important cities in North East India through National Highway 44. For the assessment of traffic congestion, at first, road intersections were selected. For this purpose, a structured questionnaire was distributed among 600 randomly selected individuals in the city, in equal proportion, individuals owning a car and daily commuters, taxi drivers, and businessmen other than taxi drivers. As per their rankings in traffic congestion, five top intersections from

the frequency distribution table were selected for the study. Out of the 16 major road intersections in the city, Mawlai point, Garikhana, Police Bazar intersection, Dhankheti intersection, and Nongthymmai intersection were chosen (Fig. 1) (Appendix 1).

Fig 1. Location of the Surveyed Intersections in Shillong City



Source: Mappery, Accessed from: http://www.mappery.com/Shillong-City-Map, Date of access: 20th April 2019.

Effects of traffic congestion are examined at these five locations in terms of time loss, rising fuel expenditure, wear and tear of cars through a comparison of those while driving in a congested road with that of a freeway or between a peak and off-peak driving period of the day. The same would also be examined by comparing the same at different stretches of a road with varied congestion used by the travellers. Indirect impact due to delay in reaching destinations and thereby loss in productivity or earning have also been examined.

Information was collected from the respondents using a questionnaire on their fuel expenditure on days of traffic congestion and days of less traffic jam, Vehicle Operating Costs (VOC). An increase in daily commuters' travel time is also estimated, which is another important cost of congestion. Social costs of congestion in terms of road rage, missed meetings, the effect on emotional state, etc. are examined through descriptive statistics.

For analysing the annual impact of congestion, indicators like fuel cost, loss in income of the taxi drivers and businessmen, and opportunity costs have been examined. The value is calculated on a per annum basis by multiplying the average loss per day by 313 (365 days less 52 days since, on Sundays, there is no congestion as revealed by the respondents and even very few taxis run on that day) to convert into annual data.

Travel time estimation between any two points of interest is a fundamental measure in transportation. So the' pen and paper' technique is used, which requires a driver and a recorder (researcher), one or two stop-watches, data collection forms, and a test vehicle. The test vehicle is driven along the study route throughout the period of interest. The first stop-watch is started when the driver passes the first checkpoint, recording the cumulative elapsed time at different checkpoints on the field datasheet. The second stopwatch is used to record the delay time incurred by the test vehicle when slowed or stopped. This procedure is followed for the entire course until the final checkpoint is reached. During travel time data collection, the researcher(s) location is very significant by fixing the length of the road. Here, travel time analyses have been conducted for all the five locations/intersections from 7.00 AM to 7.00 PM, using 15 minutes intervals. The counts have been conducted at each location from a distance of 250 meters towards each intersection.

Observation and Analysis

Direct Economic Costs of Traffic Congestion

Impact on Fuel Expenditure

Fuel expenditure of the daily commuters was collected daily for days with and without traffic jam. Respondents commute daily for their daily for multiple purposes. About 41 percent of private individuals commute daily for school, office, and marketing purposes. Taxi drivers commute daily for their sustenance. Thus, as observed during the primary survey at selected intersections, the concentration of taxis is very high throughout the city. This is because they commute multiple times every day for earnings. Respondent taxi drivers also

revealed a drastic reduction in the number of trips due to the prevalence of traffic congestion on Shillong roads. Around 75.5 percent of the businessmen commute daily for business, school, and marketing (Appendix 2). Respondents (private individuals, taxi drivers, and businessmen other than taxi drivers) revealed that they face traffic jams whenever they commute, which increases their travel time and fuel expenditure.

In the case of private individuals, the increase in fuel expenditure per Kilometre is the highest in Dhankheti junction (89.62 percent) as this is the most commuted intersection among private individuals for the purpose of work and going to school or college (Table 1). Among taxi drivers, the highest increase in fuel expenditure per Kilometre is recorded in Dhankheti junction (67.34 percent), followed by Garikhana junction. Among businessmen, the increase in fuel expenditure per Kilometre is the highest in Nongthymmai Junction (109.51 percent) and is followed by Garikhana junction (102.59 percent).

Table 1: Changes in Fuel Expenditure Per Kilometre due to Congestion

	Pvt Ind (INR)			***Taxi Drivers (INR)***			***Businessmen (INR)***		
Location	***F_E_Jam/KM***	***F_E_Freeway/KM***	***Increase (%)***	***F_E_Jam/KM***	***F_E_Freeway/KM***	***Increase (%)***	***F_E_Jam/KM***	***F_E_Freeway/KM***	***Increase (%)***
Mawlai	40.43	22.38	**80.65**	20.07	13.32	**50.68**	37.57	20.42	**83.99**
Garikhana	46.15	24.36	**89.45**	39.91	25.84	**54.45**	41.43	20.45	**102.59**
Dhankheti	38.05	20.16	**88.74**	28.13	16.81	**67.34**	32.51	16.08	**102.18**
Police Bazaar	35.97	18.97	**89.62**	33.45	21.69	**54.22**	38.71	21.97	**76.19**
Nongthymmai	27.31	14.5	**88.34**	24.02	16.48	**45.75**	37	17.66	**109.51**
Overall Increase	187.91	100.37	**87.22**	145.8	94.14	**54.64**	187.22	96.58	**93.85**

Source: Primary data collected during July to September 2018.
Note: (1) F_E_ Jam/KMindicates fuel expenditure during traffic jam per Kilometer and **F_E_Freeway/KM**indicates fuel expenditure during free-way per Kilometer.

Table 2: Average Increase in Total Fuel Expenditure Per Day

	Pvt Ind (INR)			***Taxi Drivers (INR)***			***Businessmen (INR)***		
Location	***AvgF_E_Jam (Rs)***	***AvgF_E_Freeway (Rs)***	***Increase (%)***	***AvgF_E_Jam(Rs)***	***AvgF_E_Freeway(Rs)***	***Increase (%)***	***AvgF_E_Jam(Rs)***	***AvgF_E_Freeway(Rs)***	***Increase (%)***
Mawlai	428.33	239.28	**79.01**	851.83	569.50	**49.58**	307.78	171.94	**79.00**
Garikhana	439.30	231.63	**89.66**	875.92	532.041	**64.63**	320.00	163.71	**95.47**
Dhankheti	322.22	169.44	**90.16**	713.09	428.09	**66.57**	260.67	139.33	**87.08**
Police Bazaar	301.00	159.30	**88.95**	926.8	546.8	**69.50**	350.89	182.11	**92.68**
Nongthymmai	253.50	134.25	**88.83**	840.00	576.40	**45.73**	247.24	132.24	**86.97**
Overall Increase	1744.36	933.90	**86.78**	4256.65	2767.77	**53.79**	1485.66	792.91	**87.37**

Source: Primary data collected during July to September 2018.
Note: (1) AvgF_E_ Jam (Rs) indicates average fuel expenditure during traffic jam in rupees, and Avg***F_E_Freeway*** (Rs) indicates average fuel expenditure during free-way in rupees.

Among private individuals' the maximum amount of increase in total fuel expenditure is recorded in Dhankheti, followed by Garikhana and then Police Bazaar (Table 2). Dhankheti junction is located at the heart of the city, and many vehicles have to pass through this junction to reach their destinations. Being a junction surrounded by educational institutions, hospitals, clinics, and many shops, the rising fuel costs associated with congestion in this junction are the highest for the private individuals as they are a major commuter in this junction. Cost on fuel is high due to the same work timings and increase in the number of vehicles passing through this junction for dropping and picking up children from school simultaneously. Apart from this, the bus stoppages at odd places also restrict the flow of the vehicles and thereby add to the costs of traffic congestion.

In the case of taxi drivers, the highest increase in fuel expenditure is incurred in Police Bazar crossing and followed by Dhankheti and after that Garikhana. As mentioned earlier, Police bazaar is a commercial hub with growing business activities. Many offices and banks inhabit the area, along with local and tourist taxi stands. The average rise in the taxi drivers' fuel costs is the highest in this intersection as it remains congested for most of the hours of the day, starting from 10.00 A.M. to beyond 7.00 P.M. Its geometric characteristics are not conducive for smooth driving when there are some cars on the road and narrow space, especially from the Keating Road approach.

Among businessmen other than taxi drivers, the highest fuel expenditure growth is observed in the Police Bazaar intersection and followed by Garikhana. These two intersections are surrounded by business and commercial activities; most commuters in this junction are businessmen or those who come for marketing. Businessmen daily pass through these junctions and daily bear congestion through enhanced fuel expenditure.

It is found that among study locations, the highest increase in fuel expenditure in the case of private individuals is found in Dhankheti (90.16 percent) intersection, which is

followed by Garikhana (89.66 percent) and after that Police Bazaar (88.95 percent). This is because commuters commute daily to Dhankheti mainly to drop and pick up their children (Table 2). Dhankheti is the most commuted location as it is situated in the heart of the city and surrounded by many offices and educational institutions. About 45 major institutions are surrounding Dhankheti intersection, and thus the concentration of vehicles is high in this intersection. This location bears the burden of the largest number of vehicles every day and thus remains congested for most of the day. Private individuals commuting daily through this junction faces traffic jam every day that causes a significant increase in fuel cost. Further, Woodland Hospital is located just near the intersection, and the visitors, patients' vehicles compound the problem further.

Among taxi drivers highest increase in daily fuel expenditure is recorded for Police Bazaar Intersection (69.50 percent), followed by Dhankheti (66.57 percent) and Garikhana (64.63 percent). Most of the taxi drivers commute through Police Bazaar frequently for their day to day earnings. Police Bazaar hardly remains without congestion all through the days of the week except Sunday. An increase in fuel cost also depends on road quality, and fuel expenditure increases with poor road surface. The condition of Keating Road in Police Bazaar is very rough with several ups and down, pot-holes, and face very high congestion. Thus, the impact on fuel costs among taxi drivers is very high in this intersection.

In the case of businessmen, the maximum increase in daily fuel expenditure is recorded in Garikhana (95.47 percent), followed by Police Bazaar (92.68 percent) and Nongthymmai (87.37 percent). This is because of the fact that most of the businessmen mainly commute through this junction daily. Garikhana being located very near to Bara Bazaar, mostly businessmen and market going people are found to commute through this junction. Also, this point remains congested during business hours. Same in the case of Police

Bazaar, this is also a highly commercialised intersection, and most of the commuters are businessmen; thus, fuel cost incurred by businessmen is also high in this intersection.

Impact on Travel Time

An increase in travel time, uncertainty to forecast, and related cost are some of the major direct impacts of traffic congestion. Table 3 reflects the average time required (minute) per Kilometre for onward journey from residence to working place or destination in the morning hours, and Table 4 reflects the average time required (minutes) per Kilometre for the return journey on the same way, which is relatively lower than that of an onward journey as return journey timing is distributed over different points of time for variation in closing time. The percentage difference in the respondents' average travel time for onward journey time per kilometre to their work place is highest for Dhankheti junction compared to other places (Table 3). It is clear that for private individuals, the time taken to reach their workplace get delayed mostly in Dhankheti junction. This is due to the highest institutional concentration in this particular junction leading to increased travel time.

Taxi drivers' difference of onward journey travel time with return journey is the highest at Garikhana junction, for being a location of sumo stand, taxi stand and bus stand in and around (Tables 3 and 4). This junction is also characterised as one of the major intersections with increased commercial activities and on-street parking of tourist buses and taxis for dropping and picking up of passengers. The maximum onward travel time is taken from the Barabazar point approaching towards Garikhana junction as this road remains congested with plying vehicles and parked vehicles during the time of peak hours of taxi movement. Encroachment by hawkers starting from the Barabazar point further makes the road narrower and, with several potholes, leads to increased travel time per KM.

For businessmen, onward minutes per Km to their respective workplace is the highest for those who pass through Dhankheti, followed by those who visit through Garikhana and

Police Bazar (Table 3). It is revealed by the businessmen that they face traffic jam on their way to the workplace because they start mostly by late but almost during the same time in the day from home. Similarly, the time required during the return journey is the highest in Dhankheti location (83.25 percent), followed by Garikhana (82 percent) (Table 4). During the time for returning from work, Dhankheti remains congested at the centre of the city due to a huge number of vehicles passing through this location.

Among taxi drivers, travel time for the onward journey is high at Dhankheti crossing (59.25 percent), followed by Mawlai junction (47 percent). There is a high concentration of various institutions around these two locations, and thus the majority of the taxi drivers pass through them (Table 3). Similarly, the increase in travel time on the return journey is the highest in Dhankheti point (83.25 percent), followed by Garikhana junction (82 percent) (Table 4).

Table 3: Travel Time in Case of Onward Journey (Min per KM)

Location	***Pvt Ind***			***Taxi Drivers***			***Businessmen***		
	A_TT_Jam	**A_TT_ Freeway**	**Rate of Increase (%)**	**A_TT_ Jam**	**A_TT_ Freeway**	**Rate of Increase (%)**	**A_TT_ Jam**	**A_TT_ Freeway**	**Rate of Increase (%)**
Mawlai	9.29	5.00	**85.80**	7.78	5.00	**55.60**	7.35	5.00	**47.00**
Garikhana	9.74	5.00	**94.80**	21.18	5.00	**323.60**	7.28	5.00	**45.60**
Dhankheti	9.32	4.00	**133.00**	9.02	4.00	**125.50**	6.37	4.00	**59.25**
Police Bazaar	7.15	5.00	**43.00**	12.00	5.00	**140.00**	7.12	5.00	**42.40**
Nongthymmai	10.78	6.00	**79.67**	6.31	6.00	**5.17**	8.18	6.00	**36.33**

Source: Primary data collected during July to September 2018.
Note: A_TT Jam indicates Average travel time during Jam and A_TT Freeway indicated Average Travel Time in Freeway.

Table 4: Travel Time in Case of Return Journey (Min per KM)

Location	***Pvt Ind (INR)***			***Taxi Drivers (INR)***			***Businessmen (INR)***		
	A_TT_ Jam	**A_TT_ Freeway**	**Rate of Increase (%)**	**A_TT_ Jam**	**A_TT_ Freeway**	**Rate of Increase (%)**	**A_TT_ Jam**	**A_TT_ Freeway**	**Rate of Increase (%)**
Mawlai	9.62	5.00	**92.40**	7.37	5.00	**47.40**	6.18	5.00	**23.60**
Garikhana	9.58	5.00	**91.60**	17.27	5.00	**245.40**	9.1	5.00	**82.00**
Dhankheti	11.89	4.00	**197.25**	6.81	4.00	**70.25**	7.33	4.00	**83.25**
Police Bazaar	8.16	5.00	**63.20**	8.0	5.00	**60.00**	7.27	5.00	**45.40**
Nongthymmai	8.45	6.00	**40.83**	6.56	6.00	**9.33**	8.29	6.00	**38.17**

Source: Primary data collected during July to September 2018.
Note: A_TT Jam indicates Average travel time during Jam and A_TT Freeway indicated Average Travel Time in Freeway.

It is observed that travel time (onward and return journey) in Shillong city is the highest in Dhankheti location, followed by Garikhana and Mawlai junction. Thus, it reflects

that Dhankheti is the most congested location, and it remains congested throughout the day. But onward journey takes place almost at the same interval, and it takes more time than that of return, whose timing is distributed over intervals depending on closing time.

Changing opportunity costs and monthly vehicle operating costs also form an important part of the direct cost associated with traffic congestion. Every time an individual chooses any trip to a particular destination, with delay in traffic has to forgo other options available to him. Rising opportunity costs on account of enhanced travel time are examined in the monetary value assigned to it (Table 5).

Among the five chosen locations, the average opportunity cost for private individuals is comparatively higher at Dhankheti and Police Bazaar intersections. This is for the inability to forecast travel time in these intersections as it remains congested for most of the day. Thus, the opportunity cost incurred by them is also very high in these locations. The comparatively higher opportunity cost is recorded among taxi drivers when they pass through Dhankheti and Police Bazaar intersections than the other three. The Dhankheti intersection from the Malki approach remains severely congested for sometimes more than an hour leading to high opportunity cost. Similar is the case for Keating road in Police Bazaar that remains congested during the day's peak business hour, and many passengers prefer to get down and walk instead of sitting in the taxi idle.

Vehicle Operating Costs (VOC) cost is associated with the maintenance of the vehicle from time to time. Costs associated with car maintenance include fuel costs, lubricants like engine oil, grease, other oils, expenditure on tires, spare parts, garaging charges, etc. Among private individuals, VOC increases mostly in Mawlai intersection followed by Dhankheti and Police Bazar. The VOC depends on the geometry of the road and its condition. In Mawlai intersection from Mawdatbaki approach, the road condition is very poor, leading to an increase in costs with expenditure on tires, spare parts, etc.

A similar situation is observed in the case of the rising VOC of the taxi drivers, where the maximum vehicle maintenance costs are recorded in the Mawlai intersection, followed by Garikhana and Police Bazaar intersection. In the case of Garikhana approach, the road structure is not very smooth and therefore adds to the damage and costs of maintenance. Also, in the case of Police Bazaar, Keating road remains congested due to vehicles' erratic parking on the roadsides. Also, severe upward and downward slopes of the road compound the problem of VOC. As most of them travel to Police Bazaar and Bara Bazaar, for businessmen, additions to VOC mostly occur in Police Bazaar intersection and follow by Mawlai and Garikhana.

Table 5: Average Opportunity Costs and Monthly Vehicle Operating Costs

	Average Opportunity Cost (Rs)			Monthly Vehicle Operating Costs (Rs)		
Location	***Pvt Ind.***	***Taxi drivers***	***Businessmen***	***Pvt Ind.***	***Taxi drivers***	***Businessmen***
Mawlai	426	937	522	786	1771.67	472.22
Garikhana	458	896	574	653	1361	351.61
Dhankheti	522	1043	880	733	790.48	373.33
Police Bazaar	522	940	807	684	850	402.222
Nongthymmai	297	671	868	445	522.92	328.95

Source: Primary data collected during July to September 2018.

Indirect or Social Costs Associated with Traffic Congestion

Some indirect costs associated with traffic congestion are road rage (anger), missing of meetings, delay in attending the examination, loss of job, affect on commuters' emotional state, etc. Costs vary across categories of individuals, e.g., private car owners' costs are different from taxi drivers or businessmen. Road rage has an important impact on the emotional state of commuters. Also, some individuals face delays in attending a meeting or missing it due to congestion. Since the respondents could not assign exact values, here incidence is examined in terms of gravity and the extent of the impact on the people (Table 6).

About 88% of the private individuals passing through Mawlai revealed that they mostly get angry due to traffic congestion, while over 92% of the respondents driving

through Dhankheti point informed that they mostly face road rage. The majority of taxi drivers also opined of facing road rage on several occasions in all selected crossings. Similar is the case for businessmen. The majority of the private individuals revealed that sometimes they miss or get delayed in attending important meetings even after the beginning of the journey well in advance. The figures are about 15 percent and 10.4 percent of those passes through Nongthymmai and Dhankheti, respectively (Table 6).

Table 6: Distribution of Respondents in Terms of Impact on Road Rage, Missing Meeting by Private Individuals, Taxi Drivers, and Businessmen (Percentage)

		Road Rage			***Missed Meetings***			
	Location	**Some-times**	**Most of the time**	**Always**	**Rarely**	**Some-times**	**Most of the time**	**Always**
Private Car Owner	Mawlai	12	83	5	16	78	4	0
	Garikhana	90	7.50	2.50	5	90	2.5	2.5
	Dhankheti	8.30	88	4.20	8.30	81.3	10.4	0
	Police Bazaar	82	8	18	85	84	8	0
	Nongthymmai	70	15	15	15	70	15	0
Taxi Drivers	Mawlai	3.3	85	12	NA	NA	NA	NA
	Garikhana	0	80	20	NA	NA	NA	NA
	Dhankheti	9.5	69	21.4	NA	NA	NA	NA
	Police Bazaar	8	76	16	NA	NA	NA	NA
	Nongthymmai	0	83	17	NA	NA	NA	NA
Businessmen	Mawlai	0	22.2	77.8	NA	NA	NA	NA
	Garikhana	9.7	22.6	67.7	NA	NA	NA	NA
	Dhankheti	0	30	70	NA	NA	NA	NA
	Police Bazaar	4.4	31.1	64.4	NA	NA	NA	NA
	Nongthymmai	9.9	1.3	90.8	NA	NA	NA	NA

Source: Primary data collected during July to September 2018.
Note: NA – Data not available.

Table 7: Distribution of Respondents (Children of the Private Individuals, Taxi Drivers, and Businessmen) on their Opinion on Incidence of Congestion on Attending Examination for their Children and Their Emotional State (Percentage)

		Effect on Exams			***Effect Emotional State***		
	Locations	**Rarely**	**Sometimes**	**Slightly**	**Slightly**	**Badly**	**Very Badly**
Private Car Owner	Mawlai	4.80	90	31	31	69	0
	Garikhana	0	87	12.5	12.5	80	7.5
	Dhankheti	0	79	14.6	14.6	75	10.4
	Police Bazaar	38	60	6	6	88	6
	Nongthymmai	15	80	10	10	90	0
Taxi Drivers	Mawlai	NA	NA	NA	0	17	83
	Garikhana	NA	NA	NA	0	14	86
	Dhankheti	NA	NA	NA	0	5	95
	Police Bazaar	NA	NA	NA	0	24	76
	Nongthymmai	NA	NA	NA	0	17	83
Businessmen	Mawlai	0	77.8	22.2	0	55.6	44.4
	Garikhana	41.9	58.1	0	3.2	58.1	38.7
	Dhankheti	13.3	86.7	0	0	53.3	46.7

Police Bazaar	35.6	64.4	0	2.2	71.1	26.7
Nongthymmai	40.8	59.2	0	3.9	73.7	22.4

Source: Primary data collected during July to September 2018.
Note: NA – Data not available.

Table 7 depicts the effect of traffic congestion on the status of attending exams of the children of the individuals and their emotional state. People revealed that in all five locations, occasionally or sometimes they are delayed or cannot reach the examination centre in time. Sometimes, to avoid the same harassment, those aware of severe traffic scenarios in Shillong start from home at a much earlier time to reach their exam hall in time. In terms of their emotional state's effect, almost all the respondents have revealed that traffic congestion badly affects their emotional state.

Overall Annual Costs of Congestion

For estimating the total annual costs of congestion, daily fuel cost, opportunity cost data, and monthly vehicle operating costs of the respondents have been considered. Daily fuel costs and opportunity costs of the individuals for days with traffic jam and for days without traffic jam have been collected from the respondents (private individuals, taxi drivers, and businessmen). After that, data have been multiplied by 313 (365 days less 52 days since on Sundays, there is no congestion as revealed by the respondents) to convert into annual data. The annual increase in fuel costs and opportunity costs in terms of percentage has also been calculated for all locations (Table 8 and Table 9). Likewise, the respondents' monthly vehicle operating costs have been multiplied by 12 to estimate yearly car maintenance costs (Table 10). Computation is done for 200 of each category respondents together.

Results reveal that the rate of increase in fuel expenditure is highest for Nongthymmai intersection (134.88 percent), followed by Dhankheti junction (90.16 percent) (Table 8). This is because Nongthymmai junction consumes fuel more due to more undulating roads and long queues prevailing throughout the day. The taxi drivers face a maximum rate of increase in fuel expenditure at Dhankheti junction (68.11 percent), followed by Garikhana (54.83

percent). Among businessmen increase in fuel expenditure is the highest in Nongthymmai (98.61 percent), followed by Dhankheti (97.84 percent) and Garikhana (95.47 percent).

Maximum opportunity cost is incurred by the private individuals while commuting through Garikhana junction (233.90 percent), which is followed by Mawlai (210.76 percent) (Table 9). In the case of taxi drivers, the maximum increase in opportunity costs is recorded at Police Bazaar intersection (173.26 percent), followed by Mawlai (163.85 percent) and Dhankheti intersection (160.71 percent). Among businessmen, the highest opportunity costs are incurred at Nongthymmai (145.63 percent) and followed by Garikhana (115.76 percent).

Table 8: Annual Fuel Costs and Percentage Increase due to Traffic Congestion (Location-wise)

	Pvt Ind (INR)			***Taxi Drivers (INR)***			***Businessmen (INR)***		
Location	A_F_Cost_ Jam	A_F_Cost_ Freeway	**Rate of Increase (%)**	A_F_Cost_ Jam	A_F_ Cost_ Freeway	**Rate of Increase (%)**	A_F_Cost_ Jam	O_Cost_ Freeway	**Rate of Increase (%)**
Mawlai	5630870	3145650	**79.00**	15997430	10695210	**49.58**	1734020	968735	**79.00**
Garikhana	5912570	3117480	**89.66**	13433960	8676360	**54.83**	3104960	1588475	**95.47**
Dhankheti	4538500	2386625	**90.16**	9965920	5928220	**68.11**	2469570	1248870	**97.74**
PB	4710650	2493045	**88.95**	7283510	4735690	**53.80**	4666830	2698060	**72.97**
Nongthymmai	49948540	21265220	**134.88**	6573000	4510330	**45.73**	6269390	3156605	**98.61**

Source: Primary data collected during July to September 2018.
Note: A_F_Cost_Jamindicatesannual fuel cost during Jam and A_F_Cost_Freewayindicatesannual fuel cost in Freeway.

Table 9: Annual Opportunity Costs and Percentage Increase due to Traffic Congestion (Location-wise)

	Pvt Ind (INR)			***Taxi Drivers (INR)***			***Businessmen (INR)***		
Location	O_Cost_ Jam	O_Cost_ Freeway	**Rate of Increase (%)**	O_Cost_ Jam	O_Cost_ Freeway	**Rate of Increase (%)**	O_Cost_ Jam	O_Cost_ Freeway	**Rate of Increase (%)**
Mawlai	5602700	1802880	**210.76**	17590600	6666900	**163.85**	2942200	1552480	**89.52**
Garikhana	6166100	1846700	**233.90**	13740700	5321000	**158.24**	5571400	2582250	**115.76**
Dhankheti	7355500	2967240	**147.89**	13709400	5258400	**160.71**	8263200	4131600	**100.00**
PB	8169300	2848300	**186.81**	7355500	2691800	**173.26**	11361900	6375810	**78.20**
Nongthymmai	1862350	657300	**183.33**	5042430	2253600	**123.75**	20658000	8410310	**145.63**

Source: Primary data collected during July to September 2018.
Note: O_Cost_Jamindicatesopportunity cost during Jam and O_Cost_Freewayindicatesopportunity cost in Freeway.

Table 10: Annual Vehicle Operating Costs of Private Individuals, Taxi drivers and Businessmen

	Yearly Vehicle Operating Costs (Rs)		
Location	***Pvt Ind.***	***Taxi drivers***	***Businessmen***
Mawlai	396000	1275600	102000
Garikhana	7190500	800400	130800
Dhankheti	8577500	398400	134400
Police Bazaar	9526500	255120	217200
Nongthymmai	2171750	150600	300000
Total	**27862250**	**2880120**	**884400**

Source: Primary data collected during July to September 2018.

Maintenance costs of vehicles are highest among private respondents commuting through Police Bazaar, among taxi drivers, Vehicle Opportunity Costs (VOC) is the highest in Mawlai, and among businessmen, VOC is highest for respondents commuting through Nongthymmai (Table 10). The increase in the vehicles' maintenance costs is a rough road surface, the existence of potholes on the surface of the roads, etc. Police Bazar is a commercialised location, and almost everyone in the city visits this location at least once a week for marketing. This location has multiple intersections, and the road surface is rough with poor road geometry. Thus, VOC is high in this location among private individuals. Similarly, for taxi drivers and businessmen, maximum VOC is observed in Mawlai and Nongthymmai, as both the junctions have narrow road width and very poor condition.

Average Travel Time Analysis

Travel time estimation between any two points of interest is a fundamental measure in transportation (Ayehu, 2015; Rao and Rao, 2012; Henry and Koshy, 2016; Paulose et al., 2018). Average travel time has been collected for each intersection from a distance of 250 metres from either approach through manual count. The count has been conducted taking 15 minutes intervals at the following intersections: Mawlai, Garikhana, Dhankheti, Police bazaar, and Nongthymmai from 7:00 A.M. to 7:00 P.M. The analyses of the travel time help

in identifying the most congested approach towards each intersection. The result of the travel time analysis for each intersection has been shown graphically below.

Fig 2: Average Travel Time from Each Approach in Mawlai Intersection

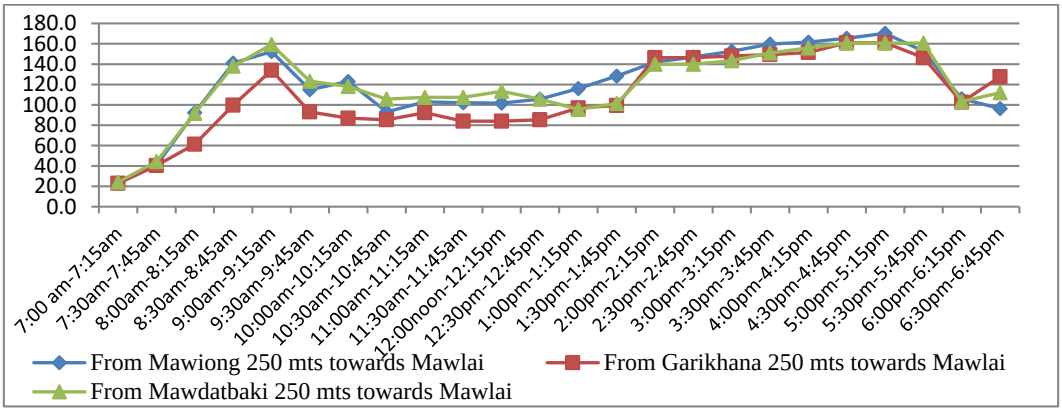


Fig 3: Average Travel Time from Each Approach in Garikhana Intersection

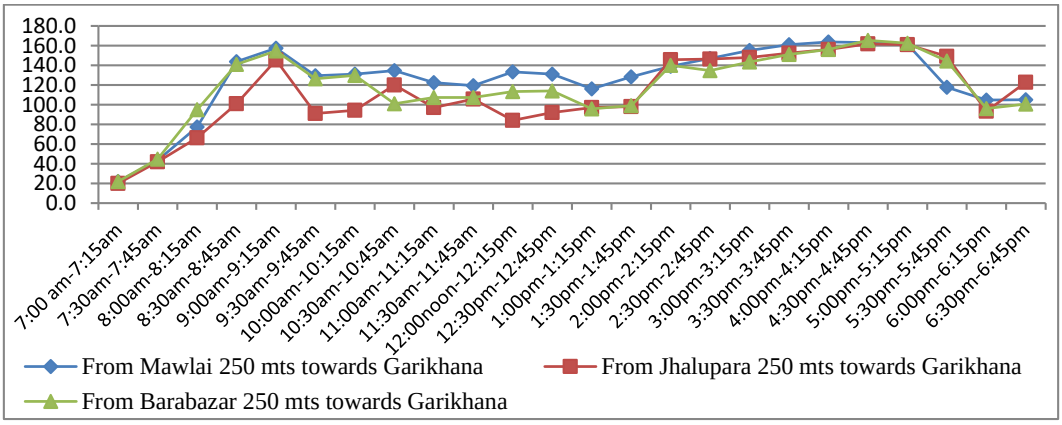


Fig 4: Average Travel Time from Each Approach in Dhankheti Intersection

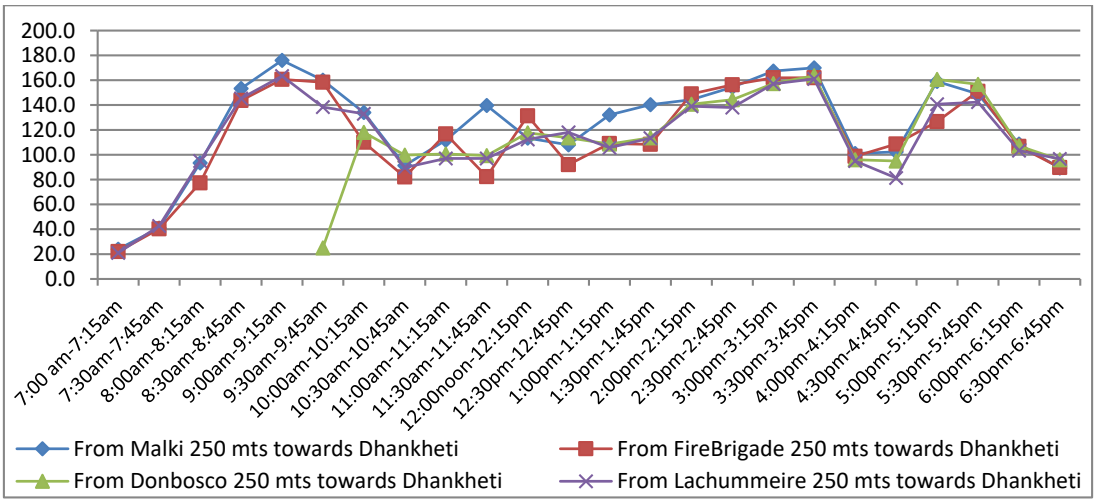


Fig 5: Average Travel Time from Each Approach in Police Bazaar Intersection

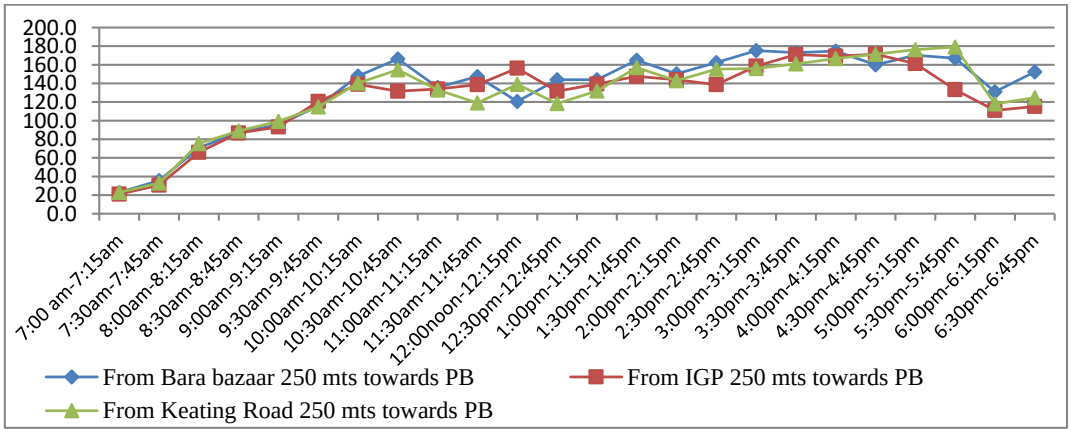
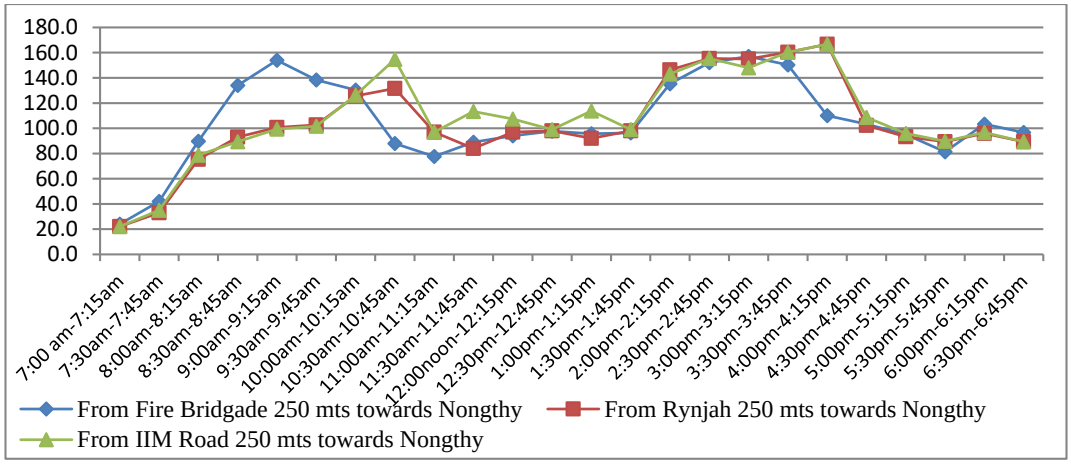


Fig 6: Average Travel Time from Each Approach in Nongthymmai Intersection



The primary data results reveal that the peak hour average travel time is obtained from 8:30 A.M. to 8:45 A.M. and 5:00 P.M. to 5:15 P.M. (Fig. 2). The average travel time is very high for vehicles coming from the Mawdatbaki Approach in the morning hours. In the afternoon, it is high for vehicles coming from the Mawiong Approach. The average travel time during morning hours is high from the Mawdatbaki Approach because the residents staying on that side use personal cars or pick up vans for dropping their children at schools at more or less the same time. Thus, traffic flow is very high during school hours, which leads to congestion, thereby increasing average travel time. Further, the nature of the road on this approach is very poor, which restricts a smooth flow of vehicles through this route leading to

a rise in travel time. In the evening hours, the flow of traffic from Garikhana side is high because of returning people from work to their home, leading to congestion and an increase in average travel time.

Fig 3 depicts the average travel time of the Garikhana Intersection. In the morning hours, the average travel time of traffic flowing from Mawiong Approach is high and during the afternoon average travel time of traffic from Barabaazar is high. In the morning hours, vehicles coming from the Mawiong approach are high as most of the students from rural areas like Mawiong, Umaim, and Umsning commute daily for educational purposes. Similarly, in the evening time, the location remains busy as several local vehicles are parked on the roadside to pick up students and passengers returning to their respective rural areas. In addition to that, the educational institution's location right at the intersection further aggravates the situation. Also, there is a huge flow of vehicles coming from Barabazaar, leading to increased travel time. Because most of the buses and local sumo-vehicles coming from villages like Nongsder, Sumer, Umsning, Sawlad, Umbang mostly return in the evening.

Data pertaining to the average travel time of the Dhankheti intersection reveals that the average travel time at Dhanketi intersection is high, from 8:30 A.M. to 8:45 A.M. 3:30 P.M. to 3:45 P.M. During morning hours, the average travel time is high for vehicles coming from the Malki approach and in the afternoon, average travel time is high for vehicles coming from the Don Bosco approach. Dhankheti is the most congested intersection of the city as it is the centre of the city, adding a link to many other cross-intersections (Fig 4). This intersection is also observed to be surrounded by approximately 45 institutions; therefore, it is found to remain congested for most of the hours of the day.

The average travel time of the Police Bazaar intersection has been presented in Fig 5. The Police Bazaar intersection remains very crowded and full of vehicles throughout the day.

This centre remains congested with people as it is a commercial hub with many shopping malls and banking institutions. Many hotels and restaurants also surround the centre point (Police Bazaar); therefore, the majority of the people and vehicles ply around this intersection are tourists and people who visit for business or family shopping. The traffic flow gradually increases after office opening hours from 10:00 A.M. onwards. In the daytime, travel time for vehicles coming from Bara Bazaar is high, and in the evening, vehicles coming from Keating road take more time to cross the same distance.

Fig 6 describes the average travel time characteristics of the Nongthymmai intersection. The Nongthymmai point is characterised as a 3- legged intersection with a very narrow road with a width of only 3.5 metres. This road stretch remains congested mostly during office and school hours. Long queues often characterise this location, and the level of traffic congestion is moderately high, like all other locations discussed above. From 11:00 A.M. to 1:30 P.M., the nature of traffic congestion is found to be moderate. During morning hours, the average travel time for vehicles coming from Fire-Bridgade is high, and in the afternoon, the travel time for vehicles coming from Rynjah approach becomes high.

Average Time Loss at Major Intersections in Shillong

Average time losses at five major intersections have been calculated by subtracting the freeway normal travel time from the actual travel time. The freeway average travel time to cross 250 metres at Mawlai crossing is 23 seconds, Garikhana 21 seconds, Dhankheti 23 seconds, Police Bazaar 22 seconds, and at Nongthymmai 23 seconds (Table 11).

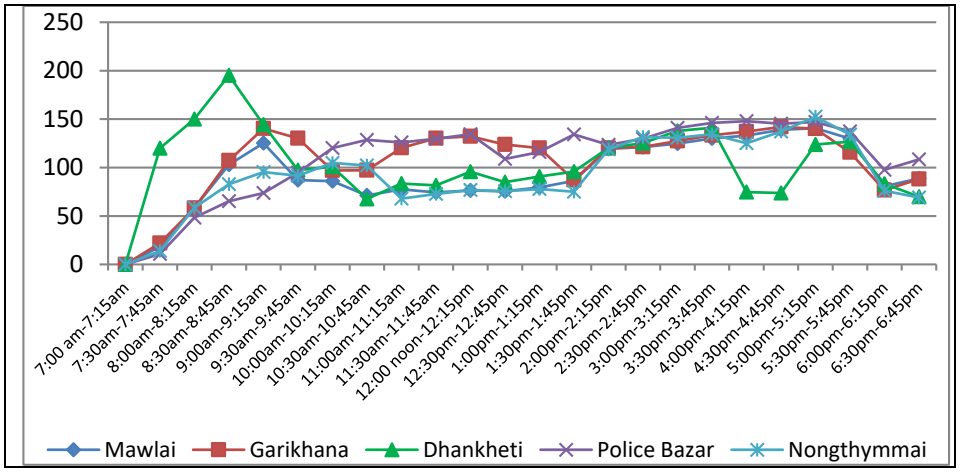
Table 11: Average Time Loss of Vehicles for Crossing 250 Metres (from Either Approach) at Various Locations in Shillong (Seconds)

Time Interval	Mawlai	Garikhana	Dhankheti	Police Bazar	Nongthymmai
7:00 am-7:15am	0.0	0.0	0.0	0.0	0.0
7:30am-7:45am	18.4	22.0	120.0	10.8	14.0
8:00am-8:15am	58.4	58.2	150.0	48.3	58.6
8:30am-8:45am	102.9	107.2	195.1	65.3	82.8
9:00am-9:15am	125.2	131.1	144.3	73.8	95.3
9:30am-9:45am	87.1	94.2	97.4	94.7	91.6
10:00am-10:15am	86.0	97.0	100.8	120.1	104.8
10:30am-10:45am	71.3	97.2	67.7	128.6	102.1
11:00am-11:15am	77.6	87.6	83.5	125.9	67.9
11:30am-11:45am	74.4	89.4	81.6	129.7	72.8
12:00 noon-12:15pm	76.3	88.9	95.7	134.3	76.8
12:30pm-12:45pm	75.6	91.0	84.9	109.0	75.6
1:00pm-1:15pm	79.6	81.6	90.8	116.1	77.8
1:30pm-1:45pm	86.3	87.1	95.9	134.2	75.1
2:00pm-2:15pm	119.4	120.2	120.3	123.4	118.9
2:30pm-2:45pm	121.1	121.3	125.3	129.8	131.6
3:00pm-3:15pm	124.7	127.4	137.9	141.0	130.7
3:30pm-3:45pm	130.0	133.4	141.2	146.0	134.3
4:00pm-4:15pm	133.0	137.2	74.7	147.9	125.1
4:30pm-4:45pm	139.0	142.0	73.8	145.2	137.1
5:00pm-5:15pm	140.7	140.2	123.8	147.0	152.6
5:30pm-5:45pm	129.9	115.7	126.8	137.4	134.1
6:00pm-6:15pm	80.7	76.7	83.4	97.7	76.0
6:30pm-6:45pm	88.7	88.1	69.9	108.4	69.1

Source: Primary data collected during July to September 2018.
Note: Average delay of vehicles moving from all directions crossing the intersection is computed.

The intensity of congestion at different points of time is examined through the loss of time in crossing a particular stretch of the road intersection. The average amount of time lost in excess of the freeway timing required to cross the stretch of 250 metres from either side of these three or four-legged road intersections on weekdays reveals a similar pattern as the congestion across different time intervals of the day (Fig 7). The loss of time varies across the time interval of the day, and it is associated with the location (presence or absence of educational institutions, government offices, or market around the intersection) of the road intersection and timing of schools, offices, and markets. The loss is more in a road intersection during the opening and closing hours of the institutions located around it.

Figure 7: Average Time Loss of Vehicles at Five Major Intersections for Crossing 250 Metres from (Either Approach) in Shillong (Second)



Conclusion and Policy Recommendation

This paper tries to evaluate various economic and social costs associated with traffic congestion in Shillong city. Ideal time loss, excessive fuel expenditure, and increased vehicle operating costs due to the prevalence of traffic congestion are observed in the hilly roads. Results showed significant variation in average opportunity cost for different categories of individuals that differ across road intersections. Results also show that the indirect impact of traffic congestion has been found prevalent in delayed attendance to examinations, meetings, road rage, etc. Further, total annual costs of congestion vary significantly across locations on different stretches of road and among individuals of varied occupations, which is more crucial for a hilly terrain like Shillong. The spatio-temporal variation is primarily due to differences in concentration of offices, institutions, and timing of operations in comparison to the capacity of road stretches. Apart from environmental impacts and productivity loss, the direct and indirect economic and social costs are significant that eat up a significant potential of welfare of the individuals in the city, as observed in several earlier studies. The geo-morphological structure of the hill city road holds additional responsibility to a certain extent.

The following policy recommendations come out of the analysis regarding Shillong city to control traffic congestion and smart and sustainable traffic management.

- Steps may be taken to relocate institutions along with the residence to the city outskirts to reduce the concentration of institutions only at a particular area and divert the traffic towards less congested locations.
- Steps should be taken to implement institutional buses for employees and students to reduce vehicles' pressure on the roads.
- An improved public mass-transportation system may be effective in reducing the number of vehicles on the road.
- Proper parking facilities should also be provided in order to prevent the stoppage of cars anywhere on the roadside and regulate it.
- Behaviour of the drivers should be observed strictly so that they do not drive impatiently, as such overtaking further aggravates the existing traffic condition and may lead to accidents on the roadside. Further, some drivers drive very slowly as they talk over mobile while driving and stop in the middle to have other interactions. It causes driving by the following vehicles difficulty in reaching their destinations on time, which is the ultimate objective of using a vehicle and not walking. Those errant driving should also be controlled.
- GPS may be encouraged to know the status of traffic in various alternative ways.
- Car-pooling should be encouraged to reduce the number of vehicles on the road, especially for school hours.

Limitations and Scope for Further Research:

This study is not without any shortcomings, and there are some further scopes for research in this line.

- Methodologically, variation in congestion levels across different stretches of the same road may be compared to bring out the impact of changing congestion levels at different time and day points.

- The study can be extended to all the city's strategic locations so that a policy can be framed on how to integrate all the intersections to distribute vehicle pressure on road intersections.
- In this study, the environmental impact of traffic congestion has not been examined. Therefore, there is much scope for future study in this area.

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Appendix 1: 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 a primary survey conducted during July-September, 2018.

Appendix 2: Distribution of Sample Respondents according to their purpose of Travel

	Private Individuals		***Taxi Drivers***		***Businessmen***	
	Frequency	*Percent*	*Frequency*	*Percent*	*Frequency*	*Percent*
Business, School, Marketing	0	0	0	0	149	75.5
Business	0	0	0	0	51	25.5
Education	18	9	0	0	0	0
Marketing	10	5	0	0	0	0
School, Marketing	36	18	0	0	0	0
Office	50	25	0	0	0	0
School, Office, Marketing	82	41	0	0	0	0
Office, Marketing	4	2	0	0	0	0
Work	0	0	189	94.5	0	0
Work, School	0	0	11	5.5	0	0

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