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Investigating the Effect of Modal Shift on Level of Service of Mixed Traffic Lane along the Dhaka BRT Corridor

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Abstract: *Bus Rapid Transit (BRT) is a very popular form of rapid transit implemented throughout the world for assisting public transport. Their operating flexibility and their ability to be built quickly, incrementally, and economically underlie their growing popularity. Like many other developing cities Dhaka is struggling with the problem of how to upgrade and improve existing public transport services at a low cost. The ever-increasing chaos and congestion, high rate of accidents and rapidly deteriorating transport operational, management and environmental condition calls for immediate considerations of an alternative transport option that could reduce the transport problem. To reduce the congestion of Greater Dhaka, Bangladesh Government, as recommended in Strategic Transport Plan (STP) is now implementing Gazipur-Joydebpur-Airport corridor as an extension of BRT line-3. The proposed BRT will take two running lanes out of the six. Then the remaining four lanes have to accommodate the mixed and slow moving vehicles within it. As a result the capacity of the mixed traffic lanes will be decreased due to the implementation of the BRT system. The service level of the mixed lanes will be greatly influenced by the modal shift scenario especially from the local bus service to the BRT system. Traffic growth rate will also be an influential determinant of the required capacity of the mixed lanes as well as for the BRT system.*

This study assesses the effect of modal shift on Level of Service of Mixed Traffic Lane due to construction of BRT Lane along the corridor. The result shows that high modal shifting from bus and other passenger carriers to BRT is necessary to keep tolerable Level of Service in the mixed traffic lane.

1. Introduction

Dhaka is the capital city of Bangladesh and the centre of administrative, political, economic and social life for the country. Such high density in a city with inadequate livable land, due mainly to the city's topography, low level of public services and inadequate infrastructure results in incredible congestion and compels the urban transport system's ability to deliver mobility for all people. To warrant a sustainable future for Dhaka, public transport concentrated on people's mobility needs and accessibility needs to be improved and given significance over simple road projects. Dhaka is one of the most densely populated cities in the world, with 45000 people per square kilometer in core area (ADB, 2011)[1]. This city is characterized by both motorized and non-motorized transport services and has a rudimentary public transport system comprising cycle, rickshaws, bus, and taxis. Experiences of various project around the world specified that Bus Rapid Transit (BRT) has been seen as an "emerging, resourceful public transit solution" which can be cost-effective in addressing urban congestion (Currie, 2006, Levinson et al. 2003, U.S.)[10, 20]. Because BRT can be managed in a relatively low operation and construction cost in comparison to Light Rail Transport (LRT) or Metro Rail Transport (MRT). In Bangladesh the government approved Strategic Transport Plan (STP) carried out by WB in 2005 and Dhaka Urban Transport Network Development Study (KEI, JICA, 2010) recommended the construction of three Bus Rapid Transit (BRT) routes including BRT line-3.

To reduce the congestion of Greater Dhaka, BRT Line-3 along Sadarghat-Gulistan-Moghbazar-Mohakhali-Airport Corridor of Dhaka city, as recommended in STP will be implemented soon under the Greater Dhaka Sustainable Urban Transport Project (GDSUTP) and the Clean Air and Sustainable Environment (CASE) project. In the first phase, Gazipur-Joydebpur-Airport corridor (20.5 km) as an extension of BRT line-3 is being implemented. This study aims to assess future level of service of the mixed traffic lanes due to construction of BRT Lane along the corridor. BRT lane will take away two lanes from the Right of Way of the Road Corridor and will significantly reduce the non BRT corridor width which is a threat to the level of service of the mixed lane traffic. BRT lane will shorten the lane for Freight vehicles and intercity bus from 6 lanes to 4 lanes. This corridor is the only corridor for accessing 8 major districts where there are significant numbers of Freight traffic as well. However, the Level of Service of the mixed traffic lane will depend on the modal shift from bus users to BRT. An attempt has been made in this study to find the impact of various scenarios of modal shift on Congestion scenario in the BRT Lane.

2. The Level of Service Concept

In Transportation Engineering, a Level of Service (LOS) is a letter designation that describes a range of operating conditions on a particular type of Road or Highway. The 1994 Highway Capacity Manual defines levels of service as "qualitative measures that characterize operational conditions within a traffic stream and their perception by motorists and passengers."

The critical point in this definition is the need to define service quality in terms that are perceived by drivers and passengers. Several key measures are used to describe service quality in these terms:

Speed and travel time: One of the most easily perceived measures of service quality is speed, or its inverse, travel time. Drivers and passengers alike are keenly aware of the amount of time it takes to get from place to place. On freeways, speed is a very evident measure of service quality, while on street systems, the driver is very sensitive to total travel time.

Density: Density is a parameter not often used in traffic analysis. Nevertheless, it is an excellent descriptor of service quality in many cases. Density describes the proximity of vehicles to each other in the traffic stream and reflects ease of maneuverability in the traffic stream, as well as the psychological comfort of drivers.

Delay: Delay can be described in many ways. Highway capacity analysis uses delay in several different ways. At intersections, delay is defined in terms of the average stopped time per vehicle traversing the intersection. On rural two-lane highways, percent time delay is defined as the percent of time that all drivers spend in platoons behind slow-moving vehicles they cannot pass. In any of its uses, it represents excess or additional travel time due to traffic conditions or controls. Delay times are portions of travel time that are particularly obvious to drivers and are particularly annoying or frustrating.

Other measures: A variety of other measures are used to describe service quality. In some cases, measures used are not directly discernible to drivers or passengers. Such measures generally rely upon volumes or flow rates because the state of the art does not yet include other calibrated quality measures. Six levels of service are defined for capacity analysis. They are given letter designations A through F, with LOS A representing the best range of operating conditions and LOS F the worst. The specific terms in which each level of service is defined vary with the type of facility involved. In general, LOS A describes a free-flowing condition in which individual vehicles of the traffic stream are not influenced by the presence of other vehicles. LOS F generally describes breakdown operations (except for signalized intersections) which occur when flow arriving at a point is greater than the facility's capacity to discharge flow. At such points, queues develop, and LOS F exists within the queue and at the point of the breakdown. Levels of service B, C, D, and E represent intermediate conditions, with the lower bound of LOS E often corresponding to capacity operations.

Level of Service Definitions: The six levels of service are generally described in Transportation Engineering which is described as follows.

Level of Service A: This is a condition of free flow, accompanied by low volumes and high speeds. Traffic' density will be low, with uninterrupted flow speeds controlled by driver desires, speed limits, and physical roadway conditions. There is little or no restriction in maneuverability due to the presence of other vehicles and drivers can maintain their desired speeds with little or no delay.

Level of Service B: This occurs in the zone of stable flow, with operating speeds beginning to be restricted somewhat by traffic conditions. Drivers still have reasonable freedom to select their speed and lane of operation. Reductions in speed are not unreasonable, with a low probability of traffic flow being restricted. The lower limit (lowest speed, highest volume) of this level of service has been used in the design of rural highways.

Level of Service C: This is still in the zone of stable flow, but speeds and maneuverability are more closely controlled by the higher volumes. Most of the drivers are restricted in their freedom to select their own speed, change lanes, or pass. A relatively satisfactory operating speed is still obtained, with service volumes suitable for urban design practice.

Level of Service D: This level of service approaches unstable flow, with tolerable operating speeds being maintained, though considerably affected by changes in operating conditions. Fluctuations in volume and temporary restrictions to flow may cause substantial drops in operating speeds. Drivers have little freedom to maneuver, and comfort and convenience are low. These conditions can be tolerated, however, for short periods of time.

Level of Service E: This cannot be described by speed alone, but represents operations at lower operating speeds, typically, but not always, in the neighborhood of 30 miles per hour, with volumes at or near the capacity of the highway. Flow is unstable, and there may be stoppages of momentary duration. This level of service is associated with operation of a facility at capacity flows.

Level of Service F: This describes a forced- flow operation at low speeds, where volumes are below capacity. In the extreme, both speed and volume can drop to zero. These conditions usually result from queues of vehicles backing up for a restriction downstream. The section under study will be serving occur for short or long periods of time because of downstream congestion.

3. Methodology

Distribution of traffic in future has been made according to the BRT corridor proposed Geometric design. Traffic counts, undertaken by Highway Development and Management (HDM.) of RHD has been considered as the baseline traffic which has been projected using traffic growth scenario of Road Master Plan 2009. Three different traffic growth scenario; low, medium and high growth of traffic have been analyzed separately. Capacity of the lane and traffic flow of the lane been assumed according to the Highway Capacity Manual 2000 using the free flow speed based on design of BRT corridor planning. Predicted Traffic flow was then compared with HCM 2000 to ascertain level of Service of the mixed traffic lane.

Level of Service of mixed traffic lane is dependent on how modal shift is taking place from bus and other carriers to BRT. Different modal shifting scenarios have been used to predict its impact on Level of Service. Due to practical consideration, it has been assumed that only modal shifting from Large and medium bus shall take place to BRT. Average occupancy has been used to predict BRT passenger for every modal shift scenario. Relative steps of the Above methodology have been described in the subsequent sections.

as a storage area during parts or all of the peak hour. Speeds are reduced substantially and stoppages may

3.1. Distribution of Traffic along BRT Corridor

Currently, the corridor is a 6 lane highway. In the BRT regime, there will be 2 dedicated lanes for BRT while 2 lanes in every direction; ie; a total of 4 lanes will be used for mixed traffic lane. The extreme left lane in each direction will be used for Non-Motorized vehicle and the slow moving vehicular traffic as mentioned below

- Auto Rickshaw(AR)
- ∟Bicycle
- Rickshaw
- Cart

The inner two lanes in every direction will be used for mixed traffic consisting of the following vehicles.

- ∟Heavy Truck
- Medium Truck
- ∟Small Truck
- ∟Large Bus
- ∟Micro bus
- ∟Pickup
- ∟Car

3.2. Traffic Count and Future projections

How Traffic will be distributed along the BRT corridor and Mixed Traffic Lanes are shown in the following Table:

Table 1: Traffic count and future distribution of traffic along the corridor (Source: RHD, 2012)

Vehicle Type	Traffic Count (AADT)	Passenger Car Unit (PCU)	Peak hour traffic volume (PCU/hr)	Distribution of Traffic in BRT regime
Heavy Truck	202	606	73	Mixed Traffic Lane
Medium Truck	685	2055	247	Mixed Traffic Lane
Small Truck	802	2406	289	Mixed Traffic Lane
Large Bus	6393	19179	1151	Mixed and modal shift to BRT
Minibus	4048	8096	0	Mixed and modal shift to BRT
Micro bus	3484	3484	419	Mixed Traffic Lane
Utility	3366	3366	404	Mixed Traffic Lane
Car	3818	3818	459	Mixed Traffic Lane
AR	3056	1528	0	SMVT Lane
MC	2069	1034.5	125	Mixed Traffic Lane
Bi-cycle	683	341.5	0	SMVT Lane
CR	2616	2092.8	0	SMVT Lane
cart	2	1	0	SMVT Lane

MT	27920	0	0
NMT	3301	0	0

The wide variety of vehicle types in use on Bangladesh roads makes it appropriate to define Traffic flow in terms of Passenger car units (PCU) rather than vehicles. Conversion factor of PCU value are shown in table 2.

Table 2: PCU conversion value of vehicles
(Source: Road design Standards, RHD, 2012)

Vehicle Type	PCU Value
Truck	3.0
Bus	3.0
Minibus	3.0
Utility vehicle	1.0
Car	1.0
Baby taxi	0.75
Motorcycle	0.75

For this study, the extreme high and low, and medium variant have been adopted, as shown in Road Master Plan 2009 (RMP, 2009). In developing assessments of what future economic growth might be, RMP 2009 assessed a continuation of the 5.5% growth as reasonable central assumption which is very much in line with World Bank assumptions. Either side of this, low growth was assumed to be 4.5% per year, and high growth 6.5% per year. Bus passenger numbers and bus services were assumed to grow in line with population and current trends in vehicle registration growth. Most recently, the typical year-on-year rise in bus registrations has been around 4%. This was taken to be the medium estimate, with low growth assumed to be 3% per year, and high growth 5% per year. Whilst this might under-estimate the propensity for increased travel with growth in GDP, this is counter-balanced by the shift towards private car travel, and train travel with the proposals for improving the railway network (RMP-2009). Under RMP-2009 study a relationship was also derived between the number of trucks in Bangladesh and industrial and agricultural GDP for truck traffic growth. The RMP 2009 however projects vehicle traffic growth until 2025. In this study the vehicle growth after 2025 has been assumed constant at 2.45, 4.64 and 6.50 for low, medium and high growth respectively. The growth rate assumed in this study has been summarized in table 5.3 this study avoided considering growth rate based for individual type of vehicle and only took general growth rate for all vehicles (last column of table 3.3). This growth rate has been used for estimating traffic in 2020, 2025 and in 2030.

Table 3: Growth rate of Traffic

Year	Truck	Bus	Car	Other	All Vehicl
Low					
2010-2015	5.95	3.00	8.30	6.70	5.25
2015-2020	7.10	3.00	6.90	5.25	5.15
2020-2041	1.40	3.00	5.50	2.00	2.45
Medium					
2010-2015	6.85	4.00	9.15	7.50	5.82
2015-2020	6.40	4.00	7.00	5.30	5.00
2020-2041	2.80	4.00	5.70	2.90	3.18
High					
2010-2015	8.00	5.00	10.60	8.30	7.25
2015-2020	6.00	5.00	6.80	5.20	5.50
2020-2041	5.22	5.00	5.45	4.20	4.90

3.3. Free flow Speed

Free flow speed is measured as the mean speed of the traffic in a low to moderate flow conditions (for example up to 1400 pcu/ln/hr). With a moderately straight road and level terrain and moderate access the free flow speed of the corridor has been assumed as 70 km/hr.

Free flow speed is related to road roughness (IRI), (RHD Road user cost report 2004-2005). National Highways of Bangladesh are of better geometrical standards and have least free flow speed and higher capacity. District roads, on the other hand are narrow and have higher free flow speed and lower capacity.

However, the analysis did not take into account the following while measuring free flow speed

- Significant presence of on street parking
- Presence of bus stops that has significant use
- ∟Significant pedestrian activity

3.4. Determination of Level of Service (LOS)

Highway Capacity Manual 2000 attributes have been used to determine level of Service of the mixed traffic lanes as mentioned in the Table:

Table 4: LOS Criteria for Multilane highways
(Source: Highway Capacity Manual-2000, TRB , Exhibits 21-2)

Free-Flow Speed	Criteria	LOS				
		A	B	C	D	E
100 km/h	Maximum density (pc/km/ln)	7	11	16	22	25
	Average Speed (km/h)	100.0	100.0	98.4	91.5	88.0
	Maximum volume to capacity ratio(v/c)	0.32	0.50	0.72	0.92	1.00
	Maximum service flow rate (pc/h/ln)	700	1100	1575	2015	2200
90 km/h	Maximum density (pc/km/ln)	7	11	16	22	26
	Average Speed(km/h)	90.0	90.0	89.8	84.7	80.8
	Maximum volume to capacity ratio(v/c)	0.30	0.47	0.68	0.89	1.00
	Maximum service flow rate (pc/h/ln)	630	990	1435	1860	2100
80 km/h	Maximum density (pc/km/ln)	7	11	16	22	27
	Average Speed(km/h)	80.0	80.0	80.0	77.6	74.1
	Maximum volume to capacity ratio(v/c)	0.28	0.44	0.64	0.85	1.00
	Maximum service flow rate (pc/h/ln)	560	880	1280	1705	2000
70 km/h	Maximum density (pc/km/ln)	7	11	16	22	28
	Average Speed(km/h)	70.0	70.0	80.0	69.6	67.9
	Maximum volume to capacity ratio(v/c)	0.26	0.41	0.59	0.81	1.00
	Maximum service flow rate (pc/h/ln)	490	770	1120	1530	1900

3.5. Occupancy of Bus

Given, the BRT lane is only 20 km of lanes and it is a BRT in the suburban area, it has been assumed that only modal shift from the bus shall take place. Average occupancy of buses has been assumed as 35 passengers per bus. The capacity of BRT Lane has been assumed as 12500 per direction per hour. Average Operation hour for BRT has been assumed as 16 hours per day. Thus, total carrying capacity of BRT system becomes 350000 passengers per day.

3.6. Modal Shift Scenario

The future modal shift scenario is very much uncertain and will depend on operational design of the BRT. 10 different modal shift scenarios have been considered here in this study. Only modal shift from large bus and medium bus was considered in this study. 0% modal shift means no passenger will be shifted from bus to BRT where as 100% modal shift scenario means all the bus passenger shall shift from bus to BRT and virtually there will be no Bus operating on the mixed traffic lane.

3.7. Analysis of result

Level of service at different time and for traffic growth scenario have been shown in picture.

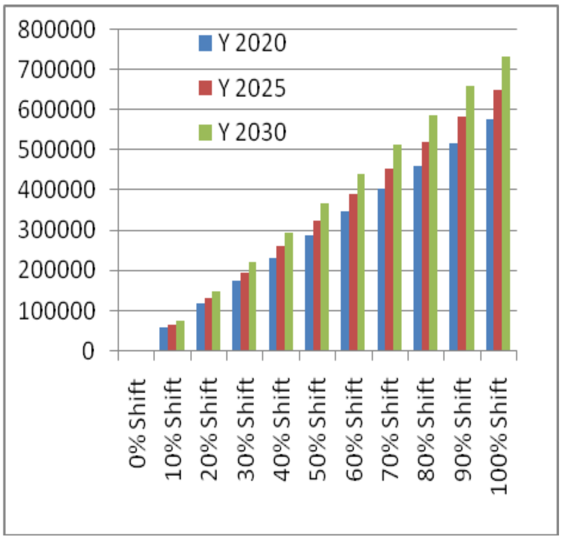

Fig 1: BRT Passenger corresponding to various modal shift ratio (Low growth scenario)

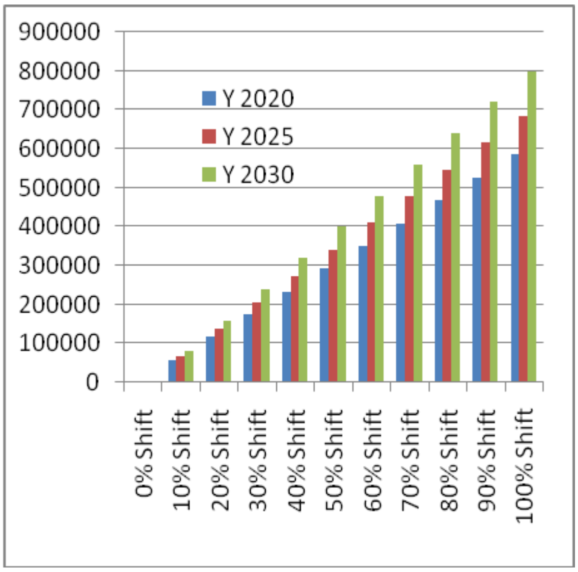

Fig 2: BRT Passenger corresponding to various modal shift ratio (Medium growth scenario)

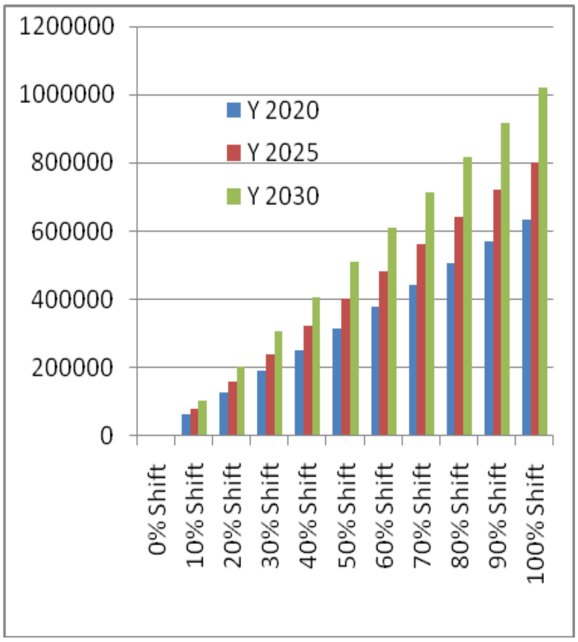

Fig 3: BRT Passenger corresponding to various modal shift ratio (High growth scenario)

The analysis result shows that with a BRT capacity of 400000 passengers per day the mixed traffic flow can vary at different traffic scenario. The capacity shall exceed the BRT carrying capacity at certain modal shift scenario

The corresponding Level of Service Scenario for three traffic growth assumptions shall be as follows.

i) Scenario for Low Traffic Growth assumption

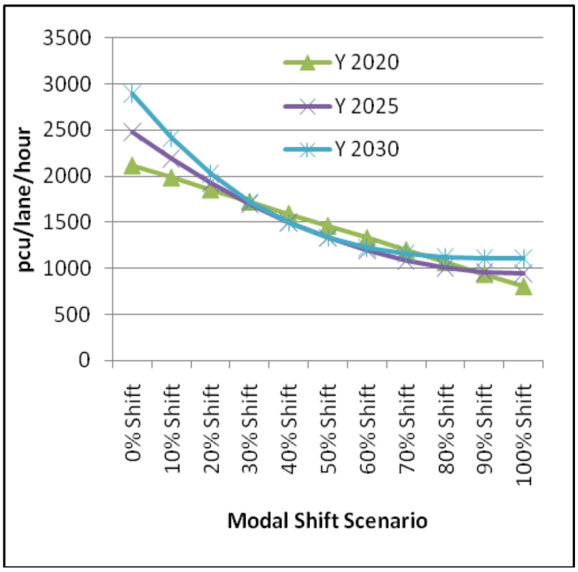

Fig 4: Projected traffic flow at different modal shift scenario (Low growth assumption)

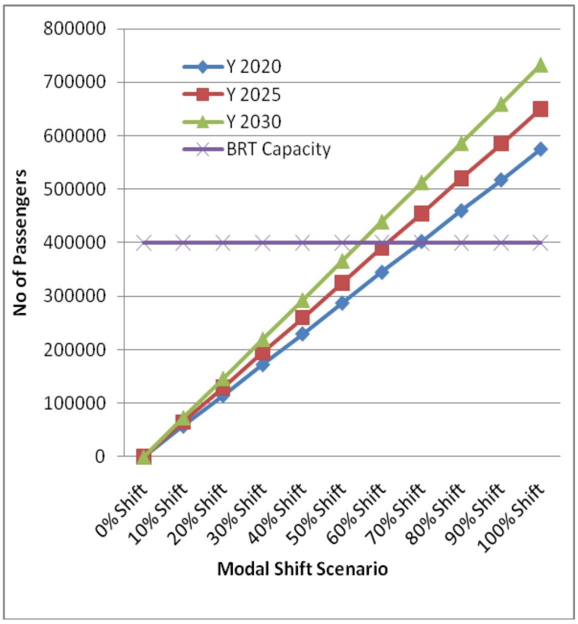

Fig 5: Passenger to be carried by BRT Passenger at different modal shift scenario (Low growth assumption)

Table 5: LOS at Low Traffic Growth Scenario

Year	2020	2025	2030	2020	2025	2030
Shift	Lane Traffic Flow (pcu/lane/hr)			Level of Service		
0%	2084	2353	2654	E	E	E
10%	1956	2077	2210	E	E	E
20%	1826	1830	1853	E	E	E
30%	1698	1612	1576	E	E	E
40%	1569	1423	1368	E	D	D
50%	1440	1262	1218	D	D	**D**
60%	1311	1132	1118	D	**D**	C
70%	1182	1030	1058	**D**	C	C
80%	1054	957	1026	C	C	C
90%	925	914	1015	C	C	C
100%	795	898	1012	C	C	C

At low traffic growth scenario in 2020 the maximum allowable modal shifting may be as much as 70% while in 2025 and 2030 the switching may be allowed up to 60% and 55% respectively. However, the Level of Service for each case would be LOS D.

ii) Scenario for Medium Traffic Growth assumption

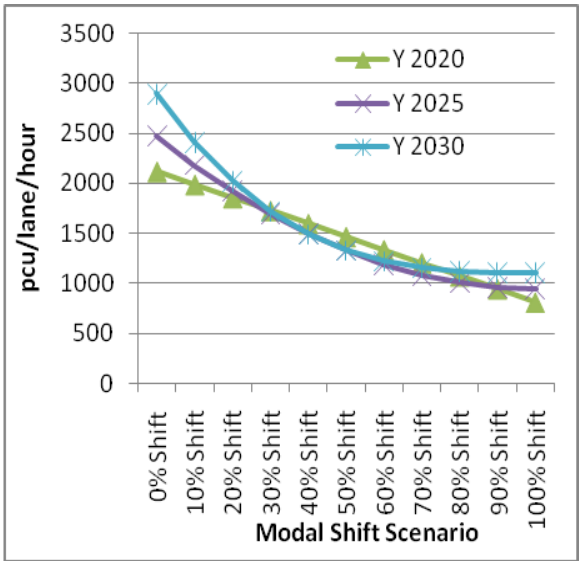

Fig 4: Projected traffic flow at different modal shift scenario (Medium growth assumption)

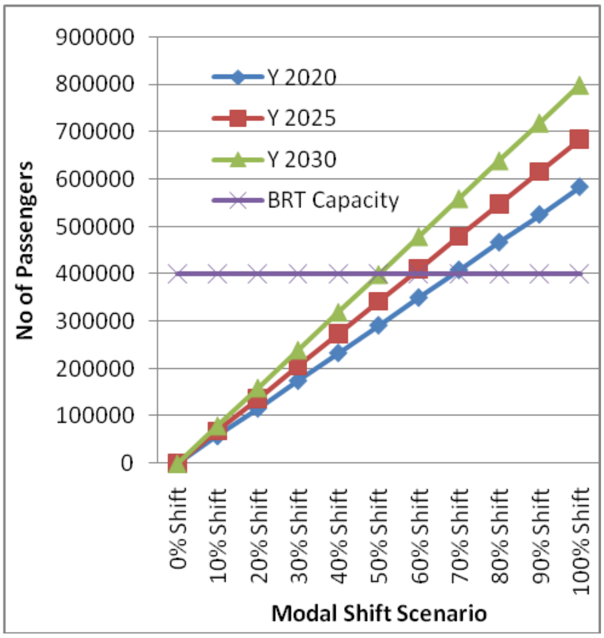

Fig 5: Passenger to be carried by BRT Passenger at different modal shift scenario (Medium growth assumption)

Table 6: LOS at Medium Traffic Growth Scenario

Year	2020	2025	2030	2020	2025	2030
Shift	Lane Traffic Flow (pcu/lane/hr)			Level of Service		
0%	2119	2479	2897	E	E	E
10%	1988	2189	2412	E	E	E
20%	1857	1928	2023	E	E	E
30%	1727	1698	1720	E	E	E
40%	1596	1499	1493	E	D	D
50%	1465	1331	1330	D	D	**D**
60%	1334	1193	1221	D	**D**	D
70%	1203	1085	1155	**D**	C	D
80%	1072	1010	1121	C	C	D
90%	941	963	1108	C	C	C
100%	809	947	1105	C	C	C

At medium traffic growth scenario the maximum allowable modal shifting is likely to be same as low growth scenario for the year 2020 and 2025 whereas it would be slightly lower at 50% in 2030 as opposed to 55% for low traffic growth assumption. The Level of Service for each case would be LOS D as well.

iii) Scenario for High Traffic Growth assumption

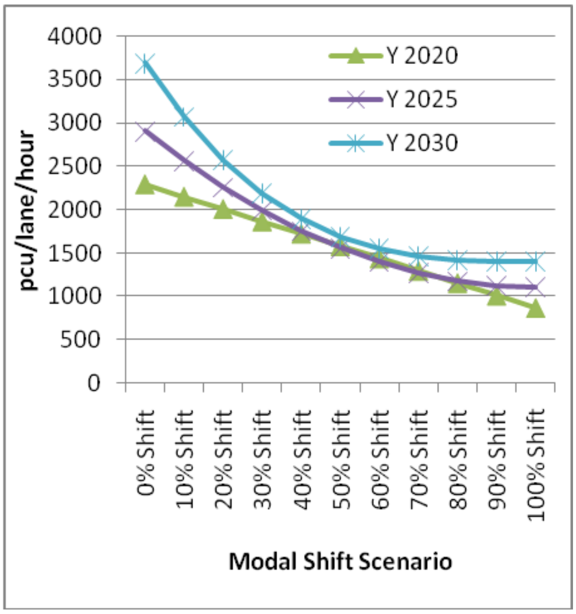

Fig 4: Projected traffic flow at different modal shift scenario (Medium growth assumption)

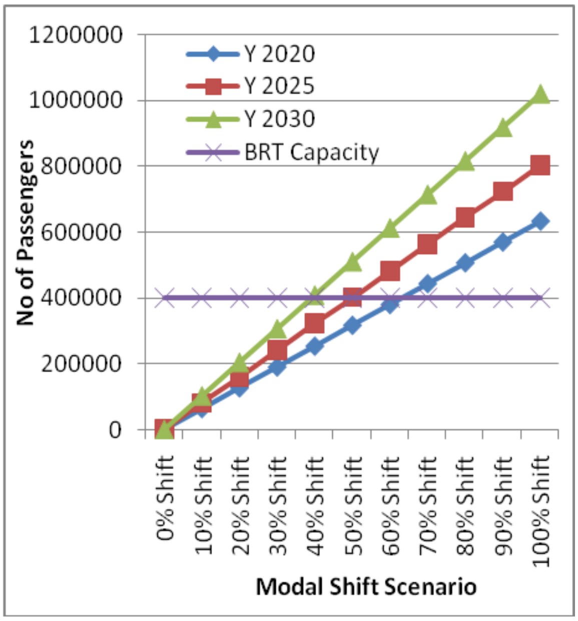

Fig 7: Passenger to be carried by BRT Passenger at different modal shift scenario (Medium growth assumption)

Table 7: LOS at High Traffic Growth Scenario

Year	2020	2025	2030	2020	2025	2030
Shift	Lane Traffic Flow (pcu/lane/hr)			Level of Service		
0%	2289	2906	3691	E	E	E
10%	2148	2565	3073	E	E	E
20%	2006	2259	2577	E	E	E
30%	1865	1990	2191	E	E	E
40%	1723	1757	1901	E	E	**E**
50%	1582	1558	1693	E	**E**	E
60%	1441	1397	1554	**D**	D	E
70%	1299	1271	1470	D	D	D
80%	1158	1181	1426	D	D	D
90%	1016	1127	1410	C	D	D
100%	873	1108	1407	C	C	D

At high traffic growth scenario, with a BRT capacity of 400000 passengers per day, modal shifting from mixed lanes to BRT lanes allows up to 60%, 50% and 40% in 2020, 2025 and 2030 respectively. The Level of Service would be LOS D in 2020 as well while the Level of Service may decline to LOS E both in 2025 and 2030 for high traffic growth.

In summary, for medium to low traffic growth scenario, the maximum allowable modal shifting varies from 50% to70% with LOS D whereas the maximum switching for high traffic growth ranges from 40% to 60% with Level of Service varying LOS D to LOS E.

4. Conclusion

The result of the analysis shows that in case of proposed BRT capacity of 400000; at low traffic growth scenario in 2020 the maximum allowable modal shifting may be as much as 70% while in 2030 the switching may be allowed up to 55%. At high traffic growth scenario, modal shifting from Bus to BRT allows up to 60% in 2020 and 40% in 2030. BRT might bring congestion in the mixed lane from the first day of operation of BRT lane. High modal shifting is necessary to address the problem. But, considering the capacity constraints of the BRT Corridor, a maximum of 50% of modal shift is optimum considering medium traffic growth rate. Optimum modal shifting from bus to BRT may vary from 40% to 55% at different traffic growth scenario. However, the corresponding Level of Service would vary from LOS D to LOS E.

With the increase of traffic along the corridor over time, Level of Service will reduce in the mixed traffic lane. Increase in the capacity of the BRT lane is required to accommodate the increase in passenger. Apart from that, modal shifting from bus and other passenger carriers to BRT is a must to keep tolerable Level of Service in the mixed traffic lane. Also, efforts should be undertaken to increase capacity of BRT by reducing headway or increasing fleet number and size.

5. Reference

[1] ADB , "Preparing the Greater Dhaka Sustainable Urban Transport Corridor Project", 2011.

[2] Consultants Report. ALG BETS LTD, TMB, GDSUTP final report, 2012.

[3] American Public Transportation Association, Recommended practice, APTA BTS-BRT-RP-001-10, Bus Rapid Transit Branding, Imaging and Marketing, 2011.

[4] American Public Transportation Association, Recommended practice, APTA BTS-BRT-RP-002-10, Bus Rapid Transit Stations and Stops, 2010.

[5] American Public Transportation Association, Recommended practice, APTA BTS-BRT-RP-003-10, Designing Bus Rapid Transit Running ways, 2010.

[6] American Public Transportation Association, Recommended practice, APTA BTS-BRT-RP-004-10, Bus Rapid Transit service design, 2010.

[7] American Public Transportation Association, Recommended practice, APTA BTS-BRT-RP-005-10, Implementing BRT Intelligent Transportation Systems, 2010.

[8] American Public Transportation Association, Recommended practice, APTA BTS-BRT-RP-007-10, Operating a Bus Rapid Transit System, 2010.

[9] Anam, S., Hoque, A.M. & Tamanna, M., "Evaluation of bus rapid transit (BRT) in context of Bangladesh", First civil engineering congress, Dhaka, Bangladesh, 2011, pp. 1-7

[9] Chang, Jason, "BRT Development in China", Paper read at Pre-Conference Workshop, Environment 2005 Conference, 2005.

[10]Currie, Graham, "Bus Rapid Transit in Australasia: Performance, Lessons Learned and Futures", Journal of Public Transportation, 2006, 9 (3): 1-22

[11] Dissanayake, Dilum., Morikawa, Takayuki., "Investigating household vehicle ownership, mode choice and trip sharing decisions using a combined revealed [1] [12] preference/stated preference Nested Logit model: case study in Bangkok Metropolitan Region", 2010.

[13] Haque, Md. Mazharul., Mohammed Ahsan, Hasib., Borua, Sudip. & Alam, Dhrubo, " BRT in metro Dhaka: Towards achieving a sustainable urban transport system", Transport research, 2012, pp. 1-10.

[14] Highway Capacity Manual, 2000.

[15] Hoque,M.M.,Hossain,T., "Augmentation of Mass Transit Mode in Dhaka, Bangladesh, CODATU XI Conference ,Bucarst (Romania), 2004.

[16] Institute for Transportation and Development policy, The BRT standard, 2014.

[17] Institute for Transportation and Development policy, The Bus Rapid Transit Guide (i-v) Lahore, 2007.

[18] Transport Company, Bus rapid transit system for city of Lahore, 2008.

[19] Lee, Seungjae., Ryuand, Seungkyu., Lee, Shinhae , Bus rapid transit operation analysis using the Downs–Thomson paradox, 2010.

[20]Levinson, H., S. Zimmerman, J. Clinger, S. Rutherford, R.L. Smith, J. Crcknell and R. Soberman, Bus rapid transit, TCRP Report 90, Transportation Research Board, 2003.

[21] Madhav G. Badami, Murtaza Haider, An analysis of public bus transit performance in Indian cities, 2007

[22] McShane, William R. and Roess, Roger P. , Traffic Engineering, 1990.

[23] Pignataro, Louis J. , Traffic Enqineering Theorv and Practice, 1973.

[24] Roads and Highways Department of Bangladesh, Road Master Plan, 2012

[25] Road Division, Bangladesh, Development Project Proposal (GDSUTP), 2012

[26] Sohel Mahmud, S. M. & Anwar, M.I., A Preliminary Feasibility Study of Bus Rapid Transit, 2008

[27] Sharmin, Nasrin., Bunker, Jonathan. & D'este, Glen, "Prospective bus rapid transit scenarios for pilot corridor in Dhaka, Conference paper (EDDBE-2011), Queensland University Technology, Brisbane, 2011, pp. 1-7.

[28] Sultana, N., Efficiency Analysis of Public Transit systems in Bangladesh: A Case Study of Dhaka City, 2013.

[29] Tiwari, Geetam., Jain, Deepty., "Accessibility and safety indicators for all road users: case study Delhi BRT", 2011.

[30] Transportation Research Board, Transit Cooperative Research Program report 90, 2003, Part 1-5.

[31] Weinstock,annie., Hook, Walter., Replogle,Michael. & Cruz, Ramon, "Recapturing Global Leadership in Bus Rapid Transit", 2011

[32] Zheng, LIN., Jiaqing, WU., "Summary of the Application Effect of Bus Rapid Transit at Beijing South-Centre Corridor of China", 2007.