CHAPTER 3

SYSTEM SELECTION

TABLES

FIGURES

Chapter - 3

SYSTEM SELECTION

3.1 GENERAL

The population growth in cities and urban centres has put a lot of pressure on the infrastructure of these cities. In rapidly developing countries like India the urban infrastructure is stretched to limit and requires very effective solutions. The rapid development in India is not unprecedented and such development earlier took place in several nations of Europe, America and in Japan. So several modes of urban mass transit are now available for solution to the problem of Urban Transit in Nagpur.

L&T Ramboll Consulting Engineers Limited had carried out the Comprehensive Traffic and Transportation Study and prepared Transportation Master Plan for Nagpur city commissioned by NMC. As a part of study they also recommended four Metro Corridors which have been discussed in Chapter-1 of this DPR..

3.2 BENEFITS OF MASS TRANSPORT SYSTEM

The main benefits addressed by mass transport are the mobility and freedom. The sustainability of mass transport has greater potential and major benefits occur through immediate means of helping the environment and conserving energy. In developing countries, like India, benefit through mass transit systems extend to urban poor with affordable fare structure when compared with costs incurred by private transportation on fuels, parking, congestion etc. The supply of planned and integrated mass public transport is the only way to relieve traffic congestion and reduce hours of delay on major travel corridors. Moreover, supply of metro rail system in Nagpur urban complex will mean a lot in terms of sustainable means of transport that meets the mobility and accessibility needs of people.

3.3 METRO SYSTEM WORLD WIDE

Metro system is used in metropolitan areas to transport large number of people at high frequency. Rapid transit evolved from railways during the late 19th Century. The first system opened was the Metropolitan Railway (London) which connected most of the main railway termini around the city. The technology swiftly spread to other cities in Europe and then to United States and other parts of the world. At present, more than 160 cities have built rapid transit systems, and about twenty five have new systems under construction. The system is seen as an alternative to an extensive road transport system with many motorways. The capital cost is high, with public financing normally required.

India is experiencing a rapid growth in both population and rate of urbanisation. Travel demand is increasing by 5% annually on average, leading to sharp increase in personal vehicles and overwhelming the limited transport infrastructure. A need was therefore felt to develop mass rapid transit systems in metro cities of India to reduce the burden on normal railways as well as road transport service providers. Major cities were facing a situation of rising population and increasing vehicles which had led to problems like congestion and pollution. To overcome these problems, Indian Railways took an initiative towards development of urban mass transit system by starting metro rail. Metro rail systems are operational in Delhi, Kolkata and Bangalore. Metro projects are taken in various cities like, Mumbai, Chennai, Hyderabad, Jaipur, Kolkata, Kochi.

A summary of metro network developed worldwide is given below in **Table 3.1**.

Table 3.1: Spread of World Metro Rail Systems

City	Country	Continent	Commencement	Network Length (km)	Daily Ridership (million)
Adana	Turkey	Asia	18-Mar-09	13.5	
Amsterdam	Netherlands	Europe	16-Oct-77	32.7	0.233
Ankara	Turkey	Asia	30-Aug-96	23.1	0.31
Antwerp	Belgium	Europe	25-Mar-75	7.6	
Athens	Greece	Europe	1954	52.0	0.937
Atlanta	USA	America	30-Jun-79	79.2	0.0932
Baku	Azerbaijan	Asia	6-Nov-67	32.9	0.482
Baltimore	USA	America	21-Nov-83	24.5	0.0356
Bangkok	Thailand	Asia	5-Dec-99	74.9	0.564
Barcelona	Spain	Europe	30-Dec-24	119.4	1.1
Beijing	China	Asia	1-Oct-69	337.0	3.99
Belo Horizonte	Brazil	America	1-Aug-86	28.1	
Berlin	Germany	Europe	18-Feb-02	147.4	1.39
Bielefeld	Germany	Europe	21-Sep-71	5.2	
Bilbao	Spain	Europe	11-Nov-95	40.6	0.238
Bochum	Germany	Europe	26-May-79	21.5	
Bonn	Germany	Europe	22-Mar-75	9.0	
Boston	USA	America	1 Sep 1897	60.5	0.4
Brasilia	Brazil	America	31-Mar-01	42.0	0.0438
Brussels	Belgium	Europe	20-Sep-76	32.2	0.364
Bucharest	Romania	Europe	16-Nov-79	67.7	0.304

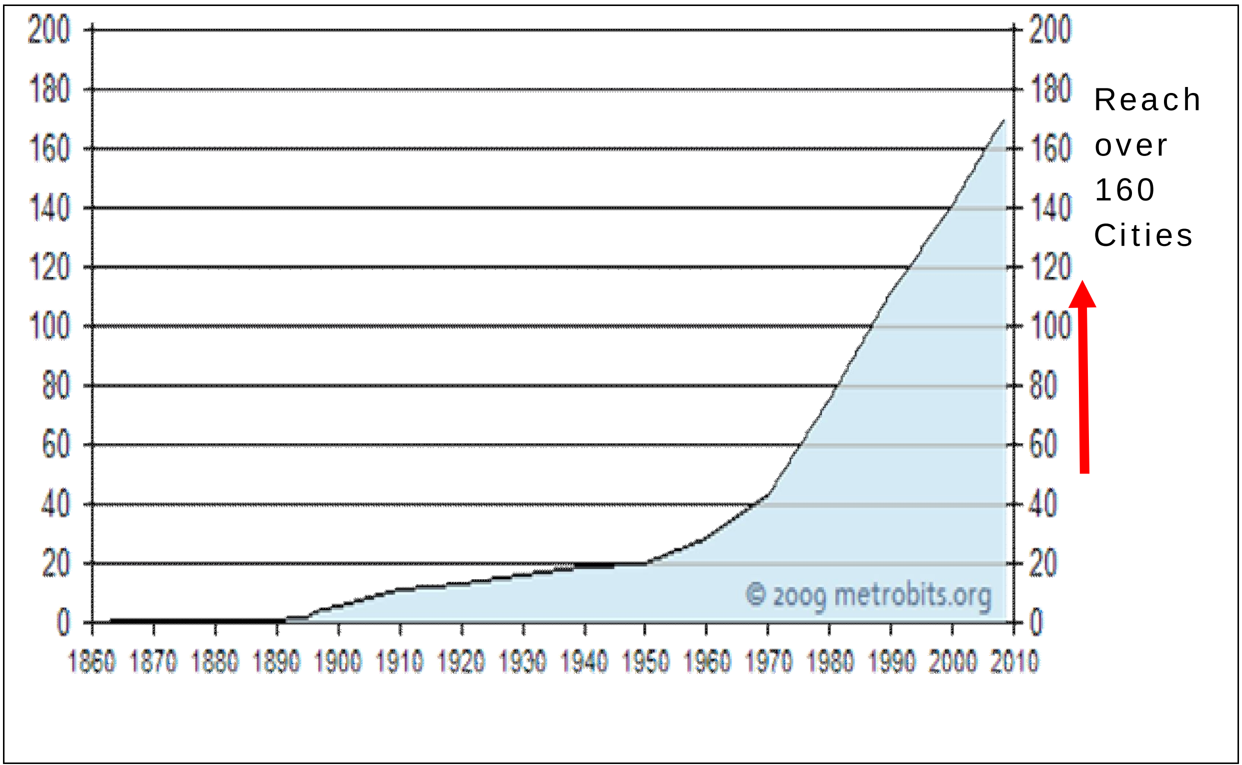
City	Country	Continent	Commencement	Network Length (km)	Daily Ridership (million)
Budapest	Hungary	Europe	2 May 1896	33.0	0.814
Buenos Aires	Argentina	America	1-Dec-13	48.1	0.789
Buffalo	USA	America	18-May-85	8.4	
Bursa	Turkey	Asia	19-Aug-02	25.4	
Busan	South Korea	Asia	19-Jul-85	95.0	0.704
Cairo	Egypt	Africa	27-Sep-87	65.5	1.92
Caracas	Venezuela	America	27-Mar-83	60.5	1.25
Catania	Italy	Europe	27-Jun-99	3.8	
Changchun	China	Asia	Oct-02	17.0	
Charleroi	Belgium	Europe	21-Jun-76	17.5	
Chengdu	China	Asia	27-Sep-10	18.5	
Chennai	India	Asia	19-Oct-97	27.0	
Chiba	Japan	Asia	28-Mar-88	15.5	
Chicago	USA	America	6 Jun 1892	166.0	0.542
Chongqing	China	Asia	18-Jun-05	19.5	
Cleveland	USA	America	15-Mar-55	31.0	0.0137
Cologne	Germany	Europe	11-Oct-68	45.0	
Copenhagen	Denmark	Europe	19-Oct-02	21.0	0.126
Daegu	South Korea	Asia	26-Nov-97	53.9	0.301
Daejeon	South Korea	Asia	16-Mar-06	22.6	0.0795
Dalian	China	Asia	1-May-03	49.0	
Delhi	India	Asia	24-Dec-02	187.3	0.838
Detroit	USA	America	Jul-87	4.8	
Dnepropetrovsk	Ukraine	Europe	29-Dec-95	7.1	0.0384
Dortmund	Germany	Europe	17-May-76	29.5	
Dubai	United Arab Emirates	Asia	9-Sep-09	52.1	
Duesseldorf	Germany	Europe	4-Oct-81	9.6	
Duisburg	Germany	Europe	11-Jul-92	14.3	
Edmonton	Canada	America	22-Apr-78	20.4	
Essen	Germany	Europe	5-Oct-67	20.2	
Frankfurt	Germany	Europe	4-Oct-68	20.5	
Fukuoka	Japan	Asia	26-Jul-81	29.8	0.34
Gelsenkirchen	Germany	Europe	1-Sep-84	5.5	
Genoa	Italy	Europe	13-Jun-90	5.2	
Glasgow	United Kingdom	Europe	14 Dec 1896	10.4	0.0411
Guadalajara	Mexico	America	1-Sep-89	24.0	
Guangzhou	China	Asia	28-Jun-99	231.9	1.85
Gwangju	South Korea	Asia	28-Apr-04	20.1	0.0466
Haifa	Israel	Asia	1959	1.8	
Hamburg	Germany	Europe	1-Mar-12	100.7	0.518
Hanover	Germany	Europe	28-Sep-75	18.6	
Helsinki	Finland	Europe	3-Aug-82	21.0	0.156
Hiroshima	Japan	Asia	20-Aug-94	18.4	0.0493
Hong Kong	China	Asia	1-Oct-79	188.1	3.62
Incheon	South Korea	Asia	6-Oct-99	29.5	0.2
Istanbul	Turkey	Europe	16-Sep-00	16.9	0.186
Izmir	Turkey	Asia	22-May-00	11.5	0.0822
Jacksonville	USA	America	30-May-89	6.9	
Kamakura	Japan	Asia	3-Mar-70	6.6	
Kaohsiung	Taiwan	Asia	9-Mar-08	42.7	0.0822

City	Country	Continent	Commencement	Network Length (km)	Daily Ridership (million)
Kazan	Russia	Europe	27-Aug-05	10.9	0.0192
Kharkov	Ukraine	Europe	23-Aug-75	37.4	0.762
Kiev	Ukraine	Europe	22-Oct-60	63.7	1.76
Kitakyushu	Japan	Asia	9-Jan-85	8.8	
Kobe	Japan	Asia	13-Mar-77	30.6	0.332
Kolkata	India	Asia	24-Oct-84	22.6	0.474
Kryvyi Rih	Ukraine	Europe	26-Dec-86	18.0	
Kuala Lumpur	Malaysia	Asia	16-Dec-96	64.0	0.299
Kyoto	Japan	Asia	1-Apr-81	31.3	0.345
Las Vegas	USA	America	15-Jul-04	6.2	
Lausanne	Switzerland	Europe	24-May-91	13.7	
Lille	France	Europe	25-Apr-83	45.5	0.203
Lima	Peru	America	13-Jan-03	10.0	
Lisbon	Portugal	Europe	29-Dec-59	41.0	0.488
London	United Kingdom	Europe	10 Jan 1863	408.0	2.99
Los Angeles	USA	America	30-Jan-93	59.3	0.129
Ludwigshafen	Germany	Europe	29-May-69	4.0	
Lyon	France	Europe	28-Apr-78	30.7	0.499
Madrid	Spain	Europe	17-Oct-19	286.3	1.78
Manila	Philippines	Asia	1-Dec-84	51.5	0.948
Maracaibo	Venezuela	America	8-Jun-09	6.5	
Marseille	France	Europe	26-Nov-77	21.8	0.159
Mecca	Saudi Arabia	Asia	13-Nov-10	18.1	
Medellin	Colombia	America	30-Nov-95	28.8	0.425
Mexico City	Mexico	America	5-Sep-69	201.7	3.88
Miami	USA	America	21-May-84	36.0	0.0493
Milan	Italy	Europe	1-Nov-64	79.4	0.899
Minsk	Belarus	Europe	26-Jun-84	30.3	0.718
Monterrey	Mexico	America	25-Apr-91	31.5	
Montreal	Canada	America	14-Oct-66	69.2	0.6
Moscow	Russia	Europe	15-May-35	302.0	6.55
Mulheim	Germany	Europe	3-Nov-79	9.0	
Mumbai	India	Asia		171.0	
Munich	Germany	Europe	19-Oct-71	94.2	0.962
Nagoya	Japan	Asia	15-Nov-57	89.0	1.17
Naha	Japan	Asia	10-Aug-03	12.8	
Nanjing	China	Asia	27-Aug-05	84.7	0.4
Naples	Italy	Europe	28-Mar-93	31.8	0.0795
New York	USA	America	27-Oct-04	368.0	4.33
Newark	USA	America	26-May-35	2.2	
Newcastle	United Kingdom	Europe	7-Aug-80	76.5	0.104
Nizhny Novgorod	Russia	Europe	20-Nov-85	15.5	0.0904
Novosibirsk	Russia	Asia	7-Jan-86	16.4	0.192
Nuremberg	Germany	Europe	1-Mar-72	34.6	0.315
Oporto	Portugal	Europe	7-Dec-02	21.7	
Osaka	Japan	Asia	20-May-33	137.8	2.36
Oslo	Norway	Europe	22-May-66	62.0	0.214
Palma de Mallorca	Spain	Europe	25-Apr-07	8.3	
Paris	France	Europe	19-Jul-00	213.0	4.05
Perugia	Italy	Europe	29-Jan-08	3.0	

City	Country	Continent	Commencement	Network Length (km)	Daily Ridership (million)
Philadelphia	USA	America	4-Mar-07	62.0	0.192
Pittsburgh	USA	America	3-Jul-85	2.9	
Porto Alegre	Brazil	America	2-Mar-85	33.8	
Poznan	Poland	Europe	1-Mar-97	6.1	
Prague	Czech Republic	Europe	9-May-74	59.1	1.6
Pyongyang	North Korea	Asia	6-Sep-73	22.5	0.0959
Recife	Brazil	America	11-Mar-85	39.7	
Rennes	France	Europe	16-Mar-02	9.0	0.063
Rio de Janeiro	Brazil	America	5-Mar-79	42.0	0.37
Rome	Italy	Europe	10-Feb-55	39.0	0.907
Rotterdam	Netherlands	Europe	10-Feb-68	47.0	0.238
Rouen	France	Europe	17-Dec-94	2.2	
Saint Louis	USA	America	31-Jul-93	73.4	
Saint Petersburg	Russia	Europe	15-Nov-55	110.2	2.25
Samara	Russia	Europe	26-Dec-87	10.2	0.0329
San Francisco	USA	America	11-Sep-72	166.9	0.293
San Juan	Puerto Rico	America	6-Jun-05	17.2	0.0247
Santiago	Chile	America	15-Sep-75	102.4	1.67
Santo Domingo	Dominican Republic	America	30-Jan-09	14.5	0.2
Sao Paulo	Brazil	America	14-Sep-74	69.7	1.93
Sapporo	Japan	Asia	16-Dec-71	48.0	0.573
Seattle	USA	America	18-Jul-09	22.2	
Sendai	Japan	Asia	15-Jul-87	14.8	0.159
Seoul	South Korea	Asia	15-Aug-74	286.9	5.61
Seville	Spain	Europe	2-Apr-09	18.0	
Shanghai	China	Asia	10-Apr-95	423.0	3.56
Shenyang	China	Asia	27-Sep-10	27.8	
Shenzhen	China	Asia	28-Dec-04	69.1	0.362
Singapore	Singapore	Asia	7-Nov-87	129.7	1.81
Sofia	Bulgaria	Europe	28-Jan-98	18.0	0.0795
Stockholm	Sweden	Europe	1-Oct-50	105.7	0.841
Stuttgart	Germany	Europe	10-Jun-66	24.0	
Sydney	Australia	Oceania	1926	22.1	
Taipei	Taiwan	Asia	28-Mar-96	100.8	1.27
Tama	Japan	Asia	27-Nov-98	16.0	
Tashkent	Uzbekistan	Asia	6-Nov-77	36.2	0.195
Tbilisi	Georgia	Asia	11-Jan-66	26.3	0.252
Tehran	Iran	Asia	21-Feb-00	66.0	1.26
The Hague	Netherlands	Europe	16-Oct-04	27.9	
Tianjin	China	Asia	28-Mar-04	72.0	0.0411
Tokyo	Japan	Asia	30-Dec-27	304.5	8.7
Toronto	Canada	America	30-Apr-54	71.3	0.762
Toulouse	France	Europe	26-Jun-93	27.5	0.115
Turin	Italy	Europe	4-Feb-06	9.6	
Valencia	Venezuela	America	18-Oct-06	6.2	0.0493
Valencia	Spain	Europe	3-Oct-88	31.8	
Valparaiso	Chile	America	23-Nov-05	43.0	
Vancouver	Canada	America	3-Jan-86	69.5	0.203
Vienna	Austria	Europe	25-Feb-78	74.6	1.4
Volgograd	Russia	Europe	5-Nov-84	3.3	

City	Country	Continent	Commencement	Network Length (km)	Daily Ridership (million)
Warsaw	Poland	Europe	7-Apr-95	22.6	0.345
Washington	USA	America	27-Mar-76	171.2	0.611
Wuhan	China	Asia	28-Sep-04	28.0	0.0356
Wuppertal	Germany	Europe	1-Mar-01	13.3	
Yekaterinburg	Russia	Asia	26-Apr-91	8.5	0.126
Yerevan	Armenia	Asia	7-Mar-81	12.1	0.0466

3.4 WORLD METRO GRAPH



3.5 FAMOUS METRO SYSTEMS:-

London

Meddellin

Taipei

Paris

Delhi

Kolkata

3.6 OPTIONS FOR PUBLIC TRANSPORT SYSTEM

3.6.1 The following systems are mainly available for Urban Mass Transit:

(i) **Metro System**: Metro system is a grade separated dedicated system for high peak hour traffic densities exceeding 40,000 PHPDT. It is characterized by short distances of stations spaced at 1 km, high acceleration and declaration and scheduled speeds of 30-35 kmph.

(ii) **Light Rail Transit**: Modern trams-Street Cars running on Rails at grade or elevated with sharp curves of 24m radius. These are extremely popular and operating in large number of European countries. Generally the stations are spaced at 500m to 1 km and have high acceleration and deceleration characteristics. In most of the countries, they are operating at-grade with prioritized signaling at road inter-section.

(iii) **Sky Train:** This is an experimental rail based system under development by Konkan Railway.

(iv) **Other Rail Based Systems:** A number of options are available but have not been introduced in India. Some of these are very briefly mentioned below:

(a) **Maglev:** This is an advanced Rail based transit system in which Magnetic Levitation is used to raise the vehicles above the rail surface. Rail wheel interaction is thus avoided and very high speeds are attainable. Maglev Levitation can either be due to attractive force or due to repulsive forces.

(b) **Linear Induction Motor (LIM) Train:** This is also an advanced Rail based transit system in which propulsion is through a Linear Induction Motor whose stator is spread along the track. The rotor is a magnetic material provided in the under frame of train. In the technology the tractive force is not transmitted through rail-wheel interaction, and so there is no limitation on account of adhesion. This technology is most appropriate for turnouts, as the height of the tunnel can be reduced to lower height of cars.

(v) **Monorail:** Monorail trains operate on grade separated dedicated corridors with sharp curves of up to 70m radius. This is a rubber tyred based rolling stock, electrically propelled on concrete beams known as guide-ways. The system is extremely suitable in narrow corridors as it requires minimum right of way on existing roads and permits light and air and is more environmental friendly. This is prevalent in several countries for traffic densities of over 20,000 PHPDT.

(vi) **Bus Rapid Transit System:** This system involves operation of buses on a dedicated corridor (except of traffic integration) at a high frequency to achieve PHPDT.

For providing a very high transport capacity say 20,000 PHPDT, about 200 buses shall be required per hour *i.e.,* at headway of 20 seconds. Such a high PHPDT can be achieved by providing two lanes of traffic in each direction and elimination of traffic intersection on the route.

(vii) **Automated Guide way Transit System:** The term is used for systems other than conventional rail based system on grade separated guide ways. The system can be rail based or rubber tire based but fully automated guided systems with driver less operation.

3.6.2 The salient features of the various Transit Systems are summarized as under**:-**

System	**LRT (Light Rail Transit) (elevated)**	**AGT (Automated Guide way Transit)**	**Straddle type Monorail**
Exterior of Vehicle	 It is a transport system that runs on the exclusive beam slab track mainly built over highways.	 It is a new transport system that runs on the exclusive track built on elevated structure with lightweight vehicle.	 It is a new transport system that runs straddling on the exclusive beam track mainly built over highways.
Rolling stock			
Length (m)	30.0 (articulated type)		
Width (m)	2.5		
Height (m)	3.7		
Number of doors	3		
Wheel arrangement	2-2-2		
Weight (tare) (ton)	44		
Axle load (max)	10tf		
Type of car load	Concentrated load	Concentrated load	Concentrated load
Running gear and track structure			
Traction system	Rotary Motor and steel wheel	Rotary Motor and rubber tire	Rotary Motor and rubber tire
Brake system	Electric brake and hydraulic brake	Electric brake and air brake	Electric brake and air brake
Guidance System	Steel rail	Lateral pinched Guidance	Guide Wheel (Rubber)
Power collector	Catenary	Conductor rail	Conductor rail
Voltage	D.C. 750 V	A.C. 750 V (three phase)	D.C. 1,500 V
Track	Steel rail	Concrete slab	Track beam

System	LRT (Light Rail Transit) (elevated)	AGT (Automated Guide way Transit)	Straddle type Monorail
Switch			
constitution	Switch and crossing	Lateral pinched switch	Flexure track beam
The Operation Characteristic			
Maximum speed	80 km/h	80 km/h	80 km/h
Schedule speed	30 km/h	30 km/h	30 km/h
Minimum curve radius	30m	30m	70m
Maximum gradient	4 %	6 %	6 %
Acceleration	3.5km/h/s	3.5km/h/s	3.5km/h/s
Deceleration Service brake	3.5km/h/s	4.8km/h/s	4.0km/h/s
Emergency brake	4.5km/h/s	6.0km/h/s	4.5km/h/s
Automatic Train operation	There is few example of it.	It has been developed aiming for automated operation. There are many examples of automated operation including driverless operation.	There are three cases of ATO operation in Japan.
Transportation capacity			
1 car seat	60		45
standing	90		60
total	150 (30m)	60 (L=9m)	105 (L=15m)
4 car seat	120		180
standing	180		240
total	300 (30m+30m)	360 (6 car L=54m)	420 (L=60m)
8 car seat	240		360
standing	360		480
total	600 (30m+30m+30m+30m)	720 (12 car L=108m)	840 (L=120m)
8 car PHPDT (170% , headway 2.5 min)	24,480	17,300 (100%)	34,300
	It is possible to deal with over 24,480 PHPDT of demand. (train length 120m)	It is possible to deal with up to 11,600 PHPDT of demand. (train length 108m)	It is possible to deal with over 34,300 PHPDT of demand. (train length 120m)
Structure			
Superstructure	Concrete slab	Concrete slab	Track beam
Pier and foundation	Concrete	Concrete	Concrete
Maintainability and cost			
Track	In addition to grinding of surface of rails, track maintenance work will require	It has small maintenance of track.	It has small maintenance of track.

System	LRT (Light Rail Transit) (elevated)	AGT (Automated Guide way Transit)	Straddle type Monorail
	much time.		
Vehicle	Maintenance of rotary motor and grinding of steel wheels shall be necessary.	Maintenance of rotary motor and exchange of rubber tires after every 120,000 km running shall be necessary.	Maintenance of rotary motor and exchange of rubber tires after every 120,000 km running shall be necessary.
Effect on ambient surrounding and harmony with urban landscape			
Effect on ambient surrounding	Its noiseproof wheels make as small noise as rubber tires make.	Level Crossing between AGT and road is not available. This system, with rubber tires, makes small noise and vibration. Because its running surfaces are made of concrete slab, there remain problems like inhibition of sunshine or radio disturbance.	This system, with rubber tires, makes small noise and vibration.
urban landscape	This system is inferior to other systems in terms of landscape because overhead wires for power collection must be installed.	Because its superstructure is made of concrete slab, oppressing feeling of view is an issue.	This system is superior to AGT or LIM Train in terms of landscape because its superstructure consists of only track beams that have small section.
Emergency evacuation			
	Evacuation other train (end to end or side by side)	Evacuation other train (end to end or side by side)	Evacuation other train (end to end or side by side)
	Walk way	Walk way	Evacuation device
	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.	In this system, supporting vehicles are needed for passengers' emergency evacuation, which is of no matter because this straddle type system have many actual performances of running in Japan and has a established method for rescue.
Operation cost			
Electric energy			2.2kwh/car-km
Rolling stock cost			
/ car			7.5 Crors

System	Urban Maglev (HSST)	Metro/Subway	Bus Rapid transit
Exterior of Vehicle	 It is a new transport system that runs on the exclusive beam slab track mainly built over highways.	 It is Medium to Heavy Rail Transit (HRT) is a specialized electrically powered rail system carrying passengers within urban areas,	 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.
Rolling stock			
Length (m)			18 (articulated type)
Width (m)			2.0
Height (m)			3.5
Number of doors			2
Wheel arrangement	5 module / car	2-2 or 3-3	Independent Axles
Weight (tare) (ton)	15.0	41	12 to 16
Axle load (max)	2.3tf/m	17tfm	9tf to 15.3tf
Type of car load	Uniform load	Concentrated l.oad	Concentrated load
Running gear and track structure			
Traction system	Linear Induction Motor and Electromagnetic levitation system	Rotary Motor and steel wheel	Rubber tyre
Brake system	Electric brake and air brake	Electric brake and hydraulic brake and Regenerative brakes	Hydraulic Brakes
Guidance System	Electromagnetic levitation system	Steel Rail	None/ special guide wheels on kerbs
Power collector	Conductor rail	Catenary or Conductor rail	Not applicable
Voltage	D.C. 1,500 V	D.C. 1500 V, A.C. 25kv	None
Track	Steel rail (Electromagnetic levitation system)	Steel rail	Road
Switch			
constitution	Flexure track beam	Switch and crossing	Road Crossings
The Operation Characteristic			
Maximum speed	80 km/h	80 to 100 km/h	80 km/h

System	Urban Maglev (HSST)	Metro/Subway	Bus Rapid transit
Schedule speed	30 km/h	35 km/h	20 km/h
Minimum curve radius	50m	100m	12m
Maximum gradient	6 %	6 %	
Acceleration	3.5km/h/s	3.5km/h/s	
Deceleration Service brake	3.5km/h/s	3.5km/h/s	
Emergency brake	4.5km/h/s	4.5km/h/s	
Automatic Train operation	There are cases of ATO operation in Nagoya Japan.	Automatic Train operation	No
Transportation capacity			
1 car seat	32	75	70
standing	42	125	40
total	74 (L=14m)	200(L=24m)	110(L=18)
4 car seat	128	300	
standing	172	500	
total	300 (L=56m)	800(L=96m)	
8 car seat	256	600	
standing	344	1000	
total	600 (L=112m)	1600(L=192m)	
8 car PHPDT (170% , headway 2.5 min)	23,100 (max 160%)	50,000	
	It is possible to deal with over 23,100 PHPDT of demand. (train length 112m)	It is possible to deal with over 50,000 PHPDT of demand. (train length 112m)	It is possible to deal with max 6,000 PHPDT of demand.
Structure			
Superstructure	Concrete slab	Concrete slab	Roads
Pier and foundation	Concrete	Concrete	
Maintainability and cost			
Track	It has less maintenance of track as there is less physical movement.	It has less maintenance of track.	It requires maintenance of roads.
Vehicle	As it has no rotary motor, it is excellent on maintenance.	Maintenance of rotary motor and grinding of steel wheels shall be necessary.	Maintenance of engine and rubber tyres shall be necessary.
Effect on ambient surrounding and harmony with urban landscape			

System	Urban Maglev (HSST)	Metro/Subway	Bus Rapid transit
Effect on ambient surrounding	There remain problems like inhibition of sunshine or radio disturbance, because its running surfaces are made of concrete slab.	This system is noisy due to steel wheel arrangement	Noise and Pollution Problems
urban landscape	This system is inferior to other systems in terms of landscape because overhead wires for power collection must be installed.	Because its superstructure is made of concrete slab, oppressing feeling of view is an issue. This system is inferior to other systems in terms of landscape because overhead wires for power collection must be installed.	No such issues
Emergency evacuation			
	Evacuation other train (end to end or side by side)	Evacuation other train (end to end or side by side)	No problems
	Walk way	Walk way	
	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.	
Operation cost			
Electric energy	2.5kwh/car-km		
Rolling stock cost			
/ car		6 to 9 Crores	Few Lakhs

3.7 CHARACTERISTICS OF URBAN TRANSIT SYSTEM

3.7.1 Transport Capacity

It is product of passenger carrying capacity of a train and maximum permissible frequency of train operation. The passenger carrying capacity is determined by number of cars (units/ coaches), which can be clubbed to form a train and dimensions of each car. To compare different systems uniform packing density is considered although for different systems different crush loading may be permissible. The passenger carrying capacity is dependent on the following:

(a) **Dimensions of vehicle:** Length and breadth- useful area. The cars vary from about 9m to 24m for most of systems. The width varies from 2.5m to 3.6m.

(b) **Passengers per m^2:** The normal to crush loading of most systems varies from 4 to 7 passengers per m^2.

(c) **No of Cars per train:** The cars can be from 1 to 15 for most of the systems and the train length can be up to 315m.

Table 3.2: Passenger carrying Capacity per Train (typical) for different Transit Systems

S. No.	Transit System	Car Size (length 'm' x breadth 'm')	Car Capacity (No. of passengers /car)	No of Cars /Train	Train Length 'm'	Train Capacity passenger /Train
1	Large-type monorail	15 x 3	175	2 to 8	120	1400 for 8cars
2	Heavy Metro Rail	21 to 24 x 2.8 to 3.6	250	8 to 15	190 to 315	2000 for 8cars
3	Bus	18 x 2.5 to 3	70 to 100	1 to 2	18	100 per bus
4	AGT	9 to 13 x 2.5 to 3	60 to 120	2 to 12	108	720
5	LRT	18* x 2.65	145*	2 to 8	72	710*
6	Maglev	16 x 2.6	170	2 to 8	128	1360 for 8 cars

(Standee Occupancy rate: 0.14 m^2/passenger)
* Smallest combination of modules for an independent LRT

(d) **Headway:** The headway and frequency of train operation depends on Signaling and Rolling Stock characteristics viz. control systems, acceleration (tractive effort) and maximum permissible speed (adhesion). A graph showing the carrying capacity of different modes and passenger capacity is given below (see next page):

(e) **Train Signaling and Control Systems:** The various train Signaling and control systems which help in increasing frequency of operation are:

- **Automatic Train Operation and Control System (ATO)**
- **Automatic Train Supervision System (ATS)**

➢ **Automatic Train Protection System (ATP)**

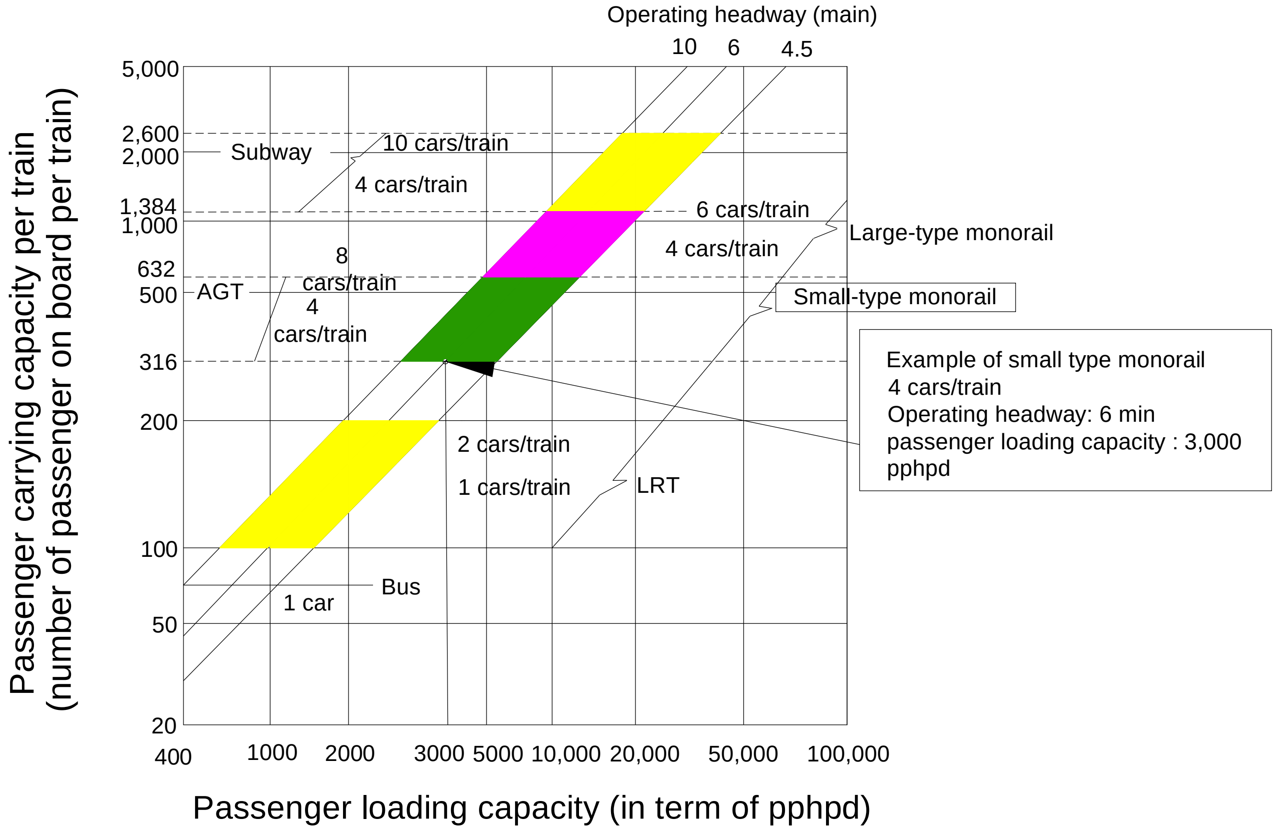


Figure 3.1 Transport Capacity of Different Modes as a Function of Headway

(f) **Tractive effort and Acceleration:** By increasing the tractive effort and acceleration it is possible to increase transportation capacity both by improving the average speed and also by permitting higher frequency of train operation. The factors influencing tractive effort/ acceleration/ speed are:

- Adhesion
- Ratio of Motor coaches to trailer coaches
- Traction Motor Rating
- No of Traction Motors per car
- Drive System

3.7.2 Geometric Characteristics:

(i) **Minimum Radius:** Varies from 25m minimum for LRT, 70m for Monorail to 120m for Metro.

(ii) **Right of Way:** The Right of way required for a Grade Separated (elevated) system is solely determined by the building line provided the piers can be accommodated on the central verge. For an At Grade system the Right of Way required is determined by lanes required for motorized/ non motorized vehicles in addition to width of road required for the mass transit system. The minimum right of way required is about 22.5m.

(iii) **Gradient:** Ruling gradient varies from system to system.

- **Environmental Characteristics Noise:**

  Rubber tyre on road is less noisy as compared to steel wheels on rails.

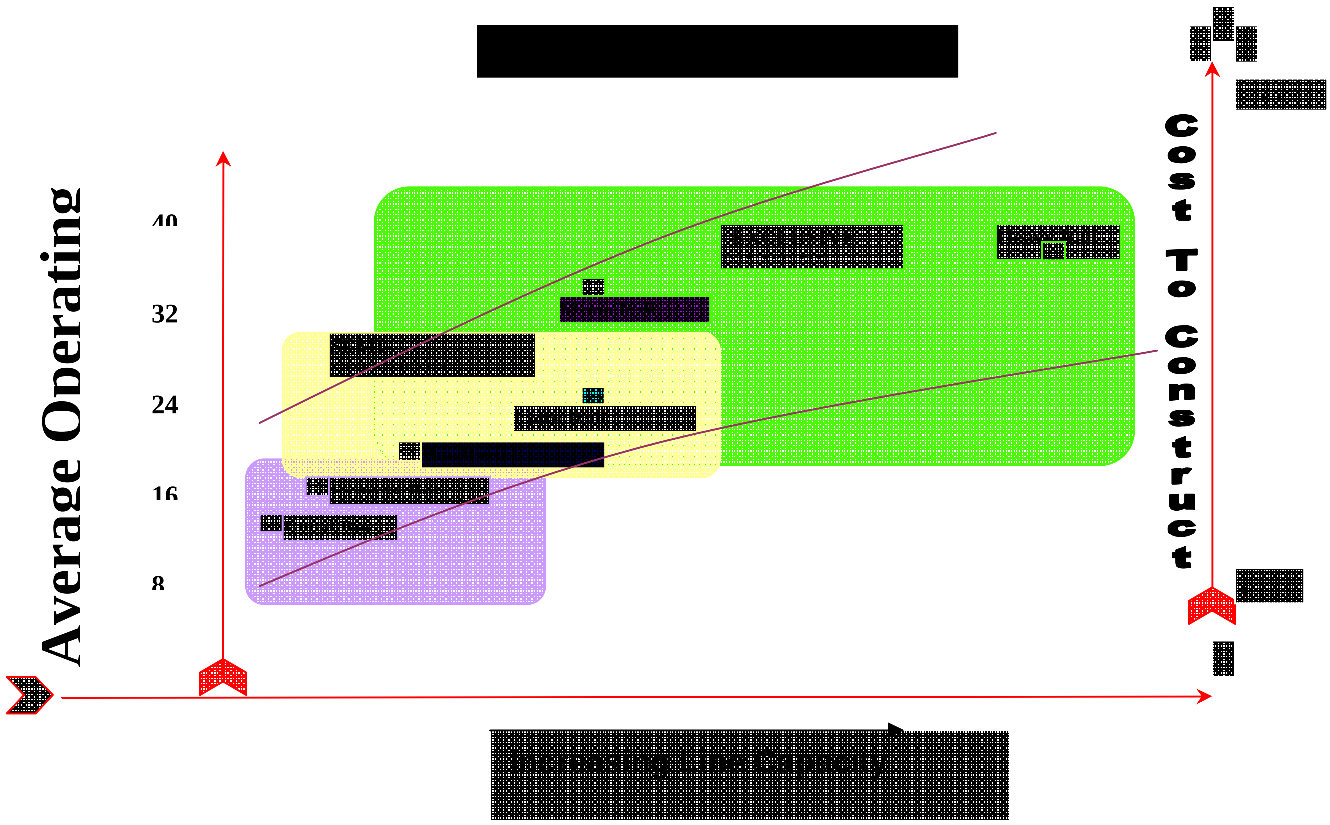
- **Aesthetics-Air and Sunshine:** The at grade systems are least restrictive in exposing the corridors, buildings next to these corridors and people (on these corridors/ inhabiting buildings next to these corridors) to natural air and sunshine.

  The effect of elevated systems on the existing buildings and their inhabitants is the worst. Comparatively the best system as far as this factor is considered is underground metro rail system.

- **Pollution:** All electrically driven systems are better than diesel operated systems. This is where Rail based systems score over the Road based vehicles.

Graphical comparisons of the most important characteristics which influence selection of different technologies are depicted in the Figure 3.2 below:-

Fig-3.2



As shown, carrying capacity increases with the speed of the service and the cost to construct. The rail family can carry more passengers per hour at a faster speed, but most systems cost more to construct than do bus-based systems.

3.7.3 Need for a Grade Separated Transit System

a) A large number of inter change points.
b) High vehicular density.
c) Excessive congestion and delays on the corridors, especially during peak hours.
d) As the corridors are normally following busy areas of the city, it is not easy to find the required areas for depots, workshops.

Additional capacity needs to be created on the corridors to accommodate more traffic on the roads. Mere re-allocation of road space to provide for dedicated bus lanes for public transport may not serve the purpose due to presence of large number of private vehicles, which will continue to operate, and whose numbers will continue to rise.
Further presence of large number of inter change points will severely restrict speed of operation of public transit system employing dedicated lanes. Considering projections of travel demand on these corridors it is essential to provide grade separated transit system for these corridors.

In view of levels of services that will be required to meet the travel demand on the corridors, a fixed guide way, grade separated system is unavoidable.

3.7.4 Discussions on suitability of various modes

The following shows the suitability of various modes of public transport in terms of parameters.

Table 3.3: Suitability Matrix of Public Transport Modes

Mode of transport	Noise Generation	Noise Effect on Road users	Noise Effect on Inhabitants	Aesthetics- Exposure to Sunshine	Aesthetics- Effect on Skyline	Energy Efficiency	Pollution
Metro Rail elevated	√	x	√	√	√	x	x
Metro Rail underground	x	x	x	x	x	x	x
LRT elevated	√	x	√	√	√	x	x
LRT at Grade	√	√	√	x	x	x	x
Monorail	x	x	x	x	x	√	x
Subway elevated	√	x	√	√	√	x	x
AGT elevated	x	x	x	√	√	√	x
LIM/Maglev elevated	x	x	x	√	√	√	x
Bus At Grade	√	√	√	x	x	√	√
Bus Elevated	x	x	x	√	√	√	√

√	Adverse
X	No Adverse Effect

3.7.5 Feasibility of other systems:

Maglev is an energy guzzler and the AGT is primarily a proprietary system. Sky train is yet on experimental stages.

3.7.6 LRT and Monorail System:

From traffic point of view LRT and monorail systems appears to be good enough to meet requirement of traffic.

3.7.7 Feasibility of Metro System for Nagpur:

From the ‘Traffic Demand Forecast’ it can be seen that peak hour peak direction trips (PHPDT) on the North South Corridor is 7375, 8526, 10987 and 14332 the year of 2016, 2021, 2031 and 2041 respectively. Similarly PHPDT on East West corridor in the year of 2016, 2021, 2031 and 2041 is 8087, 8992, 11755 and 15060 respectively.

Road-based systems can optimally carry up to a maximum of 8,000 PHPDT. Since the PHPDT assumed on the above corridors exceed 8,000, there can be two options namely 1) Mono Rail and 2) Light Capacity Metro. Mono rail can carry the PHPDT projected but this technology is not a tested one. The operation and maintenance cost is much higher that Light metro. The capital cost of Mono rail is also almost same as that of Light Metro with no experience of Mono rail in India. Even in the other countries, the Mono rail is being adopted only for small lengths and as feeder to Metro. Hence, keeping in view the above disadvantages, it is recommended to adopt an stable, tested and reliable Metro technology. However, for Nagpur it will be Light Capacity Metro System.