Journal of Bangladesh Institute of Planners ISSN 2075-9363
Vol. 8, 2015 (Printed in December 2016), pp. 49-58, © Bangladesh Institute of Planners

Vehicle Operating Cost and Environmental Cost for Delay at Major Railroad Intersections of Dhaka City Corporation Area

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Abstract

At-grade railroad intersections of Dhaka, the capital city of Bangladesh, force a notable amount of motorized vehicles to wait. Often the engines of these vehicles remain turned on during a level crossing signal. The consequences of this incident are the consumption of extra fuel and continuous production of hazardous pollutants.The paper analyzes both the cost of additional fuel required and environmental pollution during a level crossing signal at the major railroad intersections of Dhaka city.

Introduction

Railroad contributes significantly in mass transportation system of Dhaka city by providing accsess to transportation for industrial or personal purposes. From the beginning, it is playing an important role in unifying the country. Several roads including major arterial roads within the Dhaka City Corporation (DCC) area intersect with these railroads. When these railroads are at the same grade with roads, they cause a conflict between two transportation modes, which are different in physical characteristics and operations. Consequently, a variety of problems including delay, safety incidents, waste of fuel and higher pollution are occuring.

The fixed dealy generated by the numerous rail crossings in Dhaka city is difficult to offset by the vehicle users. The most notable user cost due to this delay is extra fuel cost which is over contained by the users. At a level crossing signal, vehicles have to wait for several minutes but this time is not longer enough for the drivers to feel the neccessity of turning off the engines. This leads to consumtion of extra fuel though the amount of consumption by one vehicle is not mentionable as less fuel is required at lower speed. But after the aggregation of fuel consumtions by all waited vehicles, the quantity becomes relatively high. With the increasing train traffic and vehicle levels, more vehicles are being delayed and more fuels are being wasted. In addition to this, price hike of fuels in Bangladesh has raised the misery of common people and adversely affected the economy.

Transport Canada Environmental Affairs (2006) estimated the cost of fuel wasted in congestion depending on the fuel consumption rate of various types of vehicle and unit prices of the fuel. According to this research, unit prices may vary from city to city and also according to fuel type. Furthermore, fuel consumption rates continue to vary with changing speed. These research shows that fuel consumption tends to increase with increased congestion.

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The situation becomes worst when burning of these extra fuel boosts up the emission of pollutants. In 2003, the then Bangladesh Government banned baby taxi, a two stroke three wheeled auto mobile, as its exhaust reduce the air quality dangerously. After that, the replacement of petrol with Compressed Natural Gas (CNG) significantly decreased the volume of air contaminants. But, according to the Department of Environment, a sharp increase in the number of vehicles in 2004-2008 led to a deterioration in Dhaka's air quality (IRIN Asia, 2009). According to USEPA (1994), there are some major pollutants in vehicle exhaust like NOx the Oxides of Nitrogen, PM—Particulate Matter, CO—Carbon Monoxide, HCHO, and SOx the Oxides of Sulfur. The inhaling of excess of these pollutants may cause premature death in the long run. National Institute of Diseases of Chest and Hospital (NIDCH) mentioned that nearly seven million people in Bangladesh suffer from asthma. More than half of them are children. It also said that cases of children suffering from bronchitis and chronic coughs have also shot up in recent years (IRIN Asia, 2009).

There are some methods to evaluate environmental cost in monetary term which are used in several studies. They are willingness to pay (WTP), direct methods, indirect methods, monetary valuation of mortality and morbidity etc. In this research, monetary valuation of mortality and morbidity has been used. The advantage of the model is its simplicity and availability of numerous Value of Statistical Life (VSL) estimates. VSL reflects the aggregation of individuals' willingness to pay for fatal risk reduction and therefore the economic value to society to reduce the statistical incidence of premature death in the population by one. This approach values every life lost as equal, irrespective of whether the remaining life expectancy of the people dying is a few weeks or many years (Rahman, 2010). According to Economist's View (2008), the VSL is the amount that the people are willing to pay to reduce the probability of death they face (Wadud and Khan, 2010).

A study named 'Relative Contribution of Transport Modes to Air Quality Related Mortality Impacts in USA' used VSL to determine mortality cost. The lower values of VSL are generally found from Contingent valuation studies, while the higher values are found from Revealed Preference Studies.

Different estimated values of VSL have been recommended by several researchers. In 2000, Miller suggests a value of US$ 40,000 with a range of US$30,000 – US$ 0.7 million. Mahmud estimates VSL for Bangladesh to be in the range of US$ 1,783 to US$ 2,922 in 2005. But this estimation is very smaller compared to the previous study. In 2010, Wadud and Khan suggest US$ 190,000 as the median VSL estimates for Bangladesh, while the lower and upper bound values are respectively US$ 53,000 and US$ 327,000. In Bangladeshi currency, it becomes approximately 1,47,38,300 Taka.

In general, grade separations such as overpasses and underpasses between rail lines and surface streets, are used to reduce the problems related to grade crossings. The construction of these overpasses and underpasses can effectively eliminate the delays associated with grade crossings. But for a developing country like Bangladesh, grade separations can be very expensive solution and less feasible. Due to these financial constraints, feasibility studies are required before taking decisions to determine the cost of fuel and environmental pollution in railroad intersection. It is expected that this kind of output can be used for policy implementation. A policy in the structure plan of Dhaka City Corporation (DCC) suggests for relocation of existing rail track between Khilgaon and Khilkhet (DMDP, 1995). The outcomes of this research may help the researchers, planners and policy makers to conduct railroad same grade intersection treatment properly.

Objective and Assumptions

The main purpose of this study is to determine the cost of extra fuel and environmental pollution due to the congestion at railroad intersections of Dhaka City Corporation (DCC) area. The following assumptions are considered in this study.

- It has been assumed that, all the vehicles that are counted in vehicle count survey were waiting from the beginning of the level crossing signal.
- Engines of all motorized vehicles were considered to be turned on and fuels are being consumed during the congestion period.
- Only air pollution due to the extra fuel consumption by the motorized vehicles has been considered.
- Emission of only four major pollutants were considered in calculating environmental cost.

Selection of Study Area

A development plan for Dhaka metropolitan area, titled as Dhaka Metropolitan Development Plan (DMDP) was prepared by capital development authority of Bangladesh. It covers 1528 sq. km of land including the area of former DCC. There are a total of 50 railroad intersections in the DMDP area and among them 40 are in the DCC area. Some of them are intersecting the roads which have high volume of traffic flow. Among these rail crossings across the DCC area, 28 rail crossing gates are authorized by Bangladesh Railway and twelve are unauthorized (Divisional Engineer-1, Bangladesh Railway, 2011).The nine authorized rail crossing gates are in the same grade with the major arterial roads and are divided into two categories. Six intersections have accessibility for both motorized and non-motorized and only three intersections are only for motorized vehicles. All of these nine intersections have been considered as the study area for this research.

Cost of Additional Fuel

A detailed reconnaissance survey was conducted to assess the present condition of the study area which has provided a guideline for necessary surveys required for this research. After that, vehicle count survey, delay time survey and questionnairy survey were conducted.

According to Road Master Plan 2009 (RHD, 2009) of Dhaka city, the motorized vehicles are classified into car, three wheeled auto (3W-Auto), taxi, bus, truck and motorcycle. In this research, the vehicle count survey has been conducted for these categories of motorized vehicles. Also a delay time survey was conducted. Delay time and vehicle count survey were conducted on a working day for each intersection. For a specific day (7:00am – 7:00pm), every moment when a train passes through the intersection point, time counting has started and vehicles were counted during that time.

From vehicle count survey, it has been seen that the volume of motorized vehicles is high in Malibag, Senakunja, Mahakhali and Kuril area. The lowest volume is at Saidabad. Vehicles at other intersections are in average number. Total amount of car, 3W-Auto, taxi, bus, truck andmotorcycle passing through these nine intersections were also found from the vehicle count survey. It is found that volume of car and 3W-Auto is higher than other vehicles (See Table 1).

Afterward, sample size of each type of vehicle has been calculated for a questionnaire survey by using 95% confidence level and confidence interval of 5. The sample size for car is 380. Likewise, the sample sizes of 3W-Auto, taxi, bus, truck and motorcycle are respectively 102, 245 and 39. The formula for sample size is:

$Sample\ Size = \frac{P\times(1-P)\times Z^2}{C^2}$ (Reference)

Where,

Z = Z value (e.g. 1.96 for 95% confidence level)

P = Percentage picking a choice, expressed as decimal

C= Confidence interval, expressed as decimal

Table 1: Composition of different vehicles at different intersections

Intersection	Passenger car	3W-Auto	Taxi	Bus	Truck	Motorcycle	Total
Saidabad	67	456	10	698	17	74	1322
Khilgaon	739	1610	103	211	35	1299	3997
Malibag	6714	2782	463	2092	504	954	13509
Maghbazar	2887	1543	103	458	100	618	5709
FDC	2234	1227	201	94	97	426	4279
Mahakhali	4998	3414	305	1738	2	794	11251
Banani	2282	1205	201	112	5	404	4209
Senakunja	13161	3686	1214	2597	844	972	22474
Kuril	5754	1936	564	3854	495	771	13374
Total	38836	17859	3164	11854	2099	6312	80124
Sample Size	**380**	**372**	**376**	**343**	**362**	**325**	

Source: Field Survey, 2011

Questionnaire survey was conducted by picking vehicle randomly at each intersection following stratified sampling. The questions were asked to the user of the vehicle about the type and amount of fuel required by the respective vehicle per day. It is found that three types of fuel – petrol, diesel, and CNG are being used by these motorized vehicles of Dhaka city. Both the petrol and CNG are used in cars and buses. Of the cars, only 10.79% use petrol and others use CNG. Likewise, only 21.28% of buses use petrol and others are CNG-driven. However, taxi and 3W-Auto use only CNG. On the other hand, all motorcycles are driven by petrol. Diesel is only used in truck. Beside the types of fuel, running hour per day was also asked in the questionnaire. From these data, per minute consumption rate of specific type of fuel by each vehicle is determined. The average of the consumption rates has been determined by using the following equation:

$$Average\ consumption\ rate\ (ACR) = \frac{\sum \frac{Total\ fuel\ required\ while\ running}{Total\ running\ time}}{Number\ of\ vehicle}$$

Table 2: Average Cconsumption Rate of Fuelby Different Vihicles

Vehicle type	**Petrol (lt/min)**	**Diesel (lt/min)**	**CNG (m3/min)**
Car	0.025		0.031
Bus	0.033		0.078
CNG Auto rickshaw			0.015
Taxi			0.034
Motorcycle	0.015		
Truck		0.079	

Source: Field Survey, 2011

From the delay time survey, it has been watched that trains pass for several times through a rail crossing intersection. A manual signaling system was provided to alert the people when a train approaches and a hand operated gate blocks the roads, so that no vehicles could pass. The extent of delay depends on this frequency of signals. As the frequency increases, the length of total delay also increases. Table 3 shows that frequency of level crossing signal is the highest in FDC Rail Gate and it causes 64.63 minutes of delay. On the other hand, the length of delay at Saidabad is only 45.5 min in a day, as the number of passing train through this intersection is the lowest. Width of the road is another factor that influences the length of delay. If the width of the road, intersected by the rail track increases then the length of delay will also increase. For example, at Senakunja, the length of delay is 128.22 min, but the number of level crossing signal is not the highest.

For each intersection, consumption of extra CNG, petrol and diesel has been determined every time a train has approached through the rail line. The following formula has been used for this calculation:

$$\begin{aligned} CNG\ consumption(m^3) &= Total\ delay \times [(number\ of\ CNG\ driven\ car \times ACR\ of\ CNG\ driven\ car) \\ &+ (number\ of\ CNG\ driven\ bus \times ACR\ of\ CNG\ driven\ bus) \\ &+ (number\ of\ CNG\ Auto\ rickshaw \times ACR\ of\ CNG\ Auto\ rickshaw) \\ &+ (number\ of\ taxi \times ACR\ of\ Taxi) \end{aligned}$$

$$\begin{aligned} Petrol\ consumption(lt) &= Total\ delay \\ &\times [(number\ of\ petrol\ driven\ car \times ACR\ of\ petrol\ driven\ car) \\ &+ (Number\ of\ petrol\ driven\ bus \times ACR\ of\ petrol\ driven\ bus) \\ &+ (Number\ of\ motorcycle \times ACR\ of\ motorcycle) \end{aligned}$$

$$Diesel\ consumption(lt) = Total\ delay \times number\ of\ truck \times ACR\ of\ truck$$

Table 3: Consumption of Extra Fuel in Each Intersection

Intersection	No of approach	Total delay (min)	CNG consumption (m3)	Petrol consumption (lt)	Diesel consumption (lt)
Saidabad	14	45.5	179.46	19.16	2.68
Khilgaon	32	124.45	279.49	102.24	15.71
Malibag	34	77.38	877.02	105.53	92.74
Maghbazar	36	63.33	244.82	35.14	13.21
FDC	37	64.63	205.53	27.73	14.27
Mahakhali	33	60.1	564.58	65.12	0.22
Banani	37	90.72	236.05	31.87	0.86
Senakunja	35	128.22	2475.07	259.34	236.26
Kuril	36	96.97	1241.79	141.09	106.68
Total	294	751.3	6303.81	787.22	482.63

Source: Field Survey, 2011

According to Petrobangla (oil, gas and mineral corporation of Bangladesh), unit cost of CNG, diesel and petrol are correspondingly 30 BDT/ m3, 56 BDT/lt and 86 BDT/lt. Total cost of fuel wasted in each intersection has been calculated using the following formula:

$$
\begin{aligned}
Fuel\ Cost = {} & (Total\ CNG\ consumption \times Unit\ cost\ of\ CNG) \\
& + (Total\ petrol\ consumption \times Unit\ cost\ of\ petrol) \\
& + (Total\ diesel\ consumption \times Unit\ cost\ of\ diesel)
\end{aligned}
$$

Cost of extra consumption of fuel, while passing through these intersections throughout the year is 103.6 million BDT.

Table 4: Daily and Annual Additional Fuel Cost

Intersection	VOC (BDT) - Daily	VOC (million BDT) - Annual
Saidabad	7180.97	2.62
Khilgaon	18047.21	6.58
Malibag	40575.99	14.81
Maghbazar	11104.65	4.05
FDC	9347.78	3.41
Mahakhali	22547.64	8.23
Banani	9868.42	3.60
Senakunja	109780.02	40.07
Kuril	55358.51	20.21
Total	283811.18	103.59

Source: Field Survey, 2011

Cost of Air Pollution

There are several pollutants that exhaust from the motorized vehicles of Dhaka city. Among these pollutants, major four are volatile organic compound (VOC), oxides of nitrogen (NO_X), oxides of sulfur (SO_X) and particulate matter-10 (PM-10) are considered to be menacing for mankind. The data on annual emission of these pollutants from different motorized vehicles has been collected from Vehicular Emission Inventory of Dhaka City.

Table 5: Vehicular Emission Inventory of Dhaka City

Vehicle	**Number (2004)**	**Emission (tons/year)**			
		NOx (ton)	**SOx (ton)**	**VOC (ton)**	**PM-10 (ton)**
Car	130827	2865	153	7640	191
Taxi	8600	612	0	816	12
3W-auto	11500	819	0	1091	16
Bus	12370	9978	470	2348	939
Truck	19307	7188	338	1691	677
Motorcycle	116320	382	25	5095	127
Total	298924	21844	986	18681	1962

Source: Khaliquzzaman(2006)

After dividing the annual emission of different pollutants by the number of cars, annual emission per car is derived. The procedure for car:

$$\text{Emission rate of NOx} = \frac{Amount\ of\ NOx}{Number\ of\ car}$$

$$\text{Emission rate of SOx} = \frac{Amount\ of\ SOx}{Number\ of\ car}$$

$$\text{Emission rate of VOC} = \frac{Amount\ of\ VOC}{Number\ of\ car}$$

$$\text{Emission rate of PM} - 10 = \frac{Amount\ of\ PM - 10}{Number\ of\ car}$$

Same procedure has been followed for taxi, 3W-auto, bus, motorcycle and truck. From the Table 6, it is observed that SO_X and PM-10 are mostly generated by buses. On the other hand, most of the NO_X is realesed from trucks. Taxi and 3W-auto realese maxium amount of VOC.

Table 6: Emission Rate per Vehicle

Vehicle	**Emission Rate per Vehicle (tons/year)**			
	NOx	**SOx**	**VOC**	**PM-10**
Car	0.02190	0.00117	0.05840	0.00146
Taxi	0.07116	0.00000	0.09488	0.00140
3W-auto	0.07122	0.00000	0.09487	0.00139
Bus	0.80663	0.03800	0.18981	0.07591
Truck	0.37230	0.01751	0.08758	0.03507
Motorcycle	0.00328	0.00021	0.04380	0.00109

Source: Field Survey, 2011

Using the emission rates, total amount of NO_X, SO_X, VOC and PM-10 emitted from the waiting of different vehicles in an intersection due to level crossing signal have been calculated. The equations followed are:

$$\begin{aligned} &Amount\ of\ NOx\ in\ an\ intersection \\ &\quad = Delay[(Emission\ rate\ from\ car \times Number\ of\ Car) \\ &\quad + (Emission\ rate\ from\ Taxi \times Number\ of\ Taxi) \\ &\quad + (Emission\ rate\ from\ 3W - auto \times Number\ of\ 3W - auto) \\ &\quad + (Emission\ rate\ from\ Bus \times Number\ of\ Bus) \\ &\quad + (Emission\ rate\ from\ Truck \times Number\ of\ Truck) \\ &\quad + (Emission\ rate\ from\ Motorcycle \times Number\ of\ Motorcycle)] \end{aligned}$$

Likewise, the amount of SO_X, VOC and PM-10 generated in each intersection has been determined. It is understood that the amount of generated pollutants is remarkably higher in Senakunja and Kuril railroad intersection. On the other hand, a notable amount of pollutant is also produced in Malibag and Mahakhali intersections.

The effect of pollutants has been determined in monetary term by calculating mortality cost. To calculate this cost, the number of premature death of an infant has been determined. McCubbin and Delucchi followed a grouping strategy to determine the number of premature death in each intersection. The equation is given below:

$$Number\ of\ Premature\ Death \equiv V + 69\,SOX + 97.5\,PM10 + 11.7\,NOX$$

(McCubbin and Delucchi, 1996)

Afterwards, the Value of Statistical life (VSL) for Bangladesh has been used to convert the number of premature death of an infant in monetary terms. In 2010, Wadud and Khan suggest 14.738 Million BDT as the median VSL estimates for Bangladesh. So, Mortality cost is determined by multiplying VSL with number of premature death.

Table 7: Amount of Emitted Pollutants in 2011

Intersection	**Pollutants**				**Number of premature death**	**VSL** (million BDT)	**Total Cost** (million BDT)
	NOx (ton)	**SOx (ton)**	**VOC (ton)**	**PM-10 (ton)**			
Saidabad	1.41	0.06	0.43	0.13	34	14.738	501.10
Khilgaon	1.01	0.03	0.95	0.07	22		324.24
Malibag	3.64	0.16	1.90	0.31	86		1267.49
Maghbazar	0.72	0.03	0.55	0.06	17		250.55
FDC	0.39	0.01	0.47	0.02	9		132.64
Mahakhali	2.23	0.09	1.27	0.18	52		766.39
Banani	0.41	0.01	0.52	0.02	9		132.64
Senakunja	8.74	0.37	5.04	0.73	205		3021.35
Kuril	6.84	0.31	2.62	0.61	164		2417.08
Total	25.39	1.07	13.75	2.13	598		8813.50

Source: Field Survey, 2011

Conclusion

The output of this research reflects the adverse effect of congestion at railroad intersections. From this case study of Dhaka, it is seen that total daily loss of time is 751.3 minutes in nine intersections. Due to this extra waiting period, annual cost of required additional fuel is 103.59 million BDT. This is also responsible for air pollution and its annual monetary value is approximately 8813.50 million BDT which is very alarming for Dhaka city.

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