ECONOMIC ANALYSIS

A. Introduction

1. The project will support the construction of two new lines, phases 2A and 2B, of the Bengaluru Metro, as well as technical assistance on urban development based on the transit-oriented development concept. The economic analysis was carried out in line with Asian Development Bank (ADB) guidelines.[1] The economic internal rate of return (EIRR) was calculated by assessing economic and/or societal benefits and costs of the project over a 30-year period, including 5 years of construction and 25 years of operation.

B. Demand Analysis

2. The travel demand was estimated using a 4-step travel model with parameters configured to represent Bengaluru.[2] The model established travel patterns by mode across Bengaluru. The model assessed the modal shifts that would occur as a result of new metro lines—i.e., the number of passengers who would transfer to the metro from other modes.

3. Ridership forecasts assume that a portion of users of other modes would shift to the metro within a 2-kilometer (km) catchment area (Table 3).[3] Future ridership growth at 4.11% per annum is attributed to projected growth in gross domestic product (GDP) and population growth of Bengaluru as well as planned development along the corridors. Also, ridership in the initial 2 years is discounted as ramp-up period. Table 1 outlines the daily ridership for the project in key years.

Table 1: Daily Metro Passenger Ridership

Line	2025	2030	2035	2040	2045	2050
Phase 2A	75,754	277,963	339,976	415,825	508,596	622,065
Phase 2B	81,480	298,976	393,312	481,060	588,384	719,653
Total	157,234	576,909	733,288	896,885	1,096,980	1,341,718

Note: Major assumptions for after 2028: (i) population growth (2021–2031) at 49.96%; (ii) population growth (2031–2041) at 26.51%; and (iii) employment growth (2021–2041) at 64%.
Source: Estimates based on the Bangalore Metro Rail Corporation Limited detailed project report, January 2019.

C. Economic Cost Analysis

4. Conversion factors of the government guidelines were applied when converting from the financial costs (in April 2020 prices) (Table 2). For capital expenses (capex), the conversion factors have been applied to nontraded costs only. These are in world price numeraire.

Table 2: Conversion Factors (Economic Price and/or Financial Price)

Costs	Conversion Factor
Capital Costs	0.83
Operating Costs	0.87
Time Cost Savings	1.00
Vehicle Operating Costs	0.90
Emission Costs	1.00
Accident Costs	0.90
Infrastructure Maintenance Costs	0.87

Source: Ministry of Housing and Urban Affairs. 2017. Appraisal Guidelines for Metro Rail Projects.

[1] ADB. 2017. Guidelines for the Economic Analysis of Projects. Manila.
[2] The four steps are trip generation, trip distribution, mode choice, and route assignment.
[3] As the project metro corridors are new lines, all forecast demand is assumed to comprise “shifted demand” from other modes, and hence no “generated demand” has been estimated.

5. Total economic capex for phases 2A and 2B is $1.507 billion, computed with the total financial capex of $1.816 billion (excluding financial charges). A residual value of 10% of the capex has been assumed at end-project. Similarly, total cumulative economic operations and maintenance costs over the project life, including routine maintenance, energy, and manpower, are $1.467 billion.

D. Economic Benefits Analysis

6. Economic benefits to society include savings through reduced travel times, vehicle operating costs (VOCs), accidents, and pollution. The disadvantages include an increase in congestion during construction. All benefits were calculated at market prices and then converted to economic prices using the conversion factors following government guidelines.

7. The economic benefits have been estimated based on passengers shifting to the metro from other modes. These are given in Table 3.

Table 3: Peak-Hour Trip Mode Share and Shift to Metro

	Mode Share	Shift to metro
Car and Taxi	21%	30%
2-Wheeler	23%	30%
Auto Rickshaw	8%	30%
Public Transport	48%	40%

Source: Comprehensive Mobility Plan for Bengaluru, October 2019.

8. **Journey time savings.** Time savings are calculated for (i) the passengers who are expected to shift from existing modes to the metro, and (ii) the passengers who continue to use existing modes with reduced congestion.

9. The average time saved for each trip was estimated given the total run times of the metro service, and the current road journey times along the metro corridors. The average time savings were estimated at 18 minutes per trip along the phase 2A corridor, and 45 minutes per trip along the phase 2B corridor. For passengers who continued to use the same mode, the journey time saving per trip was estimated at 5 minutes per trip, based on the assumption used in the detailed project report (DPR) prepared by the Bengaluru Metro Rail Corporation Limited.

10. The values of time per trip for each mode are in Table 4. The value of time is assumed to increase at the same rate as gross domestic product (GDP) per capita.[4]

Table 4: Values of Time by Mode
(₹/hour, 2015 prices)

Mode of Transportation	Value of Time
Car	116.4
2-Wheeler	84.9
Auto Rickshaw	55.4
Taxi	86.3
Bus	55.5

Source: Bangalore Metro Rail Corporation Limited.

11. The total metro ridership transferring from each of the other modes was estimated, then the annual value of journey time saving benefits was computed based on ridership, value of time,

[4] The value of time was conservatively assumed to increase (i) at 5% in the first 10 years, (ii) at 2% in the second 10 years, and (iii) at 0% in the last 10 years.

and reduced travel time of the modes. These are given in Table 5.

Table 5: Total Journey Time Savings
($ million)

	2025	2030	2035	2040	2045	2050
Phase 2A	18.4	86.2	116.3	157.1	192.2	235.0
Phase 2B	30.4	111.6	146.8	179.6	219.6	268.6
Total	48.8	197.8	263.1	336.7	411.8	503.6

Source: Bangalore Metro Rail Corporation Limited.

12. **Vehicle operating cost savings.** There will be savings in VOCs because of the reduced number of vehicles on the road after passengers shift to the metro. Vehicles considered for this benefit include cars, two-wheelers, autorickshaws, and buses. The average distance travelled (trip length) by vehicle type is assumed to be 16 km for cars, 16.8 km for two-wheelers, 8.4 km for autorickshaws, and 13.1 km for buses.[5] The VOC per km travelled by vehicle type is computed following the Ministry of Housing and Urban Affairs (MOHUA) guidelines. The final VOC savings are calculated as a product of the number of vehicles reduced per day, the average distance travelled (trip length) per vehicle type, and the VOC per distance travelled (km).

13. **Reduction in accidents.** The total benefit from reduced road accidents was estimated as the product of reduced road accidents and value per accident (fatal and non-fatal), following MOHUA guidelines. Reduced road accidents were calculated as the product of reduced road trips and the accident rate. The accident rate (accidents per trip) was estimated based on the 2018 figure from the Comprehensive Mobility Plan for Bengaluru (footnote 2)—661 fatal accidents and 3,950 non-fatal accidents. Dividing this by the total number of trips gives the accident rate. Accidents were assumed to cost ₹437,342 per fatal accident and ₹64,256 per non-fatal accident (both in 2004 prices), based on MOHUA guidelines and updated to 2020 prices for the analysis.

14. **Reduction in emissions.** Pollution is expected to be reduced primarily because of the reduced number of vehicles on the road owing to the shift of passengers to the metro. Emissions by vehicle type of various pollutants (PM, NOx, HC, CO, and CO_2)[6] in grams per km were estimated following MOHUA guidelines. Similarly, the value of the cost of emissions (in ₹ per ton) was also estimated following MOHUA guidelines. Multiplying these factors by the total vehicle-km (per vehicle type) taken off the roads as passengers shift to the metro gives us the value of the total benefit from a reduction in vehicular emissions. The values of emissions used were ₹134,010 per ton for CO, HC, NOx, and PM emissions, and ₹670 per ton for CO_2 emissions. These values (in 2020 prices) were taken from the Bengaluru Metro DPR. The cost of CO_2 emissions works out to $9.67/ton, as compared to the ADB guidance of $36.30/ton.

15. **Congestion during construction.** During construction, there will be disruption to traffic at key locations along the alignments. This will result in delays in journey times and would thus be *economic cost* to road users. Impacts of the slowdown in traffic at 10 major locations were considered. It was assumed that each vehicle would experience a journey time disruption (i.e., reduction) of 15 minutes. Total economic cost from congestion during the construction period was calculated as a product of the value of time and the total increase in journey.

[5] Bangalore Metro Rail Corporation Limited. 2019. *Comprehensive Mobility Plan for Bengaluru.* Bengaluru. Prepared by IDECK Limited.

[6] PM: Particular Matter, NOx: nitrogen oxides, HC: hydrocarbons, CO: carbon monoxide, CO_2 carbon dioxide.

E. Economic Internal Rate of Return

16. The total economic costs and benefits of the project (phase 2A and 2B combined) are summarized in Annex A of this assessment. The results indicate that the overall project investment delivers an EIRR of 13.41% and a net present value of $798.6 million at a 9% discount rate, which indicates that overall the project is economically feasible. The EIRR is conservatively estimated, as ridership estimates for the ramp-up period and normal operation period are estimated conservatively.

F. Sensitivity Analysis

17. Various sensitivities have been considered, which are outlined in Table 6. These include an increase in capex, and reduction in ridership, and a delay in project implementation. Switching values have also been estimated. The sensitivity analysis demonstrates that even if the capex increases by 10% or the ridership attained is 20% below the forecasts, the project is still economically viable.

Table 6: Sensitivity Analysis

	EIRR (%)	Switching Value
Reduction in ridership (10%)	12.26%	(34%)
Reduction in ridership (20%)	11.02%	–
Increase in capex (5%)	12.95%	67%
Increase in capex (10%)	12.53%	–
Delay in benefit (1 year)	13.08%	–
Delay in benefit (2 years)	12.48%	–

( ) = negative, capex = capital expenses, EIRR = economic internal rate of return.
Source: Asian Development Bank estimates.

G. Distribution and Poverty Analysis

18. The project will directly benefit low-income sections of society and vulnerable people with improved travel times and reduced pollution. A certain share of the drivers (e.g., owners of two-wheelers and auto rickshaws) who are low-income will also enjoy reduced VOCs. Most importantly, labor demand directly generated by the project is also likely to benefit low-income workers and manual laborers. It was assumed that 25% of all capex on civil and infrastructure works would be spent on wages for manual labor. Given the labor-intensive nature of construction in India, this assumption is considered reasonable.

19. There will also be indirect economic benefits in the form of improved access to jobs and education, and promotion of structural transformation within the local economy. These induced effects will, at a wider level, help those with low incomes and the vulnerable.

20. A survey of existing passengers using phase 1 of the metro, conducted in February 2020, found that about 40% of Bengaluru metro users are female, as the metro is recognized by female passengers as a safer public transport compared with conventional public transport. The Bengaluru Metro is also considered an affordable public transport mode, as 53.8% of users have monthly incomes of less than ₹25,000 (equivalent to $338), and 4% of all metro users have monthly incomes below ₹10,000.

21. The total present value of all project economic benefits is $869 million over the project life. Assuming that 4% of these benefits accrue to the poorest metro users, this gives us a total benefit of $97 million in present value terms. The other benefit that accrues to the poorest is wages paid

to low-skilled workers, which are assumed to be 25% of the capex on civil works. The present value of this has been estimated at $184 million over the project life.

22. Based on the total benefits accruing to the poorest metro users, and the benefits during construction accruing to those undertaking manual labor and earning low wages, the poverty impact ratio for this project has been estimated at 0.35, as outlined in Table 7.

Table 7: Poverty Impact Ratio

	Present Value ($ million)
Total Project NPV	799
Benefits accruing to poorest passengers (4% of total)	97
Benefits accruing to poor during construction	184
Poverty Impact Ratio	**0.35**

NPV = net present value.
Source: Asian Development Bank estimates.

Table 8: Economic Evaluation Results

($ million)

	Costs		**Benefits**						
Year	**Capital Cost**	**Operating Cost**	**Journey Time Savings**	**VOC Savings**	**Accident Savings**	**Emissions Reduction**	**Construction Congestion**	**Total Benefits**	**Net Benefits**
2021	(449.5)						(1.1)	(1.1)	(450.6)
2022	(235.7)						(1.2)	(1.2)	(236.8)
2023	(295.5)						(1.2)	(1.2)	(296.8)
2024	(301.7)						(1.3)	(1.3)	(303.0)
2025	(224.9)	(29.0)	44.9	27.1	0.3	1.0	(1.4)	71.8	(182.0)
2026		(34.2)	95.2	56.3	0.6	2.4		154.6	120.3
2027		(39.6)	151.5	88.0	0.9	4.0		244.5	204.8
2028		(39.9)	160.9	91.6	1.0	4.2		257.7	217.8
2029		(40.2)	171.0	95.4	1.0	4.4		271.7	231.6
2030		(42.8)	181.8	99.3	1.0	4.6		286.7	243.9
2031		(46.7)	190.9	103.4	1.1	4.6		299.9	253.3
2032		(47.0)	200.5	107.6	1.1	4.8		314.0	267.1
2033		(47.3)	210.6	112.1	1.2	5.0		328.8	281.6
2034		(46.6)	230.3	121.2	1.3	5.5		358.3	311.7
2035		(50.5)	241.9	126.2	1.3	5.7		375.1	324.6
2036		(50.8)	254.1	131.4	1.4	6.0		392.8	341.9
2037		(51.2)	266.9	136.8	1.4	6.2		411.3	360.1
2038		(51.5)	280.4	142.4	1.5	6.5		430.8	379.2
2039		(51.9)	294.5	148.3	1.6	6.8		451.2	399.3
2040		(55.2)	309.5	154.4	1.6	7.1		472.6	417.4
2041		(58.2)	322.2	160.7	1.7	7.3		491.9	433.7
2042		(58.6)	335.4	167.3	1.8	7.6		512.1	453.6
2043		(59.0)	349.2	174.2	1.8	8.0		533.2	474.2
2044		(59.4)	363.6	181.3	1.9	8.3		555.2	495.7
2045		(63.0)	378.5	188.8	2.0	8.7		578.0	515.0
2046		(63.5)	394.1	196.6	2.1	9.1		601.8	538.3
2047		(63.9)	410.3	204.6	2.1	9.5		626.6	562.6
2048		(64.4)	427.1	213.1	2.2	9.9		652.3	587.9
2049		(64.9)	444.7	221.8	2.3	10.4		679.2	614.3
2050		(68.9)	463.0	230.9	2.4	10.8		707.1	638.2
EIRR									**13.41%**
ENPV @9%									**798.6**

EIRR = economic internal rate of return, ENPV = economic net present value, VOC = vehicle operating cost.
Source: Asian Development Bank estimates.