Bangalore Metro Rail Corporation Limited
ಬೆಂಗಳೂರು ಮೆಟ್ರೋ ರೈಲ್ ನಿಗಮ ನಿಯಮಿತ

Alternative Analysis for
PHASE 2B METRO CORRIDOR

Final Report - October, 2019

Prepared by:
Infrastructure Development Corporation (Karnataka) Limited.

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Executive Summary

Bangalore Metro Rail Corporation Limited (BMRCL) has determined to undertake Alternatives Analysis for Phase 2B Metro Corridor to evaluate alternate transit modes available and identify the best option among alternative routes and alternative transport modes which matches the demand projections over the project life cycle and has least cost. BMRCL has awarded the consultancy work to Infrastructure Development Corporation (Karnataka) Ltd.(iDeCK).

Alternatives analysis is about finding best alternative to address the transportation related problems for specific corridors or areas of a City. Detailed appraisal guidelines for mass transport project proposals have been laid down by Ministry of Housing and Urban Affairs (MoHUA), Government of India, 2017.

The guideline enables to identify the system having maximum utility and satisfy basic criteria. The Alternative Analysis for Phase 2B Metro Corridor will include following:

a) Develop screening criteria and identify parameters
b) Assessment of parameters for the criteria set
c) Evaluation of Alternatives
d) Implementation Options for the most preferred alternative

Need for Proposed Project

The city has developed along the radials and the Bangalore Development Authority (BDA) had developed the Outer Ring Road (ORR) in 2002 in a bid to divert the heavy traffic load to ease the traffic situation in the city. NHAI as part of improving connectivity to New Airport developed, in the northern part of Bangalore, has constructed a 6-Lane access controlled corridor connecting Hebbal and Devanahalli. The corridor is mostly elevated with part sections developed on grade.

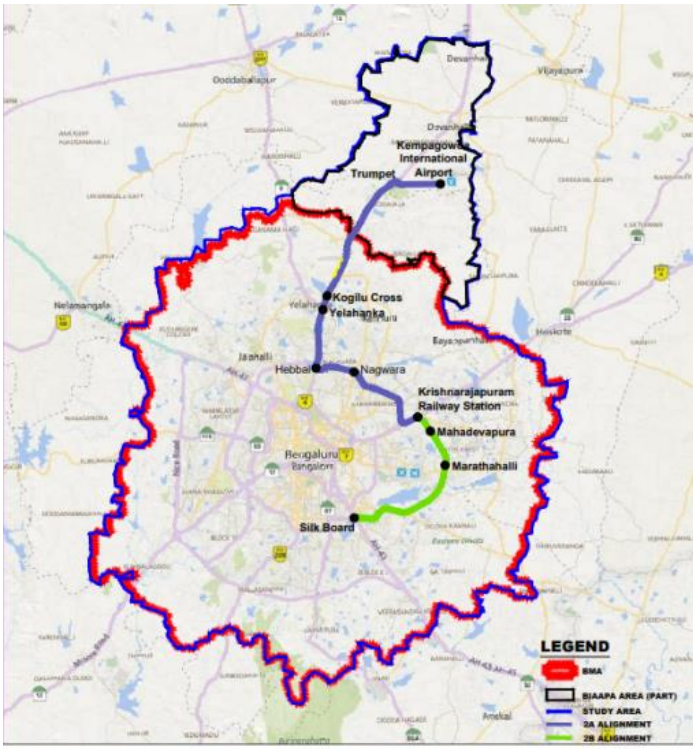
Currently, the corridor carries more than 10,000 PCU in the peak hour, while the corridor (Airport road) itself is not experiencing any congestion, Hebbal, the entry point and the network within the central parts of City is experiencing severe congestion. The segment of ORR is experiencing heavy traffic volumes with the presence of major IT hub namely Manyata Tech park and Whitefield (at the end of corridor).

As part of the mobility plan the corridor between K R Puram and Kempegowda International Airport has been identified to provide vital connectivity to the Airport and the fast growing areas of BIAPPA. There is an urgent requirement to provide mass transport facilities to reduce congestion and environmental deterioration. Therefore, it is extremely necessary that a Mass Transit System between KR Puram and Airport be provided.

A comparative analysis of alternate modes shall be an essential requirement for the transit mode selection. The mode which matches the demand projections over the project life cycle and has least cost should be chosen.

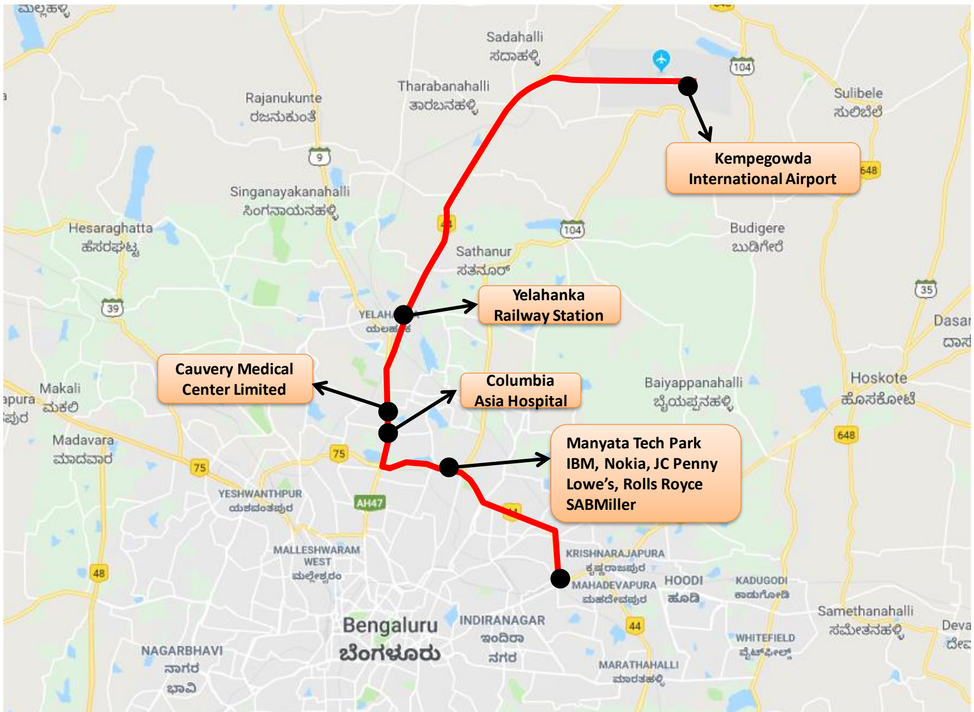
Study Area

The study area for the project includes the Bangalore Metropolitan Area (BMA area) i.e. 1294 Sq.km. (including part BMICAPA area – 79.14 Sq.km.) and adjoining areas around Bangalore International Airport Area Planning Authority (BIAAPA) (Jala and Kasba hoblis) measuring 227.85 Sq. km. Adjoining BIAAPA area has been including in the study area as public transport corridors are connecting Bangalore International Airport and some of the localities where proposed development has been listed out in BIAAPA Master Plan. Horizon year for the study is 2041.



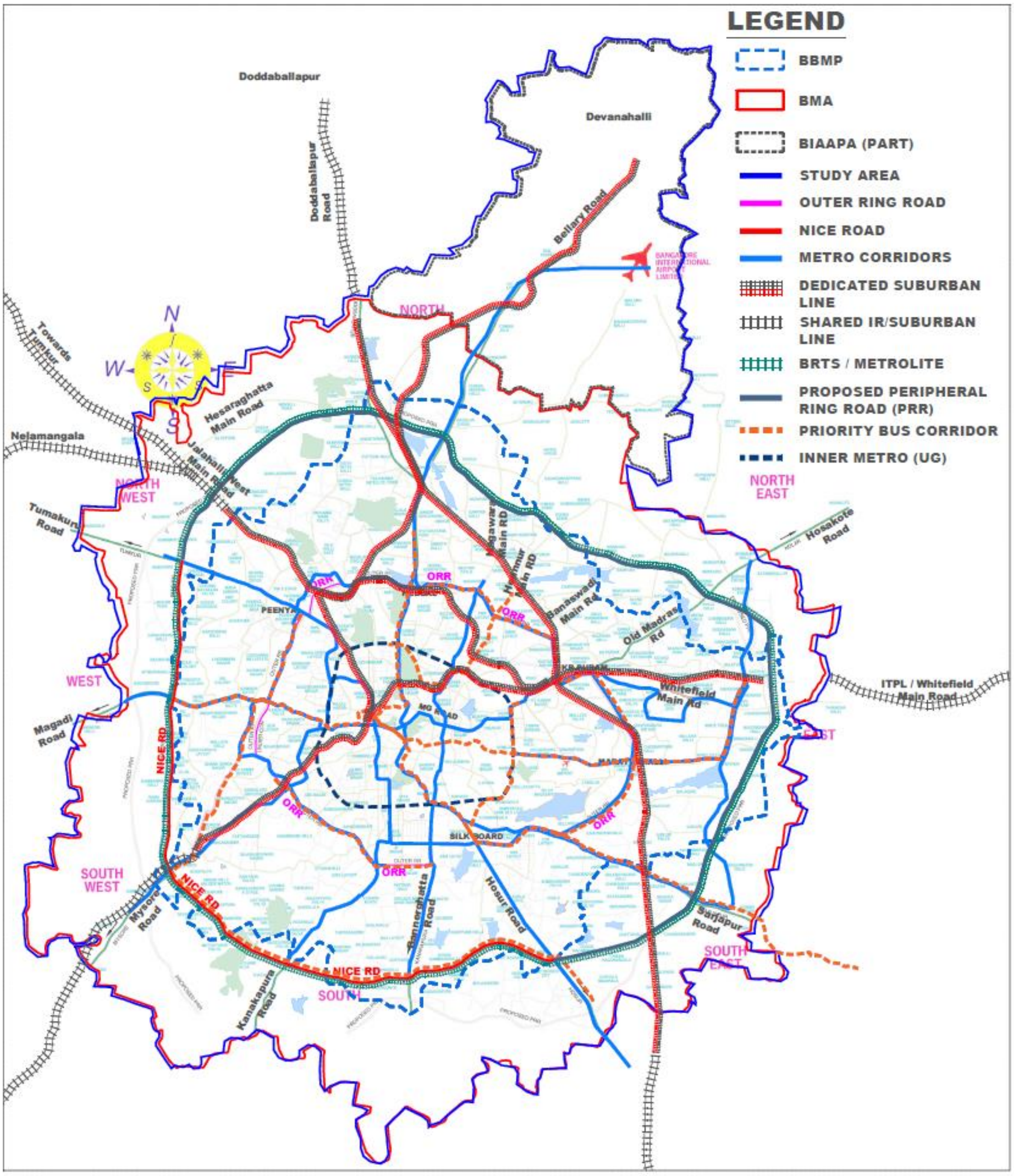
The Corridor

The corridor is part of the outer ring road of Bangalore which has witnessed a tremendous spurt of IT activity. It runs from K R Puram where proposed Silk Board –K R Puram corridor ends to Kempegowda International Airport via Hebbal. The total length off this corridor is 38 km.



Primary Public Transport Network as Proposed by CMP

Selection of a particular mass transit system for a city largely depends on the characteristics of the city and its metropolitan area, the projection of traffic demand for transit travel and the availability of suitable right-of-way (ROW) among others. High and medium capacity public transport systems have been conceived in CMP. The proposed K R Puram to Airport section would be a crucial link in the overall mass transit system development in the city and improved connectivity to Airport.



Alternative Route Alignment

The following are 4 different alternatives through which the metro line can be taken from Nagawara to Airport.

1	Alternative 1	Nagawara – RK Hegde Nagar – Jakkur – Yelahanka– Kogilu Cross – Chikkajala – Trumpet – Airport (This route mainly traverse along the National Highway(44)
2	Alternative 2	Nagawara – RK Hegde Nagar – Bellahalli – Yellahanka - NH44 – Chikkajala – Trumpet Airport
3	Alternative 3	Nagawara – RK Hegde Nagar – Bellahalli – Sathanur – Bagalur – Myalanahalli – Begur –Airport
4	Alternative 4	Nagawara – RK Hegde Nagar – Bellahalli – Kannur– Bagaluru – Mylanahalli – Begur – Airport

The Alternative 1 is the most suitable route for taking mass transit system from the point of view of connectivity (connects important areas along the route), practical feasibility (minimal land acquisition) and is also part of the network as proposed in the CMP.

Public Transit System Alternatives

The mass transport systems in cities/ urban agglomeration can be broadly classified into the following categories:

1. City Bus System
2. Bus Rapid Transit System (BRTS)
3. Mono Rail
4. Metro Lite
5. Metro Rail System
6. Heavy Metro

Choice of a particular Mass Transit System will depend on a variety of factors like demand, capacity, expandability, cost and ease of implementation. The travel demand, cost and ease of implementations being the most important parameter in the choice of system/alternative for consideration.

Peak Hour Peak Direction Traffic

The ridership prediction on this corridor for the cardinal years suggests that only a higher order mass transit system would be able to cater to the demand. Considering this, of the alternative systems as mentioned above only Metro or a Heavy Metro would be able to meet the projected travel demand.

Peak Hour Peak Direction Traffic

Year	PHPDT	BRT	Monorail	Metro Lite	Metro	Heavy Metro
Carrying Capacity		8000	15000	15000	40000	60000
2024	21,112	Fail	Fail	Fail	53%	35%
2031	35,705	Fail	Fail	Fail	89%	60%
2041	46,252	Fail	Fail	Fail	116%	77%

Screening Criteria for the identified Alternative Options

Screening of alternative modes needs to be done to shortlist most viable alternatives for Phase 2 mass transit corridors in the Study Area. The screening parameters for alternatives evaluation are considered with regard to mobility improvements, engineering feasibility, environmental benefits, cost effectiveness, operating efficiencies and economic effects.

Preliminary evaluation for the available transportation modes have been done based on need to serve the travel demand, constructability, cost, right of way etc. Further detailed evaluation for the identified alternative systems for capacity to address travel demand, civil engineering effects, capital, operation & maintenance cost etc. to arrive at the most appropriate alternative for implementation.

Five alternative mass transit systems catering to the needs of a city have been considered for the initial screening stage with the set of identified qualitative parameters:

i. Bus Rapid Transit System
ii. Mono Rail
iii. Metro Lite
iv. Metro Rail System
v. Heavy Metro System

The preliminary observation (CMP) and screening identifies that the traffic demand in this corridor is for a higher capacity mass transit system.

4 route choices have also been studied. A preliminary observation suggests that land constraints and some engineering issues restrict the option to only one (**Alternative 1**). The selected route has very minimal land issues and hence is selected. Also the selected option is in line with the overall network plan as put forward by the CMP.

Evaluation Parameters

The evaluation has been carried out over the following key parameters that help in selection of the most suitable system for the corridor:

1. Mobility Effects
    i. *Travel Demand Forecasting*
2. Conceptual Engineering Effect
    i. *Available Right-of-Way (Land Acquisition)*
    ii. *Alignment Design and Constructability*
    iii. *Geotechnical Characteristics and Civil Structures:*
    iv. *Station Planning and Intermodal Integration:*
    v. *Requirement for Utility Shifting*
3. System Effects
    i. *Interoperability with Phase-1 System*
    ii. *Rolling Stock Requirement*
    iii. *Land for Maintenance Depot*
    iv. *Indigenous Availability*
4. Environmental Effects
    i. *Air & Noise Pollution*
5. Social Effects
    i.Structures/Persons Affected
6. Cost Effectiveness & Affordability
    i. *Capital Cost per Passenger KM*
    ii. *O&M Cost per Passenger KM*
7. Financial and Economic Effects
    i. *Economic Returns*
    ii. *Life Cycle Cost*
8. Approval & Implementation
    i. *Time Required for Approvals*
    ii. *Ease of Implementation*

The identified parameters along with the overall weightages assigned to various parameters for evaluation have been summarized in Table below.

Parameters Identified for Evaluation

S.N.	Criterion	Objectives	Weightage
1	Mobility Effects	• Serve the maximum peak travel demand • Minimize congestion and reduce reliance on automobile • Provide convenient accessibility and improve interchange facilities • Increase public transportation ridership and mode share • Provide higher modal utilization	20
2	Conceptual Civil Engineering Effect	• Utilization of available of existing right of way • Suitability of Geometric parameters • Assess constructability of alternative mode • Possible extent of land acquisition considering right of way, civil structures and stations	10
3	System Effects	• Provide better safety and comfort • Ability to carry more passengers • Indigenous availability of rolling stock	15
4	Environmental Effects	• Preserve the natural environment • Reduce pollution from shifting of vehicles from private to public modes of transport • Protect and enhance cultural heritage, landmarks and archaeological monuments	10
5	Social Effects	• Impact on existing structures and families	10
6	Cost Effectiveness & Affordability	• Provide quality, affordable public transport service with an optimum investment cost • Consumption of minimum possible maintenance costs	15
7	Financial and Economic Effects	• Provision of a public transport system that would be longstanding and has a higher life cycle cost • Provision of economic friendly transport system with higher economic benefits to the society	15
8	Approvals and Implementation	• Time taken for approval of system • Ease of implementing the proposed and approved system	5
	TOTAL		**100**

Alternatives Evaluation

Summary of Evaluation of the alternatives considered are as below:

Sl. No.	Criteria	Weightage	BRT	Monorail	Metro Lite	Metro System	Heavy Metro
1	Mobility Aspect	20	5.4	10.6	6.6	19.5	20.0
2	Engineering Aspect	10	7.9	6.5	7.7	7.6	6.9
3	System Aspects	15	5.3	2.2	1.5	15.0	10.0
4	Environmental Aspects	10	6.6	7.0	7.0	10.0	10.0
5	Social Impact	10	5.7	2.8	6.3	5.5	5.0
6	Cost Effectiveness and Affordability	15	**9.0**	**4.6**	**5.1**	**14.4**	**15.0**
7	Economic Aspects	15	15.0	10.0	10.7	10.6	11.0
8	Implementation	5	4.5	4.5	4.5	4.5	4.0
	Total Score	**100**	**59.4**	**48.2**	**49.4**	**87.1**	**81.9**

It can be seen that the Metro which has the flexibility to expand would be the most suitable option for this corridor.

Implementation Options for Viable Alternative

Based on both qualitative and quantitative screening carried out, Metro Rail System has emerged as the most viable alternative mass transit system for the proposed corridor connecting K R Puram and Airport via Hebbal.

As per Metro Rail Policy 2017, it is essential to explore private participation either for complete provisioning of metro or for some unbundled components such as Automatic Fare Collection System. As per Metro Rail Policy, implementation options need to be explored for seeking Central Financial Assistance (CFA).

The various options for central financial assistance for metro projects as detailed in the Metro Rail Policy are:

i. Public Private Partnership (PPP)
ii. Grant by the Central Government
iii. Equity Sharing Model

Project Cost Estimate

The estimated project cost for the implementation of the Metro corridor along the proposed K R Puram to Airport corridor is as below:

Capital Cost of the Project-Phase 2B

Sl. No	Major Cost Head	Cost (INR Cr.)
1	Civil Works	2,928
2	Rolling Stok	1,008
3	Systems and telecommunications	1,156
4	Miscellaneous incl contingency	233
5	Land	2,171
6	Taxes	698
7	Others including escalation and IDC	1,741
	Total Cost	**9,935**

The project is expected to be completed and become operational by 2024. The O&M expenses are estimated to be about 296Cr in the year 2024, the first year of operation.

Means of Finance

The funding plan (Equity Sharing Model) for the proposed project is as below:

Sources		Rs in Cr	(% of Share)
GoI - Equity		1,139.27	11.47%
GoI - Sub-debt		174.38	1.76%
GOI Share sub total	**(1)**	**1,313.65**	**13.22%**
GoK - Equity		1,139.27	11.47%
GoK - Sub-debt		174.38	1.76%
GoK - Sub-debt (Land Cost)		2,171.39	21.86%
Subordinate-debt (State Taxes)		348.76	3.51%
GoK Share sub total	**(2)**	**3,833.81**	**38.59%**
Value Capture Financing	**(3)**	**150.00**	**1.51%**
Innovative Financing	**(4)**	**350.00**	**3.52%**
Senior Debt (Sovereign/Non Sovereign Loans)	**(5)**	**4,287.12**	**43.15%**
Total Sources	**(1) to (5)**	**9,934.58**	**100.00%**

State Government need to fund an amount of Rs. 4,287.12 Cr as equity/Sub debt towards this project. This amount includes an amount of Rs. 2171 Cr towards land acquisition &Rehabilitation & Resettlement and Subordinate-debt (State Taxes) of Rs. 349 Cr.

1 Need of Study

1.1 Background

Bangalore, an early cosmopolitan city in the country and the capital city of Karnataka, is one of the fastest growing cities in India. Bangalore City is more prominently known as the 'Silicon Valley of India' for spearheading the growth of Information and Communication Technology (ICT) based industries. Bangalore has become a cosmopolitan city attracting people and business alike, within India and internationally and has become a symbol of India's integration with the global economy.

Bangalore is the fifth largest metropolis in India, with a total population of 8.5 Million (Bangalore Urban Agglomeration) as per Census 2011. Bangalore was the fastest-growing Indian metropolis after Delhi between 1991 and 2001, with a growth rate of 38% during the decade and now is the fastest growing metropolis between 2001 and 2011 with a growth rate of 49.4%.

Development of IT/ITES industries, large public sector undertakings like BEL, BEML and HAL, along with major hardware garment industries has led to in-migration and rapid growth of the city.

Bangalore, with its strong economic base, contributes about 36%[1] to Karnataka's GSDP (2016-17). Bangalore has the highest contribution in secondary and tertiary sector's GSDP due to high concentration of major industries and infrastructure facilities. The Metropolis houses about 40% of urban population of Karnataka and has witnessed 49.4% growth in population during the decade 2001-2011, thus playing the role of a primate city in the State. In context of the State, the Population in the city of Bangalore accounts for nearly 14.6% of the state's population concentrated in only about 0.64% of the land area.

The number of registered vehicles has crossed 80 lakhs, an increase of 20 lakhs in the past 3 years. Various schemes to rid Bangalore of its traffic problems are being considered but these are not being implemented in a coordinated manner.

The growing population, vehicle numbers and economic activities, have seriously aggravated the traffic problems in Bangalore. The limited road space of Bangalore is not able to handle the current traffic generated by the ever burgeoning population. Consequently, traffic in Bangalore has become a scourge and is only worsening day by day. Network speeds are dropping at an alarming rate as capacity of the Junctions and links have exceeded the limits. These have contributed towards increasing traffic congestion, travel times and pollution levels.

In view of this, in order to have a coordinated effort to improve mobility in the city, development of high capacity mass transit network integrating various transport infrastructure addressing the needs of various segments of population becomes critically relevant.

[1] Economic Survey of Karnataka 2018-19

1.2 Guidelines for Alternative Analysis

Alternatives analysis is about finding best alternative to address the transportation related problems for specific corridors or areas of a City. Detailed appraisal guidelines for mass transport project proposals have been laid down by Ministry of Housing and Urban Affairs (MoHUA), Government of India, 2017.

The mandated framework in the policy is presented in **Figure 1.1**.

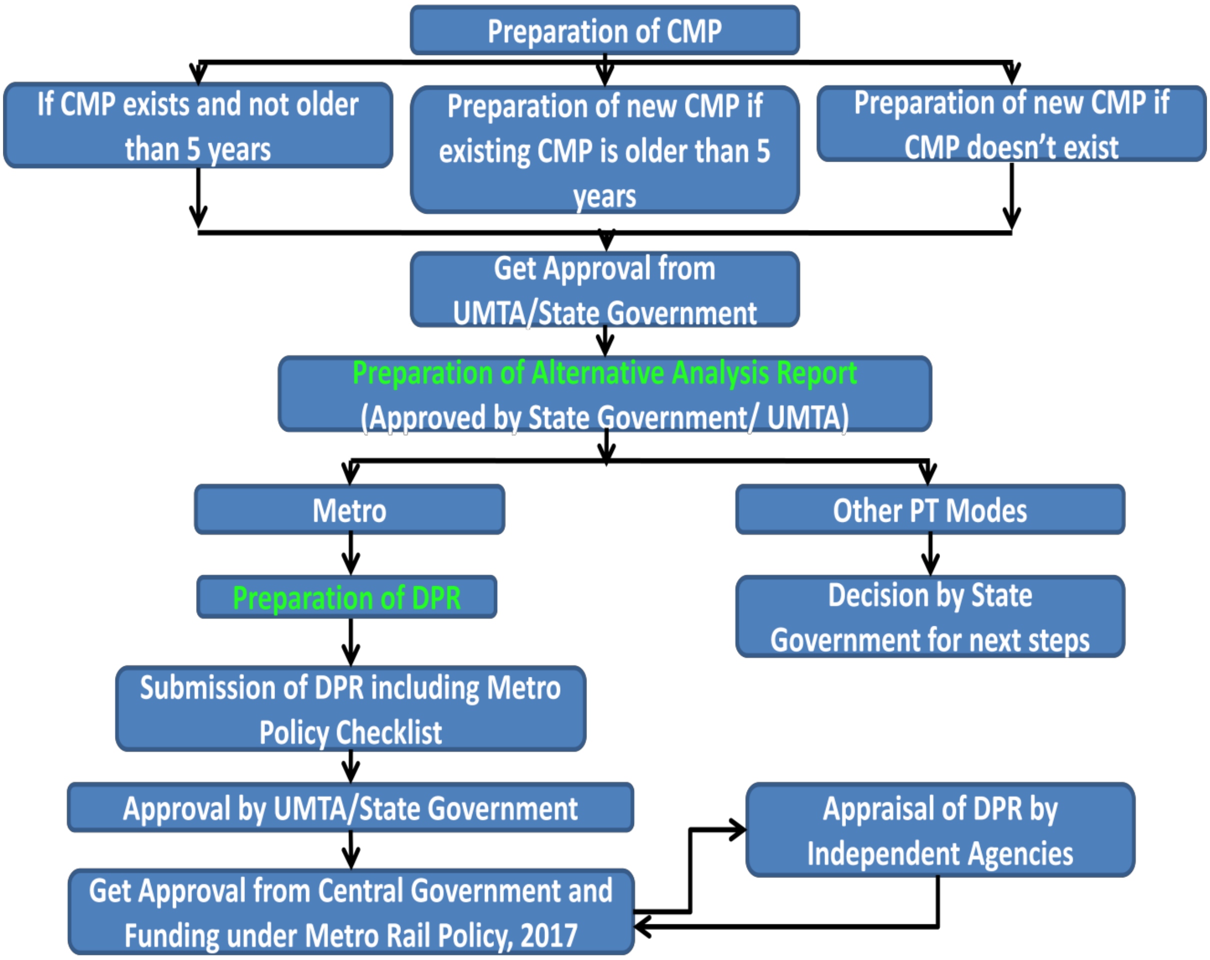


Figure 1-1: Policy Framework for Metro

The key objectives of conducting an alternative analysis report is mainly to:

- ✓ Ensure that reasonable transportation alternatives are considered
- ✓ Evaluate relative impacts of alternatives
- ✓ Select the most preferred alternative
- ✓ Consider opinion of stakeholders

The proposed system shall be capable of meeting some of the important criteria as follows:

- ✓ Meet the design traffic demand
- ✓ Flexible and economic operation

- ✓ Safe and comfortable
- ✓ Punctual and reliable services
- ✓ Provide intermodal integration with existing city network
- ✓ Allow for future expansions in the city considering the future travel demand
- ✓ Allow for future upgradation with improvement in technology
- ✓ Cost considerations

Considering the above, the Alternative Analysis has been conducted in the following stages:

Stage 1: Develop screening criteria for the identified options

Stage 2: Evaluation parameters

Stage 3: Evaluation of Alternatives

Stage 4: Implementation Options for the most preferred alternative

1.3 Overview of Study Area

The study area for the project is Bangalore City local planning area along with BIAPPA Areas (2 Hoblis Jala and Kasba) on the broader perspective while the immediate study area shall be the influence area of the proposed mass transit corridor connecting K R Puram and Airport.

The study area includes the Bangalore Metropolitan Area (BMA area) i.e. 1294 Sq.km. (including part BMICAPA area – 79.14 Sq.km.) and adjoining areas around Bangalore International Airport Area Planning Authority (BIAAPA) (Jala and Kasba hoblis) measuring 227.85 Sq. km. Adjoining BIAAPA area has been including in the study area as public transport corridors are connecting Bangalore International Airport and some of the localities where proposed development has been listed out in BIAAPA Master Plan. Horizon year for the study is 2041. The overall study area is shown in **Figure 1.2** and the proposed corridor is presented in **Figure 1.3**.

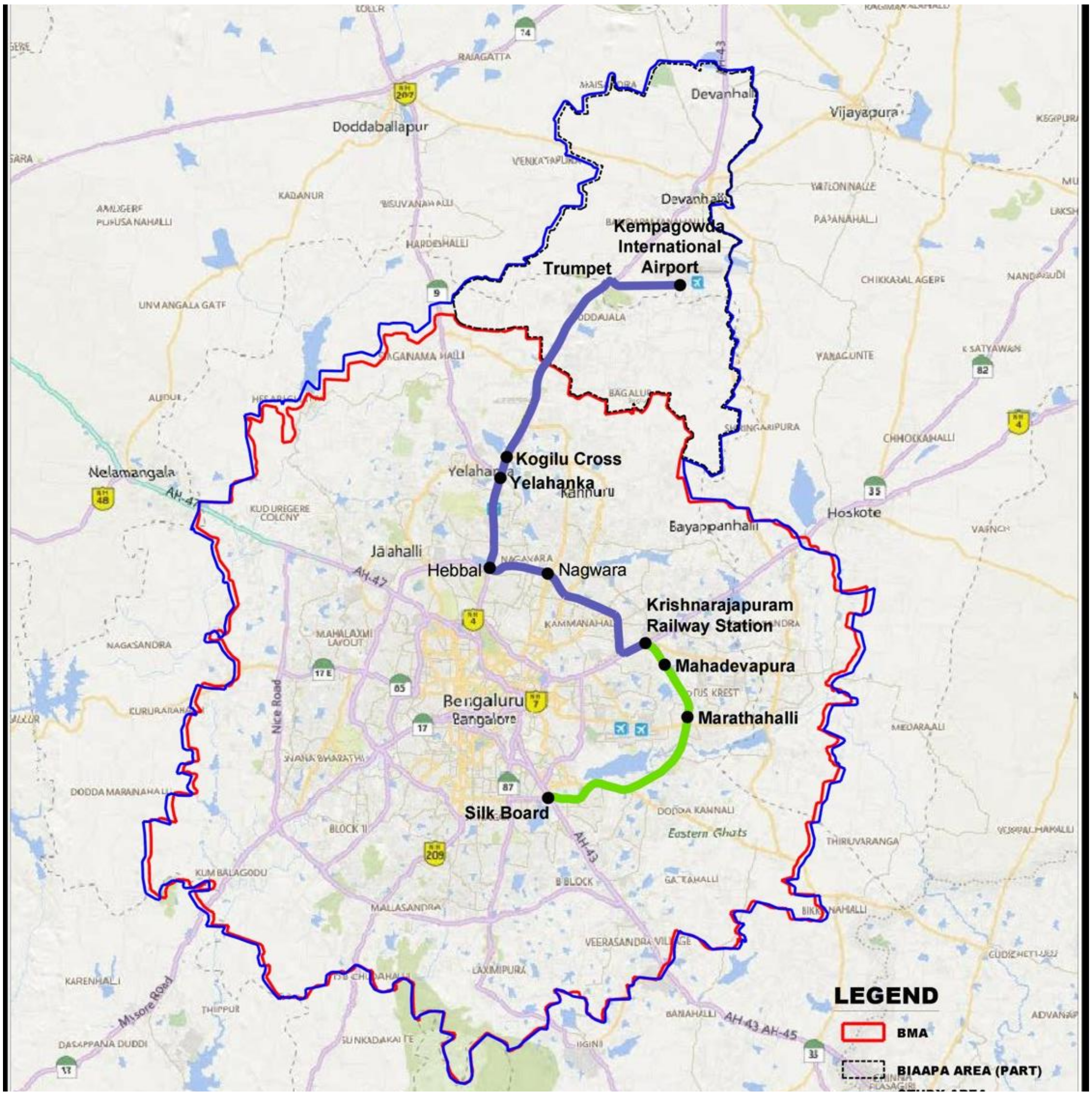


Figure 1-2: Study Area

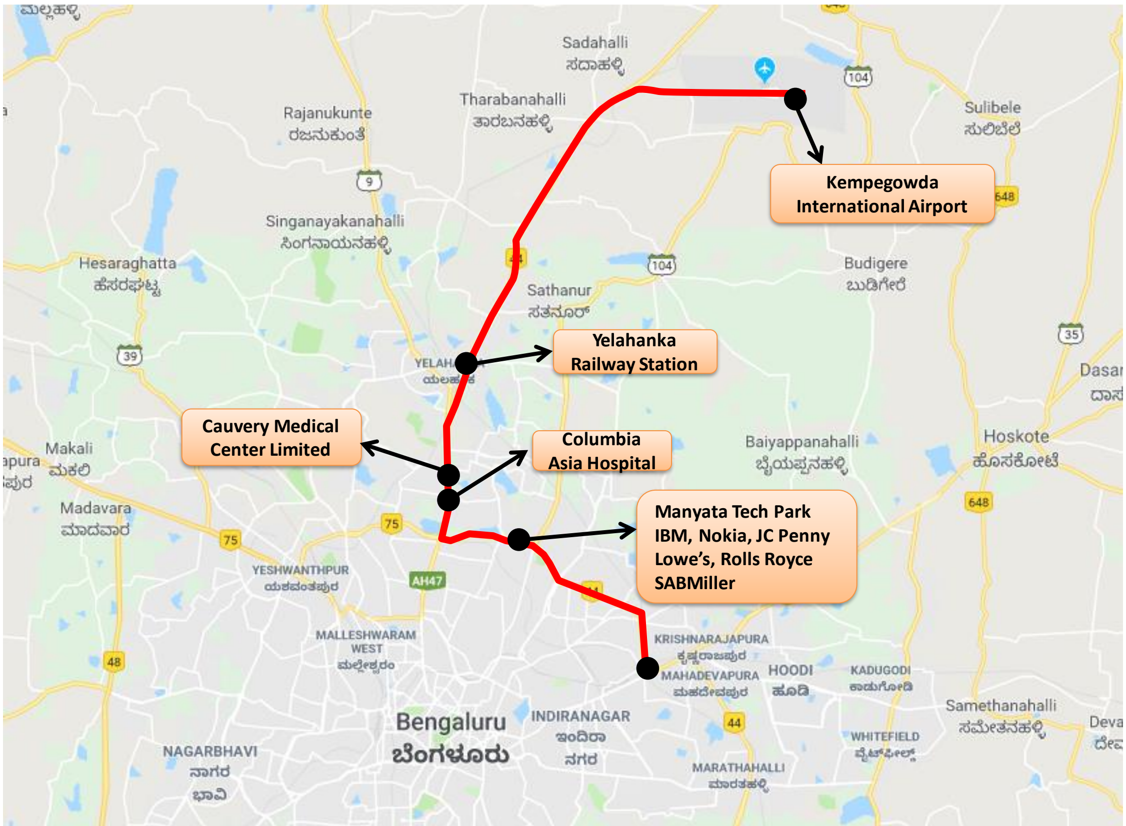


Figure 1-3: Study area for KR Puram and International Airport Corridor

1.4 Regional Goals and Objectives

Apart from meeting the critical objective of connecting the Airport, the goals for the development of this mass transit corridor shall match and be in line with the overall mobility goals for Bangalore City, seamlessly integrating into the planned Public Transport Grid. To ensure sustainability in mobility, the following goals have been considered in the Comprehensive Mobility Plan.

- Develop public transit system in conformity with the land use that is accessible, efficient and effective.
- Ensure that the urban road structure is organized and suited to the land use.
- Increase mode share in favour of public transport
- Develop traffic and transport solutions that are economically and financially viable and environmentally sustainable for efficient and effective movement of people and goods

1.5 Project Purpose

Rapid growth of population and its travel needs has laid severe stress on the urban transport system. Lack of adequate public transport in the city has led to an explosive growth in private modes leading to increase in network congestion. Limited opportunities for augmentation of road infrastructure facilities have resulted in congestion which has affected bus operations which has further fueled use of private modes resulting in drastic reduction of public transportation share in the city.

Comprehensive mobility plan prepared has laid emphasis on developing a network of mass transit system comprehensively covering the city. As part of the mobility plan the corridor between K R Puram and Kempegowda International Airport has been identified to provide vital connectivity to the Airport and the fast growing areas of BIAPPA.

At present, BMTC buses are the only modes of public transport along this corridor. A very high volume of taxis is operating to provide connectivity to the airport apart from private vehicles. Further a high growth of residential and commercial development all along the corridor after Hebbal is seen. This concentrated development already shows an adverse impact at some sections.

Therefore, there is an urgent requirement to provide mass transport facilities to meet the travel demand on this corridor and to reduce congestion and environmental deterioration. A well planned mass transit system meeting the travel demand to the vicinity and the airport would help to ease mobility concerns.

Alternative analysis is required to identify best option among alternative options available to address the travel demand. The alternative analysis for the public transit system for the identified route is an essential component before the DPR is taken up. However, the underlying fact is that the proposed system should meet the travel demand requirements as assessed to ensure a sustainable mobility and targeted public transportation share. Alternative analysis is required to identify best option among alternative options available to address the travel demand.

1.6 Need for Proposed Project

The current action in the process of development of mass transit system is to assess and evaluate alternate options available and evaluate the options. For this, Alternatives Analysis is required to identify the best option among alternative routes and alternative transport modes.

Choice of a particular Mass Transit System will depend on a variety of factors like demand, capacity, expandability, cost and ease of implementation. The travel demand, cost and ease of implementations being the most important parameter in the choice of system/alternative for consideration.

A comparative analysis of alternate modes shall be an essential requirement for the transit mode selection.

The city has a radial pattern and the Bangalore Development Authority (BDA) had developed the Outer Ring Road (ORR) in 2002 in a bid to divert the heavy traffic load to ease the traffic situation in the city. NHAI as part of improving connectivity to New Airport developed, in the northern part of Bangalore, has constructed a 6-Lane access controlled corridor connecting Hebbal and Devanahalli. The corridor is mostly elevated with part sections developed on grade.

Currently, the corridor carries more than 10,000 PCU in the peak hour, while the corridor (Airport road) itself is not experiencing any congestion, Hebbal, the entry point and the network within the central parts of City is experiencing severe congestion. The segment of ORR is experiencing heavy traffic volumes with the presence of Major IT hub namely Manyata Techpark and Whitefield (at the end of corridor).

Therefore, it is extremely necessary that a Mass Transit System between KR Puram and Airport be provided.

The eastern reach of the East-West corridor which connects Majestic City Centre to Whitefield connects the other extremity of this corridor i.e. at KR Puram. Further the corridor also provides connectivity to under construction Bannerghatta – Nagwara corridor thereby providing airport connectivity to the users of this corridor.

2 Study Area and Existing Conditions

2.1 Study Area Description

Population of Bangalore Metropolitan Area has been growing at the rate of about 3% per annum since independence as shown in **Table 2.1.** The BMA area, which had a population of about 17 Lakh in 1971, reached 85 lakhs in 2011. Bangalore was one of the fastest-growing Indian metropolises for the decade 1991–2011. It has an average density of about 148 people / hectare.

Table 2-1: Growth of Population in Bangalore Metropolitan Area

Year	Population (Lakh)	Decadal Growth (%)	Annual Growth (%)
1971	16.64	37.88	3.26
1981	29.22	75.56	5.79
1991	41.37	41.60	3.54
2001	57.01	37.81	3.26
2011	85.20	49.44	4.10
2018*	122.98		

*Source: Census of India 2011, *Estimated*

As per Census 2011 data, the literacy rate of BMA area is 89.56% which is higher than national urban average of 85% and second highest for an Indian metropolis after Mumbai. The city's workforce structure is predominantly non-agrarian with only 6% of workforce being engaged in agriculture-related activities. Roughly 10% of Bangalore's population lives in slums - a relatively low proportion when compared to other cities in the developing world.

BIAAPA which has been considered in the planning for CMP has picked up pace in development in the recent years. As on 2018, the estimated population in BIAPPA area is about 5.8 lakhs. However, the planning area includes two hoblis namely Jala and Kasba where most of the development in BIAAPA area is existing as on date. The historical population in areas under BIAPPA is presented in **Table 2.2**.

Table 2-2: Population of BIAAPA

S.N.	Years	Population (Lakh)	Decadal Growth (%)	Annual Growth (%)
1	1991	3.28	-	-
2	2001	4.05	19.01	2.13
3	2011	5.00	19.00	2.13
4	2018*	5.78		2.09

*Source: Census of India, *Estimated; The population correspond to whole of BIAAPA area*

Today, the public transport mode share has seen a significant dip from 60% in the early 2000's to 49% today. There is rampant congestion on the street networks, speed studies on 275 kms of key corridors carried out in 2008 showed an average speed of 18 KMPH which declined to 15 KMPH in 2011 and then to 11 kms per hour in 2015.

Bangalore's population is slated to double by 2031 with population growing to 20.9 million as per the estimates considered in the CMP. Transport forecasts of the do minimum estimates only spell doom with almost all streets at overcapacity and network speeds dropping to 4 kms per hour. Modal share of public transport will decline further to low levels as operating buses in congested street networks will turn unviable. The solution hence as per the Comprehensive Mobility Plan is to focus on a comprehensive mass transit network supported by other transport modes as bus (BMTC), para transit modes as auto rickshaw, call taxi/ taxi aggregators etc. To support the ever increasing needs for city transportation, Government in association with Ministry of Railways has planned for sub-urban rail system and is being moved fast for the development and complementing the proposed mass transit network in the city. In this aspect the present corridor is a critical component of the larger transport network that is being considered to ease out mobility issues in the city.

2.2 The Corridor

The corridor is part of the outer ring road of Bangalore which has witnessed a tremendous spurt of IT activity. It runs from K R Puram where proposed Silk Board –K R Puram corridor ends to Kempegowda International Airport via Hebbal. The total length off this corridor is 38 km

Bellary Road has mixed land use pattern with residential, commercial and industrial establishment's bordering the main arterial corridors. Major residential areas include Sahakar Nagar, Anand Nagar, Kempapura, Yelahanka etc. It also houses education institutes such as GKVK, Government Vetinary College, Government Flying Training School, Atria Institute of Technology. The Hebbal Lake is one of the major tourist attractor, located on the eastern side of the Bellary Road.

The stretch from KR Puram to Hebbal has mixed land use pattern. Major residential areas along this corridor include Ramamurthy Nagar, Kalyan Nagar, Nagavara, Thanisandra, Hebbal Kempapura,

There are many major establishments along the corridor. Most important are Manyata Tech park for employment and Yelahanka for residential and industrial development.

Manyata Tech Park

Manyata Embassy Business Park has a workforce of more than 1,50,000 professionals, as of November 2017. Some of the major tenant companies of the tech park are Cognizant, Lowe's, Cerner, Hudson's Bay Company, Harman, Rolls Royce Plc., Mitel, AXA Technologies Shared Services, IBM, Justdial.com, Voonik, GLOBALFOUNDRIES, Larsen & Toubro, NXP Semiconductors, Nokia Networks, Philips, Alcatel-Lucent, Fidelity Investments, Target Corporation, Northern Trust, Nvidia, and AXA.

As part of the integrated development, an 85-acre residential enclave called Manyata Residency is developed behind the tech-park

Yelahanka

Yelahanka lies to the north of Bengaluru. It was a Municipal council and Taluk (lies below the District level in administrative setup) headquarters prior to formation of BBMP (a metro corporation annexing the original Bangalore area and its suburbs) and now forms a part of greater Bengaluru. A well planned township was developed during early 1980s to the north of the city by Karnataka Housing Board and is identified by several names like 'Yelahanka Upanagara', 'Yelahanka Satellite Town', 'Yelahanka New Town' or simply 'Housing Board'.

Yelahanka with improved connectivity has transformed in to and has now become prime real estate hub in North Bengaluru owing to its vast undeveloped areas and easy access to the Kempegowda International Airport. Yelahanka has seen remarkable developments since its inception. Yelahanka zone of BBMP with 11 wards, has registered 5.5L population in 2011 a leap frog jump from earlier 250,000 populations in 2001 and is one of the fastest growing residential and commercial areas in the Bangalore City. The population of Yelahanka zone has increased by more than 110% over that in 2001.

Yelahanka is a traditional place of weavers. The silk handloom has been the lifeline of Yelahanka people for over 2 centuries, and even now in some areas silk saree development can be seen and saree products are being marketed over here. Yelahanka has the largest milk dairy of Karnataka State, known as 'Mother Diary', a processing unit of the state run Karnataka Milk Federation (KMF).

Yelahanka houses the Rail Wheel Factory (formerly Wheel and Axle Plant), a Production Unit of Indian Railways. It is the largest manufacturer of Railway Wheels and Axles and was until recently, also the proprietary manufacturer of these products in India (save the Durgapur Steel Plant, that produces a small quantity of Railway Wheels). Other industry includes Astra Zeneca Pharmaceuticals, Esanosys Technologies, Federal-Mogul Goetze (India) Limited (formerly Escorts Mahle Goetze), Ranflex India Pvt. Ltd. Hobel Flexibles Inc & Sri Pradhyumna Technologies Pvt. Ltd. Leonsoft solutions, R L FINE CHEM, CENTUM ELECTRONICE, PROVIMI, VENKTESWARA CLOTHING UNIT II. There are many large scale commercial developments coming up along the airport road of these notable is North Gate Office Park, Ecopolis IT/ITES SEZ etc.

2.3 Road Network

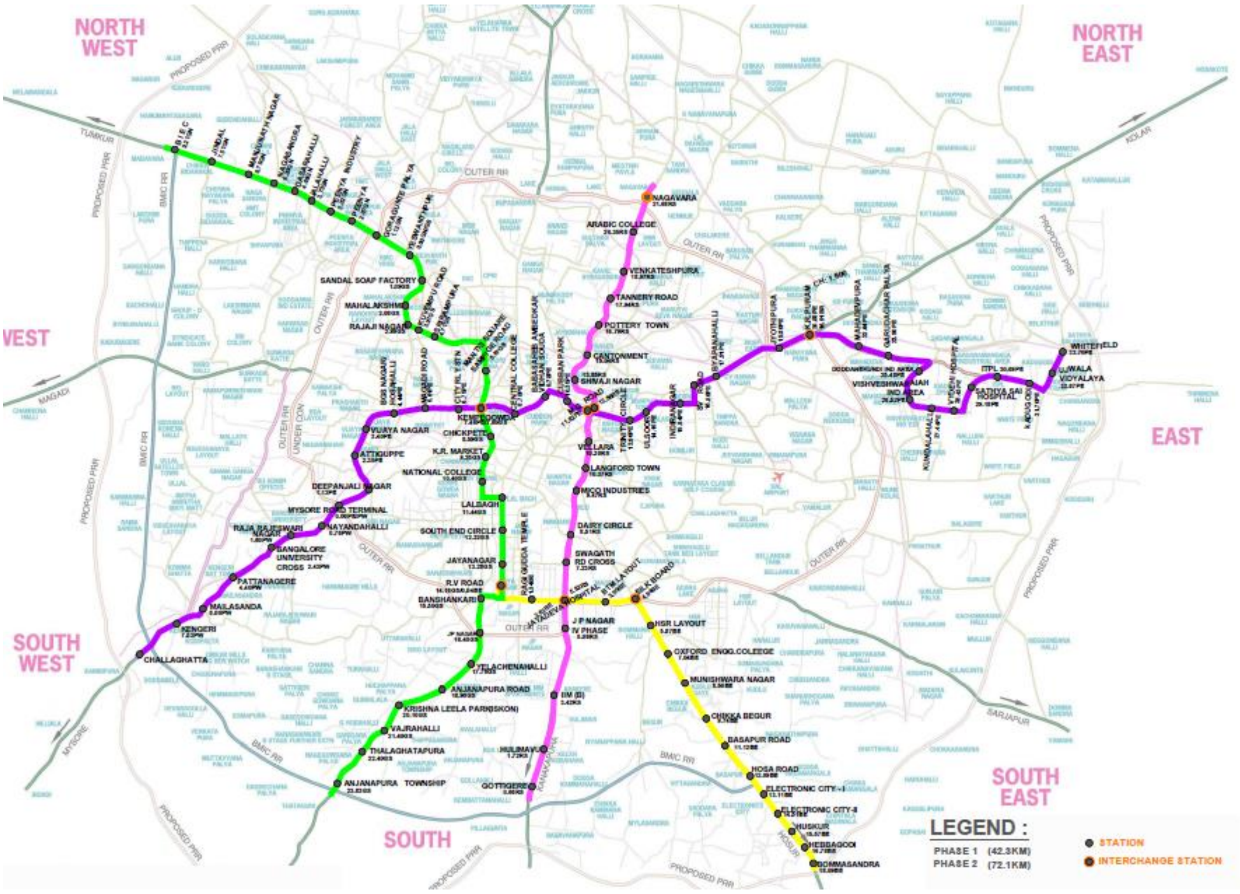
There are distinct characteristics of the road facilities for the section connecting K R Puram and Hebbal and Hebbal to Airport.

KR Puram - Hebbal connectivity is part of Outer Ring Road which has several grade separators to manage traffic at intersections. The present outer ring road has configuration of 3-Lane dual carriageway with service road on both sides of nearly the entire length, however, with the absence of access control facilities, parts of the corridor has interference from adjoining land-use. However, near Hebbal it has a two lane dual carriageway with service roads.

For the Hebbal-Airport connectivity, there are few more links in the vicinity, however there is no important arterial category road which has good right of way. With this, the only major connectivity is along NH 44 which has 6-Lane elevated/access controlled road with another 6-Lane at-grade facility and service road for substantial part of the corridor.

2.4 Existing Transit Service

The existing public transport service in the city is run by BMTC for the bus services and BMRCL for the metro services. The bus services run by BMTC are spread all over the city while the metro rail services run by BMRCL is at present limited.



Source: BMRCL

Figure 2-1: Metro Phase 1 and Phase 2 Corridors

Bus system operated by BMTC has been the primary public transport system in Bangalore City. BMTC has established 45 depots for providing services in the city. BMTC is operating 6143 schedules (as on Aug 2018) every day. The fleet size operated in the city per lakh population is as below:

Year	Population	BMTC Bus Fleet Size	Buses Per Lakh Population
2001	61.9	2658	43
2011	90.44	5949	66
2018	122.98	6143	50

The Phase 1 corridors of metro are under operation catering to an average daily ridership of 4.5 lakhs and peak daily ridership of 4.8 lakhs. Further to the operationalization of Metro in two corridors (Phase 1), work on Phase II in progress. The details of Metro corridors existing and under construction in the city is as below:

Sl. No.	Corridor	Length (km)	Status
Phase 1			
1	Baiyappanahalli to Mysore Road (East – West Corridor- Purple Line) (R1 & R2)	18.1	Operational
2	Nagasandra to Yelachenahalli (North- South Corridor- Green Line) (R3 & R4)	24.2	Operational
Phase 2			
1	N-S Line Extension from Puttenahalli Cross to Anjanapura Township (R 4B)	6.29	Construction in progress
2	N-S Line Extension from Hesarghatta Cross to BIEC (R3C)	3.77	Construction in progress
3	E-W Line Extension from Baiyappanahalli to ITPL- Whitefield (R 1A, R 1B)	15.5	Construction in progress
4	E-W Line Extension from Mysore Road Terminal to Kengeri (R2A , R2B)	6.465	Construction in progress
5	New N-S Line IIMB to Nagawara (R6)	21.25	Construction in progress
6	New E-W Line to R.V.Road to Bommasandra (R5)	18.82	Construction in progress

The on-going expansion in the form of electronic city corridor and the proposed corridors 2A & 2B (connecting Silk Board with Airport via K R Puram and Hebbal) will bring major work centers in the city accessible through Metro.

2.5 The Land-Use

2.5.1 Proposed Land-Use in Planning Area

Table 2-3 presents the proposed land use for the LPA.

Table 2-3: Land Use Area Statement

Landuse Category	Area (Sq.km)	% To Total Developable Area
Residential	450.69	37.34
Commercial	27.88	2.31
Industrial	44.90	3.72
Public & Semi Public	58.66	4.86
Public & Semi Public - Defense	43.12	3.57
Public Utility	4.32	0.36
Parks / open spaces	29.71	2.46
Transport & Communication	120.77	10.01
Forest	4.71	0.39
Water Bodies and Streams	40.75	3.38
NGT Buffer	76.36	6.33
Total Developable Area	***901.87***	***74.73***
Agriculture Zone	305.05	25.27
Total	**1206.92**	**100.00**
BMICAPA	79.14	-
Jala & Kasba Hobli	227.85	-
Total Conurbation Area	**1513.91**	-

3 Conceptual Transportation Alternatives

During the last decade, the urban sprawl in Indian cities has extended far beyond the city jurisdiction limits resulting in high usage of private modes. Despite substantial efforts, cities are facing difficulty in coping with increase of private vehicles along with improving personal mobility and goods distribution.

National Urban Transport Policy (NUTP) emphasizes on person's mobility to achieve cost-effective and equitable urban transport measures within an appropriate and consistent methodology. Accordingly, Comprehensive Mobility Plan (CMP) document lays out a set of measured steps that are designed to improve transportation in the city in a sustainable manner to meet the needs of a growing population and projected transport demand.

The vision of the Comprehensive Mobility Plan for Bengaluru is to achieve "Efficient and Sustainable Transportation for All", with a system that serves to help fulfil the economic and social needs of residents and visitors.

The strategic framework for efficient and sustainable transport has been formulated in CMP considering following strategies:

- Strategy 1: Expand reach and augment capacity of public transport systems
- Strategy 2: Improve operational efficiency of public transport systems
- Strategy 3: Promote multi-modal mobility options
- Strategy 4: Promote Transit Oriented Development
- Strategy 5: Improve efficiency of road infrastructure
- Strategy 6: Augment capacity of road infrastructure
- Strategy 7: Make commuters bear full cost of externalities of mobility modes
- Strategy 8: Influence mobility choice through regulatory, fiscal and pricing measures
- Strategy 9: Promoting use of electric and cleaner fuel vehicles
- Strategy 10: Establish mechanism for planning, capacity building and accountability

3.1 Primary Public Transport Network as Proposed by CMP

Selection of a particular mass transit system for a city largely depends on the characteristics of the city and its metropolitan area, the projection of traffic demand for transit travel and the availability of suitable right-of-way (ROW) among others.

High and medium capacity public transport systems have been conceived in CMP. The proposed corridors for developing mass transit systems are presented in **Figure 3-1.**

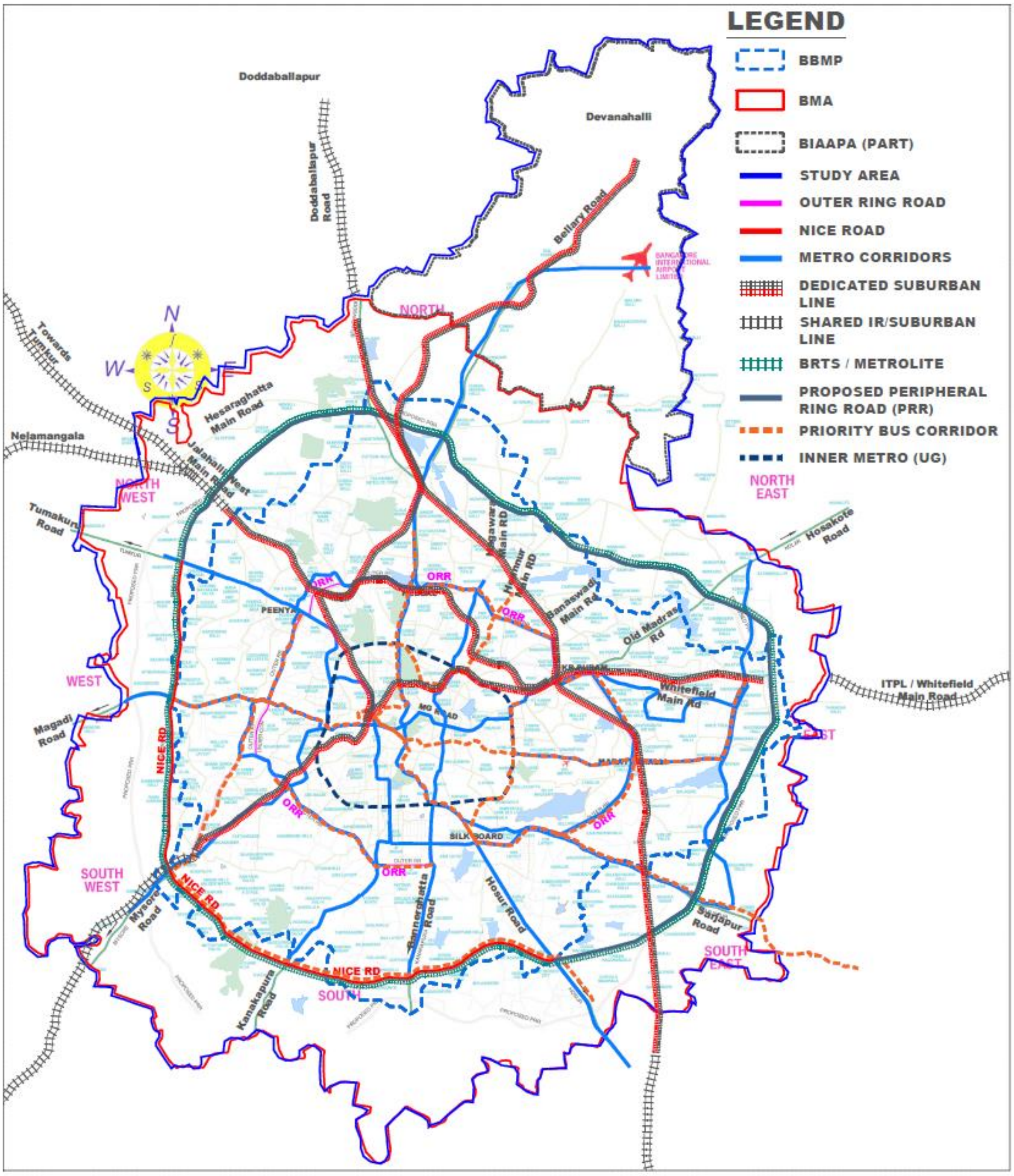


Figure 3-1: Public Transit Network

The proposed K R Puram to Airport section would be a crucial link in the overall mass transit system development in the city and improved connectivity to Airport.

3.2 Alternative Route Alignment

The following are 4 different alternatives through which the metro line can be taken from Nagawara to Airport. The section between K.R. Puram and Nagwara will follow the outer ring road.

Table 3-1: Four Options from Nagawara to Airport

1	Alternative 1	Nagawara – RK Hegde Nagar – Jakkur – Yelahanka– Kogilu Cross – Chikkajala – Trumpet – Airport (This route mainly traverse along the National Highway(44)
2	Alternative 2	Nagawara – RK Hegde Nagar – Bellahalli – Yellahanka - NH44 – Chikkajala – Trumpet Airport
3	Alternative 3	Nagawara – RK Hegde Nagar – Bellahalli – Sathanur – Bagalur – Myalanahalli – Begur –Airport
4	Alternative 4	Nagawara – RK Hegde Nagar – Bellahalli – Kannur– Bagaluru – Mylanahalli – Begur – Airport

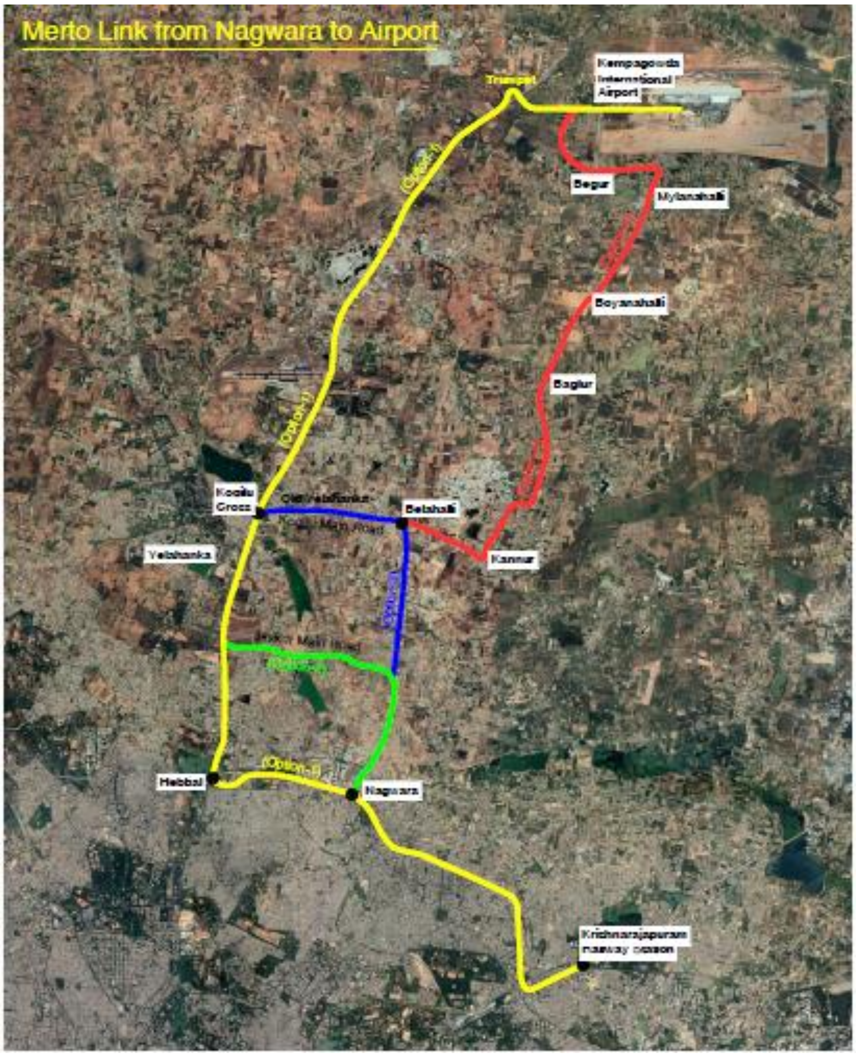


Figure 3-2: Alternative Route Alignments

3.2.1 Description of Alternatives

The description of 4 Alternatives considered is discussed in following paragraphs.

Alternative 1: Nagawara to Airport via Jakkur and Chikkajala

This line starts from Nagawara and comes up to RK Hegde Nagar and from RK Hegde Nagar it takes a left turn and goes on the median of the 100 feet road and reaches NH44 at Jakkur. At Jakkur, it takes a right turn and goes all along NH44 up to the Trumpet and from the Trumpet it goes in the middle of the main road connecting the Airport. On this route, metro stations would be RK Hegde Nagar, Jakkur, Yelahanka, Chikkajala and Airport.

Alternative 2: Nagawara to Airport via Bellahalli

This line starts from Nagawara and comes up to RK Hegde Nagar from where it goes straight up to Bellahalli cross. At Bellahalli cross, it takes a left turn and goes on the Kogilu Main Road. It reaches Old Yelahanka and at Kogilu it takes a right turn and then goes all along NH 44 just like in option No.1.

Alternative 3: Nagawara to Airport via Sathanur and Mylanahalli

The line starts from Nagawara and comes up to RK Hegde Nagar and from RK Hegde Nagar it goes straight and at Bellahalli cross it goes up to Sathanur, at Sathanur it takes a right turn and goes up to Bagaluru. At Bagaluru it takes a left turn and goes all along the road up to Mylanahalli. At Mylanahalli the line would take a left turn and near Begur village the line would make a U-turn and join the road connecting the International Airport.

Alternative 4: Nagawara to Airport via Kannur and Begur

Starting from Nagawara, the lines goes up to RK Hegde Nagar and then straight to Bellahalli and at Bellahalli cross it takes a right turn and goes up to Kannur. From Kannur the line take a left turn and goes straight on the Bagalur road, passes through Bagalure and reaches Mylanahalli. From Mylanahalli it reaches the International Airport as described in the Option No.3.

3.2.2 Comparative Analysis of all the Alternatives

- The land acquisition requirement for Alternative 1 is very minimal and BMRCL may have to acquire land at Yelahanka town and at Hebbal for construction of stations.
- The National Highway has already reserved 5.0 metres width of land which starts near Hebbal and goes up to Trumpet for the development of mass transit system. This land has been acquired on the request of the State Government for putting a High Speed Metro line to the Airport. Thus, in this option, the land is readily available for a large section and work can commence in between Hebbal to Trumpet without any delay
- Alternative 1 would provide connectivity to Yelahanka Town which happens to be a very important and highly populated area which so far as not been connected to the metro line.
- The Alternative 2 and 3 would run through areas which are not as developed as Yelahanka and almost half the route has good potential for development, but currently very little development exists.
- The Alternative 3 has engineering issues as a gas pipeline for a considerable section.

- Alternative 4 runs on virgin land from R.K. Hegde Nagar to Airport. Land needs to be acquired.
- Hence Alternative 1 is the fastest and most suitable option in connecting the Airport.

3.2.3 Most suitable route Alternative

The Alternative 1 is the most suitable route for taking mass transit system from the point of view of connectivity (connects important areas along the route), practical feasibility (minimal land acquisition) and is also part of the network as proposed in the CMP.

3.3 Public Transit System Alternatives

The Mass transport systems could be rail based consisting of Metro Lite or Metro Rail systems or Heavy Metro, and road based such as BRT or Normal Buses including a guided tyre based system the Monorail. A characteristics summary of these public transport modes has been compiled in **Table 3-2**. The various public transportation modes along with associated advantages are detailed below:

3.4 Public Transit System Alternatives

The Mass transport systems could be rail based consisting of Metro Lite or Metro Rail systems or Heavy Metro, and road based such as BRT or Normal Buses including a guided tyre based system the Monorail. A characteristics summary of these public transport modes has been compiled in **Table 3.1**. The various public transportation modes along with associated advantages are detailed below:

3.4.1 Normal Buses on Shared Right of Way

Normal/ordinary bus system is the main transport system in many major Indian cities. The public transport services in the City are generally operated by the State Governments or local Governments. They are normally characterized by sharing the common Right of Way with other modes of transport in the city. Ordinary buses normally act as a feeder mode of transport in metropolitan cities to mass rapid transit systems such as Metro System, Heavy Metro etc.

Advantages

- Very low Capital and O&M costs
- Highly flexible
- City wide coverage
- Easy to implement among all modes

Constraints

- Very low capacity
- Low speeds and frequent delays
- Frequent breakdowns
- Higher pollution compared to other modes

3.4.2 Bus Rapid Transit

Bus Rapid Systems are bus-based public transport system designed to improve capacity and reliability

relative to the conventional bus system. Typically, this system includes roadway that has dedicated lanes for high capacity buses, and gives priority to buses at intersections where buses may interact with other traffic; alongside design features to reduce delays caused by passengers boarding or leaving buses, or purchasing fares. The system aims to increase the capacity and operating speed with the flexibility, lower cost and simplicity of a bus system.

Advantages

- Capital costs lower than rail based systems
- Lower O&M costs
- Higher capacity than ordinary bus services
- Relatively simple technology and availability of manpower for O&M

Constraints

- Capacity not as high as rail based systems
- Inflexible as stopping at fixed bus stops
- More polluting than rail based systems
- Needs urban road space for dedicated corridors

3.4.3 Monorail

The monorail is a system that runs on a single guideway and is a tyre mounted system. The first monorail in India has been built in Mumbai. The system has a carrying capacity of about 15000 people and due to its tyred wheels can take steep gradients.

Advantages

- Carrying capacity of about 15,000
- Does not need too much ROW
- Can be operated as an elevated or can run with the Beam at grade
- Comfortable and safe PT system

Constraints

- Capital costs high
- Operating costs higher than bus systems
- Carrying capacity lower than metro system
- Needs extensive feeder systems for last mile connectivity
- Will need large chunk of urban land for maintenance depot
- Systems are to be imported in the initial stages

3.4.4 Metro Lite System:

Metro Lite system is similar to light rail transit which is popular system in large number of European countries. Metro Lite system proposed in Indian context is generally an at-grade system with dedicated corridor segregated from traffic thus these can only be provided where ample right of way is available. MoHUA have come-up with guidelines and specifications for the system in Indian context. This system with its characteristic of lower turning radii requirement, can be proposed through internal road system with adequate right of way. The Metro Lite system is expected to cater to the travel demands of 2000 PHPDT to 15,000 PHPDT. The capacity of at-grade system is highly depended on the intersection control. If the road intersections are congested, the development of Metro lite as at-grade system will be a challenge. In this scenario, grade separation of Metro Lite may be considered.

Exclusive right of way for Metro Lite allows the trains to run at higher speeds, however this depends on the number of intersections and traffic at these intersections. Automated and advanced signal system would be required if the higher capacity as depicted above is to be achieved.

Advantages

- Capital cost is generally less than metro system
- Needs similar urban road space compared to BRT System
- No pollution as system operates on electricity
- Comfortable and safe PT system as Metro system except for the passenger crossings and open shelters

Constraints

- Capital costs higher than bus system
- Operating costs higher than bus systems
- Needs substantial urban space if proposed at-grade
- Carrying capacity is significantly lower than metro system
- Will need large chunk of urban land for maintenance depot
- System required to be imported No indigenous availability in Indian conditions

3.4.5 Metro Rail Systems:

Metro Rail system is most prevalent mass transit system adopted worldwide. In India, metro rail is operational in various cities viz. Delhi, Kolkata, Mumbai, Bangalore, Kochi, Jaipur etc. It is a grade-separated system with exclusive right of way characterized by short distances of stations spaced at about 1 km and modern state of the art rolling stock having high acceleration and deceleration with maximum design speed of 80-90 kmph. Sharpest curve of 120 m radius is permitted for Metro. The system can be designed to meet the peak hour peak direction traffic (PHPDT) carrying capacity from 20,000 to up to 60,000 depending upon the type of systems and infrastructure adopted such as rolling stock, train set configurations, signaling system, stations platform length etc.

Advantages

- Serves Maximum peak hour peak directional traffic among all modes
- Very high carrying capacity
- Needs very little operational urban space
- High operating speed
- No pollution as system operates on electricity
- Comfortable and safe PT system leading to improved city image

Constraints

- Long gestation period
- High capital cost

- High operating cost per passenger
- Inflexible as stopping at fixed stations
- Needs extensive feeder systems for last mile connectivity
- Will need large chunk of urban land for maintenance

3.4.6 Heavy METRO System

The heavy Metro has a very heavy carrying capacity making it suitable for high density sections with travel demand more than 40,000 PHPDT. The system can operate on broad gauge or standard gauge, however the systems available in India are made for broad gauge operations. Generally, the coaches are wider and longer to accommodate higher number of passengers. The technology is available in India and the entire system could be built in India. However, the section required for elevated or underground development will be larger compared to Metro and hence would be expensive. The system also requires more generous radii at curves to enable the system negotiate safely at desired speeds. This will require comparatively higher land acquisition for the corridor as well as for depot and thus could be a costly proposition.

Advantages:

- Serves Maximum peak hour peak directional traffic among all modes
- Very high carrying capacity
- High operating speed
- No pollution as system operates on electricity
- Comfortable and safe PT system

Constraints

- High Capital costs
- Needs higher urban space (Land acquisition)

Table 3-2: Comparison of Various Mass Transport Options

Transit Mode	Heavy Metro	Metro	Monorail	Metro Lite	BRT
Exterior of Vehicle					
Description	Heavy Metro similar to Metro but with higher carrying capacity and thus higher axle load. Generally considered for very high density corridor	Most prevalent worldwide Mass Rail Transit System (Metro)	The monorail is a system that runs on a single guideway and is a tyre mounted system	It is a transport system that runs on elevated or at grade track	It is a bus operation generally characterized by use of exclusive or reserved rights-of-way (bus ways) that permit higher speeds and avoidance of delays from general traffic flows
ROW Options	Exclusive ROW Grade Separated	Exclusive ROW Grade Separated	Exclusive ROW Grade Separated	Exclusive ROW Semi-exclusive Mixed traffic lanes	Exclusive ROW Semi-exclusive Mixed traffic lanes
Station Spacing (Approx.)	1-2 Km	1-2 Km	0.7 Km to 1.5 Km	0.7 Km to 1.5 Km	0.7 km to 1.0 Km

Transit Mode	Heavy Metro	Metro	Monorail	Metro Lite	BRT
Vehicles	High platform cars operating in multiple car trains sets	High platform cars operating in multiple car trains sets	High platform cars operating in multiple car trains sets, electric propulsion	Articulated, double articulated low floor can operate in multiple car sets, electric propulsion	Standard, articulated double articulated low or high platform cars diesel/hybrid propulsion, Electric Trolley Bus
Capacity	360-400 per car	315-345 Per Car	50-120 Per Car	Upto 300 Per Car	80 per Bus
Average Speed	35 Kph	35 Kph	30 Kph	30 Kph	25 Kph
Passenger Throughput	30,000 PHPDT to 90,000 PHPDT	20,000 PHPDT to 60,000 PHPDT	Up to 15,000 PHPDT	2,000 to 15,000 PHPDT	Up to 8,000
Min. Curve Radius	220 m	120 m	25 m	25 m depot	12 m
App Capital Cost per km	220-300 Crore Rupees	Rs 180 - 250 Cr/km (Elevated) & 450 - 500 Cr/km (Underground Section)	160-180 Crore Rupees	120-180 Crore Rupees	60 Crore Rupees 110-140 Crore (Elevated)
App O & M Cost per km	350-450 lakh Rupees	300-400 Lakh Rupees	150-200 Lakh Rupees	150-200 Lakh Rupees	300-600 Lakh Rupees

Source: Compilation of information available from BEML, and studies for various public transit system projects (Mumbai Mono Rail, Delhi LRT Study, Delhi Metro, Mumbai Metro, Hyderabad Metro, Nagpur Metro, Pune Metro and other studies)

3.5 Constraints

The ridership prediction on this corridor for the cardinal years is presented in Table 3.3 and the daily boarding and alighting is presented in Table 3.4. The figure suggests that only a higher order mass transit system would be able to cater to the demand. Hence it may be appropriate to consider a metro or a Heavy Metro.

Table 3-3: Peak Hour Peak Direction Traffic

Station		PHPDT - 2024			PHPDT - 2031			PHPDT - 2041		
From	To	Forward	Reverse	Maximum	Forward	Reverse	Maximum	Forward	Reverse	Maximum
K R Puram	Kasturi Nagar	11,691	12,310	21,112	20,456	19,502	35,705	26,498	25,263	46,252
Kasturi Nagar	Horamavu	15,606	16,122		20,406	19,413		26,434	25,147	
Horamavu	HRBR Layout	20,270	20,472		26,628	27,685		34,494	35,863	
HRBR Layout	Kalyan Nagar	20,545	20,751		34,332	34,987		44,473	45,322	
Kalyan Nagar	HBR Layout	21,112	20,901		34,782	35,019		45,056	45,363	
HBR Layout	Nagawara	15,792	15,022		35,705	35,273		46,252	45,692	
Nagawara	Veeranna Palya	16,094	14,957		27,001	26,221		34,977	33,966	
Veeranna Palya	Kempapura	16,195	14,922		27,294	26,143		35,356	33,865	
Kempapura	Hebbal	18,425	18,242		27,592	26,100		35,742	33,810	
Hebbal	Kodigehalli	15,001	15,166		32,557	32,235		42,174	41,757	
Kodigehalli	Jakkur Cross	10,218	10,427		25,832	26,916		33,462	34,867	
Jakkur Cross	Yelahanka	9,823	10,114		19,645	20,228		25,448	26,203	
Yelahanka	Bagalur Cross	10,292	10,382		16,467	17,650		24,026	25,751	
Bagalur Cross	Bettahalasuru	9,191	9,460		17,462	17,975		25,478	26,226	
Bettahalasuru	Doddajala	7,505	7,234		14,260	13,744		20,806	20,053	
Doddajala	Airport City	6,613	6,508		12,564	11,063		18,331	16,142	
Airport City	KIA Terminals	6,171	6,113		11,724	10,392		17,106	15,162	

Table 3-4: Boarding and Alighting at Stations

Stations	Daily 2024		Peak 2024		Daily 2031		Peak 2031		Daily 2041		Peak 2041	
	Board	Alight	Board	Alight	Board	Alight	Board	Alight	Board	Alight	Board	Alight
K R Puram	51,983	54,737	11,691	12,310	89,845	94,604	20,456	19,502	1,16,398	1,22,549	26,498	25,263
Kasturi Nagar	13,794	13,808	3,449	3,452	22,924	22,947	5,731	5,737	29,695	29,726	7,424	7,431
Horamavu	12,790	12,823	3,198	3,206	25,507	25,572	6,377	6,393	33,041	33,125	8,260	8,281
HRBR Layout	14,488	14,690	3,622	3,672	28,893	29,295	7,223	7,324	37,427	37,949	9,357	9,487
Kalyan Nagar	19,777	18,202	4,944	4,551	32,582	31,476	8,145	7,869	42,206	40,885	10,551	10,221
HBR Layout	17,811	17,099	4,453	3,775	40,271	38,661	10,068	9,665	52,166	50,081	13,042	12,520
Nagawara	50,470	51,489	12,618	12,872	77,165	78,723	19,291	19,681	99,959	1,01,976	24,990	25,494
Veeranna Palya	19,535	19,375	4,884	4,344	32,923	32,653	8,231	8,163	42,648	42,298	10,662	10,575
Kempapura	24,013	23,907	6,003	5,727	35,960	35,802	8,990	8,576	46,583	46,377	11,646	11,109
Hebbal	60,987	60,745	15,247	15,186	1,05,406	1,04,988	26,352	26,247	1,36,542	1,36,000	34,135	34,000
Kodigehalli	20,228	20,511	5,057	5,128	51,137	51,853	12,784	12,963	66,243	67,170	16,561	16,793
Jakkur Cross	16,699	16,499	4,175	4,125	40,345	39,862	10,086	9,966	52,263	51,637	13,066	12,909
Yelahanka	30,647	29,138	7,662	7,285	58,526	55,644	14,631	13,911	75,813	72,081	18,953	18,020
Bagalur Cross	8,382	8,540	2,095	2,135	25,145	25,619	6,286	6,405	36,688	37,379	9,172	9,345
Bettahalasuru	8,048	7,551	2,012	1,888	24,145	22,652	6,036	5,663	35,228	33,050	8,807	8,263
Doddajala	5,365	5,774	1,341	1,443	16,096	17,321	4,024	4,330	23,485	25,272	5,871	6,318
Airport City	10,842	10,230	2,711	2,558	32,527	30,691	8,132	7,673	47,458	44,780	11,864	11,195
KIA Terminals	48,113	48,629	6,113	6,171	96,225	97,259	10,392	11,724	1,40,396	1,41,903	15,162	17,106
Total	**4,33,973**	**4,33,747**			**8,35,623**	**8,35,623**			**11,14,240**	**11,14,240**		

Considering the general / maximum capacities of various systems as described in the previous section, only metro and heavy metro will be able to cater to the ridership and PHPDT of the proposed corridor. Other systems as, BRT, Metro Lite or mono rail do not cater to the passenger demand expected on this corridor even in the initial years and thus would not contribute to the sustainable transportation solution for the corridor.

4 Screening Criteria for the identified Alternative Options

This chapter discusses the initial screening and short listing of the options that would be taken up the detailed evaluation. The parameters and criteria for the detailed evaluation also presented in this chapter.

4.1 Screening Parameters

Screening of alternative modes needs to be done to shortlist most viable alternatives for Phase 2 mass transit corridors in the Study Area. The screening parameters for alternatives evaluation are considered with regard to mobility improvements, engineering feasibility, environmental benefits, cost effectiveness, operating efficiencies and economic effects. The basic framework for screening and evaluation of the alternatives includes:

- **Effectiveness** – the extent to which each alternative meets established goals and objectives, including transportation and sustainability goals
- **Impacts** –the extent to which the project supports economic development, environmental or local policy goals
- **Cost effectiveness** – to show the trade-off between the effectiveness of an alternative and its capital and operating costs
- **Economic feasibility** – the ability to obtain the economic benefits for the society
- **Equity** – the distribution of costs and benefits

4.1.1 Goals & Objectives

The basic goals and objectives have been identified to establish the screening criteria that satisfy the project purpose and need. The basis for evaluation allows the benefits and impacts of each alternative to be measured with an objective set of criteria that relate to the specific needs for the project. For each identified goal, a set of objectives have been identified and listed in **Table 4.1.**

Table 4-1: Goals and Objectives to be Satisfied By Alternative Modes

S. N.	Goals	Objectives
1	Improve mobility for travel	• Provide more transportation choices, especially for transit dependent groups such as low & middle income and the aged to jobs, housing and other trip purposes. • Provide high-quality transit service for local trips between employment generating zones as well as core study area • Increase transit ridership and mode share for public transport trips • Establish a more balanced transportation system which enhances modal choices and encourages walking, bicycle and transit use • Improve mobility to the transportation Hub (Airport)
2	Contribute to and serve as a catalyst for economic development	• Encourage transit-oriented mixed-use development along the corridors that would support population and employment growth along the corridor • Reinvest in the local economy by maximizing the economic impact of transportation investments as related to land use redevelopment, infrastructure improvements, and housing • Support regional economic development initiatives • Incorporate considerations into new development design that support transit as a transportation option
3	Enhance livability, reuse and long-term environmental benefit	• Minimize adverse air, land and water environmental impacts of transportation investments • Conserve transportation energy • Serve households at all income levels • Support lifestyle choices for environmentally sustainable communities. • Implement strategies for reducing transportation-related greenhouse gas emissions. • Promote green and sustainable technologies and solutions that enhance economic development opportunities.

S. N.	Goals	Objectives
4	Improve the image and identity of the residential, commercial, and industrial areas through infrastructure improvements	• Support private investments in transit friendly, and pedestrian and bicycle-focused developments • Support improvements in neighborhood connectivity through attention to safety, comfort and aesthetics in the design of transportation infrastructure • Serve areas of and complement initiatives for affordable housing.

4.1.2 Basis for Identification of Screening Criteria for Alternatives

Considering the goals and objectives, the parameters across various transportation modes are identified for initial screening and further detailed evaluation. Available transportation modes have been screened initially such as need to serve the travel demand, constructability, cost and right of way etc. to shortlist the modes and in a quantitative and detailed way among the shortlisted alternatives such as estimation of traffic figures, civil engineering effects, capital, operation & maintenance cost etc. to result in the most viable alternative for the Phase 2 corridors.

4.1.3 Screening of Alternatives

The screening analysis of qualitative parameters will focus on eliminating the alternatives that are not feasible for the city corridors. The factors considered for this screening are as follows:

- The mode will fail to meet the project identified goals and objectives
- Do not fit with existing local, regional programs and strategies, and do not fit with wider government priorities (e.g. national programs for livability and sustainability); and,
- Would be unlikely to pass key viability and acceptability criteria (or represent significant risk)

Five alternative mass transit systems catering to the needs of a city have been considered for the initial screening stage with the set of identified qualitative parameters:

i. Bus Rapid Transit System
ii. Mono Rail
iii. Metro Lite
iv. Metro System
v. Heavy Metro

The preliminary observation (CMP) and screening identifies that the traffic demand in this corridor is for a higher capacity mass transit system (Section 3.4).

4 route choices have also been studied (**Figure 3-2).** A preliminary observation suggests that land constraints and some engineering issues restrict the option to only one. The selected route has very

minimal land issues and hence is selected. Also the selected option is in line with the overall network plan as put forward by the CMP.

4.2 Evaluation Parameters

The evaluation has been carried out over many key parameters that help in selection of the most suitable system for the corridor. They are

Mobility Effects - Primary purpose of this task is to assess the current travel demand for base year, with available future year land use data as documented in CMP. Mobility effects also cover the identified modes utilization and its connectivity.

Conceptual Engineering Effect - Engineering effects have been considered for civil aspects of alternatives. To refine the range of alternatives to relate the differences between options, all feasible alternatives have been compared including those as identified in CMP.

System Effects - The indigenous availability of rolling stock, carrying capacity, type of operation, safety, comfort, land availability for depot, are the system related characteristics which are considered.

Environmental Effects - The purpose of preliminary environmental analysis is to identify environmentally sensitive areas early on, so that these areas can be avoided if possible during design. A screening-level analysis has been conducted to determine the potential environmental impacts of each alternative identified.

Social Effects - The analysis has been conducted to determine the potential social impacts of alternatives.

Cost Effectiveness & Affordability - The capital cost and annual costs associated e.g. operation & maintenance costs etc. for each alternative have been evaluated. Preliminary costs have been estimated based upon conceptual engineering for alternatives selected for evaluation.

Financial and Economic Effects – Financial plans, economic benefits and costs associated with the project have been identified and quantified for identification of optimum solution along with economic viability.

Other Factors - Approval & Implementation - The mass transport system to be introduced will require technology and set of components well established and proven so that statutory approvals and implementation of system do not result in time delays and cost implications. Established systems already in place in India will require less time for processing of approvals and would be easy to implement.

These have been broken down further to their sub components and discussed below

4.2.1 Mobility Effects

Travel Demand Forecasting:

The system selection will largely depend on the transport demand. The travel demand forecast for the corridor estimated based on the developed conventional 4 stage transport model. For the purpose, following tasks have been performed. However, the assessment was done based on the calibrated model as part of the Master Plan Development for Bangalore 2031.

a. Development of trip matrices through House hold surveys
b. Development of a base year road and public transport network.
c. Calibration of a distribution and mode choice functions.
d. Preparation of road and transit networks for the sustainable alternative and a no-project (without project) scenario
e. Summarizing the travel demand results for base and horizon years, peak hour peak direction trips, daily system utilization (passenger km per route km) and estimating reduced number of vehicles on road due to proposed mass transit network
f. Ease of passenger transfer between the proposed alternative modes in terms of time and convenience
g. Analysis of differences among the various alternatives to provide information to Environmental Assessment

4.2.2 Conceptual Engineering Effect

i. *Available Right-of-Way (Land Acquisition)*

a. Civil engineering alignment plan has been prepared with horizontal and vertical profiling giving the arrangement of system structures along the Right of Way with an estimation of land required. For rail based mass transit systems, land might be required for construction of viaduct, at stations and also for depots. For elevated road based systems land would be required for viaduct construction, bus stops and for maintenance / repair activities at depot.

b. The road space has been identified which will be occupied by station (either underground or elevated) and the project permanently/temporarily.

ii. Alignment Design and Constructability

Alignment criteria have been considered for the shortlisted modes considering existing/proposed infrastructure, integration with other modes of transport, availability of RoW, land for ramp and options for depot. Overall ease of construction has also been compared.

Geometric Parameters consisting of basic design criteria, parameters relating to horizontal and vertical design profiles plays an important role with respect to the existing local conditions.

iii. Geotechnical Characteristics and Civil Structures:

Study of Soil characteristics of the area is necessary for construction of a new transport system. Geotechnical condition of the area has major impact on the design of foundations. Hence, At-grade systems have less impact as compared to elevated or underground systems.

iv. Station Planning and Intermodal Integration:

Intermodal integration along with provision of adequate parking spaces at stations plays an important role in providing last mile connectivity and boosting the ridership patronage. The meticulous planning of stations and intermodal integration for organized passenger movement and modal shifts will go a long way in providing convenient passenger transfers and betterment in patronage.

v. Requirement for Utility Shifting

Conception and implementation of a new transport system impacts the location of existing surface/underground utilities. At-grade systems cause less impact to utilities' shifting as compared to elevated or underground systems. The quantity and type of utilities to be shifted has considerable impact on the design efforts and costing.

4.2.3 System Effects

i. Interoperability with Phase-1 System

The interoperability between proposed Phase 2 and existing Phase I is an important parameter. The system can have better system efficiency, optimized use of system resources and enhanced passenger comfort if existing system is continued.

New mass transit modes on the extension of existing corridors may require entirely new set of infrastructure facilities for operation and maintenance. The small stretches of Phase 2 extensions spread over multiple part of the study area may require several O&M facilities for modes other than that of Phase I.

ii. Rolling Stock Requirement

The efficiency of the mass transport systems depends upon the minimum headway on which the system can be operated and the total rolling stock/fleet required for operational purposes. Both Metro and Heavy Metro systems can have same minimum possible headway, whereas Heavy Metro requires less rolling stock than Metro. Metro Lite and Mono Rail or BRT requires a large fleet to cater to the projected demand.

iii. Land for Maintenance Depot

Land in bulk amount is required within city limits for maintenance activities of rolling stock and allied facilities for the rail based system. Availability of land is an important factor in identification of mode. Since, metro rail is already under construction in Bangalore, the proposed Phase 2 can use the existing depots whereas in case of other systems, construction of new depots will be required at each end of the proposed extensions. In case of BRT, the required depots may be less but the dead mileage of operating the buses would be expensive.

iv. Indigenous Availability

Availability of rail coaches/buses is also an important factor as it has time delays and cost implications. With several operational metro rail systems in India various components like track, civil structures and rolling stock components have been standardized. Efforts have been taken by Government and Metro rail implementing agencies for taking a step towards indigenizing the metro rail systems. Whereas, in case of other rail based transport, these have to be taken afresh resulting in delay and cost implications.

4.2.4 Environmental Effects

The purpose of environmental analysis is to identify sensitive areas early on, so that these areas can be avoided if possible during design.

Air & Noise Pollution

Public transport can relieve traffic congestion and reduce air / noise pollution generated from use of personalized road transport. The use of public transport must be encouraged under sustainable transport policy. Rail based systems are advantageous and cause less pollution as compared to road based system on account of usage of electric power. Buses on the other hand use CNG, but still are more polluting than rail based systems.

4.2.5 Social Effects

Preliminary social impacts in terms of structures / persons affected have been estimated for each of the alternatives.

Structures/Persons Affected

The alignment for the mass transport system proposed in the city results in relocation of a number of structures/persons. This is a sensitive part of the project regarding land acquisition resulting in rehabilitation and resettlement of project affected families and compensation payment.

4.2.6 Cost Effectiveness & Affordability

i. Capital Cost

The mass rapid transport systems are capital intensive initiatives. It is the total capital required per passenger km for the project consisting of land, alignment and formation, station buildings in case of rail based systems, traction and power supply systems, rolling stock, signaling & telecommunication, environmental and social costs, intermodal integration, general charges etc with respect to total passenger km.

ii. O&M Cost

Operation and maintenance of a transport system requires cost and manpower on a daily basis across the operational years. The cost required for this purpose shall be an important factor in identification of mode in addition to other parameters. Since, India has limited or no experience for Metro Lite system or Mono Rail; the maintenance personnel may find difficulties in maintaining the rolling stock/subsystems. This may increase the maintenance cost during operation.

4.2.7 Financial and Economic Effects

Public and private funding options have been considered in developing the plan. Benefits and costs associated with the project have been quantified.

i. Economic Returns

Implementation of a dedicated mass rapid transit system will result in reduction of number of private vehicles on the road and increase in journey speed of road- based vehicles. This is expected to generate substantial benefits to the economy as a whole in terms of reduction in fuel consumption, vehicle operating costs and passenger time. In addition, there will be reduction in accidents and atmospheric pollution. Other benefits include reduction in noise, increase in mobility levels, improvement in quality of life and general economic growth.

ii. Life Cycle Cost

Public transport system is essentially envisioned for a longer planning period. While planning and evaluation period for rail based mass transit system is taken as 30 years, these systems are expected to serve beyond this time for upto 100 years. Rail based systems have a higher life cycle than bus system.

4.2.8 Approvals and Implementation

i. Time Required for Approvals

BRT and Metro System are implemented in several cities including Bangalore and thus appraisal and approval is easier. For other systems, with no notable previous experience in the country specifically in rolling stock design and O&M, the technical expertise will have to be developed afresh which may result in more time for approval.

ii. Ease of Implementation

Metro Rail and Bus Rapid Transit have proven experience in India with operation in various cities. Metro rail technology as well as various components like track gauge, civil structures and rolling stock components have been standardized and now available within the country. Efforts have also been made by the Government and Implementing Agencies towards indigenizing the various components of metro rail systems. Technical expertise has also been developed in the country over the period of time. Metro rail system and BRT have better ease of implementation than that of other systems as Mono Rail, Metro Lite .

The identified parameters (total 22 nos.) along with the overall weightages assigned to various parameters for evaluation have been summarized in **Table 4.2**.

Table 4-2: Parameters Identified For Evaluation

S.N.	Crite rion	Objectives	Weight age
1	Mobility Effects	• Serve the maximum peak travel demand & Flexibility to augment capacity • Minimize congestion and reduce reliance on automobile • Provide convenient accessibility and improve interchange facilities • Increase public transportation ridership and mode share • Provide higher modal utilization	20
2	Conceptual Civil Engineering Effect	• Utilization of available of existing right of way • Suitability of Geometric parameters • Assess constructability of alternative mode • Possible extent of land acquisition considering right of way, civil structures and stations	10
3	System Effects	• Provide better safety and comfort • Ability to carry more passengers • Indigenous availability of rolling stock	15
4	Environmental Effects	• Preserve the natural environment • Reduce pollution from shifting of vehicles from private to public modes of transport • Protect and enhance cultural heritage, landmarks and archaeological monuments	10
5	Social Effects	• Impact on existing structures and families	10
6	Cost Effectiveness & Affordability	• Provide quality, affordable public transport service with an optimum investment cost • Consumption of minimum possible maintenance costs	15
7	Financial and Economic Effects	• Provision of a public transport system that would be longstanding and has a higher life cycle cost • Provision of economic friendly transport system with higher economic benefits to the society	15
8	Approvals and Implementation	• Time taken for approval of system • Ease of implementing the proposed and approved system	5
		TOTAL	**100**

5 Screening and Alternatives Evaluation

5.1 Preliminary Evaluation

The proposed corridor runs along ORR till Hebbal and then follows NH 44 till the trumpet interchange and there after takes right to reach Airport. The corridor forms a component of a larger mass transit network as recommended in the CMP.

As already detailed in Section 4.2 the evaluation of the alternatives will rest on various broad aspects. The evaluation of parameters would be restricted to the selection of the most preferable system from the alternatives available capable of catering to the assessed travel demand.

The scoring criteria for the preliminary evaluation will follow the ranking system where in the best system will be ranked as 1 while the least preferred/efficient system is ranked the last i.e 5. Where qualitatively two or more systems are comparable then these systems are given same rank.

5.1.1 Mobility Aspect

The first aspect of system selection is the mobility demand which is the ridership estimation as anticipated in the year 2041. The ridership estimates for this corridor (Sectional loads from Station to Station is provided in the following table.

The alternate systems that could be considered to cater to various travel demands (summarized from Table 3.2) are as below:

System Technology	Indicative Capacity (PHPDT)	Remarks
Bus Rapid Transit	8000	Maximum Capacity
Monorail	15,000	Maximum Capacity
Metro Lite	15,000	Maximum Capacity
Metro System	40,000	6 cars running at 3 Min headway
Heavy Metro	60,000	8 cars running at 3 Min headway

As can be seen from Table 3.3 the peak demand is 46,252 PHPDT with large section of the corridor having PHPDT more than 20,000. While the last segments towards airport has shown comparatively lesser PHPDT between 15000 and 26000 PHPDT. While last segments of the corridor may not have the capacity requirements of higher order mass transit system as per the table cited, however considering the continuity in connectivity, it may be worth considering a higher order mass transit system albeit through a different operational plan.

PHPDT	BRT	Monorail	Metro Lite	Metro System	Heavy Metro
Capacity	8,000	15,000	15,000	40,000	60,000
Demand - 2041	46,252				
Meets the PHPDT Requirement	17%	32%	32%	86%	130%
Qualitative Ranking	5	3	3	2	1

From the point of view of carrying capacity, the Heavy Metro is most appropriate option for meeting the passenger demand with about 77% utilization of capacity. Metro has about 116% utilization of capacity and its capacity can further be enhanced to meet the travel demand by reducing headway to less than 3 min. This could be achieved by planning for the expansion through initial planning of infrastructure.

Monorail and the Metro Lite are systems that will not be able to satisfy the demand since less than 35% of the demand is met by these systems. While BRT can cater to less than 20% of the demand (PHPDT) estimated for the corridor.

5.1.2 Engineering Aspect

A BRT system can be fitted into the ROW and hence can be a system that is highly cost efficient. However, the Junctions will continue to have delays and thereby reducing the efficiency of the system.

The Monorail and Metro lite systems are not manufactured in India and this situation make them expensive. The construction quality of the guide beams for Monorail need to be kept at a very high standard else the ride becomes unpleasant and maintenance costs of the vehicles increase with increased wear and tear.

Like the BRT the Metro lite can be fitted into the ROW and similar issues that the BRT may face will be faced by the Metro Lite. The at-grade development leads to very low speeds due to presence of intersections and cross roads coupled with high crossing traffic.

Metro is already under development in Bangalore and the ROW of 32 meters will be adequate to accommodate an elevated system of Metro without land acquisition. The proposed alignment has higher ROW available to accommodate the metro. It is proposed to develop the metro on the central median along the ORR section and on RHS of the elevated road in NH 44 section. However, this central pillar development is expected result in constraints at the underpass locations where larger spans may need to be considered. Technically there are no apparent constraints.

Like Metro, Heavy Metro will have to be elevated/go underground if the system has to be fitted in the existing ROW. This will require a comparatively heavier structure. The geo-technical investigations conducted along the corridor indicate presence of soft rock (high dense silty sand) weathered rock/ hard rock. This situation would make the development of underground facility an expensive and time consuming affair (considering the experience during the phase 1 construction). Thus elevated would be an appropriate option and the geo-technical study recommends to have pile system ranging from 7m to 23 m depending on the depth of rock encountered and sub-strata characteristics. With the sub-soil characteristics being favorable, this is expected to facilitate development of structures that may be required to carry heavy rail systems as well. However, additional land will be required at curves to accommodate the Heavy Metro and thus the cost of construction will be higher.

Mode	Engineering Aspect	Qualitative Ranking
BRT	Can be fitted within ROW and requires reorganization of entire cross section. Exclusive and dedicated corridor is required for the development of BRT, land would be required for additional depots. Road intersections along the route except for section outside city are saturated. With rapid development happening at the outskirts, these intersections are expected to be saturated soon	1
Monorail	Land Acquisition required for stations, system is imported, also cannot be integrated with existing metro. Exclusive depot and maintenance yard would be required	3
Metro Lite	Can be fitted within ROW and requires reorganization of entire cross section. Exclusive and dedicated corridor is required for the development of Metro Lite. Land Acquisition required for Depot. Junctions below elevated corridor are highly congested. Metro Lite System is imported. Exclusive depot and maintenance yard would be required	3
Metro	Significantly lower constraints, station areas and few locations for the alignment may need land acquisition. Depot need to be developed.	1
Heavy Metro	Will require heavy structures, will require more land acquisition, and also cannot be integrated with existing metro. Exclusive depot and maintenance yard would be required	5

5.1.3 System Aspects

The BRT is an emerging transport system specifically suited to small cities and for corridors with low travel demand. The system is planned and developed in some cities notably Ahmedabad, Surat, Rajkot, Indore and Pune. The BRT operations should be separated from the normal bus operations for maximum efficiency.

The Monorail and the Metro lite systems will have considerable import requirements as there is no manufacturing facility in India and not many cities have these systems to encourage local production. In this situation, these systems are expected to be expensive apart from higher rolling stock requirements upwards of 100% more than regular Metro System even to meet modest carrying capacity (at approximately 50% of the capacity of metro system).

Since the phase 1 of Metro services are operational and Phase 2 metro corridors are under implementation, the advantage of the development of Metro compared to any other rail based system will be very high. Both in terms of interoperability and in terms of spares and maintenance.

Mode	System Aspects	Qualitative Ranking
BRT	Many cities in India have built and developed BRT systems. However, signal system will need to be automated & integrated with traffic signal for better results	1
Monorail	Most components are imported. The beam construction is very technical	5
Metro Lite	Metro lite system needs to be imported till indigenous production happens in India.	3
Metro	Already operational in Bangalore and construction of additional corridors in progress. Most components locally available	1
Heavy Metro	Technology available, however will not be possible to be integrated with existing metro systems	3

5.1.4 Environmental Aspects

The higher order public transport system such as Metro/ Heavy Metro can carry the projected demand, all other systems under comparison have much lower capacity (less than 50% of the demand). Since the rail based systems have similar characteristics on the part of systems, energy use, meet the travel demand (select systems), have land acquisition which is minimal and mostly limited to station areas and Depot development, all options are expected to have positive impact on the environment (though differ in levels of impact), reducing carbon foot print. The brief of the general impacts on the environment by the transit system development is presented in the **Table 5.1**. The Monorail, Metro Lite and the BRTS which will be able to cater to much less demand will hence provide lesser environmental relief.

Table 5-1: Environmental Impacts

Sl. No.	Environmental Parameter	Project Activities		Potential Impacts	Degree of Impact	Nature of Impact
		Project Phase	Activity			
1.	Topography	Construction Phase	Quarrying, borrowing of earth, construction of elevated metro structure	Minor changes in topography of construction sites due to excavation and filling of soil.	Medium	– ve, P
		Operation Phase	Nil	Nil	Nil	Nil
2.	Climate	Construction Phase	Construction of metro structures	Emission from machineries &	Minor	– ve, T

Sl. No.	Environmental Parameter	Project Activities		Potential Impacts	Degree of Impact	Nature of Impact
		Project Phase	Activity			
				equipment		
		Operation Phase	Plantation & Landscaping	Improvement in micro climate of project area	Minor	+ ve, P
3.	Soil Characteristics	Construction Phase	Quarrying, borrowing of earth, Construction of road Movement of construction material carrying vehicles	Loss of top soil due to excavation and Soil erosion. Contamination of top soil due to spillage of construction materials, fuels, grease and asphalt.	Minor Minor	− ve, P − ve, T
		Operation Phase	Nil	Nil	Nil	Nil
4.	Hydrology	Construction Phase	Construction of elevated metro structure near lakes and storm water drains	Contamination of canal water during construction period.	Minor	− ve, T
		Operation Phase	Nil	Nil	Nil	Nil
5.	Ambient Air Quality	Construction Phase	• Quarrying, Material transport, storage & use • Earth work and dismantling of existing buildings and structures, • Operation of concrete mix plant	Increased air pollution in terms of dust and emissions from vehicles, construction equipments and DG sets and from the construction sites.	Minor	− ve, T
		Operation Phase	Reduction in traffic congestion	Reduction in Air pollution	Major	+ve, P

Sl. No.	Environmental Parameter	Project Activities		Potential Impacts	Degree of Impact	Nature of Impact
		Project Phase	Activity			
6.	Noise levels	Construction Phase	Quarrying, material transport, storage & use, dismantling of existing buildings and structures, Construction of elevated metro structure, running of DG sets Use of construction equipment	Increase in ambient noise levels	Minor	− ve, T
		Operation Phase	Nil	Nil	Nil	Nil
7.	Surface Water Resources	Construction Phase	Extraction of surface water for construction activities	Reduction in surface water availability	Minor	− ve, T
		Operation Phase	Use of runoff water from elevated mass transit track and stations or at-grade BRT/ Metro Lite for avenue plantation & gardens	Pressure of surface water resources will be reduced.	Minor	+ ve, P
8.	Ground Water Resources	Construction Phase	Extraction of ground water for construction activities and camp site needs	Reduction in ground water availability	Minor	− ve, T
		Operation Phase	Nil	Nil	Nil	Nil
9.	Surface Water Quality	Construction Phase	Construction elevated metro structure, Earthworks and Pavement works, Discharge of sewage from construction camps, Spillage of oil, grease and hazardous materials	Increase in turbidity of river / stream water due to construction activities, Pollution of surface water bodies due to run off from construction sites during rainy season, discharge of sewage and spillage of construction materials, fuels etc.	Minor	− ve, T

Sl. No.	Environmental Parameter	Project Activities		Potential Impacts	Degree of Impact	Nature of Impact
		Project Phase	Activity			
		Operation Phase	Nil	Nil	Nil	Nil
10.	Ground Water Quality	Construction Phase	Extraction of ground water for construction activities and camp site needs.	Reduction in ground water availability and subsequent impact on ground water quality	Minor	− ve, T
		Operation Phase	Nil	Nil	Nil	Nil
11.	Terrestrial Ecology	Construction Phase	Labour camp activities	Pressure on trees due to increase in fuel demand.	Minor	− ve, T
			Cutting of trees and its branches along proposed alignment.	Negative impact on micro-climate of the area	Medium	− ve, P
		Operation Phase	Plantation of trees & shrubs and landscaping	Positive impact on micro-climate of the area. In case of BRT, unless electric buses are used, additional vehicular pollution from buses in comparison to other higher capacity systems which are run on electricity	Medium	+ve, P
12.	Aquatic Ecology	Construction Phase	Nil	Nil	Nil	Nil
		Operation Phase	Nil	Nil	Nil	Nil
13.	Land Use	Construction Phase	Acquiring residential and commercial areas	Loss of livelihood	Medium	– ve, P
		Operation Phase	Nil	Nil	Nil	Nil
14.	Socio Economic Profile	Construction Phase	Acquiring built-up areas	Loss of structures and livelihood	Major	– ve, P

Sl. No.	Environmental Parameter	Project Activities		Potential Impacts	Degree of Impact	Nature of Impact
		Project Phase	Activity			
			Requirement for labourers	Generation of local employment	Major	+ve, T
		Operation Phase	Improved connectivity	Accelerated socio-economic growth	Major	+ ve, P
				Increased accessibility for interior areas	Major	+ ve, P
15.	Solid Waste Management	Construction Phase	Demolition of buildings and structures and soil from approaches. Domestic waste from labour camp	Causing hindrance to free flow of traffic	Medium	- ve, T
				Health impacts due to improper disposal	Minor	- ve, T
		Operation Phase	Accumulation of dust and garbage on Station platforms	Chance of accidents	Minor	– ve, T
16.	Public Health	Construction Phase	Construction of new elevated metro rail	Chance of accidents	Minor	– ve, T
		Operation Phase	Free flow of traffic	Reduction in accidents	Major	+ ve, P
17	Occupational Safety & Health	Construction Phase	Construction work	Accident risk for construction workers	Medium	– ve, P
			Lack of sanitation and safe drinking water supply in labour camps	Chances of water-borne and vector borne diseases	Major	– ve, T
		Operation Phase	Electrification of the track	Electrocution of commuters & workers	Major	– ve, P

The reduction in pollution is highly depended on the efficiency of the mass transit system in attracting (resulting to modal shift in favour of public transport) and carrying large number of passengers (estimated travel demand on the corridor). Of the proposed systems, Monorail and Metro lite are constrained with carrying capacity which is less than 45% of the estimated travel demand on the corridor. While the BRT system can cater to only 22% of the demand. Thus the Metro Lite, Mono rail and BRT systems have minimal positive impact on the pollution from traffic.

While Metro is best suited to carry the estimated demand with very high capacity utilization (90%). Heavy Metro on the other hand is highly over capacity system when estimated demand for the corridor is considered. Both Metro and Heavy Metro would result in reducing similar traffic levels from roads and thus positive impact on pollution reduction.

Mode	Environment Aspect	Qualitative Ranking
BRT	Significantly lower impact to the traffic on the roads and hence very low reduction in pollution	5
Monorail	Significantly lower impact to the traffic on the roads and hence lower reduction in pollution	3
Metro Lite	Significantly lower impact to the traffic on the roads and hence lower reduction in pollution	3
Metro	High impact, caters to estimated demand leading to higher reduction in traffic on the roads and hence higher reduction in pollution	1
Heavy Metro	High impact, caters to estimated demand leading to higher reduction in traffic on the roads and hence higher reduction in pollution	1

5.1.5 Social Impact

The proposed corridor apart from connecting work centers and residential areas, provides crucial link to international airport. Today, most of the airport travelers are spending close to 2 hours in the peak day hours to reach airport and at times even more. The mobility concerns on this corridor is increasing day by day. Most commuters spend huge amount of time on the road either while going to work or home. Development of mass transit system is going to be substantially cut down the travel times.

Also the systems would provide the opportunity for the working personnel to choose more favourable residential accommodation even if this is a bit farther, as the commuting time would greatly reduce.

In this regard the BRT would have a much lower improvement to the society as it would benefit much lower number of people. The Monorail and Metro lite would also not be as beneficial as the other rail based systems.

Compared to metro system the Heavy Metro would require more generous radii at the curves to negotiate at the desired speeds. This would result in higher land take at the curves and thus the R&R requirements.

Mode	PHPDT 2041	Land Acquisition Acres	Social Impact	Qualitative Ranking
BRT	8000	15	Very Low number of passenger catered to. No land acquisition and displacements for corridor development	1
Monorail	15000	30	Low number of passenger catered to. Land acquisition required for station development. Land for depots required.	5
Metro Lite	15000	15	Low number of passenger catered to. No land acquisition and displacements for corridor development. Land for depots required	4
Metro	36360	39	Land requirement is mostly for stations. Would require lesser land than Heavy Metro and hence lesser social impact. Cater to the estimated passenger demand.	2
Heavy Metro	36360	43	Would require land more compared to Metro for corridor development to ensure smooth curves. Cater to the estimated passenger demand. Land for depots required	3

5.1.6 Cost Effectiveness and Affordability

The BRT and Metro Lite system are developed at grade and thus will require lower investment for the development. Since the rest of the alternatives are to be necessarily grade separated from the road traffic, the cost per KM would be high. In comparison to Metro systems, the viaducts and columns to accommodate Heavy Metro system will have to be heavier and hence would be more expensive to the tune of about 10% on civil construction cost. The Monorail has also proved to be expensive.

Further the rolling stock for the Heavy Metro will be larger due to its higher carrying capacity thus making the systems costlier in capital expenditure as well as O&M.

The Metro Lite and the Mono Rail due to import requirements and more rolling stock requirements (more than 2 times than required for Metro), the costs for the same is expected to be higher compared to metro systems where the rolling stock requirements is lower and is locally manufactured.

Mode	Cost effectiveness and affordability	Qualitative Ranking
BRT	Cost effective system	1
Monorail	Most components are imported. The beam construction is very technical. Cost per passenger is expected to be more than Metro	4
Metro Lite	Most components are imported. Cost per passenger is expected to be more than Metro	4

Mode	Cost effectiveness and affordability	Qualitative Ranking
Metro	Technology is now available in India and hence cost effective	1
Heavy Metro	Technology is now available in India and hence cost effective. However, when compared to metro systems, it would more expensive	3

5.1.7 Economic Aspects

The system would benefit a huge number of people residing or working along and around the corridor. Not only will users of the system get direct benefit, the road network is expected to get decongested to the extent of use of mass transit system and hence economic benefits in savings of time will also be accrued. Comparatively, the systems are expected to offer benefits in accordance with the travel demand met and with Heavy Metro system being expensive, normal metro systems is expected to be economically more efficient compared to Heavy Metro.

The BRT and Metro Lite has much lower impact on the road network since reduction in road congestion is lesser as the system itself occupies part of the road space.

The Monorail does not pick up enough riders in relation to its cost and hence gives the least economic returns.

Mode	Economic Appraisal	Qualitative Ranking
BRT	Passenger capacity low. Due to very low cost, economic returns expected to be high.	1
Monorail	Benefits are not high due to lower passenger carrying capacity. system is very expensive	5
Metro Lite	Benefits are not high due to lower passenger carrying capacity. system is expensive	3
Metro	Most efficient of the systems in economic terms, with reasonable cost per passenger carried (for the demand assessed)	2
Heavy Metro	Cost is significantly higher and hence the EIRR expected to be lower than Metro	3

5.1.8 Implementation

The implementation of the BRT/Metro Lite will pose challenges, since the entire cross section is to be reorganized at some sections. While this may not be situation for the elevated systems (Mono Rail, Metro & Heavy Metro). In case of Metro Lite, integration is required between road traffic signals and rail signal and communication system, which may prove to be complex.

The Monorail will require import. This could be very challenging may delay project delay implementation.

The implementation of the Metro which could be carried out by the SPV would be much easier, the system can be built on the Median with no impact of any underground utilities and the land acquisition will be very minimal mostly limited to station areas and is estimated at about 15.8 Ha.

The implementation of the Heavy Metro would require additional land to the tune of about 10% (especially in curve locations) intensely developed land which is an expensive and time consuming process. This situation may result in increased costs.

Mode	Implementation	Qualitative Ranking
BRT	Construction challenges due to re-organization of ROW	3
Monorail	Import of goods can be a source of delay. Construction is guideway is complex and not much expertise available with Indian contractors.	5
Metro Lite	Construction challenges due to re-organization of ROW. Integration with road traffic signals may be complex as the system is not yet implemented in India. Rolling stock will need to the imported initially	4
Metro	With a lot of Metro construction happening in India, construction and operation technologies are available. Corridor has been reserved along NH 44 and thus will pose min difficulties	1
Heavy Metro	With additional land required in the intensely developed areas for alignment, it may be time consuming and expensive for implementation.	2

5.1.9 Conclusion of the Preliminary Evaluation

Each system has been evaluated and ranked for each of the 8 parameters. The evaluation and ranking for these parameters has been discussed in the above paragraphs and the same has been summarized in the Table Below.

Sl No	Aspect	BRT	Monorail	Metro Lite	Metro	Heavy Metro
1	Mobility Aspects	5	3	3	2	1
2	Engineering Aspects	1	3	3	1	5
3	System Aspects	1	5	3	1	3
4	Environment Aspect	5	3	3	1	1
5	Social Impact	1	5	4	2	3
6	Cost Effectiveness	1	4	4	1	3
7	Economic Aspects	1	5	3	2	3
8	Implementation	3	5	4	1	2
	Overall Ranking	**3**	**5**	**4**	**1**	**2**

As can be seen from the discussion and individual and overall ranking, Metro system proves to be most efficient and suitable system for the K R Puram – Bangalore International Airport Corridor

5.2 Detailed Evaluation

The preliminary analysis of the five systems considered have been discussed and ranked in the earlier section. Further the detailed evaluation under each of the parameters is presented below.

5.2.1 Mobility Aspect

The mobility effect has been evaluated for following parameters:

- Meet the required travel demand for the horizon year and beyond
- Intermodal Interchange
- Accessibility
- Increase public transportation ridership and mode share

Travel Demand

As indicated earlier, the Heavy Metro has the carrying capacity of about 60,000 PHPDT with 8 cars train running at 3 min headway, while the regular (in operation metro) metro has a capacity of about 40,000 PHPDT considering a 6 car coach running at 3 min frequency. The Metro lite and Monorail would have a maximum capacity of 15,000 PHPDT. While the BRT system would be able to handle up to 8000 PHPDT.

To cater to the estimated maximum travel demand of about 46,252 PHPDT, the metro system is ideally placed to cater to the estimated travel demand by adding capacity through reduced headway for which, the infrastructure needs to be planned and developed now itself. This mean there is possibility of further increasing the carrying capacity of Metro up to 60,000 PHPDT.

While the Heavy Metro would result in development of an over capacity system with about only 77% capacity being utilized in the horizon year. The BRT system can cater to about 17% of the demand while Monorail and Metro lite can cater to about 32% of the demand.

Year	PHPDT	BRT	Monorail	Metro Lite	Metro	Heavy Metro
Carrying Capacity		8000	15000	15000	40000	60000
2024	21,112	Fail	Fail	Fail	53%	35%
2031	35,705	Fail	Fail	Fail	89%	60%
2041	46,252	Fail	Fail	Fail	116%	77%

As can be seen from the table above the lower capacity systems such as BRT, Mono rail, Metro lite fail to meet the estimated travel demand which is the basic criteria for selection of system in the opening year itself.

Scoring Criteria: Systems that would meet the demand for the horizon year i.e 2041, would have 100% score and for the systems with lower carrying capacity the score has been assessed based on the % demand they cater to

PHPDT	BRT	Monorail	Metro Lite	Metro	Heavy Metro
	8000	15000	15000	40000$	60000
Horizon year Demand 2041-46,252	17%	32%	32%	116%	77%
Meet Demand 2041 and beyond*	-	-	-	Up to 30% increase	Up to 30% increase
Score on a Scale of 4					
Horizon year Demand 2041-46,252	0.7	1.3	1.3	3.5	4.0
Meet Demand beyond 2041	0.0	0.0	0.0	4.0	4.0

*-Considering reduced headway of 2min for 6 coach Metro

Intermodal Interchange

Interchanges across different mass transit systems will be through common or connected concourse while the corridors themselves may be at different level or at the same level with parallel platforms.

However, in both the cases, the movement from one platform to the other (if not common) will be through concourse. The interchange with other modes will be from the ground level with pickup and drop facilities provides near the mass transit stations. With concourse facility providing grade separated crossing facility for the passengers across the road the safety of passengers is ensured.

For the at-grade systems such as BRT and Metro Lite, smooth interchange is possible if the stations are at intersections and for mid-block station locations, passengers need to cross the road (either at-grade or through foot over bridge) road for the final dispersal and interchange on to other road based modes for last mile connectivity.

Scoring Criteria: Three systems as Metro lite, Metro and Heavy Metro would offer same level of interchange facilities. Thus score of 100% is provided. While the at-grade systems would have to negotiate the road or need to take foot-over bridge to reach the side of the road, hence will undergo slight hardship for the interchange for the last mile connectivity. Thus a lower score of 50% is provided for these systems

Intermodal Interchange	BRT	Monorail	Metro Lite	Metro	Heavy Metro
Convenience	50%	100%	50%	100%	100%
Score on a scale of 4	2.0	4.0	2.0	4.0	4.0

Accessibility

Monorail, Metro System and Heavy Metro are proposed to run on elevated tracks following the same alignment with stations at one level above the ground. Access to these systems will be through elevators, lift and staircase thereby providing facility or disabled to access.

While the BRT and Metro lite run at-grade in the center of the road. The access to these stations is through at-grade road crossing if the stations are near the intersections and through foot-over bridge/ pedestrian subway if the stations are away from the intersection. Also the waiting area is not fully protected for rain or heat. Thus make lesser convenience for the passengers waiting for the service.

Scoring Criteria: The three systems as Monorail, Metro and Heavy Metro offer direct accessibility without having to cross the road as the station access is provided from both sides and thus offer comparable level of accessibility to the passengers. Thus score of 100% is provided.

However, for the passenger of BRT and Metro lite, the safety while accessing the stations and comfort in waiting is lower in comparison to other higher order systems. Thus a lower score for BRT and Mero lite systems

Accessibility	BRT	Monorail	Metro Lite	Metro	Heavy Metro
Safety and comfort	50%	100%	50%	100%	100%
Score on a scale of 4	2.0	4.0	2.0	4.0	4.0

Increase Public Transportation Ridership and Mode Share

The travel demand forecast for the sustainable transportation alternative has estimated increase of public transport mode share from the current levels of 49% to about 70%. The proposed K R Puram-Airport transit corridor is part of the overall plan of mass transit network proposed under sustainable mobility option by CMP. The mode share expected to increase once all the corridors as envisaged in CMP are developed. The systems as metro (through reduced headway to less than 3 min) and heavy Metro are capable of meeting the required travel demand for 2041, the comparative effect on the mode share is expected to be same. However, all other systems (BRT, Monorail and Metro lite) would be able to cater to less than 50% of the demand and hence, would not be able to contribute much in increasing the public transport ridership. This situation would further aggravate the congestion on roads.

Scoring Criteria: The travel demand for 2041 for metro and heavy Metro systems offer same level of influence on the mode share in favour of Public Transport, while BRT, Monorail, Metrolite would not contribute increasing public transport share to the desired levels of sustainable transportation.

Parameter	BRT	Monorail	Metro Lite	Metro	Heavy Metro
Increase Public Transportation Ridership	17%	32%	32%	100%	100%
Score on a scale of 4	0.7	1.3	1.3	4.0	4.0

Summary of Scores

The summary of scores of alternate systems considered for evaluation for mobility is as below:

Evaluation Parameter	Weightage	BRT	Monorail	Metro lite	Metro System	Heavy Metro
Meet the required travel demand (upto 2041)	4	0.7	1.3	1.3	3.5	4.0
Meet Future Demand (beyond 2041)	4	0.0	0.0	0.0	4.0	4.0
Intermodal Interchange	4	2.0	4.0	2.0	4.0	4.0
Accessibility	4	2.0	4.0	2.0	4.0	4.0
Increase Public Transportation Ridership and Mode Share	4	0.7	1.3	1.3	4.0	4.0
Total Weighted Score	**20**	**5.4**	**10.6**	**6.6**	**19.5**	**20.0**

5.2.2 Engineering Aspect

Available Right of Way

The proposed alignment of the mass transit corridor has a right of way ranging between 40m to 60m. The BRT, Metro lite being at-grade corridors would occupy maximum space on ground approximately 9m. While the Mono rail, Metro and Heavy Metro are developed on elevated viaducts and thus the foot print on the ground is limited to central pillar along the alignment and additional pillars where alignment is off the center and near stations. The pillars carrying the elevated metro will be located in the median and on NH 44 along the corridor reserved for the purpose. Additional pillars will be used where the alignment is off the central median and near stations.

Thus development of Metro would use lesser road foot print and meet fully the passenger demand. Though mono rail also uses the less foot print of ground, would not meet the demand and thus per passenger foot print would be higher compared to Metro system.

The typical cross sections for different systems is presented below:

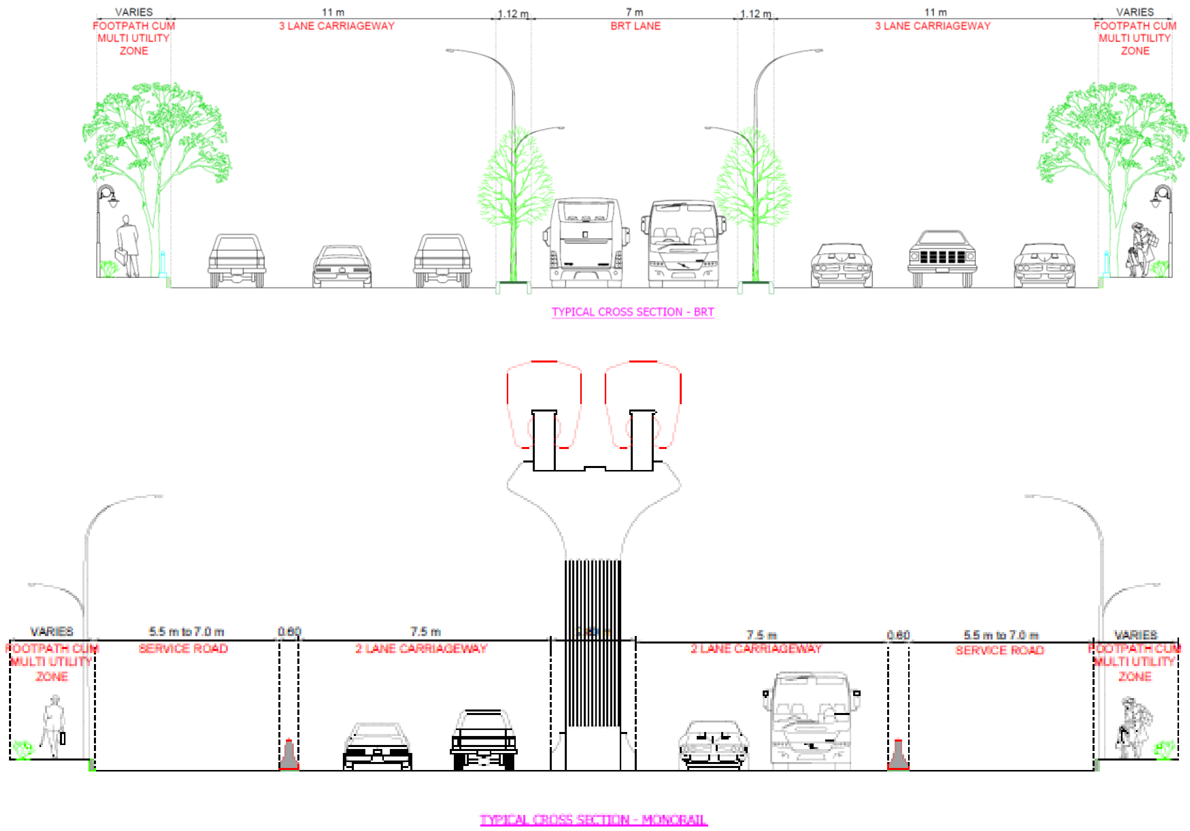
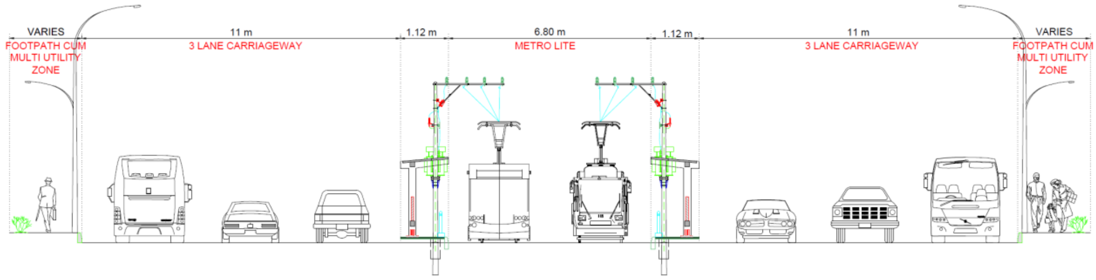
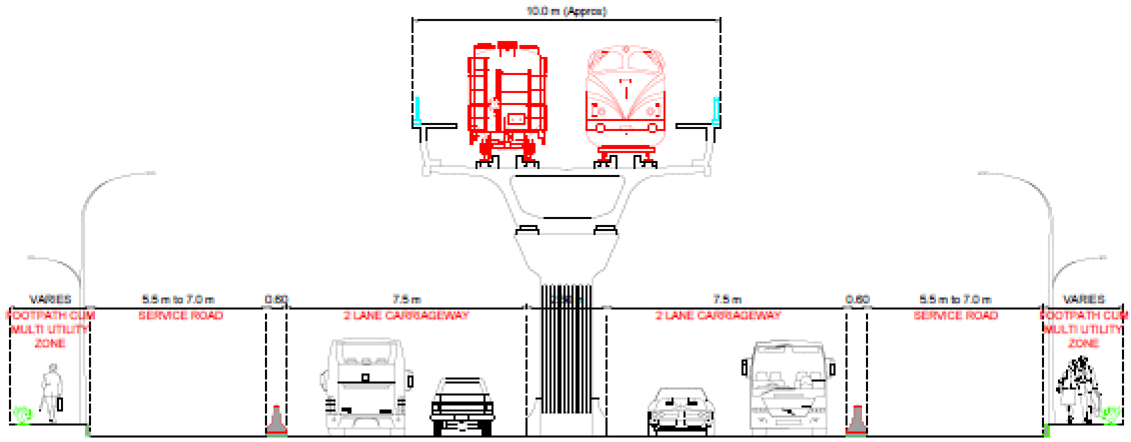


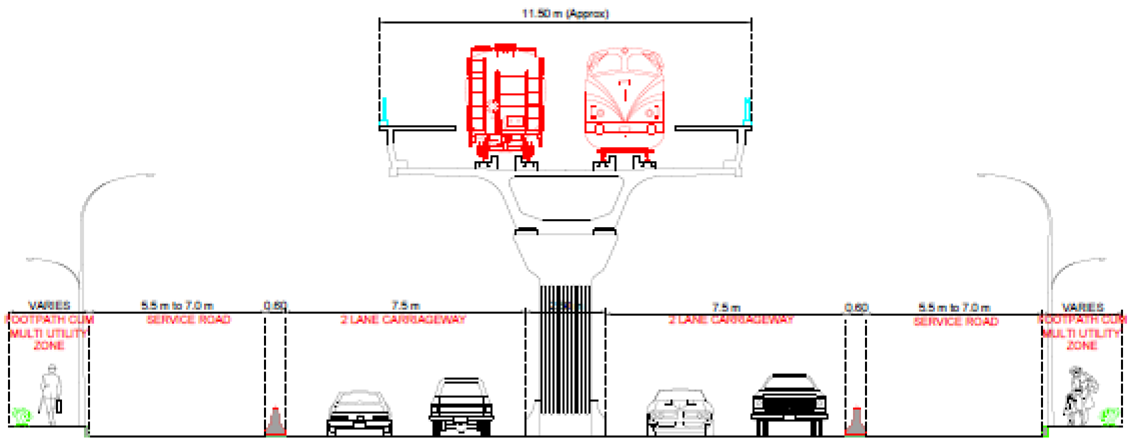
Figure 5-1: Typical Cross Sections - K R Puram to Hebbal Section



TYPICAL CROSS SECTION - METRO LITE



TYPICAL CROSS SECTION - METRO



TYPICAL CROSS SECTION - HEAVY METRO

Figure 5-2: Typical Cross Sections - K R Puram to Hebbal Section

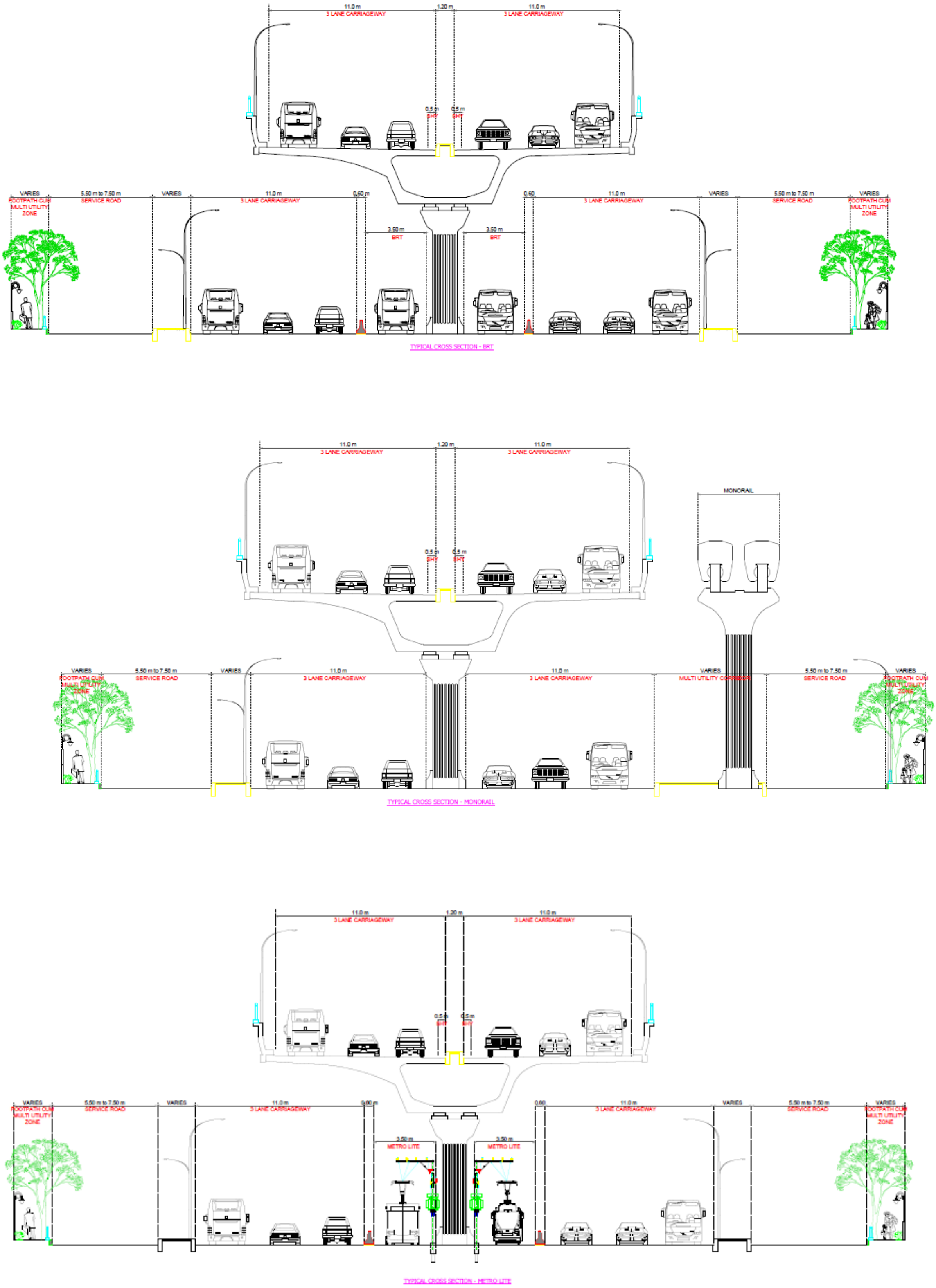


Figure 5-3: Typical Cross Sections – NH 44 Section

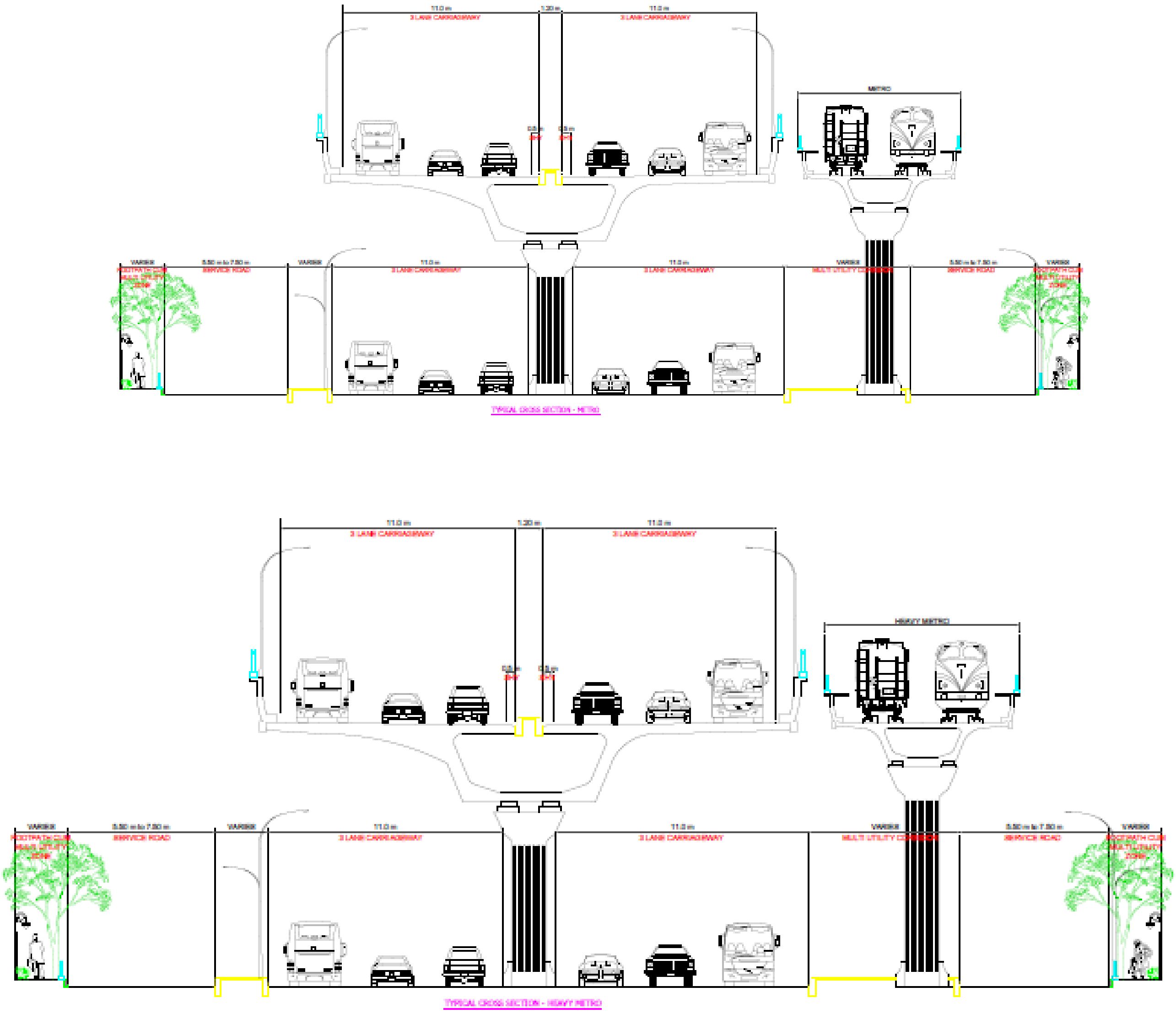


Figure 5-4: Typical Cross Sections – NH 44 Section

Scoring Criteria: Additional space is required at stations and may be at locations where the alignment is required to be outside the road space (especially at curves). The available ROW is favorable for the development Metro or Heavy Metro. The scoring is using the ground foot print per 1000 PHPDT.

Parameter	BRT	Monorail	Metro Lite	Metro System	Heavy Metro
Foot Print, m	9.2	2.8	9.0	2.8	2.8
Score on a scale of 2	0.1	0.6	0.2	2.0	2.0

Suitability of Geometric Parameters

The alignment is passing through the developed outer ring road and along the NH 44. Mostly the alignment has good geometrics except at few locations where the alignment need to go out of available road space for accommodating the Heavy Metro.

Part of the alignment between K R Puram and Hebbal is passing through the already developed outer ring road and using the central reserve for placing the viaduct pillars. Thus for Mono rail, Metro or Heavy Metro, the utilization of central part would be temporary and only the existing central verge will be used on permanent basis for the viaduct pillars and thus the pillar line would act as central median for the road corridor.

The development of BRT or Metro lite would require complete reorganization of cross section as about 9-11m of land along the center line or 4.5m to 5.5m on either side of the elevated corridor pillars along NH 44 (between Hebbal and Airport trumpet interchange) would be used for development of BRT/ Metro Lite. In the transition areas between flyover/elevated corridor and normal at-grade corridor along NH 44, there will have to be a complex system for guiding BRT and Metro Lite systems so as not to conflict with road traffic and there shall be many conflict areas (cross road traffic merging in to elevated corridor)

Scoring Criteria: The geometric parameters do not have any adverse impact other than additional LA at few curve locations. Complete reorganization of cross section is required for the development of BRT or Metro lite systems. (Metro and monorail is set as 100%. For Heavy Metro the score is proportionately reduced in line with Additional land requirements at curves).

Parameter	BRT	Monorail	Metro Lite	Metro System	Heavy Metro
Geometric Parameters	90%	100%	90%	100%	90%
Score on a scale of 2	1.8	2	1.8	2	1.8

Constructability

The BRT and Metro lite systems are developed at-grade and there are no apparent difficulties for construction. Also, the elevated systems for Mono rail, Metro and Heavy Metro are developed mostly within the ROW and soil parameters do not have any adverse impacts for the development.

Scoring Criteria: All the systems score more or less equally on the constructability except for the extent and complexity of works involved.

Parameter	BRT	Monorail	Metro Lite	Metro System	Heavy Metro
Constructability	100%	80%	90%	80%	70%
Score on a scale of 3	3	2.4	2.7	2.4	2.1

Extent of Land Acquisition

There will not be any land required for the BRT or Metro lite system as the same shall be accommodated in the available ROW. However, land will be required for the development of depot and workshops for all the systems. The estimated land requirements for each of the alternate systems and the scoring is given in the table below.

Scoring Criteria: The least land requirement is considered for full score and for other, the score is proportionate.

Parameter	BRT	Monorail	Metro Lite	Metro System	Heavy Metro
Land requirements for alignment, depot/workshop (Acre)	15	30	15	39	43
% compared to the least (BRT)	100%	200%	100%	260%	286%
Score on a scale of 3	3.0	1.5	3.0	1.2	1.0

Summary of Scores

The summary of score for the Engineering aspect is as below:

Evaluation Parameter	Weightage	BRT	Monorail	Metro Lite	Metro System	Heavy Metro
Utilization of Available ROW	2	0.1	0.6	0.2	2.0	2.0
Geometric Parameters	2	1.8	2	1.8	2	1.8
Constructability	3	3	2.4	2.7	2.4	2.1
Extent of LA	3	3.0	1.5	3.0	1.2	1.0
Total Weighted Score	**10.0**	**7.9**	**6.5**	**7.7**	**7.6**	**6.9**

5.2.3 System Aspects

Interoperability with Existing Systems

The present system operating in Bangalore city is a Metro system. Thus the Metro system if provided, would offer sharing of assets and facilities such as coaches, maintenance facilities etc.

While for other systems as Metro lite, Mono rail, Heavy Metro, the system configuration and maintenance requirements being different would require a separate set up which if to be developed for only one corridor may not result in optimum use. For BRT, the rolling stock being additional, would require additional facilities (if no spare capacity available at the existing depots close to the corridor) to accommodate the additional rolling stock.

Scoring Criteria: Metro System would be more beneficial in case of interoperability as there is already an existing facility close to the corridor and the same can be utilized. While Heavy Metro, Metro lite, Mono rail would require additional facilities and would not offer any interoperability in city mass transit system. BRT system if the rolling stock to be procured is similar to the existing fleet of buses, interoperability may be considered, however the station design need to be in line with the bus designs thus can be considered as partially interoperable (Good interoperability 100%, partial interoperability 50%, Poor interoperability 0%).

Parameter	BRT	Monorail	Metro Lite	Metro System	Heavy Metro
Interoperability	50%	0%	0%	100%	0%
Score on a scale of 5	2.5	0	0	5	0

Safety and Comfort

The system parameters on safety and comfort for Monorail, Metro and Heavy Metro would be similar. Thus the three systems are expected to have similar coaches offering comparable comfort levels. The geometrics being little better for Heavy Metro system.

However, for BRT and Metro lite, the bus stations are like normal bus stops and do not offer full protection from adverse climate and rain. Also the ride on BRT is similar to normal bus. Ride on Metro lite being on rail wheels and thus offer better comfort compared to bus.

Scoring Criteria: The three systems Mono rail, Metro and Heavy Metro would offer same level of safety and comfort to the passengers. While Metro lite would offer comparable ride comfort but safety and comfort at the stations is lesser. For BRT, both ride comfort and safety would be lesser compared to Metro or Heavy Metro (Good safety and comfort 100%, Moderate safety and Comfort 50%, Poor safety and comfort 25%)

Parameter	BRT	Monorail	Metro Lite	Metro System	Heavy Metro
Safety and Comfort	25%	75%	50%	100%	100%
Score on a scale of 3	0.75	2.2	1.5	3	3

Expandability

System wise, both Metro and Heavy Metro can be expanded by reducing the headway up to 2 min. This would result in approximately 30% to 50% increase in capacity addition. However other systems have limitations on the capacity and do not offer expandability.

Scoring Criteria: it can be concluded that both metro and Heavy Metro systems offer flexibility in expanding. (Expandable 100%, Poor expandability 0%)

Parameter	BRT	Monorail	Metro Lite	Metro System	Heavy Metro
Expandability	0%	0%	0%	100%	100%
Score on a scale of 5	0	0	0	5	5

Indigenous availability of Rolling Stock

In the initial phases of metro development in India, the coaches were imported. Subsequently, metro coach manufacturing is available now in India with BEML (through technical collaboration) is manufacturing and supplying metro coaches. Thus the technology and coach manufacturing is available in India for both Metro and Heavy Metro. However, Metro lite, Mono rail technologies are yet to be developed in India. Currently, these are required to be imported till these systems are widely adopted across cities in India to pave way for manufacturing base. BRT systems adopts normal buses with or without modification to the body and local manufacturing base is available.

Scoring Criteria: BRT, Metro and heavy Metro rank at same level on the availability of rolling stock, while Metro lite and Mono rail needs import. (Availability of Rolling Stock 100%, having to import Rolling Stock 0%)

Parameter	BRT	Monorail	Metro Lite	Metro System	Heavy Metro
Indigenous availability of Rolling Stock	100%	0%	0%	100%	100%
Score on a scale of 2	2	0	0	2	2

Summary of Scores

Summary of score assessed for various alternatives considered under system aspects is as below:

Evaluation Parameter	Weightage	BRT	Monorail	Metro Lite	Metro System	Heavy Metro
Interoperability with Existing Systems	5	2.5	0	0	5	0
Safety and Comfort	3	0.75	2.2	1.5	3	3
Expandability	5	0	0	0	5	5
Indigenous availability of Rolling Stock	2	2	0	0	2	2
Total Weighted Score	**15**	**5.3**	**2.2**	**1.5**	**15.0**	**10.0**

5.2.4 Environmental Aspects

Preserve Natural Environment

The alignment is not passing through any sensitive areas, however, trees along the alignment (in the central median) and near station areas may require to be removed to allow construction of mass transit system and stations.

In case of Heavy Metro, to accommodate smoother radii at curves, the alignment may require to run on lands adjoin the road which are mostly private properties.

Scoring Criteria: It may be considered that there is no adverse impact on the natural environment due to the development of BRT, Metro lite, Mono Rail, Metro or Heavy Metro. (Adverse impact 0%, minimal impact 100%)

Parameter	BRT	Monorail	Metro Lite	Metro System	Heavy Metro
Impact on Natural Environment	100%	100%	100%	100%	100%
Score on a scale of 3	3	3	3	3	3

Reduce Pollution

The proposed development of mass transit system is expected to promote and encourage mode shift in favor of public transport. It has been estimated that the mode share is expected to improve to about 70% from the current 49% (approx.) with the development of mass transit network as envisaged in CMP.

Both Metro and Heavy Metro systems have the capacities to cater to the estimated travel demand on the corridor for the horizon year 2041 and have the capability to further enhance their capacities if required. Thus the reduction of traffic from road and thus the road traffic related pollution reduction is the highest in the case of Metro/ Heavy Metro.

However, the BRT, Mono rail and Metro lite would not be able to cater to the estimated travel demand thereby the reduction of vehicles from the road are lesser in the case of these three systems.

The estimated reduction in emissions in ton/day from reduction of use of various private modes is in the Table below.

Mode	CO	HC	PM	Nox	CO2
BRT					
Car	0.04	0.00	0.00	0.00	6.59
Two Wheeler	0.73	0.53	0.03	0.10	108.70
Auto	0.13	0.04	0.00	0.01	19.97
Bus	0.09	0.00	0.01	0.16	19.71
BRT Bus	-0.17	-0.01	-0.01	-0.31	-36.84
Total	**1.0**	**0.6**	**0.0**	**0.3**	**155.0**
Monorail/ Metro Lite					
Car	0.19	0.02	0.00	0.02	28.83
Two Wheeler	1.37	0.99	0.05	0.19	203.82
Auto	0.25	0.08	0.01	0.01	37.45
Bus	0.16	0.01	0.01	0.28	34.19
Total	**2.0**	**1.1**	**0.1**	**0.5**	**304.3**
Metro/ Heavy Metro					
Car	0.74	0.08	0.01	0.06	109.85
Two Wheeler	5.21	3.76	0.19	0.71	776.53
Auto	0.96	0.29	0.03	0.05	142.68
Bus	0.62	0.03	0.04	1.08	130.25
Total	**7.5**	**4.2**	**0.3**	**1.9**	**1159.3**

Scoring Criteria: The maximum savings or reduction in pollution is estimated for Metro and Heavy Metro and thus these systems score full and other systems, the scoring has been reduced proportionately.

Parameter	BRT	Monorail	Metro Lite	Metro System	Heavy Metro
Pollution Reduction	14%	26%	26%	100%	100%
Score on a scale of 4	0.6	1.0	1.0	4	4

Protect Natural Cultural Heritage

There are no natural heritage structures getting affected due to the development of Metro or Heavy Metro.

Scoring Criteria: The ranking of all five systems is expected to be same as there is no impact on heritage. (No impact on heritage 100%)

Parameter	BRT	Monorail	Metro Lite	Metro System	Heavy Metro
Protect on Natural Cultural Heritage	100%	100%	100%	100%	100%
Score on a scale of 3	3	3	3	3	3

Summary of Scores

Summary of scores under environmental aspects is as below:

Evaluation Parameter	Weightage	BRT	Monorail	Metro Lite	Metro System	Heavy Metro
Preserve Natural Environment	3	3	3	3	3	3
Reduce Pollution	4	0.6	1.0	1.0	4	4
Protect Natural Cultural Heritage	3	3	3	3	3	3
Total Weighted Score	**10**	**6.6**	**7.0**	**7.0**	**10.0**	**10.0**

5.2.5 Social Impact

Social Benefits

With the development of mass transit system (Metro or Heavy Metro), there will be reduction in pollution along the alignment, improved and alternative transport facility will be available, the property valuation will go up etc. These benefits will be in proportion to the demand these systems are catered to. Metro and Heavy Metro cater to the full demand estimated for the corridor. BRT, Mono Rail and Metro lite would be able to cater to only part of the demand (less than 50% of total demand estimated for horizon year).

Scoring Criteria: Score of 100% shall be for systems which can cater to the estimated demand and for systems with lesser capacity, social impact score will be proportionate to their carrying capacity.

Parameter	BRT	Monorail	Metro Lite	Metro System	Heavy Metro
Social Benefits	14%	26%	26%	100%	100%
Score on a scale of 5	0.7	1.3	1.3	5	5

Displacement of People

This is directly related to the land acquisition. As discussed in section 5.2.2, the land acquisition requirements are higher in case of Heavy Metro development and thus the displacement of people. For purpose of this analysis only the land acquisition required for the development of alignment and stations is considered.

The BRT, Metro lite, there is no land acquisition expected for the development of corridor. For development of Mono rail, no land acquisition is expected for the development of alignment but LA would be required for the stations and Depot and LA for stations is expected to be in line with the requirements of Metro. For Metro approximately 15.8 Ha of land acquisition is estimated for alignment and stations of which only 10% account for alignment. Heavy metro would require additional 10% of land for alignment to accommodate smoother curves.

Scoring Criteria: No LA is considered for maximum score and the maximum LA in the case of Heavy Metro is considered for lowest score of 0. All other scores are calculated through interpolation. The Heavy Metro option will have about 10% more land acquisition and thus people being displaced.

Parameter	BRT	Monorail	Metro Lite	Metro System	Heavy Metro
Displacement of People	0%	70%	0%	91%	100%
Score on a scale of 5	5	1.5	5	0.5	0

Summary of Scores

Summary of scores under Social aspects is as below:

Evaluation Parameter	Weigh tage	BRT	Monorail	Metro Lite	Metro System	Heavy Metro
Social Benefits	5	0.7	1.3	1.3	5	5
Displacement of People	5	5	1.5	5	0.5	0
Total Weighted Score	**10**	**5.7**	**2.8**	**6.3**	**5.5**	**5.0**

5.2.6 Cost Effectiveness and Affordability

The cost effectiveness is measured in the cost of system per unit of passengers carried each day. The daily passengers carried by different systems estimated for the horizon year is as below:

Parameter	BRT	Monorail	Metro Lite	Metro System	Heavy Metro
Passengers Carried (Lac)	1.56	2.92	2.92	11.14	11.14

The cost of development of each of the systems is estimated based on the available reports for the Bangalore Metro, life cycle cost analysis report by IUT (the rates have been escalated from 2012 to 2019). For the rolling stock, the rates for Mono rail and Metro lite has been considered in similar lines as that of Metro (which is being produced in India) considering the import requirements. The rolling stock is estimated adopting the methodology suggested in "Life Cycle Cost Analysis of Five Mass Rapid Transit Systems". The estimation of rolling stock for the opening year is as in the Table below.

Parameter	Type of system				
	BRT	Monorail	MetroLite	Metro	Heavy Metro
Max PHPDT	8000	15000	15000	21112	21112
Section Length in Km	38	38	38	38	38
Average Speed (Kmph)	25	30	35	36 and 60	36 and 60
Carrying Capacity Metro	80	480	560	1574	1760
No. of cars per Rake	1	4	3	6	6
Rakes single direction	100	39	27	9	9
Headway	0.6	2	2.5	5 and 10	5 and 10
Rakes (both direction)	304	78	54	18	18
Rakes (Traffic reserve)	16	1	1	1	1
Rakes (Repair & Maintenance)	16	7	5	2	2
Total Rakes Required	336	86	60	21	21
Total no of Coaches/Cars	336	344	180	126	126

Thus estimated cost of development of each of the systems is in the Table below.

Table 5-2: Cost of Development Mass Transit Systems (INR Cr.)

Item	Total Cost – BRT	Total Cost - Mono Rail	Total Cost – Metrolite	Total Cost - Metro	Total Cost - Heavy Metro
Alignment and Formation	456	1,216	1,070	1,427	1,368
Station Buildings	75	288	288	661	594
Permanent Way	-	-	228	326	304
Depot				340	
Traction & power	-	304	304	613	494
Signalling (Including Depot, OBE)	31	190	190	264	228
Telecommunication (Station + Depot)	29	76	76	84	84
Automatic Fare Collection(AFC) system	53	45	45	60	72
Rolling Stock	202	2,064	1,440	1,008	1,059
Other Elements	30	228	228	367	380
Land	900	1,520	1,520	2,171	2,574
Total Cost (Including Land)	1,776	5,931	5,389	7,321	7,157
Total Cost (Excluding Land)	876	4,411	3,869	5,149	4,583
Taxes @ 15% (Excluding Land)	131	662	580	698	687
Contingency @ 3% (Excluding Land)	26	132	116	175	137
Escalation During Construction and IDC	296	1,491	1,308	1,741	1,550
Total Cost	**2,230**	**8,216**	**7,394**	**9,935**	**9,532**
Total Cost per Lakh Passenger	**1,429**	**2,814**	**2,532**	**892**	**856**

The O&M expenses are approximately estimated at 2.5% of the capital cost of the project for rail based systems and Mono Rail, while for BRT the O&M expenses shall be higher at 10% due to higher manpower per coach/bus and fuel costs.

Scoring Criteria: The score for the least cost of development per lakh passengers carried is given the highest and for rest of the systems, the score has been reduced proportionately.

Parameter	BRT	Monorail	Metro Lite	Metro System	Heavy Metro
Cost effectiveness & Affordability	**1,429**	**2,814**	**2,532**	**892**	**856**
Score on a scale of 15	**9.0**	**4.6**	**5.1**	**14.4**	**15.0**

5.2.7 Economic Aspects

The proposed mass transit system is expected to bring in benefits to the users and non-users in terms of savings in vehicle operating costs, time savings, savings in alternate infrastructure development, savings due to reduced accident costs, reduced pollution etc.

The benefits that could be accrued due to different systems is highly depended on their capacity to cater to the demand and the cost of development of the system. The summary of estimated EIRR for the different systems considered Metro and Heavy Metro option is presented in the Table below. The economic benefits for BRT system is high primarily due to its cost of development. When compared to other higher capacity systems, it can be noticed that Metro System offers the highest economic return for the investment.

Scoring Criteria: Highest EIRR is given maximum score and for other systems proportionately.

Parameter	BRT	Monorail	Metro Lite	Metro System	Heavy Metro
Economic benefits	33.7%	22.5%	24.0%	23.8%	24.7%
Score on a scale of 15	15.0	10.0	10.7	10.6	11.0

5.2.8 Implementation

As the implementation of the mass transit system will be taken up by the SPV (the implementation mode is discussed in Chapter 6), and will be built mostly on the median along the ring road and in the space acquired for the purpose along NH 44 from Hebbal to Airport link road.

For BRT and Metro lite development where the entire cross section will be reorganized will require slightly more efforts in the planning and execution. However, there may not be any land acquisition involved for the development of corridor.

The extra efforts would be required in the acquisition of additional land for the development of Heavy Metro which is to the tune of about 10% more than the land required for the development of metro. Additionally, all systems would require Depot for operations.

Scoring Criteria: Implementation efforts are considered same for all the systems except for Heavy metro due to higher LA efforts in highly developed area and construction.

Parameter	BRT	Monorail	Metro Lite	Metro System	Heavy Metro
Implementation	90%	90%	90%	90%	80%
Score on a scale of 5	**4.5**	**4.5**	**4.5**	**4.5**	**4**

5.3 Alternatives Evaluation

Evaluation of the two alternatives considered are discussed in detail in the previous section. The summary of the results is in the **Table 5.3**.

Table 5-3: Evaluation of Alternatives

Sl. No.	Criteria	Weightage	BRT	Monorail	Metro Lite	Metro System	Heavy Metro
1	Mobility Aspect	20	5.4	10.6	6.6	19.5	20.0
2	Engineering Aspect	10	7.9	6.5	7.7	7.6	6.9
3	System Aspects	15	5.3	2.2	1.5	15.0	10.0
4	Environmental Aspects	10	6.6	7.0	7.0	10.0	10.0
5	Social Impact	10	5.7	2.8	6.3	5.5	5.0
6	Cost Effectiveness and Affordability	15	**9.0**	**4.6**	**5.1**	**14.4**	**15.0**
7	Economic Aspects	15	15.0	10.0	10.7	10.6	11.0
8	Implementation	5	4.5	4.5	4.5	4.5	4.0
	Total Score	**100**	**59.4**	**48.2**	**49.4**	**87.1**	**81.9**

It can be seen that the Metro which can cater to the estimated travel demand, offers flexibility to expand and interoperability would be the most suitable option for this corridor.

5.4 Conclusion and Recommendation

From the discussions and analysis in the previous paragraphs, ***Metro System clearly emerges as the most appropriate system for this corridor*** which can cater to the travel demand assessed and has capability to further expand and offer interoperability with existing mass transit systems in the City.

a) BRT system has limited capacity (up to 8000PHPDT) while the required travel demand to be catered to is 46,252 PHPDT, which clearly BRT will not be able to cater. As a minimum, BRT system development would require dedicated corridor of about 9.0 at mid-section and about 10-11m at bus stop locations. This will impact availability of road space for other users. There are major intersections along the route, which BRTS need to negotiate, congestion at these intersections is very high, meaning high frequency movement of BRT vehicles would result in further worsening of situation at these intersections often outweighing benefits that may accrue due to BRTS development. ***Considering these it is clear that BRT is not suitable system for this corridor.***

b) Mono Rail system has lower capacity (up to 15,000PHPDT) while the required travel demand to be catered to is 46,252 PHPDT, which clearly Mono Rail will not be able to carry. Not much of experience in the development and operation of Mono Rail in India except for Mumbai. The Mono Rail requires sophisticated civil construction for the guideway to ensure smooth ride. Further the train sets are to be imported adding to the cost. With lower carrying capacity, system has to be run lower headways, thus requiring large number of rolling stock and advanced signaling system. This situation makes the Mono Rail Development expensive. ***Considering above it is clear that Mono Rail is not suitable system for this corridor.***

c) Mero Lite system has lower capacity (up to 15,000PHPDT) while the required travel demand to be catered to is 46,252 PHPDT, which clearly Metro Lite will not be able to carry. Not much of experience in the development and operation of Metro Lite in India. Like BRT system, Metro Lite development would require dedicated corridor of about 8.0 at mid-section and about 9-10m at station locations. This will impact availability of road space for other users. There are major intersections along the route, which Metro Lite need to negotiate, congestion at these intersections is so high, that high frequency movement of Metro Lite would result in further worsening of situation at these intersections often outweighing benefits that may accrue due to Metro Lite development. ***Considering above it is clear that Metro Rail is not suitable system for this corridor.***

Heavy Metro is more appropriate system for corridor with higher demand and adopting of this system leads over design over design. Further this system demands more liberal curves leading to higher land take and heavier civil structures compared Metro system. **With these, adopting Heavy Metro system will be expensive and hence not recommended**.

6 Implementation Options for Viable Alternative

Based on both qualitative and quantitative screening carried out in previous chapters, Metro Rail System has emerged as the most viable alternative mass transit system for the proposed corridor connecting K R Puram and Airport via Hebbal.

As per New Metro Rail Policy 2017, it is essential to explore private participation either for complete provisioning of metro or for some unbundled components such as Automatic Fare Collection System. As per Metro Rail Policy, implementation options need to be explored for seeking Central Financial Assistance (CFA).

6.1 Implementation Options

The various options for central financial assistance for metro projects as detailed in the Metro Rail Policy are:

iv. Public Private Partnership (PPP)
v. Grant by the Central Government
vi. Equity Sharing Model

These options have been discussed in brief in the following paragraphs.

6.1.1 Public Private Partnership (PPP)

A Public-Private Partnership is a collaborated effort between the private and public sectors to meet the paucity of capital investment for the development of infrastructure.

The PPP model as a part of the New Metro Policy 2017 aims at lessening the burden on the Central government in funding metro projects. Accordingly, the Government of India has made Public-Private Partnership (PPP) component mandatory for states for availing central assistance of new metro projects as part of its New Metro Rail Policy, 2017. Private investment and other innovative forms of financing of metro projects have been made compulsory to meet the huge resource demand for capital-intensive high capacity metro projects. As per the New Metro Policy 2017, "Private participation either for complete provision of metro rail or for some unbundled components (like Automatic Fare Collection, Operation & Maintenance of services etc) will form an essential requirement for all metro rail projects seeking central financial assistance"

Bengaluru International Airport Limited (BIAL), is the 3rd largest airport in India witnessing more than double digit growth YoY. Given the growth in passenger traffic and in line with the Master Plan, BIAL is going for expansion of airfield Works for second runway, T2 Terminal, landside connectivity etc. at an estimated investment of about Rs. 11,000 cr. BIAL's proposed expansion is approved by the board headed by Chief Secretary of GoK.

BMRCL is considering the proposal to have a metro link connecting BIAL to K .R Puram as part of Phase 2 B of the Project for which the Government has already given an in principle approval. The estimated investment for the proposed Metro line to BIAL will be to the tune of Rs. 9,922 Crore. The DPR gives the detailed cost break up and the means of financing. The GOK in its cabinet approval has requested BIAL to provide financial support of Rs. 1,000 Crore to fund this project.

BIAL will support the project to the tune of up to Rs.1,000 crore out of the approved Rs.9,922 crore for the entire project. This amount is related to the section of the metro starting from the current toll plaza at Sadahalli gate and ending at Terminal 2 of KIA and will include the stations within this section. This amount will initially have to be arranged by BMRCL or GoK during the construction of the metro infrastructure within the airport.

As per the discussions held by the State Government and BIAL with Airport Economic Regulatory Authority (AERA), the User Development Fee (UDF) can be levied only under following circumstances:

(i) The capital assets are owned by the Airport Company, i.e., BIAL.

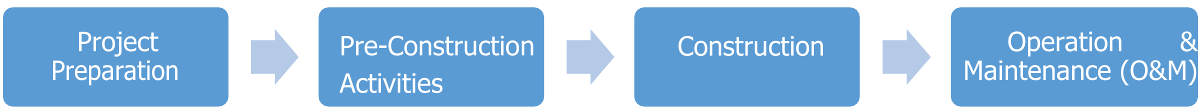
(ii) The project gets commissioned.

The AERA's regulation for private airports do not allow for levy of Advance User Development Fee (AUDF), i.e., a fee which can be levied even before commissioning of the project and can be used for financing capital expenditure. In view of this, BIAL will be in a position to take up the metro investments with AERA only during the tariff determination for the next (3rd) Control period. On completion of construction and commissioning of the facility between City & KIAB, BMRCL will transfer the asset constructed within the airport boundaries to BIAL.

Therefore, the arrangement with BIAL during the operational phase by transferring assets in the Airport area upon commissioning to BIAL and leasing them back to facilitate levy of user development fee on air travelers by BIAL as per AERA guidelines will work as Back-ended PPP. The revenue streams generated through transfer of this amount would aid in debt servicing, thus mitigating the need for shadow cash support from GOK.

However, the success of PPP will depend critically on appropriate allocation of risks, responsibilities, rewards and penalties, and create the incentives for value creation. In principal, risk allocation should be based on the ability of the entity best equipped to manage that risk.

Any infrastructure project generally goes through the following phases:



Each phase is susceptible to different types of risks. A PPP can be established during either in Construction phase / Operation & Maintenance phase; and both Construction and O&M phase. Based on the PPP models adopted across various sectors in India, the explored models of PPP are presented in **Figure 6.1**. Central financing for this model will be governed by the Viability Gap Funding (VGF) scheme of Government of India.

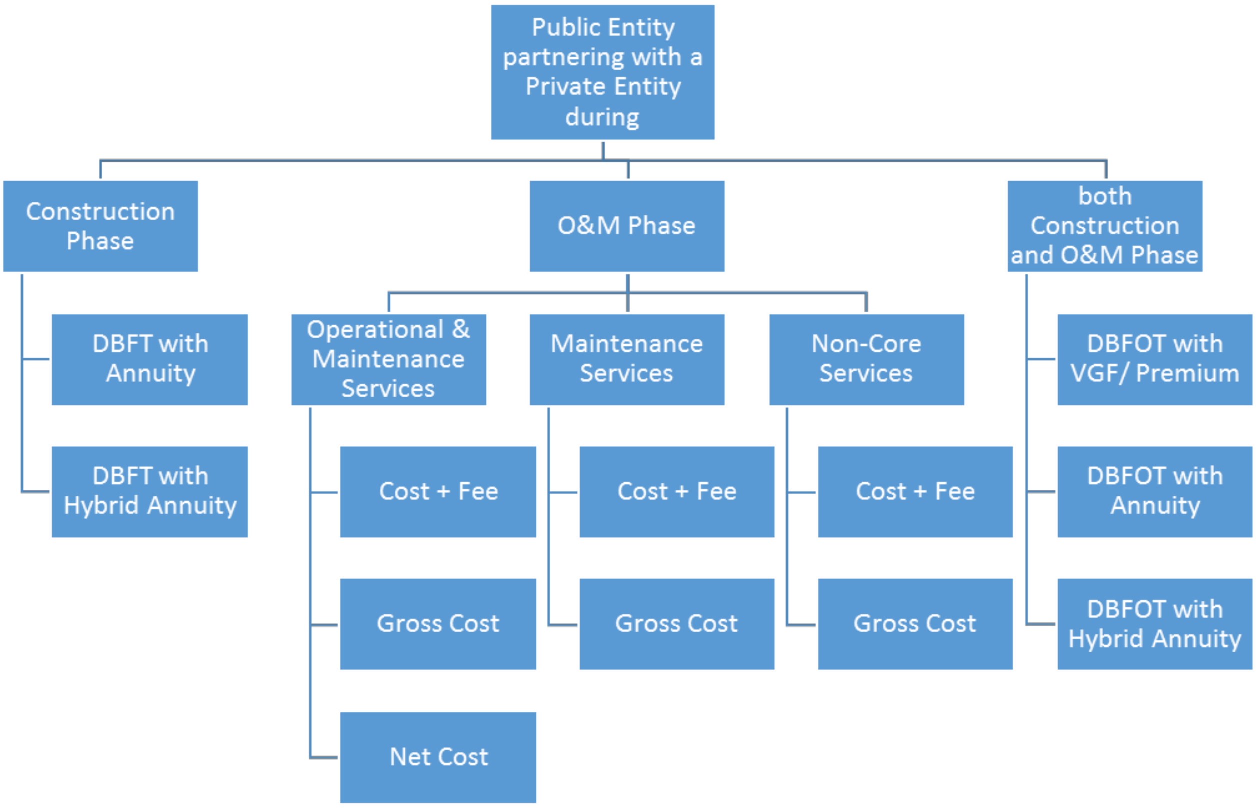


Figure 6-1: PPP MODELS

6.1.1.1 PPP Models for Metro Rail during Construction Phase

6.1.1.1.1 Development of Metro Rail System on Government Land - Design, Build, Finance and Transfer (DBFT) with Annuity.

Under this model, the public authority will provide land to the selected private developer for a definite period (Concession Period). The private partner will develop the infrastructure with its own funds and funds raised from lenders at its risk (that is, it will provide all or the majority of the financing). The authority shall be responsible for operating (supply and running of rolling stock) and managing the infrastructure life cycle (assuming life-cycle cost risks).

The bid parameter in such projects is generally annuity which is a fixed amount paid to the private partner post-construction during the concession period. The fee is generally financed through the funds coming from users after covering O&M expenses and long-term maintenance. If these funds are insufficient to meet the Annuity pay-out, the Authority shall have to arrange/finance the same through State/ Central Government.

6.1.1.1.2 Development of Metro Rail System on Government Land - DBFT with Hybrid Annuity

This model is similar to DBFT with Annuity expect for one major difference – The private entity receives certain amount (% of capital cost) during construction phase while the remaining project cost is paid out as annuity during operation & maintenance phase. Along with the annuity payments, interest shall be paid in the form of annuity on reducing balance of final construction cost. Interest rate for the same shall be prevailing Bank rate + 3 %.

6.1.1.2 PPP Models for Metro Rail during O&M Phase – O&M Services

6.1.1.2.1 Operation and Maintenance Services on Cost + Fee Model

Under this model, post-construction of civil assets, the private partner installs the system (signaling and electrical assets), procures rolling stock and operates and maintains all these assets. The authority collects all the revenue and pays the private entity a monthly/ annual payment for operations and maintenance of the system. The remuneration given could comprise of a fixed fee and a variable component, which would depend on the quality of service provided.

6.1.1.2.2 Operation and Maintenance Services on Gross Cost Model

Under this model, post-construction of civil assets, the private partner installs the system, procures rolling stock and operates and maintains all the assets. The authority collects all the revenue and the private entity is paid an agreed fixed sum for the duration of the contract.

6.1.1.2.3 Operation and Maintenance Services on Net Cost Model

Under this model, post-construction of civil assets, private partner installs system, procures rolling stock and operates and maintains all the assets. The private entity collects the complete revenue generated from the services provided. In case, the revenue generated is lower than O&M cost, the Authority may agree to compensate the difference in cost to the private entity while finalizing the agreement.

6.1.1.3 PPP Models for Metro Rail during O&M Phase – Maintenance Services

6.1.1.3.1 Maintenance Services on Cost + Fee Model

Under this model, post-construction and installation of system including provisioning of rolling stock by public authority, the private partner is awarded the contract to maintain all the assets. The authority collects all the revenue and pays the private entity a monthly/ annual payment for maintenance of the system. The remuneration given could comprise of a fixed fee and a variable component, which would depend on the quality of maintenance.

6.1.1.3.2 Maintenance Services on Gross Fee Model

Under this model, post-construction and installation of system including provisioning of rolling stock by public authority, the private partner is awarded the contract to maintain all the assets. The authority collects all the revenue and the private entity is paid an agreed fixed sum for the duration of the contract.

6.1.1.4 PPP Models for Metro Rail during O&M Phase – Non-Core Services

6.1.1.4.1 Non-Core Services on Cost + Fee Model

For carrying out certain non-core activities such as Automated Fare Collection system, Housekeeping, Non-Fare Revenue Collection etc., a private entity may be selected who shall be paid a monthly/ annual payment for undertaking these activities. The remuneration given could comprise of a fixed fee and a variable component, which would depend on the quality of service provided.

6.1.1.4.2 Non-Core Services on Gross Fee Model

For carrying out certain non-core activities such as Automated Fare Collection system, Housekeeping, Non-Fare Revenue Collection etc., a private entity may be selected who shall be paid an agreed fixed sum for the duration of the contract.

6.1.1.5 PPP Models for Metro Rail during both Construction and O&M Phase

6.1.1.5.1 Development of Metro Rail System on Government Land - Design, Build, Finance, Operate and Transfer (DBFOT) with VGF/Premium

Under this model, the public authority will provide land to the selected private developer. The private partner will develop the infrastructure with its own funds and funds raised from lenders at its risk (that is, it will provide all or the majority of the financing). The contractor is also responsible for operating (supply and running of rolling stock) and managing the infrastructure life cycle (assuming life-cycle cost risks) for a specified number of years. To carry out these tasks, the private partner, will usually create an SPV.

The bid parameter in such projects is either Premium (as percentage of revenues) if the funds coming from users are sufficient to cover O&M expenses and long-term maintenance with a surplus that can then be used as a source to repay the financing of the construction of the asset, and where no Bidder is offering a Premium, bidding parameter is the Grant required (as per VGF scheme of Government of India).

6.1.1.5.2 Development of Metro Rail System on Government Land - DBFOT with Annuity

This model is similar to DBFOT with VGF/Premium expect for two major differences-

User fees/charges are collected by the public authority 2) The private entity receives a fixed amount (called as Annuity payment) for a specified number of years. The fee is generally financed through the funds coming from users and in case the revenue from users is insufficient to meet the Annuity pay-out, the Authority shall finance the same through State/ Central Government.

6.1.1.5.3 Development of Metro Rail System on Government Land - DBFOT with Hybrid Annuity

This model is similar to DBFOT with Annuity expect for one major difference – The private entity receives certain amount (% of capital cost) during construction phase while the remaining is paid out as annuity during operation & maintenance phase.

The comparison of above models and their selection is based on the risk associated with each model. It is known that, compared with public entities, private firms usually have higher costs of capital as well as profitability requirements that significantly affect the cost of infrastructure initiatives. Therefore, the PPP arrangement which would be finalized at the time of implementation should, in principle, enhance value for money (VfM) through a combination of factors, including financing, operational efficiencies, superior risk management, greater implementing capacity, and enhanced service quality.

The transfer of risk from the public entity to the private partner in various PPP models is set out in **Table 6-1.**

Table 6-1: Comparison of PPP Models based on Risk Allocation

PPP Model	Construction Risk (including design & financing risk)	Operation Risk	Maintenance Risk	Non-Core Activities Management Risk	Revenue Risk
DBFT with Annuity	Private	Government	Government	Government	Government
DBFT with Hybrid Annuity	Private	Government	Government	Government	Government
O&M Services – Cost + Fee	Government	Shared	Shared	Shared	Government
O&M Services – Gross Cost	Government	Private	Private	Private	Government
O&M Services – Net Cost	Government	Private	Private	Private	Private
Maintenance Services – Cost + Fee	Government	Government	Shared	Shared	Government
Maintenance Services – Gross Cost	Government	Government	Private	Private	Government
Non-Core Services – Cost + Fee	Government	Government	Government	Shared	Government
Non-Core Services – Gross Cost	Government	Government	Government	Private	Government
DBFOT with VGF/ Premium	Private	Private	Private	Private	Private
DBFOT with Annuity	Private	Private	Private	Private	Government
DBFOT with Hybrid Annuity	Private	Private	Private	Private	Government

6.1.2 Grant by Central Government

Under this option Central Government would fund 10% of the project completion cost excluding private investment Land, R&R and taxes. Remaining costs are to be borne by state with Private sector participation. The private sector participation shall be from one of the models discussed above which shall be finalized at the time of implementation.

6.1.3 Equity Sharing Model

This model is commonly known as Special Purpose Vehicle (SPV) model is the most prevalent model in metro operation in Indian cities. In this model, metro projects are taken up under equal ownership of Central and State Government concerned through equal sharing of equity. The formation of a jointly owned SPV is an essential feature of this model.

After evaluating various parameters, the BMRCL has decided to opt for the Equity form of model as per New Metro Policy 2017 to obtain financial support from Government of India in form of Equity and Subordinate debt, subject to an overall celling of 20% of cost of project excluding private investment, cost of land, rehabilitation and resettlement and State share of taxes.

Bangalore Metro Rail Corporation, the SPV formed under format is implementing the metro rail projects in Bangalore City.

6.1.4 Funds from Non-Fare Box Sources

The non-fare box revenue during the operational phase includes rentals from spaces at Metro stations, advertising income, income from property development, income from parking charges, and other sources like leasing of spare capacity of optical fiber, conducting training, leasing of rail grinding machine etc.

6.2 Pros and Cons of each Option

6.2.1 Public Private Partnership

In view of the shortage of funds from budgetary source and the need of fast tracking the investments in infrastructure, one of the possible options is resorting to PPP. Accordingly, as a matter of policy, it is being promoted so that the infrastructure development can keep pace with the requirement for economic development. However, PPP is not a panacea for all situations. The Pros and cons of PPP approach in procuring a construction cum operation/maintenance contract are as under:

- It brings in private capital thereby freeing up public funds which can be put to works for social cause, not viable for PPP projects;
- It brings in efficiency - hence the pace of developing infrastructure can be ramped up to meet the urbanization challenges;
- Suitably structured, the financing, project and traffic related risks are transferred to the concessionaire thereby saving the exchequer from avoidable exposure;
- As the traffic risk is to be borne by the concessionaire, the justification for the project is to be decided by the market;
- PPP in construction phase also leads to PPP in O&M phase with ease. A private concessionaire, if awarded the responsibility of both construction and later running of the project, is likely to take a long-term perspective in design, quality and standard and would bring in cost saving innovations.
- If a project is developed and operated / maintained by different entities, risk and reward are not properly aligned for optimum results. An O&M concessionaire may attribute any disruption in service to the design fault and hence such arrangement may lead to disputes;
- The liability of Government in a PPP project is limited to paying VGF which is a onetime expenditure, determined by market.
- The Global experience of PPP in rail transit on BOT basis has not been very

encouraging. Even in India, the experience so far is not very promising

- Operations have been recently started in Hyderabad Metro after years of delay in concession
- Delhi Airport express line ran into troubles and is now being operated by DMRC
- Line I of Mumbai Metro has its share of issues to be addressed in the PPP model.

6.2.2 Equity Sharing Model

- The evidence provided by the international experience is overwhelmingly in favour of rail transit projects being developed in the Government sector. These projects are capital intensive and are not viable on the basis of fare box revenue alone, as such require support of revenue generation from non-fare box sources that generally come from land value capture which is much easier for government entity than a private developer.
- Since these projects are highly capital intensive, the cost of capital is a critical issue. Government can raise capital at a much cheaper cost as compared to a private party thus bringing down the overall cost of the project.
- The execution of project involves series of permissions, acquisition of land etc. A government agency is better placed to assume all these risks as compared to a private entity. Considering the sensitivity in acquisition of land, a government entity is better placed in doing so especially if the concerned land is for creation of a public service;
- Standardization of specification and technology is of immense value and a pre-requisite for innovation. This can be achieved more easily if the projects in different part of the countries are built by Government agencies;
- Integration of various corridors/phases of project, in case of PPP is extremely difficult;
- As development rights under a PPP contract to make it sustainable has to be specified upfront at the time of floating of bid, it implies that any rise in value of real estate which takes place subsequent to operation of project is captured by private concessionaire. From this perspective, development of capital intensive Mass Transit projects should be preferably done by Government agencies;
- Besides, the ridership in rail transit generally rises as the network gets larger and larger. Under PPP, the concessionaire of the initial segment of the project is likely to benefit from the extension of the network without contributing anything for extended network;
- In case of failure of PPP, Government will be left with huge liabilities as has been the case with most of the metro rail projects attempted on PPP in Asia- Kuala Lumpur, Bangkok and Metro Manila;
- Under Equity model, the Government of India is exposed uncertain liability.

6.3 Most suitable option for Implementation

BMRCL the SPV formed for the purpose is already operational and has developed Phase I metro and is in process of developing extensions and part of Phase II corridors.

Further, considering the fact that the development of metro systems is capital intensive with long gestation period which unless are supported by sweeteners may not be attractive for private participation. Also to meet the viability gap funding requirements would be very high.

It is, therefore, recommended to implement the project under equity sharing model by SPV with the consideration that private sector participation in different subcomponents of operations & maintenance may be considered and decided subsequently on case to case basis.

6.3.1 Funding Plan

As discussed in the previous sections, implementation of metro rail project is preferred under equity sharing model. Where in 20% of the project cost excluding land shall be funded by central government. Balance funds need to be arranged by the state through matching equity and loan.

6.3.2 Project Cost Estimate

The estimated project cost for the implementation of the Metro corridor along the proposed K R Puram to Airport corridor as per the DPR prepared by BMRCL is presented in **Table 6.2**.

Table 6-2: Capital Cost of the Project-Phase 2B

Sl. No	Major Cost Head	Cost (INR Cr.)
1	Civil Works	2,928
2	Rolling Stok	1,008
3	Systems and telecommunications	1,156
4	Miscellaneous incl contingency	233
5	Land	2,171
6	Taxes	698
7	Others including escalation and IDC	1,741
	Total Cost	**9,935**

The project is expected to be completed and become operational by 2024. The O&M expenses are estimated to be about 296 Cr in the year 2024, the first year of operation.

6.3.3 Means of Finance

The funding plan for the proposed project is presented in **Table 6.3**.

Table 6-3: Funding Plan

Sources		Rs in Cr	(% of Share)
GoI - Equity		1,139.27	11.47%
GoI - Sub-debt		174.38	1.76%
GOI Share sub total	**(1)**	**1,313.65**	**13.22%**
GoK - Equity		1,139.27	11.47%
GoK - Sub-debt		174.38	1.76%
GoK - Sub-debt (Land Cost)		2,171.39	21.86%
Subordinate-debt (State Taxes)		348.76	3.51%
GoK Share sub total	**(2)**	**3,833.81**	**38.59%**
Value Capture Financing	**(3)**	**150.00**	**1.51%**
Innovative Financing	**(4)**	**350.00**	**3.52%**
Senior Debt (Sovereign/Non Sovereign Loans)	**(5)**	**4,287.12**	**43.15%**
Total Sources	**(1) to (5)**	**9,934.58**	**100.00%**

State Government need to fund an amount of Rs. 4,287.12 Cr as equity/Subdebt towards this project. This amount includes an amount of Rs. 2171 Cr towards land acquisition &Rehabilitation & Resettlement and Subordinate-debt (State Taxes) of Rs. 349 Cr.

7

7 Conclusion and Way Forward

7.1 Findings

Bangalore with population more than 10 Million has been witnessing severe road congestion. Limited or no development of matching transport infrastructure, inefficient functioning of road based public transport system due to congestion on road corridors, high private vehicular population, limited coverage of mass transit system has been the root cause of poor mobility in the city.

The Comprehensive Mobility Plan prepared identified several corridors for development of mass transit systems including the corridor connecting Airport. As part of this the corridor from K R Puram to Airport via Hebbal has been considered for evaluation.

The assessment of peak direction passenger traffic indicated rail based systems as Metro or higher order systems as prospective mass transit systems to meet the traffic demand estimated for 2041. Metro systems which are already operating in the city is capable of handling the estimated travel demand.

Potential for expansion of the metro systems to cater to higher passenger demand beyond year 2041 by increasing the number of cars up to 8/9 and its compatibility to the existing systems operating in the city make Metro development as the best suited solution.

7.2 Recommendations

Based on the screening and analysis, Metro System has emerged as the most viable alternative mass transport system. It is also recommended to implement the project under Equity Sharing Model.

Bangalore has a successful example of metro operation on SPV model by Bangalore Metro Rail Corporation Limited (BMRCL). The SPV has developed Phase I metro and is developing additional reaches in Bangalore on equity sharing model.

7.3 Next Steps and Way Forward

After the approval of this Alternatives Analysis Report by the State Government, initiatives shall be taken for preparation of Detailed Project Report for Metro System for the K R Puram to Airport via Hebbal as per guidelines for Metro Rail Policy - 2017 issued by Ministry of Housing and Urban Affairs (MoHUA), Government of India.

Appendix A

Metro/Heavy Metro

Mode	Daily Trips	Veh km Saved	Emission Factors				
			CO	HC	PM	Nox	CO2
Car	49,625	337449	1.39	0.15	0.02	0.12	207.11
Two Wheeler	2,65,847	2368457	1.4	1.01	0.05	0.19	208.6
Auto	42,536	248669	2.45	0.75	0.08	0.12	365.05
Bus	3,50,918	105276	3.72	0.16	0.24	6.53	787.2
	7,08,926	3059851					

Mode	Emmissions Saved/day - Tonnes				
	CO	HC	PM	Nox	CO2
Car	0.47	0.05	0.01	0.04	69.89
Two Wheeler	3.32	2.39	0.12	0.45	494.06
Auto	0.61	0.19	0.02	0.03	90.78
Bus	0.39	0.02	0.03	0.69	82.87
Total	4.8	2.6	0.2	1.2	737.6

Monorail/ Metro Lite

Mode	Daily Trips	Veh km Saved	Emission Factors				
			CO	HC	PM	Nox	CO2
Car	20,472	139212	1.39	0.15	0.02	0.12	207.11
Two Wheeler	1,09,673	977089	1.4	1.01	0.05	0.19	208.6
Auto	17,548	102587	2.45	0.75	0.08	0.12	365.05
Bus	1,44,769	43431	3.72	0.16	0.24	6.53	787.2
	2,92,462	1262318					

Mode	Emmissions Saved/day - Tonnes				
	CO	HC	PM	Nox	CO2
Car	0.19	0.02	0.00	0.02	28.83
Two Wheeler	1.37	0.99	0.05	0.19	203.82
Auto	0.25	0.08	0.01	0.01	37.45
Bus	0.16	0.01	0.01	0.28	34.19
Total	**2.0**	**1.1**	**0.1**	**0.5**	**304.3**

BRTS

Mode	Daily Trips	Veh km Saved	Emission Factors				
			CO	HC	PM	Nox	CO2
Car	4,679	31820	1.39	0.15	0.02	0.12	207.11
Two Wheeler	58,493	521115	1.4	1.01	0.05	0.19	208.6
Auto	9,359	54713	2.45	0.75	0.08	0.12	365.05
Bus	83,449	25035	3.72	0.16	0.24	6.53	787.2
BRT Bus	1,55,980	-46794	3.72	0.16	0.24	6.53	787.2
	1,55,980	632683					

Mode	Emmissions Saved/day - Tonnes				
	CO	HC	PM	Nox	CO2
Car	0.04	0.00	0.00	0.00	6.59
Two Wheeler	0.73	0.53	0.03	0.10	108.70
Auto	0.13	0.04	0.00	0.01	19.97
Bus	0.09	0.00	0.01	0.16	19.71
BRT Bus	-0.17	-0.01	-0.01	-0.31	-36.84
Total	**1.0**	**0.6**	**0.0**	**0.3**	**155.0**