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An Assessment of Congestion Cost on Roadway Intersections in Chittagong City, Bangladesh

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Transportation system provides the way for movements and medium for reaching destinations. Inadequate transportation network hampers economic activities and creates hindrances for development of a city. Because of rapid urbanization as well as huge socio-economic activities vehicular movement is increasing in the city centres. As a result, different problems are occurring in transportation network such as traffic congestion, which is decreasing the performance of road network. This congestion bears huge loss in the economy of a country that is known as congestion cost. Roadway intersections are the major place of traffic congestion Traffic congestion has become a common phenomenon in many cities of Bangladesh such as Chittagong which is considered as the commercial capital of this country. In this study an attempt was taken to assess the cost of congestion occurring in a major road of this city. For study purpose three main intersections i.e. Muradpur, 2 No Gate and GEC were selected. Data were collected by primary and secondary sources. Different statistical methods are used to analyse the data. This study will give an idea to the policy makers, engineers and planners about economic consequence of the congestion at the roadway intersections. This will also help to make future policies regarding congestion eradication.

Field of Research: Civil Engineering (Transportation)

Keywords: Transportation, Urbanization, Congestion, Roadway intersection.

1. Introduction

At present the concept of urbanization has become very popular around the world. This is taking place faster both in developed as well as developing countries. But because of rapid urbanization many cities around the world are facing many problems like traffic congestion (Shamsher & Abdullah, 2013). This rapid urbanization is creating myriad challenges into cities transportation system and occurring extreme threat overall economy of a country (Awosusi & Akindutire, 2010). Like many other countries in the world traffic congestion has become a regular phenomenon in many cities of Bangladesh like Dhaka, Chittagong and Khulna (Shamsher & Abdullah, 2013; Najneen, Hoque, Mahmood, Rahman & Shamim, 2010).

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A study shows that in 1997, the annual $75 million economic wastage was occurred around the country (Najneen, Hoque, Mahmood, Rahman & Shamim, 2010). Besides this it creates losses over 08 million working hour in a day (Osman, 2010). Though traffic congestion bears huge negative impact on economy in our country, limited resources are invested to mitigate this problem. Besides this huge population growth, day to day increasing of vehicles on road, poor traffic management are stimulating this problem very much (Shamsher & Abdullah, 2013).

Chittagong is considered as the commercial capital and largest port city of Bangladesh (Qadery & Muhibbullah, 2008).

It has a population of 6.5 million according to population census 2011. The overall economy of our country is greatly boosting by the economic activates of this city. But because of this high economic activities, rapid urbanization and industrial development, traffic congestion has become a common phenomenon in this city (Shamsher & Abdullah, 2013). A studies shows that 21.67% of congestion is occurred at intersection because of indiscriminate parking and stopping of vehicle, 14.66% is for absence of traffic enforcement law, 11.67% is for indiscriminate overtaking and road space occupation, 9.67% is for road construction, 9.67% is for educational activities and road side activities and 6% is for poor signaling system in this city (Qadery & Muhibbullah, 2008). However, few studies are found on the overall congestion cost of this city. In this study an attempt is taken to access to cost of congestion of major intersections of Chittagong city. This will help to understand the negative impact of traffic congestion of this city

2. Literature Review

In the world different ways of transport have been using since the very beginning of human movement where road transport is the most useful one as well as dominates on other way of transport. Among different type vehicles of road transport system, most commons are public buses, taxies, car and freight transport (trucks), and non-motorized (Winder and Morin, 2009). These vehicles create congestion on the road mostly at the roadway intersections during peak period i.e. early part of the day when all activities start up and in the afternoon when business activities end (Ogundipe, 2007). In a basic term, traffic congestion results when the number of vehicles attempting to use a network or network element (e.g. road, intersection) exceeds the capacity or ability of the infrastructure to carry the load (Van et al., 1997). In practice, there are a variety of situations from which congestion may emerge, and these situations often work together to create or increase congestion (Wright & Huddart, 1989). According to the Federal Highway Administration of the United States of America, traffic congestion creates excess vehicles pressure, slower speeds and longer trip times on road network (Mahama, 2012).

Now a day's traffic congestion has become one of the most serious global problems for both developing and developed countries. It implies serious economic threat to the overall economy of any country (Rahman, 2008). In UK every year 6.6 billion US dollar (The Telegraph, 2012), $10.4 bn in India (Arabian Gazette, 2012) losses are occurred due to traffic congestion. In Bangladesh congestion cots is also very high. At Dhaka City every year BDT 19,555 crore loses occur due to traffic congestion

(The Daily Star, 2010). It is a serious economic threat of our country. It cannot afford this huge economic as well as environmental loss resulted from this severe traffic congestion (Shamsher & Abdullah, 2013)

In broad sense traffic congestion cost can be divided into two major types and these are internal cost and external cost. Internal cost occupy vehicle operating cost (VOC) and value of delay time (VOT); external cost occupy accident cost (AC) and environmental cost (EnC) (Kadiyali, 2007).

3. Methodology

Congestion cost (CC) is determined by adding internal cost (IC) and external cost (EC) where IC includes Value of delay time (VOT) and vehicle operating cost (VOC) & EC includes environmental cost (EnC) and accident cost (AC) (Kadiyali, 2007).

So, $CC=IC+EC$

$CC=[VOT+VOC]+[AC+EnC]$

For calculating value of delay time (VOT) some assumptions were followed such as three types of vehicles car (includes passenger car, private car, taxi and CNG auto rickshaw of same occupancy rate), Bus (includes large bus and mini bus of same occupancy rate) and NMV (includes rickshaw and bicycle of same occupancy rate) were considered, all the vehicles that are counted in vehicle count survey had been waiting from the beginning of traffic signal, Interruption in walking' and 'waiting for vehicle' has not been included in the calculation of loss in vehicle time, Journey which the wage earner has made for going to or coming back from work in working period has been considered as working time journey. There were some procedures were followed for calculating VOT such as from vehicle count survey total amount of car, bus and NMV in every direction of three intersections have been counted. Then these numbers were multiplied by their respective occupancy rate. The occupancy rate of car, bus and NMV are 3, 36.4 and 2 successively (Road User Cost Annual Report, 2004-05). Then Total populations passing through these intersections using different types of vehicles per hour as well as well as their percentage were calculated by adding up the number of car user, bus user and NMV user. Sample size of total population has been determined by using confidence level of 95% and confidence interval of 5 and these were distributed among vehicles. Questionnaire survey has been conducted by randomly picking each type of vehicle users at each intersection according to stratified sample size. The questionnaire format was prepared on the basis of vehicle user's age, trip purposes, and individual income. Each type of vehicle users was divided in to some categories such as wage earner user making working trip, non-wage earner and adult user making non-working trip, non-wage earner children user making non-working trip, wage earner user, making non-working trip for going to or coming back from work and Wage earner user, making non-working trip for leisure purposes. Then weighted average of these categories was calculated. Sample size of each user pattern has been considered as

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a weight factor. Then for each intersection, VOT was determined hourly in every direction. Following formulas were used for this calculation:

VOT = VOT (bus) + VOT (car) + VOT (nmv)

VOT (bus) = Delay × Number of bus × Occupancy Rate of bus × weighted average income of bus user

VOT (car) = Delay × Number of car × Occupancy Rate of car × weighted average income of car user

VOT (NMV) = Delay × Number of NMV × Occupancy Rate of NMV × weighted average income of NMV user

Finally by adding all the data of each intersection total amount of VOT was calculated.

For calculating vehicle operating cost (VOC), only extra fuel cost during congestion has been considered. Four types of motorized vehicle were considered (passenger car, bus, 3W-CNG auto rickshaw, truck) whose engines are assumed to be turned on during congestion. For each intersection, consumption of CNG, petrol and diesel has been determined in the congestion time in every direction using following formula:

Cost Per Hour = $(\sum_{(v,f)} N \times D \times FE) \times FC$

Where, where, N is the number of vehicle, v of a specific fuel type f; D is the Delay time in an hour; FE and FC stand for the corresponding fuel efficiency and fuel cost.

To find FE questionnaire survey was done with stratified sample of 95% confidence level and interval of 5. From questionnaire survey, fuel efficiency of specific fuel by each vehicle has been determined

Fuel efficiency (FE) of a vehicle = (Total fuel required when running) / (Total running time).

Then average fuel efficiency of specific vehicle for different fuel was determined. Number of vehicles and delay time were determined by vehicle count survey at each intersection. Using these and existing respective fuel cost VOC per hour is obtained. Total VOC that have been found in each intersection is added to get the total vehicle operating cost in three intersections in an hour.

To determine accident cost (AC) the assumptions were accident occurred due to the collision between vehicles or vehicles and human at any time in a day had been taken. Accident data has been collected from Chittagong Metropolitan Police were then classified on the basis of severity from “Road User Cost Study for LGED Road, 2009”. According to the classification, the total number of the particular type of accident is multiplied by their corresponding rate of average cost by using the following formulae:

Cost of Accident (Fatal) = Average Cost (Fatal) × No. of Accident (Fatal)

Cost of Accident (Grievous) = Average Cost (Grievous) × No. of Accident (Grievous)

Cost of Accident (Simple) = Average Cost (Simple) × No. of Accident (Simple)

Cost of Accident (PDO) = Average Cost (PDO) × No. of Accident (PDO)

Then total accident cost of a particular intersection has been calculated by adding all types of accident costs.

Total Accident Cost = Cost of Accident (Fatal) + Cost of Accident (Grievous) + Cost of Accident (Simple) + Cost of Accident (PDO)

To get the final AC each type of accident cost are converted to discounted value of 2014 by multiplying the conversion factor of 2010.

To calculate environment cost (EnC), assumption were four major pollutants are emitted from motorized vehicle according to 'USEPA (2003) Emission Inventory'. They are Volatile organic compound (V), Oxide of Sulfur (SOx) , Oxide of Nitrogen (NOx) and Particulate Matter -10 (PM-10) (U.S. Environmental Protection Agency, 2003). So only air pollution from four types of motorized vehicles (car, CNG auto rickshaw, bus and truck) was considered to be Environmental cost (EnC). All the vehicles counted in vehicle count survey assumed to be waiting from the beginning of the congestion with their engines turned on. The following procedures of calculating environmental cost were, total amount of emitted pollutants pollutants (V, NOx, SOx and PM-10) from the motorized vehicles (ton/year) collected from Vehicular Emission Inventory of Dhaka City (2004) is converted to mg/min which is then divided by the number of the specific vehicle to get the per vehicle emission rate. This rate is multiplied by number of specific vehicle and delay time to calculate total amount of pollutants (mg) emitted from four categories of vehicles which is then converted to ton/year. The effects of pollutants are determined in terms of money by calculating mortality cost. To determine the cost premature death were determined by:

No. of premature death=V+ 69 SOx+ 97.5 PM10+11.7 NOx (McCubbin & Delucchi, 1996)

Then the Value of Statistical life (VSL) for Bangladesh estimated by Wadud & Khan is used to convert the number of premature death of an infant in monetary terms. Then considering 2013 as base year and discounting each monetary value by inflation rate of USD-BDT mortality cost is determined by:

Mortality costs = No of premature death (N) × Value of Statistical Life (VSL)

Finally by adding these four costs of three intersections total amount of congestion was calculated.

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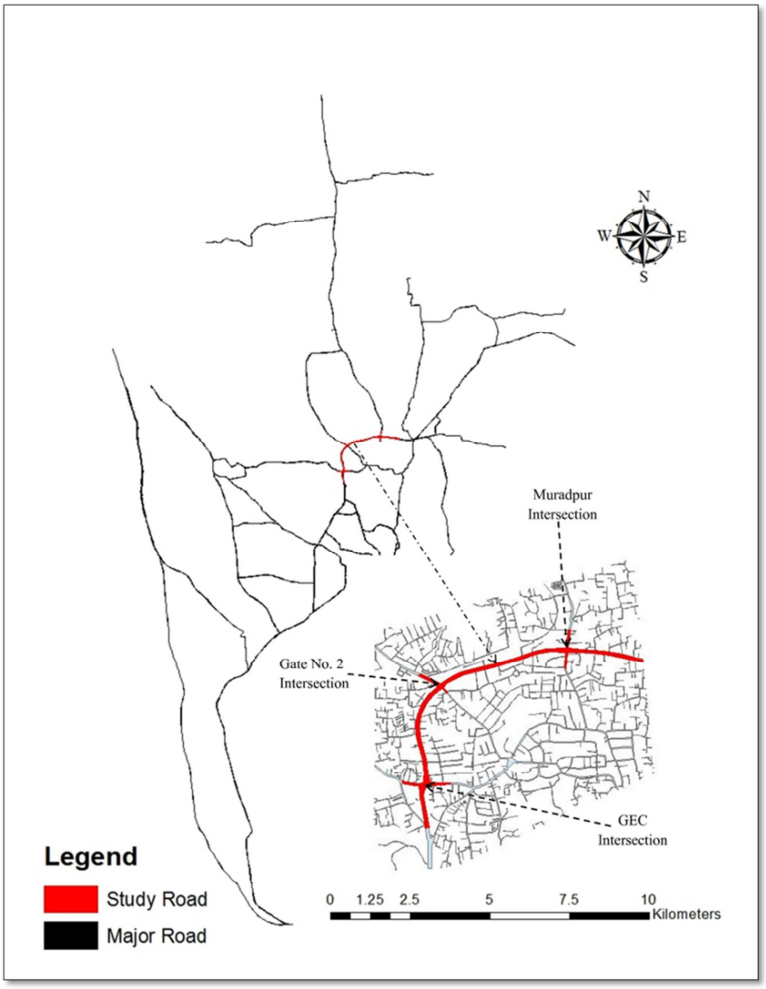
Map 1: Location map of Study Area



Source: CDA, 2010

4. Data Analysis and Findings

The developed methodology was applied to calculate the value of delay time, vehicle operating cost, accident cost and environmental cost and the complete computation has been described and analyzed with the calculation results.

a. Value of Delay Time (VOT)

Evaluation of delay can be considered as the most important part of the congestion cost determination, as the value of travel time saving can be accounted for most of the monetized benefit in cost-benefit analysis (Metz, 2008). The vehicle users passing roadway intersections have to face fixed delay in many times a day which ultimately results in wastage of their time. This wastage of time has an adverse effect on individual's income as well as national income. This can be calculated by

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evaluating value of delay time. In below there is a table showing the overall VOC of the three study intersections.

Table 1: Value of delay tome at three road intersections (2014)

Name of intersection	Name of direction	VOT (BDT) / hour
GEC	WASA – GEC	267915.50
	Wireless- GEC	275380.63
	Gate No. 2 –GEC	352141.23
Gate no. 2	Oxygen - Gate No. 2	317636.23
	GEC - Gate No. 2	282892.48
	Muradpur - Gate No. 2	261188.49
	Probortok - Gate No. 2	180906.34
Muradpur	Bahaddarhat - Muradpur	219502.14
	Gate No. 2 -Muradpur	192691.15
	Oxygen - Muradpur	268734.26
	Panchlais - Muradpur	210631.68

Source: Field survey and analyzed by author 2014

b. Vehicle Operation Cost (VOC)

Vehicle operating cost due to congestion consists of the cost of excess fuel burnt and the cost for the lubricants and additional maintenance for the vehicle. Fuel consumption rates vary depending on the type of vehicle (i.e. gasoline/diesel-

Table 2: Hourly vehicle operating cost at three intersections (2014)

Name of intersection	Name of direction	VOC (BDT) – Hour
GEC	WASA - GEC	24217.02
	Wireless- GEC	24941.32
	Gate No. 2 -GEC	28767.49
Gate no. 2	Oxygen - Gate No. 2	29071.22
	GEC - Gate No. 2	24810.75
	Muradpur - Gate No. 2	22430.81
	Probortok – Gate No. 2	16221.38
Muradpur	Bahaddarhat - Muradpur	19417.93
	Gate No. 2 -Muradpur	16304.19

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	Oxygen - Muradpur	24259.84
	Panchlaish - Muradpur	17924.93
	Total	**248366.93**

Source: Field survey and analyzed by author 2014

powered automobile) and driving environment (i.e. urban versus freeway travel, un-congested versus congested travel). In Bangladesh, there are three types of fuels used for vehicle operation-diesel, gasoline (octane/petrol) and CNG (Compressed Natural Gas). In below total amount of VOC of three intersection is given. And it's showing huge amount of loss is occurring every hour in these three intersections.

c. Accident Cost (AC)

In this study, accident means road accident and accident costs refer to the costs borne by the economy due to occurrence of a road accident. Study carried out so far has shown that the economic value of road accident costs can easily be equivalent to around one per cent of a country's Gross Domestic Product (GDP), a significant drain on any country's resources. Accident cost is considered as an external cost of congestion and it is very difficult to calculate. The main reasons are the unavailability of accident records and difficulties in accommodating intangible cost due to accident. Police report is the only source of accident data.In this study, accident data of these three intersections was collected from Chittagong Metropolitan police.

Table 3: Number of accident at different intersections (2014)

Name of intersection	Fatal	Grievous	Simple	PDO
GEC	0	0	0	3
Gate no. 2	1	0	0	2
Muradpur	0	0	0	0

Source: Chittagong Metropolitan Police, 2014

Human capital method is used in this research for calculating accident cost as it represents the victim's future output as a whole. Sometimes it also prefers to add a sum to reflect the pain and sufferings.

Table 4: Total accident cost at each intersection (2014)

Name of intersection	Total cost of accident	Discounting factor	Total cost (BDT)
GEC	19200	1.375	26400
Gate No. 2	1320700		1815962.5

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Muradpur	0		0
Total	1339900		1842362.5 = 210 BDT/Hour

Source: Field survey and analyzed by author 2014

The above table show the accident cost of the three intersections. This also implies a serious economic loss of our economy.

d. Environmental Cost (EnC)

Environmental pollution is associated with transportation system. It is one kind of external cost of congestion. Traffic congestion causes delay due to transport infrastructure and traffic movement pattern. At roadway intersections fixed delay is occurred which is responsible for extra fuel consumption by motorized vehicle and this extra fuel consumption increases the emission of pollutants. This environmental pollution is responsible for adverse health effect which results premature death in the long run. In this research, mortality costs due to vehicular emission has been determined which represents the environmental cost. The total environmental cost of each intersection is given below:

Table 5: Calculation of hourly mortality cost in different intersections (2014)

Name of intersection	Name of direction	No. of premature death	VSL for Bangladesh (BDT)	Hourly mortality cost (BDT)
GEC	WAS –GEC	0.1456521	22841032	3326845.617
	Wireless - GEC	0.152795363		3490003.777
	Gate No. 2 – GEC	0.20638113		4713957.994
Gate No. 2	Oxygen - Gate No. 2	0.189107786		4319416.987
	GEC - Gate No. 2	0.162806141		3718660.277
	Muradpur - Gate No. 2	0.152727638		3488456.876
	Probortok – Gate No. 2	0.108481178		2477822.069
Muradpur	Bahaddarhat – Muradpur	0.138253901		3157861.772
	Gate no. 2 – Muradpur	0.116284149		2656049.966

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	Oxygen – Muradpur	0.172573048		3941746.516
	Panchlais – Muradpur	0.129865734		2966267.38
			Total	**38257089.23**

Therefore, the hourly Environmental Cost (EnC) for the year 2014 is 38257089.23 BDT.

e. Total Congestion Cost

Total cost is determined by summing up VOC, VOT, AC and EnC. Therefore, hourly congestion cost of three intersections is 41335286 BDT. It's showing that huge amount economic value is wasting per hour as well as per day. That is imposing big negative impact of yearly income of our country.

Table 6: Congestion Cost per hour

Intersection	**Internal cost (BDT)**		**External cost (BDT)**		
	VOT	VOC	AC	EnC	Total
GEC	895437.36	77925.83	3.01	11530807	12504173.2
Gate No. 2	1042623.57	92534.18	207.52	14004356	15139721.27
Muradpur	891559.25	77906.91	0	12721926	13691391.8
Total	3077987 BDT		40099452 BDT		
Grand total	**4,13,35,286 BDT**				

It is seen from the table that external cost is greater than the internal cost of the three intersections and Gate No. 2 occupies the highest amount of cost then the two others.

5. Conclusions

Now a day's traffic congestion has become a global as well as local problem. Gradually this problem is becoming a very common in some big cities in Bangladesh like Dhaka, Chittagong. Day by day rapid urbanization is taking place in these cities. As a result for boosting this urbanization process traffics on this limited road is increasing that causing traffic congestion. Actually, the causes of traffic congestion and its consequences cannot be addressed in isolation. Since Chittagong is dramatically changing its structure in terms of land use, transportation and urban facilities, it requires integrated planning and implementation of its system elements for sound and sustainable urban development. The study shows that traffic congestion has a great negative impact on the economic development of Chittagong as well as the whole country. Sustainable development demands, proper policy innovations, straight law enforcement are crying need to attenuate this problem.

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