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LIFE CYCLE COST (LCC) ANALYSIS OF AHMEDABAD-MUMBAI BULLET TRAIN PROJECT

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ABSTRACT

This paper is an attempt to carry out Life Cycle Cost (LCC) analysis of a bullet train project and also to look into the financial feasibility of the project and provide a decision for finding out the feasibility of the project, there by the realization of sustainability of any transport infrastructure, LCC analysis is gaining its recognition by practitioners. A case study of Ahmedabad-Mumbai metro rail project phase-I has been considered for LCC analysis in which total cost of ownership has been calculated with the help of net present value analysis. Here the LCC analysis includes the construction cost, operation & maintenance cost, additional cost for adding rolling stock, replacement cost for replacing equipment and depreciation cost of the asset. Sensitivity analysis is also carried out between the discount rate and net present value to find out different changes in the LCC result. A model for calculating LCC per metro seat has been proposed. The outcome from this study will help to compare the LCC of various transport modes between Ahmedabad-Mumbai which would help in decision making process for deciding the technical and financial feasibility of similar high speed railway projects across the country.

KEYWORDS: Life Cycle Costing (LCC), Bullet train, Infrastructure project, Net present value, Sensitivity analysis, Feasibility analysis.

1. INTRODUCTION

Infrastructure industry is very large and complicated industry. In any infrastructure development project many study and calculation work must to be done because of large amount of investment is involved in that. Design and maintenance decisions can only be taken responsibly, when the costs and performance of decision alternatives are considered on a long-term, life-cycle basis. This also includes the delivered availability and reliability, since the infrastructure performance influences the costs and revenues of the operations.

India has undergone rapid economic growth in recent years, and along with this growth has come a sharp rise in the volume of people and goods being transported in the country. To meet this rise, Dedicated Freight Corridors (DFC) are being constructed to haul freight from Delhi to Mumbai and Kolkata. As for passenger transport, the Ministry of Railways (MOR), the Republic of India, prepared the “Indian Railways Vision 2020” in December 2009, and pre-feasibility studies are now being started in sequential order on seven routes that are candidates for the construction of High Speed Railway (HSR).

High-speed rail (HSR) is a type of rail transport that operates significantly faster than traditional rail traffic, using an integrated system of specialized rolling stock and dedicated tracks.

MOR in India formulated the “Indian Railways Vision 2020” in December 2009 as a long-term vision up to the year 2020. The Vision was formulated to address four national goals: (1) Inclusive Development, both Geographically and Socially; (2) Strengthening National Integration; (3) Large-Scale Generation of Productive Employment; and (4) Environmental Sustainability. An investment as much as 14 trillion rupee (Rs) is planned for the next ten years. Specifically, the vision sets the objectives to drastically increase revenue, expand the network and transport capacity, enhance safety and environmental sustainability, and reform passenger services. It also sets targets for business development in various fields, including passenger services on the conventional railway, HSR and rail freight, luggage, advertisements, telecommunication, and so on. For HSR that operates at the maximum speed of 250–350 km/h, the vision plans to implement projects for at least four corridors by 2020. Furthermore, it will also make plans for multiple routes to connect the commercial centers, tourist spots, pilgrimage destinations, and so on. The following is an excerpt from the Report of the Indian Railways Vision 2020.

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By 2020, at least four corridors of 2000 km would be developed and planning for 8 other corridors would be in different stages of progress. The Vision 2020 also envisages the implementation of at least 4 HSR projects to provide bullet train services at 250-350 km/h, one in each of the regions of the nation and planning for at least 8 more corridors connecting commercial, tourist and pilgrimage hubs. Six corridors have already been identified for technical studies on setting up of HSR Corridors. These are: Delhi-Chandigarh-Amritsar, Pune-Mumbai-Ahmedabad, Hyderabad-Dornakal-Vijayawada-Chennai, Howrah-Haldia, Chennai-Bangalore-Coimbatore-Ernakulam, Delhi-Agra-Lucknow-Varanasi-Patna.

The Mumbai–Ahmedabad corridor, along with 5 other high-speed rail corridors, was introduced for a feasibility study in the 2009–2010 Rail Budget. A 650 km long high-speed rail corridor was proposed to run from Pune railway station to Ahmedabad railway station via Mumbai. The point at which this route would touch Mumbai was to be decided when the feasibility report was prepared. The pre-feasibility study for the Ahmedabad–Mumbai–Pune corridor was completed by a consortium of RITES, Italferr and Systra. The top speed expected for the corridor was up to 350 km/h.

Here Ahmedabad-Mumbai Bullet Rail Project Phase-I is taken as case study. NHSRCL is implementing the project of high speed train corridor between Ahmedabad and Mumbai. The project is currently under construction, when completed, it will connect the cities of Ahmedabad, Gujarat, and India's economic hub Mumbai. It will be India's first high-speed rail line.

2. LITERATURE REVIEW

LCCAs are usually performed early in the design process when only estimates of costs and savings are available and applied to any capital investment decision in which relatively higher initial costs are traded for reduced future cost obligations. There are numerous costs associated with of a building or project falling under the categories such as initial cost (purchase, acquisition, construction cost), fuel costs, operation and maintenance cost, replacement cost, salvage value, finance charges(loan interest payments), non-monetary costs[1]. One has to take those costs which are relevant to their project. The ultimate objective of the LCCA of any product is to provide a framework for finding the total cost of design development, production, use and disposal of the product with an intention of reducing the total cost. Current LCA methods have several limitations, such as choice of system boundaries, lack of comprehensive data, modeling of anew process, and high cost and time so it is not feasible to develop a unique LCCA model, which suits all the requirements. However, it is possible to develop more elaborate models to address specific needs such as an eco-friendly, cost-effective product development [2].Four different lifetimes for buildings may be used in LCC: economic, technical, physical and utility life. Economic lifetime is an estimate of the building's profitable time. Technical lifetime is the estimated number of years until the technology renders the building obsolete. Physical lifetime is the estimated period in which it is physically possible to use the building. Finally, the buildings utility life is the estimated time the building can satisfy established performance standards. So, depending on the choice of life cycle the time perspective differs, which affects the results from the LCC calculation when discounted to a net present value. In LCC, the economic life is the most common since the calculations most often have a cost minimization perspective[3]When estimating future costs of transportation projects, discount rates play an important role as discount rates are subject to fluctuation overtime due to many reasons.[4] Probabilistic approach for selecting the discount rate is more reliable as there is some inherent uncertainty in that variable. Hence sensitivity analysis has to be carried out between the discount rate and net present value so that how much variation in the input value affects the range of economic evaluation can be known. The use of LCCA for transportation projects as an efficient decision support tool will undoubtedly continue to grow as long as the public and policy-makers demand better management of scarcer sources in the long run.[5]

3. DATA COLLECTION AND ANALYSIS

In this research, case study of Ahmedabad-Mumbai Bullet train is taken based on which the LCC of the project has been calculated. Most of the corridor will be elevated, except for a 21 km underground tunnel between Thane and Virar, of which 7 km will be undersea. The undersea tunnel was chosen to avoid damaging the thick vegetation present in the area. The corridor will begin at the underground station in the Bandra-Kurla Complex in Mumbai, and then traverse 21 km underground before emerging above ground at Thane. LCC has been

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calculated for 40 year duration with discount rate of 8.00%. In order to capture the effect of variation of discount rate, a sensitivity analysis has been presented in a later section. To carry out Life Cycle Cost analysis(LCC) authors identified which costs should be incorporated in LCC analysis. These have been derived from interactions with professionals on the field and literature of other researchers. The costs and theirs description are mentioned below:

Capital Cost Estimate: The capital cost estimated to cost ₹1.1 lakh crore (US$15 billion). The cost includes interest during construction and import duties. JICA agreed to fund 81% of the total project cost ₹88,087 crore (US$12 billion), through a 50-year loan at an interest rate of 0.1% with a moratorium on repayments up to 15 years and the remaining cost will be borne by the state governments of Maharashtra and Gujarat. 20% of the components used on the corridor will be supplied by Japan, and manufactured in India.

Operation and Maintenance Cost: The Operation and Maintenance costs are divided in different parts as below:
Labor Cost: The operation and maintenance costs include those for track maintenance, trolley wire maintenance, rolling stock maintenance, power, management and personnel affairs. Study team will estimate the costs of these items and the total amount of management and maintenance costs. Study team appropriate a sum of approx. Rs 407,500 per year for labor costs. (Source: Joint Feasibility Study for Ahmedabad-Mumbai High Speed Railway Corridor)

Maintenance Cost for Civil Engineering : The track maintenance costs include (1) the ordinary costs required to repair and maintain the fixed assets excluding contact wires, rolling stock (excluding track maintenance cars) and automatic ticket selling/cancelling machines and other machines for revenue services and (2) the labor cost for employees engaged in maintenance services. Study team appropriated an amount of approx. 6.5 Mil Rs/km/year by taking into account the fact the structures in this project are mostly earth structures and by referring to the track maintenance cost of railway promoters in Japan (excluding labor costs). (Source: Joint Feasibility Study for Mumbai-Ahmedabad High Speed Railway Corridor)

Maintenance Costs for Electricity and Signaling & Telecommunication: Maintenance costs for electricity and signaling and telecommunication include the costs required to maintain and repair contact wires, substation machines, telecommunication machines and special cars to maintain contact wires and the labor cost for employees engaged in the maintenance of contact wires. Study team appropriated a sum of approx. 3.8 Mil Rs/km/year as the contact wire maintenance costs based on the track maintenance costs (excluding labor costs) of high speed rail operator in Japan. (Source: Joint Feasibility Study for Mumbai-Ahmedabad High Speed Railway Corridor)

Rolling Stock Maintenance Cost: The rolling stock costs include the costs required to maintain and repair rolling stock (excluding those for the maintenance of tracks and contact wires) and the labor cost for employees engaged in maintenance services. Study team estimated the rolling stock maintenance costs as 14 Rs/car/kilometers/year in this project by referring to the rolling stock maintenance costs (excluding the labor cost) of high speed rail operator in Japan. (Source: Joint Feasibility Study for Mumbai-Ahmedabad High Speed Railway Corridor)

Power Cost: Study team appropriated an amount of 2.93~2.99 kWh/car/kilometers/year for power costs based on the records of Shinkansen in Japan considering the operating speed of 320km/h. As the power unit cost, Study team used that of Indian Railways, 4.73 INR/kwh. (Source: Joint Feasibility Study for Mumbai-Ahmedabad High Speed Railway Corridor)

Operating Cost: The operating costs include the station management costs and the labor costs of the train crews and employees at stations, head office, OCC and training center. Study team appropriated a sum of approx. 124.3 Mil Rs/station/year for station management costs (excluding the labor cost) based on Japanese Shinkansen station management cost. (Source: Joint Feasibility Study for Mumbai-Ahmedabad High Speed Railway Corridor).

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Additional Investment Cost: The total additional investment cost depends on additional investment plan of rolling stocks, additional investment plan of depots for meeting demand after starting operation and replacement cycle of equipment/ facilities.

Depreciation Cost: The depreciation through the straight-line method in which a fixed sum is charged as the depreciation amount throughout the lifetime of the asset. The formula for depreciation is as follows

$$D = \frac{P-F}{n} \qquad (1)$$

D = Depreciation
P = Total Capital cost estimate
F = Salvage value
n = Life of asset

Depreciation for the project is been calculated by the method given above. The value of P i.e. total capital cost estimate is the construction cost for the whole project which is Rs. 11,00,000 Million. The salvage value is considered as zero and the life of the asset is considered as 40 years. Year wise each cost component is illustrated in following table:

Table 2 Life Cycle Cost Analysis of Bullet Train (Ahmedabad-Mumbai)

Sr no.	**Year**	**Cash Outflow (Rs. In Millions)**			**Depreciation Cost (4)**	**Net Cash Flow= (1)+(2)+(3)-(4) (Rs. In Millions)**
		Construction cost (1)	**Operation & Maintainace Cost (2)**	**Additional Investment Cost (3)**		
1	2017-2018	55000	0	0	27500	27500
2	2018-2019	88000	0	0	27500	60500
3	2019-2020	110000	0	0	27500	82500
4	2020-2021	132000	0	0	27500	104500
5	2021-2022	165000	0	0	27500	137500
6	2022-2023	220000	0	0	27500	192500
7	2023-2024	330000	0	0	27500	302500
8	2024-2025	0	0	0	27500	27500
9	2025-2026	0	0	0	27500	27500
10	2026-2027	0	0	0	27500	27500
11	2027-2028	0	0	0	27500	27500
12	2028-2029	0	0	0	27500	27500
13	2029-2030	0	0	0	27500	27500
14	2030-2031	0	0	0	27500	27500
15	2031-2032	0	0	0	27500	27500

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16	2032-2033	0	0	0	27500	27500
17	2033-2034	0	1537.9075	61253	27500	35290.9075
18	2034-2035	0	1537.9075	0	27500	25962.0925
19	2035-2036	0	1537.9075	0	27500	25962.0925
20	2036-2037	0	1537.9075	959	27500	25003.0925
21	2037-2038	0	1537.9075	0	27500	25962.0925
22	2038-2039	0	1537.9075	965	27500	24997.0925
23	2039-2040	0	1537.9075	0	27500	25962.0925
24	2040-2041	0	1537.9075	1622	27500	24340.0925
25	2041-2042	0	1537.9075	0	27500	25962.0925
26	2042-2043	0	1537.9075	0	27500	25962.0925
27	2043-2044	0	2060.8075	138244	27500	112804.8075
28	2044-2045	0	2060.8075	0	27500	25439.1925
29	2045-2046	0	2060.8075	616	27500	24823.1925
30	2046-2047	0	2060.8075	1797	27500	23642.1925
31	2047-2048	0	2060.8075	0	27500	25439.1925
32	2048-2049	0	2060.8075	0	27500	25439.1925
33	2049-2050	0	2060.8075	0	27500	25439.1925
34	2050-2051	0	2060.8075	154	27500	25285.1925
35	2051-2052	0	2060.8075	0	27500	25439.1925
36	2052-2053	0	2060.8075	0	27500	25439.1925
37	2053-2054	0	2869.5075	136415	27500	111784.5075
38	2054-2055	0	2869.5075	0	27500	24630.4925
39	2055-2056	0	2869.5075	0	27500	24630.4925
40	2056-2057	0	2869.5075	0	27500	24630.4925
	Total	**1100000**	**47465.18**	**342025**	**1100000**	**1945270.265**

(Source : Feasibility Study for Mumbai-Ahmedabad HSR; Authors calculations)

Net Present Value (NPV) Analysis

For the net present value analysis, the various cost components have been listed and from that net flow of each year is calculated. The net present value of the net flow of each year is calculated and summation of each year's NPV is the total net present value of the project. The discount rate for calculation is taken at 8.00%. The formula to find the present work i.e. net present value is (Sarkar and Shah, 2018)

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$$P = \frac{F}{(1+i)^n} \quad (2)$$

Where,
P = Principal amount.
F = Future amount.
i = Discount rate.
n = No. of years.

Table 3. Net Present Value at Discount rate of 8%

Discount Rate (8%)		
Year	**Net Flow (Rs. In Millions)**	**Net Present Value (Rs. In Millions)**
2017-2018	27500	27500
2018-2019	60500	56018.51852
2019-2020	82500	70730.45267
2020-2021	104500	82955.46919
2021-2022	137500	101066.6048
2022-2023	192500	131012.2654
2023-2024	302500	190626.3121
2024-2025	27500	16045.98587
2025-2026	27500	14857.39432
2026-2027	27500	13756.8466
2027-2028	27500	12737.82092
2028-2029	27500	11794.27863
2029-2030	27500	10920.62836
2030-2031	27500	10111.69293
2031-2032	27500	9362.678637
2032-2033	27500	8669.146887
2033-2034	35290.9075	10301.07949
2034-2035	25962.0925	7016.747517
2035-2036	25962.0925	6496.988442
2036-2037	25003.0925	5793.518169
2037-2038	25962.0925	5570.120406
2038-2039	24997.0925	4965.816098
2039-2040	25962.0925	4775.480458
2040-2041	24340.0925	4145.489774
2041-2042	25962.0925	4094.204782

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2042-2043	25962.0925	3790.930354
2043-2044	112804.8075	15251.40894
2044-2045	25439.1925	3184.65157
2045-2046	24823.1925	2877.348602
2046-2047	23642.1925	2537.457868
2047-2048	25439.1925	2528.079093
2048-2049	25439.1925	2340.813975
2049-2050	25439.1925	2167.420347
2050-2051	25285.1925	1994.721796
2051-2052	25439.1925	1858.213603
2052-2053	25439.1925	1720.568151
2053-2054	111784.5075	7000.45745
2054-2055	24630.4925	1428.216818
2055-2056	24630.4925	1322.42298
2056-2057	24630.4925	1224.465722
Total	**1945270.265**	**872552.7183**

Sensitivity Analysis

Sensitivity Analysis is a tool used in financial modeling to analyze how the different values of a set of independent variables affect a specific dependent variable under certain specific conditions. Since the analysis of the LCC is based on data assumption that is sensitive to market variation, the NPV value by changing the discount rate from 8.00% to 12.00%. For different discount rate, the value of NPV is illustrated in below table.

Table 4. Sensitivity Analysis of discount rates

Discount Rate (%)	**Net Present Value (Rs. In Million)**
8	872552.7183
9	817699.6268
10	769730.3625
11	727363.8719
12	689610.8404

Profitability Index Method

Profitability Index is the ratio of present value of expected future cash inflows and Initial cash outflows or cash outlay. It is also used for ranking the projects in order of their profitability. It is also helpful in selectiong projects in a situation of capital rationing. It is also known as Benefit/Cost Ratio (BCR). It is a systematic

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approach to estimating the strengths and weaknesses of alternatives used to determine options which provide the best approach to achieving benefits while preserving savings. BCA has two main applications:

Profitability Index analysis is often used by organizations to appraise the desirability of a given policy. It is an analysis of the expected balance of benefits and costs, including an account of any alternatives. PI helps predict whether the benefits of a policy outweigh its costs (and by how much), relative to other alternatives. Generally, the accurate cost-benefit analysis identifies choices which increase welfare from a utilitarian perspective.

The Profitability Index if greater than 1, then it is acceptable or else neglected. The cost-benefit contains the total cash outflow and cash inflows are calculated from feasibility study report. The cash inflows are revenues collected from fare box. For revenue generation calculations below table is taken in consideration.

Table 5. Cash Outflow and Cash inflow

Year	Cash Outflow (Rs. in Millions)	Cash Inflow (Revenue Generation) (Rs. in Millions)
2017-2018	27500	0
2018-2019	60500	0
2019-2020	82500	0
2020-2021	104500	0
2021-2022	137500	0
2022-2023	192500	0
2023-2024	302500	19600.5
2024-2025	27500	19600.5
2025-2026	27500	19600.5
2026-2027	27500	19600.5
2027-2028	27500	19600.5
2028-2029	27500	19600.5
2029-2030	27500	19600.5
2030-2031	27500	19600.5
2031-2032	27500	19600.5
2032-2033	27500	19600.5
2033-2034	35290.9075	46282
2034-2035	25962.0925	46282
2035-2036	25962.0925	46282
2036-2037	25003.0925	46282
2037-2038	25962.0925	46282
2038-2039	24997.0925	46282

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2039-2040	25962.0925	46282
2040-2041	24340.0925	46282
2041-2042	25962.0925	46282
2042-2043	25962.0925	46282
2043-2044	112804.8075	93294
2044-2045	25439.1925	93294
2045-2046	24823.1925	93294
2046-2047	23642.1925	93294
2047-2048	25439.1925	93294
2048-2049	25439.1925	93294
2049-2050	25439.1925	93294
2050-2051	25285.1925	93294
2051-2052	25439.1925	93294
2052-2053	25439.1925	93294
2053-2054	111784.5075	169542.5
2054-2055	24630.4925	169542.5
2055-2056	24630.4925	169542.5
2056-2057	24630.4925	169542.5
TOTAL	1945270.265	**2269935**

(Source : Feasibility Study for Mumbai-Ahmedabad HSR; Authors calculations)

$$\text{Profitability Index} = \frac{Benefit\,(Cash\,Inflow)}{Cost\,(Cash\,Outflow)} \qquad (3)$$

The benefit or cash inflow is Rs. 2269935 Million and the cost or cash outflow is Rs. 1945270.265 Million.
Profitability Index = 2269935/1945270.265 = 1.17
As PI is 1.17 > 1, so the project is feasible.

4. CONCLUSION

According to the analysis it has been concluded that when evaluated over a life cycle of 40 years which is mostly the life of transport infrastructure in India, the cost is Rs. 872552.7183 Million which will be utilized in various sections in the life cycle. Also the LCC per seat for the project is about INR 98.47 lakh which is supported by NPV analysis. The LCC is very sensitive to the discount rate as the future costs are discounted to ascertain the present values and also are dependent on its usage. The life cycle cost per seat may increase if the actual demand is not fully reached up to its forecasted PHPDT values. The Profitability Index of the project is 1.17, which is supported by the benefit-cost analysis. This shows that the project is feasible and will beneficial for the society. The project will reduce the dependency on other modes of transport i.e., private vehicles, public buses, trains, air transport. This model can also be use as a financial feasibility study model for any other infrastructure projects.

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