DHAKA'S FUTURE URBAN TRANSPORT: COSTS AND BENEFITS OF INVESTMENT IN PUBLIC AND PRIVATE TRANSPORT

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Benefits and Costs of Solving Dhaka's Traffic Congestion

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Cost-Benefit Analysis: Dhaka’s Future Urban Transport

Bangladesh Priorities

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This work has been produced as a part of the Bangladesh Priorities project, a collaboration between Copenhagen Consensus Center and BRAC Research and Evaluation Department.

The Bangladesh Priorities project was made possible by a generous grant from the C&A Foundation.

Executive Summary

Dhaka is one of the world's largest and fastest growing cities. It is also the world's most crowded large city and faces acute transport problems. In 2015 an updated transport strategy for the city was prepared by consultants for the Government of Bangladesh. The Revised Strategic Transport Plan (RSTP) looked at transport infrastructure and management proposals for the next 20 years (2015-2035) and proposed public investment of $34.5 billion, or $45bn if operating and maintenance costs are included. The latter is the equivalent of building 12 Padma bridges.

The draft RSTP proposed 5 metro-rail lines, 2 bus rapid transit (BRT) lines, 6 elevated expressways totalling 126km, three ring roads and 730km of other main roads in the metropolitan area. It forecast a major share for public transport, but also a big increase in cars, jeeps, etc. – possibly trebling over the next twenty years.

Aspects of the RSTP's vision can be questioned. For example, it looked at public investment, but not at private investment in Dhaka's transport. Moreover, it assumed that past trends would continue, particularly regarding the growth in low-capacity vehicles such as cars. Furthermore, the RSTP itself questioned whether the scale of proposed investment was achievable within the 20-year period.

This paper was developed to test alternative options: in particular, to examine an alternative option involving the same level of public investment, but much greater emphasis on developing the bus network and reduced emphasis on low-capacity private modes such as cars, motor-cycles, auto-rickshaws and cycle-rickshaws.

An analysis of Option 1 (the RSTP proposals) showed that over the next 20 years, private investment in Dhaka's urban transport is likely to be much greater than the public investment, by a factor of about 2:1. Of this private investment, nearly three-quarters (72%) would be spent on running costs such as fuel, drivers, maintenance, garaging, tolls, and so on. The vehicle capital costs are relatively small in comparison.

The RSTP's forecasts suggested that automobiles in Dhaka would increase at least three-fold over the next 20 years. This paper estimated that the total investment in these private autos would be greater than all the public investment in MRT, BRT and roads added together.

An alternative Option 2 was examined, involving much greater priority for buses (6% annual growth rate instead of 4% under Option 1), and greater restraint on low-capacity private modes (e.g. autos increasing at 2% p.a. instead of 5.2%; motor-cycles at 2.5% instead of 4%; and so on).

In gross numbers, by increasing Dhaka's bus fleet to 20,000 by 2035 (instead of 11,700 under Option 1), and restricting autos to 322,000 (instead of 580,000), the alternative Option 2 would save about

$17bn over twenty years compared with Option 1 (the equivalent of 4.5 Padma Bridges); require about 20% less road space; and also offer about 16% higher passenger-capacity.

A benefit-cost ratio (BCR) was developed for the two options to quantify their relative merits. The two options were compared with a 'do nothing' scenario involving continued vehicle growth but no major public investment. The main costs were the capital and operating costs of the public and private investments. The main benefit was the reduction in congestion resulting from the two options. Three different discount rates were used: 3%, 5% and 10%.

With many assumptions (including the value of time spent travelling), the BCR for Option 2 was roughly double that of Option 1: i.e. between 4.5 and 5.9 (depending on the discount rate used), compared with 2.3 – 3.0 for Option 1.

The conclusion is that Option 2 – greatly increased priority to improving Dhaka's bus transport system, and much slower growth in cars, motor-cycles, auto-rickshaws and cycle-rickshaws – would be much more beneficial for Dhaka.

The final part of this paper looked at practical policies that could help to implement the preferred options. Seven key policy measures were briefly examined:

1. Giving top priority to developing public transport;
2. Reducing the subsidies to autos, motor-cycles and other low-capacity private modes;
3. Specific measures to encourage buses;
4. Developing walking and cycling in Dhaka;
5. Traffic management and transport planning;
6. Strengthening the institutions responsible for traffic and transport;
7. Mobilising the funds for transport improvements.

1. Introduction

Dhaka is one of the largest and fastest-growing cities in the world. From 3 million in 1971, its metropolitan population has grown exponentially to around 18 million today. Dhaka has also become the world's most crowded large city, with double or treble the population density of other world cities such as Tokyo, London and Shanghai.[1] Even Mumbai and Kolkata have less than two-thirds of Dhaka's density. Moreover, Dhaka is expected to grow to over 26 million in the next twenty years, so its density may rise by a further 50%.

Transport and movement in the city has become a major problem. There are simply too many vehicles trying to move on the existing roads, and traffic jams lasting hours are not uncommon. There are several reasons for the overloaded transport system. One is a lack of planning and forethought – as the city grew during the past forty-five years, the road network was not carefully planned and no-one anticipated the need for an urban rail system. A second factor is the deficiency of the public bus system. For various reasons there are not enough buses to meet the public demand, and those that operate are poor quality, grossly overcrowded and do not provide a joined-up network. Consequently, buses are used only by those who cannot afford alternatives, and people with money opt for cars, motor-cycles or personal public transport such as auto- and cycle-rickshaws. The private modes, however, are very inefficient in their use of road-space, hence Dhaka's roads are soon over-loaded with too many vehicles.

The government's response over the years has been to build more roads (including flyovers at the busiest junctions), and restrict some types of transport to free-up space for other road users. Cycle-rickshaws have been banned from many main roads, and licenses for auto-rickshaws are restricted to try to limit their numbers. Trucks are restricted to evenings and night-time operation.

Despite these measures, the traffic situation has continued to worsen, and now the government is considering massive investment in road-building and also a metro-rail system. In 2015 a Revised Strategic Transport Plan (RSTP) was prepared for the government by consultants funded by the Japanese Government (through JICA). The draft RSTP proposes $45bn of public investment in Dhaka's transport system over the next twenty years (2016-2035), which is the equivalent of building 12

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[1] The population density of the RAJUK metropolitan area in Dhaka was estimated at 11,094 persons per km² compared with 4,811 in London and 4,799 in Tokyo (Revised Strategic Transport Plan, 2015, Fig. 2.36).

Padma bridges.[2] The proposals in the draft plan include building 6 elevated expressways, 3 ring roads, and 5 elevated metro-rail lines.

The plan has not yet been formally adopted by the Bangladesh Government, and questions can be asked about some of its assumptions and conclusions. For example, the RSTP assumes that the rapid growth in private cars in Dhaka will continue unabated into the future (increasing from 9% to 16-18% of all trips by 2035) – but it is not clear how Dhaka's crowded roads will cope with an additional 400,000 autos, not to mention the increases in other vehicles. It is also debatable whether the government can deliver all of the infrastructure investment within twenty years – both the huge cost and past slow implementation make this somewhat unlikely.

Furthermore, the RSTP looked mainly at government investment in Dhaka's future transport system, but not at private investment, which accounts for the majority of transport investment in the city.

Reason for this Paper

The purpose of this paper is to take a wider look at potential transport investment in Dhaka over the next twenty years, considering private as well as public (government) investment, and looking at alternative options that might deliver a better transport system and environment for Dhaka's citizens, at less cost.

In particular, the paper tries to estimate the total cost of investment in Dhaka's transport system over the next twenty years, taking the RSTP proposals as one option (Option 1), and comparing this with an alternative scenario (Option 2) which focuses on:

- Much greater investment in buses and bus priorities, compared with the RSTP;
- Slower growth of private cars, motor-cycles and auto-rickshaws, as a result of more effective 'stick and carrot' policies by the government.

[2] The total capital cost of the RSTP proposals is $34.5bn; adding annual O+M costs for the proposed roads, MRT and BRT brings the 20-year total to $45bn. This sum does not include annual road maintenance costs for the existing road network.

2. Option 1: Proposals in the Revised Strategic Transport Plan

The RSTP study area covers 'Greater Dhaka', an area of about 2,160 km² extending from the River Padma to the River Meghna. However, most of the RSTP proposals focus on the metropolitan area under the RAJUK planning authority, an area of about 1,600 km². In this paper, the population and traffic figures refer to the Rajuk area unless otherwise stated.

Population: The current population in the Rajuk area is about 18 million, which puts Dhaka among the world's twenty largest metropolitan areas. The RSTP predicted that the city population would increase by about 3% per annum in the decade to 2025, and then 1.4% per annum for the next decade, leading to over 26 million by 2035.

Total Travel Demand: Based on a household interview survey, the RSTP estimated the number of daily trips in the metropolitan area and then projected this forward to 2025 and 2035 using assumed growth rates for regional GDP. Their predictions are as follows:

Table 1: Predicted future Travel Demand in Dhaka

Year	Dhaka Population, Rajuk Area (mill.)	Ave Trips per Person per day	Total Trips per Day (mill)	Ave Trip Distance (km)	Total Pass-Km per day (mill pass-km)
2014	16.0	1.86	29.8	7.5	223.5
2025	22.9	1.86	42.7	8.0	341.6
2035	26.3	1.95	51.2	8.5	435.2

Source: RSTP, Interim Report 1, August 2015, Tables 10.16 and 11.9.

Notes: 1. Total pass-km per day is estimated by the Author, using average trip rates and trip distance from RSTP. 2. Data includes walking trips. 3. Differences in total daily pass-km with Figures 2 and 3 below and Appendix 1a may be explained partly by exclusion of walking, goods and rail trips in the latter.

In other words, total travel demand (in passenger-kilometres) is expected to nearly double over the next 20 years.

Vehicle Numbers: The draft RSTP does not explicitly show forecasts of future vehicle numbers in Dhaka. However, these can be roughly estimated from information in the draft report, particularly from: (i) current vehicle numbers; and (ii) present and future (predicted) modal split.

In fact, the current number of vehicles in Dhaka is not accurately known. Even auto numbers are not accurately known, because of weaknesses in the vehicle registration system. For example, all motor vehicles must have a 'fitness' certificate, but the number of fitness certificates has varied enormously from year to year (Appendix 7, Figure 7.1). Also, the authorities do not keep records of vehicles scrapped. So estimating the current number of vehicles requires some brave assumptions.

The RSTP assumed that there were about 195,000 autos in Dhaka in 2014, based on new registrations and fitness certificates issued 2001-13 (RSTP Table 4.2). The draft report also estimated the auto's current modal share at 9% of vehicular trips, rising to 18% by 2035 under the 'do-nothing' scenario or 16% if the RSTP proposals are implemented (Table 2). Given the increase in total trips and also average trip length, this means that auto numbers could increase by nearly four-fold during the next twenty years, to around 675,000–750,000 autos by 2035 (a growth rate of 6.1 to 6.5% per annum, under the 'With RSTP' or 'Do nothing' scenarios respectively – Fig.1). The RSTP attributed this increase to rising incomes (RSTP Interim Report, page 11-18).

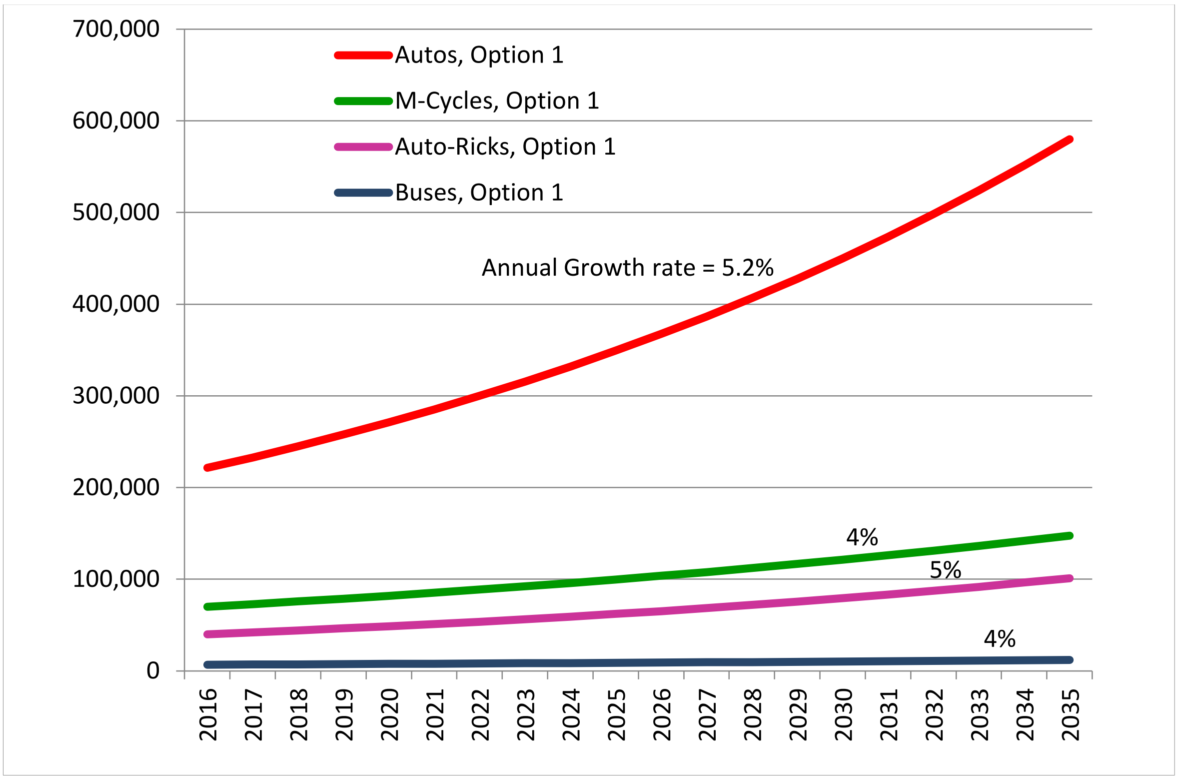
Table 2: Vehicular modal shares (Total Passenger Trips in Dhaka) predicted by RSTP for 'Do Nothing' and 'With RSTP' Scenarios. Figures in per cent.

Mode	**2014 Existing Situation**	**2025 Do Nothing**	**2025 With RSTP**	**2035 Do Nothing**	**2035 With RSTP**
Metro	0	0	3	0	14
BRT	0	0	3	0	3
Bus	47	59	63	53	40
Auto-Rickshaw	9	9	8	10	14
Cycle-Rickshaw	32	19	12	16	11
Car, jeep	9	11	9	18	16
Motor-Cycle	3	2	2	3	2
TOTAL	100	100	100	100	100

Source: RSTP Interim Report 2, August 2015, Fig. 11-17.

Note: Walking trips not included. BRT = Bus Rapid Transit

Figure 1 Author's Projection of Motor Vehicle Numbers in Dhaka, based on RSTP prediction of 'With RSTP' modal split



Source: Author's projection using RSTP 2014 vehicle numbers, own assumed growth rates, and 2035 modal split from RSTP. See Appendix 1b for details.

Future Passenger Output under RSTP (Option 1): Using the RSTP estimates, this paper makes a projection of future passenger output (Appendix 1a). Assuming the RSTP infrastructure proposals were fully implemented, the five proposed metro lines might carry about 12% of Dhaka's total passenger demand in 2035 (measured in passenger-kilometres), with buses (including BRT) carrying a further 40%. The total output from autos would be relatively modest (around 15% of total passenger-kilometres), though they would consume nearly half (44%) of the total road-space (Figs. 2 and 3; and Appendices 1a and 2a).

Figure 2 Author's Estimate of Total Passenger Output in Dhaka in 2016, measured in million pass-km/ day. (Note: Walking trips excluded in Figs. 2 and 3)

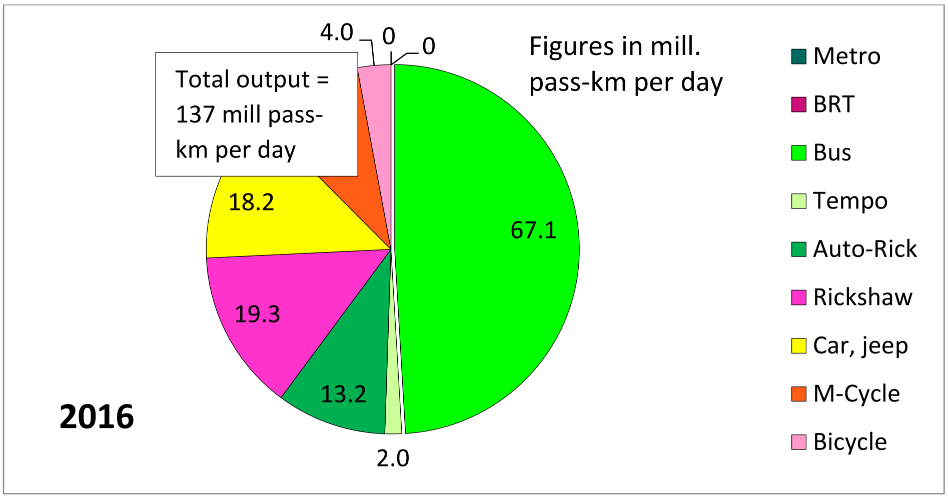
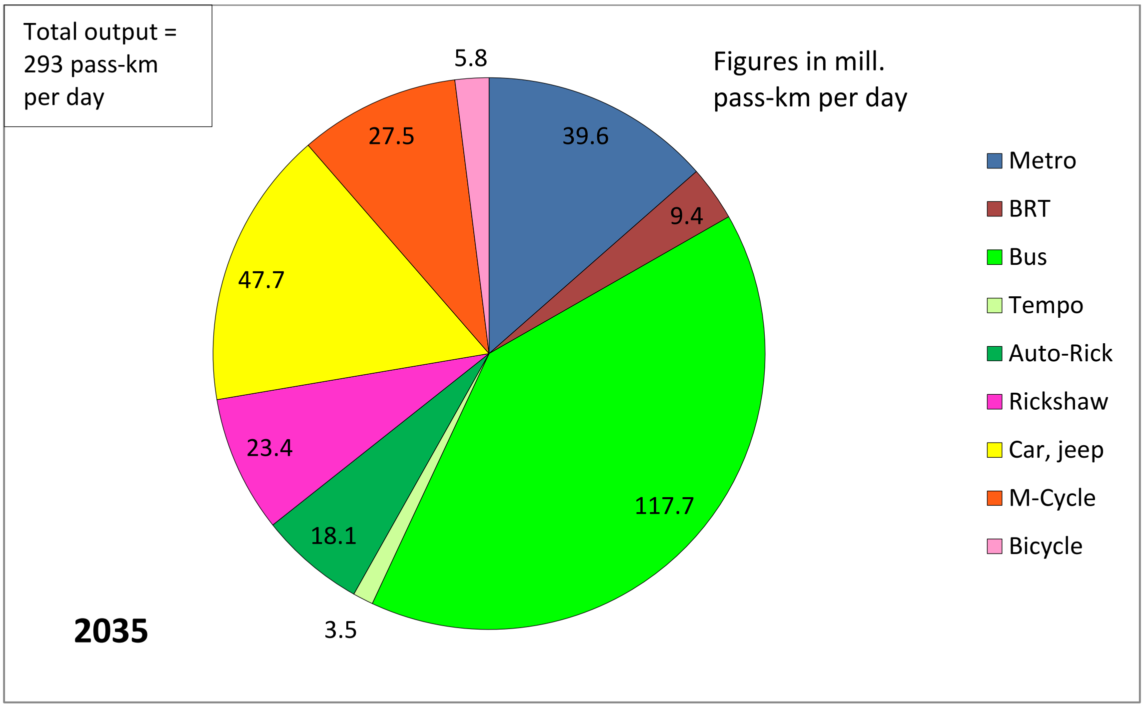


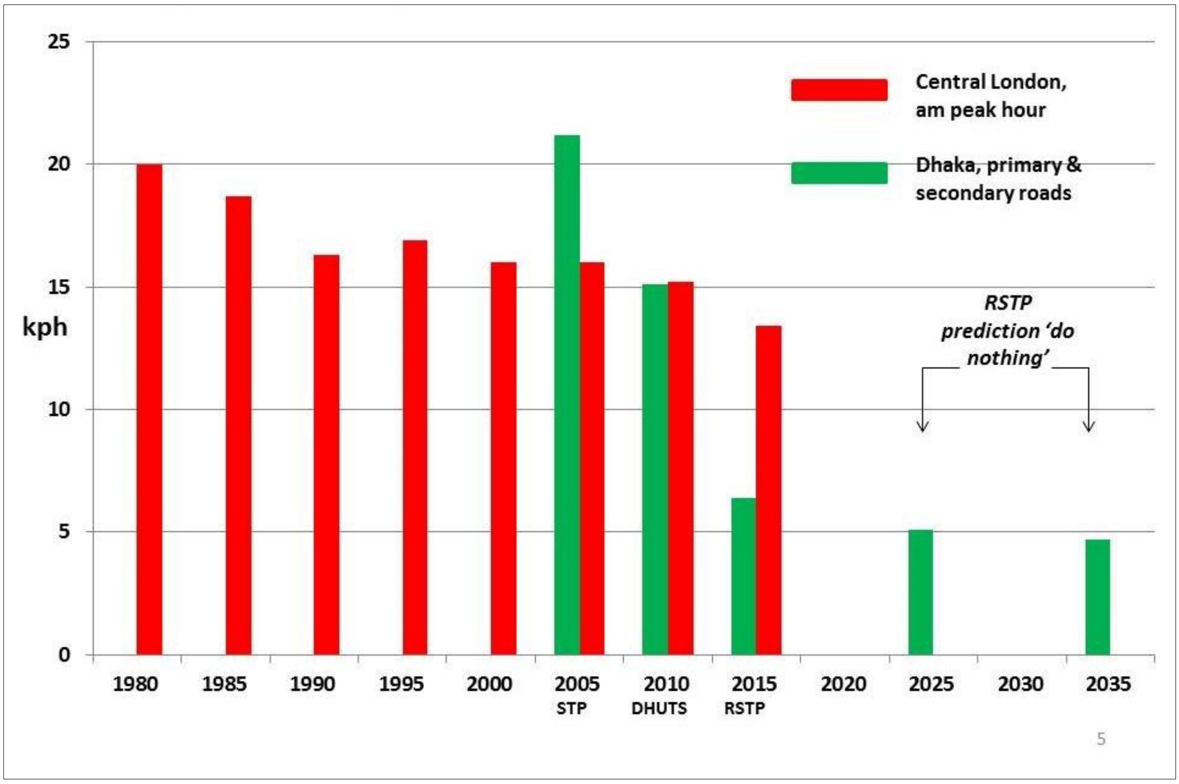
Figure 3 Total Passenger Output in Dhaka in 2035, assuming RSTP infrastructure proposals are implemented



Traffic Congestion Forecasts: The RSTP attempted to forecast future vehicle speeds and levels of traffic congestion under the 'Do-nothing' and 'With RSTP' scenarios. To do this, the consultants surveyed existing travel patterns (by means of a household travel survey) and then projected future trips between different zones in Dhaka (195 zones in total) and assigned the trips to the road network.

The results of the traffic model showed that Dhaka's already congested roads would be seriously congested in the coming years. Without remedial measures (i.e. under the 'Do-nothing' scenario) the average speed of traffic in Dhaka would fall to 5.1kph by 2025 and 4.7kph by 2035, which is about walking speed (Figure 4).

Figure 4 Average Traffic Speed in Dhaka and Central London



Sources: (1) Dhaka Strategic Transport Plan, 2005, Section 5.5.10 (note, figure applies to the DMA, Dhaka Metropolitan Area; (2) DHUTS, 2010, page E-10 (RAJUK area); (3) RSTP, 2015, Table 12.13 (RAJUK area); (4) Transport for London, Travel in London Reports (various).

RSTP Proposals to deal with Traffic Congestion: To deal with the predicted traffic congestion, the RSTP proposed a massive programme of road-building involving 1,200km of new main road (roughly double the current main road network),[3] including 5 elevated expressways and 3 ring roads (Fig. 5).

For public transport, the RSTP consultants considered the relative merits of MRT (mass rapid transit or metro-rail transit) versus BRT (bus rapid transit). Although BRT is a much cheaper option, it has a lower capacity compared with metro-rail. Given the major increases expected in population and travel demand, the consultants concluded that MRT was the better option, and hence recommended 5 MRT lines and just 2 BRT lines (Fig. 6). To assist decentralization, the consultants proposed focusing future development in sub-regional centres such as Gazipur, Ashulia, Savar, Jhilmil, Narayanganj and Purbachal, with good connections via the new roads and metro-rail. A summary of the RSTP investment proposals is given in Table 3.

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[3] In 2009 the Dhaka Metropolitan Area (which is smaller than the RAJUK area) contained about 425km of main road, according to the Dhaka Urban Transport Study, DHUTS, 2010 (Fig. 5.1-4). This consisted of 35km of national highway, 12km of regional highway, 47km of primary road, 111km of secondary road and 221km of connector road.

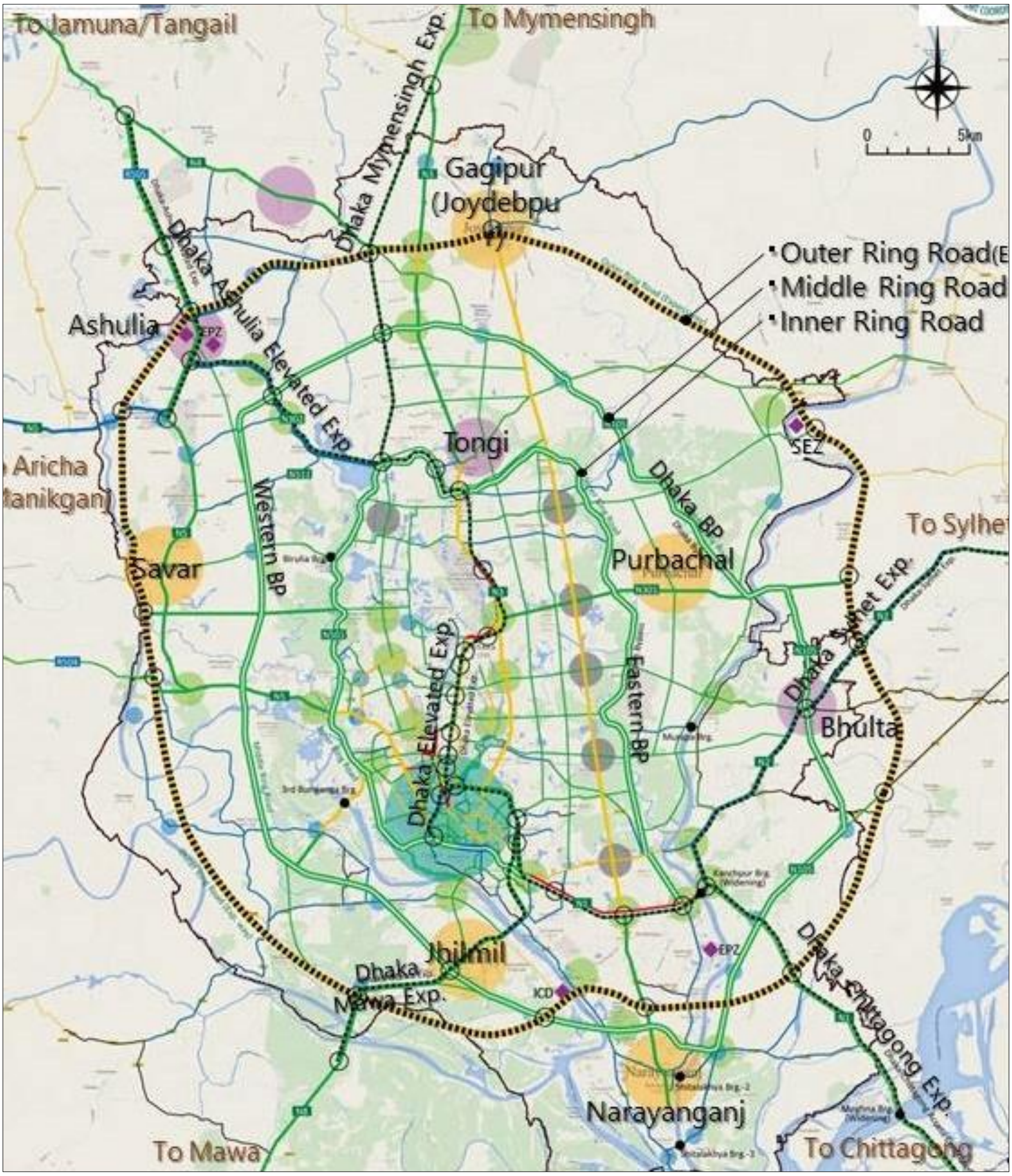
Table 3 Summary, RSTP's Main Transport Investment Proposals for Dhaka Metropolitan Area, 2016-35

Item	Length (km)	Capital Cost (Tk Crore)	Capital Cost ($ mill)	Average Cost per km ($m)	Comments
Roads:					
6 Expressways	126	31,042	4,005	31	
3 Ring Roads	310	35,335	4,559	15	
Primary Roads	290	10,984	1,417	5	
Secondary Roads	471	18,962	2,447	5	
Sub-Total (Roads)	**1,197**	**96,323**	**12,429**	10	
Mass Transit:					
5 MRT lines	145	157,212	20,215	139	See note 1
2 BRT lines	76	4,332	657	9	See notes 1, 3
Sub-Total (Mass Transit)	**261**	**162,175**	**20,872**	80	
Bus Sector Improvements		**5,024**	**646**	n.a.	
of which: 3 bus terminals			300		
New buses, stops, etc			300		
Bus lanes, priorities, etc			46		
Traffic Management Improvements:		**4,666**	**600**	n.a.	
of which: Traffic signal system			200		
Parking management			300		
Pedestrian facilities			50		
Safety and enforcement			50		
Travel Demand Management:		**Not costed**	**Not costed**	n.a.	
TOTAL INVESTMENT, 2016-2035		**268,188**	**34,547**	n.a.	See notes 1, 3

Source: JICA / Dhaka Transport Co-ordination Authority, November 2015, Revised Strategic Transport Plan, Draft Final Report.

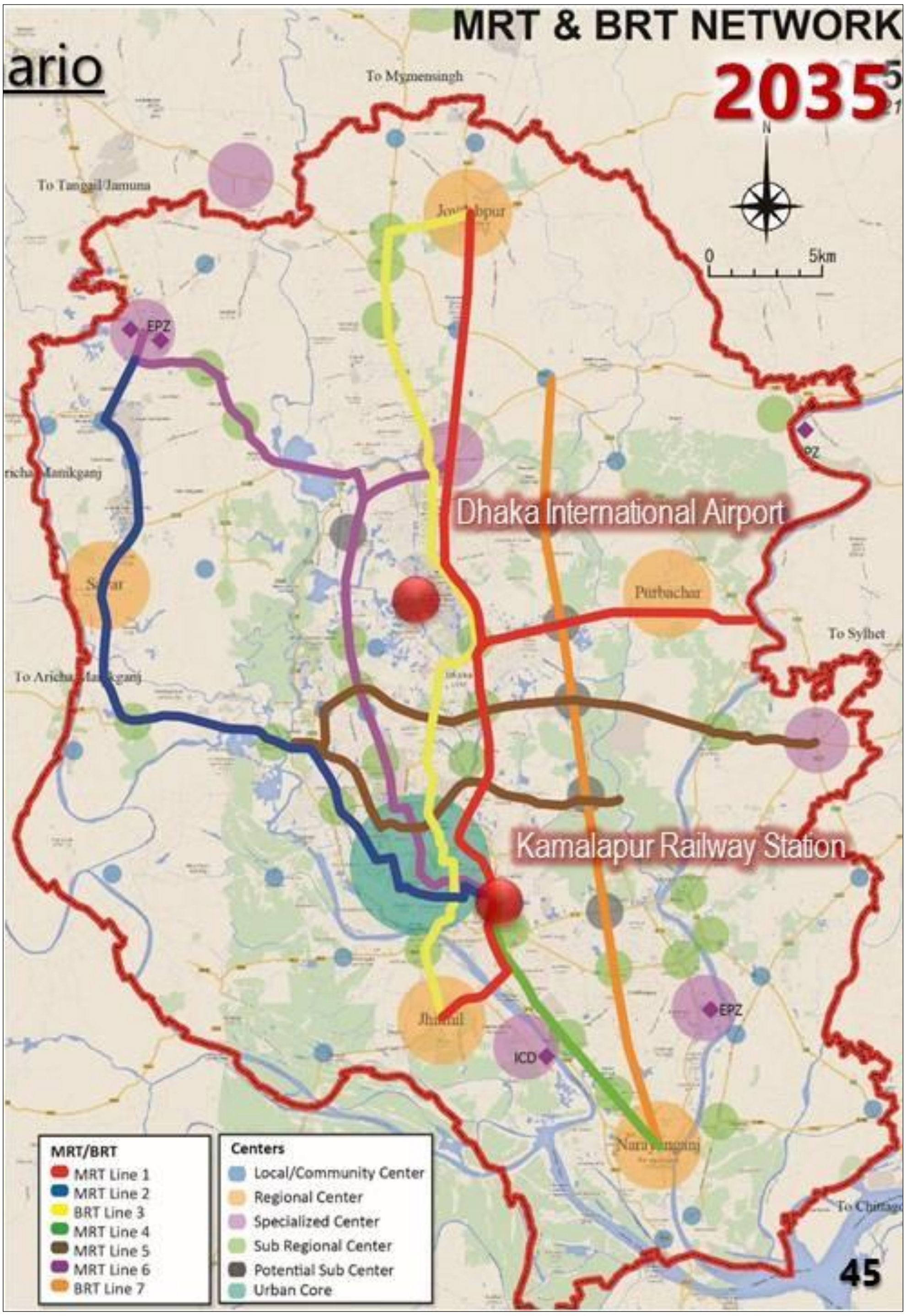
Notes: (1) The above table includes $2.5bn investment in MRT6 first phase (20km) and $400m investment in BRT3 Gazipur to Jilmeel (40km); also $1.15bn in the Dhaka Elevated Expressway. These three projects have been designed and construction will begin soon.
(2) Recent estimates for BRT3 northern section (Gazipur to Airport, 20km) suggest an average cost of around $15m per kilometer.
(3) Excludes land and compensation costs. Also excludes O+M costs for the new infrastructure.

Figure 5 RSTP Proposed Road Network by 2035, with sub-regional centres highlighted



Source: Source: JICA / Dhaka Transport Co-ordination Authority, November 2015, Revised Strategic Transport Plan, Draft Final Report

Figure 6 RSTP Proposed MRT and BRT Network by 2035



Source: Source: JICA / Dhaka Transport Co-ordination Authority, November 2015, Revised Strategic Transport Plan, Draft Final Report, Fig. 13.22

Impact of RSTP Proposals on Future Traffic Congestion: The consultants modelled the impact of the various RSTP proposals on Dhaka's future traffic flows, and concluded that with the new infrastructure, average traffic speeds would return almost to 2009 levels (13.7kph) by 2035,[4] which is

[4] Draft RSTP, Table 12.13

roughly the average speed of traffic in Central London today (Fig. 4). However, there are reasons to question this assessment.

Firstly, the traffic modelling looked only at the main road network, but not at the secondary and tertiary network. In Dhaka, there is already serious congestion on most of the secondary and tertiary roads, so the proposed expansion of the main road network would significantly increase their traffic volumes and delay (but this was not reflected in the traffic model).

Secondly, the traffic model did not consider the effects of new infrastructure on people's travel behavior. It is well known that construction of new road infrastructure results in 'induced travel' – in other words, if the road capacity is increased, many people who were previously discouraged from travelling due to congestion now find it attractive, so the 'suppressed' demand emerges, and congestion re-appears at a new level. This is largely why Delhi, which has constructed an extensive elevated road system, is experiencing worse traffic congestion (and air pollution) than ever.

Thirdly, the numbers that were fed into the model are so uncertain (see above), and the size of territory so large, that the possible error margin in the modelling makes any 'average traffic speed' very open to question.

Private Sector Investment: The RSTP looked only at future public sector investment in infrastructure, but not at the wider investment in Dhaka's transport by the private sector – in particular. the cost of acquiring and running all the vehicles that make up the city's transport system.

In one sense, the RSTP did consider these costs, by considering 'travel time savings' and 'savings in vehicle operating costs' as the main benefits of the new infrastructure. But by focusing on the 'savings', we do not see the bigger picture of total investment in Dhaka's transport.

A forecast of future total investment in Dhaka's urban transport system is attempted in this paper, with many assumptions about (a) vehicle numbers; (b) future growth rates; (c) capital cost of new vehicles, net of taxes; (d) average daily distance and passenger loads for different types of vehicle; (e) daily operating costs for different vehicles.

Two forecasts were undertaken:

(1) Option 1, based on the RSTP's prediction of future modal split in Dhaka;

(2) Option 2, with the same infrastructure investment as Option 1 but with significantly more bus transport and significantly reduced private transport (cars, motor-cycles, auto-rickshaws).

The results for Option 1 are shown in Table 4 and Figure 7, and for Option 2 in Table 5 and Figures 10 and 11.

The analysis indicates that private investment in transport will greatly out-weigh the proposed public investment by a factor of nearly 2:1. In other words, while the RSTP proposes public investment of $34bn over the next twenty years (or $45bn if operating and maintenance costs are included), the TOTAL investment in Dhaka's urban passenger transport system over the period 2016-2035 is likely to be around $123bn, including all the private sector investment (Table 4).

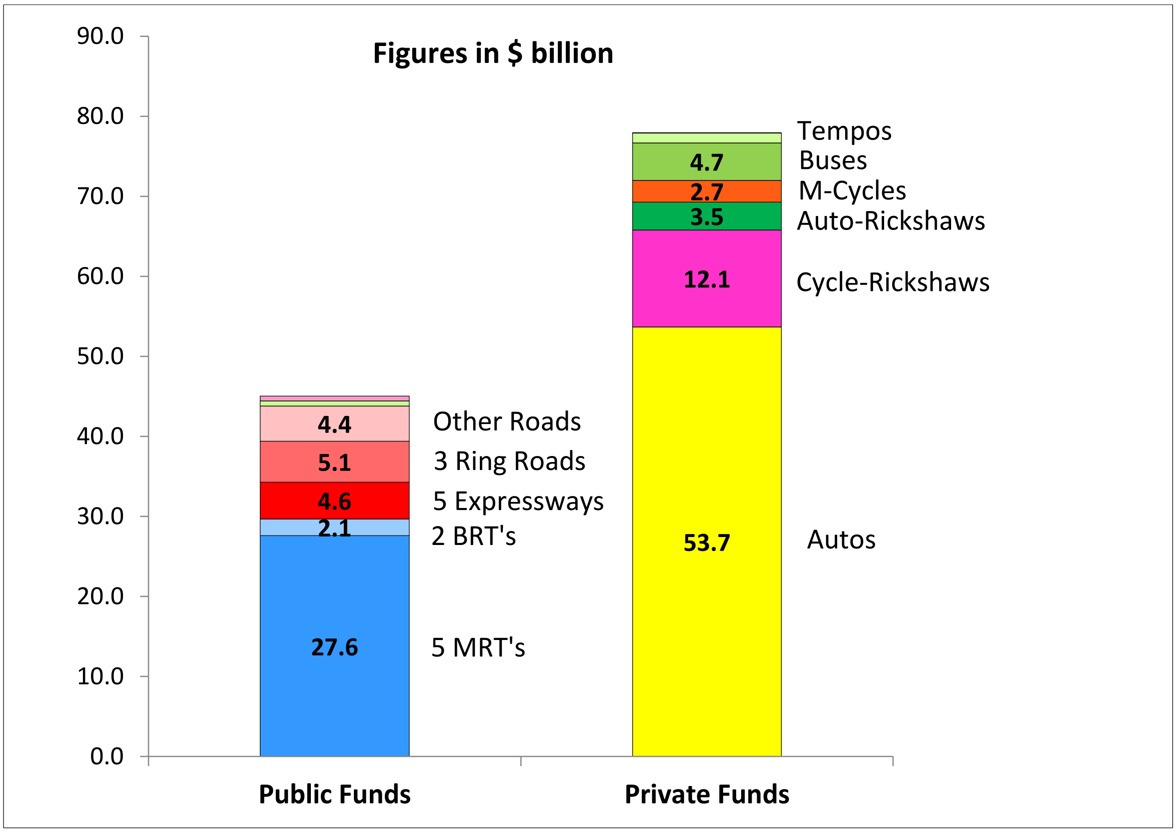
Of the private sector expenditure, approximately two-thirds (around $53.6bn) will be spent on autos (cars, station wagons, jeeps and micro-buses), if current trends continue. This is roughly double the proposed investment in Dhaka's metro-rail system.

Table 4 Option 1 Forecast of Total Investment in Dhaka's Urban Transport System, 2016-2035

	Vehicle Numbers, 2016	**Option 1 Growth Rate, pa (%)**	**Option 1 Vehicle Numbers, 2035**	**Option 1 Total Cost, 2016-35, $mill**	**% of Total Cost, 2016-35**
6 Expressways				4,625	*3.8*
3 Ring Roads				5,072	*4.1*
Pry & Secy Roads				4,446	*3.6*
5 Metro Lines			5 lines	27,581	*22.4*
2 BRT Lines			2 lines	2,097	*1.7*
Bus priorities				646	*0.5*
Traffic management				600	*0.5*
Sub-Total				**$45.1bn**	
Bus	6,695	4	11,740	4,684	*3.8*
Tempo	1,785	3	3,130	1,249	*1.0*
Auto-Rick	40,000	5	101,078	3,490	*2.8*
Rickshaw	330,000	2	480,748	12,064	*9.8*
Car, jeep	221,341	5.2	579,910	53,657	*43.5*
M-Cycle	70,000	4	147,479	2,701	*2.2*
Bicycle	200,000	2	291,362	52.8	*0.04*
Sub-Total				**$77.9bn**	
TOTAL				**$123bn**	*100%*

Notes: *1. Numbers in black are taken from RSTP. Numbers in red are Author's estimate. 2. Investment in goods transport and water transport not included. 3. RSTP total infrastructure costs are capital cost plus total O+M costs over 20 years, as given in the RSTP draft Plan 4. Vehicle numbers are estimated by the Author. 2016 vehicle numbers mostly taken from RSTP, with some adjustments; 2026-2035 growth rate derived from RSTP prediction of future total trips and modal share. 5. Vehicle costs are capital costs of new vehicles, plus operating costs of total vehicle fleet. This data was obtained from the World Bank-funded study: 'Dhaka Bus Network and Regulatory Reform Implementation Study and Design Work' – REVISED INTERIM REPORT, 2012, by ALG for World Bank and Dhaka Transportaton Co-ordination Board, Chapter 2: Public Transport Industry. 6. Full table of vehicle costs given in Appendix 4.*

Figure 7 Option 1: Author's estimate of 20-year Investment in Dhaka's Urban Passenger Transport System, 2016-2035 under Option 1 (assuming implementation of RSTP proposals)



Source: See data in Table 4 and Appendix 3

Most of the private expenditure in Dhaka's urban transport goes on running costs (drivers' wages, fuel, spare parts, garaging), as opposed to capital cost of new vehicles. For example, of the predicted $53.7bn for autos an estimated 72% will be spent on running costs, compared with 28% on purchasing new vehicles (note: the figures are net of government taxes).[5] A similar picture is found with the other modes, especially the public transport modes which are intensively operated. The cycle-rickshaws are the most extreme example, with about 99% being spent on running costs, due to the cheapness of the vehicles and cost of the rickshaw pullers' wages, spare parts, license fees, etc.

Option 1 Passenger Output and Road-space Requirement: Passenger output under Option 1 was discussed above. To re-cap, although the autos are by far the most costly component of Dhaka's transport system, their output is relatively small compared with public transport, particularly buses. Detailed estimates for Option 1 are given in Appendix 1a. Currently, autos account for about 9% of

[5] In this paper, the capital cost (net of taxes) of a reconditioned auto has been assumed at Tk.10 lakh ($13,044), and the annual running cost at Tk.4 lakh ($5,195), of which the largest share is driver's wages (90% of autos involve paid drivers, costing around Tk.1.2 lakh p.a.), garaging, fuel and spare parts. Details of vehicle costs are given in Appendix 4.

trips in Dhaka (RSTP, Fig. 11-13) and about 13% of passenger-kilometres (Appendix 1a). Buses, by contrast, account for about 47% of passenger trips and 49% of passenger-kilometres.

But even if auto numbers treble over the next twenty years, as predicted in the RSTP, they will still account for not more than 15% of total passenger-kilometres.

On the other hand, they are the most space-hungry vehicle in Dhaka (Fig. 8), and the Option 1 data suggests that 580,000 autos in 2035 would occupy about 44% of the road-space used by vehicles in the city, measured in PCU-km's per day[6] (Appendix 2a).

Figure 8 Amount of Road-Space taken up by different Modes

Average amount of road-space needed per passenger in Dhaka (in PCU's per person)

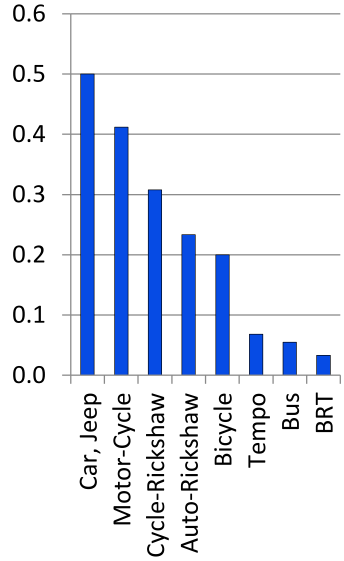
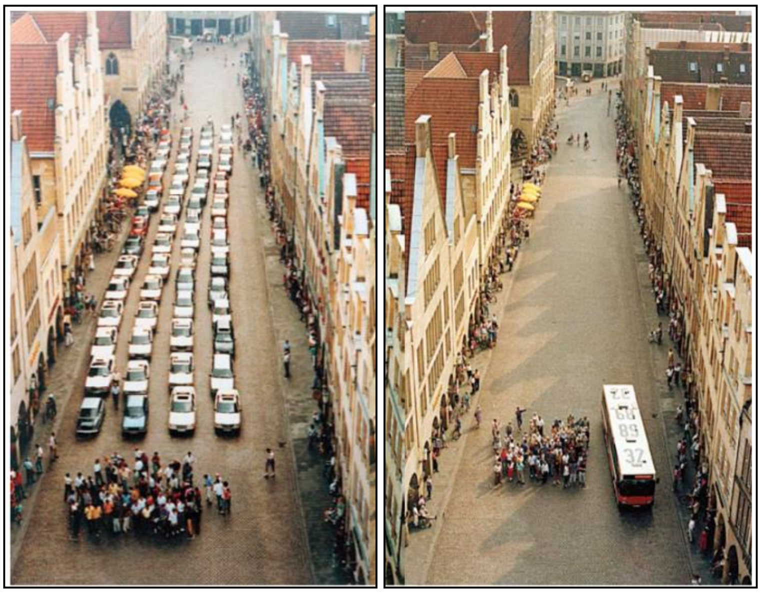


Illustration of road-space taken up by the same number of passengers using (a) cars, (b) buses



Sources: PCU values from Dhaka Urban Transport Study (DHUTS), 2010, Table 12.1-2; Average vehicle occupancies from Dhaka Bus Network Study, 2012

In conclusion, the $14bn road-building programme proposed in the RSTP <u>is to a large extent made necessary by the need to accommodate the major increase in autos that is predicted in the RSTP</u>.

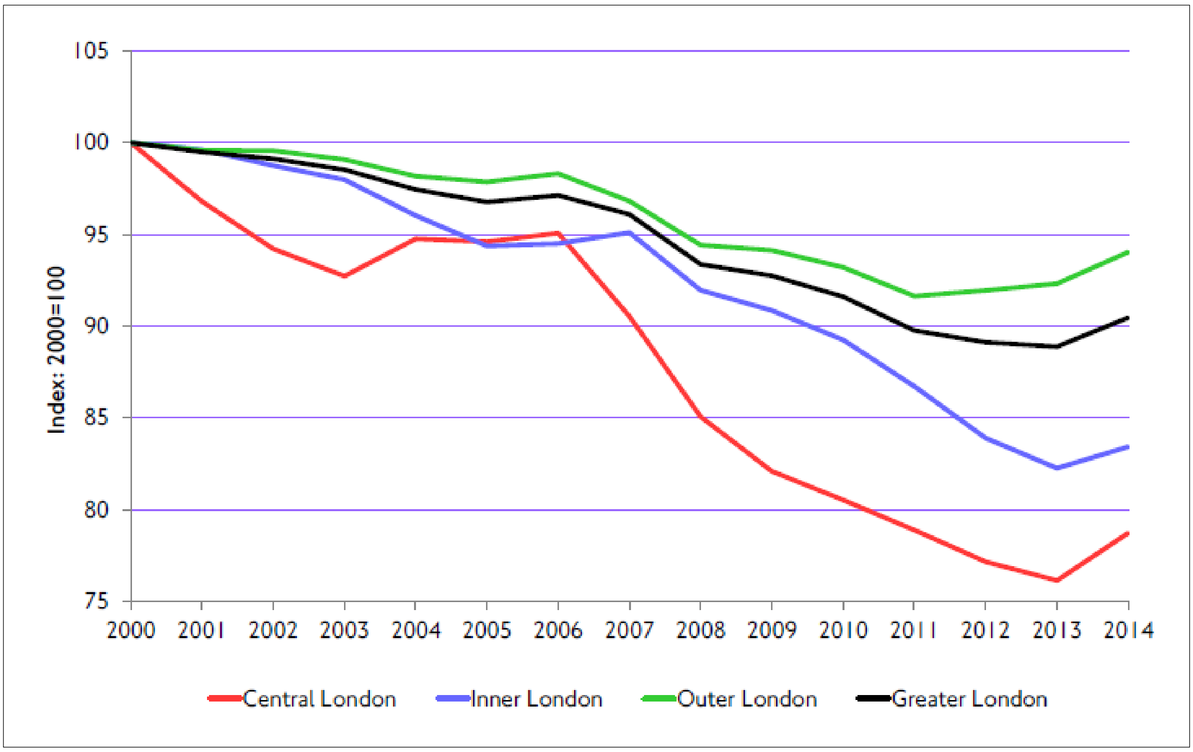
An idea of the space required to accommodate the future autos is given by the following example. If autos increase by 360,000 by 2035 (as predicted under Option 1), the area needed just to park them will take up approximately 3.6 km² of city space – almost as big as Gulshan and Banani residential areas combined.

[6] PCU = Passenger Car Unit, a measure of the amount of road-space taken up by different vehicles. The average car has a PCU value of 1.0, and other vehicles are given values relative to this unit value. Note that PCU values will vary depending on road type, width and design speed. For example, a cycle-rickshaw has a low PCU value on narrow city roads, but a high PCU value on wide, fast main roads.

3. Option 2: An Alternative for Dhaka's Future Urban Transport

It is not inevitable that autos must continue to grow exponentially in Dhaka. There are physical limits to a city's capacity to accommodate additional vehicles, and in many other major cities the total output of road traffic is actually <u>declining</u>, as the cities reach the limit of their capacity to handle more traffic. In London, for example, although total travel demand is increasing year after year, the total road traffic has been steadily decreasing for the past fifteen years or more as passengers have shifted to other modes – rail, buses, underground, walking and cycling (Fig. 9).

Figure 9 Trends in road traffic in central, inner and outer London (vehicle-kilometres, all motor vehicles)



Source: Transport for London, 'Travel in London, Report 8', 2015, Figure 3.7

An alternative transport option for Dhaka could therefore give more emphasis to an extensive, high-quality bus system, and less emphasis to space-intensive modes such as autos, motor-cycles and auto-rickshaws.

For this paper, an alternative option (Option 2) was considered for Dhaka involving the same amount of public investment in MRT, BRT and roads, BUT…….

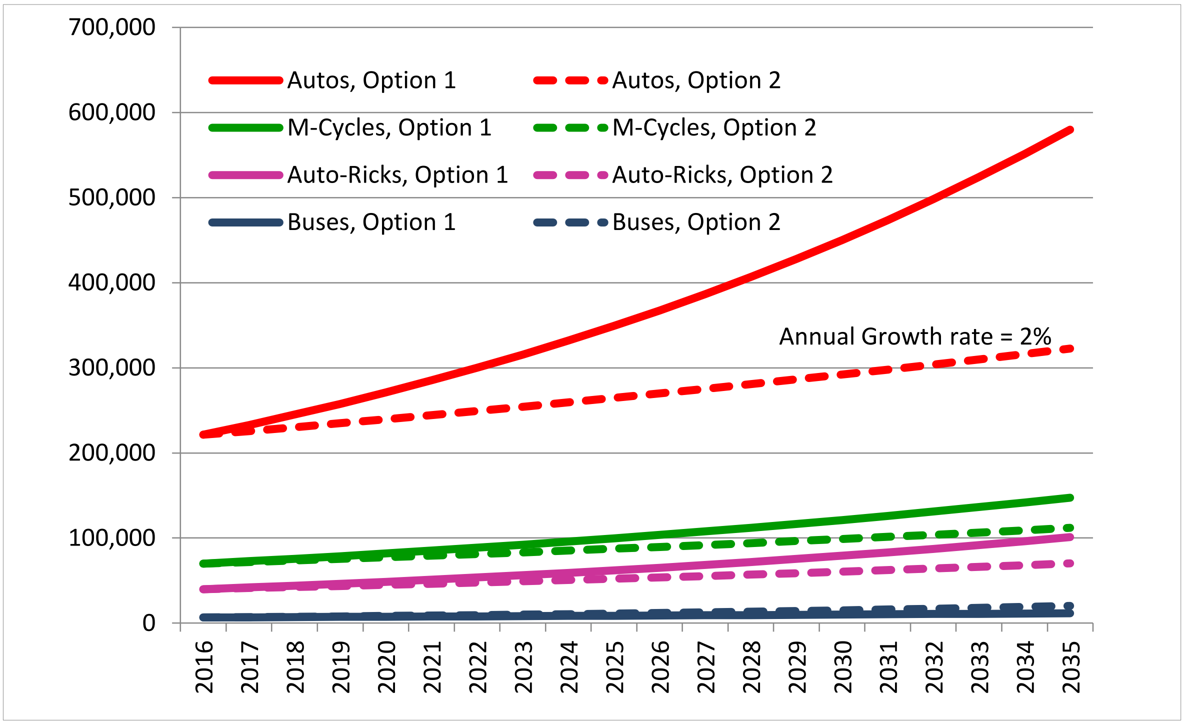
- Buses increasing by 6% per annum over the next 20 years (instead of 4% under RSTP Option 1);
- Autos growing at 2% per annum (instead of 5.2% under RSTP Option 1);
- Motor-cycles, auto-rickshaws and cycle-rickshaws growing more slowly (than under Option 1), due to increased emphasis on buses and tempos.

As well as more buses, Option 2 also involves extensive traffic management measures to ensure a high quality and efficient bus system – for example bus lanes and bus priorities, integrated routes, integrated ticketing, high quality air conditioned buses, good bus shelters and terminals, and so on.

If Option 2 is successfully implemented, Dhaka could have around 20,250 buses by 2035, nearly double the number predicted under Option 1. This is not unusually large: Bangalore, India's fifth largest urban area with 8.5 million people, currently has 6,724 buses (about as many as in Dhaka today). Therefore if Dhaka could achieve 20,050 buses by 2035, this would still be proportionately fewer buses than Bangalore has today (1,283 persons/bus compared with 1,313 persons/bus in Bangalore today).

The impact of Option 2 on reducing auto numbers would be considerable: a 2% auto growth rate would mean 250,000 fewer autos in Dhaka by 2035 compared with Option 1, and 41,000 fewer motor-cycles (Fig. 10 and Table 5).

Figure 10 Growth of Motor Vehicles in Dhaka 2016-2035 under Option 2, compared with Option 1



Source: Author's projection using RSTP 2014 vehicle numbers, own assumed growth rates, and 2035 modal split from RSTP. See Appendix 1c for details.

Table 5 Option 2 Forecast of Vehicle Numbers and Total Investment in Dhaka's Urban Transport System, 2016-2035

	Vehicle Numbers, 2016	Option 2 Growth Rate, pa (%)	Option 2 Vehicle Numbers, 2035	Option 2 Total Cost, 2016-35, $mill	% of Total Cost, 2016-35
6 Expressways				4,625	*4.4*
3 Ring Roads				5,072	*4.8*
Pry & Secy Roads				4,446	*4.2*
5 Metro Lines			5 lines	27,581	*26.0*
2 BRT Lines			2 lines	2,097	*2.0*
Bus priorities				646	*0.6*
Traffic management				600	*0.6*
Sub-Total				**$45.1bn**	
Bus	6,695	6	20,256	6,709	*6.3*
Tempo	1,785	6	5,401	1,789	*1.7*
Auto-Rick	40,000	3	70,140	2,801	*2.6*
Rickshaw	330,000	1	398,676	10,917	*10.3*
Car, jeep	221,341	2	322,452	36,357	*34.2*
M-Cycle	70,000	2.5	111,906	2,296	*2.2*
Bicycle	200,000	4	421,370	71	*0.1*
Sub-Total				**$60.9bn**	
TOTAL				**$106bn**	*100%*

Note: Numbers in black are taken from RSTP. Numbers in red are Author's estimate. Costs include Operation and Maintenance (O&M) costs.

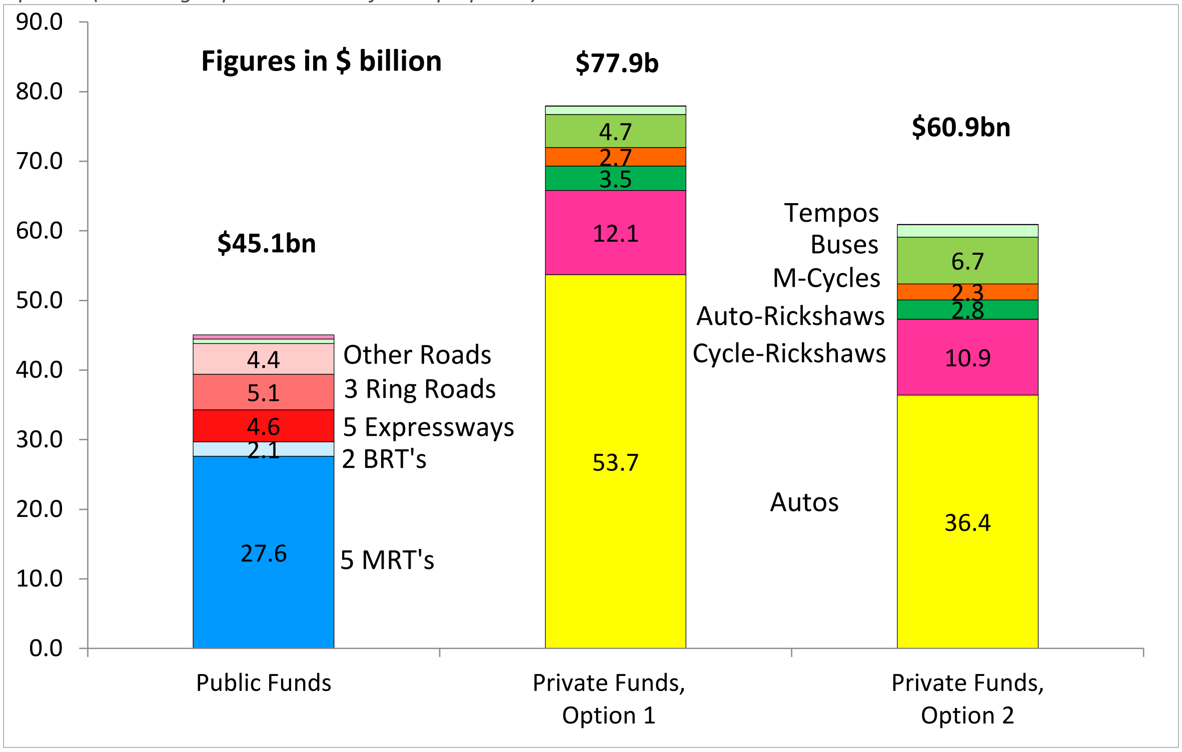
Benefits of Option 2 compared with Option 1

Reduced cost of investment: Giving more emphasis to public transport (buses) and less encouragement to private modes (autos, motor-cycles and auto-rickshaws) could reduce Dhaka's total transport bill by about $17bn over twenty years (assuming the same level of government investment in infrastructure under both options – see Figure 11). This reduction would be the equivalent of building 4.5 Padma Bridges.

Higher passenger output: Option 2 would give a greater overall passenger capacity compared with Option 1, because higher capacity vehicles are being used. As shown in Appendix 1a and 1b, the potential output from Option 2 would be 16% greater than Option 1 (360 compared with 312 million passenger-kilometres per day) – see Appendices 2a and 2b.

Less road-space required: Option 2 would also greatly reduce the pressure on the road network as the vehicles would be more space-efficient and fewer vehicles would be needed. Under Option 2, the total number of vehicles in 2035 would be about 16% less than under Option 1 (1.35 million vehicles compared with 1.61 million), and the total road-space they occupy would be about 20% less (see Table 6, and Appendices 2a and 2b for details).

Figure 11 Comparison of 20-year Investment in Dhaka's Urban Passenger Transport System, 2016-2035, under Option 1 and Option 2 (assuming implementation of RSTP proposals)



A summary of the main benefits of Option 2 compared with Option 1 is given in Table 6 below.

Table 6 Summary of Key Comparators for Options 1 and 2

Comparator	Units	Option 1	Option 2	% Difference
Total 20-year Cost (Capital & Operating Costs)	*$bn*	123	105	(-) 15%
Total Passenger Capacity (Note 1)	*Mill. Pass-km /day*	312	360	(+) 16%
Road-Space Used (Note 2)	*Mill. PCU-km / day*	60	48	(-) 20%

See Appendices 1, 2 and 3 for details

Notes:

1. Total passenger capacity is based on average vehicle loadings prevailing in 2016
2. See Footnote 7 for explanation of PCU values.

4. Cost-Benefit Analysis of Options 1 and 2

Methodology

It is a major challenge to combine all of the transport activities in a major city like Dhaka into a single cost-benefit ratio. The following pages briefly describe the approach adopted in this paper. It should be noted that the analysis applies only to passenger transport and not goods traffic, which makes up perhaps 20% of Dhaka's total traffic.

In this paper the cost-benefit analysis compares the costs and benefits of Option 1 and Option 2 against a 'do nothing' scenario. Hence the analysis focuses on the marginal costs and benefits of the two options.

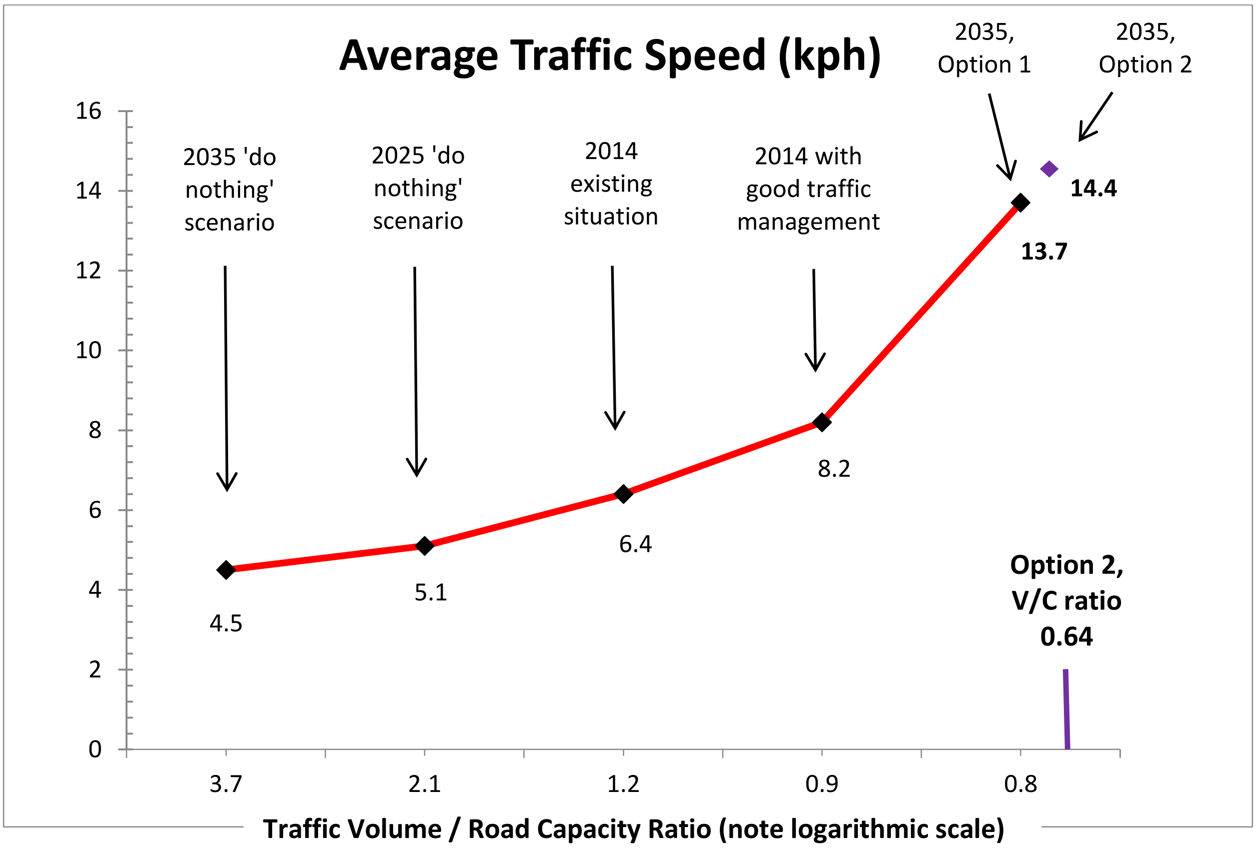
'Do nothing' scenario: The draft RSTP report did not give cost-benefit ratios, but focused on economic and financial internal rates of return (see Appendix 7). The 'do nothing' scenario was used in the RSTP traffic model to estimate the impact of future traffic volumes on the road network, and hence obtain the benefits of time savings and vehicle operating cost savings due to the RSTP proposals. However, the 'do nothing' scenario was not described in detail – hence for this paper it has been assumed that it involves no significant additional public investment, but simply continued growth of the vehicle fleet. The total cost of the do nothing scenario is $87bn over 20 years.

Costs: For Options 1 and 2, the total investment costs are those shown in Tables 4 and 5 above: namely, (i) the total public investment in roads and public transport, including operating and maintenance costs as detailed in the RSTP; and, (ii) the private investment in vehicles and operating costs, as estimated by this paper. For the purposes of this benefit-cost analysis, the marginal costs are simply the total costs under Option 1 or Option 2 less the cost of the do nothing scenario.

Benefits: The major benefit of Options 1 and 2 is the predicted time savings compared with the 'do nothing' scenario. The RSTP estimated that travel time savings were about 90% of the total 'benefits', whereas vehicle operating cost savings were only 10% of the total 'benefits'. (Other benefits such as improved air quality, reduced noise, reduced traffic domination, etc. were not included in the RSTP's economic and financial analysis). In this paper, savings in vehicle operating costs are included on the cost side of the equation (reflected in a lower denominator) and not the benefit side (which would raise the numerator). Hence the paper focuses on the relative impacts of the two options on traffic congestion. The paper also looks at the benefits of reduced air pollution (measured in PM10's)[7] and reduced greenhouse gas emissions.

Time savings: How were the time savings estimated? The RSTP's traffic model predicted the average speed of traffic in Dhaka under the 'do nothing' and 'with RSTP' scenarios. The results are illustrated in Figure 12 below. They show that average speeds in Dhaka will fall if nothing is done, but may rise if various infrastructure and management measures are implemented. The RSTP predicted that if all of the (Option 1) proposals were implemented, the average traffic speed might rise to 13.7kph. Since Option 2 requires 20% less road space (and also gives a 16% greater passenger output), it has been assumed in this paper that the V/C ratio (traffic volume to road capacity ratio) will also be 20% less than for Option 1, and accordingly the average traffic speed will be higher (at 14.4kph) – see Fig. 12 below.

Figure 12 RSTP estimate of average traffic speed in Dhaka at different Traffic Volume/Road Capacity ratios, and Author's estimate of Option 2 V/C ratio and average traffic speed



Source: Draft RSTP Final Report, Tables 12.13 and 13.13

[7] PM10's are one type of air pollutant (among many) – they refer to small particulate matter associated with vehicle emissions, dust, smoke, and other activities, which cause lung disease, respiratory problems, cardio-vascular problems and so on. PM10 stands for Particulate Matter finer than 10 micro-metres (<10 µm).

To arrive at the value of time savings under Option 1 and Option 2, the total output (in annual passenger-kilometres) has been estimated for the two options, and then the time spent travelling obtained by dividing this output by average traffic speed (see table in Appendix 6).

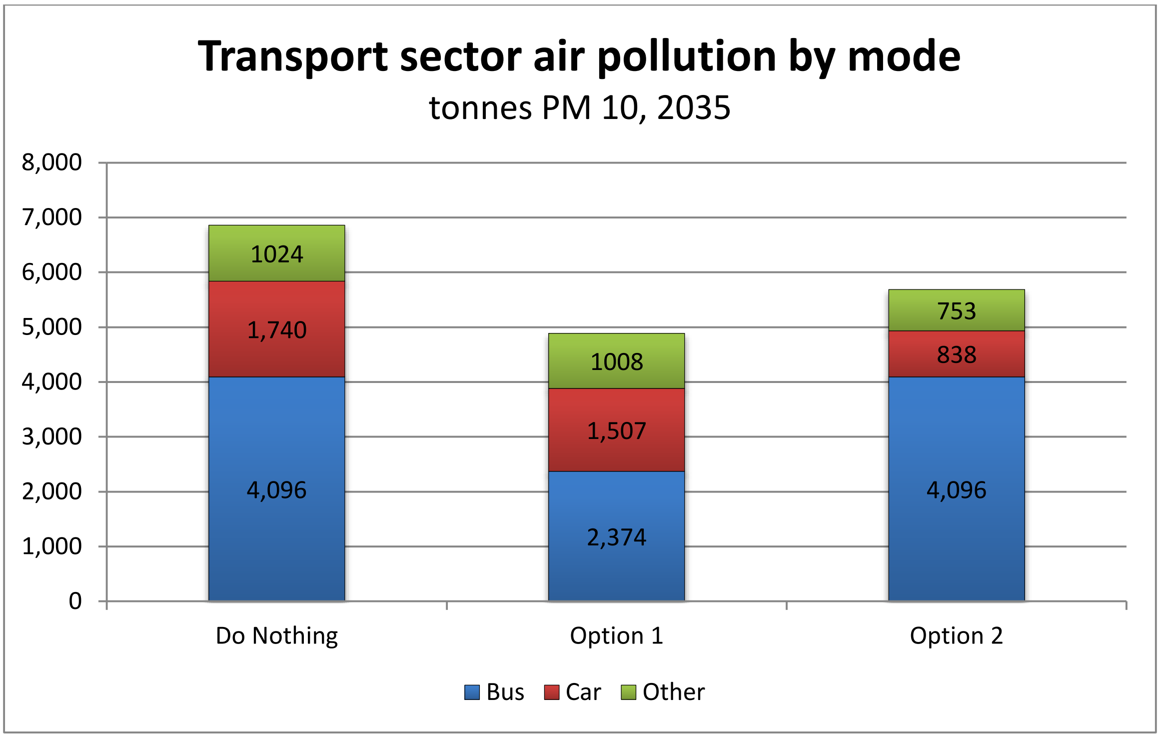
Value of travel time: A key question is what value to put on people's travel time? This paper assumed an average value of Tk. 70 per person per hour – this was based on the values used in a recent ADB urban transport study in India.[8]

Value of air pollution benefits: The contribution of PM10 from the transport sector is estimated for each scenario using the emissions per vehicle-km presented in Wadud (2010). The extent of PM10 is a factor of i) vehicle type ii) number of vehicles iii) average kilometres travelled per vehicle and iv) type of fuel used (petrol, diesel or CNG). The most polluting vehicles in Dhaka are diesel buses which produce 2.37g PM10 per km travelled. In contrast, a car run on CNG produces about 0.1g PM10 per km travelled. Under the do-nothing scenario the expected contribution of the transport sector to PM10 is around 6,900 tonnes per year in 2035. For Option 1 it is around 4,900 tonnes, while for Option 2 it is approximately 5,700 tons by 2035 (see Figure 13). As per standard cost-benefit assessment techniques, the benefit is the marginal reduction in air pollution against the do-nothing scenario.

Option 2 has significantly more polluting diesel buses than Option 1, and this explains why it has higher PM10 production than under Option 1. However, both Option 1 and Option 2 represent less polluted versions of Dhaka than under do-nothing.

[8] ADB TA 8765, 'Supporting Sustainable Urban Transport in Aizawl City', India, Final Report, 2016. The value of Tk.70 per person per hour is an average of all types of vehicular travel. Note that the RSTP assumed an average value of Tk.156 per hour (see Appendix 7, Table 7.7), which may be somewhat high.

Figure 13 Air pollution due to the transport sector in Dhaka under each scenario. Source: Author's calculations based on Wadud (2010).



Note: Other = tempo, motorcycle, auto-rickshaw, bicycles and cycle-rickshaws

To value the health effects from PM10, we refer to the literature focusing on the smaller particles PM2.5, since 95% of PM10 from exhaust is PM2.5.

The health damage of a ton of PM2.5, and consequently the health benefit of reducing emissions, depends on how much is inhaled by the population. Apte et al (2012) estimate the so-called intake fraction of distributed ground-level emission sources (e.g. emissions from road vehicles) in over 3,600 cities of the world with a population greater than 100 thousand in year 2000 based on geographic, meteorological, and demographic location specific data. An intake fraction is a measure of how much of a ton of emissions in a geographic area is breathed in by the exposed population. The higher the intake fraction the larger are the health damages and thus the health benefits of emissions reductions.

Intake fractions in these cities were found to range from less than 5 (g/ton of PM2.5) to 260 ppm in Dhaka, the city with the highest intake fraction. Health benefits per ton of PM2.5 emission reductions in Greater Dhaka are estimated based on this intake fraction (Appendix 8) and the PM2.5 ambient exposure–health risk relationship in the Global Burden of Disease 2010 Project (Appendix 9). The health benefits are then monetized valuing a disability adjusted life year (DALY) at GDP per capita in Bangladesh (Appendix 10).

Since an improvement in ambient PM2.5 air pollution is unlikely to instantaneously provide full benefits for health outcomes that develop over long periods of PM2.5 exposure, annualized health benefits of emission reductions are 71-79% of full benefits at a discount rate of 3-10%.

Estimated health benefits of PM2.5 emission reductions from road transport in Greater Dhaka are presented in Table 7. These benefits represent averages throughout the city.

Table 7: Benefits of PM2.5 / PM10 reductions in Greater Dhaka (2014 US$ per ton of PM2.5)

Discount rate	Based on DALY=GDP/capita
3%	8,382
5%	8,126
10%	7,503

Applying these values to the PM10 estimated from the different scenarios, and comparing to the do-nothing case, shows that air pollution benefits are very minor, when compared to time savings (congestion benefits). Using a 5% discount rate, the present value of benefits is $0.17bn under Option 1 and $0.1bn under Option 2.

Carbon Emission Benefit: Carbon emissions under each scenario are estimated in a similar fashion to PM10 emissions, using greenhouse gas emissions per vehicle-km presented in Wadud (2010). Under do-nothing the estimated CO2 emissions is 5.8m tonnes, while under Option 1 it is 4.4m tonnes and for Option 2 it is 3.9m tonnes by 2035. CO2 emissions are valued using social cost of carbon figures presented in Tol (2011) with the value of one tonne of CO2 equal to $22.90 under 3% discount rate, $5.18 under 5% discount rate and $0 under 10% discount rate.

As with air pollution, carbon emission benefits make a very minor contribution to the total benefits of each option. The present value of reduced carbon emissions is $0.07bn and $0.1bn for Option 1 and 2 respectively, at the 5% discount rate.

Discount rate used: Three discount rates were tested, (3%, 5% and 10%), in accordance with the methodology adopted for the *Bangladesh Priorities* project.

Cost-Benefit Results

The results are shown in Table 8 below. They show that overall, the Benefit-Cost ratio of Option 2 is approximately <u>double</u> that of Option 1. Hence Option 2 (a major increase in buses, and slower growth in cars, motor-cycles, etc.) is clearly a much better option for Dhaka in overall economic terms.

Table 8 Benefit-Cost Ratio for Options 1 and 2 (assuming travel time at Tk.70 per hour)

Travel time value = Tk.70 per hour						
	Discount Rate	**Net Present Value of Time Benefits**	**Net Present Value of Air Pollution Benefits**	**Net Present Value of Carbon Benefits**	**Net Present Value of Costs**	**Benefit/Cost Ratio**
		$bn	*$bn*	*$bn*	*$bn*	
Option 1	**3%**	$80.13	$0.17	$0.32	27	3.0
	5%	$62.24	$0.17	$0.07	23	2.8
	10%	$35.02	$0.16	$0.00	15	2.3
Option 2	**3%**	$84.07	$0.10	$0.44	14	5.9
	5%	$65.30	$0.10	$0.10	12	5.5
	10%	$36.73	$0.09	$0.00	8	4.5

5. Discussion: Implementing the Options

The following chapter discusses how the proposals put forward in the RSTP can be implemented. First, it is worth noting that both Options 1 and 2 in this paper are very similar – both include the RSTP's public investment proposals (e.g. 5 metro lines, 2 BRT lines, new roads, etc). The main differences are in (i) the level of support given to developing the city's bus network (including mini-buses and tempos), and (ii) the degree of restraint on space-inefficient private modes (cars, motor-cycles, auto-rickshaws, cycle-rickshaws).

RSTP Objectives: The draft RSTP recommends an overall objective of 'developing a public-transport-based city, with more than 60% of Dhaka's total transport demand to be met by public transport' (Draft RSTP, Chapter 15.1). Eight broad objectives are proposed, emphasising people and management rather than the building of infrastructure:

1. Promoting understanding of urban transport problems and issues;
2. Effectively managing urban growth;
3. Development of attractive public transport;
4. Efficient traffic control and management;
5. Effective management of transport demand;
6. Comprehensive development of transport space and environment;
7. Improved road safety and environment;
8. Strengthening the institutions.

In practical terms, how might these objectives be implemented? The remainder of this paper briefly considers seven key policy measures that could help Dhaka to achieve a better urban transport system.

Figure 14 Gridlock in Dhaka (typical traffic jam at the Mohakhali flyover)

1. Giving Top Priority to Developing Public Transport

Since Liberation in 1971, public transport in Dhaka has been a comparatively poor relation. For example, the 2005 Strategic Transport Plan (STP) proposed £5.5bn of public investment over 20 years for 3 MRT routes, 3 BRT routes, numerous roads and a single elevated expressway from Mohakhali to Gulistan. Two extended flyovers were also proposed, at Gulistan-Jatrabari and Moghbazar.

The 2005 STP strategy concentrated first on strengthening traffic management and the existing bus sector (through re-structuring and bus priorities). The next stage was to introduce the three BRT routes (by 2011/12). In the meantime, construction would proceed on the three MRT routes, to open in 2016, 2019 and 2021 respectively.

However, to date the government's main emphasis has been on building flyovers, and none of the public transport proposals in the STP have yet been implemented. Bus sector restructuring is still being considered; no bus lanes have yet been introduced; the first BRT line (BRT3) is about to go out to tender (but the other two BRT lines have not been progressed). A single MRT line is being developed but will not be operational before 2021, five years after the original target date. Moreover, the one BRT line that is being developed has been reduced by half because potential donor funding for the southern section (Airport to Jhilmil) was halted because of a competing elevated expressway (Gulistan to Jhilmil).

The first key policy measure is therefore to change priorities, and make public transport truly the number one priority for Dhaka.

2. Reduced Subsidies to Autos, Motor-Cycles, etc.

A second key priority for implementing the draft RSTP proposals, and Option 2 in particular, is to reduce the generous subsidies and support to private motoring. The rapid growth in cars, jeeps, SUV's and motor-cycles is not only due to rising incomes and limited public transport alternatives, but also due to substantial subsidies, particularly fuel and parking.

Fuel Prices: About 90% of autos in Dhaka, and 100% of auto-rickshaws, run on CNG (compressed natural gas). This fuel first appeared in Dhaka in the 1990's and is derived from Bangladesh's own natural gas reserves. It is a cleaner fuel than petrol or diesel – however, the retail price of CNG has been kept low, giving users a very substantial bonus. Currently, the price of CNG is Tk.35 per m^3. If a car runs on octane, the price per litre is currently Tk.99,[9] and the equivalent amount of CNG costs

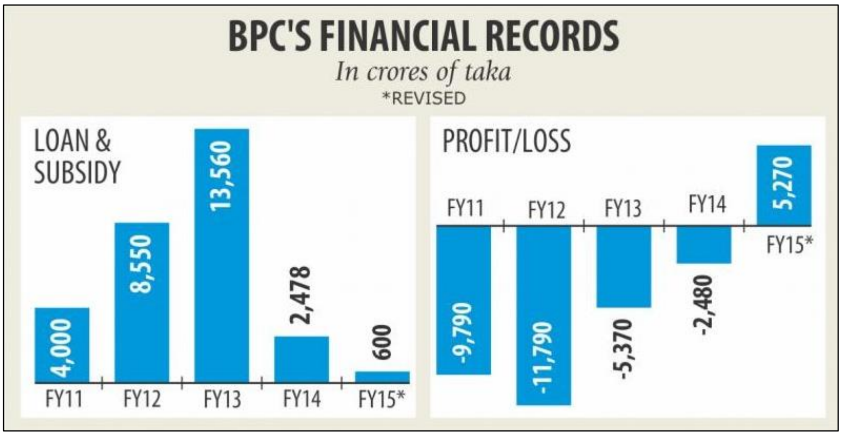
[9] As of 15/04/2016

about Tk.28.5, a saving of around Tk.70.5 per litre (71%). It is estimated that an 1800cc car travelling 60,000 km per year on CNG saves around Tk.3 lakh ($3,900) per year on fuel costs.[10]

The cheapness of **CNG** has several negative effects: firstly, it discourages the use of smaller, fuel-efficient cars, and encourages the import of larger capacity reconditioned saloons (mostly from Japan). Secondly, it greatly reduces the cost of private motoring and stimulates demand. Thirdly, the future of Bangladesh's natural gas reserves is uncertain, and before long the CNG may have to be replaced with oil-based imports – either petroleum or LPG (liquefied petroleum gas), which will be costly both for individuals and nationally.

Petrol and octane prices have also been heavily subsidized in the past, though more recently the fall in international oil prices has reduced if not eliminated this subsidy. Throughout the 2000's the Bangladesh Petroleum Corporation (BPC) incurred heavy losses (in producing diesel, kerosene and furnace oil, as well as petrol and octane). These losses have continued until recently, when the fall in international oil prices enabled BPC to make a profit and recoup some of its past losses. (Fig. 15)

Figure 15 Losses incurred by Bangladesh Petroleum Corporation 2011-16



Source: Daily Star, 13th April 2016, 'WB recommends carbon tax on fuel'

Five years ago (2011) petrol was 45% cheaper in Bangladesh compared to the UK, and diesel was 65% cheaper. Currently, the price of petrol in Dhaka is Tk.96 per litre, which is about 20% cheaper than in the UK (though significantly higher than in India, at Tk.72-77/litre).[11] Recently, the newspapers reported that the government is considering a 10-15% cut in petrol and octane prices, due to lower international oil prices. This will reduce costs for petrol users (especially motor-cycles and some autos) and correspondingly increase demand for these modes.

[10] The cost of a CNG conversion kit for private cars is around Tk.40-75,000

[11] As of 16/04/2016

Parking: On-street car parking throughout Dhaka is virtually free of cost. There are a few public off-street car parks, but since on-street parking is free there is no incentive to use them, and they end up being used for other (commercial) purposes.

The free parking is in contrast with other world cities, particularly in developed countries. In central London, on-street parking is heavily restricted and off-street parking costs $6.80 per hour (Tk.525 per hour). In addition, central London has a 'Congestion Charge' which costs car users a further $11.36 per day (Tk.875) simply to enter the central area. Hence access and parking in central London costs at least Tk.1400 per trip, which is a major incentive to use public transport.

There have been initiatives in Dhaka in the past to introduce on-street parking charges. In the mid-1990's Dhaka City Corporation developed a scheme for the Motijheel commercial area to be run by private contractors, but it fell by the wayside.

Private off-street parking: Another policy encouraging the growth of private transport is the requirement that all new multi-storey buildings must have ground level or basement car parks. In residential areas such as Banani virtually the entire ground floor area is given over to car parking. The same requirement applies to new buildings all over the city, including in high density neighbourhoods with very narrow roads – such as Old Dhaka and most 'unplanned' neighbourhoods. The effect of this policy is to encourage cars in the congested neighbourhoods, even though the narrow roads are unsuitable.

The alternative is to limit the amount of car parking provided at new buildings, and allow the existing rental market in private off-street car parking to grow, while tightly controlling on-street parking to keep roads clear for traffic. This policy would increase the cost of car use and discourage the growth of car ownership in densely populated neighbourhoods (i.e. the majority of Dhaka!).

Bank loans for car and motor-cycle purchase: Another policy stimulating the growth of private cars and motor-cycles is the availability of bank loans for vehicle purchase. Recently (2014) the Bangladesh Bank doubled the loan ceiling for private car purchase from Tk.20 lakh to Tk.40 lakh ($52,000), and raised the debt-equity level from 30-70 to 50-50. The reason, according to the central bank's Deputy General Manager, was 'in response to the higher market prices and demand for vehicles', while another source said 'the relaxation of the car loan policy arose from the need to give banks a channel to direct their huge piles of liquidity in the face of sluggish investment demand'.[12]

[12] Daily Star, 14/08/2014, 'BB relaxes car loan policy)

Car loan policy has varied over the past decade (see Table 9 below), but in general, the easy availability of generous loans is another factor driving the growth in private vehicles in Dhaka.

Table 9 Bank loan policy for private car purchase in Bangladesh, 2004-2014

Year	Bank Loan Ceiling (Tk. Lakh)	Debt-Equity Ratio
2004	50	90-10
2005	20	90-10
2010	50	50-50
2012	20	30-70
2014	40	50-50

Source: Daily Star, 14 August 2014, 'BB relaxes car loan policy'

3. Specific Measures to Encourage Buses

Buses already carry about 47% of Dhaka's total passengers (excluding walking trips – see Table 2 above). If tempos, auto-rickshaws and cycle-rickshaws are included, then the overall public transport share is about 88% of trips, a level that many other world cities would be delighted to achieve. However, the auto-rickshaws and cycle-rickshaws take up a lot of road space, and the bus system is slow, grossly over-crowded, uncomfortable and limited in coverage.

Dhaka needs a first-class bus system, and priorities for achieving this include:

- Giving buses traffic priority through bus lanes, priority signals at junctions, 'queue-jumps' and other traffic management measures to ensure that they are not slowed down by congestion and offer a reliable service quicker than the rest of the traffic.

Figure 16 Example of a BRT bus lane avoiding traffic congestion

The above example is from Indonesia. The capacity of a single BRT lane is around 10,000 to 16,000 passengers per hour, which is more than the adjoining five lanes of traffic added together.

- Creating an integrated bus network, so that routes inter-connect and passengers can move easily around the city.
- Raising the quality of the bus system through high quality buses, good bus shelters, well-managed terminals, passenger information systems, integrated ticketing, and so on.
- Providing bus services not only on the main corridors, but also within neighbourhoods using mini- and micro-bus services with priority over other traffic.

There have been efforts to introduce 'premium' bus services in the past. In 1997, following the recommendation of the 1994 Dhaka Integrated Transport Study (DITS), a Premium Bus service started operation between Uttera and Motijheel. With government and donor support a private company fielded 35 air-conditioned high quality buses with a limited-stop express service. It was very successful, and two more routes were started between Motijheel-Narayanganj and Motijheel-Savar. Another private operator also began 'premium' services between Uttera and Motijheel. However, the initiative foundered due to disagreements with BRTA over route permits, and by 2005 was closed down.

The experience highlights the importance of the government agencies in promoting or hindering the development of public transport in Dhaka.

4. Developing Walking and Cycling in Dhaka

Walking: Conditions for pedestrians in Dhaka are extremely poor. Although the traffic laws clearly state that vehicles must give way to pedestrians on zebra crossings, no one obeys the rule and a pedestrian risks his/her life if they expect traffic to stop for them. Many roads have no footways, and those that are provided are difficult to use due to obstructions, uncovered drains, low hanging wires, hawkers and parked vehicles.

Walking is an essential part of a city's transport. Even the most modern cities have a high proportion of pedestrians – for example Singapore, Tokyo, London and Berlin all have 20-30% of all trips made on foot, and this does not include walking to and from public transport.[13] In Dhaka the proportion is 40% or more.[14]

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[13] Land Transport Authority, Singapore, 'Journeys' magazine, Issue 7, Nov. 2011, page 60. Note that the statistics refer only to 'main mode' and do not include walking trips that are part of public transport journeys.

[14] RSTP,

Good footways and safe road crossings can transform a city; for example:

- Encouraging more people to walk and use vehicles less (e.g. rickshaws, cars), thus freeing-up road space;
- Making public transport more attractive through easier access;
- Saving people money;
- Making the city pleasant and livable, and boosting people's exercise, health and well-being.

As the famous transport visionary Enrique Peñalosa once said, the measure of a civilized city is whether it safe for children to walk. "Children are a kind of indicator species. If we can build a successful city for children, we will have a successful city for all people."

Cycling: Cycling is the 'invisible' mode of transport in Dhaka, at least for the policy-makers. There are over 200,000 bicycles in the city and about 2% of all trips are made by bicycle – which is about the same proportion as in London. Yet cycling is almost completely absent from policy decisions on city transport, and like pedestrians, cyclists are not considered when road infrastructure is developed.

The benefits of cycling make it one of the most efficient and environmentally-friendly modes available. For example, the bicycle's range is 15km or more. In congested urban conditions it is the fastest mode available, and gives a door-to-door service. It can carry heavy loads, and is the second cheapest mode after walking. Space-wise, it takes up less road space than all other vehicles, and in PCU terms is out-performed only by mass transport. Its environmental and health benefits are plain.

Moreover, there is great potential for cycling to make a major contribution to Dhaka's transport system. In many other developed cities, cycling accounts for 10-30% of <u>ALL</u> trips: examples include Berlin (13%); Tokyo (16%); Shanghai (20%); Amsterdam (28%); Beijing (32%).

Figure 17 The Mayor of Dhaka North City Corporation, Annisul Huq, supporting cyclists ahead of the 2015 mayoral election

Photo: Courtesy of Dhaka Star, 18th April, 2015

In Dhaka, cycling could easily account for twice or three times as many trips as at present, which would be the equivalent of building two or three extra BRT lines. The main requirements are to make the roads safer for cyclists through traffic calming and safer crossings at junctions and right turns, and encourage more cyclists through publicity, promotion, organization and financial incentives – for example, a single car loan at Tk.40 lakh could support the purchase of over 200 bikes.

5. Traffic Management and Transport Planning

Another priority for Dhaka is to improve the control of traffic and urban development. According to the 2005 Strategic Transport Plan, because of poor traffic management only half of the road capacity was being utilized; and the situation has not improved much since then (RSTP Interim Report 2, 2015, Section 14.5).

There are many traffic management measures that can be implemented to achieve a smoother traffic flow, for example:

- One-way streets
- Parking controls
- Traffic signals
- Bus stop discipline, etc.
- There are also longer-term planning measures that could be implemented, such as:

- Reserving rights of way for future roads and public transport;
- Controlling the size and location of traffic-generating buildings (for example, thirty years ago a rule was passed restricting multi-storey shopping centres at busy road junctions, but was never implemented).

According to the RSTP the average traffic speed in Dhaka could be increased by nearly one-third simply by good traffic management, and a traffic management project would pay for itself within a year, simply from the reduced traffic congestion. But strengthening traffic management and transport planning in Dhaka requires strengthening the government institutions.

6. Strengthening the Institutions Responsible for Traffic and Transport

London (population 8.4 million) has an umbrella transport authority known as Transport for London (TfL). In addition, the capital is divided into 33 separate local councils, each with its own transport planning and engineering team. The umbrella body (TfL) has a total staff of over 25,000, while each local council has at least 15 persons working in its transport / traffic engineering team.

In Dhaka, the Dhaka Transport Co-ordination Authority (DTCA) had just 10 officers in 2015 – this was after seventeen years of operation, and the numbers had decreased since it was first established in the late 1990's. Admittedly, TfL and DTCA are very different organisations; the London body is responsible for operating buses, tube trains and some rail services, which involve very large numbers of employees. However, DTCA has stagnated over the years due to low priority from central government.

The same under-staffing is found in all of the agencies responsible for transport and urban planning in Dhaka. The Dhaka North City Corporation (DNCC), for example, has fewer staff in its traffic engineering team (14 at all levels in 2013), than just one of London's 33 councils, and the combined numbers at Dhaka North and South City Corporations have hardly increased over the past fifteen years.

The tasks of managing traffic and future urban development are not possible without sufficient staff in the government agencies. Recruiting competent staff for these agencies should therefore be Dhaka's top priority for transport development.

7. Mobilising the Funds for Transport Improvements

The scale of investment proposed in the draft RSTP seems enormous compared with other sectors in Bangladesh – $45bn would be the equivalent of building 12 Padma Bridges. Where will the money come from?

A major priority for Dhaka's transport system is therefore to mobilise funds, and two potential sources are: (i) to re-direct some of the existing resources already generated by the transport sector, and (ii) to harness other sources with great potential (such as property taxes and land development). A few examples illustrate the potential.

Hawkers: In Dhaka about one-quarter of a million people are working as hawkers and in informal roadside shops. All of them pay daily rent to the authorities through an unofficial but well-organised collection system. Various estimates of the annual 'rent' collected this way vary from Tk.850 to 1,825 crore per year.[15] If we assume the middle of this range (Tk.910 crore/year), then the annual 'rent' collection from hawkers is around $118 million per year, or $2.4bn over twenty years. None of this is currently spent on footway improvements.

CNG / Auto-Rickshaws: In 2002 a ceiling was placed on auto-rickshaw licences in Dhaka, after 40,000 2-stroke petrol-driven auto-rickshaws were withdrawn due to serious air pollution and replaced with 12,000 CNG-fuelled vehicles. Subsequently, no further auto-rickshaw licences were issued (except for about 5,000 'private' CNG's) on the grounds of reducing traffic congestion.

However, CNG numbers have continued to grow (as shown in traffic counts), and consequently there is a thriving unofficial market in licence renewals. According to officials of the CNG owners' association, the actual cost of putting a new CNG on the road is around Tk.13 lakh, whereas it should be only Tk.5 lakh.[16] If we assume (conservatively) that the additional cost per new auto-rickshaw is around Tk.5 lakh, then over twenty years the additional cost of fielding new CNG's under Option 2 would be around $0.9bn.[17]

Cycle-Rickshaws: A similar situation occurs with the cycle-rickshaws: in this case the ceiling on licences is almost traditional, dating back to the Pakistan period if not before. The most recent ceiling of 80,000 was introduced in 1986 during Ershad's rule. An amnesty was declared and all rickshaws were licensed at a time. But since then the new ceiling has remained in place, though actual cycle-rickshaw numbers today probably exceed 330,000 in the RAJUK area. The ceiling has given rise to a thriving market in fake licences: a recent newspaper report suggested there were about 28 private associations involved in the sale of number plates to new cycle rickshaws and rickshaw vans.[18] Existing owners pay a monthly subscription to these associations, around Tk.190 per month per rickshaw, to

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[15] See, for example, Daily Star newspapers of 07/08/2013, 30/03/2014, 16/05/2014.

[16] Daily Star, 01/11/2015, 'Why you pay more to use the CNG'

[17] The calculation assumes Tk.5 lakh excess per vehicle and 140,000 CNG's for RAJUK area over 20 years

[18] Dhaka Tribune, 11/09/2013, 'Illegal rickshaw licences on sale'

operate under their protection.[19] At a Dhaka level this represents an annual levy of around Tk.75 crore, or possibly $0.2bn over twenty years.[20]

In conclusion, there is considerable scope to mobilise funds from existing sources, and this applies to other sectors too, such as buses, trucks, driver licences, parking charges, terminals, and so on.

Mobilising funds from fuel taxes: The recent suggestion to lower the price of petrol and octane by about Tk.10-15 per litre could be worth about Tk.370 crore per year to existing auto and motor-cycle users in Dhaka. Over twenty years, this could represent a reduction of almost $1bn in revenues collected by the government, not including the additional vehicles likely to be purchased in the coming years.[21]

6. Conclusion

The benefit-cost analysis (Chapter 4) highlighted the benefits that could be gained for Dhaka's citizens by giving more emphasis to public transport, and slowing down the growth in low-capacity private transport (particularly cars, motor-cycles, auto-rickshaws and cycle-rickshaws).

By doing so, Dhaka would be following the trend in many other world cities, especially in the more developed countries.

The policy lessons for Dhaka also apply to other towns and cities in Bangladesh, whose traffic problems are steadily increasing.

Finally, a measure of success for Dhaka's future urban transport is that proposed by the transport visionary, Enrique Peñalosa, who once said that the measure of a civilized city is whether it safe for its children to walk in: "Children are a kind of indicator species. If we can build a successful city for children, we will have a successful city for all people."

[19] Financial Express, 23/03/2016, 'Rickshaws invade capital'

[20] The calculation assumes 330,000 rickshaws paying Tk.190 per vehicle per month

[21] The calculation assumes 71,000 petrol-driven autos and 70,000 motor-cycles, and a Tk.15 reduction in petrol prices.

APPENDICES

Appendix 1a: 'Do Nothing' Scenario (RSTP) – Estimate of Passenger Travel Supply for 2016 and 2035

2016 **2035 ('Do Nothing' scenario)**

Mode	Average Passenger Load	Annual Vehicle Distance	Daily Vehicle Distance	Daily Output per Vehicle	Vehicle Numbers, 2016	TOTAL Daily Output, 2016	% of 2016 Daily Output	Assumed Vehicle Growth Rate (% pa)	Vehicle Numbers, 2035	TOTAL Daily Output, 2035	% of 2035 Daily Output	RSTP Prediction of share of total daily TRIPS, 2035 'Do Nothing' scenario (excluding walking)
	Pass.	*km/yr*	*km/day*	*pass-km/day*	*Number*	*Mill Pass-Km*	*%*	*%*	*Number*	*Mill Pass-Km*	*%*	*%*
Metro							0				0	0
BRT							0				0	0
Bus	36.6	100,000	274	10,027	6,695	67.1	49.1	6.0	20,256	203.1	53.4	53
Tempo	10.3	40,000	110	1,129	1,785	2.0	1.5	6.0	5,401	6.1	1.6	n.a.
Auto-Rick	3.0	40,000	110	329	40,000	13.2	9.6	5.0	101,078	33.2	8.7	10
Rickshaw	1.3	16,425	45	59	330,000	19.3	14.1	2.5	527,555	30.9	8.1	16
Car, jeep	2.0	15,000	41	82	221,341	18.2	13.3	6.0	669,689	55.0	14.5	18
M-Cycle	1.7	40,000	110	186	70,000	13.0	9.5	4.0	147,479	27.5	7.2	3
Bicycle	1.0	9,125	20	20	200,000	4.0	2.9	2.0	291,362	5.8	1.5	n.a.
						136.8	**100**			**380.2**	**100.0**	**100**
Source:	ALG	ALG			RG, from RSTP and others				RG, from RSTP and others	Assumes same vehicle output as in 2016		RSTP

Appendix 1b: OPTION 1 (RSTP) – Estimate of Passenger Travel Supply for 2016 and 2035

2016 **2035 (Option 1)**

Mode	Average Passenger Load	Annual Vehicle Distance	Daily Vehicle Distance	Daily Output per Vehicle	Vehicle Numbers, 2016	TOTAL Daily Output, 2016	% of 2016 Daily Output	Assumed Vehicle Growth Rate (% pa)	Vehicle Numbers, 2035	TOTAL Daily Output, 2035	% of 2035 Daily Output	RSTP Prediction of share of total daily TRIPS, 2035 (excluding walking)
	Pass.	*km/yr*	*km/day*	*pass-km/day*	*Number*	*Mill Pass-Km*	*%*	*%*	*Number*	*Mill Pass-Km*	*%*	*%*
Metro							0		5 lines	39.6	12.7	14
BRT							0		2 lines	9.4	3.0	3
Bus	36.6	100,000	274	10,027	6,695	67.1	49.1	3.0	11,740	117.7	37.7	40
Tempo	10.3	40,000	110	1,129	1,785	2.0	1.5	3.0	3,130	3.5	1.1	ns
Auto-Rick	3.0	40,000	110	329	40,000	13.2	9.6	5.0	101,078	33.2	10.6	14
Rickshaw	1.3	16,425	45	59	330,000	19.3	14.1	2.0	480,748	28.1	9.0	11
Car, jeep	2.0	15,000	41	82	221,341	18.2	13.3	5.2	579,910	47.7	15.2	16
M-Cycle	1.7	40,000	110	186	70,000	13.0	9.5	4.0	147,479	27.5	8.8	2
Bicycle	1.0	9,125	20	20	200,000	4.0	2.9	2.0	291,362	5.8	1.9	ns
						136.8	**100**			**312.6**	**100.0**	**100**
Source:	ALG	ALG			RG, from RSTP and others				RG, from RSTP and others	Assumes same vehicle output as in 2016		RSTP

Appendix 1c: OPTION 2 (Alternative Option) – Estimate of Passenger Travel Supply for 2016 and 2035

2016 **2035 (Option 2)**

Mode	Average Passenger Load	Annual Vehicle Distance	Daily Vehicle Distance	Daily Output per Vehicle	Vehicle Numbers, 2016	TOTAL Daily Output, 2016	% of 2016 Daily Output	Assumed Vehicle Growth Rate (% pa)	Vehicle Numbers, 2035	TOTAL Daily Output, 2035	% of 2035 Daily Output	RSTP Prediction of share of total daily TRIPS, 2035 (excluding walking)
	Pass.	*km/yr*	*km/day*	*pass-km/day*	*Number*	*Mill Pass-Km*	*%*	*%*	*Number*	*Mill Pass-Km*	*%*	*%*
Metro							0		5 lines	39.6	11.0	14
BRT							0		2 lines	9.4	2.6	3
Bus	36.6	100,000	274	10,027	6,695	67.1	49.1	6.0	20,256	203.1	56.4	40
Tempo	10.3	40,000	110	1,129	1,785	2.0	1.5	6.0	5,401	6.1	1.7	ns
Auto-Rick	3.0	40,000	110	329	40,000	13.2	9.6	3.0	70,140	23.1	6.4	14
Rickshaw	1.3	16,425	45	59	330,000	19.3	14.1	1.0	398,676	23.3	6.5	11
Car, jeep	2.0	15,000	41	82	221,341	18.2	13.3	2.0	322,452	26.5	7.4	16
M-Cycle	1.7	40,000	110	186	70,000	13.0	9.5	2.5	111,906	20.8	5.8	2
Bicycle	1.0	9,125	20	20	200,000	4.0	2.9	4.0	421,370	8.4	2.3	ns
						136.8	**100**			**360.4**	**100**	**100**
Source:	ALG	ALG	Annual distance divided by 365		RG, from RSTP and others				RG, from RSTP and others	Assumes same vehicle output as in 2016		RSTP

Appendix 2a: OPTION 1 (RSTP) – Road Space taken up by Different Modes, 2016 and 2035

2016 **2035 (Option 1)**

Mode	PCU Value	Ave Occupancy	Road Space per Passenger	TOTAL Daily Output, 2016	Total Daily Roadspace consumed, 2016	% of total Roadspace consumed, 2016	TOTAL Daily Output, 2035 **	Total Daily Roadspace consumed, 2035	% of total Roadspace consumed, 2035
	Units	*Pass. per vehicle*	*PCU's per pass*	*Mill Pass-Km*	*Mill. PCU-km / day*	*%*	*Mill Pass-Km*	*Mill. PCU-km / day*	*%*
Metro	*na*					*na*	39.6	*Assumed zero*	
BRT	4.0	120.0	0.03			*na*	9.4	0.3	0.5
Bus	2.0	36.6	0.05	67.1	3.67	13.1	117.7	6.4	10.8
Tempo	0.7	10.3	0.07	2.0	0.14	0.5	3.5	0.2	0.4
Auto-Rick	0.7	3.0	0.23	13.2	3.07	10.9	33.2	7.7	13.0
Rickshaw	0.4	1.3	0.31	19.3	5.94	21.2	28.1	8.6	14.5
Car, jeep	1.0	2.0	0.50	18.2	9.10	32.4	47.7	23.9	39.9
M-Cycle	0.7	1.7	0.41	13.0	5.37	19.1	27.5	11.3	19.0
Bicycle	0.2	1.0	0.20	4.0	0.80	2.8	5.8	1.2	1.9
TOTAL				**136.8**	**28.08**	**100.0**	**312.6**	**59.7**	**100.0**

** Assumes same level of output per vehicle as in 2016

Appendix 2b: OPTION 2 (Alternative Option) – Road Space taken up by Different Modes, 2016 and 2035

2016 **2035 (Option 2)**

Mode	PCU Value	Ave Occupancy	Road Space per Passenger	TOTAL Daily Output, 2016	Total Daily Roadspace consumed, 2016	% of total Roadspace consumed, 2016	TOTAL Daily Output, 2035 **	Total Daily Roadspace consumed, 2035	% of total Roadspace consumed, 2035
	Units	*Pass. per vehicle*	*PCU's per pass*	*Mill Pass-Km*	*Mill. PCU-km / day*	*%*	*Mill Pass-Km*	*Mill. PCU-km / day*	*%*
Metro	*na*					*na*	39.6	*Assumed zero*	
BRT	4.0	120.0	0.03			*na*	9.4	0.3	0.7
Bus	2.0	36.6	0.05	67.1	3.67	13.1	203.1	11.1	23.2
Tempo	0.7	10.3	0.07	2.0	0.14	0.5	6.1	0.4	0.9
Auto-Rick	0.7	3.0	0.23	13.2	3.07	10.9	23.1	5.4	11.3
Rickshaw	0.4	1.3	0.31	19.3	5.94	21.2	23.3	7.2	15.0
Car, jeep	1.0	2.0	0.50	18.2	9.10	32.4	26.5	13.3	27.7
M-Cycle	0.7	1.7	0.41	13.0	5.37	19.1	20.8	8.6	17.9
Bicycle	0.2	1.0	0.20	4.0	0.80	2.8	8.4	1.7	3.5
TOTAL				**136.8**	**28.08**	**100.0**	**360.3**	**47.9**	**100**

** Assumes same level of output per vehicle as in 2016

Appendix 3: Forecast of Total Investment in Dhaka's Urban Transport System over 20-years (2016-35) for Two Options

Option 1 - RSTP Infrastructure Proposals and High Auto Growth; Option 2 - RSTP Infrastructure Proposals and High Bus Growth/Low Auto Growth

Source of figures		Vehicle Numbers 2016	Opt. 1 Growth Rate % pa	Opt. 1 Vehicle Numbers 2035	Total Cost, 2016-35 $ mill	% of Total Cost	Opt. 2 Growth Rate % pa	Opt. 2 Vehicle Numbers 2035	Total Cost, 2016-35 $ mill	% of Total Cost
			RG	RG	RSTP, RG		RG	RG	RSTP, RG	
RSTP proposal	6 Expressways				4,625	*3.8*			4,625	*4.4*
RSTP proposal	3 Ring Roads				5,072	*4.1*			5,072	*4.8*
RSTP proposal	Pry & Secy Roads				4,446	*3.6*			4,446	*4.2*
RSTP proposal	5 Metro Lines			5 lines	27,581	*22.4*		5 lines	27,581	*26.0*
RSTP proposal	2 BRT Lines			2 lines	2,097	*1.7*		2 lines	2,097	*2.0*
RSTP proposal	Bus priorities				646	*0.5*			646	*0.6*
RSTP proposal	Traffic management				600	*0.5*			600	*0.6*
RG estimate	Bus	6,695	4	11,740	4,684	*3.8*	6	20,256	6,709	*6.3*
RG estimate	Tempo	1,785	3	3,130	1,249	*1.0*	6	5,401	1,789	*1.7*
RG estimate	Auto-Rick	40,000	5	101,078	3,490	*2.8*	3	70,140	2,801	*2.6*
RG estimate	Rickshaw	330,000	2	480,748	12,064	*9.8*	1	398,676	10,917	*10.3*
RG estimate	Car, jeep	221,341	5.2	579,910	53,657	*43.5*	2	322,452	36,357	*34.2*
RG estimate	M-Cycle	70,000	4	147,479	2,701	*2.2*	2.5	111,906	2,296	*2.2*
RG estimate	Bicycle	200,000	2	291,362	52.8	*0.04*	4	421,370	71	*0.1*
	TOTAL				**122,965**	***99.8***			**106,007**	*99.8*
					$123bn				**$106bn**	

Appendix 4: Vehicle Operating Costs for different vehicles in Dhaka, 2011

SOURCE: 'Dhaka Bus Network and Regulatory Reform Implementation Study and Design Work' – REVISED INTERIM REPORT, 2012, by ALG for World Bank and Dhaka TransportatIon Co-ordination Board, Chapter 2: Public Transport Industry

Vehicle Operating Cost (VOC)

Component	units	ref	Large Bus	Mini Bus	Micro Bus	Utility	Car	Tempo	Auto Rickshaw	Motor-cycle
Vehicle			Hino AK Series	TATA LP909	Toyota Noah	Mitsu. Pajero	Toyota Corolla		Bajaj	Honda 125
Cost (2011)	BDT		3.964.000	1.811.670	2.618.120	3.759.770	2.177.790	291.650	*200.000*	102.160
Seats	Seat		40	16-39	under 16	jeep/pick-up	5	12	3	2
Chasis length	m		11							
Useful life	Years		7	10	9	8	8	5	8	8
Average use	km/year		100.000	100.000	100.000	15.000	15.000	40.000	40.000	40.000
Interest rate	%	12%								
Loan term	Month	60								
Repayment	BDT/mo		87.304	39.901	57.662	82.806	47.964	6.423	5.617	2.250
Annualised acquisition cost			1.047.647	478.807	691.944	993.671	575.569	77.080	67.406	27.000
Fuel										
Consumption										
Diesel	L/100 km									
Petrol/Octane	L/100 km									
Octane	L/100 km									
CNG	km/m3		3,92	5,23	10,99	10,99	13,19	22,43	22,43	22,43
Diesel	BDT/L	44,00								
Petrol/Gasoline	BDT/L	74,00								
Octane	BDT/L	77,00								
CNG	BDT/m3	16,75	426.790	320.093	152.425	22.864	19.046	29.875	29.875	29.875

Component	**units**	**ref**	**Large Bus**	**Mini Bus**	**Micro Bus**	**Utility**	**Car**	**Tempo**	**Auto Rickshaw**	**Motor-cycle**
Vehicle			Hino AK Series	TATA LP909	Toyota Noah	Mitsu. Pajero	Toyota Corolla		Bajaj	Honda 125
Lubricant										
Consumption	L/3,000 km or 15 days		15	12						
Consumption	L/3,000 km or 60 days				4	4	4	4	*4*	*4*
Cost	BDT/L	*240*	120.000	96.000	32.000	4.800	4.800	12.800	12.800	12.800
Tyres										
Tyres per vehicle	T/veh		6	6	4	4	4	3	3	2
Life	Month		6	4	4	6	5	4	4	6
Unit cost (2011)	BDT		15.050	5.520	3.100	8.783	3.062	*1.500*	1.031	986
Cost	BDT/year		180.600	99.360	37.200	70.264	29.395	13.500	9.279	3.944
Crew (2010)										
Driver	BDT/mo		12.530	7.542	6.880	7.415	0	6.500	5.192	0
Helper	BDT/mo		6.147	4.000	6.354	0	0	2.644	1.647	0
Driver	BDT/h		41	29	23	20	23	21	16	0
Helper	BDT/h		16	12	8	0	0	7	6	0
Driver	h/mo		306	260	299	371	0	310	325	0
Helper	h/mo		384	333	794	0	0	378	275	0
Total crew	BDT/h		57	41	31	20	23	28	22	0
Total crew	BDT/year		224.124	138.504	158.808	88.980	0	109.728	82.068	0
Maintenance										
Spare parts			73.497	40.866	32.436	26.500	32.700	22.518	9.030	6.780
Maintenance labor			30.272	15.715	16.450	12.954	12.021	8.206	8.106	3.669
Total maintenance			103.769	56.581	48.886	39.454	44.721	30.724	17.136	10.449

Component	**units**	**ref**	**Large Bus**	**Mini Bus**	**Micro Bus**	**Utility**	**Car**	**Tempo**	**Auto**	**Motor-**
Vehicle			Hino AK Series	TATA LP909	Toyota Noah	Mitsu. Pajero	Toyota Corolla		**Rickshaw** Bajaj	**cycle** Honda125
Spare parts										
Oil filter										
Consumption	Set/3,000 km		2	2	2					
	Set/year					4	4	4	4	4
Price	BDT/set		250	180	180	100	100	100	100	100
Annual cost of oil filters	BDT/year		16.667	12.000	12.000	400	400	400	400	400
Air filter										
Consumption	Set/year		4	4	4	1	1	1	1	1
Price	BDT/set		1.500	1.000	500	400	400	200	200	200
Annual cost of air filters			6.000	4.000	2.000	400	400	200	200	200
Brake pads										
Consumption	Set/year		2	2	2	1	1	1	1	1
Price			1.800	1.500	1.200	*1.000*	*800*	*600*	*600*	*600*
Annual cost of brake pads	BDT/year		3.600	3.000	2.400	1.000	800	600	600	600
Engine overhauling										
Frequency	every 2 years									
Cost full			100.000	100.000	50.000					
Cost half			60.000	60.000	30.000					
Annualised overhauling cost	BDT/year		80.000	80.000	40.000	0	0	0	0	0
Overhead costs										
Insurance		3%	10.800	6.000	3.600	6.000	600	500	600	240
Taxes			2.660	7.315	6.650	6.000	6.000	1.200	1.200	1.200
Tolls			225.667	99.000	21.000	2.000	41.000	8.000	6.500	1.800
Office			110.000	57.000	98.000	0	52.800	9.600	6.000	0
Garage			24.000	18.000	13.000	11.700	9.000	3.250	8.000	2.600
Others			70.000	44.000	25.000	6.000	12.000	13.000	10.000	4.500
Total	BDT/year		443.127	231.315	167.250	31.700	121.400	35.550	32.300	10.340
Total costs	BDT/year		2.652.324	1.519.660	1.344.913	1.253.533	796.531	310.458	252.064	95.608

Appendix 5: Details of Total Annual Investment in Infrastructure and Vehicles, 2016-2035, based on RSTP predictions (OPTION 1)

Source: **RSTP = Revised Strategic Transport Plan; RG = Author's Estimate**

Detailed Year-Wise Investment, Roads and Private Vehicles (Based on RSTP) *Units: $ million*

	RSTP				RSTP				RSTP				RG		
Year	6 Expressways				3 Ring Roads				Other Primary & Secondary Roads				Autos		
	Capital	Cum Total	O+M 1.4% pa	TOTAL	Capital	Cum Total	O+M 1.4% pa	TOTAL	Capital	Cum Total	O+M 1.4% pa	TOTAL	Capital Cost, New Autos	Running Costs, Total Fleet	Total
2016	229	229	3	232	42	42	1	43	337	337	5	342	439	1,150	1,589
2017	229	458	6	235	43	85	1	44	337	674	9	346	462	1,210	1,672
2018	229	687	10	239	42	127	2	44	337	1011	14	351	486	1,273	1,759
2019	229	916	13	242	43	170	2	45	337	1348	19	356	511	1,339	1,850
2020	229	1145	16	245	42	212	3	45	337	1685	24	361	538	1,408	1,946
		1145				212				1685					
2021	157	1302	18	175	374	586	8	382	97	1782	25	122	565	1,482	2,047
2022	157	1459	20	177	374	960	13	387	97	1879	26	123	595	1,559	2,154
2023	157	1616	23	180	374	1334	19	393	97	1976	28	125	626	1,640	2,266
2024	157	1773	25	182	374	1708	24	398	97	2073	29	126	658	1,725	2,383
2025	157	1930	27	184	374	2082	29	403	97	2170	30	127	693	1,815	2,508
		1930				2082				2170					
2026	388	2318	32	420	151	2233	31	182	83	2253	32	115	729	1,909	2,638
2027	388	2706	38	426	151	2384	33	184	83	2336	33	116	766	2,008	2,774
2028	388	3094	43	431	151	2535	35	186	83	2419	34	117	806	2,113	2,919
2029	388	3482	49	437	151	2686	38	189	83	2502	35	118	848	2,223	3,071
2030	388	3870	54	442	152	2838	40	192	84	2586	36	120	892	2,338	3,230
		3870				2838				2586					
2031	20	3890	54	74	337	3175	44	381	250	2836	40	290	939	2,460	3,399
2032	21	3911	55	76	337	3512	49	386	250	3086	43	293	988	2,588	3,576
2033	20	3931	55	75	337	3849	54	391	250	3336	47	297	1,039	2,722	3,761
2034	21	3952	55	76	337	4186	59	396	249	3585	50	299	1,093	2,864	3,957
2035	21	3973	56	77	337	4523	63	400	249	3834	54	303	1,150	3,013	4,163
TOTAL	3,973		653	4626	4,523		549	5,072	3834		612	4,446	14,822	38,835	53,657

Appendix 5 (continued)

Detailed Year-Wise Investment, Public Transport Infrastructure (Based on RSTP)

Year	RSTP MRT Capital	Cum Total	O+M 2.6% pa	TOTAL	RSTP BRT Capital	Cum Total	O+M 16%	TOTAL	RSTP Bus Improvement Project Capital	O+M ns	TOTAL	RSTP Traffic Management Capital	O+M ns	TOTAL
2016	457	457	12	469	80	80	13	93	89		89	80		80
2017	457	914	24	481	80	160	26	106	89		89	80		80
2018	457	1,371	36	493	80	240	38	118	89		89	80		80
2019	457	1,828	48	505	80	320	51	131	89		89	80		80
2020	457	2,285	59	516	80	400	64	144	90		90	80		80
		2,285				400								
2021	1,049	3,334	87	1,136	0	400	64	64	20		20	40		40
2022	1,049	4,383	114	1,163	0	400	64	64	20		20	40		40
2023	1,049	5,432	141	1,190	0	400	64	64	20		20	40		40
2024	1,049	6,481	169	1,218	0	400	64	64	20		20	40		40
2025	1,049	7,530	196	1,245	0	400	64	64	20		20	40		40
		7,530				400								
2026	1,482	9,012	234	1,716	41	441	71	112	20		20	0		0
2027	1,482	10,494	273	1,755	41	482	77	118	20		20	0		0
2028	1,482	11,976	311	1,793	41	523	84	125	20		20	0		0
2029	1,482	13,458	350	1,832	41	564	90	131	20		20	0		0
2030	1,482	14,940	388	1,870	42	606	97	139	20		20	0		0
		14,940				606								
2031	1,532	16,472	428	1,960	10	616	99	109	0		0	0		0
2032	1,532	18,004	468	2,000	10	626	100	110	0		0	0		0
2033	1,532	19,536	508	2,040	10	636	102	112	0		0	0		0
2034	1,532	21,068	548	2,080	10	646	103	113	0		0	0		0
2035	1,532	22,600	588	2,120	11	657	105	116	0		0	0		0
TOTAL	22,600		4,981	27,581	657		1,440	2,097	646		646	600		600

Appendix 5 (continued)

RG M-C's Capital Cost, New M-C's	Running Costs, Total M-C's	Total	RG Buses Capital Cost, New Buses	Running Costs, Total Buses	Total	RG Tempos Capital Cost, New Tempos	Running Costs, Total Tempos	Total
7	83	90	35	139	174	9	37	46
8	87	95	36	143	179	10	38	48
8	90	98	37	148	185	10	39	49
8	94	102	38	152	190	10	41	51
8	98	106	39	157	196	11	42	53
9	102	111	41	161	202	11	43	54
9	106	115	42	166	208	11	44	55
10	110	120	43	171	214	11	46	57
10	114	124	44	176	220	12	47	59
10	119	129	46	182	228	12	48	60
11	124	135	47	187	234	13	50	63
11	128	139	49	193	242	13	51	64
12	134	146	50	199	249	13	53	66
12	139	151	51	205	256	14	55	69
13	144	157	53	211	264	14	56	70
13	150	163	55	217	272	15	58	73
14	156	170	56	223	279	15	60	75
14	163	177	58	230	288	15	61	76
15	169	184	60	237	297	16	63	79
15	176	191	61	244	305	16	65	81
216	2,485	2,701	942	3,742	4,684	251	998	1249

Appendix 5 (continued)

RG

Cycle Rickshaws: Capital Cost, New Ricks	Running Costs, Total Ricks	Total
8	489	497
8	499	507
8	508	516
8	519	527
8	529	537
9	540	549
9	550	559
9	561	570
9	573	582
9	584	593
9	596	605
10	608	618
10	620	630
10	632	642
10	645	655
10	658	668
11	671	682
11	684	695
11	698	709
11	712	723
188	11,876	12,064

RG

Auto-Rickshaws: Capital Cost, NewAuto Ricks	Running Costs, Total Auto Ricks	Total
9	96	105
10	101	111
10	106	116
11	111	122
12	117	129
12	123	135
13	129	142
13	135	148
14	142	156
15	149	164
15	156	171
16	164	180
17	172	189
18	181	199
19	190	209
20	200	220
21	210	231
22	220	242
23	231	254
24	243	267
314	3176	3490

RG

Bicycles: Capital Cost, New Bicycles	Running Costs, Total Bikes	Total
0.9	1.2	2.1
1	1.3	2.3
1	1.3	2.3
1	1.3	2.3
1	1.3	2.3
1	1.4	2.4
1.1	1.4	2.5
1.1	1.4	2.5
1.1	1.5	2.6
1.1	1.5	2.6
1.1	1.5	2.6
1.2	1.5	2.7
1.2	1.6	2.8
1.2	1.6	2.8
1.2	1.6	2.8
1.3	1.7	3
1.3	1.7	3
1.3	1.7	3
1.3	1.8	3.1
1.4	1.8	3.2
22.7	30.1	52.8

Appendix 6: Estimate of Total Travel Time Savings in 2035 under Do Nothing, Option 1 and Option 2 Scenarios

					Average Value of Travel Time, Tk.70/hour				Average Value of Travel Time, Tk.156/hour		
	(a)	*(b)*	*(c)*		*(d)*	*(e)*	*(f)*		*(d)*	*(e)*	*(f)*
Scenario / Option	**Daily Pass-Km Travelled in Vehicles (1)**	**2035 Average Traffic Speed**	**2035 Total Time Spent Travelling**		**2035 Value of Total Time Spent Travelling**	**2035 Value of Total Time Spent Travelling**	**2035 Value of Total Travel Time Savings Compared with 'Do Nothing' (2)**		**2035 Value of Total Time Spent Travelling**	**2035 Value of Total Time Spent Travelling**	**2035 Value of Total Travel Time Savings Compared with 'Do Nothing' (2)**
Units	*Mill pass-km per day*	*kph*	*Mill pass-hours per day*		*Mill. Taka per day*	*$bn per year*	*$bn per year*		*Mill. Taka per day*	*$bn per year*	*$bn per year*
Formula	*(a)*	*(b)*	*(a / b)*		*(a / b) x Tk70/hr*	*(d) x 340 days / Tk77 x 0.001*	*'Do nothing' minus Option*		*(a / b) x Tk156/hr*	*(d) x 340 days / Tk77 x 0.001*	*'Do nothing' minus Option*
Do nothing	261	4.5	58.0		4,060	17.9	na		9,048	40.0	na
Option 1	261	13.7	19.1		1,334	5.9	12.0		2,972	13.1	26.8
Option 2	261	15.2	17.2		1,202	5.3	12.6		2,679	11.8	28.1

Notes: (1) 2035 daily pass-km travelled in vehicles = 51.2m passenger trips (2035) x 0.6 (to exclude walking trips, 40% of total trips) x 8.5km average vehicular trip distance

(2) Travel time savings in 2035 estimated as 'Do Nothing' value minus 'Option' value

Appendix 7: Review of Methodology adopted in the Revised Strategic Transport Plan, 2015

Since 1971 there have been seven strategic master plans prepared for Dhaka, covering either transport or land use or both.[22] In addition, there have been numerous donor and government-funded transport investment projects. The most recent transport study is the Revised Strategic Transport Study, funded by JICA and prepared by international consultants. The draft final report was submitted in November 2015.

1. Study Methodology: Main Costs and Benefits

The RSTP consultants prepared a transport model for the Greater Dhaka Area based on a household interview survey of about 16,000 households, plus cordon and screen line traffic counts and a public transport users' survey. A trip assignment matrix was then developed to predict current and future traffic volumes, and traffic assignment was done for the years 2025 and 2035, with estimations for the intervening years.

The consultants collected the cost of the various project components from relevant government organisations or from previous JICA studies in the area. The benefits of the various transport projects were assumed as (i) savings in vehicle operating costs (VOC); (ii) savings in travel time (TTS).

The proposed road and mass transit projects were then evaluated to find their economic internal rate of return (EIRR), and also the financial internal rate of return (FIRR) for the mass transit projects.

The traffic management measures ($600m) were not similarly evaluated, but their potential daily VOC and TTS savings were estimated in RSTP Table 13.3.

The bus sector improvement measures ($646m) were not evaluated for either EIRR or FIRR.

1.1 Main Assumptions used in the RSTP Evaluation

The assumptions used in the RSTP evaluation have a crucial impact on its overall results, and are summarized here.

- The project duration was assumed to be 40 years; (construction period 10 years and operating period 30 years).
- The discount rate was assumed at 12% (both economic and financial evaluation).

[22] The seven strategic plans were: 1981 Dhaka Integrated Urban Development Plan, 1994 Dhaka Integrated Transport Study, 1995 Dhaka Metropolitan Development Plan, 2005 Strategic Transport Plan, 2009 Dhaka Urban Transport Study, 2015 draft Revised Strategic Transport Plan (2016-35), and 2015 draft Dhaka Structure Plan (2016-35).

- The economic cost of the project was assumed at 80% of the financial cost.
- Mass transit fare revenue was based on assumed fares; increasing over time up to 2035 (see Appendix 2).
- The Vehicle Operating Costs were estimated based on RHD's Road User Cost Annual Report for 2004/5, and updated to 2014 based on GDP growth.
- Travel Time Costs for each mode were estimated by the study team based on household income and the share of work/business trips found through the household survey. These were assumed to grow in line with GRDP per capita in the study area.

1.2 Main Findings of the RSTP Traffic Model

Surveys in 2005 for the Strategic Transport Plan found the average travel speed on primary and secondary roads in Dhaka was 21.2kph (all modes except walking).[23] This was significantly faster than the average traffic speed in Central London at that time (about 15.5kph).

More recent surveys by the DHUTP and RSTP found that average traffic speed in Dhaka had declined to 15.1kph in 2009[24] and 6.4ph in 2014[25] (Figure 4). The data was for the RAJUK area – in central Dhaka the average speed is lower.

Using the traffic assignment model, the RSTP predicted that in the 'do nothing' case, Dhaka's future average traffic speed would decrease to 5.1kph by 2025 and 4.7kph by 2035 (which is about walking speed!)

1.3 Results of RSTP's Economic and Financial Evaluation

(i) Traffic Management Measures

Using the traffic model's calculations for average travel speeds, and making assumptions about the value of time and vehicle operating costs, the RSTP calculated that the benefits of the proposed package of Traffic Management Measures (costed at $600m – see Table 1 above) would be worth about Tk.53 crore per day ($6.8m/day), or roughly Tk.30 per day for every man, woman and child in the Dhaka RAJUK area. Of these benefits, about 90% were due to travel time savings. [26]

[23] STP, 2005, Section 5.5.10 (DMA area)

[24] DHUTS, 2010, page E-10 (RAJUK area)

[25] RSTP, 2015, Table 12.13 (RAJUK area)

[26] Draft RSTP, November 2015, Table 13.13

This calculation assumed that Dhaka's existing main road network was operating at only half of its potential capacity due to poor management and poor traffic behavior, and that traffic management measures could increase overall traffic speeds by about 28% (from 6.4kph to 8.2kph average).

The assumption that the main road network was operating at only 50% of potential capacity was taken from the 2005 STP. [27] However, this assumption may be over-optimistic – whilst it may have been true in 2005, since then the traffic volume has nearly doubled and much of the spare capacity in the network has been used up.

But even if we reduce the RSTP's estimate of benefits by one-half, it would still mean that a successful traffic management project costing $600m would pay for itself within half a year, in terms of time savings.

(ii) Roads, Expressways, Metros and BRT's

The RSTP team calculated the Economic Internal Rate of Return (EIRR) for the proposed road and mass transit projects, and the Financial Rate of Return (FIRR) for the mass transit projects. The results are shown in Tables 7.1, 7.2 and7.3 below. The RSTP concluded that expressways gave a higher EIRR than the metros, and road projects overall gave a significantly higher EIRR than the metros (30.5% compared with 20.9%). The single BRT project (BRT7) gave the highest EIRR of all projects (47.9%), apart from the middle ring road.

Table 7-1 RSTP's Economic Evaluation of Road Proposals

Project	**Capital Cost (Economic)**	**O & M, opening year**	**EIRR**	**Lanes Assumed**	**Max. Capacity, PCU's**	**Max. Capacity, People**
	($m)	**($m per year)**	**(%)**		**PCU/hr/dir**	**Pass/hr/dir**
Dhaka - Ashulia Elevated Exp.	1,421.2	19.9	16.9	2x2 lane	4,400	15,400
Dhaka - Chittagong Expressway	156.2	2.2	28.3	2x2 lane	4,400	15,400
Dhaka - Sylhet Expressway	82.8	1.2	35.0	2x2 lane	4,400	15,400
Dhaka - Mawa Expressway	538.0	7.5	16.2	2x2 lane	4,400	15,400
Dhaka - Mymensingh Exp.	102.3	1.4	30.7	2x2 lane	4,400	15,400
Inner - Ring Road	1,178.3	16.5	34.4	3x2 lane	5,400	22,600
Middle - Ring Road	423.0	5.9	54.6	3x2 lane	5,400	22,600
Outer - Ring Road	2,076.7	29.1	17.2	3x2 lane	5,400	22,600
Primary - Road Package	1,143.5	16.0	29.5	na	na	na
Secondary - Road Package	1,076.2	27.6	41.7	na	na	na
Average (all roads)			**30.5**			
Average (expressways)			**25.4**			

[27] Draft RSTP, Section 13.5, page 13-15

Source: JICA / Dhaka Transport Co-ordination Authority, November 2015, Revised Strategic Transport Plan, Draft Final Report, Table 13.4. Note1: Road passenger capacity estimates are prepared by the Author for this paper. They assume: (i) motor vehicles only; (ii) the road is operating under free-flowing conditions; (iii) the proportion of buses using the road is 6% of PCU's on expressways and 22% of PCU's on bypasses. The passenger capacity of the 2x2 lane expressway is proportionately lower than that of the 3x2 lane bypass due to lower proportion of buses.

Table 7-2: RSTP's Economic Evaluation of Mass Transit Proposals

Project	Capital Cost (Economic)	O & M, opening year	EIRR	Predicted Ridership, 2035
	($m)	($m per year)	(%)	(Pass/hr/dir)
MRT1	4,937.6	78.2	22.1	37,770
MRT2	2,938.3	92.3	19.4	23,020
MRT4	1,329.1	37.0	13.2	17,930
MRT5	3,359.8	80.8	16.1	28,340
MRT6 (2nd Phase, extension)	1,671.1	50.8	33.5	45,860
BRT7	205.3	32.0	47.9	22,330
BRT3	Not calculated			25,960
Average (MRT, excl. MRT6 1st phase)			**20.9**	
Average (BRT, excl. BRT3)			**47.9**	
Average (mass transit, excl. MRT6 1st Phase and BRT3)			**25.4**	

Source: JICA / Dhaka Transport Co-ordination Authority, November 2015, Revised Strategic Transport Plan, Draft Final Report, Table 13.3

Regarding passenger capacity, the BRT's 2x1 lane carried as many passengers per hour per direction as a 3x2 lane highway, and about 50% more than a 2x2 lane expressway.

The MRT's had the highest overall passenger capacity, though their predicted ridership varied considerably from line to line. All of the MRT's and the single BRT line gave positive financial rates of return (Table 7.3).

Table 7-3 RSTP's Financial Evaluation of Mass Transit Proposals

Project	Capital Cost (Financial)	O & M, opening year	FIRR
	$m	($m per year)	(%)
MRT1	6,171.9	97.8	4.5
MRT2	3,672.9	115.4	3.0
MRT4	1,661.4	46.2	3.8
MRT5	4,199.8	101.0	4.0
MRT6 (extension)	2,088.9	63.5	9.7
BRT7	256.6	40.0	4.3
Average			**4.9**

Source: JICA / Dhaka Transport Co-ordination Authority, November 2015, Revised Strategic Transport Plan, Draft Final Report, Table 13.6
Note 1: The FIRR for BRT7 appears low, in view of its high EIRR. This may be a typing error.

1.4 Initial Selection of RSTP Projects

How were the above projects originally selected? First, the RSTP considered Dhaka's future urban structure and population distribution, based on observed trends, land-use policies in the new (draft) Dhaka regional plan , and the RSTP team's own ideas regarding desirable and efficient urban development.

Secondly, the RSTP team projected future travel demand along Dhaka's main axes, using the results of previous origin-destination surveys (DHUTS, 2009) and its own projections. This gave an indication of the scale of demand that would need to be met.

Thirdly, the RSTP team produced rough estimates of how this demand could be met through mass transport and roads, and compared this with the existing roads to see how many more might be needed.

Regarding mass transit, the team opted mostly for MRT, due to its higher capacity and speed than BRT (potentially double). The team noted that the 2005 STP had proposed a bus-based rapid transit system as the backbone of the public transport system for the first ten years, with the service eventually to be based on metro rail systems as demand increased. The RSTP team considered that Dhaka's traffic demand would soon overtake the capacity of BRT services. [28]

Regarding roads, the team took proposals that were already contained in previous plans (STP, DHUTS, Rajuk draft regional plan), plus on-going and proposed government projects.

Only one of the elevated expressways (the Dhaka Elevated Expressway) had been proposed in previous transport plans. The other five were either more recent proposals from the Government, or else the result of the RSTP team's own analysis (Figure 5).

1.5 Prioritisation of RSTP Projects

The individual road projects – 135 separate schemes ranging in cost from Tk.20cr to Tk.13,654cr – were prioritized according to nine criteria: (i) current project status; (ii) urgency; (iii) missing link; (iv) contributing to ring and radial roads; (v) traffic axis through a development area; (vi) compatibility

[28] Draft RSTP, page 12-39

with relevant development plans; (vii) traffic demand; (viii) cost. They were then allocated to four 5-year phases (of roughly equal total value) between 2016 and 2035.

To prioritize the six mass transit projects, the RSTP gave each a weighted score based on five broad criteria, of which economic rate of return was the most important (Table 7.4). The MRT1 corridor (north-south Gazipur-Jhilmil with a branch to Purbachal) received the highest priority, while BRT7 (north-south through Purbachal to Naryanganj) was given second highest priority. (Figure 6)

Table 7-4 RSTP's Financial Evaluation of Mass Transit Proposals

	Mass Transit Project	**Evaluation Weight (%)**
1	Predicted ridership	15
2	Economic return (EIRR)	40
3	Financial return (FIRR)	15
4	Consistency with urban development scenario	15
5	Environment	15

Source: JICA / Dhaka Transport Co-ordination Authority, November 2015, Revised Strategic Transport Plan, Draft Final Report, Tables 13.11 and 13.12

Note 1: Each of six mass transit projects was given a rank from 1 to 5 according to how it matched the five criteria above, and then a composite score was obtained using the above weightings.

1.6 Project Phasing

Unlike the road schemes, the majority (two-thirds) of the proposed $23.2bn investment in mass transit projects was scheduled for the second half of the plan period (i.e. 2026-2035).

2. Critical Examination of the RSTP's Cost-Benefit Assumptions

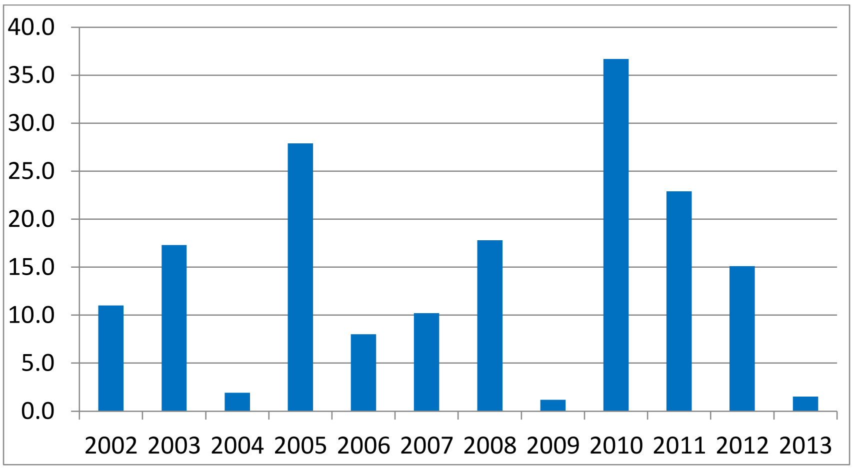
This section considers the main inputs and assumptions used in the economic and financial evaluation of the draft RSTP. The next section (Section 4) considers costs and benefits of alternative urban transport options for Dhaka.

2.1 Limitations of Available Statistics

In Dhaka a major limitation for any cost-benefit analysis is the unreliability of the available statistics. Even basic inputs such as vehicle numbers and accident statistics are very inaccurate. For example, the RSTP could not obtain statistics for motorcycle numbers. It noted that motorcycle ownership was 9.4% of households, which would suggest over 400,000 motorcycles in the RAJUK area. [29] However, the RSTP recorded 256,323 motor-cycles registered in the Greater Dhaka area in 2001-13 (RSTP Final Report, page 4-1). However, traffic counts on main roads show motorcycles to be about one-quarter to one-third the volume of cars and jeeps, and the RSTP's household survey found roughly the same proportion for household trips. If the number of cars and jeeps in Dhaka is around 200,000, a ratio of 3:1 would suggest around 66,000 motorcycles in the RAJUK area. No one knows for sure what the actual figure would be.

But even car and jeep numbers are uncertain. By summing new registrations and annual fitness certificate renewals, the RSTP assumed there were about 195,000 private cars in Dhaka in 2013.[30] But this is only a guess, as vehicle fitness renewals vary enormously from year to year (Figure 7.1).

Figure 7.1 Annual INCREASE in Vehicle Fitness Renewals in Dhaka, compared with the previous year



Source: Revised Strategic Transport Plan, Draft Final Report, Tables 4.2

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[29] See draft RSTP, Section 11.1. This figure assumes 4.38mill households in RAJUK area in 2015

[30] Draft RSTP, Table 4.2

Accident statistics are even less accurate. At a national level the officially reported deaths in road accidents in 2014 was 6,582,[31] but the World Bank and WHO have put the annual death toll at double or treble this level.[32] For Dhaka, the RSTP quoted statistics only for 2008, and noted that Dhaka accounted for about 16% of national road accidents. [33]

2.2 Road Network Performance and Average Journey Speeds

The RSTP calculated that under the 'Do nothing' scenario, average travel speeds in Dhaka would decline to 5.1kph by 2025 and 4.7kph by 2035. However, if the plan proposals were implemented, the average traffic speed would rise to 13.7kph by 2035, saving $85m (Tk.665cr) per day in travel time costs.[34]

However, the analysis may have overestimated both (i) the decline in average traffic speeds under the 'Do nothing' scenario, and also (ii) the time savings to be gained from the elevated expressways.

(i) Average Traffic Speeds

There is an 'adaptive' effect with traffic congestion, as people change their behavior in response to congestion; for example avoiding trips, travelling at different times, choosing a different route or a different mode, even re-locating in the long run. In London, there is a huge amount of 'suppressed demand' – in other words, many more people would drive to London by car, but are discouraged by the traffic congestion and the difficulty in finding parking spaces.

In Dhaka, an example of 'adaptive behaviour' can be seen in Old Dhaka, which is still functioning today although one hundred and fifty years ago it was experiencing acute traffic congestion. In the 1860's the newly established Municipal Committee considered major road schemes for relieving the congestion. However, the schemes were shelved due to cost (including compensation), and reluctance to raise taxes to pay for the scheme.[35]

Fifty years later (1917) the British town planner Patrick Geddes produced a town planning report on Dhaka and observed:

"The long Main Street from east and west (in Old Dhaka) is much too crowded and too narrow for its traffic, but no widening scheme can be suggested; the city cannot afford it. Desirable though a tramway along this line might be, the space for even a single line cannot be spared, still less the

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31 Daily Star, 01/01/2015, Road crash death toll soars
32 Daily Star, 22/10/2014, Thanks to lax law enforcement

33 Draft RSTP, page 4-50

34 Draft RSTP, Table 12.13

35 R Gallagher, Notes on the Evolution of Transport in Dhaka, Paper for the International Seminar on the History and Heritage of Capital Dhaka, Asiatic Society of Bangladesh, 17-19th February 2010

occasional doubling needed for passing. However, the future seems decidedly for the motor-bus, of which the extraordinary improvement of recent years is not ended." [36]

In the past 100 years, Old Dhaka's road network has changed very little (the Dholai Khal filling and the North-South Road being the main exceptions), yet traffic still circulates around the Old City, even though it is larger and more motorised . In other words, a certain amount of adaptation to circumstances can be expected, hence the RSTP traffic model may be too pessimistic in predicting Dhaka's future traffic speeds.

(ii) Time Savings from the Proposed Expressways

The traffic model for Dhaka necessarily concentrates on the main road network, but does not include secondary and tertiary roads (for example, Road 11 Banani is not included in the network model although it is an important local access road). The model therefore concentrates on effects on the main road network, but not the local road network.

However, increasing the capacity of the main road network, while it may reduce congestion and travel time on the main roads (until it rises to a new level of saturation), will generate more traffic both on the main network and also on the local road network. The time savings gained on the main network may well be cancelled out by increased congestion on the secondary and tertiary roads.

Dhaka suffers from a paucity of secondary roads: in many neighbourhoods the local distributors are only 6-7m wide, sometimes less – scarcely wide enough for two large vehicles (buses, trucks) to pass. This situation arose because of the failure of the town planning system to reserve adequate rights of way, and this problem is still occurring in many of the newly developing areas.

Therefore the travel time savings from expressways predicted in the RSTP may be too optimistic, when end-to-end journeys are taken into account. Moreover, increasing the main road capacity will tend to <u>increase</u> local congestion, as it will lead to higher traffic flows and higher levels of car ownership. Yet cars are the least suited for Dhaka's crowded neighbourhood.

This is not to say that Dhaka does not need more roads – simply that the benefits (in travel time savings) attributed to the road infrastructure may be significantly less than the traffic model has predicted.

2.3 Value of Time

The RSTP predicted that about 90-95% of the benefits of the proposed investments are due to travel time savings, with reduced vehicle operating costs accounting for the remainder. The value of time

[36] Patrick Geddes, 'Report on Town Planning, Dacca', 1917, page 5.

is therefore crucial to the final results, and is considered below. The values used in the RSTP were as follows:

Table 7-6 Table Value of Time Assumed in RSTP, in Taka / MINUTE / person

	Car	Motorcycle	CNG	Bus	Truck
2014	6.3	3.0	1.7	1.8	1.8
2025	8.9	4.2	2.4	2.5	2.5
2035	12.0	5.7	3.2	3.4	3.4

Source: JICA Study Team (RSTP Table 13.2)

Table 7-7 Value of Time Assumed in RSTP, in Taka / HOUR / person

	Car	Motorcycle	CNG	Bus	Truck
2014	378	180	102	108	108
2025	534	252	144	150	150
2035	720	342	192	204	204

Source: As for Table 6 above

Table 7-8 Vehicle Operating Costs Assumed in RSTP, in Taka / Vehicle / Km

Car	Motorcycle	CNG	Bus	Truck
15.0	2.0	3.7	23.0	21.5

Source, JICA study team estimated based on RHD User Cost Annual Report for 2004-2005 (RSTP Table 13.1)

In comparison with travel time costs used elsewhere (e.g. India), the above values seem high. For example, in a recent urban transport project in eastern India, the hourly value of time for a car passenger was estimated at around Tk.78 per hour, and for a bus passenger at around Tk.58 per hour.[37]

In other words, the time value used for car passengers in the Indian project was almost one-fifth the value used in Dhaka, while for bus passengers it was around one-half the Dhaka value.

The RSTP also used a much wider differential between car and bus passengers (about 3.5 times, compared with 1.3 times in the India project).

If lower values of time are used, the relative attractiveness of the road and expressway options will be reduced in comparison with the mass transit options.

[37] A range of travel time values was used to reflect different types of travel (work/non-work, new/old car), and combined to give an average value.

2.4 Costs not Included in the RSTP Evaluation

Important costs that not included in the EIRR and FIRR calculations include:

i. The cost of acquiring and operating the private transport modes – for example, the vehicle's capital cost and running costs such as fuel, spares, maintenance, driver, parking, and so on. (These are included as 'VOC savings', but the total cost of the equipment and the resources consumed are not included, unlike the mass transit options).

ii. Environmental costs, such as air pollution, noise and greenhouse gas emissions.

iii. Accidents.

iv. Impact on the quality of urban life – for example, fear of letting children walk or cycle, severance of communities, visual and aesthetic impacts, and so on.

v. Import dependence.

Appendix 8. Intake fractions

Health benefits per ton of emission reductions in a geographic area are:

$$B = \frac{h(\delta C)}{\delta E} = m\frac{\partial AF}{\delta E} \quad \text{(A1)}$$

where $h(\delta C)$ is the change in health effects associated with a change in annual ambient PM2.5 concentrations δC (μg/m^3); E is emissions of PM2.5 (tons/year); δAF is the change in the population attributable fraction of health outcomes associated with δE; and *m* is baseline annual cases of the health outcomes.

To solve for B we need a relation between emissions (E) and concentrations (C). The change in the quantity of PM2.5 that a population in a geographic area breathes into the lungs in a year is given by:

$$\partial\, iP = P * Q_d * 365 * 10^{-12} * \partial C \quad \text{(A2)}$$

where iP is population intake of PM2.5 (tons/year), P is population, Q_d is breathing rate of air (m^3/day). The change in population intake (tons/year) is also given by:

$$\delta\, iP = \delta E * iF * 10^{-6} \quad \text{(A3)}$$

where E is emissions of PM2.5 (tons/year), iF is the so called intake fraction in parts per million (ppm), or the fraction of emissions that the population breathes into their lungs.[38] From A2 and A3 follow:

$$\partial E = P * Q_d * 365 * 10^{-6} * iF^{-1} * \partial C \quad \text{(A4)}$$

This can simply be written as:

$$\delta E = K\frac{P\,\delta C}{iF} \quad \text{(A5)}$$

from which can be seen how changes in emissions and concentrations are related for a known population and intake fraction, and K is a constant ($Q_d * 365 * 10^{-6}$). Equation A1 then becomes:

$$B = \frac{m}{KP}\, iF\frac{\delta AF}{\delta C} \quad \text{(A6)}$$

which says that health benefits per ton of emission reductions in a geographic area are a function of the product of the intake fraction and the change in the attributable fraction of health outcomes per change in PM2.5 concentrations. The latter is estimated using the methodology in annex 2.

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[38] The single compartment intake fraction (ppm) is $iF = Q_s * P * 10^6/(u * H * \sqrt{A})$ where Q_s is breathing rate of air (m^3/s), P is population, u is wind speed (m/s), H is mixing height (m), and A is the geographic area (m^2).

Appendix 9. An integrated exposure-response function

Health effects of PM exposure include both premature mortality and morbidity. The methodologies to estimate these health effects have evolved as the body of research evidence has increased.

Over a decade ago, Pope et al (2002) found elevated risk of cardiopulmonary (CP) and lung cancer (LC) mortality from long term exposure to outdoor PM2.5 in a study of a large population of adults 30 or more years of age in the United States. CP mortality includes mortality from respiratory infections, cardiovascular disease, and chronic respiratory disease. The World Health Organization used the study by Pope et al when estimating global mortality from outdoor air pollution (WHO 2004; 2009). Since then, recent research suggests that the marginal increase in relative risk of mortality from PM2.5 declines with increasing concentrations of PM2.5 (Pope et al 2009; 2011). Pope et al (2009; 2011) derive a shape of the PM2.5 exposure-response curve based on studies of mortality from active cigarette smoking, second-hand cigarette smoking (SHS), and outdoor PM2.5 air pollution.

The Global Burden of Disease 2010 Study (GBD 2010 Study) takes Pope et al (2009; 2011) some steps further by deriving an integrated exposure-response (IER) relative risk function (RR) for disease outcome, *k*, in age-group, *l*, associated with exposure to fine particulate matter pollution ($PM_{2.5}$) both in the outdoor and household environments:

$$RR(x)_{kl} = 1 \qquad \text{for } x < x_{cf} \qquad \text{(A1a)}$$

$$RR(x)_{kl} = 1 + \alpha_{kl}(1 - e^{-\beta_{kl}(x-x_{cf})^{\rho_{kl}}}) \qquad \text{for } x \geq x_{cf} \qquad \text{(A1b)}$$

where x is the ambient concentration of $PM_{2.5}$ in $\mu g/m^3$ and x_{cf} is a counterfactual concentration below which it is assumed that no association exists. The function allows prediction of RR over a very large range of $PM_{2.5}$ concentrations, with $RR(x_{cf}+1) \sim 1+\alpha\beta$ and $RR(\infty) = 1 + \alpha$ being the maximum risk (Burnett et al 2014; Shin et al 2013).

The parameter values of the risk function are derived based on studies of health outcomes associated with long term exposure to ambient particulate matter pollution, second hand tobacco smoking, household solid cooking fuels, and active tobacco smoking (Burnett et al, 2014). This provides a risk function that can be applied to a wide range of ambient $PM_{2.5}$ concentrations around the world as well as to high household air pollution levels of $PM_{2.5}$ from combustion of solid fuels.

The disease outcomes assessed in in the GBD 2010 Study are ischemic heart disease (IHD), cerebrovascular disease (stroke), lung cancer, chronic obstructive pulmonary disease (COPD), and acute lower respiratory infections (ALRI) (Lim et al 2012; Mehta et al 2013). The risk functions for IHD and cerebrovascular disease are age-specific with five-year age intervals from 25 years of age, while singular age-group risk functions are applied for lung cancer (≥ 25 years), COPD (≥ 25 years), and ALRI in children (< 5 years).

An x_{cf} = 7.3 $\mu g/m^3$ is applied here based on bounds of 5.8 to 8.8 $\mu g/m^3$ used in the GBD 2010 Study (Lim et al, 2012).

The population attributable fraction of disease from PM2.5 exposure is calculated by the following expression:

$$PAF = \sum_{i=1}^{n} P_i[RR\left(\frac{x_i+x_{i-1}}{2}\right) - 1]/(\sum_{i=1}^{n} P_i[RR(\frac{x_i+x_{i-1}}{2}) - 1] + 1) \quad \text{(A2)}$$

where P_i is the share of the population exposed to PM2.5 concentrations in the range x_{i-1} to x_i. This attributable fraction is calculated for each disease outcome, *k*, and age group, *l*. The disease burden (B) in terms of annual cases of disease outcomes due to PM2.5 exposure is then estimated by:

$$B = \sum_{k=1}^{t} \sum_{l=1}^{s} D_{kl} PAF_{kl} \quad \text{(A3)}$$

where D_{kl} is the total annual number of cases of disease, *k*, in age group, *l*, and PAF_{kl} is the population attributable fraction of these cases of disease, *k*, in age group, *l*, due to PM2.5 exposure.

The potential impact fraction is applied to estimate the reduction in disease burden from a change in the population exposure distribution that can result from an intervention to control PM2.5 exposure levels among the population:

$$PIF = [\sum_{i=1}^{n} P_i RR\left(\frac{x_i+x_{i-1}}{2}\right) - \sum_{i=1}^{n} P_i' \, RR\left(\frac{x_i+x_{i-1}}{2}\right)]/(\sum_{i=1}^{n} P_i RR(\frac{x_i+x_{i-1}}{2}) \quad \text{(A4)}$$

where P'_i is the population exposure distribution after the intervention. The reduction in annual cases of disease outcomes is then estimated by:

$$\Delta B = \sum_{k=1}^{t} \sum_{l=1}^{s} D_{kl} PIF_{kl} \quad \text{(A5)}$$

This approach is applied to the five disease outcomes discussed above using the RRs from the IER function reported by Apte et al (2015).

Appendix 10. Valuation of health benefits

Two valuation measures are considered for estimating the benefit of avoided illness in this paper: i) a day of disease is valued as 50% of average labor income per day; or ii) a year lost to disease (YLD) is valued at GDP per capita as suggested by the Copenhagen Consensus Center (CCC).

Two valuation measures are considered for estimating the benefit of an avoided death in this paper: i) the value of statistical life (VSL); or ii) a year of life lost (YLL) to premature mortality is valued at GDP per capita as suggested by CCC.

A VSL for Bangladesh is estimated based on Navrud and Lindhjem (2010). Navrud and Lindhjem conducted a meta-analysis of VSL studies for OECD based exclusively on stated preference studies which arguably are of greater relevance for valuation of mortality risk from environmental factors than hedonic wage studies. These stated preference studies are from a database of more than 1,000 VSL estimates from multiple studies in over 30 countries, including in developing countries. Navrud and Lindhjem provide an empirically estimated benefit-transfer (BT) function from these stated preference studies that can be applied to estimate VSL in any country or region. A modified BT function with income elasticity of one is applied here:[39]

$$\ln VSL = 0.22 + 1.0 \ln(gdp) - 0.445 \ln(r) \qquad \text{(A1)}$$

where *VSL* is expressed in purchasing power parity (PPP) adjusted dollars; *gdp* is GDP per capita in PPP adjusted dollars; and *r* is the change in risk of mortality.[40] The VSL is then converted to a country's currency by multiplying by the PPP rate as reported in World Bank (2015b), which is the ratio "GDP in local currency / PPP adjusted GDP in dollars".

Applying the BT function also involves specifying change in mortality risk (r). The mortality risk from environmental factors depends on the environmental factor at hand. Most stated preference studies of VSL use a mortality risk in the range of 1/10,000 to 5/10,000 per year. A mid-point risk of 2.5/10,000 per year is applied in this paper.

The VSL estimated for Bangladesh for the year 2014 by this methodology is BDT 4.79 million, or about 50 times GDP per capita that year (table A1).

[39] A later version of their paper (Lindhjem et al, 2011) reports income elasticities in the range of 0.77 – 0.88 for a screened sample of VSL studies.

[40] This BT function implies that the income elasticity is 1.0, meaning that VSL varies across countries in proportion to their PPP adjusted GDP per capita level.

Table A1. Economic data and VSL for Bangladesh, 2014

GDP per capita	BDT 95,864	Bangladesh Bureau of Statistics
Average monthly wage	BDT 7,307	International Labour Organization
Value of statistical life (VSL)	BDT 4,787,591	Calculated from equation A1

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