

A Study on Cost-Benefit Analysis of Commuter Train Improvement in the Dhaka Metropolitan Area

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Abstract: A cost-benefit analysis of three possible alternatives along with the existing scenario on the Dhaka-Narayanganj route has conducted in this study. The first alternative is to reduce headway by improving existing railway tracks and signaling systems. The second alternative is to increase train frequency by introducing Diesel Electric Multiple Units (DEMU). The third alternative is to attain expected headway by double tracking with DEMU. The benefits considered are user's benefits, accident reduction savings, vehicle operating costs and emission reduction savings. The costs included capital and construction costs, operating and maintenance costs. The analyses utilized 3%, 5% and 10% Annual Average Ridership Growth Rates (AAGR) depending on passenger trends on the route. Two analysis tools such as Net Present Values (NPV) and Benefit-Cost Ratios (BCR) are used and compared among the alternatives to decide which alternatives are economically feasible on the basis of short terms and long terms perspectives.

Keywords: Commuter Train; Cost-Benefit Analysis; Existing Surface Rail Network; Megacity

1. INTRODUCTION

Dhaka, the capital of Bangladesh became the 9th largest mega city in the world in 2011. The capital grew rapidly from 2001 to 2011 and became the most densely populated urban area in the world. "Dhaka's density is estimated at 115,000 per square mile or 44,000 per square kilometer, with slum (informal dwelling) densities reported up 4,210 per acre, or 2.7 million per square mile (1 million per square kilometer)" (Wendell, 2012). According to the UN (2012) report on world urbanization prospects: the 2011 revision, Delhi, Mumbai, Dhaka, Kolkata, Karachi, Manila, and Jakarta in South and Southeast Asia are ranked within the 30 largest populated cities in the world.

Dhaka suffered from inadequate public infrastructure with railway-based urban mass transport systems, with huge traffic congestion, air pollution, and road traffic accidents. According to a RHD's study a loss of around Tk. 200 billion annually is caused by traffic congestion. "The capital is losing Tk. 120 billion for the delay the passengers suffer in traffic, Tk. 40 billion in the area of trade and exports, Tk. 25 billion for environmental causes and the rest of the amount for the medical and other purposes" (FE Report, 2012). Overall temperature, air and noise pollution level of the city are also increasing gradually.

Most of the railway networks in the country were built during old colonial period and are usually single-tracked, non-electrified and much worn, which are using only for intercity and freight transport. The main limitation of the existing tracks is good link cannot be made between the fragmented local networks. Furthermore, these railway networks are not actively involved in urban transport. It is necessary to develop a commuter rail system using the network of the existing Railways' backbone to carry more people faster, safer and causing less environmental pollution than that of road users. In recent times, Dhaka is pushing ahead with public transport systems centered on urban railway systems.

Bangladesh Railway (BR), a state-owned organization already has some network running out to the suburbs, which can be modified for commuter train services. The existing rail network can be revitalized by upgrading low-density passenger lines and freight lines through using higher performance trains and by increasing the number of stations in the routes. Dhaka can follow the good experience of Tokyo, where wide transport network have been constructed by offering through operations between new urban lines and existing suburbs lines for improved passenger convenience.

Recently, the government of Bangladesh has taken initiatives to reduce traffic congestion in Dhaka such as elevated expressways, MRT and BRT systems, and providing the districts adjacent to Dhaka with commuter train services. Presently, the capital is connected to Jamalpur, Dewanganj, Brahmanbaria, Akhaura, Mymensingh, Joydevpur and Narayanganj by 44 up-and-down train services. According to BR, approximately 40,000/day passengers are carried to and from Dhaka by these commuter rail services. Dhaka-Narayanganj commuter rail service is the most popular amongst all these services with approximately 12,000 passengers daily. The existing commuter rail services connecting Dhaka with surrounding districts is progressively attracting more passengers. However it has become difficult to increase frequency of services as per passenger demands due to decaying single railway tracks and other infrastructures and shortages of rolling stocks.

1.1 Problem Statement

Dhaka's growth is based on road transportation. "Five million commuters travel to Dhaka and its suburbs every day to attend work and most have to ride road transport as the capital lacks commuter train services" (Sultana, 2011). However, road transport and the capacity of road have reached their saturation level. Commuter train improvement in Dhaka metropolitan is now being considered as an alternative to reduce traffic congestion in Dhaka.

On-going projects of BR to improve commuter rail service between Dhaka and nearest cities are being evaluated on the basis of projected costs and revenues only. The nature and magnitude of their specific costs and benefits have not been well documented or accurately measured. As a consequence, policymakers may not have been thoroughly informed with regard to decisions on socio-economical impacts, strategies for fulfillment of future challenges and comparative analysis of different alternatives to improve commuter rail service. Maintaining support for the continued investment in commuter train improvement, including future challenges, and the development of short term and long term strategies is contingent upon developing a more complete understanding of the costs and benefits of probable alternatives, including the cost associated with future demands of commuters and the economic impacts of social benefits. In addition, it is imperative to understand the measurable benefits of an effective, efficient commuter train improvement strategy, which includes elements of train capacities to fulfill future passenger demand, operational techniques, and land use planning.

1.2 Scope and Objective

The study considered the existing Dhaka-Narayanganj rail route as an identical route for improvement of commuter train in the Dhaka metropolitan area. The study analyzes cost and benefits of different possible alternatives. Cost includes construction/capital cost, operating and maintenance cost. The considered benefits are user benefit, vehicle operating cost savings, net accident reduction savings and net emission reduction savings. The study deals with the estimation of the quantifiable benefits and costs of commuter train improvement. While many of the impacts of this study are readily quantifiable, others escape exacting measurement, either because they cannot be valued in dollars or because uncertainty prevents narrowing their expected dollar values within a reasonable range.

The objective of this study is to analyze and quantify the economic benefits and costs of possible alternatives of commuter train improvement (headway and punctuality) in the selected route. In addition to estimating the costs and benefits, BCR, and NPV are calculated for each operating alternative. These measures will help decision makers to decide which alternatives are economically feasible on the basis of short term and long term perspectives.

1.3 Methodology

The study uses both primary and secondary data for quantitative analysis. Secondary data are collected from the organization and private operator's information, publications of BR, Roads & Highways Department (RHD), Bangladesh Road Transport Authority (BRTA), various business journals and newspapers. Primary data includes records; ask people orally and interview. Apart from these, observation method has also been used to get idea about peak and off-peak hour passengers in the route.

The study considered the existing Dhaka-Narayanganj rail route as an identical route for improvement of commuter train service. Total route length is 16.11 km having single track with 5 (five) stations. The costs and benefits assessments are carried out on three improvement alternatives along with do nothing condition, which has been stated as Alternative-0 hereafter. In Alternative-1, up gradation of existing rail track will be made to increase operating speed. In Alternative-2, new imported DEMU will be introduced in addition of Alternative-1. In alternative-3, installation of double track, replacement of existing signaling system to automatic color light signal, and construction of a new station at Shyampur will be made along with using DEMU.

According to ridership trend of commuters in the route, Annual Average Ridership Growth Rate (AARGR) of 3%, 5% and 10% have considered for calculating future passenger demand and train capacity during project life of 30 years. The projected passenger demands for entire project life are modeled with the help of AutoCAD software for frequency and capacity of train movement in each scenario. The frequencies of train came from time-space diagram adjusted with train capacity to obtain supply side during entire project life. The modeled results reflect the projected passengers as well as train capacity for each scenario.

All of the quantifiable costs and benefits of the alternatives calculated into monetary value to obtain the total costs and benefits after the project life. NPV and BCR have calculated for each scenario to obtain comparative analysis among the alternatives.

2. LITERATURE REVIEW

Commuter train improvement project facilitates the riders with travel time savings compared to their previous travel mode or reductions in their trip expenses. Beside this, the availability of service at a lower price will encourage users to travel more, which will increase the total number of trips. Highway users will also be benefited through commuter train improvement, as shift of riders from auto to rail frees up capacity on the highways, which will reduce the generalized cost of highway travel and encourage new trip makers to use the roadways. Thus the benefits of the commuter train service can be estimated by considering the travel cost savings accumulating to riders staying in mode and those shifting from other modes, based on the consumer surplus methodology.

HDR Decision Economics (2010) used the following themes to estimate the benefits and costs in the analysis of Haverhill-Plaistow MBTA Commuter Rail Extension Project:

- Only incremental benefits and costs are measured.
- Benefits and costs are valued at their opportunity costs.

Haverhill-Plaistow MBTA commuter rail extension project was analyzed according to TIGER II grant application process where benefits and costs associated with specific long term outcomes criteria were estimated. The benefits measured in that project application were benefits to existing and new rail users, accident reduction savings, pavement maintenance savings, congestion savings to remaining highway users and emissions reduction savings as they relate to the five long term outcomes such as state of good repair, economic competitiveness, sustainability, livability and safety. The costs were initial construction and capital costs, operation and maintenance costs. (HDR Decision Economics, 2010)

Rhode Island Department of Transportation (2001) evaluated the South County Commuter Rail Service Operation Plan on the basis of benefits associated with Vehicle operating costs, Net accident savings, Travel time savings and Net emission cost savings and of costs included Construction/Capital costs and Operating and Maintenance Costs.

2.1 Commuter Train Improvement in South and Southeast Asia

The South and Southeast Asian megacities which have good experiences in the field of commuter train improvement on surface railways in existing rail networks are discussed below. As a rapidly growing megacity, Dhaka can follow the good practices to rebuild wide transport network by combining operations between proposed urban MRT lines and existing suburbs lines for improved passenger convenience.

2.1.1 Mumbai suburban railway: effective transportation network in India

The Mumbai suburban railway is the largest urban railway network in South Asia. This railway has two suburban networks namely Central Railway and Western Railway. The Central railway network has 255 km route with 89 stations and Western railway network has 125 km route with 64 stations. The Central and Western railways operate 1,100 and 1,000 trains respectively with each train carrying approximately 4,500 passengers during the peak hours. These urban networks are playing as lifeline for all commercial and business activities in the megacity.

Acharya's (2000) study found the following: "The Mumbai suburban rail network is the largest in the world in terms of the number of commuters carried daily, and the Central and Western railways carry a mind-boggling 5 million passengers every day. Nearly

half of all passengers using public transport are ferried by railways, which carry 80% of the total commuter passenger-km”.

The railway network has been upgraded gradually, where the trains plying on its routes are commonly referred to as local trains. This railway has taken some recent initiatives to meet up the increasing demand. The double-track section from Borivli to Virar has made quadrupled which separate slow and express traffic to improve the commuting conditions. Further a fifth 12 km line from Mumbai Central to Santacruz has been completed in addition with a 16.8 km extension from Santacruz to Borivli. Other improvement projects of providing additional track capacity and connectivity with the existing Central railway system including Thane-Turbhe-Nerul/Vashi as part of the second corridor and double tracking of the Belapur-Panvel section have completed to boost up the railway network to New Mumbai.

2.1.2 Manila urban railway: combination of surface and elevated railways

Like other densely populated cities in developing countries, Manila is facing huge traffic congestion. Manila and Dhaka city have some common characteristics like high density of population, traffic congestion, rapid rural-urban migration rate etc. The current rail transport network in Metro Manila is consisting of LRT, MRT and a commuter rail line owned and operated by the state-owned Philippine National Railways (PNR).

PNR operates two types of commuter trains namely Commuter Express, commonly called the Commex, and Bicol commuter. Commex serves for the Manila metropolitan area, extending as far south as Binan, in Laguna. The Bicol Commuter service launched on September 16, 2009 is serving stations between Tagkawayan, in Quezon province and Ligao City, in Albay. PNR has increased the number of trips per day of commuter rail service from 18 in 2009 to 48 in 2011. According to comparative report of passenger and revenue per year of PNR, they carried 1,836,665, 8,429,806 & 15,431,855 passengers in 2009, 2010 and 2011 respectively. The revenues have also been increased with passengers like P15,872,012.00 in 2009, P102,748,744.00 in 2010 and P177,466,336.00 in 2011.

2.1.3 Jabotabek railway: commuter train improvement in Jakarta

Improvement of commuter railway system in Jabotabek (a nickname derived from the first two letters of Jakarta, Bogor, Tangerang and Bekasi) area having frequent, safer and more reliable train operations achieved from the integration of existing railway facilities. Some national railway tracks have been doubled and electrified to provide upgraded urban transport and 9 km of track has been improved by grade separation. Today's railway in Jabotabek is the total output of 20 years improvement plan (1981 master plan) in the field of double tracking, electrification, improved and more densely stations, modern rolling stocks, grade separation, improved carriage depots, workshop and signaling system.

Improvement of Jabotabek railway (170.2 km) in Jakarta starts with feasibility study and the detailed design of each component according to the master plan. Priority had given to improve the function of the railway system or strengthening the transport capacity to facilitate respond to the changing circumstances of transport capacity and to cope with rapidly worsening traffic congestion in Jakarta. To mitigate the peak hour congestion, the first target was to complete the works that would allow morning hour rush operation at headways of 6 to 10 minutes by 1992.

The project faced some initial problems on the project implementation and uncertainties of funding. Therefore the project target was changed into three stages to achieve the expected headways during morning rush hours (12 to 20 minutes, 6 to 10 minutes and 3 to 6 minutes).

The first stage of targeted headway of 12 to 20 minutes was achieved in 1999 and gradual improvement made the headway of 8 to 15 minutes in 2003.

At the end of project time in 2002, the final (headway of 3 to 6 minutes) target was not achieved. However, the project gained rapid increase in passenger volumes corresponding with the increases frequencies of trains by implementing improved signaling and station facilities, double tracking, larger fleet of EMUs, etc.

According to Hata's (2003) report: The number of Jabotabek commuter trains increased by 260% from 137 trains per day in 1992 to 356 trains in 2001. Meanwhile, the increase in daily passenger volumes from 130,000 passengers per day in 1992 to 410,000 in 2001 (+320%) exceeded the 260% increase in the number of trains.

The frequency of Jabotabek commuter trains have increased from 137 trains per day in 1992 to 356 trains in 2001. In 2002, 471 trains ran each day in both directions in Jabotabek out of which 272 are commuter trains. According to Hata's study (2003) Jabotabek railways carried about 117.9 million passengers with 3,594 million passenger-km. Although Jabotabek railways account for only 3.7% of Indonesia's total railway network (4,564 km in operation), they carried about 67% of total passengers and 22% of passenger-km. The passenger density of Jabotabek railways was about 58,000 passengers/day/km, six times of the Indonesia's 9,900 passengers/day/km in 2002. Total revenue was IDR 119 billion.

3. CALCULATION OF COST AND BENEFITS FOR THE ALTERNATIVES

The study uses projected passenger demands, frequency of commuter trains and train capacity to measure future passenger demand fulfillment during the project life of different scenarios. It also considers socio-economic benefits compared with total costs to check whether the scenarios are profitable or not. Conversion of social benefits into monetary values has made to compare with future costs and analysis has made by using BCR and NPV of each scenario.

3.1 Passenger Demand and Train Capacity

Time-space diagrams have been drawn by plotting train movement in a graph having time in X axis and distance in Y axis. These diagrams facilitate the most suitable frequency of train, headways and train compositions for each scenario. In present scenario (Alternative-0), 18 and 22 pair of trains can be operated with 2 and 3 compositions respectively at 60 minutes headway. In case of Alternative-1, maximum 21 and 25 pair of trains can be operated by 2 and 3 compositions respectively with headway of 52 minutes. Fourth composition cannot be proficiently operated because of single track by Alternative-0 and 1. In Alternative-2, maximum 36 pair of trains can be operated by using 2 compositions at minimum headway of 30 minutes. Third composition cannot be introduced because of single track. For alternative-3, 232 pair of trains can be operated by 11 compositions and the minimum headway of 4 minutes can be achieved. The modeled result regarding frequencies of train for Alternative-0, 1, 2, and 3 are shown in Figure 1, 2, 3 and 4 respectively.

The actual riders in 2011 were used as the base year. Total peak hours and off-peak hours ridership are calculated according to frequencies of commuter trains from 06.00 hours to 00.00 hours for different scenarios. For 3% AAGR, future passenger demands can be fulfilled by all the alternatives. However, for 5% AAGR, passenger demands cannot be fulfilled by Alternative-0, 1 and 2 from 2035, 2038 and 2029 respectively. For 10% growth rate, passenger demands cannot be fulfilled by Alternative-0, 1 and 2 from 2023, 2025 and 2021 respectively.

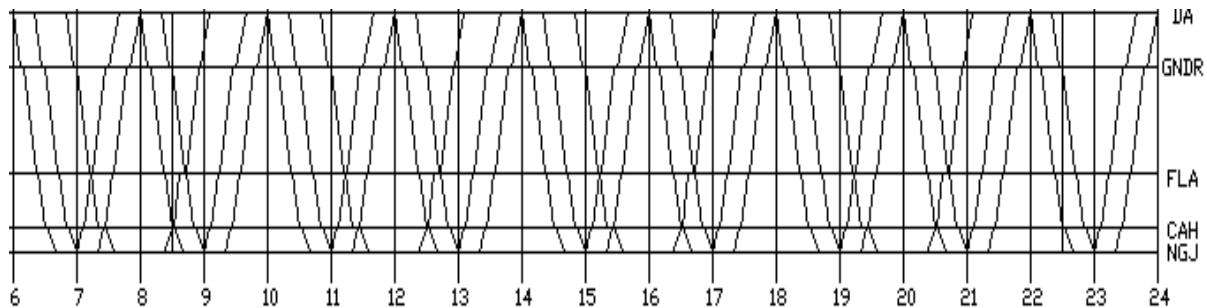


Figure 1. Frequency and proposed time table for Alternative-0

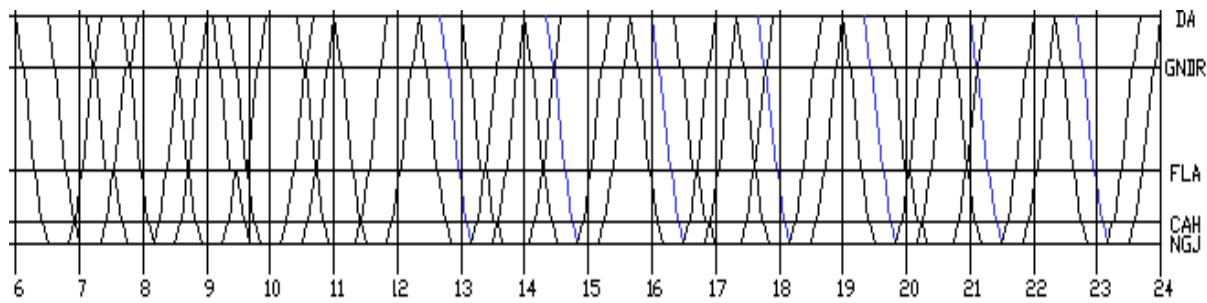


Figure 2. Frequency and proposed time table for Alternative-1

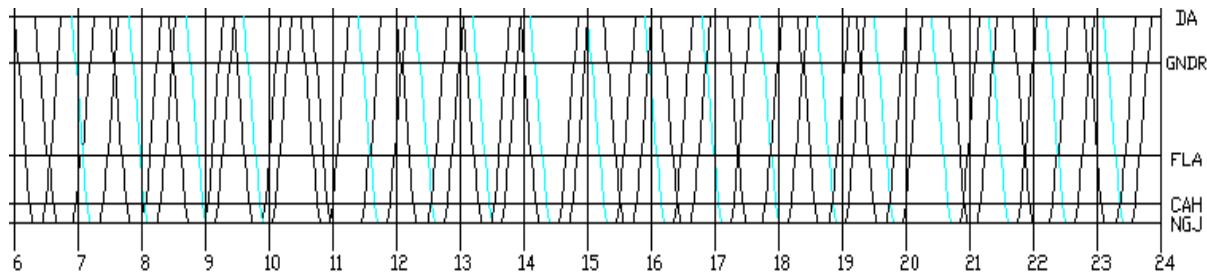


Figure 3. Frequency and proposed time table for Alternative-2

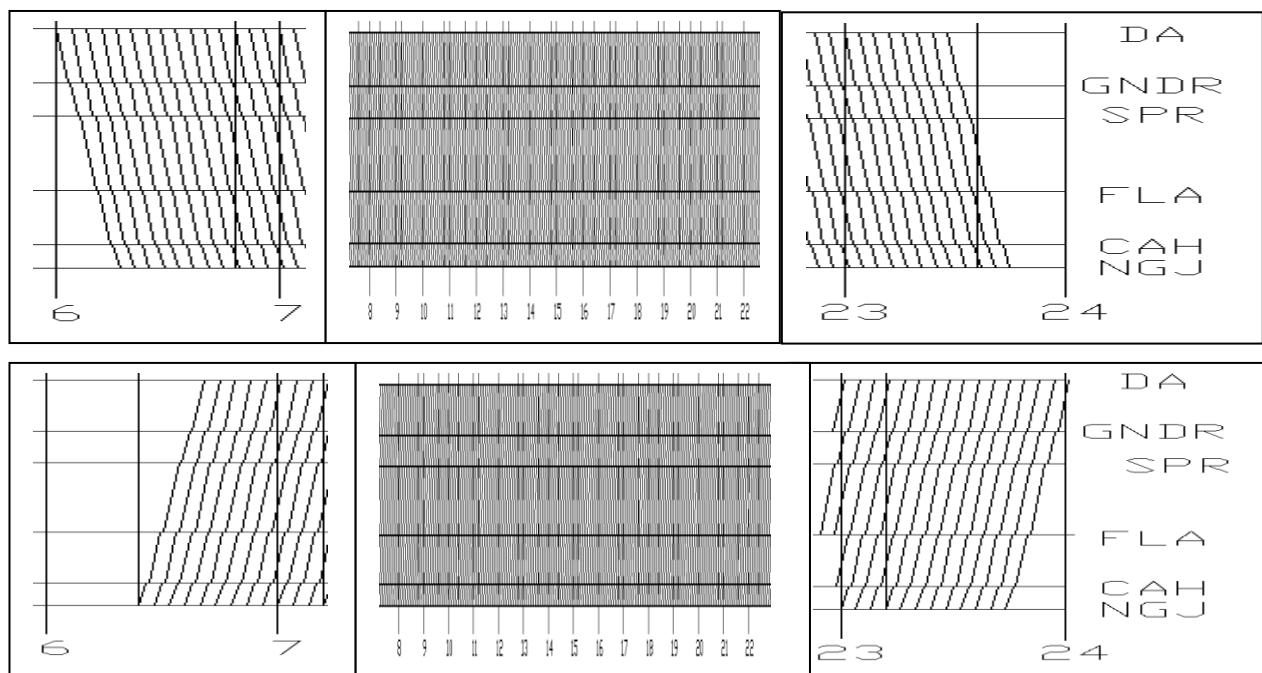


Figure 4. Frequency and time table for Alternative-3 (up & down direction)

For different alternatives, future passenger demand during project life and train capacities for 3%, 5% and 10% AARGR are shown in figure 1, 2 and 3 respectively.

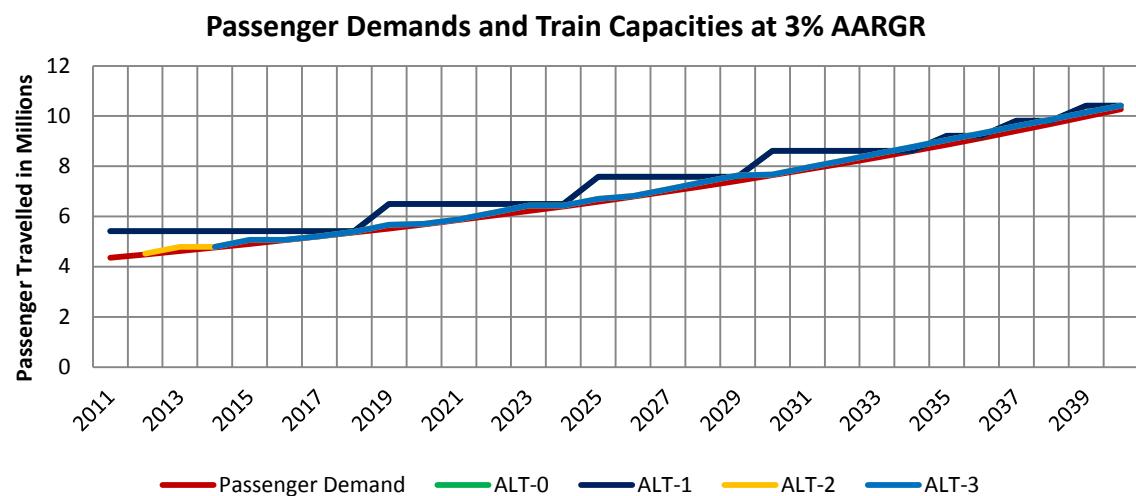


Figure 5. Projected passenger demands and train capacities for 3% AARGR

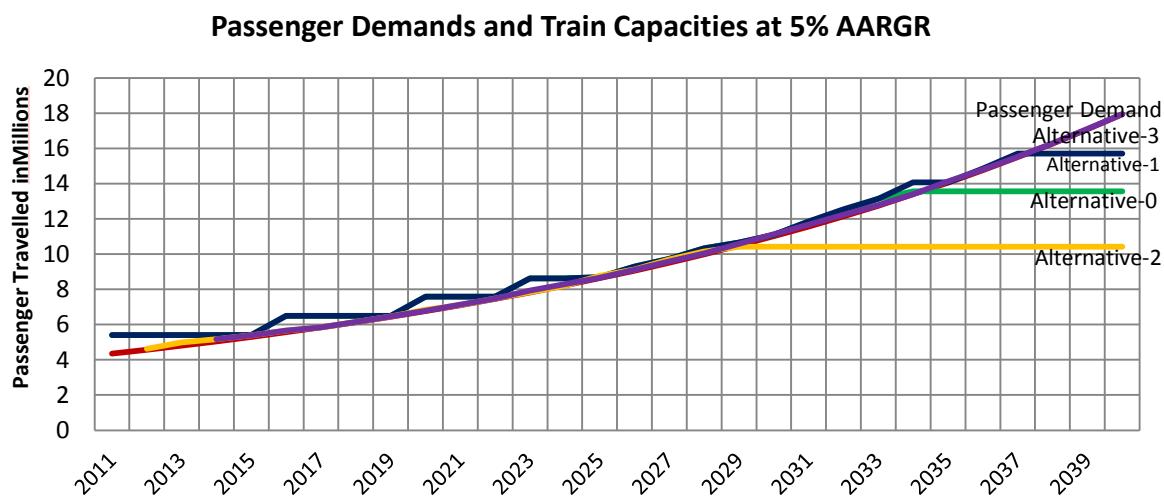


Figure 6. Projected passenger demands and train capacities for 5% AARGR

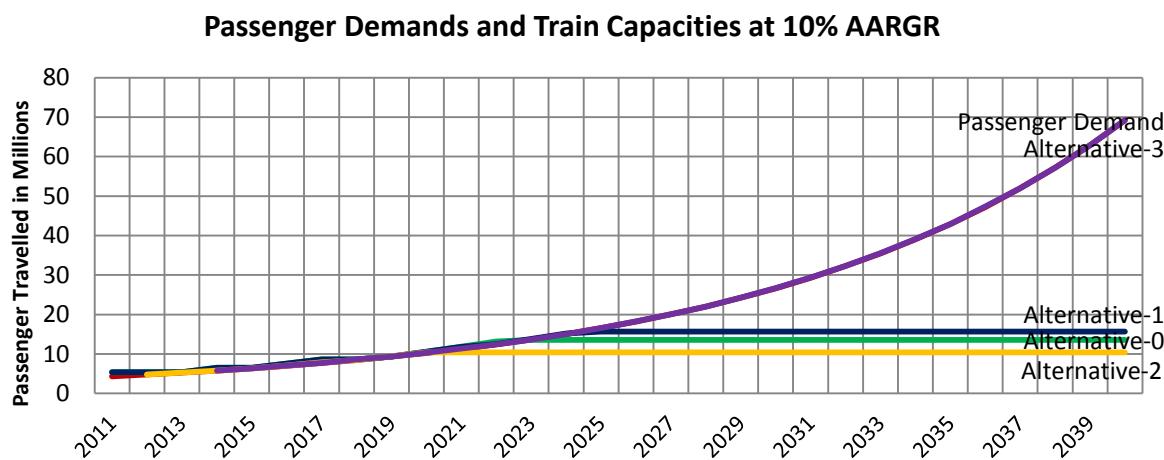


Figure 7. Projected passenger demands and train capacities for 10% AARGR

3.2 Vehicle Operating Costs (VOC) Savings

VOC for Large bus having average operating speed 36 km/hr and International Roughness Index (IRI) 15 found 31.74 Taka/km in 2005 (RHD, 2005). Usual travel time of buses at peak and off-peak hours are 30 and 90 minutes respectively on the corridor. The adjusted value of VOC was 160.09 in 2011. The road distance has taken as 17.2 km by using Google map. According to RHD report (2005), average occupancy has taken as 36.4 persons per bus. Table 1 shows the total VOC savings for different scenarios at 3%, 5% and 10% AARGR.

Table 1. VOC savings for different scenarios

Scenarios	3% AARGR	5% AARGR	10% AARGR
Alternative-0	\$ 62.25 M	\$ 82.66 M	\$ 101.27 M
Alternative-1	\$ 62.25 M	\$ 85.67 M	\$ 111.99 M
Alternative-2	\$ 60.94 M	\$ 73.03 M	\$ 82.09 M
Alternative-3	\$ 58.21 M	\$ 82.81 M	\$ 210.91 M

3.3 Accident Reduction Savings

Accident reduction savings for each scenario are calculated by deducting rail accident costs from auto accident costs for each year. According to BRTA report (2008), baseline accident counts in 2007 along Dhaka-Narayanganj route were 5 simple injuries, 11 grievous and 77 fatality incidents. RHD's reported Annual Average Daily Traffic (AADT) for road no. R110 (Jatrabari-Demra-Shimrail-Narayanganj Road) was 9,083 in 2008 (RHD, 2008) and for road no. Z1101 (Matuail-Shampur Road) was 2,090 in 2007 (RHD, 2007). Therefore, average AADT 5,586.5 for Dhaka-Narayanganj route, has used in calculating yearly Vehicle Kilometer Traveled (VKT) as 35,072,047 km. The economic cost of accident avoidance of fatality, grievous injury and simple injury are used to value auto accidents avoided.

The rail accident rate per million kilometers travelled is calculated from the accident report of Transportation department of BR. On the route, total rail accident cost was US\$ 312,998.45 and total kilometer travelled by commuter trains was 505,410 from 2008 until 2011. Rail accident cost per million kilometers was US\$ 619,296.12. Table 2 shows the total accident reduction savings of different scenarios for 3%, 5% and 10% AARGR.

Table 2. Accident reduction savings for different scenarios

Scenarios	3% AARGR	5% AARGR	10% AARGR
Alternative-0	\$ 2.18 M	\$ 3.07 M	\$ 3.70 M
Alternative-1	\$ 2.18 M	\$ 3.10 M	\$ 4.10 M
Alternative-2	\$ 1.77 M	\$ 2.14 M	\$ 2.41 M
Alternative-3	\$ 1.69 M	\$ 2.41 M	\$ 6.13 M

3.4 Net Emission Reduction Savings

Emission reduction savings are calculated by deducting rail emission from equivalent auto emission for each scenario. According to Environmental Protection Agency (EPA), emission standards for heavy-duty diesel engines, g/bhp-hr for four categories of pollutants: superset of hydrocarbons (HC), carbon monoxide (CO), Oxides of nitrogen (NO_x), and suspended particulate matter (gm) are taken as 1.3, 15.5, 5 and 0.25 respectively (DieselNet, 2012).

According to MacCarty *et al.* (2007) report, Global-Warming Potential (GWP), 100-year CO₂ equivalent of above pollutants are 12, 1.9, 296 and 680 for HC, CO, NO_x and PM respectively. Local Government Engineering Department (LGED) (2009), identified the Break Horse Power (BHP) of heavy duty passenger bus as 195 hp. Load factors for auto and rail engines are assumed as 0.4 (RIDT, 2001).

BR has 62% of the meter gauge locomotives manufactured by EMD and GE. EPA defined Tier 0 locomotives which are originally manufactured by that manufacturers from 1973 to 2001. 95% of locomotives of BR are falling in this range. Emission rates for tier 0 locomotives obtained from EPA Emission Standards (USEPA, 1998). Table 3 shows in use emission rate at g/bhp-hr used as baseline emission level of four categories of pollutants.

Table 3. Estimated baseline in-use emission rates (g/bhp-hr) for tier 0 locomotives

	HC	CO	NO _x	PM
Line Haul (Running)	0.48	1.28	8.6	0.32
Switch (Idling)	1.01	1.83	12.6	0.44

According to Wadud & Khan (2011), the social cost of CO₂ emission per ton was USD 49.00 in 2007. Applying emission values to equivalent CO₂ emission cost of \$51.47 (based on 2011 US dollars) per ton, net emission reduction savings have brought out (See Table 4).

Table 4. Emission reduction savings for different scenarios

Scenarios	3% AARGR	5% AARGR	10% AARGR
Alternative-0	\$ 25.03 M	\$ 30.22 M	\$ 39.32 M
Alternative-1	\$ 28.37 M	\$ 35.15 M	\$ 55.33 M
Alternative-2	\$ 33.55 M	\$ 40.72 M	\$ 45.62 M
Alternative-3	\$ 34.42 M	\$ 50.45 M	\$ 120.93 M

3.5 User Benefits

User benefits comprise of travel time cost savings and savings from fare of commuter train over bus services. Economic travel time cost per passenger for buses was Tk. 17.60/hr in 2005 (RHD, 2005). The travel time cost of Tk. 35.22 in 2011 has used to calculate present and future user benefits. Bus fare was Tk. 34.00 and train fair was Tk. 6.00 in 2011 for the corridor. Both modal fares have been increased by Tk. 3.00 affected from 2012. Table 5 shows travel time savings, saving from fares and total user benefits for different scenarios.

Table 5. User benefits for different scenarios (All values are in million US\$)

Scenarios	3% AARGR			5% AARGR			10% AARGR		
	Time Saving	Fare Saving	Total Benefit	Time Saving	Fare Saving	Total Benefit	Time Saving	Fare Saving	Total Benefit
Alternative-0	40.86	62.22	103.09	40.85	82.62	123.47	50.38	101.22	151.60
Alternative-1	56.39	62.22	118.61	62.74	85.63	148.38	97.28	111.94	209.22
Alternative-2	72.68	60.92	133.60	87.66	72.99	160.66	98.11	82.05	180.16
Alternative-3	67.59	58.18	125.77	99.17	82.77	181.94	236.70	210.82	447.52

3.6 Operating and Maintenance Costs

Operating and maintenance costs consist of maintenance cost of different operating departments of BR, cleaning costs of rolling stocks, salary & administrative costs, mileage

costs of operating staffs and fuel costs for the selected route. Revenues earned from the ticket fare are deducted from the added values of other costs to obtain net operating and maintenance costs for each scenario.

According to BR record, yearly maintenance cost was calculated as Tk. 4,281,750.00/loco and Tk. 1,466,083.00 in 2011/car. In case of DEMU, estimated yearly maintenance cost is Tk. 3,144,834.00 for each Driving Power Car (DPC) and Tk. 1,466,083.00 for each Trailing Car (TC). Yearly cleaning cost was calculated as Tk. 82,125.00/loco and Tk. 62,460.00/car in 2011. Cleaning cost per DEMU car has taken the same cost for existing carriage. The study uses the average fuel ration of 43 liters per trip for standard composition (locomotives with 10 cars) and reduce 0.7 liter for each car reduction. BR uses High Speed Diesel (HSD) and the price of fuel has taken Tk. 61.00 per liter in 2011.

Total salary and other benefits of operating staffs according to existing composition (7 or 8 cars) for 8 hours shift is Tk. 872,875.00 in 2011. A ticket collector's salary and other benefits of Tk. 165,305.00 are added for composition having 9 or 10 cars. According to BR, general administration cost for the study route (16.11 km) was Tk. 1,692,335.92 in 2010 (Bangladesh Railway Costing Profile, 2011). The adjusted general administration cost of the route for 2011 was Tk. 1,873,516.00. Total mileage cost per train per 100 km is Tk. 1,354.17 for composition having up to 8 cars and Tk. 1,610.00 for composition having 9 to 10 cars.

Ticket fare of the existing commuter train on the route was fixed at Tk. 6.00 and Tk. 9.00/trip in 2011 and 2012 respectively.

In Alternative-0, 1, 2 and 3, maximum of 22, 25, 36 and 232 pair of trains can be operated respectively on the route. Total operating and maintenance costs for different scenarios vary due to different frequencies of trains for different alternatives (See Table 6). The operating and maintenance cost for Alternative-3 at 10% AARGR is the highest because it will attain the highest frequency of train of 232 pairs and the minimum headway of 4 minutes.

Table 6. Total operating and maintenance costs for different scenarios

Scenarios	3% AARGR	5% AARGR	10% AARGR
Alternative-0	\$ 14.39 M	\$ 12.33 M	\$ 9.94 M
Alternative-1	\$ 14.39 M	\$ 7.58 M	\$ 3.40 M
Alternative-2	\$ 15.66 M	\$ 13.93 M	\$ 13.01 M
Alternative-3	\$ 16.05 M	\$ 14.65 M	\$ 66.41 M

3.7 Construction and Capital Costs

According to BR records, the unit price of a new locomotive was Tk. 273,052,545.00 and carriage was Tk. 20,000,000.00, the capital cost of constructing a new station building with signaling system was Tk. 32,017,500.00 in 2011. Construction cost for rail track per kilometer was 14,120,683.00, and land price per Katha (720 square feet) was Tk. 800, 000.00 in 2011. The total construction and capital costs for different scenarios are shown in Table 7. Alternative-0 scenario, has also construction and capital costs. The construction and capital costs have been calculated as written down value for existing rolling stocks and infrastructure.

Table 7. Total construction and capital costs for different scenarios

Scenarios	3% AARGR	5% AARGR	10% AARGR
Alternative-0	\$ 36.42 M	\$ 39.20 M	\$ 39.20 M
Alternative-1	\$ 37.63 M	\$ 40.41 M	\$ 40.41 M
Alternative-2	\$ 45.50 M	\$ 45.50 M	\$ 45.50 M
Alternative-3	\$ 57.85 M	\$ 66.03 M	\$ 131.47 M

4. RESULT OF THE COST-BENEFIT ANALYSIS AND DISCUSSION

Evaluation measures for the alternatives are shown in Table 8. The result shows that BCR range from 0.87 to 1.23 for 3% AARGR, from 1.01 to 1.36 for 5% AARGR and from 1.34 to 1.69 for 10% AARGR for the four alternatives. Alternative-0 and 3 at 3% AARGR generate negative NPV, while the other scenarios generate positive NPV at 15% real discount rate. Alternative-1 at 10% AARGR has the highest BCR 1.69, NPV of \$26.31 million and the lowest Annual Average Operating and Maintenance Cost (AAOMC). Alternative-3 at 10% AARGR has the highest NPV of \$26.87 M, indicating significant benefits at higher growth rate.

Table 8. Major financial and economic elements for alternatives (Figures are in USD)

Scenarios	3% AARGR			5% AARGR			10% AARGR		
	AAOMC	BCR	NPV	AAOMC	BCR	NPV	AAOMC	BCR	NPV
Alternative-0	0.15M	0.95	(2.05)M	(0.001)M	1.06	2.40M	(0.13)M	1.34	12.82M
Alternative-1	0.15M	1.02	0.76M	(0.18)M	1.16	6.25M	(0.40)M	1.69	26.31M
Alternative-2	0.13M	1.23	7.95M	0.04M	1.36	12.82M	(0.06)M	1.57	21.34M
Alternative-3	0.16M	0.87	(5.22)M	(0.1)M	1.01	0.23M	0.65M	1.60	26.87M

For 3% and 5% AARGR, Alternative -2 is the most attractive and Alternative -3 is the least attractive on the basis of BCR & NPV. However, Alternative-2 cannot fulfill the future demand and expected headway and AAOMC is the maximum at 5% AARGR. Alternative-1 at 10% AARGR performs the best in terms of BCR but cannot fit the future demand from 2025 and headway is quite long as 52 minutes. Alternative-3 at 10% AARGR generates the highest NPV of US\$ 26.87 M at the highest AAOMC. Of the four full-service alternatives at different AARGR, Alternative-3 is the most attractive in case of higher passenger growth rate, future demand fulfillment and minimum headway achievement. Figure 4 shows the bar diagram of Cost-Benefit-NPV explains the total costs, benefits and net present values for different alternatives at 3%, 5% and 10% AARGR.

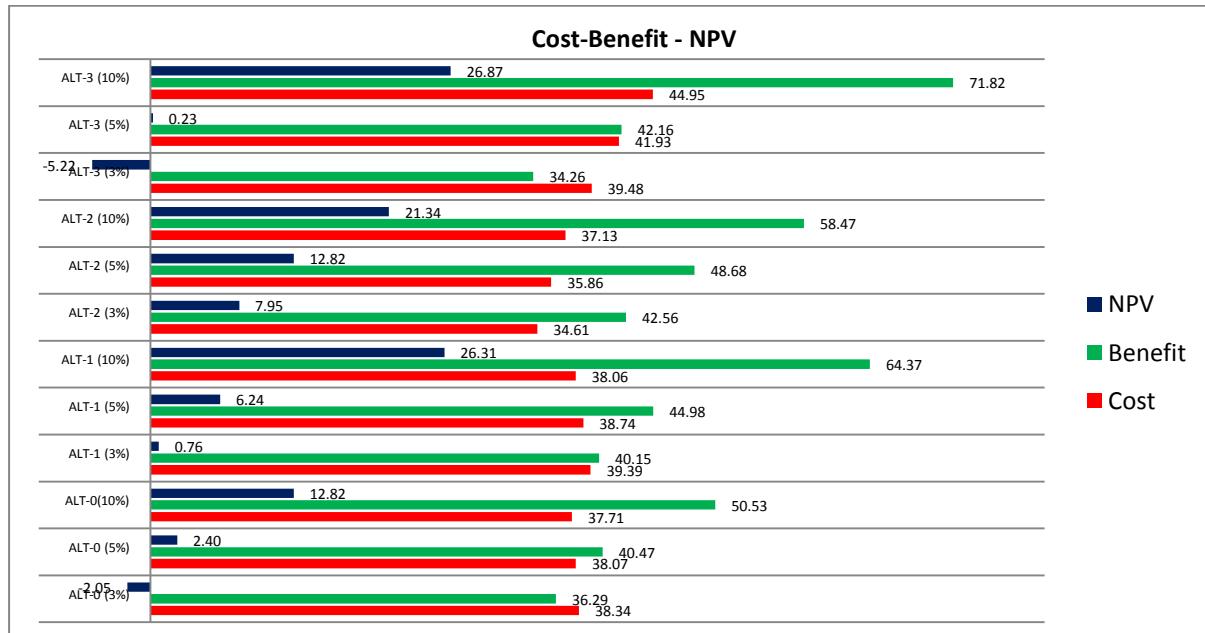


Figure 4. Bar diagram showing total costs, benefits and NPV for different scenarios

4.1 Sensitivity Analysis

A sensitivity analysis has been performed to find out the more optimistic conditions, in which the project with negative NPV would be deemed feasible. According to Table 8, Alternatives-0, and 3 at 3% AARGR generate negative NPV and are deemed economically not feasible with the assumed quantified inputs. Sensitivity analysis has been conducted to evaluate the effects of variation in the input variables considered in the cost-benefit analysis.

4.1.1 Increased value of time

In calculating the user benefits, travel time cost per hour has been taken only for bus users as Tk. 35.22 adjusted to 2011. It is assumed that riders, who are using other modes of transport (Microbus, car/utility, tempo, auto rickshaw and motor cycle) will shift from road to rail when the quality and availability of commuter train will improve. If the riders of all categories have been considered, then travel time costs per hour would be Tk. 41.25 adjusted to 2011. As shown in Table 9, an increase of this magnitude, increase BCR as well as NPV.

4.1.2 Increased ticket fare

The analysis used fixed ticket fare for the route as Tk. 6.00 for 2011 and 2012 and Tk. 9.00 for the rest of project life. It is assumed that more riders will be attracted with improved commuter train services during the project life. If the train fair is increased to Tk. 17.50 (by 94.44%), all of the operating alternatives at different AARGR will become economically feasible. That is, the BCR for each scenario is greater than one and NPV become positive. The highest NPV would be US\$ 36.23 million and BCR would be 2.29 for Alternative-1 at 10% AARGR (see Table 9).

Table 9. Sensitivity analysis summary

Scenarios	3% AARGR		5% AARGR		10% AARGR	
	Benefit Ratio	Cost	Net Present Value	Benefit Ratio	Cost	Net Present Value
Increase Value of Time (TTC) from Tk. 35.22 to Tk. 41.25						
Alternative-0	0.98	\$ (0.88) M	1.09	\$ 3.51 M	1.37	\$ 14.04 M
Alternative-1	1.06	\$ 2.44 M	1.21	\$ 7.96 M	1.76	\$ 29.10 M
Alternative-2	1.29	\$ 10.18 M	1.43	\$ 15.38 M	1.66	\$ 24.41 M
Alternative-3	0.91	\$ (3.50) M	1.06	\$ 2.39 M	1.68	\$ 30.46 M
Increase Ticket Fare by 94.44%						
Alternative-0	1.11	\$ 3.62 M	1.30	\$ 9.46 M	1.78	\$ 22.12 M
Alternative-1	1.19	\$ 6.43 M	1.42	\$ 13.40 M	2.29	\$ 36.23 M
Alternative-2	1.48	\$ 13.71 M	1.67	\$ 19.57 M	2.02	\$ 29.47 M
Alternative-3	1.00	\$ 0.05 M	1.14	\$ 5.07 M	1.88	\$ 33.58 M
Reduce Rail Accidents by 50%						
Alternative-0	0.95	\$ (1.74) M	1.07	\$ 2.72 M	1.35	\$ 13.18 M
Alternative-1	1.03	\$ 1.07 M	1.17	\$ 6.57 M	1.70	\$ 26.68 M
Alternative-2	1.24	\$ 8.32 M	1.37	\$ 13.24 M	1.59	\$ 21.85 M
Alternative-3	0.88	\$ (4.93) M	1.01	\$ 0.59 M	1.61	\$ 27.50 M

4.1.3 Elimination of rail accidents

The government of Bangladesh has taken initiatives to separate grade of railway track and roads at important rail crossings. It is assumed that the frequency of rail accidents would be

reduced by at least 50% as a result of grade separation. Table 9 shows that the impact of accident reduction is minimal- the highest BCR of the scenarios would be changed from 1.69 to 1.70 for Alternative-1 at 10% AARGR. The NPV continue to be negative and BCR continue to less than one for Alternative-0 and Alternative-3 at 3% AARGR. The highest NPV would be US\$ 27.50 million for Alternative-3 at 10% AARGR and BCR would be 1.70 for Alternative-1 at 10% AARGR.

5. CONCLUSION

The study analyzes different alternatives through which BR can upgrade existing tracks and can introduce modern technologies such as DEMU and signaling systems for more convenience of daily commuters. The study also finds out the answer whether the future demands of commuters can be fulfilled by the existing Dhaka-Narayanganj rail route or not. The time-space diagram of scenarios reveals that construction of double track and short distance stations are needed to fulfill future passenger demand on the route.

The main objective of the study is to develop a high-quality rail connection for commuters by improving the existing rail network. The improved commuter train service is expected to benefit the environment and to reduce the need to further increase road capacity. The shift of passengers from roads to rail is one of the objectives of the National Transport Plan (NTP) in order to reduce congestion and limit CO₂ emissions and air pollution. There is also an expectation that the improved commuter train service will accelerate regional development. The improvement of the line will further encouraged freight transport between two industrial cities during the off-time period of commuter train service from 00.00 A.M to 06.00 A.M.

The improvement facilities will foster planned economic development of the country. This commuter rail route will provide adjacent residents with improved access to both urban and suburban employment sites as well as garments and other industries found in both cities. It will offer opportunities to attract new development to the stations along the rail corridor. It will provide external benefits of improved travel times and capacity for the remaining road users, including motor-freight carriers, towards cost reduction for businesses. The improvement of commuter train service on the studied corridor will reduce the passenger load in other modes of transport. It will facilitate to partially fulfill the targets of reducing traffic congestion in the capital.

The result shows that Alternative-1 and 2 can increase existing train frequency approximately 14% and 64% respectively with a nominal cost. Alternative-2 is economically best feasible for short term perspective and for lower AARGR from 3% to 5%. Finally Alternative-3 demonstrates the solutions of all limitations faced in other alternatives and can increase 10.5 times of existing frequency of commuter train. Alternative-3 is feasible for long term perspective and for higher AARGR. Beside the proposed improvements, BR can facilitate Transit oriented development (TOD) and efficient use of the space and land of the stations, increase revenues from more advertising, increase the ticket fare up to the breakeven point and redesign the capacity of DEMU to haul 10 cars to generate more revenues as well as to reduce operating costs.

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