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Estimating Costs of Traffic Congestion in Dhaka City

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Abstract*— Dhaka, the capital city of Bangladesh, is one of the most traffic congested cities in the world. For any policy making to deal with the situation efficiently, the impact of traffic congestion on the national economy must be ascertained. This paper estimates in monetary terms, the cost of traffic congestion, the state is currently facing. The time spent on travelling has an opportunity cost and is the most important item cost of the total congestion cost which also includes travel time variability losses, i.e. TTV, arising from unpredictability of the journey time. This study calculates travel time costs, TTC (using value of time, VOT approach) and Vehicle operating cost, VOC, due to traffic congestion directly while it makes allowances for TTV, Dead-weight loss, DWL- the avoidable social costs of congestion, externality cost due to travel time delay (imposed on others) and environmental damages. Estimated annual TTC is obtained as about USD 1499 million per annum after allowing for the estimated TTV. VOC due to congestion is estimated yearly as USD 196 million. Adding up the Delay externality (USD 1049 million), DWL (USD 749 million) and environmental externality cost (USD 375), the total annual cost due to traffic congestion in Dhaka is found to be USD 3868 million.

Index Terms— **Dhaka, Traffic congestion, Travel-time delay.**

I. INTRODUCTION

Dhaka, the capital city of Bangladesh, is one of the most traffic congested cities in the world. For any policy making processes to deal with the worsening situation, it is the initial priority to estimate the impacts of traffic congestion on the overall national economy in monetary terms. Besides, estimates of congestion costs give the value that can be imposed on the road users as 'congestion pricing'- a very effective and widely used method of traffic demand management. This paper work is intended to determine the costs of traffic congestion in monetary terms the state is currently facing.

Congestion pricing or congestion cost is a system of surcharging users of a transport network in periods of peak demand to reduce traffic congestion. Examples include some toll-like road pricing fees, and higher peak charges for utilities, public transport and slots in canals and airports. This variable pricing strategy regulates demand, making it possible to manage congestion without increasing supply. Market economics theory, which encompasses the congestion pricing concept, postulates that users will be forced to pay for the negative externalities they create, making them conscious of the costs they impose upon each other when consuming during the peak demand, and more aware of their impact on the environment. Four general types of systems are in use; a cordon area around a city center, with charges for passing the cordon line; area wide congestion pricing, which charges for being inside an area; a city center toll ring, with toll collection surrounding the city; and corridor or single facility congestion pricing, where access to a lane or a facility is priced.

From literature background, in general, congestion pricing is a concept from market economics regarding the uses of pricing mechanisms to charge the users of public goods for the negative externalities generated by the peak demand in excess of available supply. Its economic rationale is that, at a price of zero, demand exceeds supply, causing a shortage, and that the shortage should be corrected by charging the equilibrium price rather than shifting it down by increasing the supply. Usually this means increasing prices during certain periods of time or at the places where congestion occurs; or introducing a new usage tax or charge when peak demand exceeds available supply in the case of a tax-funded public good provided free at the point of usage.

II. OBJECTIVES OF THE STUDY

The major objective of the study is to estimate the impacts of traffic congestion in monetary terms for Dhaka city. For the accomplishment of the stated objective, first of all, a detail framework of the procedure of computing the traffic congestion cost is formulated. This mainly covers the identification of different important item costs

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associated with traffic congestion using economic theory, i.e. travel time delay, travel time variability, vehicle operating cost, externality costs etc. Then, the best methods and data to estimate these item costs are proposed. Finally, the traffic congestion cost is estimated following the proposed framework and available data. Hence, the objectives can be summarized as follows:

1. Identification of the important item costs of traffic congestion
2. Proposing the methods and data to estimate different item costs
3. Estimation of the total traffic congestion cost of Dhaka city with the available data

III. METHODOLOGY & DATA

In general, the total congestion cost is made up of different costs, primarily of travel time delay costs and vehicle operating (fuel) costs. Another very important part is the externality cost (i.e. costs imposed on others, not individual private costs) due to traffic congestion. Externality includes the effects on the individual groups, society or the environment resulting from the activities of some other groups of people. In terms of travel time delay, it measures the delay costs imposed on others due to an extra motorist entering in the road and therefore it is the difference between the average cost and marginal cost. Delay externality and the Dead-weight loss (DWL) are often measured as a part of the total travel time delay costs, which will be discussed later in this section. Other most pronounced relevant externalities are air pollution, noise pollution or environmental/climate damages. Road traffic accident cost due to traffic congestion may be a part of the total congestion cost, but it is not included in the total cost estimation of this study because of some reasons that will be discussed in the Discussions section. In general, the estimation of total congestion cost can be written mathematically as:

$$TCC = TTC + DWL + Ed + VOC + Ee \qquad (1)$$

where, TCC = Traffic congestion cost

TTC = Travel time cost

DWL = Dead-weight loss (Avoidable Social Cost)

E_d = Travel delay externality cost

VOC = Vehicle operating cost (excess fuel cost due to congestion)

E_e = Environmental externality cost (air/noise pollution)

Of the components mentioned above, the study directly estimates TTC and VOC and for the remaining items, allowances are included which are estimated empirically.

The most pronounced and also the most familiar component of the traffic congestion cost is the travel time delay; commonly known as the travel time costs. It is the economic concept that the time spent on travelling has an opportunity cost as it could be used for alternate activity which could produce some significant utility. The most widely used approach to estimate the associated cost is to impose the Value of Time (VOT) on the calculated delay due to congestion. By definition, VOT is the monetary value that a person will be ready to pay for a unit travel time reduction or it is the estimates of hours lost due to congestion in monetary terms, usually determined from 'willingness-to-pay' (WTP) surveys. It certainly depends on many factors, i.e. socio-economic condition of the traveler, trip purpose, condition of travel or the mode types, time of travel and there are lots of estimates available in literature regarding VOT depending on the various factors that affect VOT.

Along with the travel time losses, there is another important cost arising from the unreliability or unpredictability of the journey times (mostly at peak periods of the day). This adds to the actual value of VOT.

Estimating Travel Time Cost (TTC)

Ideally, the model for computing TTC (for passenger travel) should be of the following form that includes all the effects of various factors:

$$TTC = \sum_i \sum_j \sum_k \sum_m (t \times TT \times VOT)_{ijkm} + TTV \qquad (2)$$

where, TTC = Travel time cost per vehicle-person per day

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t = % Trips
TT = Travel Time
i = vehicle type
j = trip purpose (i.e. work trip, W.T. or non-work trip, N.W.T)
k = Time factor (peak or off-peak hour)
m = allowance for short distance and/or less-time sensitive trips (L.T.S)
VOT = Value of Time (varying according to travel condition, travel time, mode choice, travel purpose etc)
TTV = Travel Time Variability

Due to lack of specific detail data on different factors, i.e. the portion of trips in a particular mode for different trip purposes and for different travel times (peak/off-peak hours), the formula stated in (2) is modified according to the currently available data and shown in (3) below. But with specific necessary data, travel time cost can be computed from (2). Therefore, the modified model for estimating traffic congestion cost is:

$$\text{Total TTC per day} = \%W.T. \times [\sum_i (TT_{i,W.T.} \times VOT_{i,W.T.} \times O_i \times N_i)] + \%N.W.T. \times [\sum_i \sum_m (TT_{i,m,N.W.T.} \times VOT_{i,m,N.W.T.} \times O_i \times N_i)] \quad (3)$$

Where, W.T. is the working trips (assumed to occur during peaks only) and N.W.T. is the non-working trips with different values of time (VOT) for a particular vehicle type i;

TT is the travel time for mode i determined from average vehicular kilometers travelled VKT (Km/day) and average speed. Speed is varied according to travel time condition (peaks/off-peaks). For a certain time condition (peak/off-peak),

TT_i (hr) = Average VKT_i / Average $speed_i$;

O is the passenger occupancy of the vehicle i and N is the number of vehicle i.

The major assumptions made for the estimation procedure of and relevant to the TTC are listed below:

1. All commuter or work trips are assumed to occur at the peak hours only and similarly all non-work trips are assumed to occur at the off-peak hours only
2. Average speed corresponding to economically efficient volume (discussed later) of traffic is assumed to be equal to 30 km/hr for all the vehicles and for buses 25 km/hr [4]
3. Working and non-working trips are assumed to have a 50-50% split
4. TTV, DWL and delay externality costs are estimated approximately from previous observations, not using theoretical approach

The VOT (Value of time) values for Dhaka city from willingness-to-pay survey regarding traffic congestion are collected from [4]. After reviewing the literature, 1.5 times greater VOT is adopted for the peak hour than that for the off-peak hour or N.W.T. trips. For the L.T.S trips, the off-peak hour VOTs' are halved for all the vehicles. 5% of the N.W.T. trips are assumed to be short distance trips and assigned zero VOT on those trips' travel time and 10% of the N.W.T. trips are considered as L.T.S trips [3].

About TTV losses, it may sometimes be incorporated within the VOT itself implicitly. It may be computed separately and added to the total direct travel time loss (as in (2) or (3)) or may be included within the VOT, knowing the precise values of variability and travel time, if possible. For this study, 25% allowances of the total travel time delay costs are assumed [3]. Table I enlists all the data necessary for the computation of travel time costs.

Table I: Data for Travel Time Cost Estimation

Vehicle Type	Bus	Taxi	Auto-rickshaw	Auto-tempo	Car
No. of vehicle	16527	12000	4200	10620	147283
Occupancy	35	2	2	10	3
Daily VKT (Km/day)	150	200	150	150	60
Avg Speed (km/hr)	16	20	20	20	20
Desirable Speed (km/hr)	25	30	30	30	30

VOT (W.T.) - *BDT/hr	72	80	77	50	80
VOT (N.W.T.) - *BDT/hr	48	54	52	34	54
VOT (less time-sensitive, LTS) - *BDT/hr	24	27	26	17	27

Data Sources: [2], [4], [5]; *Bangladeshi Currency

There is another very efficient and precise approach for estimating travel time losses, namely dead-weight losses (DWL) approach. According to dead-weight loss approach, the effective cost that can be saved with proper measures to reduce congestion is determined as the avoidable social cost or the cost of doing nothing about traffic congestion. DWL corresponds to the cost beyond a certain level of traffic that is said to be the economically efficient traffic volume on the road. This point can be identified by the point Q (the intersection of the demand curve with the marginal cost) on the Fig. 1 which represents the economical analysis of congestion.

Knowing the travel demand curve and plotting the average cost function and marginal cost function (differentiated average cost function), Q, A, P, T, C etc required points can be located and the area TPA corresponding to the delay externality cost and also the area APQ corresponding to the DWL can be estimated with respect to the area, TPC, i.e. the total congestion cost.

Reference [3] has estimated that typically externality cost is 60-75% of the total delay cost with the average being 70%. The DWL is estimated to be around 50% of the total cost, typically ranging between about 30-55%. In this paper, these are estimated as being 70% and 50% respectively of the computed total TTC and are added with other costs to determine the total congestion cost from (1).

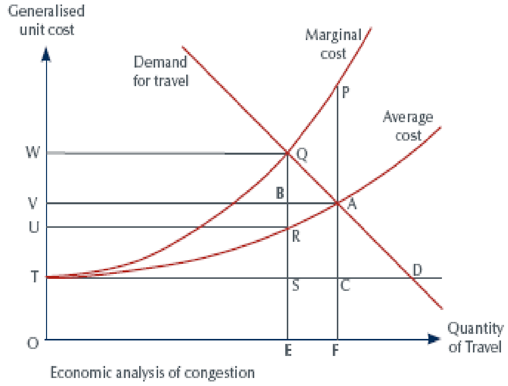

Fig. 1: Economical analysis of Congestion

Along with delay externality, there is another form of externality cost associated which is environmental externality, mentioned earlier. This refers to the health effects due to increased emissions of pollutants due to slower speed and stop-and-go situation of the vehicles in traffic congested condition. For this parameter to be determined, the most necessary information is to know the relation between vehicle speeds vs. emission rates of the different pollutants which are likely to emit more in interrupted flow condition from vehicles. Due to lack of this information for Dhaka currently, this cost item is not directly evaluated in this study but a framework is proposed which can be used to estimate this parameter if the information is available. The information which are required for the computation are summarized below:

1. Vehicle speed vs. emission rates of the pollutants
2. Fractions of high emitting vehicles (i.e. super-emitters) and their emission factors
3. Generating emissions inventory and comparison between two conditions, i.e. congested and uncongested conditions
4. Exposed population groups
5. Quantifying the health effects (using Value-of-statistical-life approach) and climate impacts from estimated greenhouse gas/aerosols emissions associated (using social cost of carbon)

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In absence of the established relationship between vehicular speed and emission rates, this cost is taken from [4]. Reference [4] has stated a rough estimate on the cost of environmental damage due to congestion on the basis of additional medical cost arising from the air quality related diseases and deaths which is about USD 375.6 million.

Estimating Vehicle Operating Cost

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-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 the current study, first the fuel consumption cost is made for three types of fuel for all vehicle types and then excess fuel burnt cost is determined with respect to congested and uncongested travel condition.

Total cost without congestion: For a specific type of vehicle,

$$Cost\ per\ day = \sum_{v,f} (N \times A \times FE \times FC) \qquad (4)$$

where, N is the number of vehicle, v of a specific fuel type f;
A is the average run per day;
FE and FC stand for the corresponding fuel efficiency and fuel cost.
Total cost with congestion: A local survey estimated that the average additional cost due to the congestion, is about 40% of the cost incurred in the congestion [4]. So, for a specific type of vehicle,
Total fuel cost /day with congestion = 1.4 times the Total fuel Cost without congestion in (4)
Therefore, Lost Fuel Cost per day = Total fuel cost /day with congestion - Total fuel cost /day without congestion
Hence, Annual Lost Fuel Cost = Lost Fuel Cost per day * 240 days (240 working days assumed instead of 365 days of a year).

IV. RESULTS & ANALYSIS

Total travel time cost is calculated according to (3). For each part of the calculation, i.e. for the different vehicles, obtained cost is multiplied by 240 working days in a year to get the total annual cost for a particular vehicular category. All are summed up and allowing travel time variability as having 25% contribution to the whole TTC, the total travel time cost due to congestion is estimated which are shown in Table II.

Table II: Travel Time Cost Estimates

Vehicle Type	Yearly TTC - (50%) W.T. (USD million)	Yearly TTC - (42.5%) N.W.T. (USD million)	Yearly TTC - 5% LTS *(10% of N.W.T)* (USD million)
Bus	600.7	217.9	12.8
Taxi	29.5	11.3	0.66
Auto-rickshaw	7.5	2.9	0.17
Auto-tempo	61.3	23.6	1.4
Car	163	62.4	3.7
Yearly TTC for a trip purpose for all vehicles (USD million)	862	318	18.7
Yearly Total TTC (USD million)		1198.8	
TTV losses (25% of TTC, USD million)		300	
Total TTC including variability (USD million)		1498.5	
Delay Externality, Ed (70% of total TTC, USD million)		1049	
DWL (50% of total TTC, USD million)		749	

Vehicle Type	*Number of Vehicle***			*Average Run per day (km)***			*Fuel Economy (litre/km or m^3/km)***			*Regular Fuel cost/day (USD million)*	*Congested Fuel cost/day (USD million)*	*Yearly Cost (USD million)*
	Diesel	Gasoline	CNG	Diesel	Gasoline	CNG	Diesel	Gasoline	CNG			
Car	0	20620	126663	50	50	60	0	0.111	0.111	0.46	0.64	44.2
Jeep/SUV	2989	4396	10197	75	60	65	0.125	0.143	0.125	0.1	0.14	9.6
Microbus	2872	2872	35282	55	50	100	0.125	0.143	0.125	0.21	0.29	20
Taxi	0	0	12000	200	200	200	0	0.111	0.111	0.102	0.143	9.95
Bus	1970	0	6240	150	150	150	0.333	0	0.333	0.19	0.28	18.85
Minibus	749	0	7568	150	150	150	0.25	0	0.25	0.13	0.18	12.85
Auto-rickshaw	0	0	14820	150	150	150	0	0.04	0.111	0.095	0.13	9.1
Motor Cycle	0	219443	0	55	55	55	0	0.03	0	0.44	0.61	41
Others	2093	1196	26616	50	50	100	0.125	0.143	0.125	0.15	0.21	13.
Excess Cost of Fuel Burnt due to Congestion												178.55

Table III: Cost of Excess Fuel Burnt due to Traffic Congestion

****Data Sources: [1], [2], [5]**

Table II also includes the delay externality and DWL components. The total travel time costs and its components are shown in million US dollars (2011). Table II shows that the cost due to delay (excluding variability) is the greatest for buses. The delay cost for buses include around USD 600 million for the peak hour or working trips, USD 218 million for off-peak hour trips and around USD 13 million for the less time sensitive trips.

While the value of time for buses is lower than those for taxi, auto-rickshaw and car as is evident from Table I (given in the previous section), the maximum share of the total travel delay cost is carried by buses. This finding can be explained easily from the combined effects of less values of willingness to pay survey which may be mostly due to the socio-economic condition of the passengers, of a relatively higher occupancy than other modes and also of overall less average speed (i.e. more delays) in comparison with other travel modes in a shared carriageway. From Table II, the second largest proportion of travel delay cost is carried by motor cars for which the value of time is the highest in Bangladesh currency. Although the ratio of numbers of cars to buses is quite high, i.e. around 9 times and the value of time is also higher, car has a travel time cost about 73% less than that of the bus, mainly because of the higher average speed and less occupancy. For cars, the overall delay cost including peak/off-peak/less-time sensitive trips is about USD 229 million whereas for buses, the peak hour work trips alone is USD 600 million, around 2.6 times higher than cars. Such findings from economical analysis draws the attention of the policy maker to the fact that public transportation is a much more important sector and gives a definitive conclusion that a little investment on and traffic management of this transport sector can actually reduce the overall social cost from congestion to a large extent since in that case private vehicle usage will also reduce leading to overall reduction of the traffic congestion and an efficacious transportation system.

25% allowance for the travel time variability in the overall travel time cost while in journey for all types of vehicles gives an estimate of the losses due to unpredictability or uncertainty of the traffic congestion which is about USD 300 million per year. Moreover, delay externality cost which is imposed upon others is around USD 1050 million per annum.

Vehicle Operating Cost

Table III shows the detail data and computation of cost of excess fuel burnt due to traffic congestion in Dhaka city. The estimation gives a total additional fuel cost of about USD 179 million per year due to congestion.

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It is assumed that the 10% of the above cost can be added for the lubricants and additional maintenance which is USD 17.85 million per year. So, the total cost of excess fuel burnt is about USD 196.4 million per annum. In Table III, it can be observed that the greatest share of the extra fuel cost from the entire fleet is carried by the motor cars, i.e. around 24% of the total fuel cost, followed by that of the largest numbers of motor-cycles. Jeeps/SUVs, auto-rickshaws and taxis have the smallest proportions (5.4%, 5.1% and 5.6% respectively) of the overall fuel cost. It can also be observed from Table III that buses and mini-buses together carry about 18% of the overall fuel cost in spite of the less numbers as compared to those of motor cars. This result again depicts the fact that in order to meet the disorganized traffic demand, the public transportation certainly needs more number of trips which is also evident from relatively high VKT, i.e. 150 Km/day. It is important to note that the fuel cost due to traffic congestion is subject to the fluctuations of fuel prices, taxes and/or subsidized fuel and hence constitute a major source of uncertainty in such estimations.

Total Congestion Cost Estimates

Combining the values from Table II and Table III provide estimates on travel time cost along with allowances for travel time variability, delay externality, dead-weight losses and cost of excess fuel burnt due to congestion respectively. This gives a yearly cost of about USD 3492 million excluding the environmental damage cost. Adding up the estimate on environmental externality cost from the secondary data source mentioned in the methodology, the cost rises to USD 3868 million per year. Comparing the results of travel time cost and vehicle operating cost from Table II and Table III, it is clear that the travel time cost of congestion is a much more important and more unpredictable value than the VOC. Therefore, to increase the precision of results, it is important to focus the future research on the variables of travel time cost and also travel time variability costs.

V. DISCUSSIONS

Despite the limitations regarding the model data or due to model simplifications, this study provides a comprehensive framework for the economical analysis of the traffic congestion for Dhaka city. More precise estimate is possible with more accuracy and reliability of data which is a major concern in many developing countries of the world.

The latest available data, following the detail estimation procedure, helps to determine the estimates of total traffic congestion cost and its individual item costs in Dhaka city. This paper defines the congestion cost as composed of mainly three component costs, namely, travel time costs, vehicle operating costs and externality cost due to delay and environmental damages. It is important to mention here that a number of related studies often refer to two additional associated costs and accordingly require the estimates on freight traffic cost as an important business cost and road traffic accident cost arising from traffic congestion.

The excess cost of freight traffic is mainly due to the average waiting time that the freight has to face for traffic congestion during peak hours. For Dhaka city, this is not a prime source of congestion cost because the freight traffic is only allowed to enter the city during off-peak hours at night in order to avoid the congestion. Hence this is majorly related to policy-making of government and not related to congestion particularly for Dhaka city currently. On the other hand, regarding the road traffic accident cost, it is very difficult to find out the exact number of accidents that take place due to congestion. Here the fatality of accidents depends on the speed of the vehicle which is mainly due to the tempted drivers tending to drive faster in order to avoid the speed loss, but in this case, the percentage of lives saved or less fatality due to slower speed during congestion should also be considered. For these controversial issues, these two items are not included in this study though many studies refer to these two costs as regular components of total congestion cost. The breakdown of the total costs of traffic congestion is summarized in Table IV.

Analyzing the values in Table IV, it is found that travel time cost with variability alone is 39% of the entire cost whereas externality costs bears 37% and vehicle operating cost in terms of excess fuel burnt and lubrication cost is about 5% only. The dead-weight losses representing the avoidable social cost of congestion or cost of actually doing nothing about congestion is about 19% of the entire cost. Again, among the externalities, delay externalities have a greater share, i.e. 27% of the total cost, than the environmental externalities (10% of the total cost).

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Therefore, it is evident that the cardinal factors in computing the traffic congestion cost are the travel time delay and the factors related to travel time delay estimation, i.e. travel time variability, delay externalities, DWL etc. Hence, the future studies should be directed toward more reliable estimation of the factors required for the accurate determination of the travel time delay costs from the precise model and pertinent policy-making processes can be based on this important item cost of traffic congestion.
This economical analysis of traffic congestion cost will inform the policy-makers in monetary terms the actual impact of the traffic congestion that the society actually bears. Also it will support further policy making processes to allocate the resources efficiently in order to control the increasing traffic demand. The different government economical policies and contradictory issues discussed, i.e. vehicle operating cost with tax or subsidy on fuel price, overall fuel pricing, freight traffic cost, pricing or taxation of roads for demand management etc. can be more closely and efficiently controlled by policy-makers' choice which becomes an ad-hoc decision without such a detail economical analysis. Starting with such economical analyses, effective traffic demand management strategies, i.e. congestion pricing, peak hour pricing, road pricing etc. can be implemented with proper planning under informed choices – the real costs of supplies and the corresponding imposing surcharge to control the growth and management of traffic demand.

Table IV: Traffic Congestion Cost Estimates

	Travel Time Cost	Travel Time Variability	Delay Externality	Social Costs of congestion (DWL)	Vehicle Operating Cost	Environ-mental Externalities	Total Congestion Cost
Annual Cost Estimates (USD million)	1199	300	1049	749	196	375	3868

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