Journal of Engineering Science 10(1), 2019, 103-112

JES

an international Journal

TRAFFIC CONGESTION INDUCED COST OF A ROAD SECTION: A STUDY ON FULBARIGATE TO DAKBANGLA MIDBLOCK, KHULNA

Palash Chandra Das*, Neeti Zaman Bintee, A. K. Azad and Tusar Kanti Roy

Department of Urban and Regional Planning, Khulna University of Engineering &Technology Khulna-9203, Bangladesh

Received: 01 March 2019 Accepted: 19 June 2019

ABSTRACT

The study aims to monetize congestion cost of selected road sections in Khulna city where the congestion problem is severe. Opportunity cost, vehicle operating cost and negative externality cost were calculated for 10 modes of transport available from Fulbarigate to Dakbangla intersection. Questionnaire survey resulted highest value of time for car (89 tk/day) and motor cycle (70 tk/day) because of having higher income with lower working days. Opportunity cost is estimated 815 tk/peak/day which is the highest for Mahindra and auto as these vehicles are contributing largely to the volume. Larger vehicles consume more fuel and are prone to greater delay time (around 7 minutes/peak). Moreover, speed failure is highest for heavy vehicles which are causing delay for three wheeler vehicles also. Overall vehicle operating cost and externality cost are 13,458tk/peak/day and 374,516 tk/peak/day, respectively. These two costs exist only for six modes of vehicle using fuel. Total monetized value of congestion cost results in 17.1 million tk/month which incurs huge loss to Khulna City. Moreover, being a linear city Khulna is still under major construction works. Increment of overall economic activities can deteriorate the congestion scenario with no doubt. Lane separation, off-street parking and improving public transport services are some of the suggestions to reduce congestion loss in Khulna City.

Keywords: *Externality cost, Opportunity cost, Value of time, Vehicle operating cost*

1. INTRODUCTION

Congestion, a term that is making urban life slower, generating such a trouble that is now seeking attention almost in all developing and developed countries also. Traffic congestion is characterized by slower speeds, longer trip times etc. (Lee *et al*., 2015). In third world countries loss of working hours in cities are negatively affecting the GDP. Here in Bangladesh one's valuable time is going in vain, drivers are counting extra money for vehicle operating purposes, environment is getting polluted by excess fuel brunt in this process. Loss of valuable time that could be used effectively in productive purposes are hampering simply because of congestion. A developing country like Bangladesh cannot afford the economic and environmental loss resulted from this severe traffic obstruction (Najneen *et al*., 2010). Major cities like Dhaka (eats up to 3.2 million working hours/day), Chittagong and Khulna are under alarming concern of this problem (Henry and Koshy, 2016; Shamsher and Abdullah, 2013).Traffic congestion that is now facing by mega city Dhaka is an alarming concern for other cities that are under major infrastructural development. Khulna, the third largest city in Bangladesh, in such case is the next to recur the same incidence (BBS, 2015; Moniruzzaman, 2013). Major development projects e. g. Padma Bridge, Khulna Mongla Rail Road project have been taken to link Khulna with the other parts of the country in order to increase the economy of the country. After the completion of these projects, the resulting extra traffic can deteriorate the present scenario of congestion. Assessment of economic loss is helpful to see whether the country GDP is significantly threatened due to congestion of Khulna city or not. Cost of traffic congestion refers to loss due to congestion in monetary values which may include excess fuel cost (USD 179 million per year in Dhaka city), environmental externality cost (air/noise pollution), travel time delay cost, vehicle operating cost etc. (Khan and Islam, 2013). The traffic congestion cost is USD 3 billion a year and the city losses over 8 million working hours daily (Shamsher and Abdullah, 2013).

Congestion is a condition that arises as more people wish to travel at a given time than the transportation system can accommodate (Miller and Li, 1994). Traffic congestion can be of two main types- recurrent (too many vehicles want to use the road at the same time) and non-recurrent **(**disabled vehicles, accidents, work zones such as street cleaning**)** congestion (Chakrabartty and Gupta, 2015). While travel demand exceeds 90% of the capacity results slower speeds and longer trip times can also be termed as traffic congestion (Rosenbloom, 1978; Chakrabartty and Gupta, 2015). The growth of traffic is affected mainly by four major factors: (1) the natural growth of population, (2) locational patterns (i.e. spatial distribution of residence, work, shopping and entertainment places), (3) transportation characteristics and policies, and (4) transport behavior of individuals and household manifested in their mode, departure time, route choice and so on. The effects of traffic congestion are multiple including: (1) loss of productive time, (2) loss of fuel, (3) increase in pollutants (because of both the additional fuel burnt and more toxic gases produced while internal combustion engines are in idle or in stop-and-go traffic), (4) increases in the wear and tear of automobile engines, (5) slow and inefficient

* Corresponding Author:chandra.palash46@gmail.com

emergency response and delivery services, (6) negative impact on people's psychological state, which may affect productivity at work and personal relationships (Papacostas and Prevedouros, 2001). The summation of all these effects yields a considerable loss to the society and of an urban area. Traffic congestion cost can be monetized considering dead weight loss (avoidable social cost), travel time cost, travel time variability cost, delay externality cost and environmental externality cost (Khan and Islam, 2013; Ali *et al*., 2013). Congestion can be quantified using different indices such as Congestion Index, Travel Rate Ratio and Delay Rate Index. Travel time-based measure is well understood by professional community and general public as a measure of congestion. Congestion levels in different stretches of road can be compared through Congestion Index (CI) = $(C-C_o)/C_o$, where C_o = Free flow travel time and C = Actual travel time. Here, CI close to 0 defines very low level of congestion and CI > 2 means severely congested condition (Anil *et al*., 2007). Level of Service (LOS) can also be a qualitative measure for describing operational characteristics in a traffic stream. The congestion costs are estimated at Dutch guilder (DFl) 300 to 700 million per year, representing up to 10% of the total external costs of road transport (Hansen, 2000).

The objective of the study is to estimate economic loss due to traffic congestion. This paper provides answer of the following research questions- (1) which types of cost are to be arisen due to congestion? And (2) to what extent economic loss will occur due to congestion? The study will measure three major types of hidden cost (i.e. opportunity cost, vehicle operating cost and externality cost) due to traffic congestion in monetary values.

While calculating congestion cost, all sectors of negative externality cost (noise pollution, air pollution) were not considered; only CO_2, CO, SO_2 and NO_x emission costs were calculated. Discount factor such as inflation rate was not considered while monetizing congestion cost. Only present value of cost was estimated in this study. Moreover, in initial phase of engine life cycle, vehicle runs more mileage using the same quantity of fuel. Here, variation of engine life span was not considered while considering fuel consumption quantity (litre/km).

2. METHODOLOGY

2.1 Study Area

Khulna is the 3rd largest city after Dhaka and Chittagong having a population of 759,877 (BBS, 2015). Khulna is located in the Southwestern part of Bangladesh at 22°49′0″N and 89°33′0″E, on the banks of the Rupsha and Bhairab River (BBS, 2015). The city has a strong industrial base on shrimp cultivation, which is the second biggest foreign exchange earner in Bangladesh (Ahmed, 2011). Major industries such as jute mill and trade-commerce are developed beside Khulna-Jashore highway. For the study, the road section from Fulbarigate to Dakbangla intersection was considered as the study area. Total length of the study road section is 10.73 km. As a whole 10 types of traffic modes were available throughout the road section. These modes are bus, truck, auto, mahindra, rickshaw, bike, car, cycle, van and CNG. Here public transport vehicles are high in number than private vehicles (i.e. car).

Eight sub-sections of study stretch (from Fulbarigate to Dakbangla) were considered to conduct volume survey. Only the major intersections were considered to divide the whole road as minor road intersections do not contribute largely to the traffic volume. A volume survey was conducted to identify the preliminary congested nodes throughout the eight sections.

Table 1: Physical features throughout the road sections

Road Section	Location	Effective Road Width*	Length of the Road Section (km)	Number of Lane	Illegal Parking Spots	Number of Speed Breaker	V/C Ratio**
1	Fulbarigate to Railigate	35″	1.7	1	2	2	0.21681
2	Railigate to Mohsin Mor	44″	1.3	2	0	3	0.353393
3	Mohsin Mor to B.L. College	44″	0.6	2	4	3	0.161204
4	B.L. College to Notun Rasta	40″	0.8	1	2	1	0.629357
5	Notun Rasta to Boikali	35″	2.5	1	4	4	0.55800
6	Boikali to Boyra	35″	0.5	1	1	2	0.682018
7	Boyra to Joragate	35″	1.4	1	0	3	0.784232
8	Joragate to Dakbangla	44″	2.0	2	7	0	0.433018

Source: Traffic Survey, 2017

* Effective road width indicates carriage way width except roadside illegal blockings

**Volume to capacity ratio (V/C ratio) ranges from 0 to 1. One indicates highest level of congestion while road capacity standard is 1400 PCU/lane/hour

Overall volume to capacity ratio shows that the road should not be under congestion in peak hour (as V/C ratio is less than 0.7 in most cases (Lindley, 1987)). This ratio remains highest (0.78) in case of Boyra to Joragate intersection.

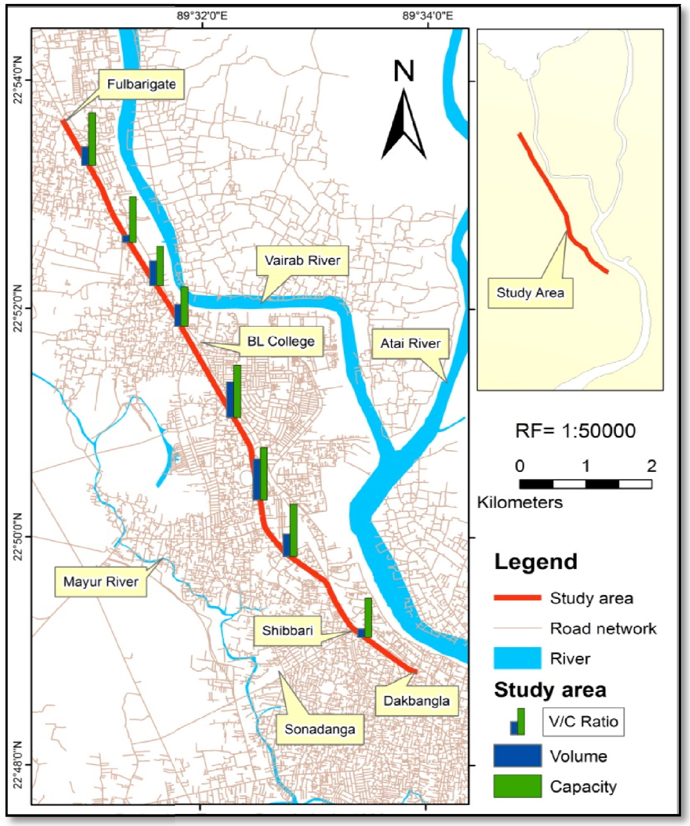

Figure 1: Study area map from Fulbarigate to Dakbangla Mor.

2.2 Data Collection Procedure

From the past studies possible factors that can contribute to congestion were listed out. Both questionnaire and physical survey were conducted to collect primary data. Sample size was estimated at 384 with a z value of 1.96 at confidence level of 95% against 759,877 populations (BBS, 2015). Sample size was determined by the formula of $[\{Z^2 \times p \times (1-p)\}/\, c^2]$ where p is "%" of picking a choice (Freedman *et al.*, 1997). Stratified random sampling was conducted to identify mode specific value of time (Alvi, 2016). This survey covers all the 10 modes available in the study area. Questionnaire survey covered responses from both drivers and trip makers. Finally, three types of congestion cost were calculated for each mode of available transport in the study area.

Table 2: Data requirement for the study

Type of Data		Source
Opportunity Cost	VOT	Socio-economic Survey
	Delay Time	Physical Survey
	Vehicle Occupancy	Physical Survey
Vehicle Operating Cost	Mode specific volume	Physical Survey
	Fuel Cost	Local Filling Station
	Fuel usage proportion	Local Filling Station
Externality Cost	VKT	Physical Survey
	Vehicle Composition	Physical Survey
	Mode specific pollutant emission rate (kg/L)	Secondary Source (Guttikunda, 2008)

2.2.1 Opportunity Cost (OC)

Time spent in congestion has an opportunity cost and hence can be used significantly (Khan and Islam, 2013). This indicates more work can be done by using this saved time (Singh and Singh, 2006). Opportunity cost is also known as Travel Time Cost (TTC) which defines that the value of time spent in traveling could be used in other activities (LGED, 2009). Opportunity cost of congestion can be calculated by estimating delay time due to congestion and monetary value of time. Through equation (1) opportunity cost was estimated (Sunny and Thomas, 2015).

$$OC = \sum_{m=1}^{m}(VOT_m * Delay_m * V_m * V_{occu_m}) \quad (1)$$

Where, OC = Opportunity Cost of traffic congestion, VOT_m= Value of time for specific mode m (tk/hr), $Delay_m$ = *T*ravel delay in time units observed for mode m (estimated through Smeed's equation), V_m= Number of vehicles of type m per day, V_{occu_m}= Vehicle occupancy for specific mode m.

2.2.1.1 Value of Time (VOT)

While calculating VOT, only work trips were considered. Then a survey of 384 questionnaires was conducted with the ten modes along the study corridor. Stratified sampling method was followed while preparing the survey design. Commuters travelling through different types of transport mode were also considered while conducting the questionnaire survey. Survey of 39 questionnaires for each of the modes of Rickshaw, Mahindra, Auto and Motor cycle was conducted as these vehicles contribute largely in vehicle composition than others. For the rest of the modes, survey of 38 questionnaires for each carried out. Passengers, drivers and conductors were also taken into account while conducting questionnaire survey. Then an average value of time for each mode was calculated.

Occupation of respondents, their origin-destination, income, working day and working hour per day were considered as variables for estimating value of time (Kadiyali, 1997). According to Thomas, value of time is a function of commuter's income and amount of time saved (Thomas, 1968). It denotes that the rich will pay more to save time than the poor do. As a result, car users (as fast moving vehicle) will want to pay more for saving their time than passengers travelling to slow moving vehicles (i.e. van, auto etc.). So, a constant value of time was not considered. Moreover, constant value of time may overestimate or underestimate the actual value of time for the study stretch (due to heterogeneous traffic).

Finally, overhead cost was ignored while calculating VOT. Overhead cost consists of office administration, rental charge, garaging, insurance, VAT, tolls/route permit fees etc. Overhead costs are high (i.e. 60% for medium trucks and large buses, 45% for small trucks and mini buses) in Bangladesh for roads where toll is an issue (LGED, 2009). But all the concerned study road sections free of toll. Here, valuation of non-work trip was not considered. As for developing country, valuation of work trip is too low as unemployment and under-employment are very common here (Kadiyali, 1997). Moreover, savings up to 10 minutes have a lower value per minute comparing savings from 10 to 20 minutes (Black, 1995). Small savings of time cannot be used effectively for productive purposes.

2.2.1.2 Delay time

Physical survey was conducted using Speedometer *GPS* app in peak and off-peak hour. Through this app, mode specific average speed data was collected in free flow and congested condition of the study corridor. This survey was repeated for 10 modes of vehicle. Then Smeed's equation was followed for calculating time loss per vehicle due to congestion by comparing peak and off-peak hour speed of a mode for certain road length (10.73 km). Delay time according to Smeed's equation is as follows (Smeed, 1968):

$$c = \left(\frac{l}{v} - \frac{l}{v_o}\right) \quad (2)$$

Here, c = Delay time, l = Length of road segment, v = Average traffic speed, v_o = Free flow speed.

2.2.1.3 Number of vehicles of type *m* per day

A video of ten minutes was recorded in both peak and off-peak periods through the 8 sections. Then volume data was extracted manually from the video. Vehicle composition of a certain type of vehicle was estimated from this volume data.

2.2.1.4 Average vehicle occupancy for specific mode m

To calculate average vehicle occupancy 120 samples for each mode were considered. This data was extracted manually from the recorded video. Here, vehicle occupancy includes drivers of the vehicles also (Committee of

Transport Officials, 2013). The number of occupants was divided by total number of vehicles observed to find out average vehicle occupancy based on the following equation (3) (Jeffery and Hasse, 2006):

$$AVOL_i = \frac{P_i}{VPV_i} \tag{3}$$

Where, $AVOL_i$ = Average vehicle occupancy for location i, (occupants/vehicle)
P_i = Number of occupants counted at location i and VPV_i = Number of passenger vehicles counted at location i

2.2.2 Vehicle Operating Cost (VOC)

Physical costs of operating a vehicle were calculated through the following equations (Ali *et al*., 2013).

$$VOC = L * \sum_{m=1}^{m}(FC_m * Delay_m * V_m) \tag{4}$$

Here, VOC = Vehicle Operating Cost, L = Length of road, FC_m = Fuel cost in tk/hr for specific mode m, $Delay_m$ = Travel delay in time units observed for mode m (estimated through Smeed's equation), V_m= Number of vehicles of type m per day. Where, fuel cost was calculated as follows:

$$FC_m = \sum_{Ft=1}^{n}\left(F_{cq_m^{Ft}} * F_p^{Ft} * \mu^{Ft}\right) \tag{5}$$

Here $F_{cq_m^{Ft}}$ = Fuel consumption quantity in liters/km of specific mode m, F_p^{Ft}= Fuel price of specific fuel types Ft (i.e. diesel, petrol etc.) in tk/liter. μ^{Ft}= Proportion of specific mode type m using a particular fuel type for travelling on that road stretch.

2.2.2.1 Fuel consumption quantity (liters/km)

Drivers were asked about the vehicle millage using a litre of fuel through questionnaire survey. The survey result outlines vehicle millage for Mahindra is 27 km/litre, for bike 35 km/litre. In case of car, bus and truck vehicle millage is 20, 3 and 3.5 km/litre respectively.

2.2.2.2 Fuel price of specific fuel types (tk/liter)

The price for a specific type of fuel is found constant in all over the Khulna metropolitan area. Price for diesel goes for 65 tk/litre whereas petrol, octane and gasoline are 86, 89 and 54 tk/litre respectively. Fuel type mobil is available at a price of 200 tk/litre though it is not used as vehicle operating purposes (Field Survey, 2018).

2.2.2.3 Fuel usage proportion

According to arrival of vehicles (per day) in a fuel station and their fuel usage type, fuel usage proportion was estimated.

2.2.3 Negative externality cost

Four types of pollution cost were considered while vehicles remain in a state of stop and go in congestion. From delay time of different vehicles, equivalent VKT (vehicle kilometers travelled) was estimated considering mode specific running speed. Pollution cost can be calculated using the equation as follows (Sunny and Thomas, 2015).
Pollution cost = Traffic volume Distance* Emission factors of pollutants*Value of cost of pollution* (6)
For this study, estimated VKT in mode specific delay time was used instead of distance.

3. RESULTS AND DISCUSSION

3.1 Traffic composition

A total of 384 respondents were surveyed to calculate mode specific value of time. Drivers were considered for questionnaire survey while passengers were absent (i.e. van, cycle, truck etc.). Working class female passengers were less in number throughout the road section. Volume of trucks (102/hr) is contributing 1% in vehicle composition. These trucks are mainly because of roadside development. Moreover, Khulna-Jashore Highway is the only route for truck to enter the main city. Thus, truck is contributing in congestion of this road section. Mahindra (22%), Rickshaw (22%), Auto (20%) and Motor bike (17%) are contributing largely in vehicle composition.

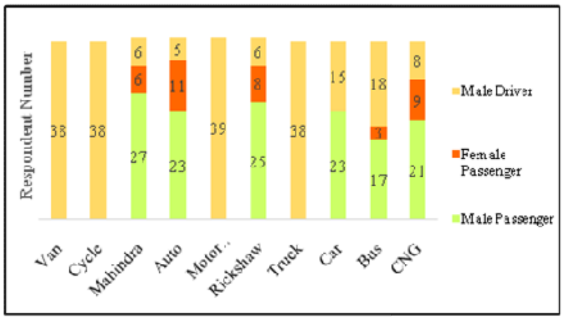

Figure 2: Composition of the respondents (***Source:*** Field Survey, 2018)

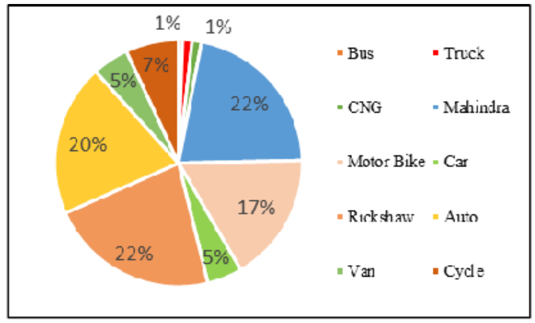

Figure 3: Vehicle composition (***Source:*** Questionnaire Survey, 2018)

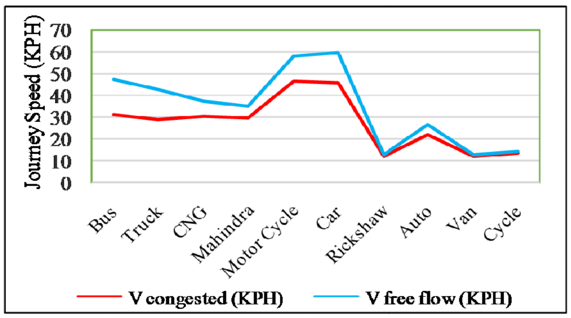

Figure 4: Mode specific speed for delay time (***Source:*** Field Survey, 2018)

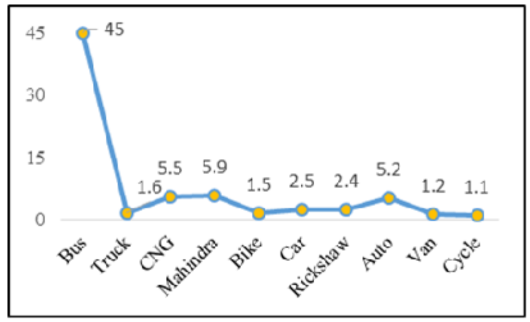

Figure 5: Mode specific vehicle occupancy (***Source:*** Physical Survey, 2018)

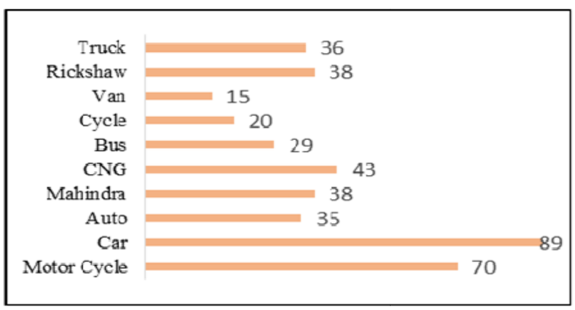

Figure 6: Mode specific *VOT* (tk/day) (***Source:*** Questionnaire Survey, 2018).

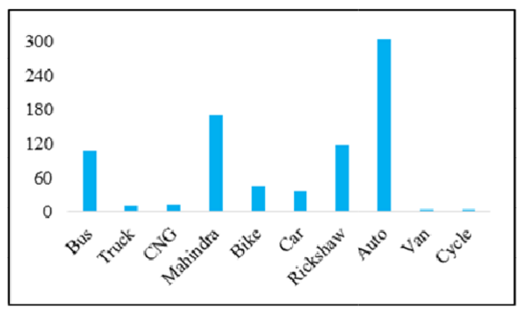

Figure 7: Mode specific opportunity cost.

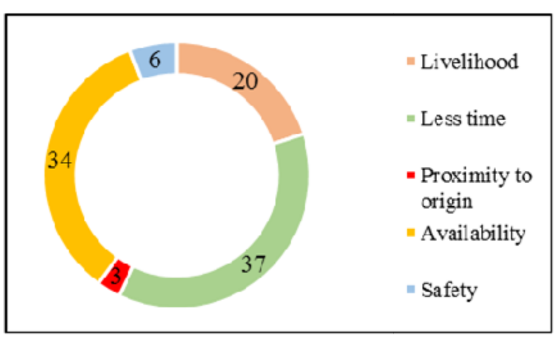

Figure 8: Mode choice reason for Mahindra (***Source:*** Questionnaire Survey, 2018).

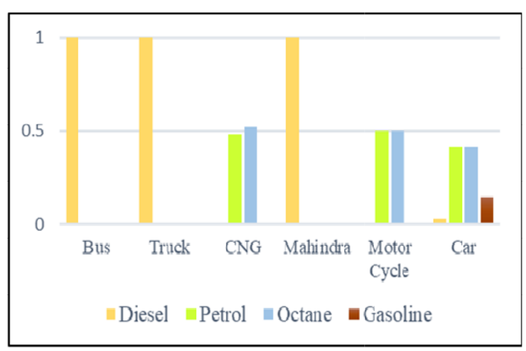

Figure 9: Mode specific fuel consumption ratio.

3.2 Speed variation between peak and off-peak hour

Free flow speed is found less than the speed that a certain vehicle should have. Reasons could be the illegal parking spots, road side construction points and speed breakers. Within last 5 km of the study route, 5 illegal parking spots were identified. Figure 4 shows that the non-motorized vehicles don't differ much in speed when comparing to the motorized vehicles during the congested and free flow state. Again, heterogeneous vehicle composition (i.e. van, rickshaw, bus, bike etc.) also triggers the speed drop factors of vehicles.

3.3 Opportunity Cost (OC)

Considering delay per mode, volume of a certain mode was calculated from the collected volume data. Total amount of loss mentioned here was calculated for one peak time (morning peak hour). Estimated total OC is 815 tk/peak/day and OC is the highest for Auto (305 tk/peak) and Mahindra (171 tk/peak) as these vehicles are the highest (20% and 22% respectively) in vehicle composition. Also, these two vehicles have larger vehicle occupancy (5.2 and 5.9 respectively). Value of time for car (89 tk/day) and bike (70 tk/day) remained higher compared to other modes available in the study corridor. Main reason being the higher income earned from these two modes. VOT for van is the lowest as these are only used for carrying goods. Working class passengers do not use this mode for their movement throughout the road section. Income of 74% of van drivers remained between the ranges of BDT 5,000-BDT 10,000 with a majority working day of 7 days in a week. Thus this results lowest wage per day compared to other modes. Vehicle occupancy of Mahindra is estimated5.9 which is larger than other 3 wheeler vehicles (i.e. CNG, auto, rickshaw, van).

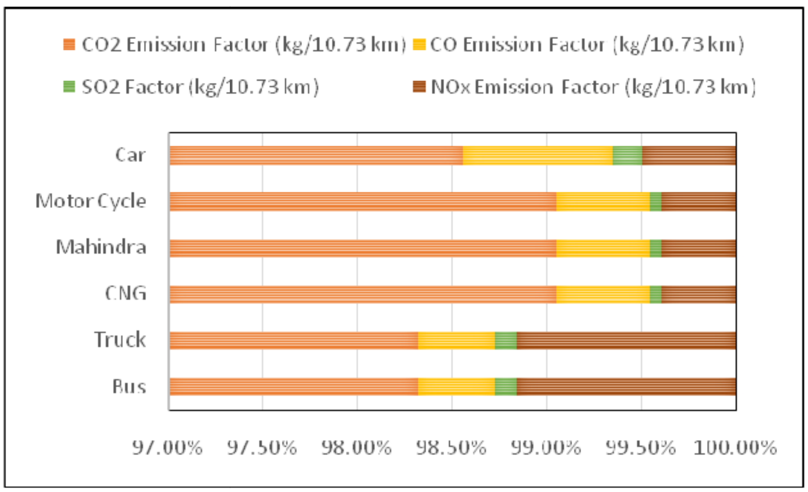

Figure 10: Release of four pollutants

Table 3: Mode specific VOC

Mode	Ft	F_{cq} (lt/km)	F_p (tk)	μ (Ft)	F_{cq}* F_p*μ	Fc (tk/km)	Fc * Delay$_m$ * V_m	VOC (tk/peak)
Mahindra	Diesel	0.04	65	1.00	2.600	2.600	265.889	2852.987
Motor cycle	Petrol	0.03	86	0.50	1.229	2.500	145.634	1562.653
	Octane	0.03	89	0.50	1.271			
Bus	Diesel	0.33	65	1.00	21.667	21.667	240.334	2578.787
Truck	Diesel	0.29	65	1.00	18.571	18.571	488.955	5246.483
	Diesel	0.05	65	0.03	0.093			
	Petrol	0.05	86	0.41	1.781			
Car	Octane	0.05	89	0.41	1.844	4.104	90.842	974.738
	Gasoline	0.05	54	0.14	0.386			
	Petrol	0.04	86	0.48	1.529			
CNG	Octane	0.04	89	0.52	1.714	3.243	22.566	242.138

Trucks and buses are responsible for higher delay time (around 7 minutes for each of the vehicle/peak) only because of larger vehicle size. Motor bikes and cycles are contributing less (around 2 minutes) in total opportunity cost. Only reason behind this would be less delay time because of smaller vehicle size. Bicycles and vans are contributing lowest to the monetized value of congestion cost than other vehicles. Opportunity cost for Bicycle and Van due to congestion is found to be the lowest (3.5 tk/peak and 4 tk/peak respectively). Mainly lower income people use bicycle to go to their working places. A large portion (74%) of them is lower income businessmen.

3.4 Vehicle Operating Cost (VOC)

Collecting data from 9 fuel filling stations, fuel usage proportion (μ factor) has been calculated. As car is the only vehicle using gasoline for this road section, this results in lower value for μ of gasoline.VOC exists only for vehicles using fuel. Hence rickshaw, auto, cycle, van etc. have no value of VOC. Bus, truck and Mahindra use diesel for its lower price (65 tk/liter). Vehicles that require a larger amount of fuel to travel one kilometer incur greater fuel consumption cost. Thus, bus and truck have fuel consumption quantity of 0.33 lt/km and 0.29 lt/km respectively. These two vehicles also have larger fuel consumption cost (22 and 19 tk/km respectively).

3.5 Externality Cost

Only six modes using fuel are subjected to externality cost. Four types of pollutant release were considered while calculating negative externality cost. These pollutants were CO_2, CO, SO_2 and NO_x. According to Central Pollution Control Board of India and Vehicular Air Pollution Information System Organization, mode specific emission factors were considered (Guttikunda, 2008). In case of larger vehicles, rate of pollutant emission was greater (i.e. CO_2 emission ranges from 250-850gm/km, CO: 2-3.5 gm/km, SO_2: 0.4-1.0 gm/km and NO_x: 1.25-10 gm/km). The value for cost of pollution was considered as 7.22 Rs per kg as recommended by Aditi Singh and P.K. Sarkar (2009) and Sunny and Thomas (2015). This cost values 9.24 tk/kg (1 rupee = 1.28 tk) for Bangladesh. Here mode specific free flow speed was considered while calculating vehicle mileage during delay time.

Table 4: Mode specific four types of externality cost.

Mode	CO_2 cost (tk/peak)	CO cost (tk/peak)	SO_2 cost (tk/peak)	NO_x cost (tk/peak)	Externality cost (tk/peak)
Bus	6387.37	243.06	69.45	694.47	7394.35
Truck	128194.29	521.65	302.57	3025.70	132044.21
CNG	8898.06	44.49	5.34	35.59	8983.48
Mahindra	111983.24	559.92	67.19	447.93	113058.28
Motor Cycle	90691.72	453.46	23.85	159.03	91328.06
Car	20872.62	166.98	162.03	506.35	21707.98
Total	367027.30	1989.56	630.43	4869.07	374516.36

Truck as a heavy good transport mode, releases more pollutants (equivalent to 132,044 tk/peak) comparing to light transport vehicles (i.e. CNG, car etc.). Larger delay time (around 7 minutes/trip) for bus and truck generates huge amount of pollutants. Volume of Mahindra and motor cycle are found to be higher and thus generating higher externality cost though these are among LDV (Light Duty Vehicle) category (Guttikunda, 2008). A total amount of externality cost of 374,516 tk/peak was estimated for six types of vehicle.

In light of the previous discussion the total cost for congestion can be calculated as the opportunity cost, vehicle operating cost and externality cost have already been estimated. Table 5 shows the breakdown of total cost of congestion which is 777,578 tk/day, 17.1 million tk/month (considering 22 working day/month, 2 peaks/day).

Table 5: Summary of the monetized value of congestion cost/peak.

Mode	OC (tk/peak/day)	VOC (tk/peak/day)	Externality Cost (tk/peak/day)	Total cost (tk/peak/day)
Bus	107.861	2578.787	7394.35	10081
Truck	11.3	5246.483	132044.21	137302
CNG	12.263	242.138	8983.48	9237.881
Mahindra	170.844	2852.987	113058.28	116082.1
Motor Cycle	45.577	1562.653	91328.06	92936.99
Car	36.698	974.738	21707.98	22719.42
Rickshaw	118.109	-	-	118.109
Auto	304.584	-	-	304.584
Van	4.183	-	-	4.183
Cycle	3.472	-	-	3.472
Total	814.891	13457.786	374516.36	388789

4. CONCLUSIONS

This study is mainly for monetizing peak hour congestion cost for 10 modes of vehicle available from Fulbarigate to Dakbangla intersection. Among the heterogeneous traffic composition, three wheeler vehicles are mostly in number and thus are responsible for more congestion cost after heavy vehicles like trucks, buses etc. Total monetized value of congestion induced cost was estimated at 777,578 tk/day. It integrates 17.1 million tk/month considering 22 working days/month and 2 peaks/day. In case of Dhaka, this cost goes for 322.33 USD million/month considering six types of costs (Khan and Islam, 2013). It indicates congestion cost is more than thousand times larger in Dhaka than Khulna. This loss is huge for a developing country like Bangladesh. As Khulna City is being developed day by day, scenario would definitely deteriorate from the present scenario. Moreover, this loss is a resolution of congestion cost regarding one city. If we consider the cost of congestion for other mega cities of Bangladesh, the exact scenario will give troublesome result without any doubt. So, it is high time to rethink all the possibilities to abate traffic congestion.

5. RECOMMENDATIONS

Based on the overall findings of the study, feasible recommendations are mentioned below:

i. Individual lane for motorized and non-motorized vehicles could be proposed for this NH-7 road. Lower speed variation results in lower congestion cost. Due to heterogeneous traffic composition vehicles cannot acquire their maximum permissible speed. Thus, total cost of congestion (loss due to congestion) increases while speed interruption increases.

ii. Off- street parking could have been a better solution for effective utilization of total road width.

iii. Promoting public transport services (i.e. Bus, minibus etc.) with higher vehicle occupancy could be another effective solution to minimize total cost of congestion.

ACKNOWLEDGEMENT

The authors are thankful to the Deputy Director of Bangladesh Road Transport Authority (BRTA) for his endless support and guidelines during the research work. The authors are also grateful to the editor and two anonymous reviewers for their priceless inputs to this article.

REFERENCES

Ahmed, B., 2011. Modelling Spatio-Temporal Urban Land Cover Growth Dynamics Using Remote Sensing and GIS Techniques: A Case Study of Khulna City. *Bangladesh Institute of Planners*, 4, 15-32.

Ali, M. S., Adnan M., Noman S. M., and Baqueri S. A., 2013. Estimation of Traffic Congestion Cost-A Case Study of a Major Arterial in Karachi. *Procedia Engineering*, **77** (2014), 37-44.

Alvi, M., 2016. A Manual for Selecting Sampling Techniques in Research. Karachi: Munich Personal RePEc Archive, 1-56

Anil, R., Satyakumar D. M., and Basheer S., 2007. Estimating Traffic Congestion & LOS on Urban Roads using GPS Data. Trivandrum: 5th Urban Mobility of India, 1-35

BBS, 2015. Bangladesh Population and Housing Census 2011. Dhaka: Bangladesh Bureau of Statistics, 1-363

Black, A., 1995. Estimating System Costs. In J. W. B. J. Clark (Ed.), *Urban Mass Transportation Planning* (329-347). Brekeley: McGRAW-HILL, 329-347

Chakrabartty, A., and Gupta S., 2015. Estimation of Congestion Cost in the City of Kolkata—A Case Study, *Current Urban Studies*, 3, 95-104.

Committee of Transport Officials., 2013. South African Trip Data Manual. The South African National Roads Agency Limited, 1-84

Freedman, D., 1938. "Sampling" in Statistics, 4th Edition, Freedman D., Pisani R. and Purves R. Ed. United States of America: W. W. Norton & Company, 333-353.

Guttikunda, D., 2008. Simple Interactive Models for Better Air Quality, India: Vehicular Air Pollution Information System, 1-20

Hansen, I., 2000. Determination and Evaluation of Traffic Congestion Costs, *European Journal of Transport and Infrastructure Research*, 1, 61-72.

Henry, S., and Koshy B., 2016. Congestion Modelling for Heterogeneous Traffic. *International Journal of Engineering Research & Technology (IJERT)*, 5(02), 114-119.

Jeffery J., and Hasse P. E., 2006. Vehicle Occupancy Study, Lincoln, Nebaska: The Schemmer Associates, 1-13

Kadiyali, L., 1997. Traffic Engineering and Transport Planning. Delhi: Khanna Publishers, 772-794

Khan, T., and Islam R., 2013. Estimating Costs of Traffic Congestion in Dhaka City. *International Journal of Engineering Science and Innovative Technology (IJESIT)*, 2(3), 281- 289.

Lee, J., Hong B., Lee K., and Jang Y. J., 2015. A Prediction Model of Traffic Congestion Using Weather Data. *IEEE International Conference on Data Science and Data Intensive Systems*, 81-88.

LGED., 2009. Road User Cost Study for LGED Roads. Dhaka: LGED, 30-38

Miller , M., and Li K., 1994. An Investigation of The Costs Of Roadway Traffic Congestion: A Preparatory Step for IVHS Benefits' Evaluation. Berkley: Institute of Transport Studies, University of California, 3-8

Moniruzzaman, M., 2013. Sustainable and Inclusive Transport Development of Khulna City, Khulna: Khulna City Corporation, 1-27

Najneen, F., Hoque K., Mahmood S., Rahman S., and Sharmin M., 2010. Traffic Congestion Due to Unplanned Activities on Road-A Case Study on Gollamari-Satkhira, Outer by-pass (PhaseII) and Gollamari-Batiaghata Road. *Bangladesh research publications Journal*, 2(3), 185-197.

Papacostas, C., and Prevedouros P., 2001. Transportation Engineering & Planning, New Jersey: Prentice Hall, 223-229

Rosenbloom, S., 1978. Peak-period Traffic Congestion: A State-of-art Analysis and Evaluation of Effective Solution, *Transportation,* **7**(2), 167-191.

Shamsher, R. and Abdullah M. N., 2013. Traffic Congestion in Bangladesh- Causes and Solutions: A study of Chittagong Metropolitan City. Asian Business Review, 2(3), 13-18.

Singh, G., and Singh J., 2006. *Highway Engineering* (3rd ed.). Delhi: Standard Publishers Distributors, 69-90

Smeed, R. J., 1968. Traffic Studies and Urban Congestion, *Journal of Transport Economics and Policy,* 2, 33-70.

Sunny, T. M., and Thomas J., 2015. Determination of Congestion Charge for Car Users in CBD Area of Thiruvananthapuram City, *International Journal of Research in Engineering and Technology*, 4(11), 220-227.

Thomas, C., 1968. Value of Time for Commuting Motorists, *Highway Research Record,* 245, 17-35.