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Economic Evaluation of Namma Metro Transport System-Phase-1, Bengaluru

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ABSTRACT

Bengaluru city is one of the major fastest growing metropolises, with an 8.50% economic growth, and has world-class housing, education, and research facilities in the country. Over 36% of the economy of the State of Karnataka and 98% of the State's software exports come from Bangalore, making it a significant contributor to the economy of all of India. In the past 20 years, the population is growing at faster pace and almost has doubled facing the challenges of traffic and transportation problems. The existing BMTC (Bengaluru Metropolitan Transport Corporation) is working hard to meet the demands of the increasingly growing commuter population for a quick, more efficient, and user-friendly method of public transportation but is still unable to accomplish, hence there is need for developing an efficient MRTS (Mass Rail transit System). Namma metro is one of the few MRTS projects undertaken in India and perhaps to became the first underground metro system in South India.

The objective of the study is to understand the benefits that the metro projects provide are more important from the government's economic and social point of view compared to the financial benefits that accrue from implementing the project. This paper discusses about the Namma Metro improving the traffic and transportation problems in Bangalore city providing numerous benefits to the citizens and society, such as. savings in fuel consumption, vehicle operating costs, travel time, reduction in road accidents and air pollution etc. These economic benefits would overweigh the financial benefits and hence assessing the same would also be of more significance. It further attempts to investigate the Economic Analysis using Framework for Economic Appraisal based on MOHAU (Ministry of Housing & urban affairs) Appraisal Guidelines for metro rail projects to enumerate all benefits and the economic viability of the project of Namma Metro Phase- I.

Key words: *Public Transport, Namma Metro, Economic Analysis, Cost-benefit Analysis (CBA).*

I. INTRODUCTION

Bengaluru, with a population of over 13 million in 2022, a 3.35% increase from 2021 is a key engine for driving country's growth. It is now the 24th most populous city in the world and the fastest-growing Indian Metropolis behind New Delhi, growing at a whopping 47.18% from 2001 to 2011. Bengaluru among the 20 best start up city ecosystems in the world has emerged as the IT Start Up Capital of India with more than 30 per cent of national share. However, the rapid growth of IT sector along this corridor has placed a huge burden on the transport infrastructure. As a result, this growth corridor has become a transportation bottleneck.

The implementation of the Bengaluru Metro Rail Project is the responsibility of Bengaluru Metro Rail Corporation Limited (BMRCL), a joint venture between the governments of India and Karnataka. By implementing the metro project, it has shall relieve the city congestion and assure that development is greener, with lower greenhouse gas emissions. Improvement in quality of life and reduction of travel times: from 2022, 1.4 million passengers/day will benefit from the metro Development of infrastructure and commercial facilities near the station.

BMRCL began work on Phase I of the Bangalore Metro in 2008, which includes building two metro lines with a north-south route of 24 km and an east-west route of 18 km. These lines have been partially operating since 2011. It involved building 40 stations, among other things. There is a stop every mile, and the cost structure is appealing to make the metro system widely accessible. Phase II comprises of building two additional lines in alignment with extending the two currently operating lines to connect the city's major economic zones. It is anticipated that 400,000 and more passengers are expected to travel daily by metro.

1.1. Metro Rail Transport in India

Indian Metro Rail Transport System, However, India has fallen behind, despite the fact that its first metro, the Kolkata Metro, opened for service about 25 years ago. Since such initiatives are known to need substantial financial inputs, a lengthy gestation period, and complex technology, the causes may be linked to a lack of funding. Other factors could be the absence of thorough traffic and transportation planning as well as the lack of integration between various mass transit systems. While studies indicate that the ideal modal share for public transportation should be about 70%, India's major cities only achieve a modal share of between 35% and 40%. India wants to build a world-class infrastructure using its already-existing metro systems in Delhi and Kolkata with the addition of Mumbai, Bengaluru, Chennai, Hyderabad, Lucknow, Jaipur, and Kochi metros in the next few years while Metro rail proposals for Pune, Chandigarh, Ahmadabad, Kanpur, Ludhiana, Bhopal, Indore and Faridabad are being made

1.1.1. Benefits of Metro Rail Transport in India

- *Cost Factor*
  - Metro rail projects are designed to serve cities with a population of more than four million, and their prices are tied to locations that would be served by an elevated, underground, or grade alignment. larger the elevated and underground proposal, larger costs will be incurred. Obtaining finance via the PPP model (Public-Private Partnership) is desirable as seen in Hyderabad and Mumbai or by DMRC model by the state or the central government as in Bangalore, Chennai and Kolkata.

- *Pros & Cons*
  - **Key Benefits:** The immediate and long-term benefits of metro rail are unmatched by any other type of transportation system.
  - **Eco-friendly:** Energy use in metros is minimal. Along with that, it lessens noise and air pollution. Facilitating fuel-saving; metros lessen carbon footprint by limiting emission of create carbon credits and greenhouse gases.
  - **Most affordable:** The passenger carrying capacity of metros is extremely high. They produce huge amounts of peak hour directions. They take up less area on the ground than other systems. They use very little energy per person, which results in lower costs for travelers without sacrificing both speed and comfort.
  - **Reduced trip time:** Using the metro cuts travel time in half. Passengers can easily reach their destination due to the close proximity of the stations. Due to metros' exclusive right-of-way, many of the drawbacks of alternative surface transportation, such recurring traffic jams and the challenge of parking, can be avoided. Additionally, the integration of the metro with additional modes of transportation like buses, trams, and cab services helps the traveler save time and money.

In addition to being an affordable mode of transportation, metro rail also reduces energy consumption, is environmentally friendly (runs on electricity, reducing air and noise pollution), prevents accidents, is space-efficient, and offers comfort with ultra-modern coaches and cutting-edge systems like automatic ticketing, sophisticated signaling systems, automatic train protection systems, and integrated security systems.

The only drawback of metros is an insignificant amount of traffic congestion on the roads during construction, which must be managed through mitigation measures. To address this issue, metros should be integrated with other systems that take into account the volume, structure, availability of space, and resources for traffic and transportation.

1.2. Transportation Problems in Bengaluru

Bangalore has numerous transportation problems, just like every other Indian metropolis. Low travel speeds, a high rate of fatal accidents, and increased vehicle pollution are primarily caused by:

- Narrow roads with heavy traffic congestion
- Little room for network expansion due to densely populated areas
- Regular traffic jams at numerous road intersections
- 75% of traffic made up of low occupancy vehicles, such as two-wheelers
- A high number of autos rikshaws
- High parking demand due to proliferation of homes and businesses.

There has long been a need for an effective rail-based system, and several studies have been done in the past. With the introduction of Namma metro a significant effort was made with private support to put into place an ELRTS system in Bengaluru.

1.3. Aim & Objective of the Study

The main objectives are:

- To evaluate the economic benefits of the Bengaluru Phase-1 Namma Metro Project
- To comprehend the project's significance towards improving Traffic and transportation problems in Bengaluru city
- To attempt Economic analysis for Phase-1 Namma metro project using Framework for Economic Appraisal based on MOHAU (Ministry of Housing & urban affairs) Appraisal Guidelines for metro rail projects that is widely used for identifying project feasibility analysis.

1.4. Overview of Bengaluru Mass Rapid Transit System (MRTS)

Namma Metro has a mix of underground, at grade, and elevated stations. There are 43 elevated stations, 8 underground stations, and 1 at-grade station among Namma Metro's 52 operational metro stations as of November 2022.

Namma Metro, also known as Bengaluru Metro, is a rapid transit system that serves the city of Bengaluru. It is divided into four phases: Phase 1, Phase 2, Phase 2a, and Phase 3. Namma Metro has four lines in total: the purple line, the green line, the yellow line, and the red line.

Phase Information	***Length in KM***			***No of Stations***		
Phase 1(2007-2017)	UG	Elevated	Total	UG	Elevated	Total
The east west corridor is named Purple Line (Purple Line) =18.10km						
The northernmost corridor is named Green Line (Green Line) =24.20km	8.79	33.51	42.3	8	32	40

Table 1: Operational Summary of Phase-1 Bengaluru Metro
Note: UG-Underground, Source: Namma Metro Bengaluru

Section	**Phase**	**Length (km)**	**Terminal stations**	
Reach 1 (east)	1	6.7	Baiyappanahalli	M G Road
Reach 2 (west)	1	6.4	Mysuru Road	Magadi Road
Underground UG1 (east–west)	1	4.8	Mahatma Gandhi Road	Magadi Road
Reach 3 (north)	1	5.1	Sampige Road	Yeshwanthpura
Reach 3A (north)	1	4.8	Yeshwanthpura	Peenya Industry
Reach 3B (north)	1	2.5	Peenya Industry	Nagasandra
Underground UG2 (north–south)	1	4	Sampige Road	National College
Reach 4/4A (south)	1	6.4	National College	Yelachenahalli

Table 2: Namma Metro, Section details and Opening Stage, Source: Namma Metro Bengaluru

II. LITERATURE REVIEW

The authors [6], carried out study on “Social Cost-Benefit Analysis of Delhi Metro”, while studying the purpose of social benefit, The purpose of the analysis was to determine the financial benefits of each project, an approach for making decisions in light of shadow prices because initiatives affect people's savings and investments, and the impact of development on revenue sharing in society. Furthermore, it is critical to consider how specific factors such as employment and self-sufficiency will be achieved if the strategy is implemented. The identification of the advantages and the affected economic agents is required for the Metro's social cost-benefit analysis. By comparing Delhi's economy with and without the Metro, one can estimate the incremental changes in the earnings of various economic agents such as passengers, transporters, the public and government, and unskilled labour.

The author [11], while carrying out study on “Toward Sustainable Mobility in Urban India”, focuses on how India's rapidly increasing number of personal motor vehicles is causing increased congestion and deteriorating air quality. The previous study, conducted in 2005, paid little attention to remedial measures, with overpasses and new roadway capacity being the primary focus. At the time, only Delhi, Calcutta, and Chennai had operational metro rail systems. However, only a year and a half later, in the second half of 2006, the situation had changed dramatically, and public transportation had become the focus of attention in the majority of large and medium-sized cities. The study investigates the national initiatives that aided in these changes. Adoption of a national urban transportation policy, as well as the launch of a significant financial national urban renewal mission.

The authors [16], while carrying out the study on Delhi Metro “An Investigation of Financial Analysis of Delhi Metro & Factors Influencing Ridership” has highlighted on Factor analysis, that is a statistical technique which reduces data and simplifies the co-relationships between continuous variables. The study focuses on analysing the various costs and benefits associated with Delhi Metro, the factors contributing to an increase in Delhi Metro ridership, and the various commuter profiles. Principal components analysis is used to extract data, which aids in determining the factor underlying the relationship between variables. Overall, the Delhi metro has proven to be a profitable investment.

The authors [19], in their study carried out research on “Economic Analysis of Hyderabad Metro Rail Project”, and They have made recommendations on how Policymakers have recently recognised the importance of conducting a Cost-Benefit Analysis (CBA) and the necessity of using CBA in evaluating the feasibility of a public transportation project. As a result, they use a choice experiment approach to implement CBA in a new project called the Osaka Monorail Station Line Extension. The benefit-cost ratio is estimated to be 1.87 in a basic scenario. A number of sensitivity analyses are also performed with various types of future uncertainty in mind. According to the findings of sensitivity analyses, the possibility of generating net benefit for the project under consideration is extremely high.

The authors [22], while studying on “Social Cost Benefit Analysis of Pune Metro”, proposes a social benefits analysis and other benefits of using the metro, which results in a reduction in road accidents, air pollution, and travel time for those who use Pune roads and metro. The Pune public will benefit significantly from the introduction of the Metro service, including socioeconomic benefits.

This paper attempts to comprehend the technical aspects and economic significance of Bengaluru metro rail transport system as successful joint venture of Government of India and the State Government of Karnataka project,with the help of the city's transportation and traffic conditions.

III. METHODOLOGY

The research methodology is carried out to identify some of the important factors that can be used for analysis of socio-economic benefits arising from the metro transportation system

3.1. Project Horizon

The analysis period of the project is taken as 33 years from the base year 2020-21 as follows:

- Base Year – 2020-21
- Construction period – 2007-17
- Project opening for traffic – 2017
- No. of operating years, considered for economic analysis – 30 years

Thus, 30 years of operation, in effect, from the start of operation i.e., 2017-18 has been considered for economic evaluation for the project.

3.1.1. Population Growth Traffic and Transportation in Namma Metro-Phase-1

Bengaluru, is one of the fastest growing cities in the world with metro area population is 13.193 million as reported in 2022. Bengaluru is the third most populated city of India and the hub of "new economy". It needs to address the challenges of urbanization and population growth. Public health, urban efficiency, and economic attractiveness are all significantly impacted by the increasing traffic congestion on road networks and excessive air pollution.

3.1.2. Population Growth

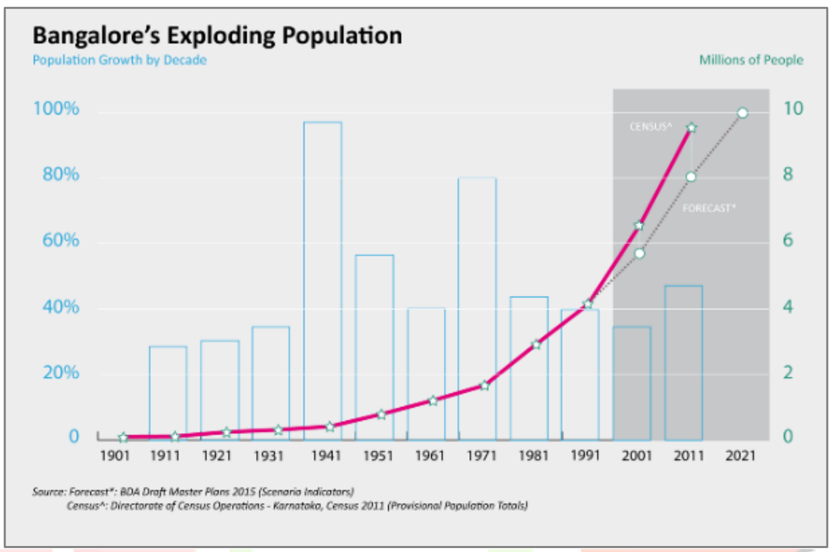

Figure 1: Population Growth of Bangalore
Source: Evolution of Bangalore, cargocollective.com

The current metro area population of Bangalore in 2022 is 13,193,000, a 3.35% increase from 2021. Bangalore's metro area population in 2021 was 12,765,000, a 3.55% increase from 2020. Bangalore's metro area population in 2020 was 12,327,000, a 3.74% increase from 2019. Much of the population growth in Bangalore is due to migration from other states, which has increased tension between locals and immigrants. Bangalore also has a very skewed female-male gender ratio 908 women for every 1,000 men

3.1.3. Motor Vehicle Growth

The city has witnessed tremendous population growth in the last two decades, as per census of India 2022, the population of Bangalore urban agglomeration was 13crores growing at the rate of 3.35%,

The rapid growth of city and the associated urban sprawl has accentuated the demand supply amidst limited connectivity. Of transport infrastructure resulting in economic and social externalities the state capital has seen in 10 years, the number of vehicles increased exponentially,

In 2011-12, a total of 41.56 lakh vehicles were registered. Cut to 10 years later: as per November 2021 data, the number of vehicles in Bengaluru has crossed one crore – 1,00,44, 491.When it comes to private vehicles, the number of two-wheelers jumped from 28.67 lakh to 66.97 lakh, During the same 10-year period, car registrations rose from 8 lakh to 20.94 lakh. The public mode share in the city is only 10% approximately 94% of the city registered vehicles are privately owned

Registered vehicles and their forecast in Bangalore

Type of vehicle	2000	2010	2020	2030
Two wheelers	1067430	2951520	4835610	6719700
Three wheelers	61424	115401	169378	223355
Cars	201052	697745	1194438	1691131
Jeeps	6827	9104	11381	13658
Taxi	6299	32818	59337	85856
Buses	20656	35723	50790	65857
Trucks	41887	139573	237259	334945
Tractors	6158	20555	34952	49349
Trailers	5544	12487	19430	26373
Maxi cab	4238	23153	42068	60983
Others	16542	84018	151494	218970
Total	1438057	4122097	6806137	9490177

Figure 2: Registered Vehicles and their forecast in Bangalore
Source: Dr. Manjunath N, The Effect of Urbanization on Environment In Bangalore, December, 2019

3.1.4. Road Accidents

Accident Statistics					
YEAR	**Fatal**	**Killed**	**Non-Fatal**	**Injured**	**Total**
2007	957		7469		8426
2008	864		6908		7772
2009	737		6138		6875
2010	816		5667		6483
2011	727	757	5297	4976	6024
2012	740	760	4767	4471	5502
2013	737	771	4493	4289	5230
2014	711	737	4293	4096	5004
2015	714	740	4114	4047	4828
2016	754	793	6752	4193	7506
2017	609	642	4455	4256	5064
2018	661	684	3950	4133	4611
2019	744	766	3944	4253	4688
2020	622	647	2,614	2,760	3,236
2021	618	651	2593	2828	3211
2022(Sep)	562	577	2,245	2,392	2,807

Table 3: Reduction in the number of people killed, injured, and vehicles damaged year wise, Above data shows the number of fatal and non-fatal cases reported persons killed & injured from the year 2007 -2019 & 2011 to 2022 September in Bengaluru city
Source: Bengaluru Traffic Police

Since the metro became operational between MG Road and Mysore Road and from Sampige to Nagasandra, of Metro Phase-1, The study shows there has been a 30-percent fall in the number of Accidents and Drunken driving cases where the metro traverses. This shows positive sign and further Namma Metro should also start late night services to help those working late to take the Metro home as it is a safe and fast mode of city transport. The introduction of the Metro system is anticipated to decrease accident rates. Any decrease in the number of accidents will result in savings from car damage as well as savings for those injured in accidents in terms of medical and insurance costs. The savings from accidents avoided as a result of the introduction of the Metro network came to Rs. 78 crores in 2007 (As per BMRCL-DPR-2003).

3.2. Funding pattern of Bangalore Metro – Phase I

The BMRCL is a Special Purpose Vehicle entrusted with the responsibility of implementing the Bangalore Metro Rail project. The primary source of income of the Bengaluru Metro is the fare collection by travelers. However, with higher fares, the ridership is expected to decline given that the willingness of passengers to travel by Metro depends on the value they place on time savings, frequency and safety of service, comfort and ease of travel, capacity to pay.

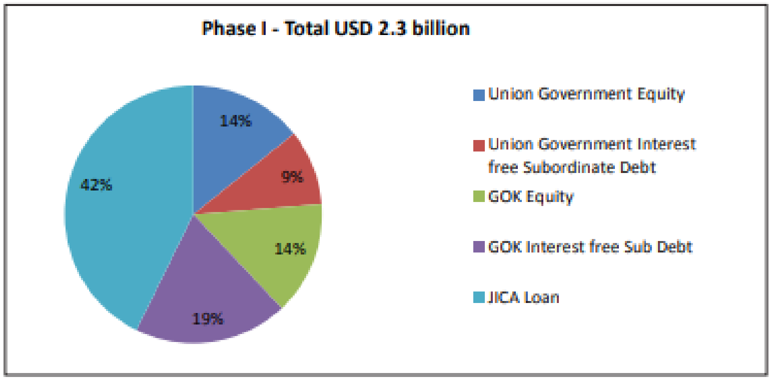

Figure 3: Mode of Finance
Source: Pg 67, Annexure 4,1. Bangalore Metro, PROMOTING LOW CARBON TRANSPORT IN INDIA Case Study of Metro Rails in Indian Cities

The Central and State Governments contributed 58.91% of the total cost. The remaining 41.09% was funded by loans from domestic and international financial institutions. BMRCL obtained 6,500 crore (US$810 million) in long-term loans and 300 crore (US$38 million) in bonds, with the remainder funded by the Central Government and the State Government. BMRCL received loans from several agencies, including the Japan International Cooperation Agency (JICA) for 3,000 crore (US$380 million), the Housing and Urban Development Corporation Limited (HUDCO) for 600 crore (US$75 million), the Asian Development Bank (ADB) for 25 crore (US$3.1 million), and the French Development Agency for the rest. The BMRCL was required to pay interest on approximately 10% of the 6500 crore each year. According to the Federation of Karnataka Chambers of Commerce and Industry (FKCCI), this amounted to a daily interest payment of 2 crore (US$250,000). BMRCL stated that interest component wasn't that high but it was "definitely more than ₹1 crore (US$130,000) per day".
Phase-I of the Bangalore Metro was intended to be finished by 2011 but the entire phase 1 of the metro was to be completed in 2017.The project cost for Phase I was increased by the Karnataka government from Rs. 8,158 crores to Rs. 11,609 crore and then again to Rs. 13,845 crores.

3.3. Bengaluru Metro Ridership Trend

The following table shows annual ridership and farebox revenue of Namma Metro since its inception.

Year	Passengers	Fare Box Revenue (Rs.)
2011–12	4,166,000	6.17 Crore
2012–13	6,636,000	8.70 Crore
2013–14	7,255,000	9.86 Crore
2014–15	11,400,000	17.83 Crore
2015–16	16,800,000	28.29 Crore
2016–17	54,225,130	110.09 Crore
2017–18	109,206,905	281.00 Crore
2018–19	133,738,555	355.02 Crore
2019-20	174,219,000	376.88 Crore

Table 4: annual ridership and farebox revenue of Namma Metro
Source: Namma Metro Ridership

Note: Ridership on selected routes of Phase-1 is approximately 4.2lakhs to 4.5lakhs per day spread across 42.3km consisting of 40 station, For the purpose of evaluation, 4.35lakhs passenger /day is considered

3.4. Traffic Demand Forecast & Air Pollution

3.4.1. Traffic Demand

Traffic and Transportation Study has been carried out to analyse the traffic volume and assesses the variation of traffic level, composition, growth rate and forecasts the future traffic for the selected corridor.

3.4.2. Air Pollution

- Air Pollution, the study shows there is considerable improvement in Air Quality along Phase-1 Corridor and most of the places have moderate impact of pollution on people.
- It has been noted that, except from SO2 concentrations, all other pollutants are trending upward.
- The values were often above the allowed limits, with the exception of one or two intersections.
- In numerous locations, the levels of nitrogen oxides were extremely high but few intersections show positive level by reducing the pollution level in these locations

• Other intersections also recorded NOX values showing a high pollution trend during from the time of inception of metro but there is significant reduction at certain locations due to improved connectivity of metro.

IV. ECONOMIC BENEFIT EVALUATION OF BENGALURU METRO PHASE-1

Bangalore's Metro System will significantly reduce the number of buses, the use of private vehicles, air pollution, and the speed of road-based vehicles. The subsequent decrease in fuel use, vehicle operating costs, and passenger journey times will have significant social advantages. Other advantages to society as a whole include decreases in accidents and air pollution. The project's economic study was done utilizing the social cost-benefit analysis method. A framework of scenarios "with" and "without" the project has been taken into consideration. The "with" the project scenario accounts for the expected total costs that would be placed on the local economy.

The "without" the project scenario imagines a future in which the existing infrastructure is still used, but with higher anticipated expenditures because of increased projected traffic.

The advantages that result from project implementation are calculated and taken into consideration, including reductions in vehicle operating costs due to decreased congestion, time savings for passengers, decreased pollution, and fuel usage.

The cost and benefit streams resulting from the aforementioned circumstances have been calculated as economic values by converting the former using the proper shadow pricing. This has been done to eliminate externality-related distortions and anomalies that can occur in real-world pricing systems. In order to do the economic analysis, a number of assumptions were made in reference to Reports of BMRCL-DPR-2003 and BMRCL-DPR-2A of Bangalore Metro, Volume-1,2019

4.1. Framework for Economic Analysis by MOHUA

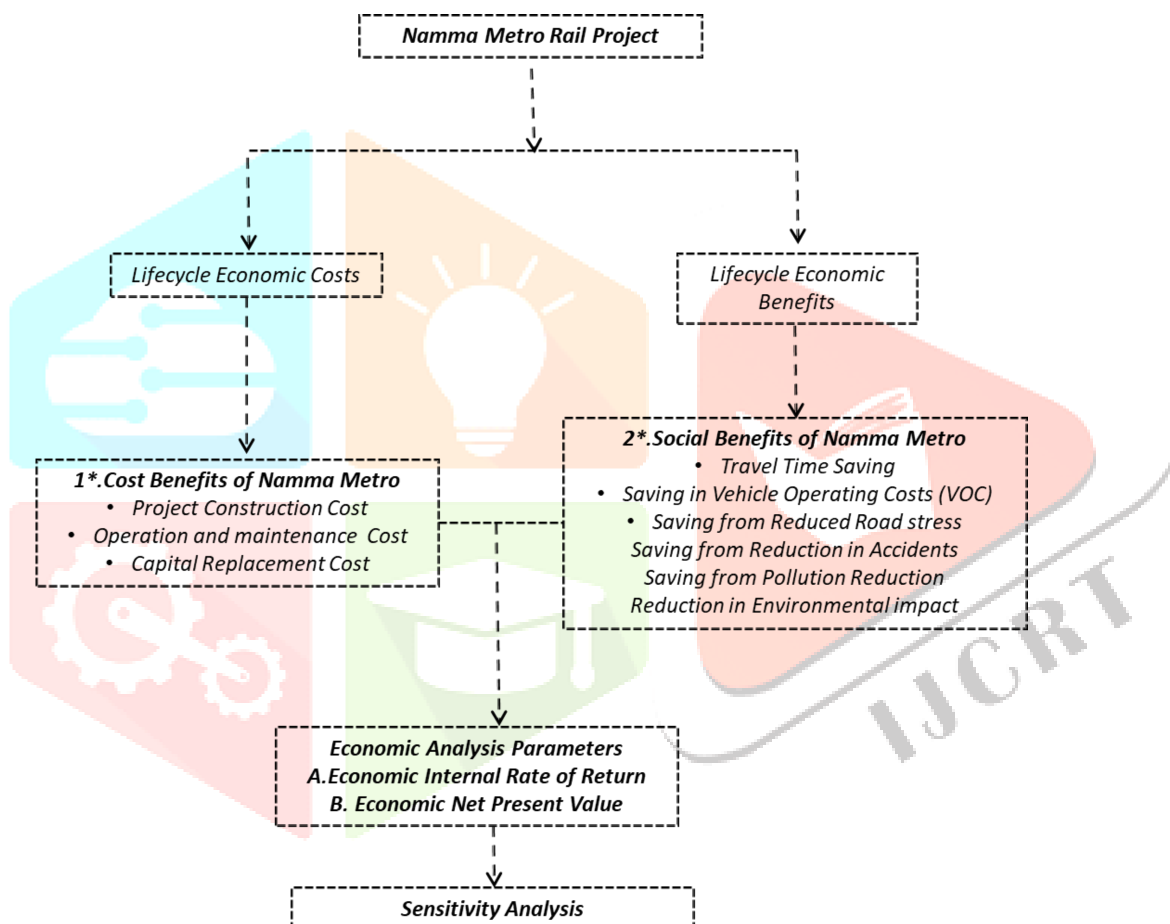

Figure 4: Framework of CBA of Bengaluru Metro Project established based on Framework for Economic Analysis MOHAU

Source: Appraisal Guidelines for Metro Rail Project Proposals, Ministry of Housing and Urban Affairs GoI"

*Note: **1*:** Conversion of Financial Cost to Economic Cost by excluding taxes, subsides, interest payments etc. and considering only actual prices.*

***2*:** Benefits derived by comparing user benefits in with project and without project scenarios*

A: **Economic Internal Rate of Return and Sensitivity Analysis** is not projected in this paper due to lack of information on exact Cost Components, hence Economic Analysis is evaluated based on Appraisal Guidelines and cost figures projected by BMRCL is considered for the purpose of calculation.*

The benefits that the metro projects provide are more important from the government's economic and social point of view compared to the financial benefits that accrue from implementing the project. The proposed system will provide a variety of benefits to the city and society, viz. savings in fuel consumption, vehicle operating costs, travel time, reduction in road accidents and air pollution etc. These economic benefits would overweigh the financial benefits and hence assessing the same would also be of more significance

The economic analysis for Phase-1 Line has been carried out within the broad framework of EIRR (Economic Internal Rate of Return) based on Appraisal Guidelines for metro rail projects taken from website of Ministry of Housing & urban affairs

4.2. Approach for Economic Analysis

The approach adopted for carrying out the Economic Assessment of the Project is as shown below

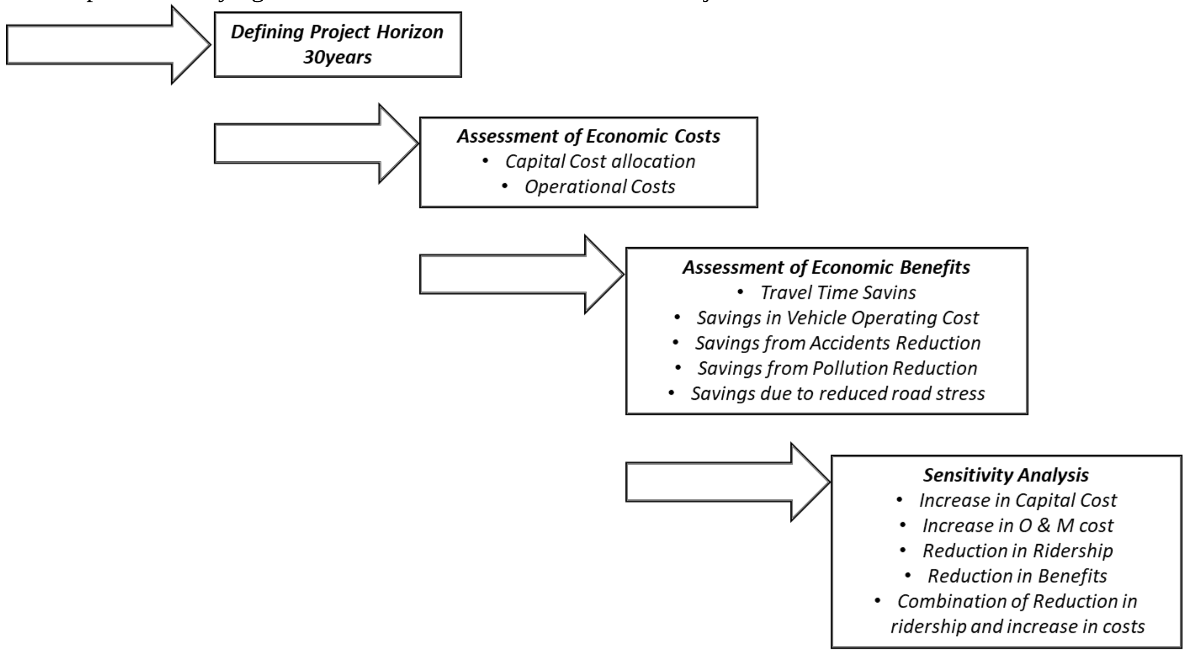

Figure 5: Approach for Economic Analysis established based on Framework for Economic Analysis MOHAU
Source: Appraisal Guidelines for Metro Rail Project Proposals, Ministry of Housing and Urban Affairs GoI"

• Project horizon comprises of the construction and operation period of the metro rail project. During the project horizon, the cost and benefits associated with project are estimated. The horizon period for the purpose of economic analysis is taken as 33 years including three years of Construction Period.
• Economic Cost comprises of Capital Expenditures incurred during the Construction period and the Operation & Maintenance cost during the Project Operation period.
• Economic Benefits - Year wise project benefits are estimated during the project operation period. The "Most Likely" scenario is compared with the other factors through Sensitivity assessment
• Sensitivity Analysis is undertaken within the range of 5% to 15% of the critical factors which impacts the Economic Assessment.

4.3. Assessment of Economic Benefits

The following parameters are considered for evaluating the economic benefits from this proposed metro
Modal shift from current options to proposed metro line;
• Fuel saved by the passengers by using the public transport;
• Savings in Operating cost of the Private vehicles;
• Reduced time in travel on increasing the schedules and modal shift;
• Reduction in number of fatal accidents and injuries;
• Reduction in traffic congestion;
• Reduction in Road Infrastructure maintenance cost.

The Economic benefits have been estimated based on Passengers shifting to the metro from other modes of transportation
The expected daily trips for the year 2021-22 along Phase-1 Metro line in operation is approx. 4.35lakhs to 4.5 lakhs which is expected to grow at 4.18% p.a for the year 2024 to 2030, 2.64% p.a for the year 2031 to 2040 and 2.18% p.a for the year 2041 onwards. Interpolating the above modal share for the proposed daily trips in the metro would provide the daily trips saved by other modes

The modal shift that is expected from the various modes using road transport to the metro as mentioned in this DPR is also presented below.

Modes	Total Daily Trips in by various modes Bengaluru urban area		Modal shift pattern to Metro from existing mode
Cars & Taxis	7.0%	7,71,140	20%
Two wheelers	34.5%	38,09,052	30%
Three wheelers/Auto	8.9%	9,86,648	10%
Bus	49.5%	54,65,250	40%
Total	**100%**	**1,10,32,090**	**100%**

Table 5: Daily Trips by various modes & Modal shift pattern to Metro from existing mode
Source: BMRCL-DPR-2A of Bangalore Metro, Volume-1,2019, S. No 4, Table 19.26 Modal share for the passenger trips 2021 phase I & II & S. No 5 the modal shift of the passenger trips for different modes of transport

4.4. Economic Cost- benefit Analysis

With reference to Appraisal guidelines MOHAU and 'Economic Analysis of Hyderabad Metro Rail Project' Economic Cost Benefit Analysis is carried out for the purpose of evaluation.

Note: Cost-benefit analysis is the process Comparing expected or estimated costs and benefits (or opportunities) connected with a project choice in order to assess if it makes sense from a business perspective Cost benefit analysis is carried out.

Cost-Benefit Analysis (CBA) is a tool for comparing alternate projects by reference to net social benefits that they produce for the community as a whole. The term 'net social benefit' refers to the difference between social benefits and social costs. Benefits and costs are 'social' i.e., They are not restricted to specific market transactions; they are measured to whom they accrue. Thus, they are identified on a more comprehensive basis than private sector evaluations. Here cost-benefit analysis proceeds by estimating hypothetical values that reflect real economic values. Therefore, there values are measured as direct and indirect values.

4.4.1. Modal shift pattern to Metro from existing Ridership

The modal shift that is expected from the various modes using road transport to the metro as per Table 5. and current ridership is approx. 4.35lakhs is considered for the purpose of Evaluation traffic for Phase-1 corridor line is presented below.

Modal Shift to Metro		
Category of Vehicles	**Average Traffic**	**Percentage**
Cars & Taxis	30450	20%
Two wheelers	139200	30%
Three wheelers/Auto	52200	10%
Buses	213150	40%
Total	**4,35,000**	**100%**

Table 6: Peak Hour Trip Mode of shifting of commuters from road–based transportation to Namma Metro Bengaluru
Source: Ridership trend Namma Metro

the total trips that are made along the Phase-1 metro corridor without metro could be estimated and the total number of vehicles that could possibly be off the road after metro could be estimated

Mode	**Total Daily Trips in by Various modes along Phase-1 Corridor [*1] (A)**	**Modal shift to the proposed Metro line (B)**	**Daily Trips saved due to Metro (C)**	**Total Daily Trips without Metro along the proposed corridor D=(C/B)**	**Occupancy factor (E)**	**Total number of vehicles F=(A/E)**	**Total number of vehicles off the road G =(C/E)**	**Total number of vehicles on road with metro H=(F-G)**	**Average distance travelled in km (I)**	**Vehicle kms saved Daily J=(G*I)**
Cars & Taxis	7,71,140	30%	30,450	101500	2.9	265910	10500	255410	13	136500
Two-wheeler + Auto	47,95,700	30%	1,91,400	638000	1.5	3197133	127600	3069533	8	1020800
Buses	54,65,250	40%	2,13,150	532875	37	147709	5761	141949	10.7	61641
	1,10,32,090	**100%**	**4,35,000**	**12,72,375**		**36,10,753**	**1,43,861**	**34,66,892**		**12,18,941**

Table 7: Total number of vehicles and vehicle Km saved due to Metro

Source: BMRCL-DPR-2A of Bangalore Metro, Volume-1,2019, S. No 4, Table 19.26 Modal share for the passenger trips 2021 phase I & II & S. No 5 the modal shift of the passenger trips for different modes of transport

4.3. Lifecycle Economic Cost Analysis of Namma Metro

S.No.	Total Direct (Construction cost)	Cost Benefits
i	**Savings in Capital and Operating Cost of Diverted vehicles** The following are the estimated costs of Metro Rail Construction and Operating Cost Reduction in the capital and operating cost of vehicles due to the introduction of the Namma Metro is given by the product of the diverted traffic stream, the annual run and the VOC/V-km	**Rs 609.10 crores**
ii	**Savings in fuel consumption** Value of fuel saving due to shift to metro from conventional transportation mode	**Rs. 37286.15 crores**
	Indirect Cost-Benefits	
iii	**Environmental Cost** According to BMRCL, many the number of trees were removed and equally & more than double were translocated, transplanted	Cost of loss of trees and environmental monitoring required to be evaluated.
iv	**Social disturbance costs and Severance costs** Construction of various proposed structures for the Metro will lead to displacement of business and households, who lose their properties who need to be compensated at a premium (As per information of 35% over cost of property) for livelihoods loss and attachment to land. Construction of structures is also going to form a divide that leads to discontinuity and extra effort (to cover extra distance and take more time) is required to overcome it.	The Estimated Social Disturbance Costs and Severance cost are not evaluated after completion of Phase-1 as per information provided by the BMRCL officials

Table 8: Cost benefit--Direct & Indirect benefits based on Appraisal guidelines MOHAU

4.4. Lifecycle Economic Benefits Analysis of Namma Metro

S. No	Direct Benefits	Social benefits
i	**Rail User Time Benefits** The Value of travel time savings depends upon time savings per rail passenger per trip, number of total trips and monetary value of travel time. The average Value of time savings was Rs 55.5 each rail trip, with an estimated average time savings of 15 minutes and Per Capita Income Per Hour 120 per hour.	**Rs.591.30 crores**
ii	**Rail User Comfort Benefits** Due to improved rail travel comfort, the distance of about 15 kms was covered in flat 30 minutes at a cost of Rs 32 (one way) which otherwise would take at least 60 minutes by Uber at 6 times cost and 90 mins by BMTC. Stations can be equipped with commuter amenities such as coffee shops and quick-service restaurants. Free wi-fi is an option both at stations and on trains.Once the entire planned length is completed and operational, Metro will be the 1st choice of commuters.	
	Indirect Benefits	
iii	**Saving of Time** With an average time, savings of 15 mins per minute per vehicle and annual benefits of roughly estimated. Construction of Rows' will increase average speed from 25 to 45 kmph (that may increase with traffic growth). The air pollutants emission is likely to come down to a greater extent with extensive savings on consumption of fuel because of shift of commuters to metro system from other modes of vehicular traffic on outer ring road after implementation of the project.	
iv	**Reduction and Accident-Avoidance benefit** The shift of approximately 3.2 lakhs or more Passengers daily from buses, two wheelers, three wheelers and cars (currently used) to metro rail transport system will lead to significant reduction in road accidents to commuters and road users. Currently on average 4.35lakhs and more commuters are using the benefits from Metro phase-1. Based on the incidence of traffic accidents across various junctions (fatal& non-fatal) and unit cost of them under each such accident category, the accident cost was estimated. Accidents reduction due to modal shift on the corridor Phase-1-48nos estimated average cost of per accident.	Compensation Values-Saving **Rs.3.13 crores** average cost of per accident. **Rs 6,42,783/-**
v	**Reduction in Environmental impact –Flood Mitigation Benefits** The RoW of metro will lead to poor drainage and result in flooding which was estimated to cause damages to road, utilities, property, health, traffic delays and inconvenience, and drainage works to prevent to be yet estimated	The cost for Flood Mitigation Benefits is not estimated as per Information from BMRCL
vi	**Air Quality Benefits** There would be net improvement in air quality after metro (in terms of reduction in CO, NOx, HC and PM) which leads to savings in health damage costs.	**Rs.22.0crores**
vi	**Health Benefits** The most important Health problem observed by large number of people daily commuting in traffic faced back pain compared to neck or leg pain, this is due to sitting for long hours in a vehicle while stuck at traffic Body pain was also not affected by the mode of transportation; people who travelled by bus, two-wheeler, auto rickshaw, or metro had similar pain to people who travelled by four-wheeler, prolonged exposure to air pollution thereby increasing their risk of developing respiratory tract infection	Due to shift to metro, there were significant improvement among daily commuters and hence Health benefits were appraised

Table 9: Social benefits of Metro Rail Project-Direct & Indirect benefits based on Appraisal guidelines MOHAU

4.6. Summary Of Economic Cost Evaluation of Phase -1 Namma Metro

Based on the information from BMRCL, the following table summarizes the economic costs and benefits measured from Bengaluru Metro rail system for Phase 1 using CBA framework and their relative share.

Metro Cost	Amount (Crores)	Percentage	Remarks
Construction Cost	13,845	66%	Cumulative expenditure up to January 2017 was Rs 14,291.20 crore.)
Rolling stock	1672.5	8%	BMRC procured 150 metro coaches for fifty 3-car train sets in DMC-TC-DMC formation for Phase l of Namma Metro from BEML - Hyundai Rotem at a cost Rs 16.72 billion (Source: Namma Metro)
Operating Cost	3,359.66	16%	The annual O&M cost per RKM is ***about Rs 3.75 Cr*** (including energy cost)
Annual ridership	17.422	0.10%	During 2019–20, the annual ridership was 174.22 million (average during the year was thus 477,315).
Land acquisition	2,163	10%	As per BMRCL official, it was estimated that land acquisition would cost ₹2,100 crore
Construction Congestion	49.32	0.23%	Bengaluru's congestion cost is estimated at $6 billion per year. (Source: www.adb.org)
Total	**21,058**	**100**	

Table 10: Summary of Economic costs of Bengaluru Metro
Source: BMRCL, Namma metro

Financing Costs: Interest expense on loans drawn for this project-43% of construction costs are financed through debt
Note: Phase 1 missed nine deadlines, and its cost was revised four times. The initial cost estimate for Phase 1 when it had been approved in 2006 was ₹6,395 crore. The increase in length from 33 to 42.3 km increased the total cost to ₹8,158 crore. Delays caused further escalations. The cost escalated to ₹11,609 crore in 2011 and ₹13,845 crore in 2015. The final cost to build Phase 1 was estimated at ₹14,405.01 crore.

4.7. Summary Of Economic Cost Benefits of Namma Metro Phase-1

S. No.	Metro Benefits	Savings		Percentage
1	**Reduction in Vehicles Due to Metro (Phases I)**			
i	Mode of shifting of commuters from road–based transportation to Namma Metro -Daily Trips saved due to Metro	4,35,000	Nos	
ii	Total number of vehicles on road with metro along Phase-1 Metro corridor approximately	34,66,892	Nos.	
iii	Total number of vehicles and vehicle Km saved due to Metro	1218941	Nos.	
2	**Time saving for passengers**			
i	Annual Passenger Time Savings	39150000	Hrs.	
ii	**Total Value of Time Savings** Mode of shifting of commuters from road–based transportation to Namma Metro with current average ridership of 4.35lakhs on avg Time saving for passengers travelling by metro in 15mins Per Capita Income Per Hour Rs.120/hr (2020-2024)	**591.30**	crores	1.54%
3	**Reduction in Vehicle Operating Costs**			
i	Savings in Vehicle Operating Cost by modal shift passengers	250.6	crores	
ii	Savings in Vehicle Operating Cost from other mode	358.5	crores	
iii	Savings on account of Vehicle Operating Cost	**609.1**	crores	1.6%
4	**Savings in fuel consumption**			
i	Value of fuel savings	**37286.15**	crores	96.8%
5	**Reduction in Accidents:**			
i	Accidents reduction due to modal shift on the corridor Phase-1	48	Nos.	
ii	Compensation Values-Saving	**3.13**	crores	0.008%
6	**Reduction in Air pollution:**			
i	Average Cost saved per ton of emissions	**22.00**	crores	0.06%
7	**Economic Benefit due to Reduction in Road Infrastructure Maintenance Cost**			
ii	Reduction in Road Infrastructure Maintenance Cost	**1.42**	crores	0.004%
Total		**38,513.1**	**Crores**	**100%**

Table 11: Summary of Economic-Cost Benefits of Namma metro Phase-1

Benefit-Cost Ratio Formula = $\frac{\textbf{PV of Benefit Expected from the Project}}{\textbf{PV of the Cost of the Project}} = \frac{\textbf{38,513.1}}{\textbf{21,058}} = \textbf{1.82}$

Note: PV is present value
It can be concluded that the economic benefits of Bengaluru metro rail project outweigh the economic costs. The Cost benefit ratio of 1.82 of the projects indicates that benefits are marginally higher than costs.

VI. CONCLUSIONS

The benefits incurred from the implementation of Metro project provide more important from the government's economic and social perspective, the benefits that the metro projects provide are more significant than the financial benefits that result from the project's implementation. The planned system will help the city and society in a number of ways, including saving of fuel, reduction in travel time, vehicle operating costs, road accidents, and air pollution, etc. The financial benefits would be outweighed by these economic benefits, making it more important to evaluate them.

The implementation of Namma Metro Phase-1 has significantly improved socio-economic benefits to the society particularly that within the corridor's influence zone, including

- Providing safe public mass transit that is reliable, inexpensive, and environmentally sustainable transit systems for Bengaluru city, which will enhance mobility and benefit approximately 4.6lakhs commuters daily and support efforts for planned urban development in Bengaluru.
- Bring the roads back to the community for the social and economic development of the zone.
- Results in a higher percentage of public transportation being used to meet the city's mobility demands.
- lead to an increase in the city's economic productivity and, as a result, help to create more jobs.

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