Social Cost-Benefit Analysis of Mass Transport System A Case of Namma Metro Phase-1, Bengaluru

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***Abstract*: A sustainable transportation system is critical because it is characterized by continuous urbanization, The growing demand for sustainable transport system has impact on Urbanization and its ecosystems due to atmospheric pollution from and on its built environment. A public transit system that offers reliable connections to the main activity areas is also necessary for a sustainable transportation system, with alternative modes of transportation, which results in the use of environmentally friendly fuels and land use patterns. Metro provides numerous benefits, including reduction in air pollution, time saving to passengers, reduced accidents, reduction in traffic congestion, and fuel savings. There are incremental benefits and costs to a variety of economic representatives, including the government, private transportation companies, passengers and the general public.**

The study attempts to investigate on the social cost and social benefits of the Namma Metro to enumerate all benefits and socio-economic aspects of the project from Phase- I covering a total distance of 42 Km in Bengaluru city.

The project discusses on the benefits that is recognized by use of metro in lieu of usage of personal vehicle and time required to reach their destination, as well as level of congestion will be undertaken for study hence, social cost benefit analysis of Bangalore Metro will be evaluated.

Key words: Public Transport, Air Pollution, Social- Cost Benefit Analysis (SCBA).

I. INTRODUCTION

Bengaluru is one of the fastest growing cities in the world with metro area population is 13.193Million 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.

Bangalore Metro Rail Corporation (BMRC), the contracting authority, is 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 stations

BMRC 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. Transports in Bengaluru

Bengaluru metropolitan area covers 137 zones of the City Corporation area and the remaining 22 Zones are in Urban Municipalities covering an area of about 531 sq.km. According to the 2001 Census, Bengaluru has a population of 5.67 million, of which the population of the city Municipal Corporation is 4.5 million. Bengaluru currently has a more than 1.6 million cars have been registered, of which 1.2 million are two-wheelers, accounting for 75% of all vehicles. The entire car the population is growing at a 10% annual rate, whereas two-wheelers alone are growing at a 17% annual rate.

The primary form of public transportation in Bengaluru is the BMTC (Bengaluru Metropolitan Transport Corporation) bus. A total of 2450 buses in the BMTC fleet carry roughly 22.28 lakh passengers daily, while another 1.65 million passengers are transported by other buses (such as factory buses and rented buses). Auto-rickshaws are the other important form of public transportation, with 2.2 lakh trips each day.

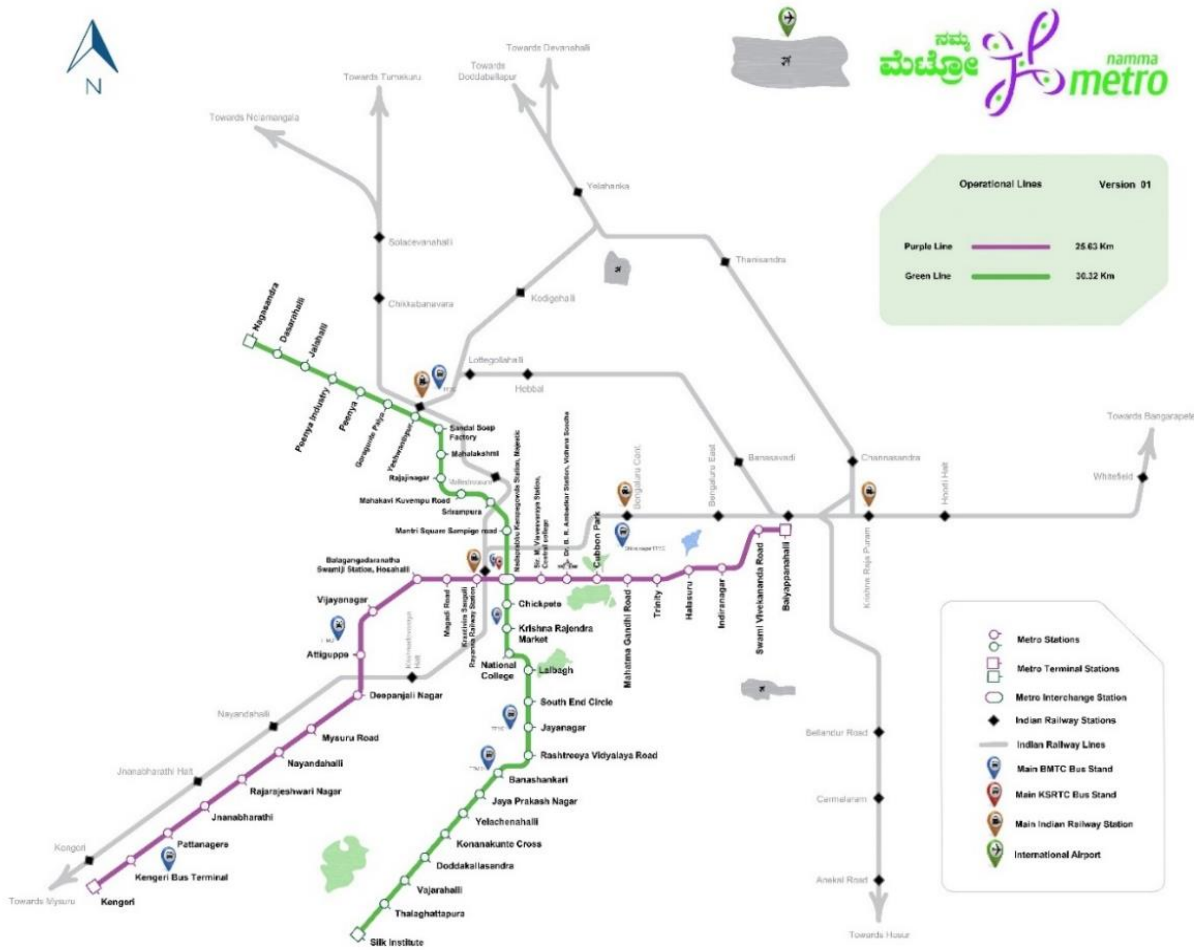

Figure 1: Schematic-route-map of Phase 1-Purple & Green Line Namma Metro
Source: Namma Metro, 'https://english.bmrc.co.in/#/schematic-route-map'

1.2. Aim & Objective of the Study

Bengaluru's rapid growth and the need to address the city's mounting traffic issues, alternate transportation networks are increasing to solve the ever-growing congestion problem.

The main objectives are:

- To evaluate the social cost benefits of the project pertaining to Bengaluru metro Phase-1
- To measure numerous benefits such as time saving to passengers, fuel savings, reduced accidents and improved environment by reducing traffic pollution and congestion.
- To understand importance of the project from transport and traffic conditions in the city and the socio-economic analysis of Bengaluru metro project towards meeting objectives.

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

Namma Metro, also known as Bengaluru Metro, is a rapid transit system serving the city of Bengaluru, 'has 4 phases - Phase 1, Phase 2, Phase 2a, and Phase 3. Namma Metro includes 4lines in total being the purple line, green line, 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, Source: Namma Metro

Line-1	
Purple line	Baiyyappanahalli – Mysore Road
Length	18.10 km
Depot	Baiyappanahalli
Type	Elevated & Underground (4.8 km)
Number of Stations	17
Station Names:	Mysore Road, Deepanjali Nagar, Attiguppe, Vijayanagar, Hosahalli, Magadi Road, City Railway Station, Majestic, Sir M Visveswaraya, Vidhana Soudha, Cubbon Park, MG Road, Trinity, Halasuru, Indiranagar, Swami Vivekananda Road and Baiyappanahalli
Line-2	
Green line	Nagasandra – Yelachenahalli
Length	24.20 km
Depot	Peenya
Type	Elevated & Underground (4 km)
Number of Stations	24
Stations Names	Nagasandra, Dasarahalli, Jalahalli, Peenya Industry, Peenya, Goraguntepalya, Yeshwanthpur, Sandal Soap Factory, Mahalaxmi, Rajajinagar, Kuvempu Road, Srirampura, Sampige Road, Majestic, Chickpet, KR Market, National College, Lalbagh, Southend Circle, Jayanagar, Yelachenahalli (formerly Puttenahalli)

Table 2: Operational Projects Details of Phase-1 Bengaluru Metro, Source: Namma Metro

II. LITERATURE REVIEW

The authors[2], in their study have caried out research on “Toward Sustainable Mobility in Urban India” and they have come out with the suggestions that focuses on how the rapid increase in the number of personal motor vehicles in India are experiencing increased congestion and deteriorating air quality. The previous study done in 2005 has paid liitle attention with remedial measures focusing primarily on overpasses and new roadway capacity, then Only Delhi, Calcutta, and Chennai had operational metro rail systems. However, by the second half of 2006, only a year and a half later, the situation had changed dramatically, and public transportation had become the focal point of attention in the majority of large and medium-sized cities. The study examines the national initiatives that contributed to those changes. Adoption of a national urban transportation policy, as well as the launch of a national urban renewal mission with a substantial financial commitment.

The authors [5], carried out research on “Social Cost-Benefit Analysis of Indian Railways”, the paper highlights on the understanding of scientific and systematic social cost benefit analysis of a project or its relation that is necessary to evaluate each project or concern’s advantages (benefits) and disadvantages (costs) to the society or nation as whole. To be more specific, external economies and diseconomies are social benefits and costs, respectively. Economists define externalities as spillover effects, third-party effects, etc. The scientific understanding on positive and negative impact that arises externally whenever an organization’s activities have a negative or positive impact on the environmental for which the organisation is not held accountable. If the impact is positive, it is called an external economy or social benefit if the impact is negative, it is external diseconomy or social costs.

The authors[7], have caried out study on “The Planning and Development of a New Metro System: The Case of The Dubai Metro”, while studying they have suggested the main theme of analyzing the appropriateness of building a new metro system to solve the current transport problems in Dubai.thye also focuses on the strategic decisions to improve infrastructure support in Dubai, including the a massive network and construction of the Dubai Metro,. The factors which affect the government policies and planning decision of building Dubai Metro are identified.The comparitve studies of transport policy and planning between Dubai and Hong Kong drew some useful guidance for other cities as reference. This paper contains two major findings:The success of implementing transportation policies to address transportation issues which is dependent on the policy formulation process. It is suggested that a public consultative approach be used to better understand the needs of the community. The ultimate goal of developing transportation policies would be to benefit the community. The success of Dubai Metro in reducing traffic congestion is dependent on people changing their travel habits from private car to mass transit system.

The authors [8], while studying on Delhi Metro caried out research on "An Investigation of Financial Analysis of Delhi Metro & Factors Influencing Ridership" has focused on Factor analysis which is a statistical technique that reduces data and allows simplification of the co relational relationships between continuous variables. The study highlights upon analyzing the various cost and benefits incurred corresponding to Delhi Metro, the reasons contributing to increase in ridership of Delhi Metro and different profile of commuters. Data is extracted using Principal components analysis that helps determine the factor underlying the relationship between variables. Overall, the Delhi metro has proved a profitable venture.

The authors [9], have performed research on "Social Cost-Benefit Analysis of Delhi Metro", while carrying out the study, the paper tries to measure all the benefits of Phase I & II, the analysis was to establish the financial benefits of each project, an approach for making decision in perspective of shadow prices because initiatives impact people's savings and investments and the development's impact on the revenue sharing in society. Additionally, it is critical to consider how certain factors like employment and self-sufficiency will be achieved if the strategy is delivered. Identification of the advantages and the affected economic agents is necessary for the social cost-benefit analysis of the Metro. By comparing the economy of Delhi with and without the Metro, one may estimate the incremental changes in the earnings of different economic agents, including passengers, transporters, the public and government, and unskilled labour. The public, government, passengers, and unskilled labour all see increases in income as a result of the Metro.

The authors [10], have carried out research on "Promoting Low Carbon Transport in India Case-Study of Metro-Rails in Indian Cities" The study in detail gives the various phases of the Delhi Metro Rail project, and displays how planning helps to determine the economic, social and environmental impacts of selected transportation projects. This paper examines the costs and benefits of metro rail projects for achieving the twin goals of inclusive and sustainable development and low-carbon growth. While the current case study deals with Metro projects, the other three studies cover freight transport Bus Rapid Transit projects and non-motorized transport projects. All of the above-mentioned projects are perceived by policymakers as interventions that can contribute to sustainable development. This study is based on the premise that metro rail projects in cities are considered inevitable for efficient urban transport by many planners and policy makers, however, these projects have major implications for achieving inclusive sustainable low-carbon development goals. The focus of the study is to Analyze performance of metro rail project investments in terms of objective, ridership, revenue, and capital cost and is not whether or not to undertake the metro project, but rather clearly discuss the costs and benefits to different stakeholders.

The authors [11], in their study have carried out research on "Economic Analysis of Hyderabad Metro Rail Project", explains the significance of the Hyderabad Metro Rail Project (HMRP) in terms of enhancing traffic and transportation for the people of Hyderabad. Using the framework of "Cost Benefit Study (CBA)," which is frequently used in the conventional project feasibility analysis to broaden it to incorporate socio-economic aspects of projects, it then makes an attempt to conduct an economic analysis of the HMRP. The authors highlights that the project is beneficial according to the CBA of HMRP on the numeraire measure of Cost-Benefit ratio.

The author [12], have performed research on "Mass Urban Transportation in India: Features of Three Models and Learning", while studying they have assessed the efforts to provide mass urban urban transportation systems in three major Indian cities:

Mumbai, Delhi, and Ahmedabad and the learning and way forward for the remaining metro cities have also been predicted.He also highlights on how urbanization and urban population growth have now firmly gripped in India, and metropolitanization of cities has followed suit. It is expected that metro class cities (cities with a population of more than one million people) will have mass urban transportation systems in order to sustain their growth and function efficiently on that scale. All three modes of transportation i,e, rail, road, and water can contribute significantly to the development of an appropriate transportation system in Indian cities.

The authors [13], while carrying out study on "Social Cost Benefit Analysis of Pune Metro" proposes the social benefits analysis and other benefits by the use of metro that results in reduction of road accidents, air pollution, and travel time for those utilizing Pune roads and metro. The Pune public will gain substantially with the introduction of the Metro service such as Socio- economic benefits.

The Authors[15], in their study have caried out research on "A Critical Evaluation of Impact of Jaipur Metro on Means of Transport", the study emphasises on the increased travel demand and an inadequate transportation system in Indian Metropolitan Cities. Most of the cities s in India are experiencing a water crisis and effective mode of public transportation. Despite of road investment,infrastructure and transportation development, traffic congestion,Road traffic accidents and air pollution are on the rise. Metro Rail has been implemented to improve connectivity and give more enjoyable travel experience thereby reducing travel time, Rapid Transit system being environmentally friendly, comfortable and less expensive mode of urban transportation, the primary goal is to reduce traffic congestion by encouraging people to use public transportation. The current study is an attempt to visualize the opening and operation of Jaipur Metro and its impact on the other means of present transport system within the city. Further, the study observes the transit situation of Jaipur city and examines the significance of metro in the city.

III. METHODOLOGY

3.1. Formulating the Research

This research focuses on the data collection for the study involved two stages:

The *primary data* included data collection carried out through a questionnaire survey targeted to a select group of commuters, students and construction professionals and working people. Primary data was required to estimate the traffic on road, vehicles estimate, route analysis for selected areas, trip generation and distribution pattern, average travel cost and time, estimated ridership and public opinion.

The *secondary data* was collected from the Literature studies, Newspaper, Reports & articles to evaluate and respond to the research objectives of the study. Secondary source of information was gathered in order to understand various types of public transit, their relative benefits, and shortcomings, restrictions, and so on.

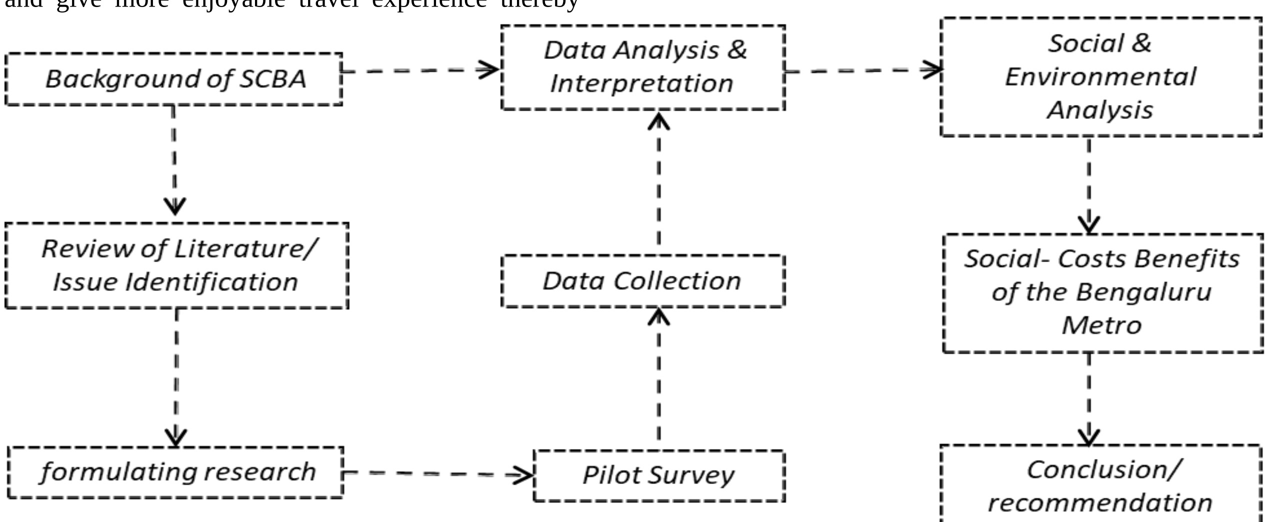

Figure 2: Methodology Process

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 and its impact on the Environment, Quality of life and time. The perspectives of client, consultants, contractors, and people associated with metro directly or indirectly regarding the relative importance of causes and consequences due to Namma metro are then evaluated to respond to research objectives.

3.2. Findings of Survey

3.2.1. Users Response Survey

The user response was carried out by the following method

a. Questionnaire: Survey for Public mode preference, views about present transport, present travel behavior, cost and distance travel, target population students and their families were information obtained is used for benefit analysis

b. Interviews: public service vehicle (PSVs)Operators survey, daily trips, ownerships and earnings.

c. Field Survey: Average Vehicle counts on Bengaluru Road and along the stretch of Phase-1(42.2km) along, different types of vehicles on road. Based on data approximately the Estimates of diverted traffic to Metro (Phase I) is considered for have been estimated based on Passengers shifting to the metro from other modes of transportation The growth rates of registered cars, two-wheelers, three wheelers, taxis and buses in Bengaluru are calculated as 7.1, 7.4, 4.6, 9.9 and 4.2 percent, respectively using data for these vehicles for the period 2007-2017.

3.2.2. Opinion Survey

The responses were received from the respondents through Questionnaire Survey that was conducted for Phase -1 Namma Metro, Service, public mode preference, views about present metro transport system, present travel behavior, cost and distance travel, time saving, parking facilities. The target population were commuters, students and professionals and working people using metro for their basic mode of transportation. Table 3 shows the Summary of Opinion Survey for Phase-1 Namma Metro

Results of the Opinion survey conducted to take opinion reason to shift to metro

S.No.	Reasons to shift to metro	Percentage	
		Pre-Metro (As per BMRCL-DPR-2003)	Post-Metro (As per opinion survey conducted in 2022)
1	Commuters are willing to shift to Metro if walking distance to the station is up to 250 meters	48%	30%
2	Commuters are ready to shift to Metro with a walking distance of 500 meters.	38.84%	36%
3	Commuters prefer only one interchange & two interchanges while the rest accept more than two interchanges.	65%-one 30%-two	51.6%-one 38.7%-two
4	Commuters are ready to shift with feeder bus services.	89%	85%
5	Commuters prefer 5-minute frequency	46.18%	65%
6	Accept frequency up to 10 minutes and rest 15 minutes.	32.16 %	30%
7	Commuters prefer monthly passes.	88%	90%
8	Commuters are willing to pay parking fee at the stations	80%	85%

Table 3: Summary of Opinion Survey for Phase-1 Namma Metro

3.2.3. Interviews

With BMRCL Construction professionals' officials, Bangalore Traffic Police, & Videonetics department, Traffic Management Centre, Karnataka Transport Department, PCB/CPCB Engineers, L&T engineers, Professionals, metro Commuters, workers, etc.; based on the information further study was social cost benefit analysis of Bangalore Metro will be evaluated.

3.2.4. Pollution & Nosie levels

Before and after construction Bengaluru metro- 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. with the introduction of the metro, there reduction of vehicles along the corridor and the noise levels have significantly reduced (by roughly 30%).

The analysis and integration of collected survey data (both field survey and user response survey) can be combined for a better model development of Bengaluru Metro study and estimated for the purpose of the study

IV. SOCIAL BENEFITS AND COSTS BENEFITS OF THE BNEGALURU METRO PHASE 1

In this section of study social benefits and Cost benefits will be enumerated.

SOCIAL BENEFITS	COST BENEFITS
Reduction in Air pollution	Construction cost
Time saving for passengers	Financing cost
Saving in fuel consumption	Environment costs
Reduction in accidents and traffic congestion	Operation and maintenance charges

Table 4: The benefits accruing as a result of implementation of Namma Metro Project-Phase 1

The five key parameters outlined by the MOHAU (Ministry of Housing and Urban Affairs) Appraisal Guidelines have been used to quantify the Economic Benefits.

1. Travel Time Savings
2. Savings in Vehicle Operating Cost
3. Savings from Accident Reduction
4. Savings from Pollution Reduction
5. Savings due to Reduced Road stress

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
	Percentage	No of vehicles	
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

4.1. Reduction In Vehicles Due to Metro (Phases I)

The estimation for private vehicles has been done for cars, 2 wheelers and 3 wheelers. the reduced number of vehicles to ply on the road will be as follows

Reduced number of vehicles due to Shift to metro		
Category of Vehicles	Pre-Metro (As per BMRCL-DPR-2003)	Post Metro (As per Average Ridership in 2022)
	No of vehicles	No of vehicles
Cars	7250	30450

Two wheelers	34667	139200
Three wheelers/	8111	52200

Table 6: Reduced Number of Vehicles due to shift of metro

4.1.2. Modal shift pattern to Metro from existing mode

For the purpose of Evaluation, the modal shift that is expected from the various modes using road transport to the metro as per Table 5. and approx. traffic flow along the Phase-1 corridor line is used to estimate is presented below.

Category of Vehicles	Mode of Share		Shift to metro	
	Approx. Traffic count along the corridor	Percentage	Avg Traffic	Percentage
Cars & Taxis	86,574	8%	17315	20%
Two wheelers	3,46,298	32.0%	103889	30%
Three wheelers/Auto	1,29,862	12%	12986	10%
Buses	5,19,446	48%	207779	40%
Total	1082180	100%	341969	100%

Table 7: Peak Hour Trip Mode of shifting of commuters from road–based transportation to Namma Metro Bengaluru, Source: Average traffic count along Phase 1 route for the year 2002, Bengaluru Traffic Department and BMRCL-DPR-2A of Bangalore Metro, Volume-1,2019, S. No 5 the modal shift of the passenger trips for different modes of transport

From the above Table 7, 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 Bengaluru urban area (A)	Modal shift along the Phase-1 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%	17,315	57716	2.9	265910	5971	259940	13	77618
Two-wheeler + Auto	47,95,700	30%	1,16,875	389585	1.5	3197133	77917	3119216	8	623336
Buses	54,65,250	40%	2,07,779	519446	37	147709	5616	142094	10.7	60087
	1,10,32,090	100%	3,41,969	9,66,747		36,10,753	89,503	35,21,250		7,61,041

Table 8: 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

4.2. Monetization Benefits of Namma Metro- Phase-1

4.2.1. Time Saving for Passengers: Saving of Time due to the use of the metro

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.

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 about 90 minutes per trip along the phase-1 corridor. based on the assumption presented in BMRCL-DPR-2A of Bangalore Metro, Volume-1,2019

and Appraisal Guidelines MOHAU.

Passenger Time Savings= Time Savings of Modal Shift passenger + Time savings of passenger travelling on other mode.

Passenger Time Savings = 1.5hrs/Day ≅ 540hrs/Annually

Annual Passenger Time Savings by Modal Shift = 184663195hrs

Total Value of Time Savings = Rs.2010.84 Crores
Note: from the study the Time savings of modal shift passengers to metro per trip is 60-90mins and & based on Appraisal Guidelines MOHAU Time Savings of passengers travelling on other modes is 3mins, Per Capita Income Per Hour is Rs.120.4 Per hour.

4.2.2. Reduction in Accidents: Reduction in the number of people killed, injured, and vehicles damaged
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 Appraisal guidelines. The difference between reduced road trips and the accident rate was used to compute the number of accidents. Based on the 2018 figures from the Comprehensive Mobility Plan for Bengaluru, the accident rate (accidents per trip) was estimated. Average Number of accident cases in a year 2021 & 2022 is 1204(fatal accidents and non-fatal accidents). Estimated number of accidents along the corridor is 106 with 9% share of trips using metro. Average compensation value for person (Rs. 642783) and Average Compensation value for Vehicle Rs 3952, Accidental Cases reduced during the year 2022 is 37nos.

Total Savings for Year 2022=2.37crores
Note: Accidents were assumed to cost ₹437,342 per fatal accident and ₹64,256 per non-fatal accident (both in 2004 prices), based on MOHUA Appraisal guidelines and updated to 2020 prices for the analysis.

4.2.3. Savings in vehicle operating costs (VOCs): reduction in traffic i.e., decongestion
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, three-wheelers, 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 autos, and 13.1 km for buses. The VOC per km travelled by vehicle type is computed following the MOHUA Appraisal guidelines. The sum of the daily reduction in the number of vehicles and the daily average distance travelled, the final amount of VOC savings (trip length), per vehicle type, and the VOC per distance travelled (km)

Savings in Vehicle Operating Cost by modal shift passengers to Metro =Rs. 180.56 Crores

Savings in Vehicle Operating Cost on account of smoother operations of passenger trips of other mode vehicles owing to congestion reduction = Total Vehicle on road with Metro (Daily)* Vehicle Km saved * Avg VOC per km saved *No of days* Congestion Index
Savings in Vehicle Operating Cost from other mode = Rs.364.08 Crores

Total Savings on account of Vehicle Operating Cost is estimated= Rs. 544.6 Crores
Note: Subsequent values can be calculated based on the assumption that it shall be escalated at the rate of 5% p.a and following the above method and taking into considerations the above assumptions, the value of savings for the subsequent years/ period
- Increase in vehicle operating cost p.a, as per the MoHUA Appraisal Guidelines
-Average journey speed in Bengaluru urban region in km/hr. and Annual growth rate of vehicle trips across various modes in Bengaluru, the assumption is based on the Traffic Demand Forecast report by RITES for Bengaluru Metro
-Congestion index of 0.45 is applied to the Vehicle Operating Cost due to the reduced journey speed from the actual speed as determined in the Bengaluru Mobility Indicators study by DULT (Directorate of Urban Land Transport)

4.2.4. Reduction in Fuel Consumption: Due to a portion of Bengaluru Road traffic being diverted to the metro and less traffic for the vehicles that are still on the roads, there are savings in fuel consumption (including both CNG and petrol) fuel usage has decreased.

Fuel saved due to traffic diverted to the Metro is estimated given the estimates of diverted traffic described above and the annual run and fuel consumption norms of different vehicles.

Due to reduction in traffic: number of Car reduced x Avg Fuel Consumption x price of Fuel
Daily Trips saved due to Metro approx. 3,41,969 and Fuel Consumption norm for car/taxis, two-wheeler / three-wheeler and bus is 13, 35 and 18 litre/km and daily run is 30, 25, 100 and 210 km.

Annual Value of fuel savings=Rs. 27,466.7 Crores
Note: Savings in fuel consumption with the project scenario from year 2017 to 2022
Considering Price of fuel in 2022 for cars and two-wheelers using petrol, price is Rs. 102/- per litre and for buses using Diesel price is Rs. 88/- per litre, CNG price is Rs 85/- per litre.
Petroleum: 1 litre = 0.79 kilogram; Gas, diesel, light fuel oil: 1 litre = 0.84 kilogram

4.2.5. Reduction in Air pollution: This is due to fewer vehicles and decongestion
Pollution is anticipated to be reduced mainly because of the reduced number of vehicles on the road due to the shift of passengers to the metro. According to MOHUA criteria, the 6grams per km emissions of several pollutants (PM, NOx, HC, CO, and CO2) were estimated for each type of vehicle. In a similar manner, the cost of emissions (measured in per tonne) was also estimated in accordance with MOHUA guidelines. The value of the overall benefit from a reduction in vehicular emissions can be obtained by multiplying these parameters by the total vehicle-km (per vehicle type) taken off from the roads as passengers shift to the metro. For CO2, CO, HC, NOx, and PM emissions, the values utilised were 134,010 and 670 per tonne, respectively. The Bengaluru Metro DPR was used to calculate these estimates (in 2020 prices). CO2 emissions costs works out to, the daily savings resulting from reduced CO2 emissions come up to Rs. 63,679 per tonne.

Pollution reduction benefits due to Metro = Rs.13.73 Crores
Note: Following the above method and taking into considerations the above assumptions Estimation of vehicular emission saved due to shifting of commuters from road–based transportation to Namma Metro Bengaluru with Average Treatment Cost Per Ton Rs. 4,958 as per the MOHUA Appraisal Guidelines

4.2.6. Economic Benefit Due to Reduction in Road Infrastructure Maintenance Cost
-Estimate the cost of labour and materials used to operate the project
-O & M cost is projected based on proportion of revenue

Total reduction in road infrastructure Maintenance cost= Rs. 1.42 Crores
Note: The methodology adopted for the computation of benefit for this parameter is as stated below
Step 1 – Determined the Average maintenance cost per trip per year without metro. The cost is determined by collating information on the expenditures incurred on Road Maintenance works by BBMP over the last 3- 5 years along the Phase-1 metro corridor
Difference between the above values provided for the savings in the Road Maintenance Cost.
Based on MOHUA guidelines and taking into considerations the above assumptions, the value of savings

4.2.7. Environmental Cost: Cost of loss of trees and environmental monitoring required to be evaluated.
According to BMRCL, many the number of trees were removed and equally & more than double were translocated, transplanted along the stretch during the construction Phase-1 and after the completion of the project.
Note: The Estimated Social Disturbance Costs and Severance cost are not evaluated after completion of Phase-1 as per information provided by the BMRCL.

4.2.8. Financing Costs: Interest expense on loans drawn for this project
43% of construction costs are financed through debt

4.2.9. Construction costs
Rs 13,845 crores for Phase -1(Cumulative expenditure up to January 2017 was Rs 14,291.20 crore.)
Note: Financing Costs: Interest expense on loans drawn for this project-43% of construction costs are financed through debt
-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.

Considering that there are still flaws to be found today, with many of them being addressed in the future, there is still hope that Namma Metro will one day connect the city's residents. Certainly, its significant positive impact on real estate markets advocates for this project. Although, this project is not viable financially but in terms of economic viability, it seems significantly viable.

It can be concluded that the economic benefits of Bengaluru metro rail project outweigh the economic costs. The Cost benefit ratio of 1.41 of the projects indicates that benefits are marginally higher than costs.

V. FINDINGS

5.1. Social-Cost Benefit Evaluation of Bengaluru Metro

Due to the shift to metro from conventional transport system, the following positive social costs benefits and its environmental implications can be anticipated.

5.1.1. Reduction in Air Pollution

Air pollution reduction leads to promotion of a better, healthier city and ensuring a better quality of community's health According to estimations, the Metro operation can enhance the city's air quality, which is now classified as severe on the AQI(Air Quality Index) scale, while reducing air pollution loads by an average of 30% from the current state.

- The launch of the full Phase I of Namma Metro had a significant improvement in the air pollution levels across areas in its North-South(N-S) line as well as the East-West (E-W) line.
- Air monitoring by the KPSCB (Karnataka State Pollution Control Board) has revealed a 13.3% dip in air pollutants along the Baiyappanahalli to Mysore Road stretch (E-W) and an 8.9% dip along the Yelachenahalli-Nagasandra (N-S) stretch.
- The decrease of carbon emissions has been considerably aided by metro rail services.

5.1.2. Traffic Decongestion and Road Safety

The Metro Rail would significantly reduce traffic congestion issues in city's roads to an extent of almost 30% while guaranteeing a quick, user-friendly mode of transportation. This will assure that the number of accidents on the roads will be reduced by this amount while also significantly reducing traffic congestion. Additionally, because the Metro Rail will carry a substantial portion of the traffic load, there will be fewer vehicles on the roads, which will minimize the strain on the road and provide the existing road network a longer lifespan.

5.1.3. The introduction of Metro Rails

It is anticipated to encourage the suburban sections of the city to flourish in a planned manner, benefiting the local economy and offering a high-quality infrastructure to the nearby rural population providing overall employment opportunities.

5.1.4. The reduction of vehicles

- decrease in the use of fossil fuels, particularly petrol.
- Less traffic will mean that the roads will be in better condition and last longer. By reducing the need for and cost of road maintenance by around 30%, this will result in savings for the public exchequer.
- As per BMRCL official over 1.41 lakh vehicles have been taken off the road, leading to savings of over 13.25 lakh vehicle kms since the metro has been operationalized.

5.1.5. Noise Reduction

There will be a noticeable reduction in noise levels, especially in the corridor routes, by around 30%, as a result of the decrease in traffic along the corridors.

5.1.6 Socio-Economic Benefits

There is significant and overall positive impact on society both direct and indirect thereby increasing the quality of life on Environmental Factors through the above-mentioned benefits. Its noteworthy that the Millions of man-hours saved by travelling public transport. Overall Improvement in quality of life and reduction of travel times: from 2022, 14 lakhs passengers/day will benefit from the metro

5.2. Summary Of Social-Cost Benefits of Namma Metro Phase-1

From the study carried out through evaluation of Monetization Benefits of Namma metro- Phase-1 and based on the Comprehensive Mobility Plan for Bengaluru, October 2019, Passengers shifting to the metro from other modes of transportation. Following economic benefits have been estimated that could be attributed to the Metro's reduction in the number of vehicles on Bengaluru roads.

Social-Cost Benefits due to Shift to Metro	Cost Saving
Time saving for passengers	Rs. 2094.84crores (6.95%)
Vehicle Operating Cost (VOC) due to decongestion	Rs. 544.6crores (1.8%)
Reduction in accidents	Rs. 2.37 Crores (0.008%)
Savings in fuel consumption	Rs. 27466.66 crores (91.2%)
Reduction in Pollution	Rs.13.73 crores (0.05%)
Savings in the cost of Road Infrastructure and Maintenance Cost	Rs.1.42 crores (0.005%)

Table 9: Summary of Social-Cost Benefits of Namma metro Phase-1

5.3 Quantified Benefits

Based on the Social Cost Benefit Analysis of Namma Metro, the following quantifies Benefits are estimated

Time Saved by Metro Passengers in Cr. Hr.	2094.84
Fuel Saved by Metro Passengers in Tons/Annually	6364
Daily vehicles reduced (off the road)	3,41,969/day
CO2 reduced daily in tons/daily	95.04
Annual Vehicle km Reduced in Thousand Km.	2,73,974.91
Petrol Daily saving Lt/Km	25,75,351
Reduced No of Fatal Accidents annually	37

Table 10: Quantified benefits for Phase-1 based on the Social Cost Benefit Analysis

Ridership on selected routes of Phase-1 is approximately 4.35lakh per day travelling on weekdays. this improvement is due to increase in fuel prices which has led people shifting to metro. As a result, it can be observed that the proposed and in operation metro project is profitable and economically attractive.

5.4. Social & Environmental Analysis

Environmental and Social Analysis by using Bengaluru metro system phase-1 as base case, social and environmental benefits can be evaluated. The outcome of Namma metro phase-1 benefits include the following:

- Presently 5.0lacs passengers are using metro per day on an average of 4.35lacs/day.

During the year 2017, the results of PM10 exceeded the prescribed limits of 100µg/m3 and decreased gradually from 2018 onwards. As per the air quality monitoring, the PM10 concentration at all the monitoring sampling metro stations are within the limit of 100µg/m3 from the year 2018 to 2021, as prescribed by CPCB.

The total reduction of carbon dioxide emission per annum by the Metro commuters are estimated as 79.4 gigagrams (Gg) for 2017-2018; 92.4 Gg for 2018-2019; 100 Gg for 2019-2020; 19.6 Gg for 2020-2021; and 120.4 Gg for 2021-2022, The study also mentions that over the years, metro travel has also brought down carbon dioxide emissions.

MRTS projects such as the Bengaluru metro have the potential to reduce CO2 emissions as well as traditional vehicular emissions such as PM, CO, HC, NOx, and so on, by shifting commuters from other modes to a more efficient public transportation system such as the metro rail system.

- During the construction phase, the project will cause temporary negative impact. To avoid and minimize project impacts during the project's development phase, sufficient mitigation measures have been proposed and recommended. However, these effects can be reduced during construction phase of project implementation Noise and vibration impacts throughout the operation phase of the metro project are determined to be significant.

- According to BMRCL, Environmental *Impact Assessment report 2020*, Other positive effects of the metro project include better accessibility and a reduction in atmospheric air pollution. Additionally, there will be a decrease in PM, NOx, HC, and CO pollutants.

The introduction of a Bengaluru metro system has various positive social impacts including reduced travel time, a cleaner environment to breathe in, and a systematic approach that overall improves public health, attitude, and stress levels.

VI. CONCLUSIONS

Social benefits and Cost Benefits to the society in terms of reduction in cost and time of travel, bringing down noise pollution. Substantial reduction in per capita pollution emissions resulting in reduction in chronic diseases, hence, results in huge public health benefits.

- reduction in road accidents, thereby increased safety and quality of life
- The project will facilitate movement of people from one part to other. And there will be reduction in time and traffic on the roads.
- Fuel costs for public transportation will be decreased due to shift to metro
- Namma Metro will benefit society since it has a low, transient social cost and higher, longer-lasting benefits.
- The metro system will benefit, if it can maintain its overall travel distance while increasing the number of passengers to its maximum capacity. This is only achievable through urban planning, city growth strategies, and changes in people's preferences for where to live, work, and travel.
- Namma Metro will decrease air pollution and enhance the people’s quality of life. Multi-modal integration in station planning and design more efficiently and integrate passenger information and ticketing. “Improving on all these aspects will ensure that Namma Metro contributes substantially to improving quality of life.

Namma Metro will benefit society since it has a low, transient social cost and higher, longer-lasting benefits. By increasing the quality of life on Environmental Factors through the above-mentioned benefits and overall positive impact on Society (both direct & indirect) the socio-economic benefit is positive and significant. The Millions of man-hours saved by travelling Public if quantified in terms of money is substantial and Noteworthy.

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