MAHARASHTRA METRO RAIL CORPORATION LIMITED

ALTERNATIVES ANALYSIS REPORT FOR NAGPUR MRTS PHASE 2

JULY 2018

RITES Ltd.
(A Government of India Enterprise)

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0.1 NEED OF STUDY

Nagpur, the Orange city of India, is third largest city as well as second capital of the state in Maharashtra. It is the seat of annual winter session of the Maharashtra State Vidhan Sabha. Nagpur lies precisely at center of the country with Zero Mile Marker indicating the geographical center of India. It is a major commercial and political centre of the Vidarbha region of Maharashtra. The city is also considered as the second greenest city in India along with title 'Tiger Capital of India' as it connects to many tiger reserves in the country. Due to its proximity from various parts of country, the city is also emerging as one of economical hubs in recent times.

The city of Nagpur acts as the district headquarters with a population of about 46 Lakh of which about 24 Lakh population accounts to Nagpur Municipal Corporation as per 2011 Census data.

In addition to the existing public transport and under construction Nagpur metro Phase-1, the Government of Maharashtra through Maha Metro has decided to introduce efficient, safe and high capacity public transport system for Phase-2 corridors and has engaged RITES Ltd. to prepare an 'Alternatives Analysis Report for Mass Transit System'.

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 in September 2017 and this Report has been prepared adhering to these guidelines.

0.2 STUDY AREA, EXISTING TRAFFIC & TRANSPORT CHARACTERISTICS

0.2.1 The geographic area within the jurisdiction of Nagpur Municipal Corporation (NMC) along with the other areas including Municipal Councils of Kamptee, Kalameshwar, Hingna and surrounding villages is taken as Study Area comprising of about 1550 sq km out of total 3567sq km of NMA area.

0.2.2 The population of NMC area is estimated at 26.5 Lakh in the year 2018. Other areas including Kamptee, Kalmeshwar, Hingna and surrounding villages within the study area is 7.8 Lakh. The total population of study area is estimated at 34.3 Lakh in 2018.

0.2.3 The registered vehicles in Nagpur have increased significantly over the years. The high density and rapid growth of vehicles have worsened the transport situation to a significant extent. The sharp increase of two-wheelers and cars could be attributed to the improved economic status of people and deficient public transport supply. An insight into the trends and type of accidents occurred in the Nagpur city indicates a total of 1373 road accidents have taken place in the year 2017 out of which 291 were fatal and 1082 were non- fatal.

0.2.4 The average household size in the Study Area is 4.3 persons per household, average monthly household income is about Rs. 27,000. The Study Area has a total of about 43 lakh daily motorized trips with per capita trip rate of 1.3.

0.3 PUBLIC TRANSPORT PLAN IN CMP

The CMP considers bus rationalization, bus augmentation and mass rapid transit system for Nagpur. Multi Modal Hub are also proposed in CMP. Apart from physical integration fare integration, information integration is also proposed. Intelligent Transport System is considered for Nagpur city including AFCs, Validators, Electronic Ticket Machines, Security Access Modules etc.

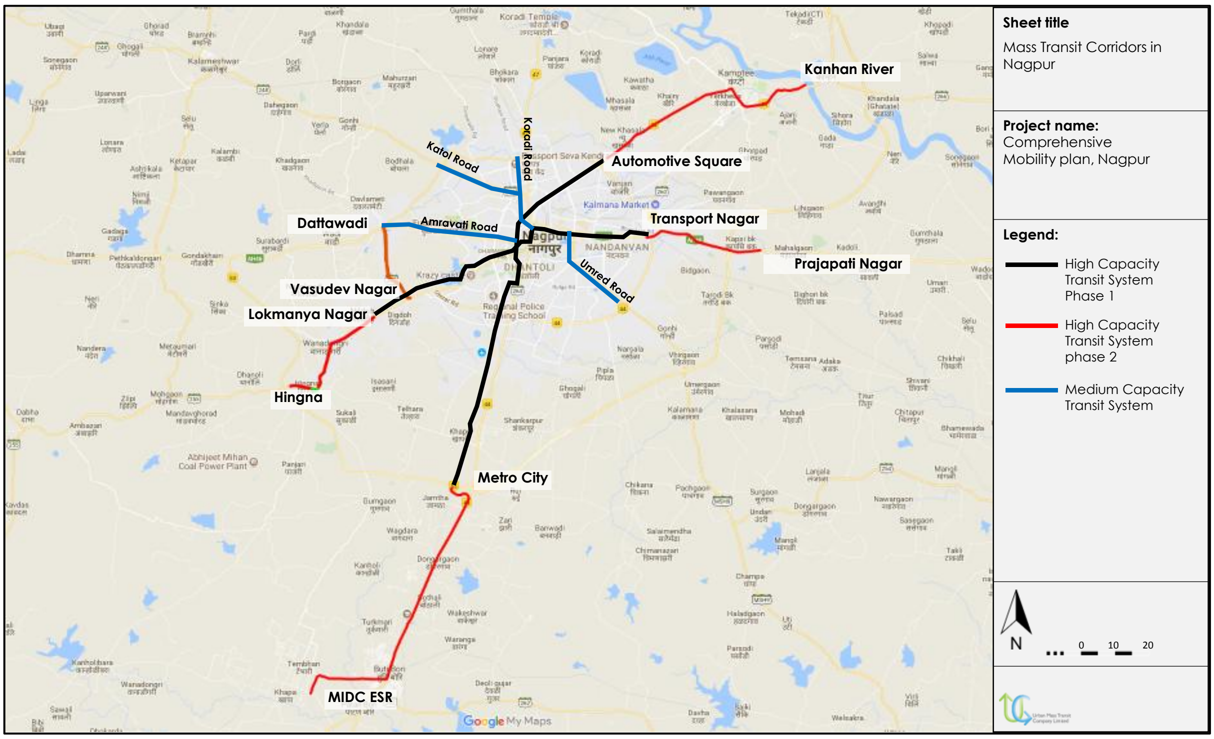
High and medium capacity public transport systems have also been conceived in CMP. A total of about 110 km of rail based public transport network in 2 phases have been proposed. The proposed corridors for rail based public transport systems are presented in **Figure 0.1.**

0.4 SCREENING CRITERIA FOR IDENTIFIED ALTERNATIVES

0.4.1 Screening of alternatives modes has been done to shortlist most viable alternatives for following proposed Phase-2 corridors in the Study Area:

i. MIHAN to MIDC ESR (18.5 km)
ii. Automotive Square to Kanhan River (13 km)
iii. Lokmanya Nagar to Hingna (6.7 km)
iv. Prajapati Nagar to Transport Nagar (5.6 km)
v. Vasudev Nagar to Dattawadi (4.5 km)

FIGURE 0.1: PROPOSED PUBLIC TRANSPORT CORRIDORS IN CMP



0.4.2 The alternative analysis process covers 4 stages **(Figure 0.2)**. Based on the existing study area characteristics and options available for different modes of transport, possible alternatives of public transport for Nagpur have been identified as Metro Rail System, Light Rail System, Elevated Bus Rapid Transit and Normal Buses **(Figure 0.3)**.

FIGURE 0.2: ALTERNATIVES ANALYSIS PROCESS

0.4.3 Metro Rail Policy guidelines of MoHUA, 2017 suggest several screening criteria for alternatives analysis. Following screening criteria have been identified for both the qualitative and quantitative evaluation:

1. **Mobility Effects -** Primary purpose of this task is to assess the current travel demand for base year, with available future year networks and land use data as documented in CMP.

2. **Conceptual Engineering Effect -** Engineering effects have been analysed 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.

3. **System Effects -** The indigenous availability of rolling stock, carrying capacity, type of operation, safety, comfort, land availability for depot, are some of the core transport system related characteristics to be considered.

4. **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.

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

6. **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.

7. **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.

8. **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.

0.4.4 The qualitative evaluation will be the initial level of screening for the identified parameters to narrow the number of alternatives for further evaluation in quantitative analysis stage. A total of 25 nos. screening parameters for qualitative evaluation and 22 nos. for quantitative evaluation have been identified.

FIGURE 0.3: VARIOUS ALTERNATIVE MODES

1. Normal Bus System

2. Elevated Bus Rapid Transit System

3. Light Rail Transit System

4. Metro Rail System

0.4.5 A scoring criterion for each of screening parameters has been developed for the initial qualitative evaluation. The following weightage has been considered as provided in **Table 0.1.**

TABLE 0.1: WEIGHTAGE OF SCREENING CRITERIA FOR QUALITATIVE EVALUATION

SN	Criterion	Weightage
1	Mobility Effects	20
2	Conceptual Civil Engineering Effect	15
3	System Effects	10
4	Environmental Effects	15
5	Social Effects	5
6	Cost Effectiveness & Affordability	15
7	Financial and Economic Effects	15
8	Approvals & Implementation	5
Total		**100**

0.5 SCREENING AND ALTERNATIVE EVALUATION BASED ON GRADING FOR EACH MODE

0.5.1 The scoring criteria have been classified on the basis of the importance and value of the parameter associated with specific transport system. The alternatives are ranked based on their relative performance under each criterion. Four scoring classifications considered for each parameter are:

1. Excellent (100%)
2. High (75%)
3. Medium (50%)
4. Low (25%)

The highest performing alternative receives a score of 100%, followed by 75%, 50% and 25% scores. The summary of analysis of various modes for the given qualitative screening parameters is presented in **Table 0.2.**

0.5.2 Basis of Scoring the Screening Parameters for Qualitative Evaluation

- **Mobility Effects** – Mobility effects namely travel demand and existing transport characteristics in the City influence in determining the mass transport system required. Fulfillment of projected demand in long term scenario, ease of passenger transfer, utilization factor, possibility of intermodal integration between systems and catchment area connectivity are the identified parameters. Guided systems score high in mobility effects as they offer higher carrying capacity and frequency of regulated services, better utilization in terms of more passenger-km and thus reducing congestion on roads.

Metro rail, as a result of the advantages of continuity of Phase 1 corridors, scores 20 points while other modes LRT, Elevated BRT and Normal Bus score 15.5, 12.5 and 8.0 respectively based on their individual mobility related performances. Passengers of road based Elevated BRT and Normal Bus systems will have to physically interchange at Phase 1 metro terminal points thereby largely affecting the safety and convenience.

- **Conceptual Civil Engineering Effects** –The parameters covered are available right of way, alignment design & constructability, geotechnical characteristics, station planning & intermodal integration and requirement for utility shifting.

  Road based systems score high as it requires less right of way and have easy constructability than grade separated rail based systems and BRT. Rail based systems and elevated BRT with dedicated guideway systems have impact on shifting of existing surface / underground utilities. However, Metro Rail, LRT and BRT can offer better station planning and intermodal integration opportunities. Normal buses as a result score of 14.25 out of 15.0 whereas Elevated BRT, Metro Rail and LRT score 11.25, 10.0 and 10.0 respectively.

- **System Effects** – The influential parameters are interoperability with existing Metro Phase-1, passenger's safety & comfort, type of operation and indigenous availability of the system.

  Rail based systems and Elevated BRT are more automated in operations while normal bus system is manually operated in mixed traffic conditions. Metro rail would be the most suitable mode considering continuity / interoperability with the under construction phase 1 metro system. Rail based systems offer better quality of travel and offer safe travel conditions than road based systems. Except for LRT, other modes namely Metro, BRT and Normal bus have indigenous availability in the country. Considering these Metro Rail, LRT, Elevated BRT and Normal Bus score 10.0, 7.0, 6.0 and 4.0 respectively on a scale of 10.

- **Environmental Effects** - The parameters considered are air & noise pollution, trees affected and management of hazardous waste.

  Rail based systems have been assigned better scores more than bus based systems considering their ability to reduce pollution levels on the city roads. Grade separated Metro Rail and LRT being electrified systems play an important role in minimizing the air and noise pollution levels in the city. However, these grade separated systems require exclusive right of way and might impact more affected trees. Under environmental effects, Metro rail and LRT systems score a maximum of 13.50 each, followed by Elevated BRT and Normal bus system with 9.25 and 6.0 respectively on a scale of 15.

- **Social Effects** – Normal Bus based system score high as very few structures / families are affected. Normal buses score 5.0 out of 5.0 whereas elevated BRT, LRT and Metro rail score 3.75, 3.75 and 2.50 respectively.

- **Cost Effectiveness & Affordability** – Bus based systems are more affordable than rail based systems due to lower capital and O&M costs per passenger-km and accordingly are assigned higher scores than metro and light rail systems.

  Rail based systems incur high capital cost whereas normal bus systems require comparatively less investment costs as buses share the existing roadway system with other modes. However, Metro, LRT and elevated BRT consume more construction and O&M costs as they are planned for a much higher operational period and an exclusive guideway system. Accordingly, Normal bus system, Elevated BRT, Metro Rail and LRT score 15.0, 11.25, 7.50 and 7.50 respectively on a scale of 15.0.

- **Financial and Economic Effects** – Economic benefits and Life cycle cost of rail based systems is much higher than road based systems considering reduction in pollution levels, number of accidents and overall social benefits.

  The cost incurred in road based systems considers fuel, operation and maintenance costs. Rail based systems on the other hand result in saving considerable travel time, provide convenient and safe travel conditions thereby resulting in optimizing overall travel cost.

The rail based systems also allow Transit Oriented Development along dedicated corridors which generate additional revenue for the implementing agency/development authority. Metro among rail based systems have higher carrying capacity and offer higher economic returns than all other systems.

Considering these Metro, LRT, Elevated BRT and Normal bus system score 15.0, 12.5, 11.25 and 6.25 respectively on a scale of 15.0.

- **Approvals and Implementation** –Road based systems and Metro score higher than LRT as these systems have set standard procedures for approvals and implementation. LRT would consume more time as it has not been introduced yet in India. Accordingly, the scores are 5.0, 3.75, 3 and 1.25 for Normal bus system, Elevated BRT, Metro and LRT respectively.

TABLE 0.2: QUALITATIVE SCREENING - SCORING OF IDENTIFIED PARAMATERS

S. No	Parameters	Total Score	Metro	LRT	Elevated BRT	Normal Bus System
A. Mobility Effect						
1	Ability to cater Travel Demand - Max. PHPDT	6.0	6.0	4.5	3.0	1.5
2	Ease of Passenger Transfer at Terminals	4.0	4.0	2.0	2.0	1.0
3	Daily System Utilisation-PKM/Route KM	4.0	4.0	3.0	2.0	1.0
4	Average Trip Time	3.0	3.0	3.0	2.25	1.5
5	Catchment Area Connectivity and Circulation	3.0	3.0	3.0	3.0	3.0
	Total A	**20.0**	**20.0**	**15.5**	**12.25**	**8.0**
B. Conceptual Civil Engineering Effect						
1	Available Right of Way (Required Viaduct & Station Widths)	4.0	3.0	3.0	3.0	4.0
2	Alignment Design and Constructability	3.0	1.5	1.5	2.25	3.0
3	Geotechnical Characteristics and Civil Structures	3.0	1.5	1.5	1.5	3.0
4	Station Planning and Intermodal Integration	3.0	3.0	3.0	3.0	2.25
5	Requirement for Utility Shifting	2.0	1.0	1.0	1.5	2.0
	Total B	**15.0**	**10.0**	**10.0**	**11.25**	**14.25**
C. System Effects						
1	Interoperability with Phase-1 System	4.0	4.0	2.0	1.0	1.0
2	Safety & Comfort	2.0	2.0	2.0	1.0	0.5
3	Type of Operation (Guided / Open)	2.0	2.0	2.0	2.0	0.5
4	Indigenous Availability	2.0	2.0	1.0	2.0	2.0
	Total C	**10.0**	**10.0**	**7.0**	**6.0**	**4.0**
D. Environment Effects						
1	Air Pollution	6.0	6.0	6.0	3.0	1.5

S. No	Parameters	Total Score	Metro	LRT	Elevated BRT	Normal Bus System
2	Noise Pollution	4.0	4.0	4.0	2.0	1.0
3	Trees Affected	3.0	1.5	1.5	2.25	3.0
4	Waste Management Including Hazardous Substance	2.0	2.0	2.0	2.0	0.5
	Total D	**15.0**	**13.5**	**13.5**	**9.25**	**6.0**
E. Social Effects						
1	Structures/Persons Affected	5.0	2.5	3.75	3.75	5.0
	Total E	**5.0**	**2.5**	**3.75**	**3.75**	**5.0**
F. Cost Effectiveness & Affordability						
1	Capital Cost (per Passenger KM)	10.0	5.0	5.0	7.5	10.0
2	Operation & Maintenance Cost (per Passenger KM)	5.0	2.5	2.5	3.75	5.0
	Total F	**15.0**	**7.5**	**7.5**	**11.25**	**15.0**
G. Financial and Economic Effects						
1	Economic Returns	10.0	10.0	7.5	7.5	5.0
2	Life Cycle Cost	5.0	5.0	5.0	3.75	1.25
	Total G	**15.0**	**15.0**	**12.5**	**11.25**	**6.25**
H. Approvals and Implementation						
1	Time Required for Approvals	3.0	1.5	0.75	2.25	3.0
2	Ease of Implementation	2.0	1.5	0.5	1.5	2.0
	Total H	**5.0**	**3.0**	**1.25**	**3.75**	**5.0**
	Grand Total A+B+C+D+E+F+G+H	**100.0**	**81.5**	**71.0**	**68.75**	**63.5**

0.5.3 From the screening and analysis of qualitative parameters for different alternative modes in Nagpur, it is inferred that Metro and LRT score 81.5 and 71.0 respectively on a scale of 100. The other bus based modes elevated BRT and Normal Bus System score 68.75 and 63.5 respectively. Considering this, Metro, LRT and Elevated BRT (scores being very close to LRT) have qualified for next stage evaluation. This quantitative evaluation is more rigorous than that of qualitative analysis involving quantification of influential parameters.

0.5.4 Basis of Scoring the Screening Parameters for Quantitative Evaluation

Mobility Effects

The factors contributing to mobility effects considering the local conditions which have been quantified include max. PHPDT, ease of passenger transfer at terminals, passenger utilization in terms of passenger-km/ km and betterment of environment with reduced number of vehicles on road due to proposed mass transit system. The number of commuters travelling in the peak direction in peak hour will be most important guiding factor as the proposed system has to be designed based on this peak hour demand. The comparison of maximum PHPDT on Phase 2 corridors for horizon years is provided in **Tables 0.3.**

Metro will have a 3-car arrangement (as per minimum permissible system motorisation of 67% as recommended by Metro Rail Policy 2017 and configuration adopted in Nagpur Metro Phase 1). While LRT considered is to have 2-car arrangement as this configuration will satisfy the maximum PHPDTs upto various horizon years. Thus on basis of car configuration, LRT caters to a maximum PHPDT of 12,500 while BRT around 8,000. Metro Rail will be catering to maximum PHPDT of 23,000 PHPDT with a 3-car arrangement.

The following corridors in Phase 2 have been considered for mass transport system:

i. MIHAN to MIDC ESR (18.5 km)
ii. Automotive Square to Kanhan River (13 km)
iii. Lokmanya Nagar to Hingna (6.7 km)
iv. Prajapati Nagar to Transport Nagar (5.6 km)
v. Vasudev Nagar to Dattawadi (4.5 km)

The travel demand in terms of maximum PHPDT and Daily Passenger trips for horizon years of 2024, 2031, 2041 and 2051 have been estimated for alternative options of Metro Rail, LRT and BRT. It has been assumed that traffic demand will grow at a rate of 2% per annum beyond 2041. All the four Phase-2 corridors (except Automotive Square - Kanhan) will be catered by any of three systems namely Metro, LRT and BRT till horizon year 2051 as observed (**Table 0.3**) projected maximum PHPDTs are well within peak hour carrying capacities.

TABLE 0.3: MAX. PHPDT FOR MASS TRANSIT SYSTEM FOR PHASE-2 CORRIDORS

Phase	Corridor Details	Maximum PHPDT			
		2024	2031	2041	2051
2	MIHAN to MIDC ESR	3,501	4,387	5,695	6,942
	Lokmanya Nagar to Hingna	3,462	3,887	5,137	6,262
	Prajapati Nagar to Transport Nagar	3,511	3,858	5,213	6,355
	Vasudev Nagar to Dattawadi	3,806	4,862	5,835	7,113

However, for Automotive Square to Kanhan Corridor, it is observed that BRT will be saturated since the beginning from 2024. While Metro and LRT will cater to same number of maximum passengers in peak hour upto the year 2047. Beyond 2047, maximum PHPDT of LRT will get saturated at 12500 and Metro will be able to further cater to peak travel demand till 2051 and beyond (**Table 0.4**).

TABLE 0.4: MAX. PHPDT FOR AUTOMOTIVE SQUARE KANHAN CORRIDOR

Ph 2 Corridor	Max. PHPDT				
	2024	**2031**	**2041**	**2047**	**2051**
Automotive Square to Kanhan River	9,012	9,546	11,445	12,889	13,951

Table 0.5 presents the daily trips for Phase-1 (DMRC DPR Figures) and projected ridership for combined Phase-1 & 2 Corridors. The daily incremental travel demand for Phase-2 corridors ranges from 2.9 lakh passengers in 2024 to 5.0 lakh passengers in 2051.

All the corridors will be catered by any of three systems namely Metro, LRT and BRT till horizon year 2044. Beyond 2044, BRT will get saturated to cater the projected daily passenger demand (Considering peak hour factor of 9% and max. PHPDT of 8000 passengers, BRT can cater upto a total of 4.4 lakh daily passenger trips in five Phase-2 corridors). On similar lines, LRT will get saturated by 2047 (by this time, maximum PHPDT of 12500 will be attained by the system) with a total of 4.6 lakh passenger trips. Beyond 2047, Metro will continue to cater to higher daily passenger trips beyond 2047 owing to its higher carrying capacity.

TABLE 0.5: DAILY INCREMENTAL PASSENGERS (IN LAKH) ON PHASE-2 CORRIDORS

Horizon Year	Phase-1 DPR (DMRC)	Phase-1 & 2 (RITES)	Incremental Passenger Trips due to Phase-2 Implementation
2024	2.6	5.5	2.9
2031	2.9	6.3	3.4
2041	3.7	7.8	4.1
2044*	3.9	8.3	4.4
2047**	4.1	8.8	4.6
2051	4.5	9.5	5.0

* Year of BRT System Saturation, **Year of LRT System Saturation

The utilisation of a system can be established by number of passengers travelling on the specified route length. This ratio of passenger-km over the total transit route length will provide the utilisation of the proposed system. The same ATL has been considered for Metro, LRT and BRT to estimate total daily PKMs. Accordingly, the utilisation in terms of PKM/KM ratios are compared and provided in **Table 0.6.**

TABLE 0.6: DAILY SYSTEM UTILISATION (PKM/KM, IN LAKH)

System Network / Year	2024	2031	2041	2044	2047	2051
Phase 1 Metro + Phase 2 Metro	0.63	0.74	0.89	0.94	1.00	1.08
Phase 1 Metro + Phase 2 LRT	0.63	0.74	0.89	0.94	1.00	1.00
Phase 1 Metro + Phase 2 BRT	0.63	0.74	0.89	0.94	0.94	0.94

The PKM/KM has been estimated till 2041 and further projected upto 2051. It is observed from the table above that Metro provides better utilisation in the longer perspective whereas BRT and LRT get saturated in year 2044 and 2047 respectively. Considering the fact that a mass transport system has to serve the city for long period of time, Metro system appears to be more serviceable mode of transport for Nagpur with the long term perspective.

The 'With & Without Project Scenario' is compared for mass transport systems. The mode-wise passenger trips for the horizon years have been worked out and shown in **Table 0.7.**

TABLE 0.7: MODE-WISE TRIPS IN 'WITH & WITHOUT' PROJECT SCENARIOS

Mode	Trips Without Phase II MRTS Extension (Lakh)				Trips with Phase II MRTS Extension (Lakh)				Daily Trips Reduced on Roads due to Ph 2 MRTS (in Lakh)			
	2024	2031	2041	2051	2024	2031	2041	2051	2024	2031	2041	2051
Car	4.8	5.7	7.0	8.7	4.6	5.4	6.7	8.2	0.2	0.2	0.3	0.4
2-W	32.7	37.7	43.5	50.2	31.6	36.5	42.0	48.4	1.1	1.2	1.5	1.8
Auto	5.4	6.4	9.1	13.0	5.3	6.3	8.9	12.6	0.1	0.2	0.2	0.3
S. Auto	2.0	2.8	3.9	5.3	1.5	2.2	3.1	4.2	0.4	0.6	0.8	1.1
Bus	4.8	5.3	5.8	6.4	3.8	4.1	4.6	5.1	1.1	1.2	1.2	1.3
MRTS	2.6	2.9	3.7	4.6	5.5	6.3	7.8	9.5	2.9	3.4	4.1	4.9
Total	**52.3**	**60.9**	**73.0**	**88.1**	**52.3**	**60.9**	**73.0**	**88.1**	-	-	-	-

Considering the fact that a mass transport system has to serve the city for long period of time, Metro system appears to be more serviceable mode of transport for Nagpur with the long term perspective.

0.5.5 Conceptual Civil Engineering Effects

Civil engineering effects have been worked out for three alternative modes of Metro, LRT and elevated BRT.

0.5.5.1 Geometric Parameters

TABLE 0.8: DESIGN CRITERIA

S. No.	Criteria	Metro	LRT	Elevated BRT
1	Gauge	1435 mm	1435 mm	NA
2	Design Speed	90 kmph	90 kmph	100 kmph
3	Maximum Axle Load	16T	12T	70R – 20T
4	Electric Power Traction	25 KV AC (OHE)	750 V DC (3rd Rail)	NA

TABLE 0.9: TRACK CENTRE, VIADUCT AND HEIGHT ADOPTED IN ELEVATED SECTIONS

System	Track Centre	Viaduct width	Rail /Road Level at mid section	Rail / Road Level at elevated station
Metro	4.60 m	10.50 m	8.0 m	12.5m
LRT	4.45 m	9.85 m	8.0 m	12.5m
Elevated BRT	NA	14.6 m	9.0 m	

TABLE 0.10: GRADIENT PARAMETERS

Description	Metro		LRT		Elevated BRT	
Gradient	Desirable	Absolute Minimum	Desirable	Absolute Minimum	Desirable	Absolute Minimum
Mid-Section	Upto 2%	Upto 4%	Upto4%	Upto6%	Upto3.3%	Upto5%
Stations	Level	Upto 0.1%	Level	Upto 0.1%	Level	

TABLE 0.11: VERTICAL CURVE PARAMETERS

Parameter	Metro	LRT	Elevated BRT
Desirable Radius on Main line	2500 m	2500 m	2500 m
Absolute Minimum Radius on Main line	1500 m	1500 m	1500 m
Minimum Length of Vertical Curve	20 m	20 m	20 m

Design Speed

The design speed will be 80 kmph for Metro and LRT system and 100 kmph for elevated BRT system, subject to further restriction by radius of horizontal curves, cant and cant deficiency.

Station Planning

The Platform length Metro, LRT and elevated BRT systems are worked out and compared as below in **Table 0.12.**

TABLE 0.12: STATION PARAMETERS

Station Parameter	Value		
System	**Metro**	**LRT**	**Elevated BRT**
Coach length	22m	18m	12m
No. of coaches	6	6	1
Platform Length	140m	120m	27m
Elevated station dimensions	140m x 27/24m	120m x 27/24m	30m x 24m

0.5.5.2 Alignment Design

Corridor – 1: MIHAN to MIDC ESR

The proposed alignment of Corridor-1 starts from MIHAN to MIDC ESR. The corridor is extension of North-South corridor of Phase-1 that runs from Automotive Square to MIHAN. The length of the corridor is 18.5 km and is completely elevated. There are 10 stations proposed in this section at approximate interstation distance of 1.9 km.

Corridor – 2: Automotive Square to Kanhan River

The proposed alignment of Corridor-2 starts from Automotive square to Kanhan River. The corridor is extension of North-South corridor of Phase-1 that runs from Automotive Square to MIHAN. The length of the corridor is 13 km and is completely elevated. There are 13 stations proposed in this section at approximate interstation distance of 1 km.

Corridor – 3: Lokmanya Nagar to Hingna

The proposed alignment of Corridor-3 starts from Lokmanya Nagar to Hingna. The corridor is extension of East-West corridor of Phase-1 that runs from Prajapati Nagar to Lokmanya Nagar. The length of the corridor is 6.7 km and is completely elevated. There are 6 stations proposed in this section at approximate interstation distance of 1 km.

Corridor – 4: Prajapati Nagar to Transport Nagar

The proposed alignment of Corridor-4 starts from Prajapati Nagar to Transport Nagar near Asoli. The corridor is extension of East-West corridor of Phase-1 that runs from Prajapati Nagar to Lokmanya Nagar. The length of the corridor is 5.6 Km and is completely elevated. There are 3 stations proposed in this section at approximate interstation distance of 1.9 km.

Corridor – 5: Vasudev Nagar to Dattawadi

The proposed alignment of Corridor-5 starts from Vasudev Nagar to Dattawadi. The corridor is spur of East-West corridor of Phase-1 that runs from Prajapati Nagar to Lokmanya Nagar. The length of the corridor is 4.5 Km and is completely elevated. There are 5 stations proposed in this section at approximate interstation distance of 1 km.

0.5.5.3 Land Requirement

Abstract of land requirements for different components of corridors are worked out for Metro, LRT and BRT systems and compared in **Table 0.13.**

TABLE 0.13: LAND REQUIREMENT FOR SYSTEM ALTERNATIVES (IN HA)

Land Ownership	Acquisition Type	Metro	LRT	Elevated BRT
Central Govt.	Permanent	1.2	1.1	0.5
	Temporary	0.0	0.0	0.0
	Structures- Permanent	0.0	0.0	0.0
State Govt.	Permanent	1.8	33.0	14.4
	Temporary	50.0	45.0	3.23
	Structures -Permanent	0.1	1.0	3.23
Private	Permanent	7.2	6.5	3.0
	Structure	0.7	0.7	0.75

0.5.6 System Effects

0.5.6.1 Interoperability

The interoperability between proposed system in Phase 2 and the mass transit system already in place in Phase 1 is an important parameter and has maximum weightage. The same system can have better system efficiency, optimized use of system resources and enhanced passenger comfort.

Introduction of a new mode 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-1.

0.5.6.2 Rolling Stock Requirement

The corridor wise rolling stock requirement for the systems is presented in **Table 0.14.**

TABLE 0.14: HEADWAY AND ROLLING STOCK REQUIREMENT

System	Parameter	2024	2031	2041
Metro	Coach Requirement (nos.)	60	60	75
LRT	Coach Requirement (nos.)	70	82	98
Elevated BRT	Bus Requirement (nos.)	197	238	292

Bus being the lowest capacity of all systems requires highest number of rolling stock followed by LRT. Metro has least possible rolling stock owing to high capacity.

0.5.6.3 Land Requirement for Depot

Four depots would be required for LRT as well as BRT system as the Phase 2 corridors are at the ends of existing two Phase 1 Metro corridors. In case of Metro, augmentation of Phase 1 depots would be sufficient to meet the maintenance needs of the rolling stock.

0.5.7 Environmental & Social Effects

0.5.7.1 Environment savings will be same for all three modes till 2044 when BRT gets saturated. LRT will reach its capacity in 2047 after which Metro will continue to provide the savings.

It has been estimated that metro rail results in more air pollution savings as BRT and LRT get saturated in 2044 and 2047 respectively.

TABLE 0.15: POLLUTION REDUCTION (TONS/YEAR)

Pollutant	Metro or LRT or Elevated BRT				Metro or LRT	Metro
	2024	2031	2041	2044	2047	2051
Carbon Monoxide (CO)	490.07	579.50	724.11	774.71	829.13	908.15
Hydro-Carbons (HC)	197.68	233.50	289.01	310.56	331.83	362.56
Nitrogen Oxide (NOx)	138.32	156.42	181.16	191.38	200.78	214.22
Particulate Matter (PM)	17.43	20.48	25.03	26.92	28.70	31.28
Carbon Dioxide (CO2)	20506.09	23679.82	27238.50	30621.24	32567.81	35403.67

0.5.7.2 Noise & Vibration Levels for Metro, LRT are in the same order of magnitude.

0.5.8 Structures in Impact Zone

Structures in impact zone are those which are located in a corridor of width 130 m i.e. 65 m on either side of transit line right of way. This width of 65 m is based on screening distance recommended for vibration measurement. The total structures affected are 2051 in numbers along all 5 Phase 2 corridors.

0.5.9 Cost Effectiveness and Affordability

0.5.9.1 Capital Cost

Preliminary Cost estimate **(Table 0.16)** for Metro, LRT and elevated BRT systems has been prepared at February 2018 price level.

TABLE 0.16: PRELIMINARY COST ESTIMATES (RS. IN CRORE)

SN	Item	Metro	LRT	Elevated BRT
1	Land	215.06	451.54	309.65
a	Govt	176.06	412.54	270.65
b	Private	39.00	39.00	39.00
2	Alignment and Formation	2208.33	2033.90	2779.85
3	Station Buildings incl. Civil works, EM works, ECS, TVS, Lift, escalators & Architectural Finishes etc.	1532.35	1302.90	494.39
4	Depot including civil, EM, Machinery & plants, general works	250.00	380.00	193.00
5	P-Way for main line, depot and depot connectivity	506.81	481.47	0.00
6	Traction & power supply for main line and depot incl. OHE, ASS, GIS etc.	785.80	878.80	46.16
7	Signaling and Telecom. Incl. AFC, CCHS etc.	728.54	746.54	170.47
8a	Environmental	37.50	37.50	37.50
8b	R & R incl. Hutments etc.	10.00	10.00	10.00
9	Misc. Utilities, road works, Topographic Surveys, Geotechnical Investigation, Barricading, Tree Cutting and replanting, other civil works such as signage's, Environmental protection and traffic management	411.34	411.34	103.60
10	Capital Expenditure on Security including civil and EM works	13.71	13.71	50.60
11	Staff Quarters and buildings including civil, electrical works and green building concept (Cost of OCC building is included in corridor-1 only)	107.61	158.61	158.61

SN	Item	Metro	LRT	Elevated BRT
12	Rolling Stock	651.60	882.00	162.40
13	Capital Expenditure on Inter modal integration including Footpath for pedestrians, Feeder Buses and Bicycles @2% of Total Cost excluding Land	144.87	146.74	84.13
14	Total of all items except Land	7388.46	7483.50	4290.71
15	General Charges incl. Design charges, including Metro Bhawan, (Civil+EM works) @ 5% on all items except land. (Metro Bhawan is charged to coridor-1 only and it will cater to both the corridors)	369.42	374.17	214.54
16	Total of all items including G. Charges	7757.88	7857.67	4505.25
17	Contingencies @ 3 %on all items except land	232.74	235.73	135.16
Gross Total including Contingencies (excluding Land Cost)		7990.62	8093.40	4640.40
Gross Total including Contingencies (including Land Cost)		8205.68	8544.94	4950.06
SGST @6% (on Total cost excluding Land and R&R)		478.84	485.00	277.82
CGST @6% (on Total cost excluding Land and R&R)		478.84	485.00	277.82
Total Cost including Taxes & Duties		**9163.35**	**9514.95**	**5505.71**

0.5.9.2 Operational & Maintenance Costs

The O&M cost for the three systems for horizon years have been calculated and presented in **Table 0.17.**

TABLE 0.17: O&M COST AT CURRENT PRICES (IN RS. CRORE)

System	2024	2031	2041
Metro	356.37	596.69	1279.34
LRT	371.64	624.45	1332.24
Elevated BRT	2.7	3.2	3.9

0.5.10 Financial and Economic Effects

0.5.10.1 Economic Returns

The economic costs of the capital works and annual operation and maintenance costs have been calculated from the financial cost estimates by excluding price contingencies/price escalations, Import duties and taxes, Sunk costs and Interest payment, principal payment and interest during construction period. The economic costs have been derived from financial costs using following shadow price factor (0.83 for Capital Cost and 0.87 for O&M Cost) to take care of the distortions. The economic costs of Metro, LRT and elevated BRT are presented in **Table 0.18.**

TABLE 0.18: ECONOMIC COSTS OF METRO, LRT& BRT - CAPITAL AND O&M

Cost Component	Metro	LRT	Elevated BRT
	(In Rs Crore)		
Construction Cost Including land and R&R	6811	7389	4109
O&M Costs			
2024	213	213	1.5
2031	215	217	1.8
2041	219	223	2.3

The quantifiable benefits are accrued to the society owing to implementation of the Mass Transport System (Metro/LRT/BRT) project include Travel time savings, savings in Vehicle Operating Cost, savings from Accident reduction and Pollution reduction. The accrued benefits for horizon years are summarized in **Table 0.19.**

TABLE 0.19: COMPARISONS OF SAVINGS FROM THREE SYSTEMS IN 2041

SN	BENEFITS	Metro		LRT		Elevated BRT	
		Amount	% Share	Amount	% Share	Amount	% Share
1	Travel Time Savings	546	32	444	43	386	44
2	Savings in Vehicle Operating Cost	834	49	440	43	391	44
3	Savings from Accidents, Pollution & Road maintenance Reduction	326	19	149	14	105	12
	Total	**1706**	**100%**	**1033**	**100%**	**883**	**100%**

For deriving the values of economic indicators (EIRR, NPV), cost and benefit stream for the systems has been constructed in terms of money value. The ENPV has been derived considering the acceptable discount rate of 14%. The summary of the ENPV, EIRR and Cost Benefit ratio is presented in **Table 0.20.**

TABLE 0.20: COMPARISON OF ECONOMIC INDICATORS OF THREESYSTEMS IN 2041

SN	Parameter	Metro	LRT	Elevated BRT
1	EIRR	14.73%	8.16	14.89%
2	ENPV (in Rs. Crore) - Social cost of capital @14% - Government Security Rate@ 7.2%	 260 5521	 -1894 618	 195 3437

0.5.10.2 Life Cycle Cost

The requirement of rolling stock is higher in case of LRT and BRT system attributed to smaller dimensions of coach as compared to Metro thereby requires less headways to cater to same demand as that of Metro. This results in additional coaches for LRT and BRT for operating in higher frequencies to cater the demand resulting in more wear and tear.

0.5.11 Approvals and Implementation

0.5.11.1 Time required for Approvals

Light Rail Transit system is new in India. With no previous experience in light rail technology in the country specifically in rolling stock design and O&M, the technical expertise will have to be developed afresh which may result in time delays in approval of LRT. As there are set standards and procedures for Metro Rail and BRT, these two modes will relatively consume less time for approvals than LRT.

0.5.11.2 Ease of Implementation

With several operational metro rail and BRT systems in India, the 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 and BRT systems have better ease of implementation than that of LRT attributed to prior experiences and expertise.

0.5.12 Scoring of Quantitative Parameters

The quantitative evaluation of parameters has focused on eliminating the alternative among Metro, LRT and elevated BRT that is less viable for Nagpur.

0.5.12.1 Basis of Scoring Parameters for Quantitative Evaluation

The weightage for various criteria for quantitative evaluation has been considered same as that of qualitative evaluation. However, detailed evaluation of quantitative parameters has been carried out. The basis of scoring these parameters is as follows:

- **Mobility Effects -** Mobility effects namely Peak Hour Peak Directional Traffic, ease in passenger transfer, system utilization and reduced vehicles on road have been considered as influential parameters. Metro Rail system score high as it offers higher carrying capacity and high frequency of regulated services, better utilization in terms of more passenger-km and higher convenience in ease of passenger transfers than BRT and LRT due to continuity in existing system as Phase-2. Accordingly, Metro, LRT and BRT have been assigned 20.0, 15.0 and 7.25 on a scale of 20.0 based on mobility related performance.

- **Conceptual Civil Engineering Effects –** The parameters covered are available right of way, alignment design and constructability, geotechnical characteristics & civil structures, station planning & intermodal integration, utility shifting.

  Rail based systems and elevated BRT with dedicated guideway systems impact shifting of existing utilities along the alignment. Among Metro, LRT and BRT, LRT consumes least possible right of way for land acquisition. Alignment design and constructability parameters are relatively easier for BRT system. Rail based system are more efficient in station planning and intermodal integration opportunities. Metro Rail, LRT and Elevated BRT score 13.75, 12.75 and 11.5 respectively on a scale of 15.0.

- **System Effects –** The influential parameters are interoperability with Phase-1, rolling stock requirement, land for maintenance depot and indigenous availability.

  Metro rail has highest carrying capacity among Metro, LRT and BRT and results in having least possible rolling stock. On the other hand, LRT and BRT require more quantum of rolling stock to cater to the peak demand. Metro rail would be the most suitable mode considering continuity/interoperability with the under construction metro rail. Except for LRT other modes Metro rail and BRT have indigenous availability. In India, Metro Rail and BRT are operational in various cities and have the technology in place. Consideration of LRT will result in time and cost implications attributed to import of rolling stock, design specifications for Indian conditions. Considering the above Metro Rail, LRT and Elevated BRT score 10.0, 7.0 and 5.0 respectively on a scale of 10.

- **Environmental Effects –** The parameters considered are air & noise pollution. Rail based systems have been assigned better scores more than bus based systems considering their ability to reduce pollution levels on the roads. Metro Rail, LRT being electrified systems play an important role in minimizing the air and noise pollution levels in the city. Accordingly, Metro rail score a maximum of 15.0, followed by LRT systems and Elevated BRT with 12.5 and 7.5 respectively in environmental effects on a scale of 15.0.

- **Social Effects –** LRT consuming minimum space for alignment related acquisition scores more over Metro and BRT. Accordingly, LRT, BRT and Metro score 5.0, 3.75 and 3.75 respectively on a scale of 5.0.

- **Cost Effectiveness & Affordability –** BRT is more affordable than rail based systems due to lower capital and O&M costs per passenger km and accordingly is assigned higher scores than metro and light rail systems.

  Rail based systems incur high capital cost whereas bus system require comparatively less investment costs. Similarly, rail based systems like Metro rail and LRT consume more O&M costs as they are planned for a much higher operational period. Accordingly, Elevated BRT, Metro and LRT have been assigned 15.0, 8.75 and 7.5 on a scale of 15.0.

- **Financial and Economic Effects –** Metro scores higher than LRT considering life cycle costs and economic benefits. Economic benefits and Life cycle cost of rail based systems is much higher than road based systems considering reduction in pollution levels, number of accidents and overall social benefits.

  Metro rail among rail based systems cater more passengers and offer higher economic returns attributed to comparatively less rolling stock. Considering these, Metro, Elevated BRT and LRT score 12.5, 12.5 and 10.0 respectively on a scale of 15.0.

- **Approvals and Implementation** – BRT scores higher than Metro and LRT as there are set standard procedures for approvals and considering ease of implementation. LRT would consume more time as it has not been introduced yet in India. Accordingly, the scores are 5.0, 3.75 and 1.25 for Elevated BRT, Metro Rail and LRT respectively.

The summary of scoring for Metro, LRT and elevated BRT based on the quantitative evaluation is presented in **Table 0.21.**

0.5.12.2 From the quantitative evaluation of parameters for Metro, LRT and elevated BRT Systems, it can be inferred that Metro System with a score of 87.5 scores higher than

LRT and elevated BRT which score 71.0 and 67.50. The Metro System henceforth emerges to be the most viable mass transit mode for Phase 2 corridors of Nagpur Mass Transport System.

TABLE 0.21: QUANTITATIVE EVALUATION - SCORING OF PARAMATERS

S. No	Parameters	Total Score	Metro	LRT	Elevated BRT
A. Mobility Effect					
1	Ability to cater Travel Demand - Max. PHPDT	6.00	6.00	4.5	3.00
2	Ease of Passenger Transfer at Terminals	6.00	6.00	4.5	1.50
3	Daily System Utilisation-PKM/KM	5.00	5.00	3.75	1.25
4	Reduced Vehicles on road due to proposed system	3.00	3.00	2.25	1.50
	Total A	**20.00**	**20.00**	**15.0**	**7.25**
B. Conceptual Civil Engineering Effect					
1	Available Right of Way (Land Acquisition)	4.00	3.00	4.00	2.00
2	Alignment Design and Constructability	3.00	2.75	1.50	3.00
3	Geotechnical Characteristics and Civil Structures	3.00	3.00	3.00	3.00
4	Station Planning and Intermodal Integration	3.00	3.00	2.25	1.50
5	Requirement for Utility Shifting	2.00	2.00	2.00	2.00
	Total B	**15.00**	**13.75**	**12.75**	**11.50**
C. System Effects					
1	Interoperability with Phase-1 System	4.00	4.00	3.00	1.00
2	Rolling Stock Requirement	2.00	2.00	2.00	1.00
3	Land for Maintenance Depot	2.00	2.00	1.00	1.00
4	Indigenous Availability	2.00	2.00	1.00	2.00
	Total C	**10.00**	**10.00**	**7.00**	**5.00**
D. Environment Effects					
1	Air Pollution	10.00	10.00	7.5	5.00
2	Noise Pollution	5.00	5.00	5.00	2.50
	Total D	**15.00**	**15.00**	**12.50**	**7.50**
E. Social Effects					
1	Structures/Persons Affected	5.00	3.75	5.00	3.75
	Total E	**5.00**	**3.75**	**5.00**	**3.75**
F. Cost Effectiveness & Affordability					
1	Capital Cost (per Passenger KM)	10.00	5.00	5.00	10.00
2	Operation & Maintenance Cost (per Passenger KM)	5.00	3.75	2.50	5.00
	Total F	**15.00**	**8.75**	**7.50**	**15.00**
G. Financial and Economic Effects					
1	Economic Returns	10.00	7.50	5.00	10.00

S. No	Parameters	Total Score	Metro	LRT	Elevated BRT
2	Life Cycle Cost	5.00	5.00	5.00	2.50
	Total G	**15.00**	**12.50**	**10.00**	**12.50**
H. Approvals and Implementation					
1	Time Required for Approvals	3.00	2.25	0.75	3.00
2	Ease of Implementation	2.00	1.50	0.50	2.00
	Total H	**5.00**	**3.75**	**1.25**	**5.00**
	Grand Total A+B+C+D+E+F+G+H	**100.00**	**87.50**	**71.00**	**67.50**

0.6 IMPLEMENTATION OPTIONS FOR VIABLE ALTERNATIVE

Based on both qualitative and quantitative screening carried out in previous sections, Metro Rail System has emerged as the most viable alternative mass transport system to meet the transport needs of Nagpur city along Phase 2 corridors.

0.6.1 Capital and O&M Costs

TABLE 0.22: COST OF NAGPUR METRO PHASE-2 AT FEBRUARY 2018 PRICE LEVEL

Cost Component	Amount (Rs. in Crore)
Construction Cost Including land &R&R	8206
Taxes @12% for GST	957
Total Including Taxes	**9163**
Completion Costs	
Cost Without Taxes	9627
With Central Taxes	10430
With both Central and State taxes	11008
O&M Costs	
2024	356
2031	597
2041	1279

0.6.2 Options of Central Financial Assistance (CFA)

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

- Public Private Partnership (PPP)
- Grant by the Central Government
- Equity Sharing Model

0.6.2.1 The fundamental principle underlying Public Private Partnerships (PPPs) as a development option for any infrastructure project is to combine the strengths of the private sector with those of the public sector in order to overcome challenges faced during construction & operation and to achieve superior outcomes.

As per the rules of GOI, the CFA in terms of viability gap funding has a cap of 20% of the project completion cost excluding Land, R&R and state taxes for PPP projects provided the state government also contribute same or more amount towards the project. Accordingly for Nagpur Metro Phase 2 corridors, the VGF requirement from GOI shall be Rs. 2041 Crore. Year wise outflow of funds from GOI for CFA would be as presented in **Table 0.23**.

TABLE 0.23: FUND REQUIREMENT FROM GOI UNDER PPP MODEL

Year	Central Financial Assistance (Rs in Crore)
2019-2020	89
2020-2021	280
2021-2022	392
2022-2023	514
2023-2024	540
2024-2025	227
Total	**2041**

0.6.2.2 Under Grant by Central Government option, the CFA is 10% of the project completion cost excluding private investment land, R&R and state taxes. Total outgo from the GOI as CFA would be Rs. 1021 Crore. Year wise fund requirement is detailed in **Table 0.24**.

TABLE 0.24: FUND REQUIREMENT FROM GOI UNDER GRANT MODEL

Year	Central Financial Assistance (Rs in Crore)
2019-2020	44
2020-2021	140
2021-2022	196
2022-2023	257
2023-2024	270
2024-2025	113
Total	**1021**

0.6.2.3 The central financial assistance under Equity Sharing Model is same as that of PPP model i.e. 20% of project completion cost excluding land, R&R and state taxes. But in this model, the CFA consists of central government equity and subordinate debt towards central taxes to the project. Generally the share of subordinate debt varies from 5-6% and equity component varies between 14-15%. **Table 0.25** gives the year wise out flow of funds as Central Financial Assistance from GOI.

TABLE 0.25: FUND REQUIREMENT FROM GOI UNDER EQUITY SHARING MODEL

Year	Total Funds (Rs in Crore)
2019-2020	89
2020-2021	280
2021-2022	392
2022-2023	514
2023-2024	540
2024-2025	227
Total	**2041**

0.6.3 Funds from Non-Fare Box Sources

Metro Rail Policy envisages fund generation by state from non-users beneficiaries which may include dedicated levies on on-user beneficiaries mainly property. The value created in the proximity zones can be recovered through land monetization; i.e. additional FAR, a 'Betterment Levy' or 'Land Value Tax' or enhanced property tax or grant of development rights. Transit Oriented Development (TOD) in the influence areas of MRT corridors will help to generate funds for financing of the MRT. The estimation of funds generation from these sources will be done at DPR stage.

0.6.4 It is recommended to implement the project under equity sharing model by SPV with private sector participation in different subcomponents of operations & maintenance.

0.7 CONCLUSION

- Qualitative parameters evaluation of the available alternatives namely Normal Bus System, Elevated Bus Rapid Transit, Metro and Light Rail Transit have been carried out on the identified mass transport corridors.

- In the preliminary screening of qualitative parameters, Metro, Light Rail Transit and Elevated BRT have emerged as prospective mass transport systems for Phase 2 corridors in Nagpur for further quantitative evaluations. Normal Bus has been ruled out in view of inability to meet the passenger demand in future and significant greenhouse gas emissions.

- All three modes namely Metro (3 car train), LRT (2 car train) and BRT systems can cater to Peak Hour Peak Direction Passenger Trips upto the horizon year 2044. BRT and LRT Systems will get saturated in the years 2044 and 2047 respectively and no additional traffic can be catered by these two modes beyond 2047. However, Metro system will continue to cater the peak hour passenger demand much beyond 2047 attributed to its higher carrying capacity.

- With metro being constructed in Phase 1, its technology as well as various components like track gauge, civil structures and rolling stock components are easily available and standardised in Nagpur. Efforts have also been made by Government and implementing agencies to indigenize various components of metro rail systems. Technical expertise has also been developed in the country over the period of time.

  Light Rail Transit system is new for India. With no previous experience in light rail technology in the country specifically in rolling stock design and O&M, the technical expertise will have to be developed afresh which may result in implementation delays and cost implications. BRT System gets saturated over a period of time thus warranting a high carrying capacity system which can address the transport demand with a much longer perspective even upto 100 years.

- The interoperability between proposed system in Phase 2 and the mass transit system already in place in Phase 1 is an important parameter. The introduction of same system can have better system efficiency, optimized use of system resources and enhanced passenger comfort at the terminal stations as well. Whereas, a different mode 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-1.

- Based on detailed quantitative evaluations of screening parameters, Metro System has scored higher than that of LRT and Elevated BRT Systems.

- Based on both qualitative and quantitative screening and analysis, Metro System has emerged as the most viable alternative mass transport system for Phase II corridors in Nagpur. It is also recommended to implement the project under Equity Sharing Model with private sector participation in different subcomponents of operations & maintenance. Maharashtra has a successful example of metro operation in Mumbai on SPV model by Mumbai Metro Rail Corporation (MMRC).

- 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 Phase 2 corridors of Nagpur Metro as per guidelines for Metro Rail Policy - 2017 issued by Ministry of Housing and Urban Affairs (MoHUA), Government of India.

Chapter – 1.
NEED OF STUDY

1. NEED OF STUDY

1.1 BACKGROUND

Nagpur, the Orange city of India, is third largest city as well as second capital of the state in Maharashtra. It is the seat of annual winter session of the Maharashtra State Vidhan Sabha. Nagpur lies precisely at center of the country with Zero Mile Marker indicating the geographical center of India. It is a major commercial and political centre of the Vidarbha region of Maharashtra. The city is also considered as the second greenest city in India along with title 'Tiger Capital of India' as it connects to many tiger reserves in the country. Due to its proximity from various parts of country, the city is also emerging as one of economical hubs in recent times.

The city of Nagpur acts as the district headquarters with a population of about 46 Lakh of which about 24 Lakh population accounts to Nagpur Municipal Corporation as per 2011 Census data with an average density of 11,000 persons/sq.km.

Nagpur has large number of technical education institutes catering to rising needs of IT-ITES industry in the region by generating enough manpower resources. Nagpur, also considered as a low living cost city, has become a prime destination for Information Technology Enabled Services (ITES) and Business Process Outsourcing (BPO) units. In addition, Multi-modal International Cargo Hub & Airport at Nagpur (MIHAN) is also expected to be established as one of the major IT centers in the country.

Rising per capita income and changes in economy structure are generating greater demand for mobility to meet business and personal needs. There is an increase in demand for physical infrastructure in general and transportation in particular. Rapid urbanization and intense commercial developments in the recent past have resulted in steep rise in travel demand putting Nagpur's transport infrastructure to stress. However, increase in capacity of the transport system has not been compatible with transport demand.

Comprehensive approach to planning for urban landuse and transport infrastructure has to be adopted for alleviating the traffic and transportation problems of city. Comprehensive Mobility Plan (CMP) is now considered as a prerequisite for planning of public transportation in a City. By treating urban area as a system and recognizing interactions between landuse and traffic & transport, it shall be possible to predict the future requirements and accordingly evaluate alternative modes for most optimum mobility plan for the city with most sustainable mode (s).

In addition to the existing public transport and under construction Nagpur metro Phase-I, the Government of Maharashtra through Maharashtra Metro Rail Corporation have decided to introduce efficient, safe and high capacity public transport system for Phase-II corridors and has engaged RITES Ltd. to prepare an 'Alternatives Analysis Report for Mass Transit System' in Nagpur.

1.2 GUIDELINES FOR ALTERNATIVES 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.

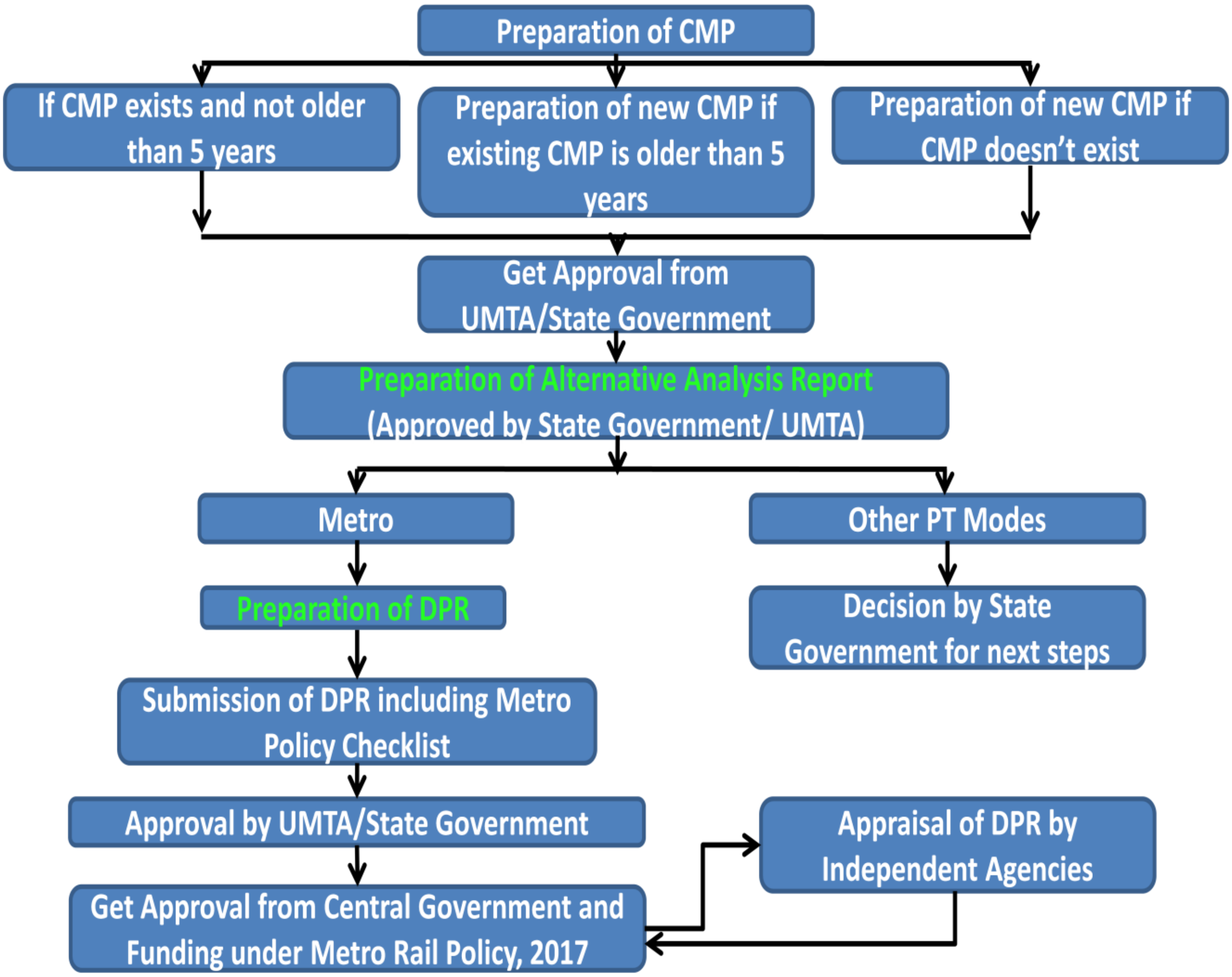
The guideline stresses CMP to be pre-requisite for conception of mass transport projects in cities. Comprehensive Mobility Plan for Nagpur has been prepared in 2013 and updated in 2018. The mandated framework in the policy is presented in **Figure 1.1.**

The guideline enables to identify the system having maximum utility and satisfy basic criteria. The policy document has listed guidelines for preparation of Comprehensive Mobility Plan (CMP), Alternatives Analysis and Detailed Project Report (DPR) for most viable alternative.

The objectives of Alternatives Analysis include:

- Ensure that reasonable transportation alternatives are considered
- Evaluate all impacts due to project
- Consider opinion of stakeholders
- Select the locally preferred alternative

FIGURE 1.1: POLICY FRAMEWORK OF METRO POLICY 2017



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, fast, comfortable
- Punctual and reliable services
- Run at grade/elevated viaduct/underground
- 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

Following 4 stages have been outlined for preparation of Alternatives Analysis Report:

1. **Stage 1:** Develop Screening Criteria for Identified Alternative Options suggested in CMP
2. **Stage 2:** Evaluation Parameters for various Alternatives
3. **Stage 3:** Alternatives Evaluation
4. **Stage 4:** Implementation Options for most viable Alternative

1.3 OVERVIEW OF STUDY AREA

The geographic area within jurisdiction of Nagpur Municipal Corporation (NMC) along with the other areas including Municipal Councils of Kamptee, Kalameshwar, Hingna and surrounding villages is taken as Study Area. It comprises of about 1550 sq km out of total 3567sq km of NMA area. Majority of population of Study Area resides within NMC area. As per Census 2011, the population of NMC area is about 24 Lakh. The study area map has been shown in **Figure 1.2**.

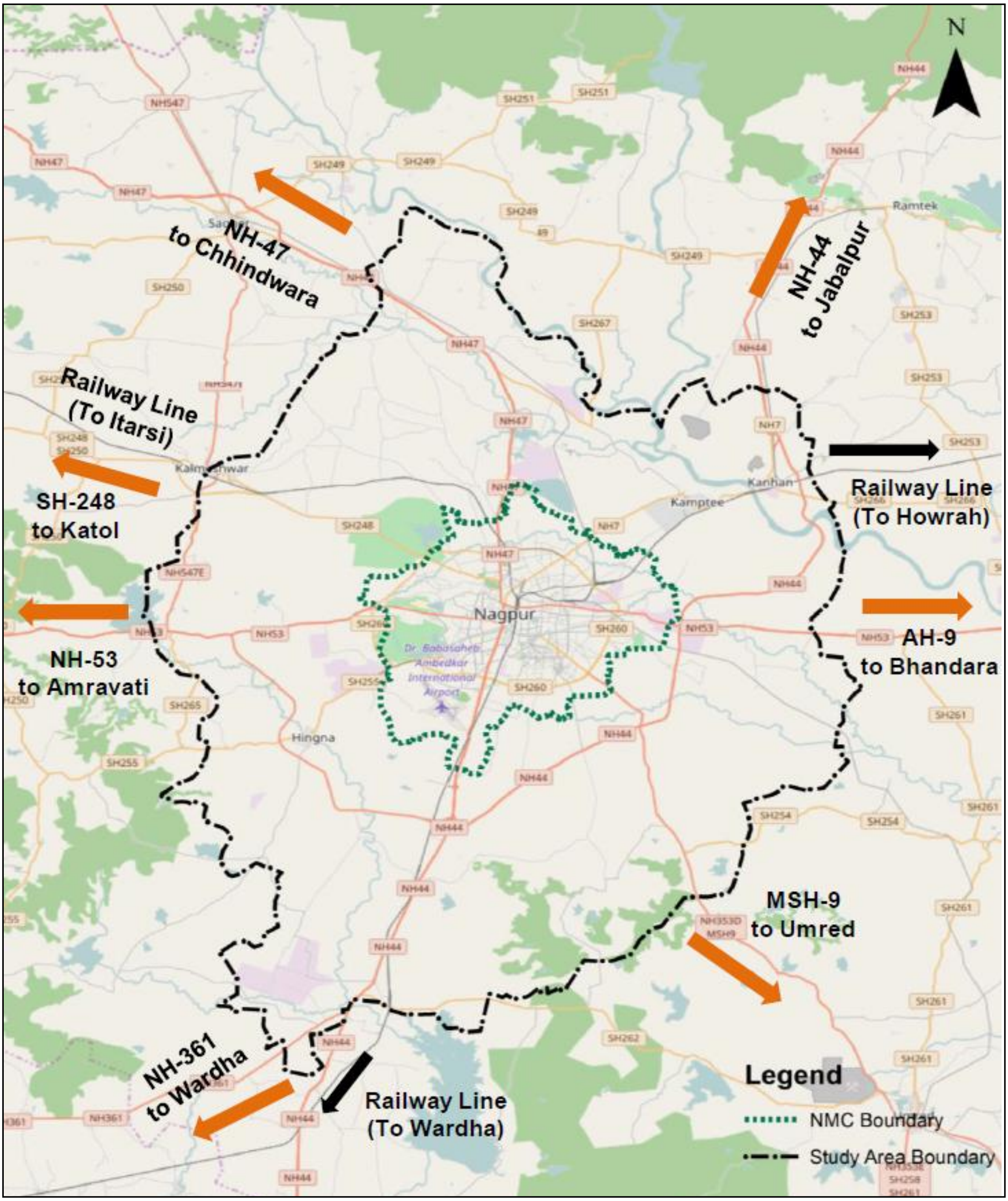
1.4 REGIONAL GOALS AND OBJECTIVES

The regional goals and objectives are conceived with a broader perspective of the Study Area having specific attention to the core city area with a view to ensure Smarter, Accessible and Safe & Secure urban transport.

The objectives/targets from the city level studies such as development plans and mobility plans include the following:

- Ensure safe pedestrian facilities in areas of pedestrian concentration and along major corridors.
- Restrict entry of personal vehicles in the core city area and reduction of on street parking.
- Public Transport improvement plan which includes convenient access, integration with existing Intermediate Public Transport System, provision of Non-Motorised Transport facilities, creation of infrastructure facilities.
- Implementation of traffic management measures like one way system, access restrictions for heavy vehicles etc.

FIGURE 1.2: STUDY AREA MAP



- Develop immediate/ short term strategies to ease flow of traffic at major congestion points within the city.
- Develop medium and long term measures to ease traffic flow along major roads within the city.

Mobility strategies have been considered giving due importance to integrated landuse-transport planning, control on movement of personal vehicles and encourage public transport system and other sustainable modes.

1.5 PROJECT PURPOSE

Urbanization and rapid growth of vehicles population has laid severe stress on the urban transport system in Nagpur. Increase in vehicular traffic and limited augmentation road infrastructure facilities have been observed in the City. Private modes have gained more usage due to limited public transport facilities with poor level of service.

Alternatives Analysis is required to identify the best option among alternative transport modes to address the traffic related problems in the city. Identification and implementation of most feasible transport system would alleviate the existing transportation woes.

1.6 NEED FOR PROPOSED PROJECT

1.6.1 Indian cities have been growing rapidly. There is a need to direct growth in a planned manner with adequate attention to transport system at early stages in their development. Cities are witnessing fast growth in the number of personal motor vehicles, with severe congestion and pollution being the most visible manifestation of the growth in the number of motor vehicles. Efforts at providing solutions to the situation will need to focus on improving the public transport system. In several cities this would require implementation of mass transit systems such as bus rapid transit, light rail, metro rail etc.

1.6.2 Mass Rapid Transit System (MRTS) in urban areas not only facilitate easy and quick movement of people but also have a positive impact on the economic growth and quality of life. This will result in increased income and various benefits to the society like reduced external cost due to reduction in traffic congestion, road and parking cost, transport cost and per-capita traffic accidents. MRTS tends to reduce per capita vehicle ownership and encourage more compact & walkable development pattern which provide developmental benefits to the society. Reduction in cost and time of travel lowers the cost of production of goods and services which significantly improves city's competitiveness. One of the significant contributions is substantial reduction in per capita pollution emission bringing down various chronic diseases; hence, results in huge public health benefits.

1.6.3 Maha Metro has already begun the construction of following Phase 1 Corridors of total length about 40 km.

i. North-South Corridor - Automotive Square to MIHAN (About 20 km)
ii. East-West Corridor - Prajapati Nagar to Lokmanya Nagar (About 20 km)

In addition to the proposed Phase-I metro rail system there is a necessity felt for Phase-II mass transport system to cater to the ever growing transport demand in the Study Area.

1.6.4 Options of Mass Transport Systems

The mass transport systems in cities/ urban agglomeration can be broadly classified into the following 6 categories:

a. **Normal Bus System:** Normal/ordinary bus system is the main public transport system in many major Indian cities. The buses are operated by the State Governments and respective development authorities for public transport in the city. They are normally characteriterised by sharing the common Right of Way with other modes of transport in the city.

b. **Bus Rapid Transit System (BRTS):** BRTS are physically demarcated bus lanes along the main carriageway with a segregated corridor for movement only for buses. At the intersections, buses may be given priority over other modes through a signalling system. BRTS is an enhanced form of a busway which incorporates features such as facilities for pedestrians, non-motorised vehicles (NMV) and many other associated infrastructures including operations and control mechanism. Elevated BRTS is preferred system to have higher capacity in terms of peak hour peak directional traffic.

c. **Tramways:** These are generally at-grade rail based systems that are not segregated from the main carriageway and often move in mixed traffic conditions.

d. **Light Rail Transit System (LRT):** LRT is at-grade/grade separated rail based mass transit system, which is generally segregated from the main carriageway.

e. **Metro Rail System:** Metro rail is a fully segregated rail based mass transit system, which could be at grade, elevated or underground. Due to its physical segregation and system technology, metro rail can have a very high passenger carrying capacity of 40,000 – 80,000 peak hour peak directional traffic (PHPDT).

   Metro rail, though being capital intensive, provides the much needed high capacity rapid transit in cities. Though they have a life of 100 years and beyond, due to the nature of construction, the flexibility in design changes after the construction is very limited. Hence, they should be planned and executed with a longer future perspective. Being a high capacity transport system, they are suited for growing cities having prospective increase in population over several years.

f. **Regional Rail:** Regional rail caters to passenger services within a larger urban agglomerate or metropolitan area connecting the outskirts to the center of the city. The services have greater number of halts at smaller distances compared to long distance railways but fewer halts and higher speeds compared to metro rail. Regional rail are common in large metropolitan cities and help in decongesting the city center by providing safe, and speedy access to the city center for commuters residing in less congested suburbs.

1.6.4 Choice of a particular MRTS will depend on a variety of factors like demand, capacity, cost and ease of implementation. ABRT or LRT system at grade may require linear pathway to be carved out of existing land if additional space cannot be made available on the sideways and will reduce the space for other traffic depending on the width of existing roads. LRTs and Tramways without horizontal separation will have reduced speed and hence reduced capacity.

Cities with a well spread out spatial pattern, even if they have a high population, may not have sufficient number of corridors with adequate density to justify investments in metro rail. Yet cities with a linear spatial pattern may justify a metro even at lower population levels as they have fewer corridors and each would have a high traffic density. 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.

Hence, there is a need to carry out Alternatives Analysis to identify the most feasible transport system for the city.

1.7 REVIEW OF PAST STUDIES

1.7.1 Revised Draft Development Plan 1986-2011

Revised Draft Development Plan 1986- 2011 was prepared by Nagpur Improvement Trust (NIT) and sanctioned by the Government of Maharashtra (GoM) in 2000. Recently, the GoM has passed a resolution empowering the Nagpur Municipal Corporation (NMC) as a planning authority for areas under its jurisdiction – this includes the municipal limits of Nagpur City except certain areas that come under the purview of NIT. Consequently, task of preparation of revised development plan has been transferred from NIT to NMC.

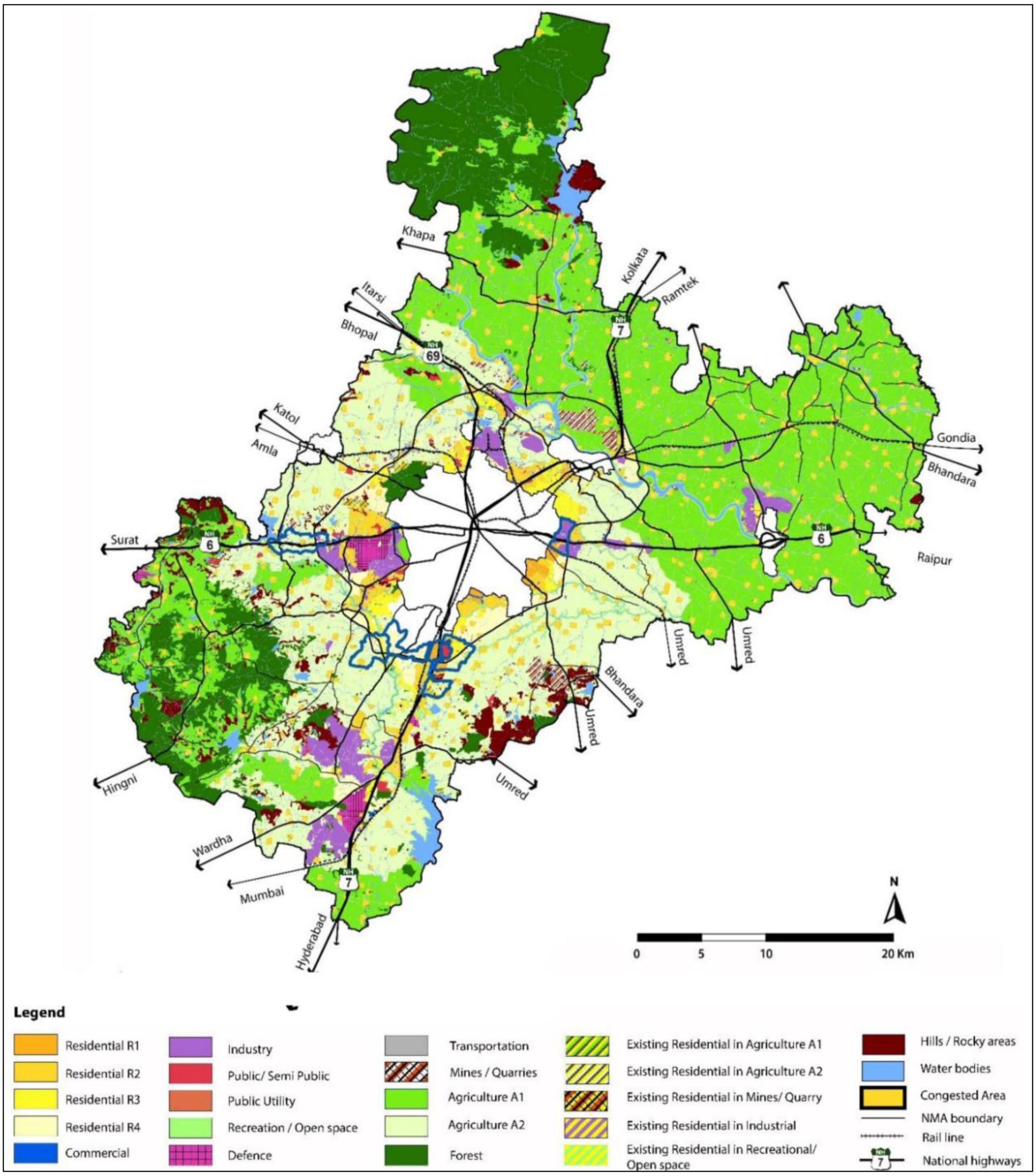
A comparatively higher percentage of land allocated to public purpose indicates the administrative importance of the city. At present, Nagpur is spread over an area of 21,756 ha. As per 1984 land use, only 80% of the land was developable, which has increased in 2011 to 100%. Also, 15033 hectares of area is developed, which is 69% of the total area and developed area in last three decades (since 1984) has doubled. As per the existing land use, majority of the land portion is developed as residential, 45% commercial and industrial land use is 6% land under public use is approximately 41% and 8% is under parks and gardens.

Total area considered under the revised development plan being prepared by NMC is 235 sq km. Of this, 217.56 sq km is under NMC jurisdiction, and rest 7.25 sq km is located outside NMC limits. An area of 17.65 sq km is earmarked for sewerage and drainage disposal schemes. Area of newly merged census town is 7.25 sq km will also be added to the NMC area for future development under revised development plan. In order to improve the land use and conform to the required norms as per 'Urban and Regional Development Plans Formulation and Implementation' (URDPFI) guidelines, the Town Planning department has prepared the revised development plan for Nagpur.

1.7.2 Revised Nagpur Metropolitan Area Development Plan, 2012 - 2032

The State Government formed Nagpur Metropolitan Area (NMA) in 1999. The metropolitan region includes Nagpur city, Nagpur Gramin (rural), Hingna, Parshivni, Mauda, and Kamptee tehsils and parts of the Savner, Kalmeshwar, Umred, and Kuhi tehsils. The total metropolitan area considered for carrying out planning and preparing the land use plan is 3,780 sq km, excluding the Nagpur city area under NMC jurisdiction. Preparation of the land use plan for NMR was carried out in two phases. The areas earmarked are shown in the **Figure 1.3.** This revised plan along with Development Control Regulations (DCR) has been sanctioned under Section 31(1) of MRTP Act, 1966 vide State Government Notification No.TPS-2416/CR-122(A)/2016/DCPR-NMA/UD-9 dated 5th January, 2018.

FIGURE 1.3: PROPOSED LANDUSE PLAN FOR NMA



1.7.3 Detailed Project Report for Nagpur Metro Rail Project, 2013

Detailed Project Report for Phase 1 corridors was prepared by DMRC in year 2013. The salient features of the recommended metro rail system and engineering are summarized below:

- Standard Gauge (1435 mm)
- Maximum permissible speed 80 kmph, Scheduled speed for North-South & East-West Corridors is 32-34 kmph and 30 kmph respectively.
- 3 Car rake with 25 KV AC, Overhead Current Collection System
- Signalling System - Cab signaling and continuous automatic traincontrol with Automatic Train Protection (ATP)
- Telecommunication - Integrated System with Fibre Optic cable, SCADA, Train Radio, PA system etc.
- Automatic Fare collection system with POM and Smart card etc.
- Depot- cum- workshop near Khapri Station (MADC Land) and near Lokmanya Nagar Station (SRP Land)

The summary of DPR for Phase-1 is presented in **Table 1.1.**

TABLE 1.1: SUMMARY OF DPR FOR NAGPUR METRO PHASE 1

Description	Max. PHPDT			No. of Stations (Elevated, At Grade)
	2021	2031	2041	
Line 1 (North-South Corridor): Automotive Square to MIHAN	10936	12934	15729	17 (15, 2)
Line 2 (East-West Corridor): Prajapati Nagar to Lokmanya Nagar	8460	9906	11882	19 (19, 0)

1.7.4 Comprehensive Mobility Plan (CMP) for Nagpur

Comprehensive Mobility Plan (CMP) has been prepared in 2013 and updated in 2018 for Nagpur. CMP envisions a need for a mass rapid system where long distance trips within the City are conveniently addressed and are complimented by safe efficient and economical services.

Comprehensive Mobility Plan has been prepared for a planning period of 15 years with a vision for transport in Nagpur to ensure that the city has a planned, best performing transport systems to address the needs and concerns of the City. The objectives of CMP is to develop specific actions in form of short, medium and long term improvement proposals that will achieve the transportation vision for the area.

a. Mass Transit Proposals:

Based on the PPHPD values estimated from the transport model developed for CMP, the mobility corridors are proposed as High Capacity Mass Transit Corridors (about 88 km) and Medium Capacity Transit corridors (about 22 km).

Improvement of City Bus System is also considered by proposing route rationalisation, new terminal and depots. At each proposed location, land required for a Depot would be approximately 5 acres for 100 buses and some additional area would be required for terminal facility.

Multi Modal Hub are also proposed in CMP. Apart from physical integration fare integration, information integration is also proposed. Intelligent Transport System is considered for Nagpur city including AFCs, Validators, Electronic Ticket Machines, Security Access Modules etc.

b. Non-Motorized Transport (NMT) Plan:

To promote NMT in the city, a Public Bike-Sharing scheme is also suggested. All the mobility corridors are recommended for dedicated cycle tracks on both side of the roads. As part of their infrastructure requirement and bike sharing scheme, the major docking stations are proposed at each Transit station. Cycle Tracks are also proposed for total road length of 146 km, 87 km is proposed to be constructed in Phase-I and the remaining in Phase-2. Footpath construction is also proposed for new roads as well as existing road network. Also some zones namely Sitabuldi, Mahal, Itwari and Sadar are proposed as a vehicle free zones considering the heavy pedestrian movement.

c. Freight Management Strategy and Proposal

For freight management of the city, the proposal has been worked out in phases. Phase 1 includes Improvement of existing Transport Nagar, Movement Restrictions of heavy vehicles in the city from 09:00 AM – 07:00 PM, these restrictions may be relaxed for Ring Roads and Movement restrictions for animal carts on all Orbital and Radial roads from 09:00 AM - 06:00 PM. Proposals for phase 2 & 3 includes setting up of truck terminals at various locations like Koradi, Kamptee, Kapsi, Gumgaon etc., identification of a mobility corridor for goods vehicles, movement to be restricted completely on all other roads and segregated high speed goods vehicle lane on Ring Road, promotion of use of small and medium size vehicles with modern emission controls in the central city areas.

d. Parking Strategy and Proposal

Parking in Nagpur, especially in the core area, has become a serious concern and needs immediate attention. NMC decided to develop the “Parking Policy and Parking Master Plan for the city” with an aim of closing down the demand-supply gap and manage the future parking demand. Concept of paid parking mechanism is used and applied along the mobility zone- metro corridors and major corridors in the city Central Business District (Commercial areas*) and Mixed zone. Pay and Parking is proposed at following locations:

1. Gaurakshan Rahate colony
2. Indian Gymkhanna ground
3. Panchsheel chowk to lokmat chowk (Area above and below the fly over)
4. Area in front of Yashvant stadium
5. Kachipura chowk to Creams Hospital (south)

e. Prioritization of Projects

All the proposals are broadly grouped under following three categories;

- Long Term Improvements – The usefulness of these improvements will last for more than 10-15 years
- Medium Term Improvements – The usefulness of these improvements will last for about 5-10 years
- Short Term Improvements – These are short term proposals that need to be reviewed and revised within 5 years as per the requirement.

Short Term Projects : Traffic and Pedestrian Management measures, Junction Improvements, Footpath, cycle track and Provision of Pedestrian Zone and Pedestrian Infrastructure

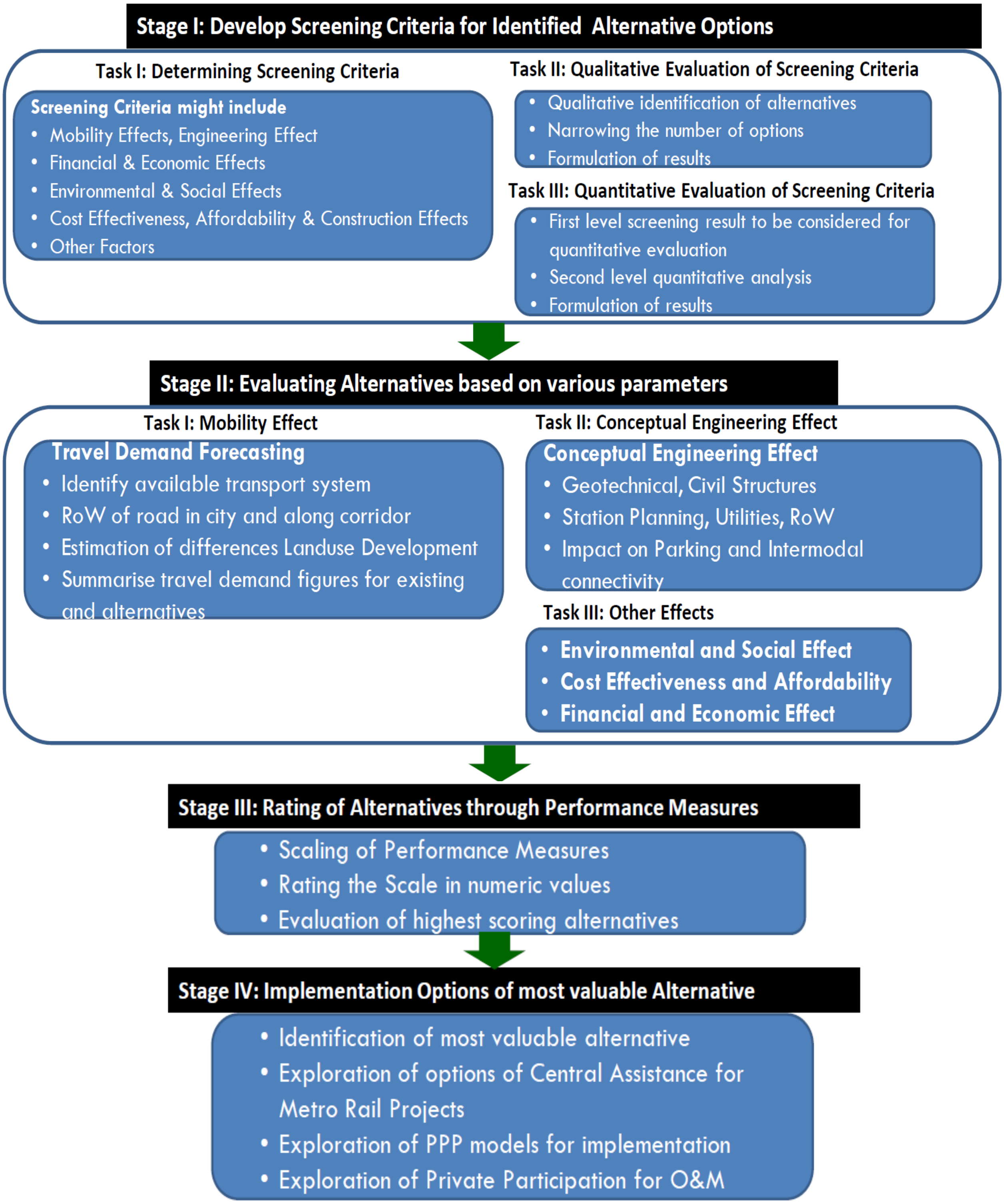
Medium Term Projects : FOB/ Walkways Bus Augmentation, Bus shelters, Off Street Parking, ITS, Rail Over Bridges, Truck Terminal, Redevelopment of Bus terminals, Bus Depot and Workshop, Bike Sharing Plan : Docking Station etc.

Long Term Projects: High/Medium Capacity Mass Transit System, Road network improvement plans, Freight terminals and Multimodal Hubs.

1.8 SCOPE OF PRESENT ASSIGNMENT

The scope of work will be to find the best alternative (s) to solve transport related issues in particular corridors and / or areas (s). Based on input data, evaluation of all feasible alternatives across all modes of transportation and recommend the most suitable option specific to the priority public transport corridors in the City as identified in CMP. The methodology as per policy is presented in **Figure 1.4.**

FIGURE 1.4: METHODOLOGY FOR ALTERNATIVES ANALYSIS



STAGE I - DEVELOP SCREENING CRITERIA FOR THE IDENTIFIED ALTERNATIVE OPTIONS

Task 1: Develop Screening Criteria to identify most reasonable and feasible alternatives based on the options suggested in CMP

- **Mobility Effects**: These criteria relate to travel demand forecasting and facility capacity, presence/absence of different modes, access, connectivity and circulation.
- **Conceptual Engineering effect:** These criteria relate to developing all civil aspects of the system
- **Financial and Economic Effects:** To identify & quantify benefits and costs associated with project to help in identification of the optimum solution along with the economic viability in terms of its likely investment return potential.
- **Environmental and Social Effects:** Screening criteria assessing environmental impacts related to land-use and natural environment like water, air etc. The social impact of the alternatives is evaluated to see potential social costs and benefits.
- **Cost Effectiveness and Affordability:** The capital and annual costs associated with each of the alternatives would be evaluated. It also assesses the cost-effectiveness and affordability of the alternatives.
- **Other Factors:** How each of the alternatives complies with the local policies and priorities are assessed.

Task 2: Qualitative Evaluation of Screening Criteria

First-level screening criteria will be developed to quickly and efficiently identify the alternatives considering all available modes of transportation that most warrant further consideration and evaluation, which will include preliminary qualitative evaluations to narrow the number of alternatives.

Task 3: Quantitative Evaluation of Screening Criteria

With the first screening of alternatives considering all available modes of transportation completed, the second level of evaluation involves quantitative screening, wherein various parameters will be screened based on quantitative assessment.

STAGE II -EVALUATION PARAMETERS OF VARIOUS ALTERNATIVES

Task 4: Mobility Effect

Travel Demand Forecasting: The primary purpose of this task is to assess the most current version of the City/regional travel demand model (from CMP) for base year data, with available future year networks and land use data, and model documentation. While preparing the travel demand analysis, following tasks has been completed:

a. Identify available transport system, right of way of roads in city and along corridor
b. Prepare road and transit networks for each alternative and a no-project scenario (without project).
c. Summarize the travel demand results for existing and all future year alternatives, including corridor and region-wide travel demand, peak period volumes and congestion levels, and person trips by mode for the corridor and the region.
d. Analyze the differences among the alternatives to provide information to Environmental Assessment (in Task 6).
e. Opportunity for intermodal integration at various levels
f. Similar analysis to be conducted for the future horizon year to assess how conditions would change over time.

Task 5: Conceptual Engineering Effect

Further to refine the range of alternatives to a sufficient level of detail to compare the relative differences between alternatives, conceptual engineering report must be prepared for all feasible alternatives, including those specified in the Comprehensive Mobility Plan (CMP) and any other viable/practical “alternative” (or combination of features that are not identified in the CMP).

a. Geotechnical

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. Geotechnical investigations should help in the understanding of existing soil characteristics.

b. Civil Structures

Develop sufficient detail concerning the structures to allow preparation of preliminary cost estimates. Identify the road space to be occupied by civil structure and the project permanently/temporarily.

c. Station Planning (Bus Stations/Rail Stations etc.)

Provide preliminary considerations to identify the road space to be occupied by station (either underground or elevated) and the project permanently/temporarily.

d. Utilities

The quantity of utilities to be shifted for implementing a mass transport system plays a role in impacting the day today traffic operations.

e. Right-of-ways

Status of current rights-of-way and other properties potentially affected by the project. Prepare preliminary estimates of the valuation of any property to be acquired or needed for temporary construction easements.

f. Other Planning Parameters like impacts on parking, inter-modal connectivity, etc.

Task 6: Environmental Effect: Environmental Assessment

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. The preliminary environmental analysis will also assist in determining the level of additional environmental documentation that will be required in subsequent project phases. A screening-level analysis or environmental scan will be conducted to determine the potential environmental impacts of alternatives.

Task 7: Social Effect: Social Assessment

Preliminary screening of the social impacts for alternatives has been carried out. A detailed assessment would be done at the DPR stage. Stake holder consultation is to be carried out at important stages.

Task 8: Cost Effectiveness and Affordability

Project cost estimates: Provide preliminary cost estimates based upon conceptual engineering completed for alternatives selected for evaluation. Broad cost estimates for all elements including right-of-ways, easements, relocations, environmental mitigation, protection of facilities and any other elements affecting project cost. Detail items of work, estimates of quantities and costs shall be included at DPR stage.

Task 9: Financial and Economic Effect

A preliminary project financial plan for implementing the project has been worked out. Public and private funding options have been considered in developing the plan. Based on funding options, central government assistance has also been assessed. Identification and quantification of benefits and costs associated with the project along with the economic viability has been worked out to help in identification of the optimum solution in terms of its likely investment return potential.

STAGE III - ALTERNATIVES EVALUATION

Objective is to conduct an evaluation that would lead to identification of those alternatives that is most likely to be implemented. The goal is to conduct an evaluation that would lead to the identification of those alternatives that are most likely to:

a. Meet the purpose and need identified for the project.
b. Concurrently avoid or minimize environmental and community impacts.
c. Allow for effective and feasible project phasing and constructability.
d. Provide a cost-effective transportation investment.
e. The evaluation of alternatives should include a No-Build Alternative (without project).

A Draft Alternative Analysis Report describing reasonable and feasible alternative that is recommended shall include the analysis supporting the recommendation. The scoring can be done for each of the alternatives which shall be the basis for comparing alternatives. The option with highest score may be considered for further preparation of DPR.

STAGE IV - IMPLMENTATION OPTIONS FOR THE MOST VIABLE ALTERNATIVE

The implementation options have been identified for best suitable alternative. If metro system is identified as the most viable alternative, then implementation options needs to be explored for those projects seeking Central Financial Assistance (CFA) as mentioned in guidelines document for mass transport proposals from MoHUA, Government of India.

Public Private Partnership (PPP) models have been explored for implementation. Private participation either for complete provisioning of metro rail project or for some unbundled components will form an essential requirement for all metro rail project proposals seeking Central Financial Assistance. The various options for CFA considered based on guidelines are:

i. Further, Private participation in Operation and Maintenance also to be explored for PublicPrivatePartnership(PPP): CentralGovernmentfinancingtobegovernedby the Viability Gap Funding (VGF) Scheme of Government of India or any other Guide-lines issued by Government of India from time to time.

ii. Grant by the Central Government: Central Government will consider providing a grant upto 10% of project cost excluding items as mentioned in the Metro Policy 2017, which do not seek project funding as per the VGF Scheme of GoI or under the Equity Sharing Model.

iii. Equity Sharing Model: Central Government will provide financial support to Metro Rail projects upto 20% of the project cost excluding items as per the Metro Policy 2017.

As per the policy, State Government needs to decide the project implementation options. Reasonable and feasible alternative along with the implementation model are the outcome of the Alternative Analysis Report.

1.9 COMPOSITION OF THE REPORT

The ‘Draft Alternatives Analysis Report’ consists of following chapters:

1. Chapter 1 gives the need of study covering overall study background, overview of study area, regional goals and objectives and project purpose.
2. Chapter 2 summarises the study area characteristics and existing traffic and travel conditions including study are landuse and traffic analysis zoning.

3. Chapter 3 gives the conceptual transportation alternatives as discussed in Comprehensive Mobility Plan with planning considerations, description of alternatives and related constraints.
4. Chapter 4 gives the screening criteria for identified alternative options.
5. Chapter 5 details the screening and alternatives evaluation based on grading for each mode.
6. Chapter 6 gives most suitable option for implementation of viable alternative.
7. Chapter 7 provides conclusion including the way forward.

Chapter – 2.
STUDY AREA AND EXISTING CONDITIONS

2. STUDY AREA AND EXISTING CONDITIONS

2.1 STUDY AREA DESCRIPTION

The geographic area within the jurisdiction of Nagpur Municipal Corporation (NMC) along with the other areas including Municipal Councils of Kamptee, Kalameshwar, Hingna and surrounding villages is taken as Study Area comprising of about 1550 sq km out of total 3567 sq km of NMA area divided into 182 internal and 12 external traffic analysis zones. The study area map has been shown in **Figure 1.2** with NMC, NMA and regional connectivity.

The majority of population of study area resides within NMC area. As per Census 2011, the population of NMC area is about 24 Lakh. The population growth shows not so steep trend in the last decade with annual growth being only about 1.6%. The decadal population growth during the last six decades is shown in **Table 2.1** & **Figure 2.1.**

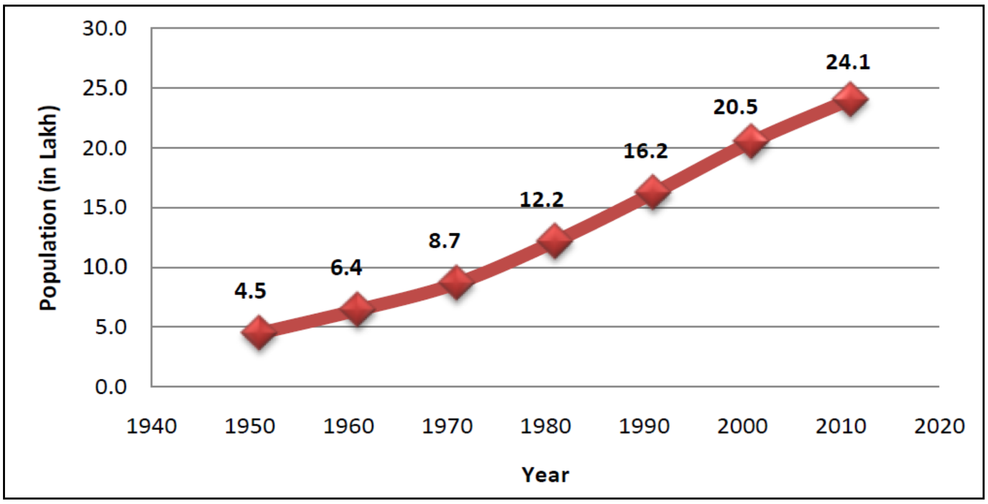
TABLE 2.1: DECADAL POPULATION GROWTH IN NMC AREA 1951-2011

S. No	Year	Population	Growth Rate
1	1951	4,49,000	-
2	1961	6,44,000	43.4%
3	1971	8,66,000	34.5%
4	1981	12,17,000	40.5%
5	1991	16,22,820	33.3%
6	2001	20,51,320	26.4%
7	2011	24,05,665	17.3%

Source: Census of India, 1951-2011

The population of NMC area is estimated at 26.1 Lakh in the year 2017. Other areas including Kamptee, Kalmeshwar, Hingna and surrounding villages within the study area is 7.6 Lakh. The total population of study area is estimated at 33.7 Lakh in 2017.

FIGURE 2.1: DECADAL POPULATION GROWTH IN NMC



The population for various years in the study area is presented in **Table 2.2**.

TABLE 2.2: POPULATION IN STUDY AREA

SN	Area	Population (Lakh)				
		2016	2018	2021	2031	2041
1	Nagpur Municipal Corporation	25.7	26.5	27.6	31.1	34.8
2	Other than NMC Areas Including Kamptee, Kalmeshwar, Hingna and surrounding villages	7.4	7.8	8.6	12.3	15.5
Total		**33.1**	**34.3**	**36.2**	**43.4**	**50.3**

Source: Census 2011& Agreed Growth Rates

2.1.2 Growth of Motor Vehicles

The registered vehicles in Nagpur have increased significantly over the years. The number of vehicles registered in the last four years is given in **Table 2.3**. The high density and rapid growth of vehicles have worsened the transport situation to a significant extent. The sharp increase of two-wheelers and cars could be attributed to the improved economic status of people and deficient public transport supply. The phenomenal increase of cars - demand more road space and has resulted in dense concentration of traffic on roads.

TABLE 2.3: REGISTERED MOTOR VEHICLES IN NAGPUR

S.No.	Vehicle Category	Registered Vehicle in Nagpur City			
		2014-15	2015-16	2016-17	2017-18
1	Total Two Wheelers	42958	42617	42280	61412
2	Motor Cars	6524	7498	8094	11157
3	Jeeps	1789	1851	2187	734

S.No.	Vehicle Category	Registered Vehicle in Nagpur City			
		2014-15	2015-16	2016-17	2017-18
4	Stn. Wagons	0	0	0	4
5	Taxies a) Meter Fitted	3	0	0	0
	b) Luxury & Tourist Cabs	413	576	1752	866
6	Autorickshaws	2746	1079	1884	1920
7	Stage Carriage	0	0	40	53
8	Contract Carriage	35	43	58	45
9	School Buses	254	303	224	137
10	Pvt. Ser. Vehicle	4	1	2	0
11	Ambulance	27	43	40	30
12	Multi & articulated Veh.	22	41	63	151
13	Trucks	144	166	187	200
14	Tanker	11	15	309	0
15	Del. Van. (4 Wheelers)	911	833	846	860
16	Del. Van. (3 Wheelers)	1041	985	808	719
17	Tractors	30	68	213	88
18	Trailers	8	16	10	3
19	Other Tippers	0	2	20	34
Total		**56920**	**56137**	**59017**	**78413**

Source: RTO, Nagpur

2.1.3 Accident Statistics

The increase in number of private vehicles and inter mixing of slow and fast moving vehicles on road has led to increase in number of accidents on roads in Nagpur, which is a cause of concern. Considering the urban expanse, population growth and increased trends of vehicles on city roads; the safety of commuters is equally vital.

There are many reasons for the growth in the number of accidents in Nagpur such as increase in population and rise in vehicle ownership. They are also caused due to the casual approach of road users in observing driving rules, adhering to safety precautions and regulations. Over-speeding and negligent driving have proved to be a frequent cause of serious and fatal accidents. Similarly, poor road geometry has also increased the incidence of accidents on urban roads. One of major causes of pedestrian safety is endangered by extended trading activities of shops and commercial activity on footpaths and sidewalks. This compels the pedestrians to clog the road space, hence give a chance to accidents.

Table 2.4 shows the number of accidents in recent years along-with the number of fatalities and series/ minor injuries occurred.

TABLE 2.4: ROAD ACCIDENT STATISTICS

Type of Accidents	2016			2017			January, 2018		
	Accidents	Fatalities	Injured	Accidents	Fatalities	Injured	Accidents	Fatalities	Injured
Fatal	222	232	66	291	310	116	18	21	8
Serious	473	0	604	553	0	774	49	0	68
Minor	547	0	615	529	0	620	35	0	40
Total	**1242**	**232**	**1285**	**1373**	**310**	**1510**	**102**	**21**	**116**

2.1.4 Air Pollution Levels

Air pollution levels are determined by existing Ambient Air Quality Index (AQI). The AQI considers eight pollutants (PM_{10}, $M_{2.5}$, NO_2, SO_2, CO, O_3, NH_3, and Pb) in which one of PM10 or PM2.5 parameter is mandatory. There are six AQI categories namely Good, Satisfactory, Moderately polluted, Poor, Very Poor, and Severe. The AQI values for identified pollutants are provided in **Table 2.5.** From AQI values, it is observed that Nagpur has moderate pollution levels from 101-200.

TABLE 2.5: AIR QUALITY INDEX PARAMETERS

AQI Category, Pollutants and Health Breakpoints								
AQI Category (Range)	PM_{10} 24-hr	$PM_{2.5}$ 24-hr	NO_2 24-hr	O_3 8-hr	CO 8-hr (mg/m^3)	SO_2 24-hr	NH_3 24-hr	Pb 24-hr
Good (0-50)	0-50	0-30	0-40	0-50	0-1.0	0-40	0-200	0-0.5
Satisfactory (51-100)	51-100	31-60	41-80	51-100	1.1-2.0	41-80	201-400	0.5 –1.0
Moderately polluted (101-200)	101-250	61-90	81-180	101-168	2.1- 10	81-380	401-800	1.1-2.0
Poor (201-300)	251-350	91-120	181-280	169-208	10-17	381-800	801-1200	2.1-3.0
Very poor (301-400)	351-430	121-250	281-400	209-748*	17-34	801-1600	1200-1800	3.1-3.5
Severe (401-500)	430 +	250+	400+	748+*	34+	1600+	1800+	3.5+

Source: NAQI Status of Indian Cities 2015-16, Central Pollution Control Board

2.2 EXISTING ROADWAY NETWORK

Two important highways NH-7 (Varanasi - Kanyakumari) and NH-6 (Mumbai - Sambalpur – Kolkata) pass through Nagpur. The city is developed with radial and circumferential network pattern, of which outer ring is partly constructed, while inner ring road is completely operational. The Nagpur Municipal Corporation (NMC) has executed an Integrated Road Development Project (IRDP) to improve the transportation system within the city limits.

Ghat Road, Ajni Road, Railway Station Road, Manewada Road, Subhash Road, and Ambazari Road are some of the major sub-arterial roads within the city. The old part of Nagpur has network of narrow roads. The road infrastructure facilities such as signages, traffic signals, etc. have not expanded in accordance with the increase of population and vehicles.

Primary traffic & travel surveys covering road network inventory were carried out along all arterial and major roads in the study area. It can be observed from the table that about 22% of the road network has less than 20 m RoW, 32% has 20-30 m RoW and only 19% has RoW above 40 m as presented in **Table 2.6**.

TABLE 2.6: DISTRIBUTION OF ROAD NETWORK AS PER RIGHT OF WAY

SN	Right of Way (m)	Length (km)	Percentage
1	< 10	5.0	0.7
2	10 – 20	161.8	21.1
3	20 – 30	247.5	32.3
4	30 – 40	204.7	26.7
5	>40	148.0	19.3
Total		**767.08**	**100.0**

The journey speed characteristics during peak and off-peak period are presented in **Table 2.7**. It is observed that about 54% of the total road network has journey speed upto 30 kmph and 28% of network has journey speed more than 40 kmph during peak hours. Average Journey Speed during peak hour is observed to be 23.4 kmph.

TABLE 2.7: DISTRIBUTION OF ROAD LENGTH BY PEAK HOUR JOURNEY SPEED

SN	Journey Speed (km/hr)	Peak Hour	
		Road Length (km)	Percentage (%)
1	<=20	163.6	21.3
2	21-30	250.6	32.7
3	31-40	139.2	18.1
4	41-50	148.8	19.4
5	>50	64.9	8.5
Total		**767.1**	**100.0**

2.3 EXISTING TRANSIT SERVICES

2.3.1 Existing Public Transport Operations

Public transport plays a crucial role in the commuter transportation in any city. It offers economies of scale with minimised road congestion and low per capita road usage. Cheaper and affordable public transport systems world over have proved to promote mobility – move people more efficiently and safely with increased opportunities for education, employment, social development etc.

At present the public transport services are rather limited and bus is the only mass transport system in Nagpur in addition to Phase-1 Metro system which is under construction. Nagpur Mahanagar Parivahan Limited (NMPL) operates the city bus services consisting of normal buses, low floor buses and mini buses. The fleet size of about 252 buses in 2016 is a noticeable feature of limited supply public transport. The present supply of buses per lakh populations works out to only seven buses. Private auto, shared auto, cycle rickshaw and e-rickshaws supplement these transportation services. With the rise in population, the number of commuters has increased manifold. However, the transport system has been unable to cope up with increased demand. Existing fare of public buses starts from Rs. 8 and maximum fare is Rs. 30.

The present intra city bus fleet in Nagpur city is insufficient for current travel demand. IPT modes have been popularised and play a vital role in city passenger transport movement. The IPT system comprising of auto-rickshaw, taxi, cycle rickshaw and e-rickshaw are the backbone of passenger movement which cause acute traffic congestion and environmental pollution in the city. With their limitations and drawbacks they continue to keep the city mobile and active. The IPT operation is reasonably self-regulated and looked after by operators' unions. This necessitates the need for upgradation of public transport system.

2.3.2 Existing Traffic Characteristics

Primary traffic & travel surveys had been carried out by RITES in the Study Area. The summary of existing traffic and travel characteristics are appraised in the subsequent sections.

The daily traffic volumes at major midblock locations and outer cordon locations are presented in **Tables 2.8** and **2.9** respectively. Bhandara Road near Pardi Bazar Chowk has maximum daily traffic and other major arterials in the city like Tajbagh Road, Kamptee Road, Wardha Road, Subhash Road and Ring Road etc. register high traffic.

TABLE 2.8 DAILY TRAFFIC VOLUME AT SCREEN LINE/MID-BLOCK LOCATIONS

SN	Location's Name	Total Vehicles	Total PCUs
1	Bhandara Road near Pardi Bazar Chowk	79564	72079
2	Wardha Road near Ajni Square	94706	65689
3	Subhash Road RUB near Cotton Market Chowk	81912	60666
4	Wardha Road near Zero Mile Chowk	73484	55866
5	Ajni Road ROB	78686	51719
6	Wardha Road ROB near Butibori	28500	49614
7	Ring Road RUB near Narendra Nagar	74494	48617
8	Kamptee Road RUB near Gurudwara Singh Sabha	76944	47204
9	Tajbagh Road near SakkardaraSqaure	72936	46995
10	Ring RoadROB near Namdeo Nagar	38539	46487

Among the Outer Cordon locations of the city, Bhandara Road at Sawali has highest traffic volumes followed by other major highways leading in/out the city.

TABLE 2.9: DAILY TRAFFIC VOLUME (24 HOURS) AT OUTER CORDON LOCATIONS

SN	Name of Locations	Grand Total (Nos.)	Grand Total (PCU's)
1	Bhandara Road near Sawali	22068	39039
2	Chandrapur Road Near Wardha Crossing	20829	35252
3	Amravati Road near Pethkaldongari	17198	23505
4	Jabalpur Road Near Oriental Toll Plaza	13395	22508
5	Savner - Kalameshwar Road near Waroda	13398	15528
6	Umred Road near Champa	10234	14156
7	Chhindwara Road near Patansaongi	15256	13412
8	Katol Road near Sun City Restaurant	9002	8922
9	Kuhi Road near DongarGaon	5892	7665
10	Tarsa Road Near Nilaj	6812	6273
11	Hingna Road near Ujjayani Buddha Vihar	6175	4914
12	Parshivni Road (Near Dhruv Motors)	5924	3916

Boarding and Alighting counts were carried out at major bus and rail terminals. It is observed from **Table 2.10** that Mor Bhawan Bus Terminal caters to the maximum number of daily passengers with 21777 Boarding & 21217 Alighting.

It is observed from **Table 2.11** that Nagpur Railway Station caters to the maximum number of daily passengers with 47530 Boarding & 43826 Alighting.

TABLE 2.10: BOARDING & ALIGNTING AT BUS TERMINALS

SN	Name of Location	Daily Boarding	Daily Alighting	Total Daily (B+A)	Peak Time	Peak Hour Boarding	Peak Hour Alighting	Peak Hour (B+A)
1	Mor Bhawan Bus Terminal	21777	21217	42994	0815 - 0915	2288	1879	4167
2	Ganesh Peth Bus Terminal	18630	18514	37144	1745 - 1845	3386	1648	5034
3	Sitabuldi Bus Terminal	12737	11337	24074	1700 - 1800	1153	1022	2175
4	Aashirwad Talkies Bus Terminal	7990	6191	14181	1700 - 1800	941	767	1708
5	Chhatrapati Bus Terminal	4345	4248	8593	0915 - 1015	387	396	783

TABLE 2.11: BOARDING & ALIGNTING ATRAIL TERMINALS

SN	Name of Location	Total Boarding	Total Alighting	Total (B+A)	Peak Time	Peak Hour Boarding	Peak Hour Alighting	Peak Hour (B+A)
1	Nagpur Railway Station	47530	43826	91356	0915 - 1015	3880	4768	8648
2	Itwari Railway Station	7886	7813	15699	0945 - 1045	956	1718	2674
3	Kamptee Railway Station	6838	6816	13654	1030 - 1130	668	1013	1681
4	Ajni Railway Station	4048	3950	7998	1745 - 1845	1028	404	1432
5	Butibori Railway Station	327	279	606	1900 - 2000	199	120	319

2.3.3 Travel Characteristics

The study area travel characteristics have been appraised based on the detailed primary surveys.

2.3.3.1 Average Household Size

The average household size in the study area is 4.3 persons per household. The distribution of households by size is presented in **Table 2.12**. It can be observed that majorly i.e. 61% of the households fall under the category of 3-4 persons per household and 31% of household's fall under category of 5-6 persons group.

TABLE 2.12: DISTRIBUTION OF HOUSEHOLDS BY SIZE

SN	Household by Size	Number of Households	Percentage
1	Upto 2	299	3.7
2	3-4	4928	60.7
3	5-6	2523	31.1
4	7-8	276	3.4
5	9-10	89	3.4
6	>10	8	0.1
Total		**8123**	**100.0**

2.3.3.2 Average Monthly Household Income

The average monthly household income in the study area is about Rs. 27,000/-. **Table 2.13** presents the distribution of surveyed population by monthly income. It indicates that 13% of the households earn Rs. 5000 to Rs. 10,000. About 1% households are earning even less than or equal to Rs. 5000 per month. About 9% of the households have monthly income more than Rs. 50,000.

TABLE 2.13: DISTRIBUTION OF HOUSEHOLDS BY MONTHLY INCOME

SN	Income Group (Rs.)	No. of Households	Percentage
1	<5000	69	0.8
2	5000-10000	1075	13.2
3	10001-15000	1223	15.1
4	15001-20000	1319	16.2
5	20001-25000	1012	12.5
6	25001-50000	2702	33.3
7	>50000	723	8.9
Total		**8123**	**100.0**

2.3.3.3 Per Capita Trip Rate

The total daily trips are estimated about 51.2 lakhs derived from the household survey. Distribution of daily trips by modes is presented in **Table 2.14**. About 90% of these are vehicular trips while 10% are walk trips. The per capita trip rate is 1.4 for the trips excluding walk trips.

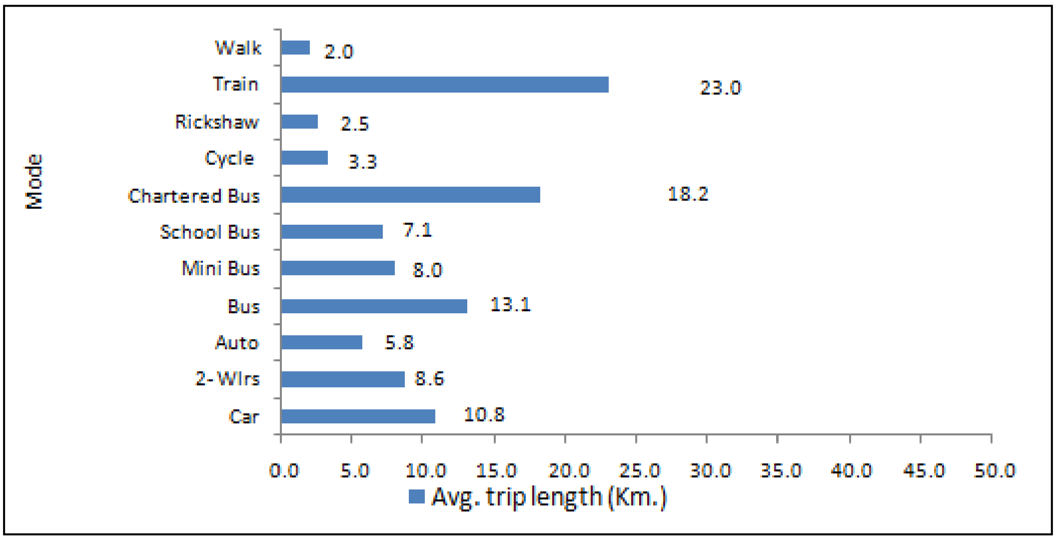
TABLE 2.14: DISTRIBUTION OF DAILY PASSENGER TRIPS BY MODE

Mode	No. of Trips	Percentage	
Car	2,92,557	5.7	90.5
2- Wheeler	21,81,173	42.6	
Auto	10,15,885	19.8	
Bus	5,03,656	9.8	
Mini Bus	51,838	1.0	
School Bus	2,38,904	4.7	
Chartered Bus	4,688	0.1	
Cycle	3,07,865	6.0	
Rickshaw	18,731	0.4	
Train	17,152	0.3	
Walk	4,88,202	9.5	9.5
Total Trips	**51,20,651**	**100.0**	**100.0**
Total Motorized Trips	**43,05,853**		
PCTR for Motorized Trips	**1.3**		

2.3.3.4 Trip Length

Average trip length of 7.6 km (including walk) and 8.2 km (excluding walk) is observed in the study area. The analysis of trips lengths covered up by different modes reveals that long distance trips of average trip length 23 km are being covered up through trains. **Figure 2.2** indicates that an average trip length of 2.0 km is being covered up by walk. Cars travel an average trip length of 10.8 km, two wheelers 8.6 km while cycles and cycle rickshaws covers average trip distance of 3.3 km and 2.5 km respectively.

FIGURE 2.2: DISTRIBUTION OF AVERAGE TRIP LENGTH BY MODE



2.4 OTHER TRANSPORTATION CORRIDORS

The CMP based on travel demand assessment has identified high demand mobility corridors which are eligible for a Mass Rapid Transit Systems. These high demand corridors in the City include:

- Automotive Square to Khapri
- Pardi to Mount View (Hingna)
- Kanhan River to Automotive Square
- Prajapati Nagar to Transport Nagar
- MIHAN to MIDC ESR
- Lokmanya Nagar to Hingna and
- Vasudev Nagar to Dattawadi

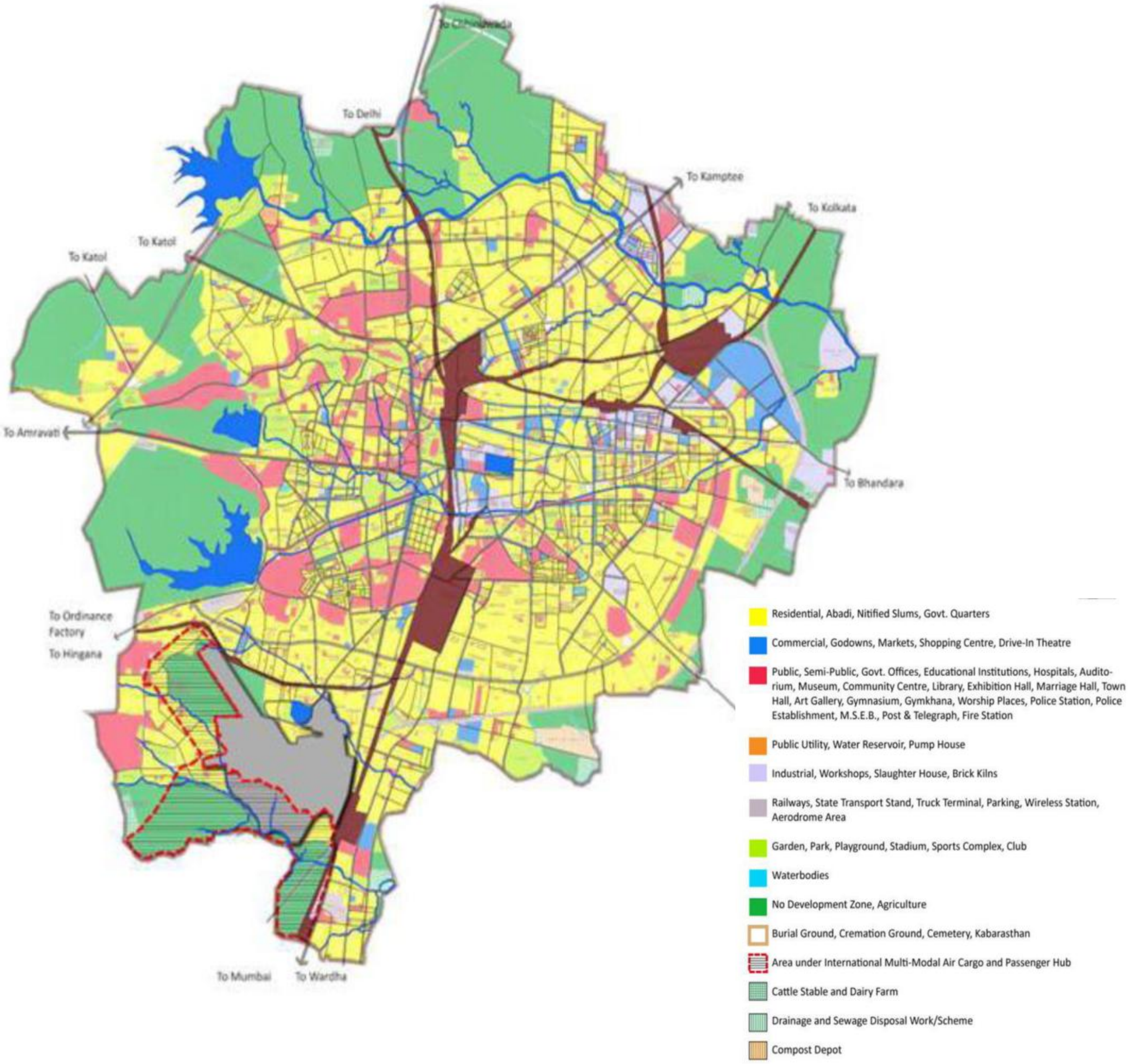
In addition to above routes, medium capacity MRTS corridors are Amavathi Road, Katol Road, Koradi Road and Umred Road. Short, medium and long term proposals comprising of rail and road based mass transit system had been proposed on the major corridors in the CMP.

2.5 EXISTING LANDUSE AND ZONING

2.5.1 Revised Draft Development Plan 1986-2011 was prepared by NIT and sanctioned by the Government of Maharashtra (GoM) in 2000. This development plan as given in **Figure 2.3** is currently in force and is due for revision. Recently, the GoM has passed a resolution empowering the NMC as a planning authority for areas under its jurisdiction – this includes the municipal limits of Nagpur City except certain areas that come under the purview of NIT. Consequently the task of preparation of revised development plan has been transferred from NIT to NMC. The landuse distribution indicates the cosmopolitan nature of the city with a fair distribution of land uses.

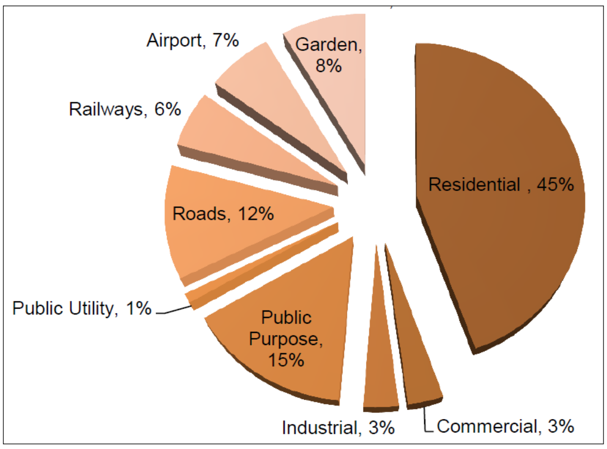
A comparatively higher percentage of land allocated to public purpose indicates the administrative importance of the city. At present, Nagpur is spread over an area of 21,756 ha. As per 1984 land use, only 80% of the land was developable, which has increased in 2011 to 100%. Also, 15033 hectares of area is developed, which is 69% of the total area and developed area in last three decades (since 1984) has doubled. As per the existing land use, majority of the land portion is developed as residential, 45%; commercial and industrial land use is 6%; land under public use is approximately 41%; and 8% is under parks and gardens **(Figure 2.4)**.

FIGURE 2.3: REVISED DRAFT DEVELOPMENT PLAN 1986-2011



Source: Revised Draft Development Plan of Nagpur City, 2011

FIGURE 2.4: EXISTING LANDUSE BREAKUP OF NAGPUR, 2011



Total area considered under the revised development plan being prepared by NMC is 235 sq km. Of this, 217.56 sq km is under NMC jurisdiction, and rest 7.25 sq km is located outside NMC limits. An area of 17.65 sq km is earmarked for sewerage and drainage disposal schemes. NMC has divided the entire area into 10 planning units for preparing the development plan. Area of newly merged census town is 7.25 sq km will also be added to the NMC area for future development under revised development plan. In order to improve the land use and conform to the required norms as per URDPFI guidelines, the Town Planning department has prepared the revised development plan for Nagpur. The proposed land use for horizon years 2021 and 2031 is given in **Table 2.15**.

TABLE 2.15: PROPOSED LANDUSE PLAN FOR NAGPUR CITY

Sr. No.	Land use	2021			2031		
		Area in Ha.	% of Developed Area	% of Total Area	Area in ha.	% of Developed Area	% of Total Area
1	Residential	6,706	44.6	30.8	7000	46.6	32.2
2	Commercial	501	3.3	2.3	700	4.7	3.2
3	Industrial	495	3.3	2.3	800	5.3	3.7
4	Public Purpose	2,312	15.4	10.6	2312	15.4	10.6
5	Public Utility	149	1.0	0.7	150	1.0	0.7
6	Roads	1,754	11.7	8.1	1800	12.0	8.3
7	Railways	873	5.8	4.0	900	6.0	4.1
8	Airport	993	6.6	4.6	1000	6.7	4.6
9	Garden	1,251	8.3	5.8	1300	8.6	6.0
10	Developable Vacant Land	0	0.0	0.0	0	0.0	0.0
	Total	**15,033**	**100.0**	**69.1**	**15,962**	**100.0**	**73.4**
11	Agriculture Land	5,774		26.5	4,846		22.3
12	Water Bodies &Nallahs	463		2.1	463		2.1
13	Non-Developable Land	0		0.0	0		0.0
14	Drainage & Sewage Disposal	141		0.6	141		0.6
15	Cattle Stable & Dairy Farm	212		1.0	212		1.0
16	Compost Depot	131		0.6	131		0.6
	Total	**6,723**		**30.9**	**5793**		**26.6**
	Grand Total	**21,756**		**100.0**	**21,756**		**100.0**

Source: Nagpur Environment Assessment Report 2008, CDP for Nagpur 2041, NMC

2.5.2 REVIEW OF EXISTING LAND USE AND DEVELOPMENT CONTROL REGULATIONS

The existing Land Use Plan (Revised Draft Development Plan for 1986 to 2011) was prepared in 1986 by Nagpur Improvement Trust (NIT) and handed over to Nagpur Municipal Corporation upon a resolution passed by Government of Maharashtra. Nagpur is the only Municipal Corporation in the district with a jurisdiction area of about 225.08 sq. km.

The revised Development Plan 2012-32 plan along with Development Control Regulations has been sanctioned under Section 31(1) of MRTP Act, 1966 vide State Government Notification No.TPS-2416/CR-122(A)/2016/DCPR-NMA/UD-9 dated 5th January, 2018.

Residential

Existing residential in the NMA includes urban land uses categorized as residential under the particular use. Concentrations of the residential areas are majorly observed along the major transportation corridors on the periphery of the city.

Commercial

Land uses that include retail shopping and general business have been classified as commercial use. Commercial areas amount to 6.82 sq.km which is 0.19% of entire NMA.

Industrial

This area is the second largest developed land use component of the NMA region. Presence of major transport corridors such as NH-6 and NH-7 has facilitated the growth of the industrial area. The MIDC Industrial Estate at Butibori is one of the largest Industrial Areas planned in Asia. Hingna MIDC towards the south-west and some other private industrial estates in Kapsi (due east of the City along NH – 6) are prime Industrial areas.

2.5.3 PROPOSED LAND USE PLAN

The proposed Landuse as described under the Draft DP 2016 contains provision of 381 sq.km (50.53%) of the total urban uses. Additionally sub-listed Residential uses are enumerated as follows:

Residential R1:

Residential R1 Zone is allocated to areas close to existing employment centres such as Nagpur City which are witnessing major development activities. The gross average density in this zone is considered to be 35 – 55 dwelling units per Hectare (du / Ha) or approx. 150 – 220 persons per Ha.

Residential R2:

The residential R2 zone is intended to be characterized with relatively higher intensity development, but lower than R1. The gross average density in this zone is considered to be around 110 – 150 persons per Ha or 25 – 35 du / Ha.

Residential R3:

The Residential R3 zone is intended to be developed with similar intensity as R2, but with fewer non-residential uses with a limitation on maximum permissible built-up area for certain commercial uses within mixed-use plots. The gross average density in this zone is considered to be around 25- 15 du/Ha or approximately 110- 65 persons per Ha.

Residential R4:

Areas which are currently rural in character, and in the future intended to support only low to very low density development, but which are in close proximity to other planned urban uses are zoned under R4.

2.5.4 SYNOPSIS OF TRANSIT ORIENTED DEVELOPMENT (TOD) NOTIFICATION

The zoning regulations, planning norms and redevelopment of building falling within Transit Oriented Development Corridor classification for transit oriented development and mixed land use have been notified in Development Control and Promotion Regulations for Nagpur Metropolitan Regional Development Authority (Nagpur Metropolitan Area Development Plan) as published by Urban Development Department, Government of Maharashtra (sanctioned under section 31 (1) of MRTP Act, 1966 vide Government Notification No. TPS-2416/CR-122(A)/2016/DCPR-NMA/UD-9 dated 5th January 2018.

Basic FSI permitted by Government of Maharashtra in for buildings in Nagpur is 1 for residential area and 2.5 for industrial and commercial area. Land owners may utilize FSI of common spaces like passages upto an extent of 30% of built-up area on payment of premium. Accordingly, the maximum potential will vary from 1.3 to 2.8. At present there is no limitation on utilization of TDR loading but the owner has to fulfill parking norms and therefore parking requirement is the governing criteria for utilization of FSI in plot/land. Utilization of TDR is not allowed in NMRC corridor.

2.6 ISSUES AND CONCERNS

Existing issues and concerns are listed as follows and are presented in **Figure 2.5.**

- Encroachment of footpaths / Unorganized On-street parking causing reduction in efficient roadway width
- Lack of pedestrians facilities like footpath along major roads resulting in pedestrian spill over on right of way
- Chaotic operations of shared auto services
- Absence of necessary infrastructure such as bus stop, lighting etc.

FIGURE 2.5: EXISTING ISSUES AND CONCERNS

Encroachment of Footpath

Pedestrian & Vehicular Interference

Passenger Traffic

Median without maintenance

Absence of Footpath

Roadside Encroachment and Cyclists in Wrong Side

The above said issues and concerns are widespread in the City which reduces the efficiency of road carriageway leading to congestion and causes vulnerability to road users. Other reasons for congestion include encroachment of road space by street vendors, unauthorized movement of auto-rickshaws and tempos which have not been regularized. With increase in population and dependence on personalized modes of transport, increase in road accidents the transport system requires expansion and augmentation for safe, efficient and convenient travel.

Chapter – 3.
CONCEPTUAL TRANSPORTATION ALTERNATIVES AS PER CMP

3. CONCEPTUAL TRANSPORTATION ALTERNATIVES AS PER CMP

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.

CMP envisions providing sustainable mobility solutions for Nagpur in a bid to ensure free-flowing city, smarter, accessible, safe & secure urban transport and also to have a substantial improvement in service level benchmark.

The strategy framework to approach mobility planning has been formulated in CMP considering the following:

- Land Use and Transport Strategy
- Road Network Development Strategy
- Public Transit Improvement Strategy
- Non-Motorized Transport Strategy
- Freight Management Strategy
- Traffic Engineering Measures
- Travel Demand Management Strategy

3.1 PLANNING CONSIDERATIONS

3.1.1 The ultimate Goal of a CMP is to provide a long-term strategy for the desirable mobility pattern of a city's populace. To achieve this goal, the following are the main objectives

- Goal 1: Develop public transit system in conformity with the land use that is accessible, efficient and effective.

- Goal 2: Ensure safety and mobility of pedestrians and cyclists by designing streets and areas that make a more desirable, livable city for residents and visitors and support the public transport system.
- Goal 3 : Develop traffic and transport solutions that are economically and financially viable and environmentally sustainable for efficient and effective movement of people and goods
- Goal 4: Develop a Parking System that reduces the demand for parking and need for private mode of transport and also facilitate organized parking for various types of vehicles.

3.1.2 The CMP which is prepared in accordance with the Revised CMP Toolkit, published by the MoHUA, will also focus on the following:

- A study of Service Level Benchmarks as per MoHUA's Handbook on Service Level Benchmarks for Urban Transport.
- Study on Sustainable Habitat Mission for the city to make habitat sustainable through modal shift to public transport, as per National Mission on Sustainable Habitat. The study will also look in to the possibility of enhancing the NMT programs to make the sustainable habitat an integral part of the planning process.

3.1.3 The broad Scope of the Comprehensive Mobility Plan is listed below:

- To review the demographical profile of the city which includes location, land area etc.
- To delineate the traffic analysis zones and review the existing urban transport and environment
- To describe the existing traffic and transportation system in the study area
- To identify in detail, the problematic situations related to the existing transportation infrastructure and traffic operation
- To understand the level of service provided to the citizens with the help of service level benchmarking
- To develop a Business as Usual (BaU) scenario based on land use transitions and socio-economic projection and comparing the travel characteristics of BaU scenario with the base year as well as SLB
- To present the projected travel demand in the study area for different horizon years
- To develop and evaluate various transport strategies

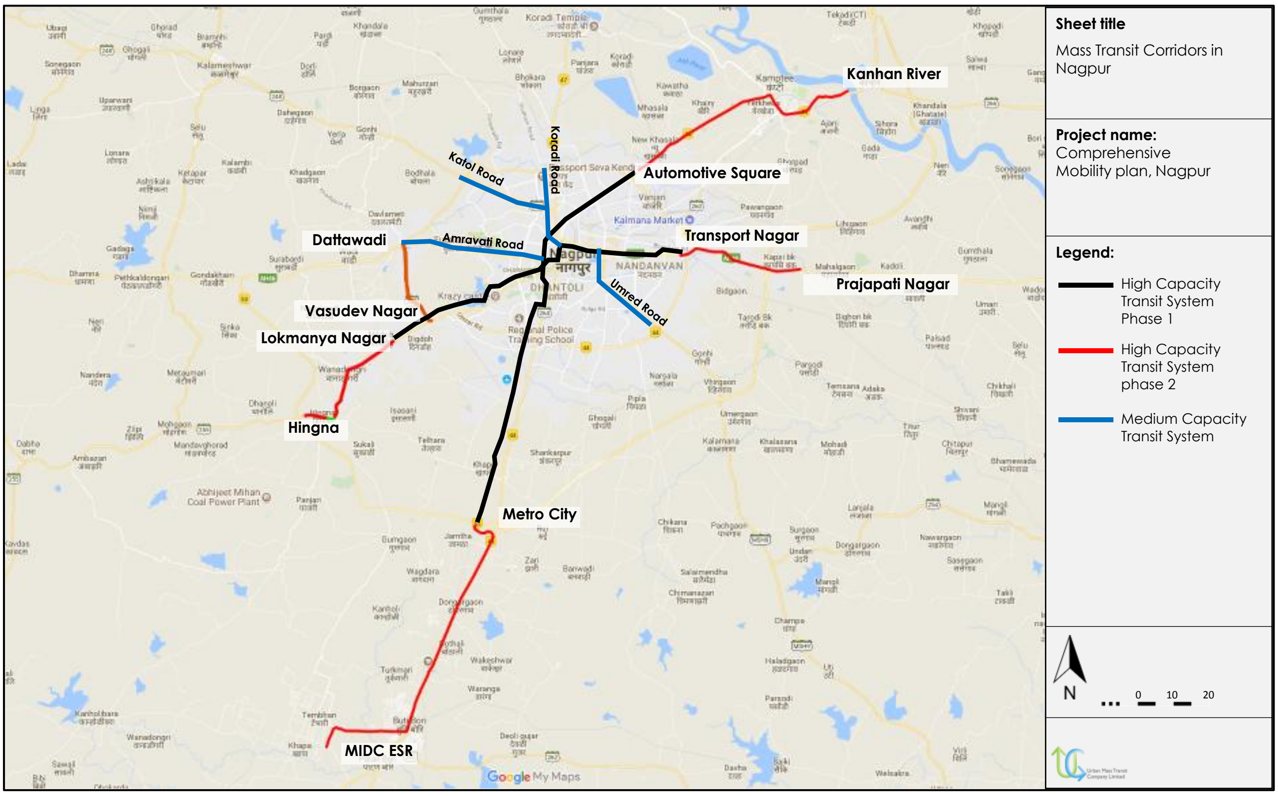
- To recommend various medium-term and long-term traffic improvement measures based on the scenarios and to develop an Urban Mobility Plan
- To develop Transport Investment Options and Implementation Plan
- To suggest an Institutional Arrangement

3.1.4 Primary Public Transport Network

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 also been conceived in CMP. A total of about 110 km of rail based public transport network in 2 phases have been proposed. The proposed corridors for rail based public transport systems are presented in **Figure 3.1.**

FIGURE 3.1: PROPOSED PUBLIC TRANSPORT CORRIDORS IN CMP



3.1.5 Non-Motorised Transport (NMT) Plan

Provision of footpath, pedestrian facilities, cycle tracks and public bike sharing scheme are part of NMT plan complementing to the proposed public transport system for last mile connectivity. Footpath improvement, cycle docking station development and pedestrian zones in important areas of city are key features of the plan.

3.2 DESCRIPTION OF ALTERNATIVES

Two alternative public transportation modes have been proposed for Nagpur as a part of CMP namely Bus and Rail based public transport system.

Considering the above, mass transport systems could be rail based consisting of light rail or metro rail systems and road based such as BRT or Normal Buses. A characteristics summary of these public transport modes has been compiled in **Annexure 3.1**. The various public transportation modes along with associated advantages are detailed below:

1. Normal Buses on Shared Right of Way:

Normal/ordinary bus system is the main transport system in many major Indian cities. The buses are operated by the State governments and respectivel development authorities for public transport in the city. They are normally characteriterised by sharing the common Right of Way with other modes of transport in the city. Ordinary buses normally act as a fedeer mode of transport in metropolitan cities to mass rapid transit systems such as metro rail, light rail and suburban rail systems.

Advantages:

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

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 combine the capacity and speed of a metro 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
- Needs urban space for dedicated corridors

3. Light Rail Transit System:

Light Rail Transit (LRT) system is popular system in large number of European countries. LRT system can have elevated, underground or at grade alignment. Generally, LRT systems are at grade, thus these can only be provided where ample right of way is available. In the Indian context, providing the right of way at-grade may not be easy. Also, at grade LRT tend to ply at slower speeds as their speeds are restricted due to traffic flows.

Modern trams – street cars running on rails and having high acceleration and deceleration characteristics are adopted for Light Rail Transit (LRT) system. Exclusive right of way for LRT allows the trains to run at higher speeds. LRT permits sharper curves (upto 25 m), thus minimizing need for property acquisition. The Light Rail System is a preferred mode of transport in areas with a maximum PHPDT of around 30,000.

Advantages:

- Capital cost slightly less than metro system - cost could be significantly lower if LRT can be planned at grade
- Needs less urban space than bus based systems
- No pollution as system operates on electricity
- Comfortable and safe PT system as Metro system

4. **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 80-120 kmph. Sharpest curve of 120 m radius is permitted for MRTS. The system can be designed to meet the peak hour peak direction traffic (PHPDT) carrying capacity from 40,000 to up to 80,000 depending upon the type of systems and infrastructure adopted such as rolling stock, train set configurations, signalling 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

The characteristics of metro rail system covering attributes like travel demand, carrying capacity, structural requirements, rolling stock, traction system, operational characteristics, effect on ambient surrounding & urban landscape, maintainability etc. are provided as a part of **Annexure 3.1**.

3.3 CONSTRAINTS

In addition to above, various identified constraints of public transportation modes are briefed below:

Normal Bus System on Shared Right of Way:

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

Bus Rapid Transit:

- Capacity not as high as rail based systems
- Inflexible as stopping at fixed bus stops
- More polluting than rail based systems

Light Rail Transit System:

- Capital costs higher than bus system
- Operating costs higher than bus systems
- Needs substantial urban space if proposed at-grade
- Carrying capacity lower than metro system
- Needs extensive feeder systems for last mile connectivity
- Non availability of large chunk of urban land for maintenance depot
- No indigenous availability in Indian conditions

Metro Rail System:

- 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
- Non availability of large chunk of urban land for maintenance depot

Annexure 3.1

System		Normal Bus System	Bus Rapid Transit (BRT)	Light Rail Transit (LRT)	Metro Rail System
Exterior of Vehicle					
Description		It is a bus operation generally characterized by use of shared rights-of-way along the general traffic flows.	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.	It is a transport system that runs on elevated or at grade track suitable for carrying 10000 (at grade) to 29000 PHPDT (Elev.) considering 6 car trains (@6p/m^2)	Most prevalent worldwide Mass Rail Transit System (MRTS), Suitable for carrying PHPDT of more than 25000.
Structure	Superstructure	Roads	Roads	Concrete slab	Concrete slab
	Pier and foundation	Not Required	Not Required	Concrete	Concrete
Track & Switch	Track	Road	Road	Steel rail	Steel rail
	Switch constitution	Road Crossings	Road Crossings	Switch and crossing	Switch and crossing

System		Normal Bus System	Bus Rapid Transit (BRT)	Light Rail Transit (LRT)	Metro Rail System
Rolling stock	Length (m)	12 m	12 m, 18 m (articulated type)	17.5 m	22.0 m
	Width (m)	2.5 m to 2.6 m	2.5m to 2.6 m	2.65 m	2.9 m
	Height (m)	3.25 to 3.5 m	3.25 to 3.5 m	3.9 m	3.9 m
	Wheel arrangement	Independent Axles	Independent Axles	2-2-2	2-2 or 3-3
	Weight (tare)	12.0 to 16.0 T	12.0 to 16.0 T	30.0 T	40.0 T
	Axle load (max)	6.0 to 10.0T	6.0 to 10.0T	12.0 T	16.0 T
	Type of car load	Concentrated load	Concentrated load	Concentrated load	Concentrated load
Running gear & Traction System	Traction system	Rubber tyre	Rubber tyre	Rotary Motor and steel wheel/LIM	Rotary Motor and steel wheel
	Brake system	Hydraulic/Compressed air Brakes	Hydraulic/Compressed air Brakes	Electric brake and hydraulic brake	Electric brake, Pneumatic brake and Regenerative brakes with Brake Blending
	Guidance System	None	None/ special guide wheels on kerbs	Steel rail	Steel Rail
	Power collector	Not applicable	Not applicable	Conductor rail	Catenary
	Voltage	None	None	D.C. 750 V	A.C. 25kV

System		Normal Bus System	Bus Rapid Transit (BRT)	Light Rail Transit (LRT)	Metro Rail System
Operation Characteristics	Maximum speed	80 km/h	80 km/h	90 km/h	90 km/h
	Schedule speed	10 to 15 km/h	20 to 25 km/h	34 Kmph including turnaround time	34 Kmph – Corridor 1 33 Kmph – Corridor 2
	Minimum curve radius	12 m	12 m	70 m mainline, 50 m depot	120 m
	Maximum gradient	10%	10%	6 %	3 %
	Acceleration	–	–	1.2 m/s^2	1.2 m/s^2
	Deceleration Service brake	–	–	1.0 m/s^2	1.1 m/s^2
	Emergency brake	–	–	1.3 m/s^2	1.3 m/s^2
	Automatic Train operation	No	No	Available	Available

System		Normal Bus System	Bus Rapid Transit (BRT)	Light Rail Transit (LRT)	Metro Rail System
Transportation capacity	1 car seat	35	35	24 - 25	43
	Standing @6p/m^2	65	65	140	205
	Total	100(L=12)	100(L=12)	165 (Length 17.5m)	248(Length=22m)
	4 car train	–	–	650	1034
	6 car train	–	–	976	1574
	Max. PHPDT	Up to 3000 (Buses at 120 sec headway)	6000 (Buses at 60 sec headway)	29000 (6 car trains with 2 min headway)	47000 (6 Car at 2 min headway)
			It is possible to deal with max 6,000 PHPDT of demand.	It is possible to deal with PHPDT demand of about 29000.	The train configuration can be extended upto 9 car to carry higher traffic.
Surrounding& Harmony	Effect on ambient surrounding	Noise and Pollution Problems	Noise and Pollution Problems	Noisy due to steel wheel arrangement/ Quieter operation.	This system is noisy due to steel wheel arrangement
	urban landscape	No such issues	No such issues	Superior to MRTS due to lesser width of viaduct and no overhead wires for traction (if third rail traction is considered).	This system is inferior to other systems in terms of landscape if overhead traction is considered.

System		Normal Bus System	Bus Rapid Transit (BRT)	Light Rail Transit (LRT)	Metro Rail System
Emergency evacuation		Walk way	Walk way	Walk way	Walk way
		No Issues	No Issues	In case of emergency, supporting vehicles will engage in rescue activities. If supporting vehicles cannot do that, it is possible for passengers to evacuate to nearest stations through evacuation passage by walk.	In case of emergency, supporting vehicles will engage in rescue activities. If supporting vehicles cannot do that, it is possible for passengers to evacuate to nearest stations through evacuation passage by walk.
Maintainability and cost	Track	Extensive maintenance of roads required.	Extensive maintenance of roads required.	It has less maintenance of track as compared with Metro rail transit system.	Requires extensive track maintenance work due to rail-wheel interaction.
	Vehicle	Maintenance of engine and rubber tyre is necessary.	Maintenance of engine and rubber tyre is necessary.	Maintenance of rotary motors and turning of steel wheels necessary/Low maintenance cost if LIM propulsion is used.	Maintenance of rotary motors and turning of steel wheels necessary.
Capital cost per km (Cr/km)		About Rs 10 Cr/km	Rs 70 – 80 Cr/km	Rs 110 Cr/km (at Grade) &Rs. 180 Cr/km (Elevated Section)	Rs 200 - 250 Cr/km (Elevated) & 450 - 500 Cr/km (Underground Section)

Chapter – 4.
SCREENING CRITERIA FOR IDENTIFIED ALTERNATIVES

4. SCREENING CRITERIA FOR IDENTIFIED ALTERNATIVE OPTIONS

4.1 SCREENING PARAMETERS

4.1.1 Goals & Objectives

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

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. As the evaluation progresses with respect to these criteria, the most suitable options will emerge for more detailed analysis, eventually leading to the adoption of the preferred alternative by decision makers. While the methodology offers an objective procedure for comparing potential public transportation options, it also takes into consideration criteria for evaluating public transportation projects based on an economic appraisal - facilitating fully informed decision making. Based on the review of the goals and objectives, a set of parameters have been identified and listed in **Table 4.1.**

TABLE 4.1: GOALS AND OBJECTIVES TO BE SATISFIED BY ALTERNATIVE MODES

SN	Goals	Objectives
1	Improve mobility for the residents and visitors	• 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
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 a range of 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.
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 on a qualitative basis 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.

Based on the existing study area characteristics and options available for different modes of transport, possible alternatives of mass transit system for Nagpur have been identified. The alternative analysis process covers following 4 stages **(Figure 4.1)**.

Stage 1: Develop screening criteria for identified alternative options

Stage 2: Evaluation parameters for various alternatives (For qualitative and quantitative screening)

Stage 3a: Alternatives qualitative evaluation

Stage 3b: Alternatives quantitative evaluation (Screening of alternatives shortlisted from initial screening)

Stage 4: Implementation options for most viable alternative

FIGURE 4.1: ALTERNATIVES ANALYSIS PROCESS

4.2 EVALUATION PARAMETERS OF VARIOUS ALTERNATIVES

Metro Rail Policy, 2017 suggests several screening criteria for alternatives analysis. Following screening criteria have been identified for both the qualitative and quantitative evaluation:

4.2.1 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 utilisation and its connectivity.

4.2.2 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.

4.2.3 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.

4.2.4 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.

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

4.2.6 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.

4.2.7 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.

4.2.8 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.

4.3 PARAMETERS FOR QUALITATIVE SCREENING

The evaluation parameters under various heads have been identified and summarised in subsequent sections. The first level screening has been performed to quickly and efficiently identify the alternatives considering available modes of transportation specific to local conditions.

The qualitative evaluation will hence be the initial level of screening for the identified parameters to narrow the number of alternatives for further evaluation in quantitative analysis stage. The following set of parameters has been considered as qualitative screening:

4.3.1 Mobility Effects

i. Ability to Cater Travel Demand – Max. Peak Hour Peak Direction Trips (Max. PHPDT)

PHPDT is a measure of capacity of a public transport system. The peak hour travel demand along an arterial road helps in determining which public transport mode will be helpful in catering to the demand as different modes of public transport systems have different carrying capacity. Considering the travel demand for Nagpur, existing services and capacity of operational bus transport system are inadequate. Rail based mass transport systems with dedicated guideways and frequencies can cater to a larger travel demand.

ii. Ease of Passenger Transfer at Terminals

A continuous mass transit system helps passengers in safe, comfortable and convenient travel. Additional transfer points on a continuous corridor from one mode to another consume additional time and causes inconvenience to passengers.

iii. Daily System Utilisation in terms of Passenger KM (PKM) per Route Km

Daily passengers kilometer (PKM) is a multiplicative measure of total passenger carried and total distance covered by the public transport system. The daily PKM per route km gives the utilization factor of mode under consideration. The higher the utilization factor, there are more chances of selecting specific mode for travel.

iv. Average Trip Time

Average trip time depends upon the trip length of passengers using the system. Road based systems will have more trip time attributed to congested travel characteristics on the roads.

v. Catchment Area Connectivity and Circulation

The mass transport system should be convenient to offer excellent catchment area connectivity and circulation covering major traffic generation / attraction points in the city. This would help in achieving better patronage for the proposed mass transit system.

4.3.2 Conceptual Engineering Effects

i. Available Right of Way (RoW) – Required Viaduct & Station Widths

Available right of way along the major arterials plays an important role in alignment design of mass transit. Both the elevated rail/road based mass transit systems require considerable road width for viaduct and station construction unlike the at-grade normal bus transport system.

ii. Alignment Design and Constructability

The constructability of road based transport system is relatively easier and flexible than rail based systems. Rail based systems are more technology driven and require more radius of curvature and other land acquisition components. Alignment of rail based systems once built cannot be changed and offers little flexibility.

iii. Geotechnical Characteristics and Civil Structures

The geotechnical characteristics and possible structures for the mass transit system play an important role in selection of mass transport system alternative.

iv. Station Planning and Intermodal Integration

The stations of the proposed mass transit system along with efficient parking spaces and intermodal connectivity with other modes of transport play an important role in providing last mile connectivity and boosting the patronage of the mass transit system.

v. Requirement for Utility Shifting

Conception and implementation of a new transport system impacts the location of existing surface/underground utilities. At-grade normal bus system cause less impact to utilities' shifting as compared to underground rail based systems.

4.3.3 System Effects

i. Interoperability with Phase-1 System

The interoperability between proposed system in Phase 2 and the mass transit system already in place in Phase I always scores high. The same system can have better system efficiency, optimized use of system resources and enhanced passenger comfort.

ii. Safety & Comfort

Safety and comfort are some of the prime factors before commuters undertake a travel. Convenient and state-of-the-art public transport systems can go a long way in attracting people from private modes to public transport. Technology driven public transport system will instill better sense of safety among the passengers.

iii. Type of Operation (Guided/Open)

The transport system for a city can either have an guided system of operation or an open system. Automatic operation of rail based public transport systems with a dedicated guideway efficiently caters to larger number of passengers during peak hours. Elevated bus rapid transit can also serve more passengers as compared to at-grade normal bus system.

iv. Indigenous Availability

Indigenous availability of rolling stock is an important factor as it lead to lesser system cost, availability within short span of time and easy procurement/maintenance for operations. Technical expertise developed in country over the period of time is helpful in mitigating implementation delays.

4.3.4 Environment Effects

i. Air & Noise Pollution

Public transport offers range of alternative modes to the private modes. Public transport can relieve traffic congestion and reduce air and noise pollution generated from use of personalized road transport.

ii. Trees Affected

The trees affected/proposed to be removed for the implementation is a sensitive environmental impact to the city. The proposal with maximum social benefits and least damage to the environment in cutting of trees would have preference.

iii. Waste Management including Hazardous Substance

The system as well as station locations shall have provisions to handle generated waste during construction, operation & maintenance and passenger handling. Grade separated guided mass transport systems with planned stations amenities generally have better waste management in comparison to a normal bus system.

4.3.5 Social Effects

i. Structures/Persons Affected

The grade separated mass transport system requires relocation of structures/persons along the alignment over unavoidable populated areas. Such displacement cause inconvenience to residents and sometimes greatly affecting the livelihood.

4.3.6 Cost Effectiveness & Affordability

i. Capital Cost per Passenger KM

Mass rapid transport systems are capital intensive initiatives. It is total capital required for project consisting of land, alignment and formation, station/bus stop buildings, traction and power supply systems, rolling stock, environmental and social costs, intermodal integration, general charges etc. Bus based systems have major expenditure towards fleet and bus stops infrastructure. Capital Cost per passenger km will be more for rail based systems.

ii. Operation & Maintenance Cost per Passenger KM

In addition to the capital cost, there are associated recurring annual costs such as operation and maintenance expenditures. The expenses incurred across modes have been compared.

4.3.7 Financial and Economic Effects

i. Economic Returns

The implementation of a dedicated mass rapid transit system will result in reduction of number of private vehicles on the road and thus increase in journey speed of road-based vehicles. Rail based systems will have higher benefits to the society compared to bus based systems like reduction in accidents and pollution.

ii. Life Cycle Cost

Mass rapid transport system for a city is envisioned for a longer planning period. Systems with longer life cycle with higher durability and less replacement such as rail based systems have higher score than road based systems.

4.3.8 Other Factors - Approvals and Implementation

i. Time required for Approvals

The mass transport system to be introduced will require technology and set of components well established and proven so that the approvals for the 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.

ii. Ease of Implementation

Normal Bus System, Bus Rapid Transit and Metro are easy to implement and score more than that of LRT. LRT is yet to be implemented in India and thus may take a slightly more time and cost.

The identified screening parameters (total 25 nos.) for qualitative evaluation are summarised in **Table 4.2**.

TABLE 4.2: PARAMETERS IDENTIFIED FOR QUALITATIVE EVALUATION

S. No.	Criterion	Parameters
1	Mobility Effects (5 nos.)	Ability to cater to Travel Demand – Max. Peak Hour Peak Direction Trips (Max. PHPDT)
		Ease of Passenger Transfer at Terminals
		Daily System Utilisation PKM/Route KM
		Average Trip Time
		Catchment Area Connectivity and Circulation

S. No.	Criterion	Parameters
2	Conceptual Civil Engineering (5 nos.)	Available Right of Way
		Alignment Design and Constructability
		Geotechnical Characteristics and Civil Structures
		Station Planning and Intermodal Integration including Parking
		Requirement for Utility Shifting
3	System Effects (4 nos.)	Interoperability with Phase-1 System
		Safety and Comfort
		Type of Operation
		Indigenous Availability
4	Environment Effects (4 nos.)	Air Pollution
		Noise Pollution
		Trees Affected
		Waste Management including Hazardous Substance
5	Social Effects (1 no.)	Structures/Persons Affected
6	Cost Effectiveness & Affordability (2 nos.)	Capital Costs per Passenger KM
		Operational & Maintenance Cost per Passenger KM
7	Financial and Economic Effects (2 no.)	Economic Returns
		Life Cycle Cost
8	Approvals & Implementation (2 no.)	Time Required for Approvals
		Ease of Implementation

4.4 PARAMETERS FOR QUANTITATIVE EVALUATION

After first level screening of alternatives considering available modes of transport, the second level involves detailed assessment of screening parameters for quantitative evaluation to find most viable public transport system. The following set of screening parameters has been considered for quantitative evaluations:

4.4.1 Mobility Effects

i. Travel Demand Forecasting:

While analysing the travel demand for the Study Area, following tasks have been performed:

a. Summarizing the Right of Ways along public transport corridors and in city

b. Preparation of road and transit networks for each alternative and a no-project (without project) scenario

c. Summarizing the travel demand results for base and horizon years for Phase 2 corridors, peak hour peak direction trips, daily system utilisation (passenger km per route km) and estimating reduced number of vehicles on road due to proposed Phase 2 system
d. Ease of passenger transfer between the proposed alternative modes in terms of time and convenience
e. Analysis of differences among the various alternatives to provide information to Environmental Assessment

4.4.2 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 of utilities to be shifted for implementing a mass transport system plays a role in impacting the day today traffic operations.

4.4.3 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 LRT systems can have same minimum possible headway, whereas Metro requires less rolling than LRT. Elevated BRT requires a big fleet of buses 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 Nagpur, the proposed Phase 2 can use the existing depots whereas in case of other systems like LRT, 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 guage, civil structures and rolling stock components have been standardised. 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 LRT, these have to be taken afresh resulting in delay and cost implications.

4.4.4 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.

i. 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.

4.4.5 Social Effects

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

i. 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.

4.4.6 Cost Effectiveness & Affordability

i. Capital Cost per Passenger KM

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 per Passenger KM

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 no experience for light rail system, the maintenance personnel may find difficulties in maintaining the rolling stock/subsystems. This may increase the maintenance cost during initial years of operation.

4.4.7 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.

4.4.8 Approvals and Implementation

i. Time Required for Approvals

Light Rail Transit system is new in India. With no previous experience in light rail technology 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 for approval of LRT. Whereas the other two systems namely Metro Rail and Bus have systems and standards put in place for sooner approvals.

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 LRT attributed to prior experiences and expertise.

The identified parameters (total 22 nos.) for quantitative evaluation is summarised in **Table 4.3**.

TABLE 4.3: PARAMETERS IDENTIFIED FOR QUANTITATIVE EVALUATION

SN	CRITERION	PARAMETERS
1	Mobility Effect (4 nos.)	Ability to cater to Travel Demand – (Max. PHPDT)
		Ease of passenger transfer at terminals
		Daily System Utilisation PKM/KM
		Reduced Vehicles on Road due to proposed system
2	Conceptual Civil Engineering (5 nos.)	Available Right of Way (Land Acquisition)
		Alignment Design & Constructability
		Geotechnical Characteristics and Civil Structures
		Station Planning and Intermodal Integration
		Requirement of Utility Shifting

SN	CRITERION	PARAMETERS
3	System Effects (4 nos.)	Interoperability with Phase-I System
		Rolling Stock Requirement
		Land for Maintenance Depot
		Indigenous Availability
4	Environment Effects (2 nos.)	Air Pollution
		Noise Pollution
5	Social Effects (1 no.)	Structures/Persons Affected
6	Cost Effectiveness & Affordability (2 nos.)	Capital Cost per Passenger KM
		Operation & Maintenance Cost per Passenger KM
7	Financial and Economic Effects Cost (2 nos.)	Economic Returns
		Life Cycle Cost
8	Approvals & Implementation (2 no.)	Time Required for Approvals
		Ease of Implementation

4.5 QUALITATIVE SCREENING OF ALTERNATIVES

4.5.1 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 liveability and sustainability); and,
- Would be unlikely to pass key viability and acceptability criteria (or represent significant risk)

4.5.2 Four alternative options reviewing the CMP and other local conditions have been considered for the initial screening stage with the set of identified qualitative parameters (**Figure 4.2**):

i. Normal Bus System
ii. Elevated Bus Rapid Transit System
iii. Light Rail Transit System
iv. Metro Rail System

FIGURE 4.2: ALTERNATIVE OPTIONS FOR QUALITATIVE EVALUATION

1. Normal Bus System

2. Elevated Bus Rapid Transit System

3. Light Rail Transit System

4. Metro Rail System

4.5.3 A scoring criterion for each of screening parameters has been developed for the initial qualitative evaluation leading to shortlisting for further evaluation.

- A weightage of 20% of total score has been given to travel demand under mobility effects as the conception of a public transport system is based and various passenger facilities designed on existing as well as peak hour travel demand in horizon year.

- Conceptual Civil Engineering Effect has been assigned 15% weightage as outcome of engineering surveys, geometric requirements, availability of right of way for viaduct and stations, extent of land required for the project have direct implications on conception of the project.

- System related aspects have been given a weightage of 10% considering inter-operability with existing Metro Phase-I, operation & maintenance, passenger safety and comfort parameters.
- Environmental and Social effects carries a relatively higher weightage of 20% (15% for Environmental Effects & 5% for Social Effects) as mass transport system plays major role in reducing pollution levels and preserving actual natural environment. The structures impacted by project implementation and affected population requiring rehabilitation & resettlement has been considered as an important factor.
- The influencing parameter of cost effectiveness & affordability namely project cost estimates of all project components and life cycle costs have been considered with 15% weightage.
- Financial & Economic Effects have also been assigned 15% weightage as public transport systems are helpful in providing larger economic and social benefits to the society thereby improving the quality of life.
- The time taken for approvals and ease of implementation of the proposed mass transport system has been given a weightage of 5%.

The overall weightages assigned to various parameters for qualitative evaluation have been summarised in **Table 4.4.**

TABLE 4.4: SCORING CRITERIA FOR QUALITATIVE EVALUATION

SN	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 utilisation	20
2	Conceptual Civil Engineering Effect	• Utilisation 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	15

SN	Criterion	Objectives	Weightage
3	System Effects	• Provide better safety and comfort • Ability to carry more passengers • Indigenous availability of rolling stock	10
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	15
5	Social Effects	• Impact on existing structures and families	5
5	Cost Effectiveness & Affordability	• Provide quality, affordable public transport service with an optimum investment cost • Consumption of minimum possible maintenance costs	15
6	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
7	Approvals and Implementation	• Time taken for approval of system • Ease of implementing the proposed and approved system	5
	Total		**100**

4.5.4 The relative influence of each of screening parameters for qualitative evaluation with respect to each alternative mode has been considered while assigning score to the parameters. The result of this qualitative evaluation will narrow down the alternatives from the identified modes for further quantitative evaluation of the mass transport modes.

Chapter – 5.

SCREENING AND ALTERNATIVE EVALUATION BASED ON GRADING FOR EACH MODE

5. SCREENING AND EVALUATION BASED ON GRADING FOR EACH MODE

5.1 EVALUATION BASED ON SCORING CRITERIA

5.1.1 The scoring criteria have been classified on the basis of importance and value of parameter associated with specific alternative. The scoring against each parameter for each of alternative option will help shortlisting modes further for a detailed quantitative analysis. The alternatives are ranked based on their relative performance under each criterion. Four scoring classifications considered for each parameter are:

1. Excellent (100%) – Most attractive mode for the given parameter will score excellent rating
2. High (75%) – High rating equivalent to 75% of weightage will be assigned to modes on a relative scale
3. Medium (50%) – Medium rating equivalent to 50% of weightage will be assigned to a mode based on attractiveness on a relative scale between high and low
4. Low (25%) – Mode unattractive towards a specific parameter will receive least rating of low

The highest performing alternative receives a score of 100%, followed by 75%, 50% and 25% scores.

5.1.2 Basis of Scoring the Screening Parameters for Qualitative Evaluation

- **Mobility Effects** – Mobility effects namely travel demand and existing transport characteristics in the City influence in determining the mass transport system required. Fulfillment of projected demand in long term scenario, ease of passenger transfer, utilization factor, possibility of intermodal integration between systems and catchment area connectivity are the identified parameters. Guided systems score high in mobility effects as they offer higher carrying capacity and frequency of regulated services, better utilization in terms of more passenger-km and thus reducing congestion on roads.

Metro rail, as a result of the advantages of continuity of Phase 1 corridors, scores 20 points while other modes LRT, Elevated BRT and Normal Bus score 15.5, 12.25 and 8.0 respectively based on their individual mobility related performances. Passengers of road based Elevated BRT and Normal Bus systems will have to physically interchange at Phase 1 metro terminal points thereby largely affecting the safety and convenience.

- **Conceptual Civil Engineering Effects** –The parameters covered are available right of way, alignment design & constructability, geotechnical characteristics, station planning & intermodal integration and requirement for utility shifting.

  Road based systems score high as it requires less right of way and have easy constructability than grade separated rail based systems and BRT. Rail based systems and elevated BRT with dedicated guideway systems have impact on shifting of existing surface / underground utilities. However, Metro Rail, LRT and BRT can offer better station planning and intermodal integration opportunities. Normal buses as a result score of 14.25 out of 15.0 whereas Elevated BRT, Metro Rail and LRT score 11.25, 10.0 and 10.0 respectively.

- **System Effects** – The influential parameters are interoperability with existing Metro Phase-I, passenger's safety & comfort, type of operation and indigenous availability of the system.

  Rail based systems and Elevated BRT are more automated in operations while normal bus system is manually operated in mixed traffic conditions. Metro rail would be the most suitable mode considering continuity / interoperability with the under construction Phase 1 metro system. Rail based systems offer better quality of travel and offer safe travel conditions than road based systems. Except for LRT, other modes namely Metro, BRT and Normal bus have indigenous availability in the country. Considering these Metro Rail, LRT, Elevated BRT and Normal Bus score 10.0, 7.0, 6.0 and 4.0 respectively on a scale of 10.

- **Environmental Effects** - The parameters considered are air & noise pollution, trees affected and management of hazardous waste.

  Rail based systems have been assigned better scores more than bus based systems considering their ability to reduce pollution levels on the city roads. Grade separated Metro Rail and LRT being electrified systems play an important role in minimizing the air and noise pollution levels in the city. However, these grade separated systems require exclusive right of way and might impact more affected trees. Under environmental effects, Metro rail and LRT systems score a maximum of 13.50 each, followed by Elevated BRT and Normal bus system with 9.25 and 6.0 respectively on a scale of 15.

- **Social Effects** – Normal Bus based system score high as very few structures / families are affected. Normal buses score 5.0 out of 5.0 whereas elevated BRT, LRT and Metro rail score 3.75, 3.75 and 2.50 respectively.

- **Cost Effectiveness & Affordability** – Bus based systems are more affordable than rail based systems due to lower capital and O&M costs per passenger-km and accordingly are assigned higher scores than metro and light rail systems.

  Rail based systems incur high capital cost whereas normal bus systems require comparatively less investment costs as buses share the existing roadway system with other modes. However, Metro, LRT and elevated BRT consume more construction and O&M costs as they are planned for a much higher operational period and an exclusive guideway system. Accordingly, Normal bus system, Elevated BRT, Metro Rail and LRT score 15.0, 11.25, 7.50 and 7.50 respectively on a scale of 15.0.

- **Financial and Economic Effects** – Economic benefits and Life cycle cost of rail based systems is much higher than road based systems considering reduction in pollution levels, number of accidents and overall social benefits.

  The cost incurred in road based systems considers fuel, operation and maintenance costs. Rail based systems on the other hand result in saving considerable travel time, provide convenient and safe travel conditions thereby resulting in optimizing overall travel cost.

  The rail based systems also allow Transit Oriented Development along dedicated corridors which generate additional revenue for the implementing agency/development authority. Metro among rail based systems have higher carrying capacity and offer higher economic returns than all other systems.

  Considering these Metro, LRT, Elevated BRT and Normal bus system score 15.0, 12.5, 11.25 and 6.25 respectively on a scale of 15.0.

- **Approvals and Implementation** –Road based systems and Metro score higher than LRT as these systems have set standard procedures for approvals and implementation. LRT would consume more time as it has not been introduced yet in India. Accordingly, the scores are 5.0, 3.75, 3 and 1.25 for Normal bus system, Elevated BRT, Metro and LRT respectively.

5.2 SCREENING RESULTS

5.2.1 The screening of parameters in qualitative evaluation results in shortlisting of alternatives to be taken forward for further evaluation. The summary of analysis of various modes for the given qualitative screening parameters is presented in **Table 5.1.**

TABLE 5.1: QUALITATIVE SCREENING - SCORING OF PARAMATERS

S. No	Parameters	Total Score	Metro	LRT	Elevated BRT	Normal Bus System
A. Mobility Effect						
1	Ability to cater Travel Demand - Max. PHPDT	6.0	6.0	4.5	3.0	1.5
2	Ease of Passenger Transfer at Terminals	4.0	4.0	2.0	2.0	1.0
3	Daily System Utilisation-PKM/Route KM	4.0	4.0	3.0	2.0	1.0
4	Average Trip Time	3.0	3.0	3.0	2.25	1.5
5	Catchment Area Connectivity and Circulation	3.0	3.0	3.0	3.0	3.0
	Total A	**20.0**	**20.0**	**15.5**	**12.25**	**8.0**
B. Conceptual Civil Engineering Effect						
1	Available Right of Way (Required Viaduct & Station Widths)	4.0	3.0	3.0	3.0	4.0
2	Alignment Design and Constructability	3.0	1.5	1.5	2.25	3.0
3	Geotechnical Characteristics and Civil Structures	3.0	1.5	1.5	1.5	3.0
4	Station Planning and Intermodal Integration	3.0	3.0	3.0	3.0	2.25
5	Requirement for Utility Shifting	2.0	1.0	1.0	1.5	2.0
	Total B	**15.0**	**10.0**	**10.0**	**11.25**	**14.25**
C. System Effects						
1	Interoperability with Phase-1 System	4.0	4.0	2.0	1.0	1.0
2	Safety & Comfort	2.0	2.0	2.0	1.0	0.5
3	Type of Operation (Guided / Open)	2.0	2.0	2.0	2.0	0.5
4	Indigenous Availability	2.0	2.0	1.0	2.0	2.0
	Total C	**10.0**	**10.0**	**7.0**	**6.0**	**4.0**
D. Environment Effects						
1	Air Pollution	6.0	6.0	6.0	3.0	1.5
2	Noise Pollution	4.0	4.0	4.0	2.0	1.0
3	Trees Affected	3.0	1.5	1.5	2.25	3.0

S. No	Parameters	Total Score	Metro	LRT	Elevated BRT	Normal Bus System
4	Waste Management Including Hazardous Substance	2.0	2.0	2.0	2.0	0.5
	Total D	**15.0**	**13.5**	**13.5**	**9.25**	**6.0**
E. Social Effects						
1	Structures/Persons Affected	5.0	2.5	3.75	3.75	5.0
	Total E	**5.0**	**2.5**	**3.75**	**3.75**	**5.0**
F. Cost Effectiveness & Affordability						
1	Capital Cost (per Passenger KM)	10.0	5.0	5.0	7.5	10.0
2	Operation & Maintenance Cost (per Passenger KM)	5.0	2.5	2.5	3.75	5.0
	Total F	**15.0**	**7.5**	**7.5**	**11.25**	**15.0**
G. Financial and Economic Effects						
1	Economic Returns	10.0	10.0	7.5	7.5	5.0
2	Life Cycle Cost	5.0	5.0	5.0	3.75	1.25
	Total G	**15.0**	**15.0**	**12.5**	**11.25**	**6.25**
H. Approvals and Implementation						
1	Time Required for Approvals	3.0	1.5	0.75	2.25	3.0
2	Ease of Implementation	2.0	1.5	0.5	1.5	2.0
	Total H	**5.0**	**3.0**	**1.25**	**3.75**	**5.0**
	Grand Total A+B+C+D+E+F+G+H	**100.0**	**81.5**	**71.0**	**68.75**	**63.5**

5.2.2 From the screening and analysis of qualitative parameters for different alternative modes in Nagpur, it is inferred that Metro and LRT score 81.50 and 71.0 respectively on a scale of 100. The other bus based modes elevated BRT and Normal Bus System score 68.75 and 63.5 respectively. Considering this, Metro, LRT and Elevated BRT (scores being very close to LRT) have qualified for next stage evaluation.

Alternatives Evaluation in the form of quantitative analysis has been carried out for the said three modes. These three alternatives are most likely to:

a. Meet the purpose and need identified for the project.

b. Concurrently avoid or minimize environmental and community impacts.

c. Allow for effective and feasible project phasing and constructability.

d. Provide a cost-effective transportation investment.

5.3 QUANTITATIVE EVALUATION OF ALTERNATIVES

5.3.1 Mobility Effects

5.3.1.1 The mobility effects have been considered with the recent travel demand data available. The transport systems available along with details of right of way have been identified for the Study Area. Travel demand analysis for coded road and transit networks for base and horizon years have been carried out. The differences among these alternative modes to environmental assessment have also been quantified.

The factors contributing to mobility effects considering the local conditions which have been quantified include max. PHPDT, ease of passenger transfer at terminals, passenger utilization in terms of passenger-km/ km and betterment of environment with reduced number of vehicles on road due to proposed mass transit system. The number of commuters travelling in the peak direction in peak hour will be most important guiding factor as the proposed system has to be designed based on this peak hour demand.

5.3.1.2 The distribution of the road network as per right of way (ROW) is presented in Table 2.6 in Chapter 2. It can be observed from the table that 21% has 10-20 m ROW and while about 27% has ROW above 30-40 m. The road and transit network as a part of travel demand development have been carried out for mass transport system.

Metro will have a 3-car arrangement (as per minimum permissible system motorisation of 67% as recommended by Metro Rail Policy 2017 and configuration adopted in Nagpur Metro Phase 1). While LRT considered is to have 2-car arrangement as this configuration will satisfy the maximum PHPDTs upto various horizon years. Thus on basis of car configuration, LRT caters to a maximum PHPDT of 12,500 while BRT around 8,000. Metro Rail will be catering to maximum PHPDT of 23,000 PHPDT with a 3-car arrangement.

The following corridors in Phase 2 have been considered for mass transport system:

i. MIHAN to MIDC ESR (18.5 km)
ii. Automotive Square to Kanhan River (13 km)
iii. Lokmanya Nagar to Hingna (6.7 km)
iv. Prajapati Nagar to Transport Nagar (5.6 km)
v. Vasudev Nagar to Dattawadi (4.5 km)

The travel demand in terms of maximum PHPDT and Daily Passenger trips for horizon years of 2024, 2031, 2041 and 2051 have been estimated for alternative options of Metro Rail, LRT and BRT. The proposed Phase-2 Corridors will result in enhancement of ridership of existing Phase-I Corridors as well. Maximum PHPDT of Phase-I Corridors in full network scenario (Phase 1 & Phase 2 combined) is presented in **Table 5.2.** It has been assumed that traffic demand will grow at a rate of 2% per annum beyond 2041.

TABLE 5.2: MAX. PHPDT IN PHASE 1 CORRIDORS

Phase-I	Max. PHPDT			
	2024	2031	2041	2051
Automotive Square to MIHAN	12,952	13,407	15,743	19,191
Prajapati Nagar to Lokmanya Nagar	10,195	11,411	16,889	20,588

All the four Phase-2 corridors except Automotive square to Kanhan River corridor will be catered by any of three systems namely Metro, LRT and BRT till horizon year 2051 as observed (**Table 5.3**) projected maximum PHPDTs are well within peak hour carrying capacities.

TABLE 5.3: MAX. PHPDT FOR PHASE 2 MASS TRANSIT CORRIDORS EXCEPT KANHAN RIVER CORRIDOR

Phase	Corridor Details	Maximum PHPDT			
		2024	2031	2041	2051
2	MIHAN to MIDC ESR	3,501	4,387	5,695	6,942
	Lokmanya Nagar to Hingna	3,462	3,887	5,137	6,262
	Prajapati Nagar to Transport Nagar	3,511	3,858	5,213	6,355
	Vasudev Nagar to Dattawadi	3,806	4,862	5,835	7,113

However, for Automotive Square to Kanhan River Corridor it is observed that BRT will be saturated since the beginning from 2024. While Metro and LRT will cater to same number of maximum passengers in peak hour upto the year 2047. Beyond 2047, maximum PHPDT of LRT will get saturated at 12500 and Metro will be able to further cater to peak travel demand till 2051 and beyond (**Table 5.3**).

TABLE 5.4: MAX. PHPDT FOR AUTOMOTIVE SQUARE TO KANHAN RIVER CORRIDOR

Ph-2 Corridor	Max. PHPDT				
	2024	2031	2041	2047	2051
Automotive Square to Kanhan River	9,012	9,546	11,445	12,889	13,951

5.3.1.3 **Table 5.5** presents the daily trips for Phase 1 (DMRC DPR Figures) and projected ridership for combined Phase 1 & 2 Corridors. The daily incremental travel demand for Phase-2 corridors ranges from 2.9 lakh passengers in 2024 to 5.0 lakh passengers in 2051.

All the corridors will be catered by any of three systems namely Metro, LRT and BRT till horizon year 2044. Beyond 2044, BRT will get saturated to cater the projected daily passenger demand (Considering peak hour factor of 9% and max. PHPDT of 8000 passengers, BRT can cater upto a total of 4.4 lakh daily passenger trips in five Phase-II corridors). On similar lines, LRT will get saturated by 2047 (by this time, maximum PHPDT of 12500 will be attained by the system) with a total of 4.6 lakh passenger trips. Beyond 2047, Metro will continue to cater to higher daily passenger trips beyond 2047 owing to its higher carrying capacity.

TABLE 5.5: DAILY INCREMENTAL PASSENGERS (IN LAKH) ON PHASE-2 CORRIDORS

Horizon Year	Phase-1 DPR (DMRC)	Phase-1 & 2 (RITES)	Incremental Passenger Trips due to Phase-2 Implementation
2024	2.6	5.5	2.9
2031	2.9	6.3	3.4
2041	3.7	7.8	4.1
2044*	3.9	8.3	4.4
2047**	4.1	8.8	4.6
2051	4.5	9.5	5.0

* Year of BRT System Saturation, **Year of LRT System Saturation

5.3.1.4 The utilisation of a system can be established by number of passengers travelling on the specified route length. This ratio of passenger-km over the total transit route length will provide the utilisation of the proposed system. The same ATL has been considered for Metro, LRT and BRT to estimate total daily PKMs. Accordingly, the utilisation in terms of PKM/KM ratios are compared and provided in **Table 5.6.**

TABLE 5.6: DAILY SYSTEM UTILISATION (PKM/KM, IN LAKH)

System Network / Year	2024	2031	2041	2044	2047	2051
Phase 1 Metro + Phase 2 Metro	0.63	0.74	0.89	0.94	1.00	1.08
Phase 1 Metro + Phase 2 LRT	0.63	0.74	0.89	0.94	1.00	1.00
Phase 1 Metro + Phase 2 BRT	0.63	0.74	0.89	0.94	0.94	0.94

The PKM/KM has been estimated till 2041 and further projected upto 2051. It is observed from the table above that Metro provides better utilisation in the longer perspective whereas BRT and LRT get saturated in year 2044 and 2047 respectively. Considering the fact that a mass transport system has to serve the city for long period of time, Metro system appears to be more serviceable mode of transport for Nagpur with the long term perspective.

5.3.1.5 The travel demand model has been developed for Business As Usual (BAU – Without Project) and 'With Project' scenario. The 'Without Project Scenario' is essentially the present condition but it includes existing and committed transport infrastructure proposals that will be constructed in the near future including Phase-1 MRTS. The 'Without Project Scenario' includes the existing road network and improvements that are likely to be implemented within the next few years, except for the Phase-2 mass transit system corridors being considered in this study. The Without Project Scenario provides a baseline for comparing travel benefits in both 'with and without project scenarios'. The mode-wise passenger trips for the horizon years upto 2051 have been worked out and shown in **Table 5.7.**

TABLE 5.7: MODE-WISE TRIPS IN 'WITH' & 'WITHOUT' PROJECT SCENARIOS

Mode	Trips Without Phase II MRTS Extension (Lakh)				Trips with Phase II MRTS Extension (Lakh)				Daily Trips Reduced on Roads due to Ph 2 MRTS (in Lakh)			
	2024	2031	2041	2051	2024	2031	2041	2051	2024	2031	2041	2051
Car	4.8	5.7	7.0	8.7	4.6	5.4	6.7	8.2	0.2	0.2	0.3	0.4
2-W	32.7	37.7	43.5	50.2	31.6	36.5	42.0	48.4	1.1	1.2	1.5	1.8
Auto	5.4	6.4	9.1	13.0	5.3	6.3	8.9	12.6	0.1	0.2	0.2	0.3
S. Auto	2.0	2.8	3.9	5.3	1.5	2.2	3.1	4.2	0.4	0.6	0.8	1.1
Bus	4.8	5.3	5.8	6.4	3.8	4.1	4.6	5.1	1.1	1.2	1.2	1.3
MRTS	2.6	2.9	3.7	4.6	5.5	6.3	7.8	9.5	2.9	3.4	4.1	4.9
Total	**52.3**	**60.9**	**73.0**	**88.1**	**52.3**	**60.9**	**73.0**	**88.1**	**-**	**-**	**-**	**-**

5.3.1.6 The mass transit system with a continuous connectivity is a prerequisite for safe, comfortable and convenient travel. Additional transfer points on a continuous corridor from one mode to another (Metro to LRT, Metro to Bus and vice versa) consume additional time and causes inconvenience to passengers. Transfer penalties from one mode to other results in decrease in attractiveness of a system and discourages the passengers to use the system. There will be no interchange points at Phase 1 terminal stations in case of Metro system is extended for Phase 2.

The introduction of mass rapid transit system in the Study Area will help in reducing vehicular traffic on the road thereby contributing to relieving traffic congestion along proposed corridors, reduction in accidents and larger environmental savings.

5.3.2 Conceptual Civil Engineering Effects

Civil engineering effects have been worked out for three alternative modes of Metro, LRT and BRT along the five extensions of Phase-1 corridors proposed to be constructed in Phase-2, in subsequent paragraphs.

5.3.2.1 Geometric Parameters

Design Criteria for alternative options have been compared in **Table 5.8.**

TABLE 5.8: DESIGN CRITERIA

S. No.	CRITERIA	Metro	LRT	Elevated BRT
1	Gauge	1435 mm	1435 mm	NA
2	Design Speed	90 Kmph	90 Kmph	100 Kmph
3	Maximum Axle Load	16T	12T	70R – 20T
4	Electric Power Traction	25 KV AC (OHE)	750 V DC (3rd Rail)	NA

1. Horizontal Alignment

Horizontal alignment gives the details of curves in horizontal plane. The alignment on mainline track shall consist of tangent sections connected to circular curves by spiral transitions.

A) Circular Curves

Larger radii shall be used whenever possible to improve the riding quality. The minimum radius of curvature for mainline track is governed by the design speeds and by the limits for cant. Horizontal curve parameters for elevated Metro, LRT and BRT systems are compared in **Table 5.9**.

TABLE 5.9: HORIZONTAL CURVE PARAMETERS

<table>
<tr><th>Description</th><th>Elevated Metro</th><th>Elevated LRT</th><th>Elevated BRT</th></tr>
<tr><td>Desirable Minimum Radius</td><td>200 m</td><td>90 m</td><td>90m</td></tr>
<tr><td rowspan="2">Absolute Minimum Radius</td><td rowspan="2">120 m</td><td>90m for main section</td><td>40m</td></tr>
<tr><td>60m for depot section</td><td>Nil</td></tr>
<tr><td>Minimum curve radius at stations</td><td>1000 m</td><td>1000 m</td><td>NA</td></tr>
<tr><td>Maximum permissible cant (Ca)</td><td>110 mm*</td><td>110 mm*</td><td>7%</td></tr>
</table>

Description	Elevated Metro	Elevated LRT	Elevated BRT
Maximum cant deficiency (Cd)	85 mm	85 mm	--
* The applied cant will be decided in relation to normal operating speeds at specific locations like stations/vicinity to stations.			

B) Reverse Curves

The use of reverse curves is discouraged but where necessary, the two curves have been separated by minimum 25 m for Metro and 20 m for LRT. If provision of straight length is restricted by physical constraints, the two curves have been provided without any straight in between. In BRT, reverse curves may be provided with zero straight in between.

C) Transition Curves

It is necessary to provide transition curves at both ends of the circular curves for smooth transition from straight section to curved section and vice-versa. **Table 5.10** shows required Length of transitions for Horizontal curves.

TABLE 5.10: LENGTH OF TRANSITIONS OF HORIZONTAL CURVES

Parameter	Metro & LRT	Elevated BRT
Minimum Length	0.44 *actual cant (in mm) 0.44 * cant deficiency (in mm) whichever is higher	$Ls = 0.0215\ V^3 /CR$, Ls = Length of transition curve in metres, V = Speed in km/hr, R = Radius in metres, C = 80/(75 + V) (subject to a maximum of 0.8 and minimum of 0.5)
Desirable Length	0.72 * actual cant (in mm) 0.72 * cant deficiency (in mm) whichever is higher	
Minimum Straight between two transition curves	25 m or NIL for Metro 20 m or NIL for LRT	Nil
Minimum horizontal curve length between two transition curves	25 m for Metro 20 m for LRT	Nil
No overlap is allowed between transition curves and vertical curves		

2. Vertical Alignment

The criteria for use in all design stages of vertical alignment and track centre of the viaduct, tunnel, station and depot area have been established as follows:

- **Elevated Section**

  As per para 2.12.2 of IRC: SP-73, "Minimum 5.50 m vertical clearance shall be provided from all points of the carriageway of project Highways to the nearest surface of the overpass structure". However, it is recommended to keep suitable margin for future raising of road by resurfacing etc. Rail level will also depend upon the type and detailed design of pier cap and super-structure elements. Rail levels at elevated station locations shall be governed by structural design of concourse floor slabs and viaduct. **Table 5.11** shows required track centres and height for elevated stations for both system alternatives.

TABLE 5.11: TRACK CENTRE, VIADUCT AND HEIGHT ADOPTED IN ELEVATED SECTIONS

System	Track Centre	Viaduct width	Rail /Road Level at mid section	Rail / Road Level at elevated station
Metro	4.60 m	10.50 m	8.0 m	12.5m
LRT	4.45 m	9.85 m	8.0 m	12.5m
Elevated BRT	NA	14.6 m	9.0 m	

- **Gradients**

  ✓ The grade on the mid-sections shall not be generally steeper than 2.0% in elevated section for Metro & LRT whereas for BRT it shall not be steeper than 3.3%. Suitable longitudinal grades with drains at the low point are proposed for assuring proper drainage in underground section.

  ✓ Preferably, the stations shall be on level stretch with suitable provision for drainage by way of cross slope and slope of longitudinal drains.

  ✓ There shall be no change of grade on turnouts on ballastless track. There shall be no change of grade within 30 m of any points and crossing on ballasted track.

TABLE 5.12: GRADIENT PARAMETERS

Description	Metro		LRT		Elevated BRT	
Gradient	Desirable	Absolute Minimum	Desirable	Absolute Minimum	Desirable	Absolute Minimum
Mid-Section	Upto 2%	Upto 4%	Upto4%	Upto6%	Upto3.3%	Upto5%
Stations	Level	Upto 0.1%	Level	Upto 0.1%	Level	

- **Vertical Curves**

  Vertical curves are to be provided when change in gradient exceeds 0.4% for Metro, LRT and elevated BRT system. However, all changes in grade shall be connected by a circular curve or by a parabolic curve. It is proposed that vertical and transition curves of horizontal alignment do not overlap. Minimum radius and length of vertical curves are tabulated in **Table 5.13**.

TABLE 5.13: VERTICAL CURVE PARAMETERS

Parameter	Metro	LRT	Elevated BRT
Desirable Radius on Main line	2500 m	2500 m	2500 m
Absolute Minimum Radius on Main line	1500 m	1500 m	1500 m
Minimum Length of Vertical Curve	20 m	20 m	20 m

3. **Design Speed**

   The design speed will be 80 kmph for Metro and LRT system and 100 kmph for elevated BRT system, subject to further restriction by radius of horizontal curves, cant and cant deficiency.

4. **Station Planning**

   Station platform length is decided by length of single coach unit & no. of coaches required in one rake and other facilities provided in station building. Platform length for 6 coach rake for Metro & LRT system are compared in **Table 5.14**.

TABLE 5.14: STATION PARAMETERS

Station Parameter	Value		
System	**Metro**	**LRT**	**Elevated BRT**
Coach length	22m	18m	12m
No. of coaches	6	6	1
Platform Length	140m	120m	27m
Elevated station dimensions	140m x 27/24m	120m x 27/24m	30m x 24m

5.3.2.2 **Alignment Design**

The five corridors are considered for both alternative options, on the basis of traffic and other parameters listed below:

- Existing / Proposed Infrastructure & Future expansions
- Integration with Railway stations & Bus terminals

- Availability of ROW
- Availability of land for Ramp
- Options for Depot

Corridor – 1: MIHAN to MIDC ESR

The proposed alignment of Corridor-1 starts from MIHAN to MIDC ESR. The corridor is extension of North-South corridor of Phase-1 that runs from Automotive Square to MIHAN. The length of the corridor is 18.5 km and is completely elevated. There are 10 stations proposed in this section at approximate interstation distance of 1.9 km.

Corridor – 2: Automotive Square to Kanhan River

The proposed alignment of Corridor-2 starts from Automotive square to Kanhan River. The corridor is extension of North-South corridor of Phase-1 that runs from Automotive Square to MIHAN. The length of the corridor is 13 km and is completely elevated. There are 13 stations proposed in this section at approximate interstation distance of 1 km.

Corridor – 3: Lokmanya Nagar to Hingna

The proposed alignment of Corridor-3 starts from Lokmanya Nagar to Hingna. The corridor is extension of East-West corridor of Phase-1 that runs from Prajapati Nagar to Lokmanya Nagar. The length of the corridor is 6.7 km and is completely elevated. There are 6 stations proposed in this section at approximate interstation distance of 1 km.

Corridor – 4: Prajapati Nagar to Transport Nagar

The proposed alignment of Corridor-4 starts from Prajapati Nagar to Transport Nagar near Asoli. The corridor is extension of East-West corridor of Phase-1 that runs from Prajapati Nagar to Lokmanya Nagar. The length of the corridor is 5.6 Km and is completely elevated. There are 3 stations proposed in this section at approximate interstation distance of 1.9 km.

Corridor – 5: Vasudev Nagar to Dattawadi

The proposed alignment of Corridor-5 starts from Vasudev Nagar to Dattawadi. The corridor is spur of East-West corridor of Phase-1 that runs from Prajapati Nagar to Lokmanya Nagar. The length of the corridor is 4.5 Km and is completely elevated. There are 5 stations proposed in this section at approximate interstation distance of 1 km.

5.3.2.3 **Land Requirement**

Abstract of land requirements for different components of corridors are worked out for Metro, LRT and BRT system and compared in **Table 5.15.**

TABLE 5.15: LAND REQUIREMENT FOR SYSTEM ALTERNATIVES (IN HA)

Land Ownership	Acquisition Type	Metro	LRT	Elevated BRT
Central Govt.	Permanent	1.2	1.1	0.5
	Temporary	0.0	0.0	0.0
	Structures- Permanent	0.0	0.0	0.0
State Govt.	Permanent	1.8	33.0	14.4
	Temporary	50.0	45.0	3.23
	Structures -Permanent	0.1	1.0	3.23
Private	Permanent	7.2	6.5	3.0
	Structure	0.7	0.7	0.75

5.3.2.4 **Preliminary Geotechnical Investigations**

The district forms part of Deccan Plateau having flat topped and terraced features. Eastward and northeastwards the landscape changes due to the change in the underlying rocks. The rocks of Gondwana series present a low rolling topography with a poor soil cover and vegetation. On the north the upland ranges are the extension of Satpuras which gradually narrows down towards west. South of these upland range stretches the Ambegad hills, the western extremity of which is the Nagpur district. The Ramtek temple is on the spur of this range. The Girad hill range extends along the southeast and separates the valley of the Kar from that of Jamb upto Kondhali. Another main hill range runs northwards through Katol taluka from Kondhali to Kelod separating the Wardha and Wainganga valleys. The northeastern and east central parts of the district are drained by the Wainganga and its tributaries. The central and western portion is drained by the Wena which is a tributary of Wardha river.

In total, 21 BHs have been drilled upto a maximum 30 m depth each for all along the length of proposed corridors. The strata met mostly rocky at most of the sites at shallow depth hence the safe bearing capacity has been computed for shallow foundations as well as for Pile Foundation.

TABLE 5.16: SAFE PILE LOAD CARRYING CAPACITY

Location	Pile Stem Dia. D (m)	Length of pile below cut-off (m)	Vertical Safe Load Capacity of Pile , (KN)	Vertical Safe Load Capacity of Pile , (T)
BH-1	1.0	13.00	2886.00	288.00
	1.2	13.00	3994.00	399.40
BH-2	1.0	7.00	2603.00	260.00
	1.2	7.00	3587.00	358.70
BH-3	1.0	14.00	2564.00	256.40
	1.2	14.00	3180.00	318.00
BH-4	1.0	7.00	2461.00	246.010
	1.2	7.00	3053.00	305.00
BH-5	1.0	7.00	2540.00	254.00
	1.2	7.00	3664.00	366.00
BH-6	1.0	9.00	2833.00	283.00
	1.2	9.00	3867.00	386.70
BH-7	1.0	7.50	2664.00	266.40
	1.2	7.50	3727.00	372.70
BH-8	1.0	7.00	2887.00	288.70
	1.2	7.00	3524.00	352.40
BH-9	1.0	12.00	2788.00	278.80
	1.2	12.00	3722.00	372.20
BH-10	1.0	15.00	2845.00	284.50
	1.2	15.00	3826.00	382.60
BH-11	1.0	13.50	2554.00	255.40
	1.2	13.50	3456.00	345.60
BH-12	1.0	15.00	2661.00	266.10
	1.2	15.00	3380.00	338.00
BH-13	1.0	14.00	2214.00	221.00
	1.2	14.00	3460.00	346.00
BH -14	1.0	14.00	2638.00	263.00
	1.2	14.00	3664.00	366.00
BH-15	1.0	15.00	2678.00	267.80
	1.2	15.00	3689.00	368.90
BH- 16	1.0	14.00	2554.00	255.00
	1.2	14.00	3542.00	354.00
BH-17	1.0	11.00	2775.00	277.50
	1.2	11.00	3747.00	374.70
BH -18	1.0	12.00	2038.00	203.0
	1.2	12.00	2799.00	279.00
BH-19	1.0	15.00	2445.00	244.50
	1.2	15.00	3652.00	365.20
BH-20	1.0	14.50	2336.00	233.60

Location	Pile Stem Dia. D (m)	Length of pile below cut-off (m)	Vertical Safe Load Capacity of Pile , (KN)	Vertical Safe Load Capacity of Pile , (T)
	1.2	14.50	3454.00	345.40
BH-21	1.0	15.00	2446.00	244.60
	1.2	15.00	3679.00	367.90

5.3.3 System Effects

System Effects describes the quantification of system related components contributing to evaluation of modes.

5.3.3.1 Interoperability

The interoperability between proposed system in Phase 2 and the mass transit system already in place in Phase 1 is an important parameter and has maximum weightage. The same system can have better system efficiency, optimized use of system resources and enhanced passenger comfort.

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 1

5.3.3.2 Rolling Stock Requirement

The carrying capacity for the LRT system is less in comparison to the medium capacity metro system. Therefore, the two systems will operate at different frequencies to cater to similar traffic demand. It is expected that LRT rolling stock will have high scheduled speed. Thus, for the same peak traffic demand, the rolling stock requirement for the two systems will be different. The headway and the rolling stock requirement for the three systems including Metro, LRT and BRT have been worked out based on the following assumptions:

- Rolling Stock Specifications for Metro
  - Metro Coach Dimensions - 22.6m x 2.9m
  - Train Configuration - **3 car** : DMC-TC-DMC
  - Train Capacity - **3 car:** 766 @6 p/m^2, 975 @8 p/m^2
- Rolling Stock Specifications for LRT
  - LRT Coach Dimensions - 17.5m x 2.65m
  - Train Configuration - 2 car
  - Train Capacity - **2 car:** 324 @6 p/m^2, 416 @8 p/m^2

- Rolling Stock Specifications for BRT
  - Bus Dimensions - 12m x 2.6m
  - BRTS Configuration – Single Bus
  - Bus Capacity – 80 passengers
- Scheduled speed of 34 kmph and turn round time as 4 min at terminal stations for metro.
- Scheduled speed of 34 kmph including turnaround time
- Scheduled speed of elevated BRT: 32 kmph
- Traffic reserve is taken as 5% to cater to failure of train on line and to make up for operational time lost.
- Repair and maintenance has been estimated as 10% of total requirement (Bare + Traffic Reserve).

The rolling stock specifications for the Light Rail Transit system for the corridors have been considered from 'Technical Report on Appropriate Propulsion Technology for Light Metro Railways'. The rolling stock specifications adopted for Nagpur is similar to the specifications provided for Taipei Circular Line LRT.

BRT specification has been taken from Urban Bus Specification-II of MoUD for BRT systems. Speed and capacity have been taken from report on "Life Cycle Cost Analysis (LCCA) of Five Urban Transport System" prepared by IUT, MoUD and reported for Ahmedabad BRT.

The rolling stock requirement for all the systems has been presented in **Table 5.17.**

TABLE 5.17: ROLLING STOCK REQUIREMENT FOR METRO, LRT AND ELEVATED BRT

System	Parameter	2024	2031	2041
Metro	Coach Requirement (nos.)	60	60	75
LRT	Coach Requirement (nos.)	70	82	98
Elevated BRT	Bus Requirement (nos.)	197	238	292

Bus being the lowest capacity of all systems requires highest number of rolling stock. It has been observed that the rolling stock requirement for LRT is more than Metro. Also, the cost of the LRT rolling stock is approx. 12.6 Crore/car (Taipei Circular Line Rolling Stock Cost). This is higher than the rolling stock cost of Metro (Rs. 10.86 Crore/car: LMRC Rolling Stock Rates). The cost difference is mainly due to fact that metro are being indigenized which has resulted in reduced cost of metro in India.

Cost of a bus at 2018 prices has been estimated at Rs. 0.7 Cr. It has been derived using 7.5% escalation factor at Rs. 0.4 Crore at 2011 prices (LCCA Report MoUD).

5.3.3.3 Land Requirement for Depot

Four depots would be required for LRT as well as BRT system as the Phase 2 corridors are at the ends of existing two Phase 1 Metro corridors. The land requirement for the same is presented in **Table 5.18**.

TABLE 5.18: DEPOT LAND AREA FOR LRT & BRT SYSTEM

Depot Land	Corridor – 1: Automotive Square to Kanhan River	Corridor – 2: MIHAN to MIDC ESR	Corridor – 3: Prajapati Nagar to Transport Nagar	Corridor – 4 & 5: Prajapati Nagar to Transport Nagar and Vasudev Nagar to Dattawadi
LRT	8 Ha	8 Ha	7 Ha	8 Ha
Elevated BRT	3 Ha	3 Ha	2.5 Ha	3 Ha

In case of Metro, augmentation of Phase I depots would be sufficient to meet the maintenance needs of the rolling stock.

5.3.4 Environmental Effects

Diversion of users from road transport modes to Metro/LRT results in reduction in consumption of diesel, petrol and LPG. It is also results in reduction of ambient air pollution and consequent reduction in treatment cost to Human Health. Reduction in ambient pollution due to operation of Metro, LRT and elevated BRT has been estimated.

Benefits in terms of fuel saved, monitory value and reduction in ambient pollution are summarized in **Tables 5.19, 5.20** and **5.21** respectively. Savings will be same for all three modes till 2044 when BRT gets saturated. LRT will reach its capacity in 2047 after which Metro will continue to provide the savings.

TABLE 5.19: FUEL SAVED PER YEAR

Year	Diesel (million liters)	Petrol (million liters)	LPG (million kg)
Metro or LRT or BRT			
2024	2.28	5.80	0.22
2031	2.51	6.88	0.27
2041	2.83	8.73	0.37
2044	2.94	9.38	0.41

Year	Diesel (million liters)	Petrol (million liters)	LPG (million kg)
Metro or LRT			
2047	3.05	10.08	0.45
Metro			
2051	3.22	11.10	0.50

TABLE 5.20: NET SAVING IN FUEL EXPENDITURE PER YEAR (RS. MILLION)

Fuel	Metro or LRT or Elevated BRT				Metro or LRT	Metro
	2024	**2031**	**2041**	**2044**	**2047**	**2051**
Diesel	165	181	204	212	220	233
Petrol	493	585	741	797	856	943
LPG	12	15	21	23	25	28
Total	**670**	**781**	**966**	**1032**	**1101**	**1204**

TABLE 5.21: POLLUTION REDUCTION (TONS/YEAR)

Pollutant	Metro or LRT or Elevated BRT				Metro or LRT	Metro
	2024	**2031**	**2041**	**2044**	**2047**	**2051**
Carbon Monoxide (CO)	490.07	579.50	724.11	774.71	829.13	908.15
Hydro-Carbons (HC)	197.68	233.50	289.01	310.56	331.83	362.56
Nitrogen Oxide (NOx)	138.32	156.42	181.16	191.38	200.78	214.22
Particulate Matter (PM)	17.43	20.48	25.03	26.92	28.70	31.28
Carbon Dioxide (CO2)	20506.09	23679.82	27238.50	30621.24	32567.81	35403.67

Treatment cost of Human Health saving from pollutants emission based on the Appraisal Guidelines for Metro by MoUD, Sept 2017 are given in **Table 5.22.**

TABLE 5.22: TREATMENT COST SAVINGS FROM EMISSIONS (RS LAKH)

	2024	**2031**	**2041**	**2044**	**2047**	**2051**
CO	490.07	579.50	724.11	774.71	829.13	908.15
HC	197.68	233.50	289.01	310.56	331.83	362.56
Nox	138.32	156.42	181.16	191.38	200.78	214.22
PM	17.43	20.48	25.03	26.92	28.70	31.28
CO2	102.53	118.40	136.19	153.11	162.84	177.02
Total	**946.03**	**1108.30**	**1355.49**	**1456.68**	**1553.28**	**1693.23**

5.3.4.1 **Noise and Vibration Levels**

Typical noise level due to rapid rail transit on viaduct at speed 50 mph and distance 50 feet from tracks is 85 dBA; respective value for at grade is 80 dBA. Typical ground borne vibration (GBV) level due to rapid transit (Metro) is 70VdB (*Fig. 1.5, Fig 1.11 and Fig. 2.3 respectively, Metro Rail Transit System Guidelines for Noise and Vibrations, RDSO, Sept 2015*). Typical noise from at grade LRT at 50 mph at distance of 100 feet from track is 78 dBA; typical GBV for normal LRT track is 68 VdB (*Fig 3-12.1 and Fig. 3.12-2, Exposition Corridor Transit Project Phase 2 FEIR, December 2009*).

Commuting by car or bus 76 to 78 dBA (*Noise levels associated with New York City`s Mass Transit Systems, Richard Neitzel et al, American Journal of Public Health, Aug. 2009*). Considering the poorer pavement condition, higher frequency and the comparable or worse quality of modern urban bus this noise level in Indian cities is likely to be higher. Typical vibration level due to bus or truck is 65 VdB at 50 feet distance (*Figure 2.3, Metro Rail Transit System Guidelines for Noise and Vibrations, RDSO, Sept 2015).* Considering the poorer pavement condition level in Indian cities is likely to be higher.

It can be seen that noise and vibration due to Metro/LRT and BRT are in the same order of magnitude. The higher number of vehicle trips operated in normal bus system and BRT *vis a vis* Metro and LRT will result in cumulative noise and vibration; maintenance of Metro/LRT can be controlled better than on road and bus. Therefore BRT/normal buses are likely to result in higher impact than Metro/LRT.

5.3.5 Social Effects

Social impact has been compared in terms of structures located in impact zone along the priority mass transport corridors:

5.3.5.1 Structures in Impact Zone

Structures in impact zone are those which are located in a corridor of width 130 m i.e. 65 m on either side of transit line right of way. This width of 65 m is based on screening distance recommended for vibration measurement. Number of structures in the impact zone as derived from the alignment drawing are summarised in **Table 5.23.** These figures remain unchanged for Metro, LRT and elevated BRT.

TABLE 5.23: STRUCTURES IN IMPACT ZONE

Corridor	Structures In Impact Zone	
	Left	Right
MIHAN to MIDC ESR	37	49
Automotive Square to Kanhan River	647	409
Lokmanya Nagar to Hingna	171	254
Prajapati Nagar to Transport Nagar	221	119
Vasudev Nagar to Dattawadi	66	78

5.3.6 Cost Effectiveness and Affordability

The cost effectiveness and affordability includes the analysis / estimation of preliminary capital costs and associated operational & maintenance costs of Metro, LRT and elevated BRT projects.

5.3.6.1 Capital Cost

Preliminary Capital Cost estimates for Metro, LRT and elevated BRT system have been prepared covering civil, electrical, S&T works, rolling stock, environmental protection, rehabilitation, etc. at February' 2018 price level.

While preparing the capital cost estimates, various items have generally been grouped under three major heads on the basis of (i) Route km length of alignment, (ii) Number of units of that item and (iii) Item being an independent entity. All items related with alignment, construction, permanent way, OHE, Signaling & Telecommunication, whether in main lines or in maintenance depot, have been estimated at rate per route km/km basis. The preliminary cost estimates for both Metro, LRT and elevated BRT is presented in **Table 5.24.**

TABLE 5.24: PRELIMINARY COST ESTIMATES (RS. IN CRORE)

SN	Item	Metro	LRT	Elevated BRT
1	Land	215.06	451.54	309.65
a	Govt	176.06	412.54	270.65
b	Private	39.00	39.00	39.00
2	Alignment and Formation	2208.33	2033.90	2779.85
3	Station Buildings incl. Civil works, EM works, ECS, TVS, Lift, escalators & Architectural Finishes etc.	1532.35	1302.90	494.39

SN	Item	Metro	LRT	Elevated BRT
4	Depot including civil, EM, Machinery & plants, general works	250.00	380.00	193.00
5	P-Way for main line, depot and depot connectivity	506.81	481.47	0.00
6	Traction & power supply for main line and depot incl. OHE, ASS, GIS etc.	785.80	878.80	46.16
7	Signaling and Telecom. Incl. AFC, CCHS etc.	728.54	746.54	170.47
8a	Environmental	37.50	37.50	37.50
8b	R & R incl. Hutments etc.	10.00	10.00	10.00
9	Misc. Utilities, road works, Topographic Surveys, Geotechnical Investigation, Barricading, Tree Cutting and replanting, other civil works such as signage's, Environmental protection and traffic management	411.34	411.34	103.60
10	Capital Expenditure on Security including civil and EM works	13.71	13.71	50.60
11	Staff Quarters and buildings including civil, electrical works and green building concept (Cost of OCC building is included in corridor-1 only)	107.61	158.61	158.61
12	Rolling Stock	651.60	882.00	162.40
13	Capital Expenditure on Inter modal integration including Footpath for pedestrians, Feeder Buses and Bicycles @2% of Total Cost excluding Land	144.87	146.74	84.13
14	Total of all items except Land	7388.46	7483.50	4290.71
15	General Charges incl. Design charges, including Metro Bhawan, (Civil + EM works) @ 5% on all items except land. (Metro Bhawan is charged to coridor-1 only and it will cater to both the corridors)	369.42	374.17	214.54
16	Total of all items including G. Charges	7757.88	7857.67	4505.25
17	Contingencies @ 3 %on all items except land	232.74	235.73	135.16
Gross Total including Contingencies (excluding Land Cost)		7990.62	8093.40	4640.40
Gross Total including Contingencies (including Land Cost)		8205.68	8544.94	4950.06
SGST @6% (on Total cost excluding Land and R&R)		478.84	485.00	277.82
CGST @6% (on Total cost excluding Land and R&R)		478.84	485.00	277.82
Total Cost including Taxes & Duties		**9163.35**	**9514.95**	**5505.71**

5.3.6.2 **Operation and Maintenance Cost**

a) Rail Based Systems:

The Operation and Maintenance costs for Phase 2 Metro & LRT systems have been worked under three major heads:

i. **Staff cost**- O&M staff@ 35 persons per km and average staff salary of Rs. 7.77 lakh per annum in the year 2018, escalation factor used for staff costs is 9% per annum. It is expected that the staff cost for two systems viz. Metro and LRT will be same.

ii. **Maintenance cost**- includes expenditure towards upkeep and maintenance of the system and consumables, Rs. 1.45 crore per km in year 2018 and considering 5% escalation per year.

The LRT rolling stock is similar to the existing metro rolling stock in use in India except for specific changes in the bogie design to make it suitable for LRT application. Changes in the bogie designs can make them more complicated and more prone to frequent maintenance thereby increasing the overall life cycle cost of the system.

iii. **Energy Cost**

The energy consumption for the mass transit system is comprised of two major components viz. traction energy consumption and non-traction or auxiliary energy consumption. The traction energy cost of system is mainly dependent on weight of the rolling stock and the frequency of operation. Vehicle weight for the two systems is calculated considering 65kg as average weight of the passengers. The weight of the rolling stock for Metro trains (177 T) is higher than LRT (84T). The frequency of operation in case of LRT is higher than Metro system due to low capacity of rolling stock.

The station length for LRT system will be less in comparison to metro as the length of rolling stock is less in case of LRT. Thus, the station auxiliary load for LRT system will also be reduced. For the purpose of calculation, the station auxiliary load for LRT is considered as 90% of that of Metro.

b) BRT System:

The Life Cycle Cost Analysis Report, MoUD, 2012 has estimated the O&M cost of BRT System based on study of two operational BRT system of Ahmedabad and Delhi. It suggests the cost of Rs. 0.62 Cr/ km per annum at 2011 prices. The O&M cost for BRTS system at Nagpur has been derived for 2018 assuming an escalation factor of 7.5% and is estimated at Rs. 1.03 Cr/ km per annum.

Based on the above assumptions, the O&M cost for the three systems for different horizon years have been calculated and presented in **Table 5.25.**

TABLE 5.25: O&M COST AT CURRENT PRICES (IN RS. CRORE)

System	2024	2031	2041
Metro	356.37	596.69	1279.34
LRT	371.64	624.45	1332.24
Elevated BRT	2.7	3.2	3.9

5.3.7 Financial and Economic Effects

5.3.7.1 **Economic Returns**

Economic effects of the system are measured by undertaking economic analysis (cost benefit analysis) of the alternative mass transit project. Economic analysis captures all project related expenditure flow; and all benefits likely to accrue to the society during a pre-defined analysis period.

The project benefits are estimated through comparison of costs arising out of “with project” and “without project” scenario. In the analysis, the cost and benefit streams arising under the above project scenarios are estimated in terms of economic prices computed by using appropriate shadow prices. This is done to iron out distortions due to externalities and anomalies arising in real world pricing systems.

Total net savings/or benefit from a project to the society is obtained by subtracting the economic cost of the project (incurred for construction (Capital) and maintenance (recurring) costs for the project from the benefits out of the project in each year. The cost benefit flow is used to estimate the economic parameters namely (i) Economic Internal Rate of Return (EIRR) (ii) Economic Net Present Value (ENPV).

i. Project Horizon

Project horizon comprises of the construction and operation period of the rail based transit project. The annual streams of project costs and benefit have been compared over the analysis period of 30 years to estimate the net cost / benefit and to calculate the economic viability of the project in terms of EIRR. The key assumptions used in the evaluation are listed in **Table 5.26.**

TABLE 5.26: KEY EVALUATION ASSUMPTIONS

Parameter	Assumption
Price Level	February 2018
Construction period	2019-2024
First year of operation	2024
Daily to annual factor	340

ii. Development of 'With' and 'Without' Scenarios

The development of the two scenario starts with estimating daily traffic and modal share in these scenarios for the three shortlisted systems.

Table 5.5 in Section 5.3.1 gives the estimated traffic and modal share in different horizon years for the three systems under evaluation. It can be seen that the total estimated daily traffic demand for all modes in the year 2024 is 52 Lakh trips which is expected to rise to about 73 Lakh trips in the year 2041.

iii. Economic Costs

The economic costs of capital works and annual operation & maintenance costs have been calculated from the financial cost estimates by excluding:

1. Price contingencies/price escalations
2. Import duties and taxes
3. Sunk costs
4. Interest payment, principal payment and interest during construction period

The economic costs (**Table 5.27**) have been derived from financial costs using following shadow price factor for each component to take care of the distortions brought by above factors.

TABLE 5.27: FACTORS USED FOR CONVERTING PROJECT COSTS TO ECONOMIC COSTS

S. No	Item	Factor
1	Capital Cost	0.83
2	Operations & Maintenance Cost	0.87

Tables 5.28 and **5.29** give the capital and O&M costs of the three systems at February' 2018 Price levels in financial and economic terms respectively.

iv. Economic Benefits

Nagpur Mass Rapid Transport (Metro/ LRT/ elevated BRT) will yield tangible and non-tangible savings due to equivalent reduction in road traffic and certain other socio-economic benefits. The Introduction of mass rapid transit will result in reduction in number of mini buses, IPT, usage of private vehicles, air pollution and increase in the speed of road-based vehicles. This in turn, will result in significant social benefits due to reduction in fuel consumption, vehicle operating cost and travel time of passengers. Reduction in accidents, pollution and road maintenance costs are the other benefits to the society in general.

As Phase 2 is the extension of the under construction Phase 1 of Nagpur Metro systems, the benefits of the Phase 2 will not be limited to Phase 2 corridors only but will accrue to whole city. Accordingly for Metro scenario, the benefits from the project have been estimated assuming 70% of the traffic gets impacted. In case of LRT and elevated BRT, as an interchange from one system to other system is involved, the benefits to traffic little more than corridor traffic have been assumed.

TABLE 5.28: FINANCIAL COSTS OF METRO, LRT AND BRT SYSTEM - CAPITAL AND O&M

RS IN CRORE *(at Feb'2018 Prices)*

Cost Component	Metro	LRT	Elevated BRT
Construction Cost Including land and R&R	8206	8544	4950
Taxes @12% for GST	958	1013	556
O&M Costs			
2024	245	245	1.7
2031	247	250	2.1
2041	252	256	2.6

TABLE 5.29: ECONOMIC COSTS OF METRO, LRT AND BRT SYSTEM - CAPITAL AND O&M

RS IN CRORE *(at Feb'2018 Prices)*

Cost Component	Metro	LRT	Elevated BRT
Construction Cost Including land and R&R	6811	7389	4109
O&M Costs			
2024	213	213	1.5
2031	215	217	1.8
2041	219	223	2.3

The benefit stream includes:

- Savings in Capital and operating cost (on present congestion norms) of carrying the total volume of passenger traffic by existing modes in case the mass rapid transit project is not taken up.
- Savings in operating costs of different modes due to de-congestion including those that would continue to use the existing transport network even after the mass rapid transit is introduced.
- Savings in time of commuters using the mass rapid transit over the existing transport modes because of faster speed of mass rapid transit.
- Savings in time of those passengers continuing on existing modes, because of reduced congestion on roads.
- Savings on account of prevention of accidents and pollution with introduction of mass rapid transit.
- Savings in road infrastructure and development costs that would be required to cater to increase in traffic, in case mass rapid transit is not introduced.

The quantification of some of the social benefits has not been attempted because universally acceptable norms do not exist to facilitate such an exercise. However, it has been considered appropriate to highlight the same, as given below:

- Reduced road stress
- Better accessibility to facilities in the influence area
- Economic stimulation in the micro region of the infrastructure
- Increased business opportunities
- Overall increased mobility
- Facilitating better planning and up-gradation of influence area
- Improving the image of the city

Following factors **(Table 5.30)** have been used for converting project benefits to economic costs.

TABLE 5.30: FACTORS USED FOR CONVERTING PROJECT BENEFITS IN TERMS OF ECONOMIC COSTS

S. No	Item	Factor
1	Savings in Capital & Operating Cost of Buses	0.83
2	Savings in Capital & Operating cost of Private Vehicles	0.9
3	Savings in Passenger Time	1.0

S. No	Item	Factor
4	Savings in VOC	0.9
5	Savings in Accident Costs	0.9
6	Savings in Pollution Costs	1.0
7	Infrastructure Maintenance Cost Savings	0.87

v. Input Parameters

Inputs used for Economic analysis have been collected from primary and secondary data sources. The input parameters for economic analysis of BRT systems have been taken from a Report on Life Cycle costs of Five Urban Transport Systems by Institute of Urban Transport, MOUD in 2012. The report has used the parameters from Delhi and Ahmedabad BRT Systems. The parameters used for Economic Analysis of the three systems namely, BRT, LRT and MRT are as under:

Vehicle Operating cost (VOC) is a function of speed, road roughness, carriageway, width/capacity, rise and fall per unit. The VOC unit cost can have been taken from the "Manual on Economic Evaluation of Highway Projects in India, 2009" by the Indian Road Congress (IRC). The VOC has been adjusted for Nagpur according to the traffic, road conditions, fuel cost in the city as recommended in the manual. **Table 5.31** gives the mode wise VOC to estimate benefits accruing to the society from the project.

TABLE 5.31: MODE WISE VOC FOR NAGPUR

Mode	VOC* RS /KM
Car	7.94
2w	2.92
Auto	5.96
Bus	19.22

**Source IRC SP 30 (2009) Values brought to 2018 price level using factor of 5%*

Value of Travel Time (VOT) is another important parameter of Economic Analysis. It refers to the cost of time spent on transport. It includes costs of both work and non work trips. Mode wise value of time has also been taken from IRC SP 30 (2009) Values brought to January 2018 level using factor of 5%. The value of travel time for Metro / LRT /BRT passengers has been taken as that of deluxe bus.

Table 5.32 gives the mode wise VOT to estimate benefits accruing to the society from the project.

TABLE 5.32: MODE WISE VOT FOR NAGPUR METRO, LRT AND ELEVATED BRT

Mode	Value of Travel Time**Passenger/ Hr
Car	89
2w	42
Auto	42
Bus	42
Metro/LRT/BRT	67

**Source IRC SP 30 (2009) Values brought to February 2018 level using factor of 5%*

Other operational parameters required to assess the savings in VOC and VOT for the three systems in the year 2041 are presented in **Table 5.33**.

TABLE 5.33: MODE WISE OPERATIONAL PARAMETERS – METRO/ LRT/ BRT

Mode	Avg Lead (km)	Veh-km/ day	Average Speed (km/hr)*		Occupancy per Trip
			Without Metro	With Metro	
Bus	11	200	15	18	60
Car	11	27	22	25	2.8
2wh	7	18	24	30	1.3
Auto	6	80	18	20	1.8

Source: RITES Primary Surveys 2017

The emission factors by vehicle category as given by CPCB are presented in **Table 5.34** as per the appraisal guidelines. The vehicle accident statistics and cost of accidents are presented in **Tables 5.35** and **5.36** respectively.

TABLE 5.34: VOLUME OF POLLUTANTS EMITTED (EMISSION FACTORS IN GM/KM)

Vehicle Type/ Pollutant	CO	HC	NOX	PM	CO_2
2-wheeler	1.4	0.7	0.3	0.05	28.58
Auto	2.45	0.75	0.12	0.08	77.89
Cars (incl. cabs)	1.39	0.15	0.12	0.02	139.52
Bus (incl. BRT)	3.72	0.16	6.53	0.24	787.72
Treatment Cost (Rs. /ton)	1,00,000	1,00,000	1,00,000	1,00,000	500

Source: Appraisal guidelines for Metro Rail Project Proposals MoHUA, GOI 2017

TABLE 5.35: VEHICLES AND ACCIDENTS STATISTICS IN NAGPUR

Year	Registered Vehicles	Total Accidents	Fatal Accidents
2013	1310344	1265	298
2014	1378051	1149	263
2015	1426694	1254	254

TABLE 5.36: COST OF ACCIDENTS

Type of Accident	Accident Cost (Rs.)	
	(2004 prices)*	(2018 prices)**
Cost of fatal accident	437342	865907
Cost of major accident	64256	127222
Cost of damage to Two wheelers	2286	19330
Cost of damage to Car	9763	64977
Cost of damage to buses in road accidents	32818	4526

Source: * Appraisal guidelines for Metro Rail Project Proposals MoHUA, GOI 2017
** derived using escalation factor of 5%

vi. Estimation of Project Benefits

1. Travel Time Savings

- Travel Time Savings due to higher speed of mass rapid transit project as compared to Without project scenario.
- Congestion reduction due to modal shift leads to fewer vehicles on roads. This also contributes to time savings of passengers travelling on other modes.

2. Savings in Vehicle Operating Cost

- Absence of vehicles on road due to modal shift passengers on mass rapid transit
- Smoother operations of passenger trips of other mode vehicles owing to reduced congestion on roads.

3. Savings from Accident Reduction

- Reduction in fatal and injury accidents due less no of vehicles on roads
- Savings in damage cost to vehicles involved in accidents.

4. Savings from Pollution Reduction

- Absence of vehicles on road due to shift of passengers to mass transit mode
- Less pollution due to reduced congestion on roads.

5. Savings in Road Infrastructure Maintenance

- With less no of vehicles on roads, expenditure on road maintenance is expected to go down. In the absence of data, a lumpsum expenditure of Rs 60Cr/ year has been assumed.

Above socio-economic benefits have been converted in money cost. With input from above considerations, the accrued project benefits for the three systems during the frame work period of 20 years have been summarized in **Table 5.37**.

TABLE 5.37: COMPARISONS OF SAVINGS FROM THREE SYSTEMS IN 2041

SN	Benefits	Metro		LRT		Elevated BRT	
		Amount	% Share	Amount	% Share	Amount	% Share
1	Travel Time Savings	546	32	444	43	386	44
2	Savings in Vehicle Operating Cost	834	49	440	43	391	44
3	Savings from Accidents, Pollution & Road maintenance Reduction	326	19	149	14	105	12
Total		**1706**	**100%**	**1033**	**100%**	**883**	**100%**

It is clear from the table that benefits irrespective of the system benefits mainly come from VOC savings and savings from travel time.

vii. Economic Benefit Stream

For deriving the values of economic indicators (EIRR, ENPV), cost and benefit stream for the three systems has been constructed in terms of money value. The Toolkit on Finance and Financial Analysis 2013 by MoHUA, suggests that ENPV to be calculated on social cost of capital or government security rate. Accordingly, ENPV for the three systems have been calculated on both the rates.

Metro Rail Policy 2017 prescribes 14% as acceptable EIRR rate for metro project, same has been considered as the social cost of capital. The government security rate in January 2018 is 7.2%. Accordingly, ENPV for the three systems has been calculated based on these rates. The summary of the ENPV, EIRR and Cost Benefit ratio is presented in **Table 5.38.**

TABLE 5.38: COMPARISON OF ECONOMIC INDICATORS OF Three SYSTEMS IN 2041

SN	Parameter	Metro	LRT	Elevated BRT
1	EIRR	14.73%	8.16	14.89%
2	ENPV (in Rs. Crore) - Social cost of capital @14% - Government Security Rate@ 7.2%	 260 5521	 -1894 618	 195 3437

The cost and benefit streams for Metro, LRT and BRT systems are presented in **Table 5.39, 5.40** and **Table 5.41** respectively.

5.3.7.2 **Life Cycle Cost**

The requirement of rolling stock is higher in case of LRT and BRT system attributed to smaller dimensions of coach as compared to Metro thereby requires less headways to cater to same demand as that of Metro. This results in additional coaches for LRT and BRT for operating in higher frequencies to cater the demand resulting in more wear and tear.

5.3.8 Approvals and Implementation

5.3.8.1 **Time required for Approvals**

Light Rail Transit system is new in India. With no previous experience in light rail technology in the country specifically in rolling stock design and O&M, the technical expertise will have to be developed afresh which may result in time delays in approval of LRT. As there are set standards and procedures for Metro and elevated BRT, these two modes will relatively consume less time for approvals than LRT.

5.3.8.2 **Ease of Implementation**

With several operational metro rail and BRT systems in India, the 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 and BRT systems have better ease of implementation than that of LRT attributed to prior experiences and expertise.

TABLE 5.39: COST AND BENEFIT STREAM FOR METRO SYSTEM

YEAR	CAPITAL	RUNNING EXPENSE	TOTAL COSTS	SAVINGS FROM		SAVINGS FROM			INFRASTRUCTURE & MAINTENANCE SAVING	TOTAL SAVINGS	NET CASH FLOW
				BUSES	OTHER VEHICLES	TIME	VOC	POLLUTION & ACCIDENT			
2019-20	425	0	425	0	0	0	0	0		0	-425
2020-21	1087	0	1087	0	0	0	0	0		0	-1087
2021-22	1325	0	1325	0	0	0	0	0		0	-1325
2022-23	1656	0	1656	0	0	0	0	0		0	-1656
2023-24	1656	0	1656	0	0	0	0	0		0	-1656
2024-25	662	213	875	23	117	546	398	196	52	1332	456
2025-26	0	213	213	23	119	555	404	199	52	1352	1139
2026-27	0	213	213	24	121	563	410	202	52	1372	1159
2027-28	0	214	214	24	123	572	417	205	52	1393	1179
2028-29	0	214	214	25	125	581	423	208	52	1414	1200
2029-30	0	214	214	25	127	591	430	211	52	1436	1221
2030-31	27	215	242	25	129	600	437	215	52	1457	1216
2031-32	0	215	215	26	131	609	444	218	52	1480	1265
2032-33	0	215	215	26	133	621	452	222	52	1506	1291
2033-34	0	216	216	27	136	632	460	226	52	1534	1318
2034-35	0	216	216	27	138	644	469	231	52	1561	1345
2035-36	0	217	217	28	141	656	478	235	52	1590	1373
2036-37	0	217	217	28	143	669	487	239	52	1618	1401
2037-38	0	218	218	29	146	681	496	244	52	1648	1430
2038-39	0	218	218	29	149	694	505	248	52	1678	1460
2039-40	0	218	218	30	152	707	515	253	52	1708	1490
2040-41	0	219	219	30	154	720	524	258	52	1739	1520
2041-42	108	219	328	31	158	735	535	263	52	1773	1445
2042-43	0	220	220	32	161	749	545	268	52	1807	1588
2043-44	0	220	220	32	164	764	556	274	52	1842	1622
2044-45	645	221	866	33	167	779	567	279	52	1878	1012
2045-46	0	221	221	34	171	795	579	285	52	1915	1694
2046-47	0	222	222	34	174	811	590	290	52	1952	1730
2047-48	0	222	222	35	177	827	602	296	52	1990	1768
2048-49	0	223	223	36	181	844	614	302	52	2029	1806
2049-50	0	223	223	36	185	861	627	308	52	2068	1845
										IRR	**14.73%**
										ENPV@14%	**260**
										ENPV@7.2%	**5521**

TABLE 5.40: COST AND BENEFIT STREAM FOR LRT SYSTEM

YEAR	CAPITAL	RUNNING EXPENSE	TOTAL COSTS	SAVINGS FROM		SAVINGS FROM			INFRASTRUCTURE & MAINTENANCE SAVING	TOTAL SAVINGS	NET CASH FLOW
				BUSES	OTHER VEHICLES	TIME	VOC	POLLUTION & ACCIDENT			
2019-20	527	0	527	0	0	0	0	0		0	-527
2020-21	1198	0	1198	0	0	0	0	0		0	-1198
2021-22	1342	0	1342	0	0	0	0	0		0	-1342
2022-23	1677	0	1677	0	0	0	0	0		0	-1677
2023-24	1677	0	1677	0	0	0	0	0		0	-1677
2024-25	671	213	884	46	117	444	115	81	52	855	-29
2025-26	0	213	213	47	119	451	117	82	52	868	654
2026-27	0	214	214	48	121	458	118	83	52	880	666
2027-28	0	215	215	48	123	465	120	84	52	893	679
2028-29	0	215	215	49	125	473	122	86	52	907	691
2029-30	0	216	216	50	127	480	124	87	52	920	704
2030-31	125	216	342	51	129	488	126	88	52	934	592
2031-32	0	217	217	51	131	495	128	90	52	948	731
2032-33	0	218	218	52	133	505	130	92	52	964	747
2033-34	0	218	218	53	136	514	133	93	52	982	763
2034-35	0	219	219	54	138	524	135	95	52	999	780
2035-36	0	219	219	55	141	534	138	97	52	1017	797
2036-37	0	220	220	56	143	544	141	99	52	1035	815
2037-38	0	220	220	58	146	554	143	100	52	1053	833
2038-39	0	221	221	59	149	564	146	102	52	1072	851
2039-40	0	221	221	60	152	575	149	104	52	1091	870
2040-41	0	222	222	61	154	586	151	106	52	1111	889
2041-42	167	223	390	62	158	597	154	108	52	1132	742
2042-43	0	223	223	63	161	609	157	110	52	1153	930
2043-44	0	224	224	65	164	621	161	113	52	1175	952
2044-45	727	224	951	66	167	634	164	115	52	1198	247
2045-46	0	225	225	67	171	646	167	117	52	1221	996
2046-47	0	225	225	68	174	659	170	120	52	1244	1019
2047-48	0	226	226	70	177	673	174	122	52	1268	1042
2048-49	0	226	226	71	181	686	177	124	52	1292	1066
2049-50	0	227	227	73	185	700	181	127	52	1317	1090
										IRR	**8.16%**
										ENPV@14%	**-1894**
										ENPV@7.2%	**618**

TABLE 5.41: COST AND BENEFIT STREAM FOR BRT SYSTEM

YEAR	CAPITAL	RUNNING EXPENSE	TOTAL COSTS	SAVINGS FROM		SAVINGS FROM			INFRASTRUCTURE & MAINTENANCE SAVING	TOTAL SAVINGS	NET CASH FLOW
				BUSES	OTHER VEHICLES	TIME	VOC	POLLUTION & ACCIDENT			
2019-20	325	0.0	325	0	0	0	0	0		0	-325
2020-21	709	0.0	709	0	0	0	0	0		0	-709
2021-22	769	0.0	769	0	0	0	0	0		0	-769
2022-23	961	0.0	961	0	0	0	0	0		0	-961
2023-24	961	0.0	961	0	0	0	0	0		0	-961
2024-25	384	1.50	386	23	117	386	106	33	52	718	332
2025-26	0	1.53	2	23	119	392	108	34	52	728	727
2026-27	0	1.56	2	24	121	399	109	34	52	739	737
2027-28	0	1.59	2	24	123	405	111	35	52	750	748
2028-29	0	1.62	2	25	125	411	113	35	52	761	759
2029-30	0	1.65	2	25	127	418	115	36	52	772	770
2030-31	88	1.68	90	25	129	424	116	36	52	783	693
2031-32	0	1.81	2	26	131	431	118	37	52	795	793
2032-33	0	1.85	2	26	133	439	120	38	52	809	807
2033-34	109	1.89	111	27	136	447	123	38	52	823	712
2034-35	109	1.92	111	27	138	456	125	39	52	837	727
2035-36	0	1.96	2	28	141	464	127	40	52	852	850
2036-37	0	2.00	2	28	143	473	130	41	52	867	865
2037-38	0	2.05	2	29	146	482	132	41	52	882	880
2038-39	0	2.09	2	29	149	491	135	42	52	898	896
2039-40	0	2.13	2	30	152	500	137	43	52	914	912
2040-41	0	2.18	2	30	154	509	140	44	52	930	928
2041-42	161	2.22	163	31	158	520	143	45	52	948	785
2042-43	0	2.27	2	32	161	530	145	45	52	965	963
2043-44	0	2.31	2	32	164	541	148	46	52	984	981
2044-45	109	2.36	111	33	167	551	151	47	52	1002	891
2045-46	0	2.41	2	34	171	562	154	48	52	1021	1019
2046-47	0	2.45	2	34	174	574	157	49	52	1041	1038
2047-48	0	2.50	3	35	177	585	161	50	52	1060	1058
2048-49	0	2.55	3	36	181	597	164	51	52	1081	1078
2049-50	0	2.60	3	36	185	609	167	52	52	1101	1099
										IRR	**14.89%**
										ENPV@14%	**195**
										ENPV@7.2%	**3437**

5.4 SCORING OF QUANTITATIVE PARAMETERS

5.4.1 The quantitative evaluation of parameters has focused on eliminating the alternatives among Metro, BRT and LRT that is less viable for Nagpur Phase-2. The process involves discarding of alternatives that may not be suitable to the existing local conditions.

5.4.2 Basis of Scoring Parameters for Quantitative Evaluation

The weightage for various criteria for quantitative evaluation has been considered same as that of qualitative evaluation. However, detailed evaluation of quantitative parameters has been carried out. The basis of scoring these parameters is as follows:

- **Mobility Effects -** Mobility effects namely Peak Hour Peak Directional Traffic, ease in passenger transfer, system utilization and reduced vehicles on road have been considered as influential parameters. Metro Rail system score high as it offers higher carrying capacity and high frequency of regulated services, better utilization in terms of more passenger-km and higher convenience in ease of passenger transfers than BRT and LRT due to continuity in existing system as Phase-2. Accordingly, Metro, LRT and BRT have been assigned 20.0, 15.0 and 7.25 on a scale of 20.0 based on mobility related performance.

- **Conceptual Civil Engineering Effects –** The parameters covered are available right of way, alignment design and constructability, geotechnical characteristics & civil structures, station planning & intermodal integration, utility shifting.

  Rail based systems and elevated BRT with dedicated guideway systems impact shifting of existing utilities along the alignment. Among Metro, LRT and BRT, LRT consumes least possible right of way for land acquisition. Alignment design and constructability parameters are relatively easier for BRT system. Rail based system are more efficient in station planning and intermodal integration opportunities. Metro Rail, LRT and Elevated BRT score 13.75, 12.75 and 11.5 respectively on a scale of 15.0.

- **System Effects – The** influential parameters are interoperability with Phase-I, rolling stock requirement, land for maintenance depot and indigenous availability.

  Metro rail has highest carrying capacity among Metro, LRT and BRT and results in having least possible rolling stock. On the other hand, LRT and BRT require more quantum of rolling stock to cater to the peak demand. Metro rail would be the most suitable mode considering continuity/interoperability with the under construction metro rail. Except for LRT other modes Metro rail and BRT have indigenous availability. In India, Metro Rail and BRT are operational in various cities and have the technology in place. Consideration of LRT will result in time and cost implications attributed to import of rolling stock, design specifications for Indian conditions. Considering the above Metro Rail, LRT and Elevated BRT score 10.0, 7.0 and 5.0 respectively on a scale of 10.

- **Environmental Effects –** The parameters considered are air & noise pollution. Rail based systems have been assigned better scores more than bus based systems considering their ability to reduce pollution levels on the roads. Metro Rail, LRT being electrified systems play an important role in minimizing the air and noise pollution levels in the city. Accordingly, Metro rail score a maximum of 15.0, followed by LRT systems and Elevated BRT with 12.5 and 7.5 respectively in environmental effects on a scale of 15.0.

- **Social Effects –** LRT consuming minimum space for alignment related acquisition scores more over Metro and BRT. Accordingly, LRT, BRT and Metro score 5.0, 3.75 and 3.75 respectively on a scale of 5.0.

- **Cost Effectiveness & Affordability –** BRT is more affordable than rail based systems due to lower capital and O&M costs per passenger km and accordingly is assigned higher scores than metro and light rail systems.

  Rail based systems incur high capital cost whereas bus system require comparatively less investment costs. Similarly, rail based systems like Metro rail and LRT consume more O&M costs as they are planned for a much higher operational period. Accordingly, Elevated BRT, Metro and LRT have been assigned 15.0, 8.75 and 7.5 on a scale of 15.0.

- **Financial and Economic Effects –** Metro scores higher than LRT considering life cycle costs and economic benefits. Economic benefits and Life cycle cost of rail based systems is much higher than road based systems considering reduction in pollution levels, number of accidents and overall social benefits.

  Metro rail among rail based systems cater more passengers and offer higher economic returns attributed to comparatively less rolling stock. Considering these, Metro, Elevated BRT and LRT score 12.5, 12.5 and 10.0 respectively on a scale of 15.0.

- **Approvals and Implementation** – BRT scores higher than Metro and LRT as there are set standard procedures for approvals and considering ease of implementation. LRT would consume more time as it has not been introduced yet in India. Accordingly, the scores are 5.0, 3.75 and 1.25 for Elevated BRT, Metro Rail and LRT respectively.

The summary of scoring for both the modes based on quantitative evaluation is presented in **Table 5.42.**

TABLE 5.42: QUANTITATIVE EVALUATION - SCORING OF PARAMATERS

S. No	Parameters	Total Score	Metro	LRT	Elevated BRT
A. Mobility Effect					
1	Ability to cater Travel Demand - Max. PHPDT	6.00	6.00	4.5	3.00
2	Ease of Passenger Transfer at Terminals	6.00	6.00	4.5	1.50
3	Daily System Utilisation-PKM/KM	5.00	5.00	3.75	1.25
4	Reduced Vehicles on road due to proposed system	3.00	3.00	2.25	1.50
	Total A	**20.00**	**20.00**	**15.0**	**7.25**
B. Conceptual Civil Engineering Effect					
1	Available Right of Way (Land Acquisition)	4.00	3.00	4.00	2.00
2	Alignment Design and Constructability	3.00	2.75	1.50	3.00
3	Geotechnical Characteristics and Civil Structures	3.00	3.00	3.00	3.00
4	Station Planning and Intermodal Integration	3.00	3.00	2.25	1.50
5	Requirement for Utility Shifting	2.00	2.00	2.00	2.00
	Total B	**15.00**	**13.75**	**12.75**	**11.50**
C. System Effects					
1	Interoperability with Phase-1 System	4.00	4.00	3.00	1.00
2	Rolling Stock Requirement	2.00	2.00	2.00	1.00
3	Land for Maintenance Depot	2.00	2.00	1.00	1.00
4	Indigenous Availability	2.00	2.00	1.00	2.00
	Total C	**10.00**	**10.00**	**7.00**	**5.00**
D. Environment Effects					
1	Air Pollution	10.00	10.00	7.5	5.00
2	Noise Pollution	5.00	5.00	5.00	2.50
	Total D	**15.00**	**15.00**	**12.50**	**7.50**

S. No	Parameters	Total Score	Metro	LRT	Elevated BRT
E. Social Effects					
1	Structures/Persons Affected	5.00	3.75	5.00	3.75
	Total E	**5.00**	**3.75**	**5.00**	**3.75**
F. Cost Effectiveness & Affordability					
1	Capital Cost (per Passenger KM)	10.00	5.00	5.00	10.00
2	Operation & Maintenance Cost (per Passenger KM)	5.00	3.75	2.50	5.00
	Total F	**15.00**	**8.75**	**7.50**	**15.00**
G. Financial and Economic Effects					
1	Economic Returns	10.00	7.50	5.00	10.00
2	Life Cycle Cost	5.00	5.00	5.00	2.50
	Total G	**15.00**	**12.50**	**10.00**	**12.50**
H. Approvals and Implementation					
1	Time Required for Approvals	3.00	2.25	0.75	3.00
2	Ease of Implementation	2.00	1.50	0.50	2.00
	Total H	**5.00**	**3.75**	**1.25**	**5.00**
	Grand Total A+B+C+D+E+F+G+H	**100.00**	**87.50**	**71.00**	**67.50**

5.4.3 From the quantitative evaluation of parameters for Metro, LRT and elevated BRT Systems, it can be inferred that Metro System with a score of 87.5 scores higher than LRT and elevated BRT which score 71.0 and 67.50. The Metro System henceforth emerges to be the most viable mass transit mode for Phase 2 corridors of Nagpur Mass Transport System.

Chapter – 6.
IMPLEMENTATION OPTIONS FOR VIABLE ALTERNATIVE

6. IMPLEMENTATION OPTIONS FOR VIABLE ALTERNATIVE

6.1 IMPLEMENTATION OPTIONS

Based on both qualitative and quantitative screening carried out in previous chapters, Metro Rail System has emerged as the most viable alternative mass transport system to meet transport needs of Nagpur city along Phase 2 corridors.

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). Following section discusses the funding options for Nagpur Metro Rail System and CFA requirement.

6.1.1 Capital and O&M Cost

It has been estimated that at February' 2018 prices, the capital cost of Nagpur Phase-2 would be Rs 8,206 Crore and with taxes it would be Rs 9,163 Crore. With an escalation factor of 5% p.a., the Completion Cost of the project is estimated to be Rs. 9,853 Crore. With Central GST, the completion cost becomes Rs 10,430 Crore. The land Costs has not been escalated since land acquisition would be completed in the initial two years. The total O&M cost in 2024 is estimated at Rs. 356 Crore and Rs. 597 Crore in the year 2031. The details of costs are presented in **Table 6.1**.

TABLE 6.1: COST OF NAGPUR METRO PHASE-2 AT FEBRUARY 2018 PRICE LEVEL

Cost Component	Amount (Rs. in Crore)
Construction Cost Including land &R&R	8206
Taxes @12% for GST	957
Total Including Taxes	**9163**
Completion Costs	
Cost Without Taxes	9627
With Central Taxes	10430
With both Central and State taxes	11008
O&M Costs	
• 2024	356
• 2031	597
• 2041	1279

Considering that the construction of Nagpur Metro will take 5-6 years, **Table 6.2** gives the year wise fund requirements based on typical construction schedule.

TABLE 6.2: DETAILS OF COMPLETION COSTS (RS IN CRORE)

Year	Completion Cost	Land and R&R Cost	Central Taxes	Total Completion Cost
2019-2020	419	113	25	557
2020-2021	1,320	113	79	1,512
2021-2022	1,848	-	111	1,959
2022-2023	2,425	-	146	2,571
2023-2024	2,546	-	153	2,699
2024-2025	1,069	-	64	1,134
TOTAL	**9,627**	**225**	**578**	**10,430**

6.1.2 OPTIONS OF 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

Subsequent paragraphs describe the various models with respect to funding of Nagpur Metro Phase 2:

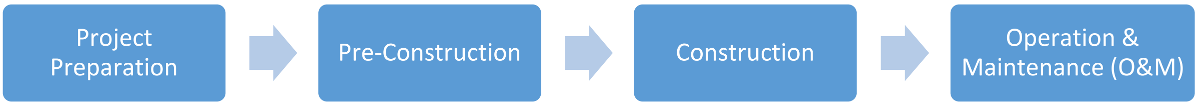
i. Public Private Partnership (PPP)

The fundamental principle underlying Public Private Partnerships (PPPs) as a development option for any infrastructure project is to combine the strengths of the private sector with those of the public sector in order to overcome challenges faced during construction & operation and to achieve superior outcomes.

The private sector can be expected to contribute to efficiency gains in the development of land, construction, operations and maintenance through the use of technology, better management and construction practices. In addition, the private sector should be expected to bring economies of scale from large projects and by involving a larger number of private partners.

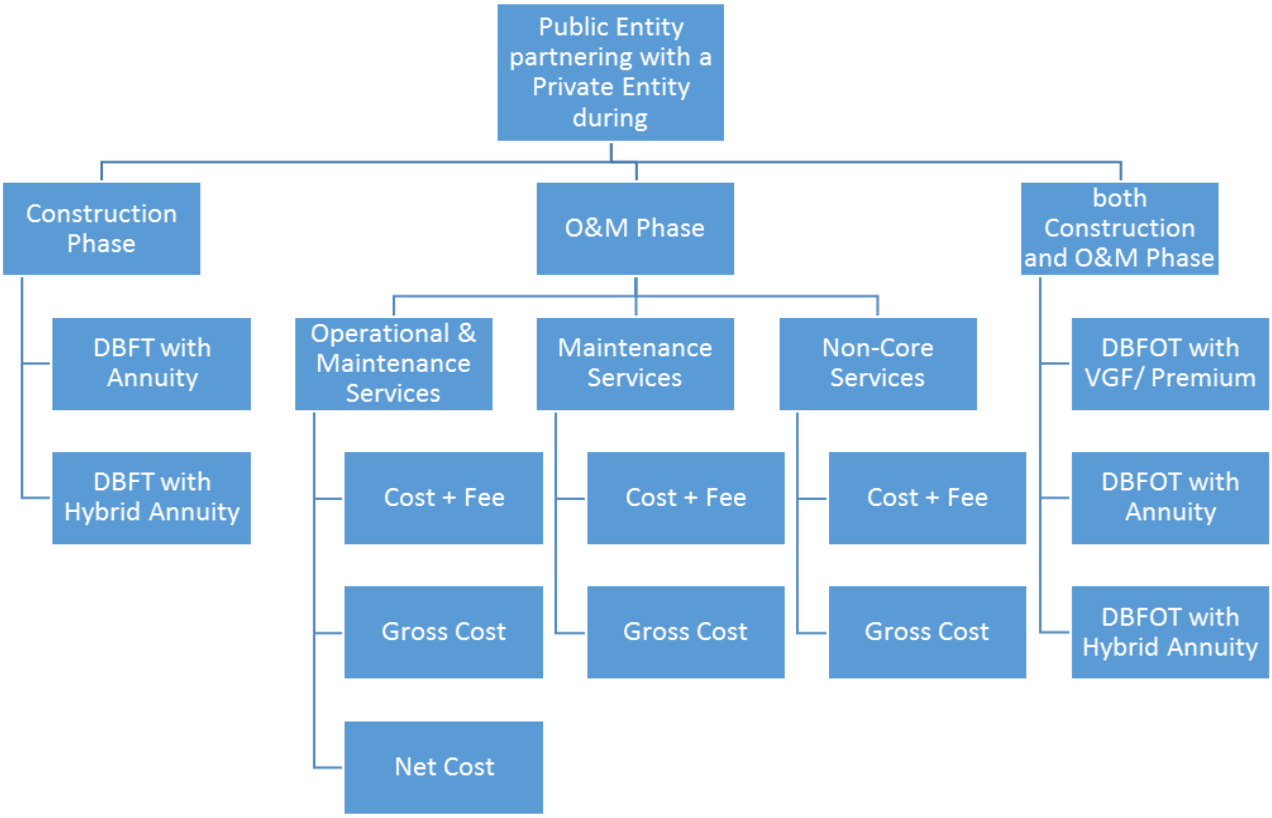
However, the success of PPP will depend critically on designing PPP structures that make an appropriate allocation of risks, responsibilities, rewards and penalties, and create the incentives for value creation. Indeed, this risk allocation is the defining feature of the PPP strategy. The golden principle is that risks should be allocated to the entity best equipped to manage each risk. The expectation is that such an allocation of risks will not only produce the best possible program and project outcomes but also optimize costs. This should lead to good quality outcomes at optimum prices.

Any infrastructure project generally goes through the following phases:



Each phase is susceptible to different types of risks. A PPP can be established in either in Construction phase / Operation & Maintenance phase; and both Construction and O&M phase. Based on Metro Policy 2017 and PPP models adopted in 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: PUBLIC PRIVATE PARTNERSHIP MODELS



A. PPP Models for Metro Rail during Construction Phase

Model 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. 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 and during Operation & Maintenance 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 finance the same through State/ Central Government.

Model 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 is paid out as annuity during operation & maintenance phase.

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

Model 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.

Model 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.

Model 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.

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

Model 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.

Model 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.

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

Model 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.

Model 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.

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

Model 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).

Model 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- 1) 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.

Model 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 6.3**.

TABLE 6.3: RISK BASED COMPARISON OF PPP MODELS

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

ii. Grant By Central Government

Under this option Central Government would fund 10% of the project completion cost excluding private investment Land, R&R and state 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.

iii. 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.

As per the prevalent practice, Central Government contributes 20% of the project cost excluding land, R&R and state taxes as their equity contribution. An equal amount can be contributed by State Government aggregating the total equity to 40%. Remaining 60% is arranged as soft loan from funding agencies. Delhi Metro Rail Corporation, Bangalore Metro Rail Corporation, Chennai Metro Rail Corporation & Kolkata Metro Rail Corporation are some of the examples of success of such a SPV.

The State Government has already constituted a fully owned company in the name of Maha Metro Rail Corporation, a SPV company and is responsible for the implementation of all the metro rail corridors in the state. SPV can obtain loan from international funding agencies such as JICA, PIB etc on low interest rates. This loan is provided to Central Government which in turn releases the same to SPV under a Pass Through Assistance (PTA) mechanism.

Department of Economic affairs, Ministry of Finance, Government of India has issued policy guidelines no 3/11/2015-PMU on official Development Assistance for development cooperation with bilateral partners. This assistance can be availed can be availed of for metro rail projects. The prevailing interest rate is 0.3% p.a. The loan is repayable in 40 years including moratorium period of 10 years. The loan assistance is up to 85% of the total project cost excluding taxes and land costs. Since the loan is generally in currency of lending country, any fluctuation in exchange rate at the time of repayment are generally borne by SPV.

Private sector participation in this model can be explored for O&M phase. The PPP model to be adopted for the same shall be decided at the time of implementation.

6.1.3 FUNDS FROM NON-FARE BOX SOURCES

Metro Rail Policy envisages fund generation by state from non-users beneficiaries which may include dedicated levies on on-user beneficiaries mainly property. The value created in the proximity zones can be recovered through land monetization; i.e. additional FAR, a 'Betterment Levy' or 'Land Value Tax' or enhanced property tax or grant of development rights. Transit Oriented Development (TOD) in the influence areas of MRT corridors will help to generate funds for financing of the MRT. The estimation of funds generation from these sources will be done at DPR stage.

6.2 PROS AND CONS OF IMPLEMENTATION OPTIONS

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, hence the pace of developing infrastructure can be ramped up to meet the urbanization challenge;
- It brings in efficiency;
- 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. On the other
- If a project is developed and operated / maintained by different entities, risk and reward are not properly aligned. 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 of India in a PPP project is limited to paying VGF which is a onetime expenditure, determined by market and hence not open ended.
- 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 - operation has just started for 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 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 MRTS 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 CENTRAL FINANCIAL ASSISTANCE (CFA)

6.3.1 Under PPP Model

As per the rules of GOI, the CFA in terms of viability gap funding has a cap of 20% of the project completion cost excluding Land, R&R and state taxes for PPP projects provided the state government also contribute same or more amount towards the project. Accordingly for Nagpur metro the VGF requirement from GOI shall be Rs. 2041 Crore. Year wise outflow of funds from GOI for CFA would be as presented in **Table 6.4.**

TABLE 6.4: FUND REQUIREMENT FROM GOI UNDER PPP MODEL

Year	Central Financial Assistance (Rs in Crore)
2019-2020	89
2020-2021	280
2021-2022	392
2022-2023	514
2023-2024	540
2024-2025	227
Total	**2041**

6.3.2 Under Grant Model

Under this option, the CFA is 10% of the project completion cost excluding private investment land, R&R and state taxes. Total outgo from the GOI as CFA would be Rs. 1021 Crore. Year wise fund requirement is detailed in **Table 6.5**.

TABLE 6.5: FUND REQUIREMENT FROM GOI UNDER GRANT MODEL

Year	Central Financial Assistance (Rs in Crore)
2019-2020	44
2020-2021	140
2021-2022	196
2022-2023	257
2023-2024	270
2024-2025	113
Total	**1021**

6.3.3 Under Equity Sharing Model

The central financial assistance under this model is same as that of PPP model i.e. 20% of project completion cost excluding land, R&R and state taxes. But in this model, the CFA consists of central government equity and subordinate debt towards central taxes to the project. Generally the share of subordinate debt varies from 5-6% and equity component varies between 14-15%. **Table 6.6** gives the year wise out flow of funds as Central Financial Assistance from GOI.

TABLE 6.6: FUND REQUIREMENT FROM GOI UNDER EQUITY SHARING MODEL

Year	Total Funds (Rs in Crore)
2019-2020	89
2020-2021	280
2021-2022	392
2022-2023	514
2023-2024	540
2024-2025	227
Total	**2041**

6.4 MOST SUITABLE OPTION FOR IMPLEMENTATION

The SPV, Maha Metro Rail Corporation is already constructing Metro Phase 1 in Nagpur City on equity sharing model.

Further, considering the fact that the funds from non fare box revenue sources shall due only to the government instrumentalities and not to the private operator.

Moreover, all successful metro systems operating in the country are operating on SPV model. The experience with private sector participation in Airport express line, Delhi and Mumbai Metro Line 1 has not been very encouraging.

It is, therefore, recommended to implement the project under equity sharing model by SPV with private sector participation in different subcomponents of operations & maintenance.

Chapter – 7.
CONCLUSION: THE PATH FORWARD

7. CONCLUSION: THE PATH FORWARD

7.1 FINDINGS

1. Nagpur, the Orange city of India, is third largest city in the state of Maharashtra and acts as the headquarter for the Nagpur district with a population of about 46 Lakh as per Census 2011 with about 24 Lakh residents in Nagpur Municipal Corporation area. Sharing of limited Right-of-Way by variety of private modes has resulted in traffic congestions, inadequate parking spaces, accidents and environment deterioration in the study area. Owing to traffic congestion, the Government of Maharashtra has already started the construction of two metro corridors of about length 40 km in Phase I.

2. The Government of Maharashtra through Maha Metro has decided to introduce augmentation of mass transport corridors in Phase-II. These corridors have been proposed in the Comprehensive Mobility Plan for Nagpur.

3. Qualitative parameters evaluation of the available alternatives namely Normal Bus System, Elevated Bus Rapid Transit, Metro and Light Rail Transit have been carried out on the identified mass transport corridors. Normal Bus has been ruled out in view of inability to meet the passenger demand in future and significant greenhouse gas emissions.

4. In the preliminary screening of qualitative parameters, Metro, Light Rail Transit and Elevated BRT have emerged as prospective mass transport systems for Phase II corridors in Nagpur for further quantitative evaluations.

5. All three modes namely Metro (3 car train), LRT (2 car train) and elevated BRT systems can cater to Peak Hour Peak Direction Passenger Trips upto the horizon year 2044. BRT and LRT Systems will get saturated in the years 2044 and 2047 respectively and no additional traffic can be catered by these two modes beyond 2047. However, Metro system will continue to cater the peak hour passenger demand much beyond 2047 attributed to its higher carrying capacity.

6. With Metro System being constructed in Phase I, its technology as well as various components like track gauge, civil structures and rolling stock components are easily available and standardized in Nagpur. Efforts have also been made by Government and implementing agencies to indigenize various components of metro rail systems. Technical expertise has also been developed in the country over the period of time.

Light Rail Transit system is new for India. With no previous experience in light rail technology in the country specifically in rolling stock design and O&M, the technical expertise will have to be developed afresh which may result in implementation delays and cost implications. BRT System gets saturated over a period of time thus warranting a high carrying capacity system which can address the transport demand with a much longer perspective even upto 100 years.

7. The interoperability between proposed system in Phase II and the mass transit system already in place in Phase I is an important parameter. The introduction of same system can have better system efficiency, optimized use of system resources and enhanced passenger comfort at the terminal stations as well. Whereas, a different mode on the extension of existing corridors may require entirely new set of infrastructure facilities for operation and maintenance. The small stretches of Phase II extensions spread over multiple part of the study area may require several O&M facilities for modes other than that of Phase-I.
8. Based on detailed quantitative evaluations of screening parameters, Metro System has scored higher than that of LRT and Elevated BRT Systems.

7.2 RECOMMENDATIONS

Based on both qualitative and quantitative screening and analysis, Metro System has emerged as the most viable alternative mass transport system for Phase II corridors in Nagpur. It is also recommended to implement the project under Equity Sharing Model with private sector participation in different sub components of operations & maintenance.

Maharashtra has a successful example of metro operation in Mumbai on SPV model by Mumbai Metro Rail Corporation (MMRC). The SPV Maha Metro Rail Corporation is already constructing Metro Phase-I in Nagpur 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 Phase 2 corridors of Nagpur Metro as per guidelines for Metro Rail Policy - 2017 issued by Ministry of Housing and Urban Affairs (MoHUA), Government of India.

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