DEVELOPMENT OF MAJOR ARTERIAL ROAD IN KEMPEGOWDA LAYOUT

DETAILED PROJECT REPORT – VOLUME I (MAIN REPORT)

SEPTEMBER 2017

Tandon Urban Solutions Pvt. Ltd.

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Bangalore.

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Issue and Revision Record:

Rev	Date	Originator	Checker	Approver	Description
R0	24-12-2015	RDS	VP / CB	ST	Draft Final Report with 61m ROW
R1	06-02-2017	RDS	VP / CB	ST	Revised with 45m ROW
R2	20-09-2017	RDS	CB	ST	Final Report with 100m ROW

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1 INTRODUCTION

1.1 PROJECT BACKGROUND

The genesis of the InfoTech revolution sweeping the country was in Bangalore, known as the 'Silicon Valley' of India. Though this sudden growth has brought in much prosperity, the city infrastructure has not been able to cope up with the sudden pressure. It is being increasingly felt that, in order to remain the favoured destination of knowledge based industries and to emerge as a truly dynamic global city, the development must be dispersed across a wider area to avoid the highly saturated core areas.

These and the increasing cost of bringing water to Bangalore from river Cauvery have prompted the state government to promote shifting of economic activity to the south of Bangalore, nearer to the river Cauvery. The BDA, since its inception has formed about 62 layouts and has made site allotments of about 2 lakh numbers to general public, and has added 10 more new layouts in the past decade. With this end in view, the BDA, is currently developing a township at the Nadaprabhu Kempegowda Layout, named in loving memory of the king who laid the first foundations of this city. This layout was approved by the government of Karnataka on 02.04.2008. Along with this, BDA is also planning to develop a major arterial road running through the heart of Nadaprabhu Kempegowda Layout.

The BDA has appointed M/s. Tandon Urban Solutions Pvt. Ltd. (TUSPL) for providing therequired consultancy services for preparation of Feasibility & Detailed Project Report forDevelopment of Major Arterial Road in Nadaprabhu Kempegowda Layout.

1.2 PROJECT NEED

The Major Arterial Road has been proposed to reduce the traffic congestion of internal roads and to directly travel between internal parts of the city. Thus Major Arterial Road becomes important in connecting the city areas.

The Major Arterial Road (MAR) is envisaged from the following:

- Need to ease traffic flow and provide traffic solution by bypassing the through traffic from the city and strengthening city road network by providing additional linkages and network augmentation facilities. The development of Major Arterial Roadin the city is expected to reduce the pressure on city's internal roads and act as stimulus for bringing significant socioeconomic benefits to the city.

- Initiate Development & Growth towards the sub-urban regions. The proposed corridor can augment and enhance the pace of this development thus extending the growth towards the otherwise lesser developed region.

Major Arterial Road is accorded Highest Priority in Comprehensive Traffic & Transportation Plan (CTTP) prepared for Bangalore with provision of High Capacity BRT System and Cycle Tracks.

This road has been included in Master Plan of NPKL and integrated in RMP for Bengaluru by BDA.

Major Arterial Road will be further connected with 15m/18m/24m/30m wide east west RMP connectors at 6 locations to improve the accessibility from local streets.

1.3 KEY ADVANTAGES OF MAJOR ARTERIAL ROAD DEVELOPMENT

The Major Arterial Road if constructed will offer the following advantages:

- Provide improved access and connectivity to all parts of the city efficiently without passingthrough congested city areas.
- Reduce congestion in the interior parts of the city by allowing through traffic to bypass the city. The Major Arterial Road would be useful for the floatingpopulation which is coming from outside of the city and moving out.
- The Major Arterial Road would connect major arterial roads and also some proposed roadsoriginating from city centre and thereby strengthen city Road Network.
- The proposed Major Arterial Road would act as a connection to the suburban areas in the city whichare not properly connected and are expected to grow in future. It will also help indecongesting the traffic along the sub arterial roads of the city.

Due to de-congestion, ease of transport, more efficient road-network there would beimmense savings in time and cost of travel and significant. The proposed Major Arterial Road will unlock the land parcels and act as catalyst for development ofcorridors.

1.4 OBJECTIVES OF CONSULTANCY SERVICES

The main objective of the consultancy services is to establish technical, economical,and financial viability of the project and prepare feasibility and detailed project report for development of Major Arterial Road for required configuration. The Terms of Reference for the consultancyservices has laid down the following guiding principles:

- The viability of the project shall be established taking into account the requirements with regard to rehabilitation,upgrading and improvement based on highway design, pavement design, divided carriageway, wherever necessary, type ofintersections, flyovers/ROB's, rehabilitation and widening of existingand/or construction of new bridges and structures, road safety features,quantities of various items of works and cost estimates vis-à-vis theinvestment and financial return through revenues.
- The feasibility study would inter – alia include preliminary highway design,design of pavement and overlay with options for flexible or rigid pavements,inventory of bridges and cross drainage structures and quantities of variousitems, detailed working drawings, detailed cost estimates, economic andfinancial viability analyses, documents required fortendering the project on commercial basis for international /local competitivebidding.
- Ensure enhanced safety of the traffic, the road users and the people livingclose to the highway.
- Ensure enhanced operational efficiency of the highway.
- Ensure fulfilment of the access needs of the local population.
- Ensure minimal adverse impact on the road users and the local population dueto construction.
- Minimal additional acquisition of land.

1.5 SCOPE OF CONSULTANCY SERVICES

The study includes all field works and preparation of feasibility and detailed project report for the development of Major Arterial Road and allied structures.

1.6 EARLIER SUBMISSIONS AND RESPONSES

TUSPL has submitted the Feasibility Report with recommendation for right of way of 100m and presented to Technical Advisory Committee (TAC) on 12th June 2014 in Bengaluru. Recommended width of 100m is in line with Revised Master Plan (RMP) prepared for Bangalore for the year 2015 and Master Plan prepared for Nadaprabhu Kempegowda Layout. However, BDA issued letter to TUSPL on 5th November 2015 for submission of

detailed project report with Right of Way of 61m. Same was prepared and submitted to BDA in December 2015.

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Bangalore Development Authority

No: BDA/EE(NPKL)/124/2015-16

Office of the Executive Engineer
Nada Prabhu Kempegowda Layout Division
Bangalore Development Authority
MRCR Layout, BDA Complex
Vijayanagar, Bangalore-560040
Bangalore: Dated: 05/11/2015

To,

Tandon Urban Solutions Pvt. Ltd.
No.1, 1/1 & 1/2, 1st Floor,
10th Cross Road, 11th Main Road,
Vasanth Nagar, Bangalore – 52.

Sir,

Sub: Preparation of Detailed Project Report for the proposed Major Arterial Road Passing through Nadaprabhu Kempegowda Layout, regarding

Ref: Work Order no. BDA / EE(NPKL) / W.O / 23 / 2014-15 dated:06/10/2014

*****

The work of consultancy services for the proposed Nadaprabhu Kempegowda Layout is entrusted to you vide ref(1). The prefeasibility report of the proposed major arterial road submitted by you.

In continuation to this it was decided to have 60m width for the proposed major arterial road. Hence you are hereby instructed to work out and submit the land details (Sy No and Extent) to be acquired and extent and survey no of land to be returned to the farmers.

Further you are instructed to prepare the detailed project report for the proposed major arterial road of width 60m and submit at the earliest.

Executive Engineer,
NPKL Division, BDA, Bangalore

Further to cut down the construction cost and to make the construction of major arterial road financially viable, Out of 100m ROW as proposed in Feasibility Report BDA has decided to construct the said road with 45m and remaining shall be kept as Park / Green Space for future development. .

2 PROJECT SITE AND REGIONAL CONTEXT

The Project site is located in the western to south western quadrant of the outer fringes of Bengaluru within the proposed development of Sri Nadaprabhu Kempegowda Layout.

2.1 INTRODUCTION TO BENGALURU

Bangalore, the capital of Karnataka, has a history of over four hundred years, having been founded by Magadi Kempegowda in the year 1537 AD. Since then the city has throughout retained its importance as could be seen by the great desire of every chieftain or rulers not only in the South but even the Mughal Kings of Delhi to acquire possession of this city.Though historical references to the city predate AD 900, a modern written history of continuous settlement exists only from 1537, when Kempe Gowda I, a vassal of the imperial Vijayanagara Empire built a mud-brick fort at the site and established it as a province of the empire. During the British Raj, it became a centre of colonial rule in South India. The establishment of the Bangalore Cantonment brought in large numbers of migrants from other parts of the country.

With the establishment of the cantonment, the prospects of trade, employment and other means of livelihood increased and people started setting on the fringes of the cantonment area and various localities now known as Tasker Town, Maciever Town, Richmond Town, Frazer Town etc., started springing up. By 1890 the population of the cantonment area had crossed a lakh mark while that of the old city, which also had a prosperous period of trade and commerce, had increased to over 80,000.Perhaps the most spectacular growth of the City Started after the independence of the country, with the establishment of Central Sector Industries like the Hindustan Machine Tools (H.M.T), Indian Telephone Industries (I.T.I.) etc.

Described by its older residents as Garden City, Air-conditioned City etc., Bangalore attracted the people not only from Karnataka and surrounding areas but people from other states also on account of its salubrious climate, natural beauty and the abounding greenery. Today as a large city and growing metropolis, Bangalore is home to many of the most well-recognized colleges and research institutions in India. Numerous public sector heavy industries, software companies, aerospace, telecommunications, and defence organisations are located in the city. Bangalore is known as the Silicon Valley of India because of its position as the nation's leading IT exporter. A demographically diverse

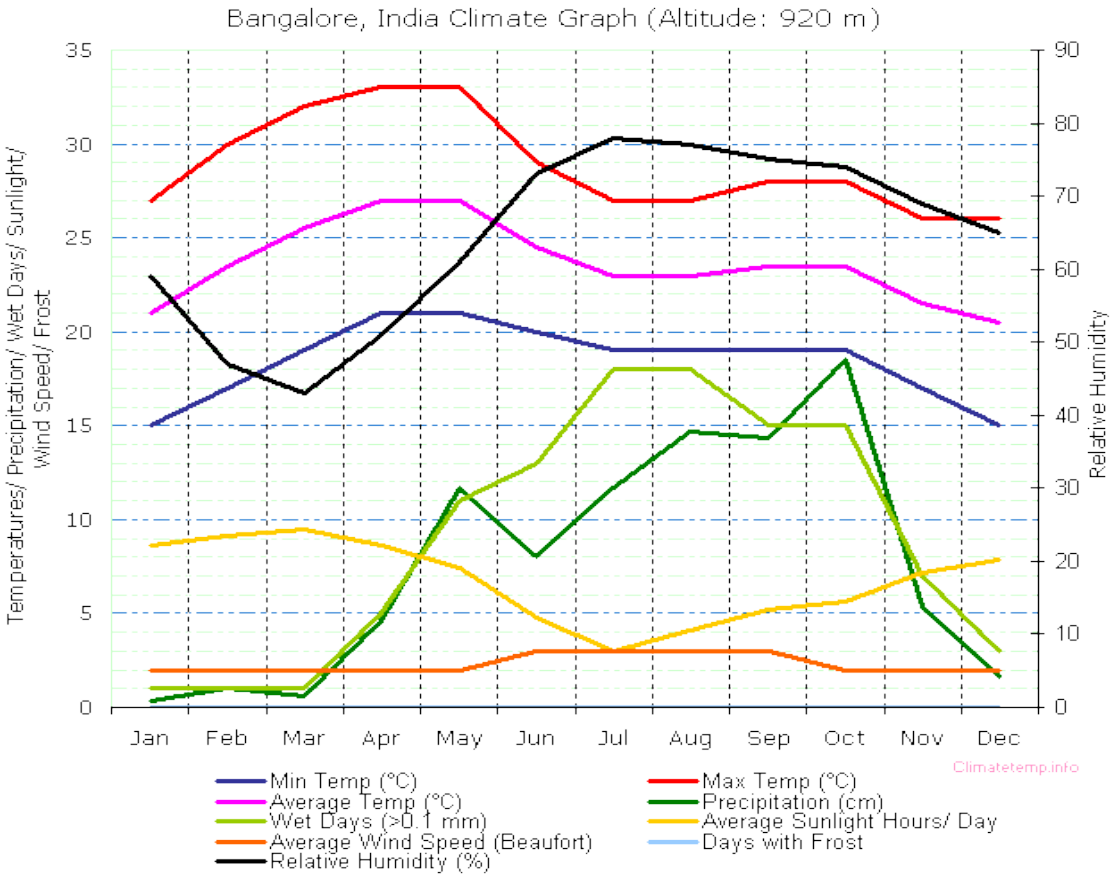
city, Bangalore is a major economic and cultural hub and the fastest growing major metropolis in India.

Bangalore lies in the heart of the Mysore Plateau (a region of the larger Precambrian Deccan Plateau) at an average elevation of 920 m (3,018 ft). It is positioned at 12.97°N 77.56°E and covers an area of 741 km^2.The majority of the city of Bangalore lies in the Bangalore Urban district of Karnataka and the surrounding rural areas are a part of the Bangalore Rural district. The region consists of the Bangalore Urban and Rural districts is known as Bangalore (region). The topology of Bangalore is flat except for a central ridge running NNE-SSW. The highest point is Vidyaranyapura Doddabettahalli, which is 962 m (3,156 ft) and lies on this ridge. Bangalore has a handful of freshwater lakes and water tanks, the largest of which are Madivala tank, Hebbal lake, Ulsoor lake and Sankey Tank. Vegetation in the city is primarily in the form of large deciduous canopy and minority coconut trees. Though Bangalore has been classified as a part of the seismic zone II (a stable zone), it has experienced quakes of magnitude as high as 4.5.

2.2 CLIMATE OF BENGALURU

Bangalore experiences a tropical savannah climate (Köppen climate classification) with distinct wet and dry seasons. Due to its high elevation, Bangalore usually enjoys a more moderate climate throughout the year, although occasional heat waves can make things very uncomfortable in the summer. The coolest month is January with an average low temperature of 15.1°C and the hottest month is April with an average high temperature of 33.6°C. The highest temperature ever recorded in Bangalore is 38.9 °C (recorded in March 1931) and the lowest ever is 7.8°C (recorded in January 1884).The monsoons begin in July and carry on till September. About 85% of the rainfall is recorded between 4 and 7 in the evening.

Figure 1: Climate of Bangalore

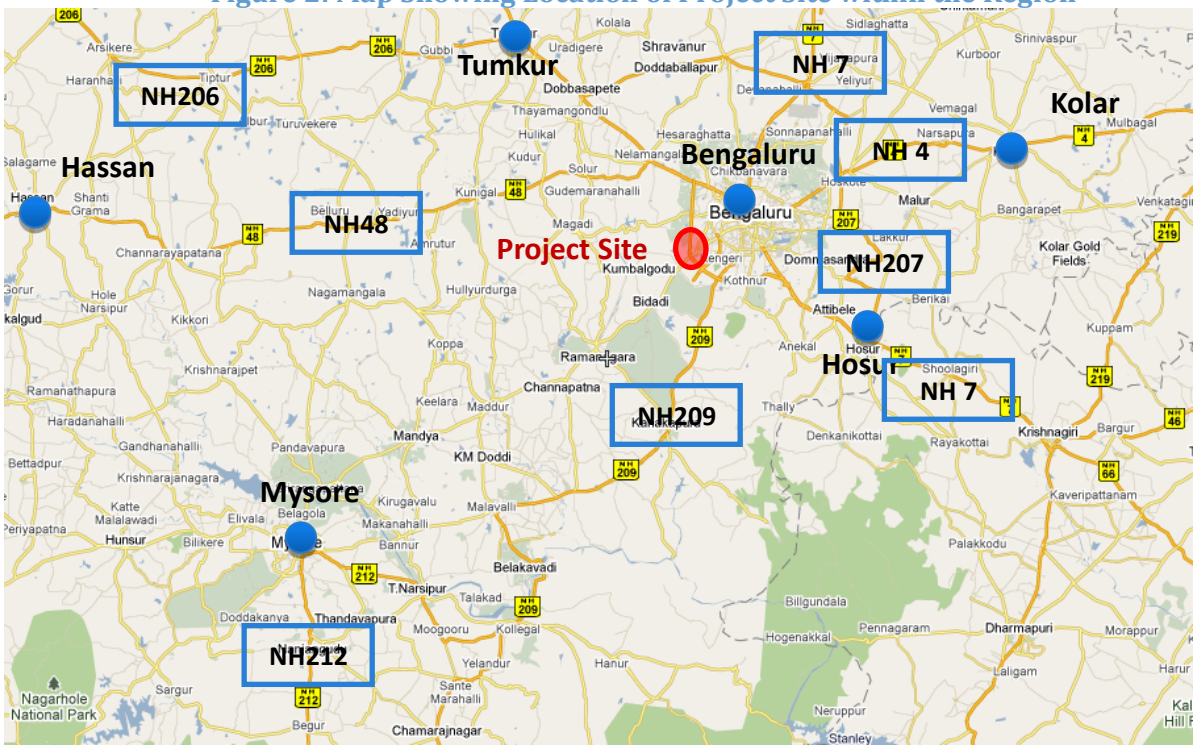


2.3 SITE LOCATION

Sri Nadaprabhu Kempegowda Layout is located at the Western to South Western fringes of Bangalore outside the jurisdiction of Municipal Corporation. Geographically, it is situated between Latitudes 12°59' 11.28" N & 12°53'15.71" N; and Longitudes 77°25' 47.88" E & 77°29' 06.70" E. It is spread across Kengeri Hobli in Bengaluru South Taluk and across Yeshwanthpura Hobli in Bangalore North Taluk. The total Site area as provided by the Bangalore Development Authority is 4043.87 Acres – Gunthas.

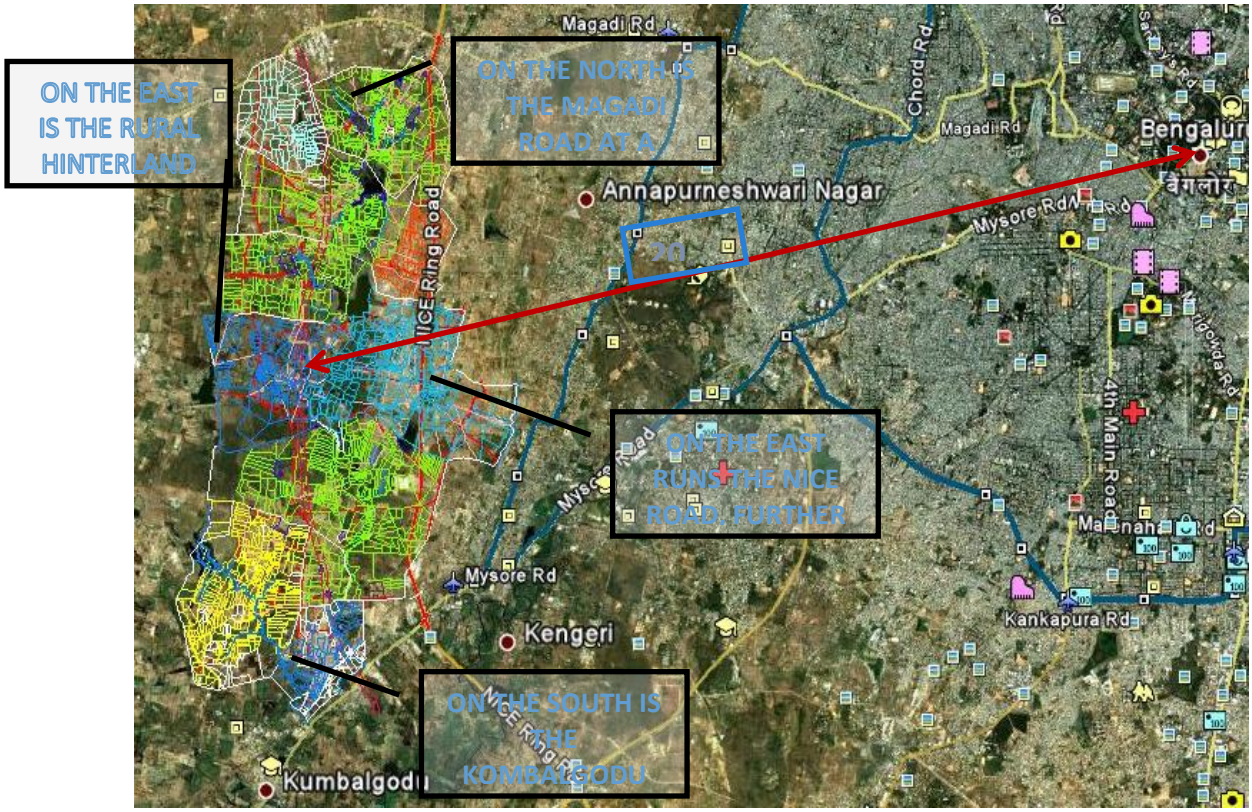
The Map below shows the site location in the Regional Context. Regionally more developments have taken place north of the Bangalore City. The site lying on the south east is located on the Bangalore Mysore corridor, which is the new development corridor promoted by the BDA.

Figure 2: Map Showing Location of Project Site within the Region



The Site is bounded on the north by Magadi Road at a distance of approximately 0.5 to 1 km from the site boundary. On the Eastern side the NICE road runs almost parallel to the site boundary at a distance of 1 Kms approximately. The old Bangalore Mysore state highway also runs along the east and south of the site. Further on the eastern side lies the entire city of Bangalore. At the southern side of the site is the Kumbalgod industrial estate.

Figure 3: Map Showing the Site Boundaries in Relation to Bangalore



2.4 SITE ACCESSIBILITY AND CONNECTIVITY

The Map showing the air and rail connectivity with respect to the project site is given below.

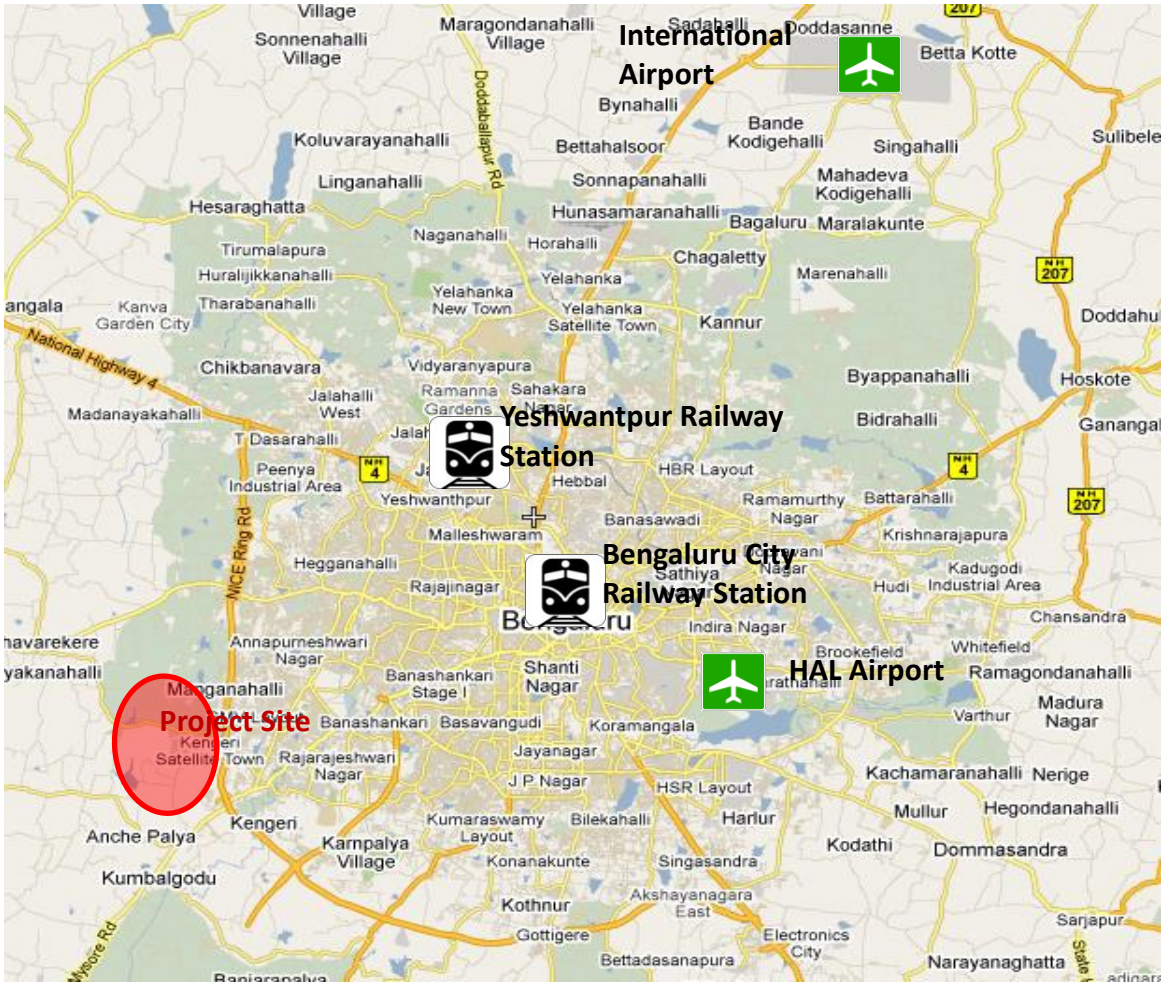
2.4.1 AIR

The Devanhalli International Airport is located at a distance of 50 Kms approximately from the Site. The Devanhalli airport is located on the northern fringes of Bangalore Region. There are shuttles which connect the International Airport to various locations near the city centre and the site can be accesses from the city centre by road transport both private and public. The erstwhile civil airport i.e. the HAL airport is located closer to the site at a distance of approximately 20 kms from the site.

2.4.2 RAIL

Two Railway Stations connect Bangalore to rest of India – Bangalore City Railway Station and Yeshwantpur Railway Station. Bangalore city railway station is approximately 15 Kms from site and Yeshwantpur railway station is at a distance of 20 kms from the site. The broad gauge line from Bangalore to Mysore passes near the southern edge of the site.
The railway stations are well connected to the site by a network of roads and can be accessed by means of private or public transport.

Figure 4: Map Showing Connectivity of the Site with respect to Bangalore



2.4.3 ROAD

The site is accessible through the Magadi Road at the north of the site through a local road. The site is also accessible through the old Bangalore Mysore state highway through a local connector which passes through Kengeri village and then passes under the NICE road to enter the site at the centre. The site can be accessed at its southern boundary again through a local connector from the Bangalore Mysore State highway.

The NICE road, an access controlled toll road, which passes along the eastern limits of the site, can also provide connectivity to the site in future. Further the proposed Major Arterial Road which is being developed by the BDA would provide a very good connectivity to site as it would pass longitudinally across the centre of the site.

2.4.4 PROPOSED BANGALORE METRO

The Proposed Bangalore Metro phase one is currently under construction and scheduled to be completed by year 2012. In this phase two intersecting diagonal lines from south west to north east Bangalore and south east to north-west Bangalore city. The total alignment currently is within the areas bounded by the Outer Ring Road. The map below shows the Map of Bangalore Metro Phase 1 Development.

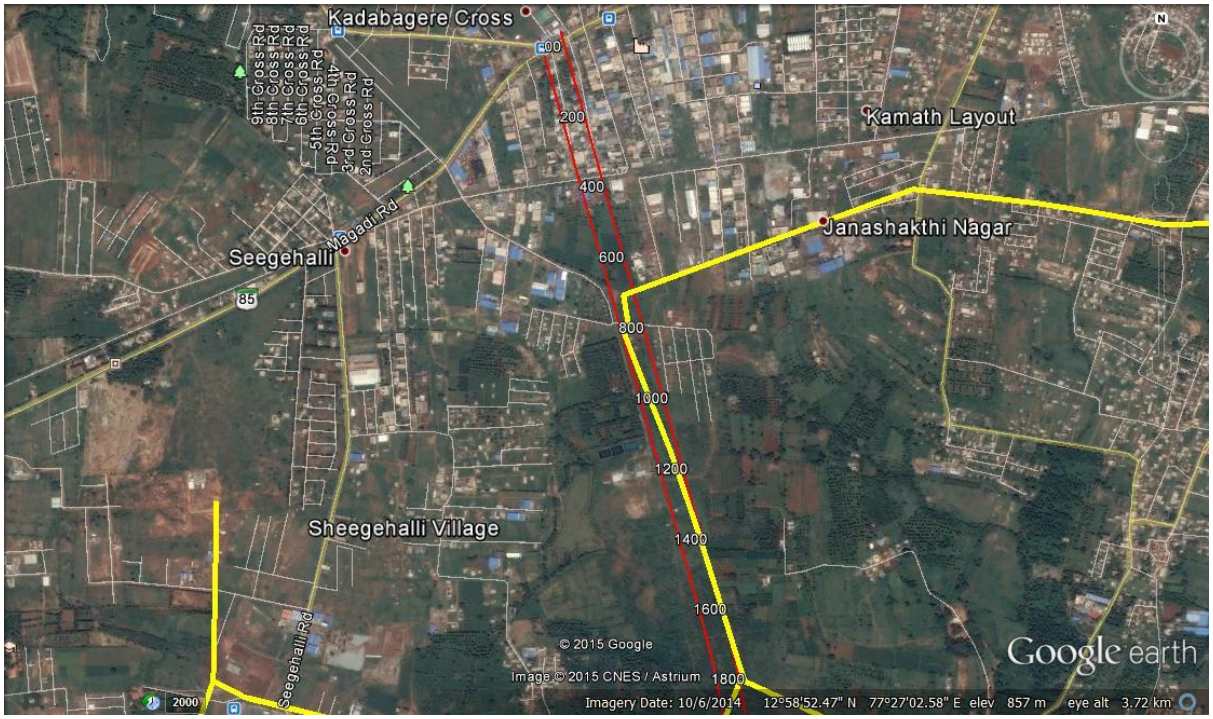
Figure 5: Map showing the proposed Bangalore Metro Rail Phase 1

The nearest station to the project site is the Mysore Road Terminals which would lie at a distance of 5-10 kms. In future phases the Metro may be extended along the Bangalore Mysore Road to provide improved connectivity to the project site.

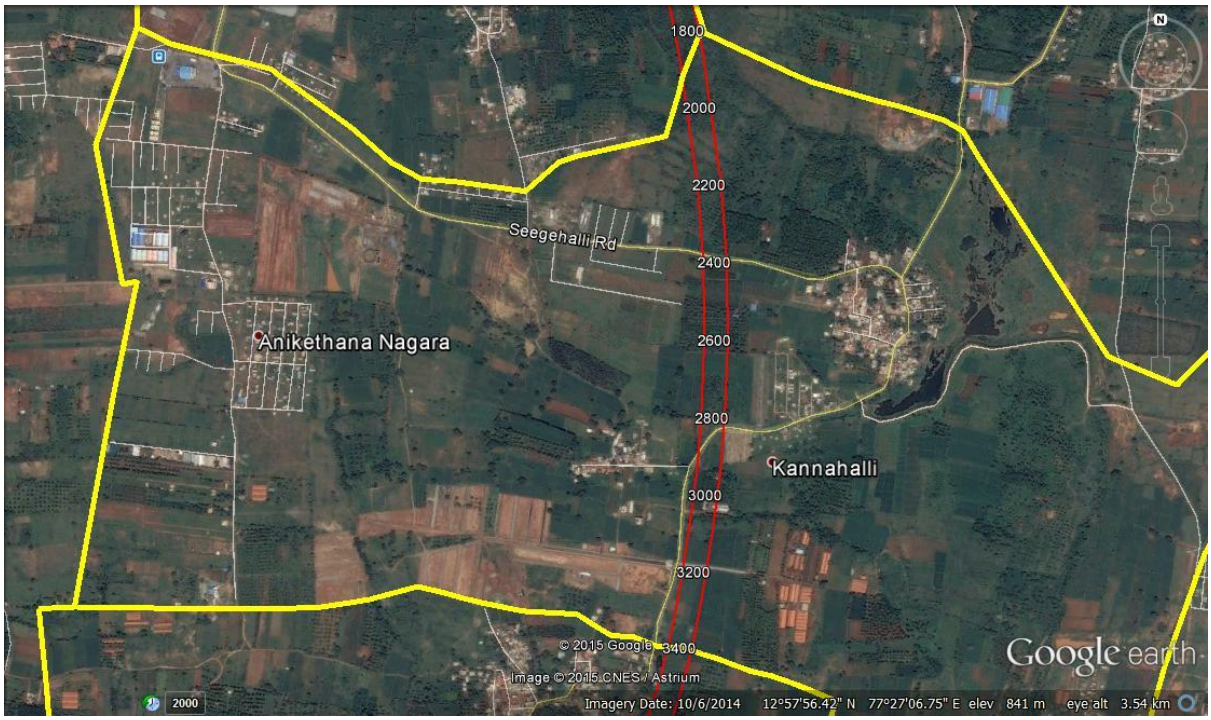
2.5 ALIGNMENT DESCRIPTION

Initial part of Major Arterial Road, after crossing over Magadi Road at Ch. 0+000 near Kamath Layout, passes through Sheegehalli Village as shown below admeasuring 1.8 Kms.

Alignment Crossing over Magadi Road at Ch. 0+000.

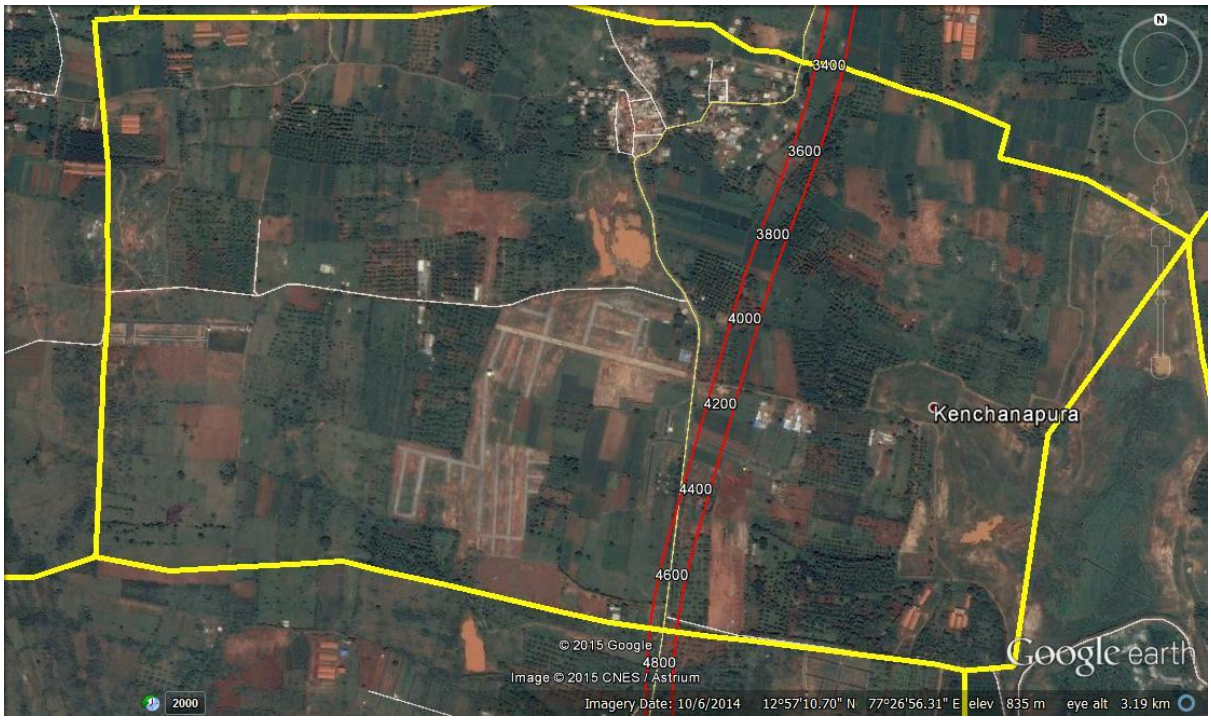


Thereafter alignment passes through Kanahalli Village as shown below admeasuring 1.6 Kms and crossing Seegehalli Road at Ch. 2+400 & 2+800.

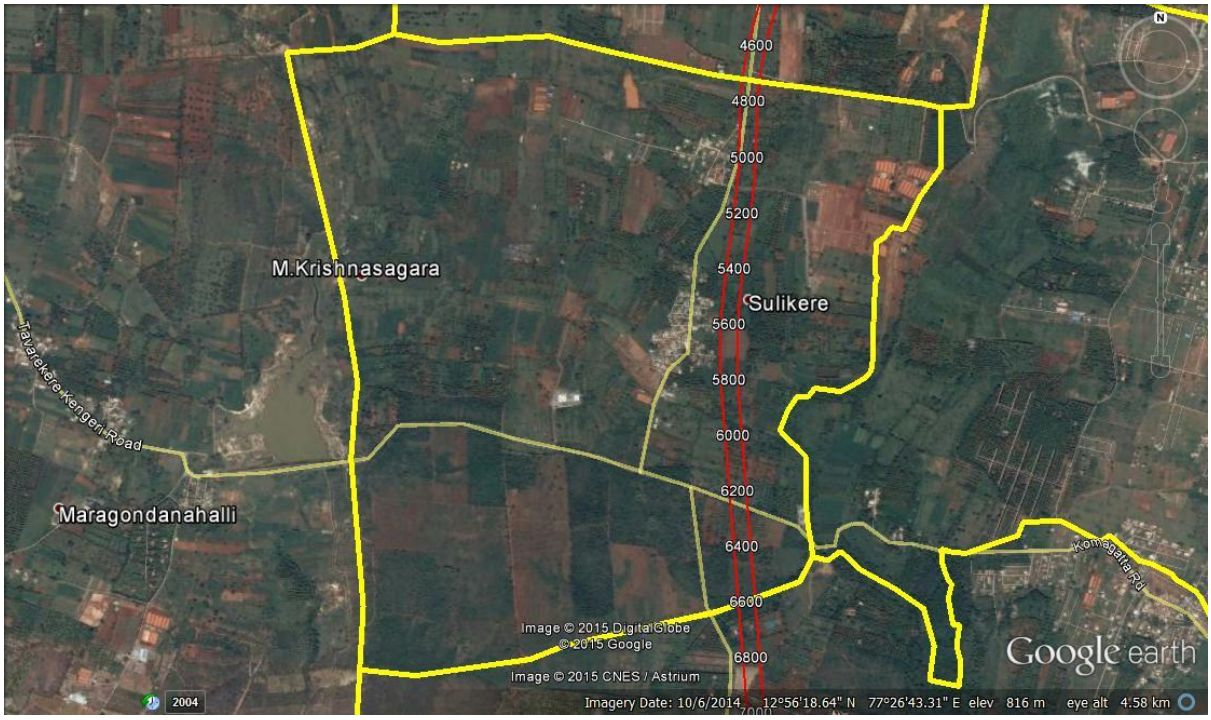


Alignment Crossing over Existing Road at Ch. 2+800.

Thereafter alignment passes through Kenchanapura Village as shown below admeasuring 1.3 Kms and crossing existing Road at Ch. 4+700.



Thereafter alignment passes through Sullikere Village as shown below admeasuring 1.9 Kms and crossing Taverekere Kengeri Road (MDR) at Ch. 6+250.

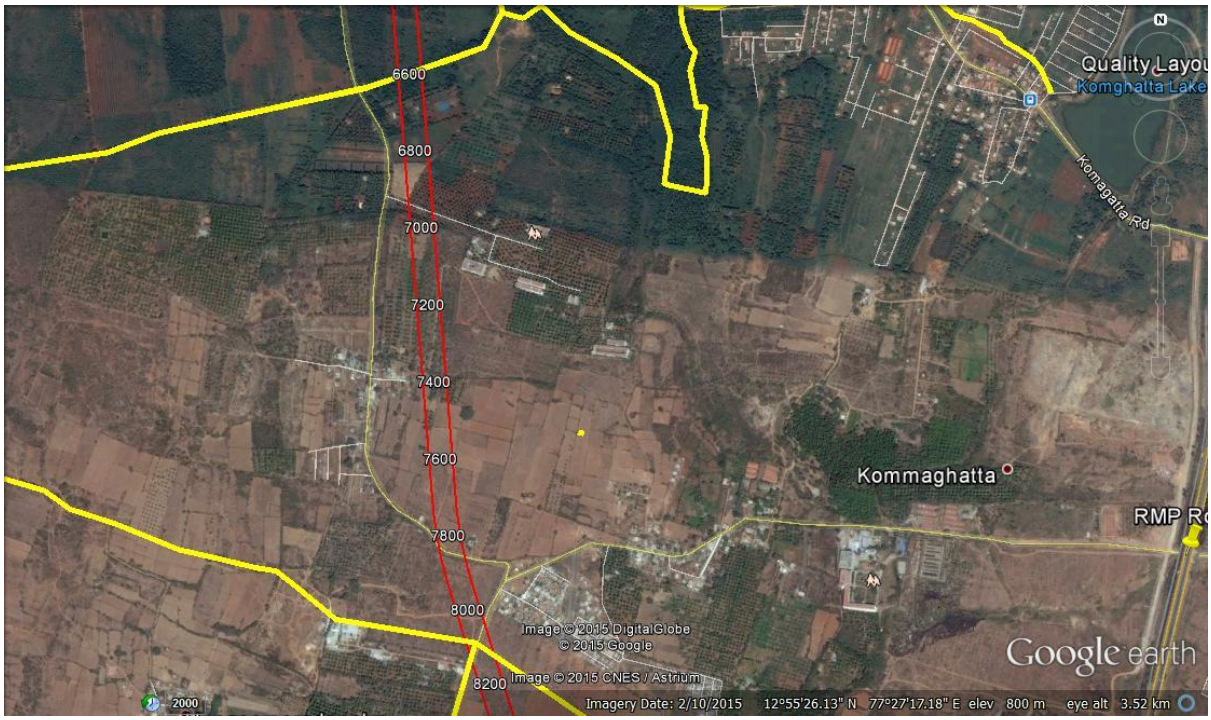


Alignment Crossing over Taverekere Kengeri Road (MDR) at Ch. 6+250.

Meanwhile expected crossings of existing nallah's have been identified over existing roads and details have been captured.

Expected crossings of existing nallah's over existing roads

Thereafter alignment passes through Kommaghatta Village as shown below admeasuring 1.5 Kms and crossing existing road at Ch. 7+850 and 8+100.



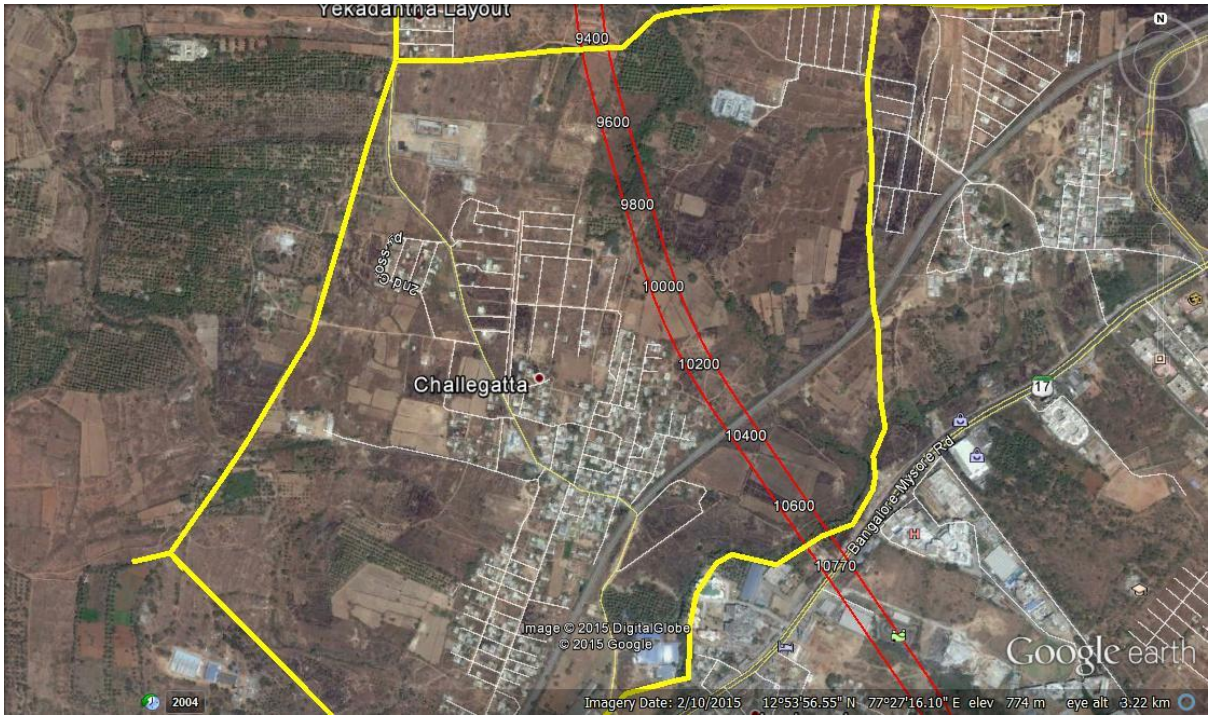
Alignment Crossing over existing road at Ch. 8+100.

Further alignment passes through Kommaghatta Krishnasagara Village as shown below admeasuring 1.3 Kms and crossing Extra High Tension Line at Ch. 8+700 and existing kuccha road at Ch. 9+000.

Alignment Crossing Extra High Tension Line at Ch. 8+700.

Alignment Crossing over existing kuccha road at Ch. 9+000.

Finally before terminating at Ch. 10+770 on Mysore Road, alignment passes through Challaghatta Village as shown below admeasuring 1.37 Kms and crossing Extra High Tension Line at Ch. 9+500.



Alignment Crossing Extra High Tension Line at Ch. 9+500.

Alignment terminating on Mysore Road at Ch. 10+770 beside Rajarashwari Medical College & Hospital.

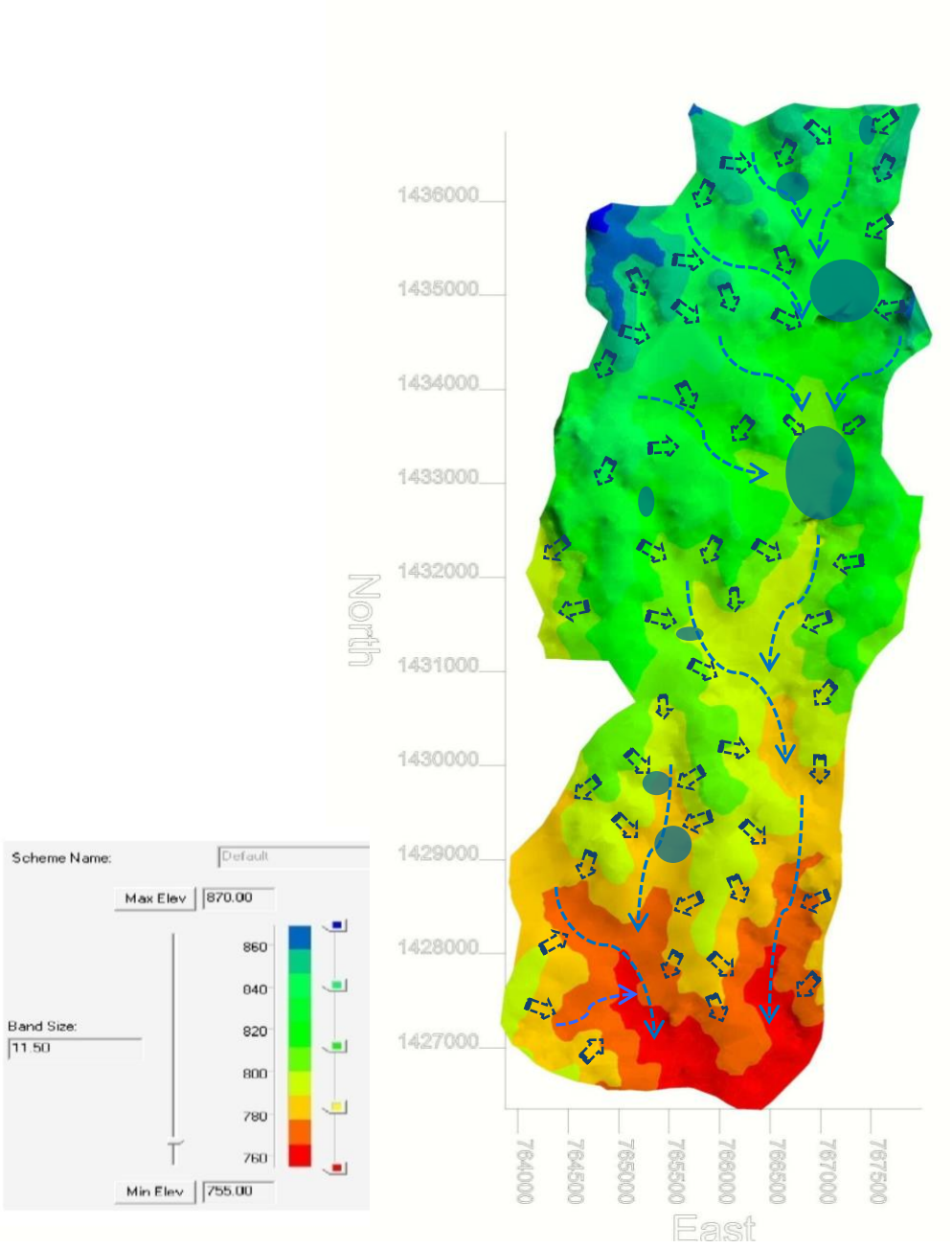
2.6 SITE ANALYSIS

The analysis of topography and existing land use will determine the suitability of the site and parts of site for development and land use and/or development allocations.

2.6.1 TOPOGRAPHY

The site has a slightly undulating profile with valleys/natural drains in between. The general direction of slope is from North West to South East. The slope is very gradual with the highest level being +860.0 Metre at the North West and the lowest level is +765.0 Metres at the South East.

Figure 6: Map Showing Slope Analysis for the site



The slope analysis diagram shown above is self-explanatory. The highest levels are represented by Blue colour and the lowest levels are depicted by Red Colour. The brown arrows show local flow direction from the ridges and the blue arrow show the general scheme of flow representing the valleys.

2.6.2 VEGETATION

The vegetation across the site varies from minimal at some sections to very dense at some sections. There are dense coconut plantations at locations within the site. The site also has forest areas bounding on the north and the eastern side. Major part of the site is sparsely planted or cultivated with pockets of human habitation.

2.6.3 SITE AREA AND VILLAGES INCLUDED

The project site is bounded by parts of 12 villages, which have been notified by the Bangalore Development Authority vide Notification (Final Notification) number" UDD MNX 2010 dated 18th February 2010".The preliminary notification was notified vide notification number BDA/COMMR/DC(LA)/ ALAO/158/2008-09 dated 21 May 2008.

Table 1: List of Villages Included Partly or Wholly Within the site

DISTRICT TALUK	HOBLI	VILLAGE NAME	ACRES-GUNTHA
BANGALORE DISTRICT – BANGALORE NORTH TALUK	YESHWANTHPUR	SEEGEHALLI	99.38
		KODIGEHALLI	453.25
		KANNELLI	413.13
		MANGANAHALLI	37.24
BANGALORE URBAN – BANGALORE SOUTH TALUK	KENGERI	KENCHANAPURA	250.38
		SULIKERE	318.14
		RAMASANDRA	391.14
		KOMMAGHATTA	721.34
		KOMMAGHATTA KRISHNASAGARA	154.12

DISTRICT TALUK	HOBLI	VILLAGE NAME	ACRES-GUNTHA
		BHEEMANAKUPPE	833.25
		CHALLAGHATTA	328.03
		BHEEMANAKUPPE RAMSAGARA	40.27

2.7 EXISTING LAND USE

The existing land use map had been provided by the Bangalore Development Authority in the form of spatial information data and maps.The Existing Landuse of the Site is predominantly residential. Landuse features of the site are given below:

- There are forest and agricultural areas near the north and west boundaries which have been excluded from the site.
- A large industrial area located in the north central part within the site boundaries, is excluded from the site area.
- There are numerous water tanks in the site, largely located in the northern part as can be seen in the landuse map.
- Numerous small parcels of denotified land fall within the site boundary marked by brown colour or brown hatches, which are excluded from the site. The entire site is not contiguous as a result.
- Village hamlets are also excluded from the site.
- Public and semi-public areas are excluded from the site area.
- A HT 400 KVA Line passes longitudinally through the site inbetween the Major Arterial Road and the eastern boundary. A 66 KVA line is also seen at the site which may in probability being used to provide electricity needs of current inhabitants

- The Major Arterial Road passes longitudinally through the site dividing the site into two halves. The Major Arterial Road has a ROW of 100Metre.
- The Bangalore – Mysore Railway line passes through the southern edge of the site.
- Pockets of land are currently being used for plantations and for cultivation.

The village wise landuse statement as calculated from the site landuse map is given below. The table includes notified as well as not notified areas. Not Notified areas fall within the site boundaries but are excluded from the site area for physical planning.

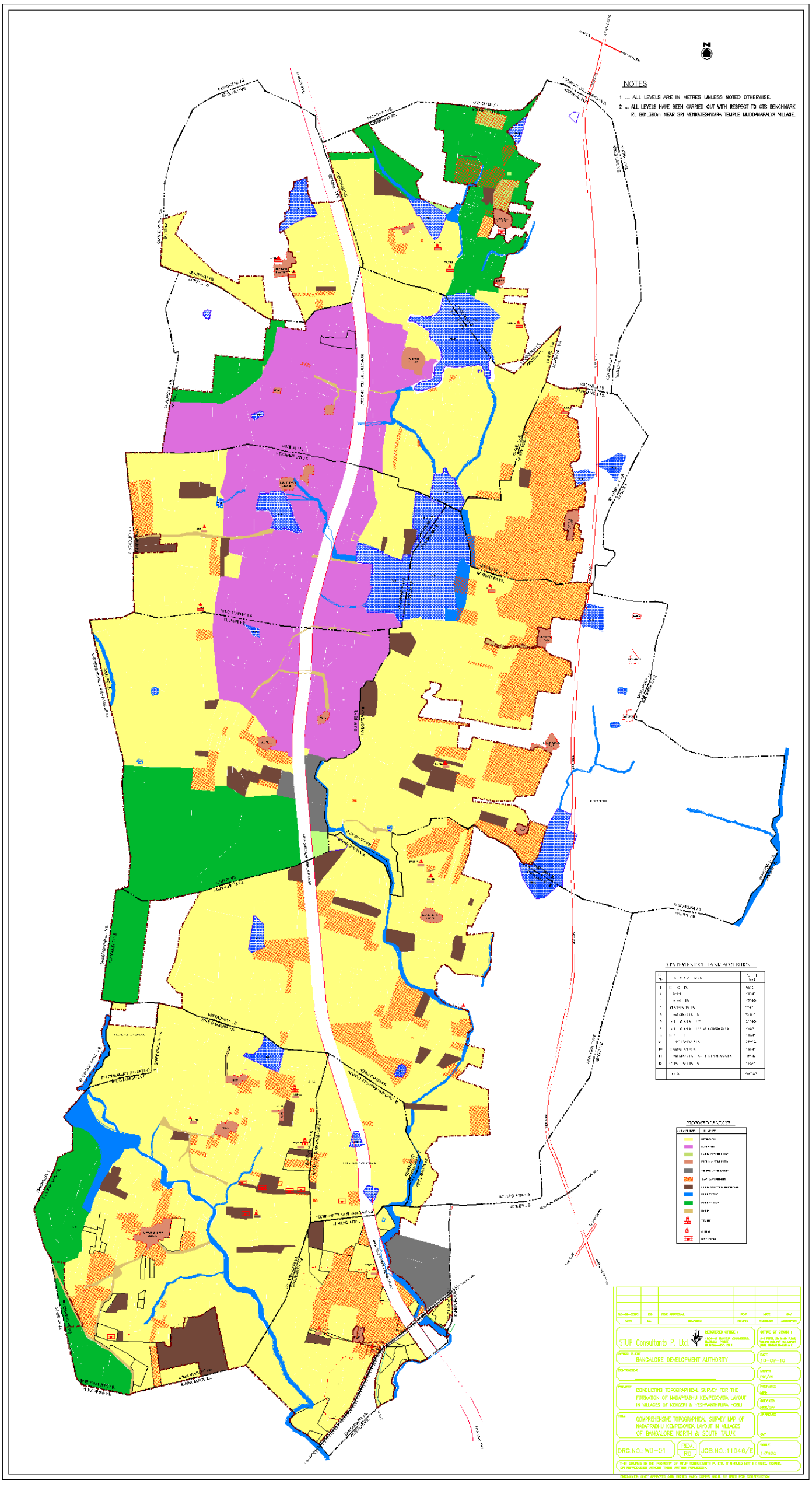
Table 2: Village wise Existing Landuse Statement for the site

S.No	Village Area	Village Area	Residential (includes Non Notified area)	Public Semi Public	Traffic Transport	Roads	Tank	Site Area as per Map	Site Area as per BDA Notification (A-G)
1	KANNELLI V.B.	911.69	309.21	79.78	0	2.63	64.83	**456.45**	**413.13**
2	SEEGEHALLI V.B.	534.48	137.24	21.25	36.54	0.87	14.82	**210.72**	**99.38**
3	BHEEMANAKUPPE V.B.	1233.76	1009.98	17.9	0	19.88	3.13	**1050.89**	**833.25**
4	KODIGEHALLI V.B.	993.92	168.86	75.45	0	0.75	31.01	**276.07**	**453.25**
5	KOMMAGHATTA V.B.	1732.87	903.86	9.51	0	0	0	**913.37**	**721.34**
6	RAMASANDRA V.B.	1610.88	677.73	9.35	1.91	6.62	131.59	**827.2**	**391.14**
7	SULIKERE V.B.	937.34	330.24	4.69	22.41	4.49	2.58	**364.41**	**318.14**
8	KENCHANAPURA V.B.	728.29	262.1	5.55	0	7.94	61.11	**336.7**	**250.38**
9	CHALLAGHATTA V.B.	500.13	347.49	3.24	47.36	0.58	0	**398.67**	**328.03**
10	MANGANAHALLI V.B.	359.12	214.59	5.01	0	0	36.9	**256.5**	**37.24**
11	KOMMAGHATTA KRISHNASAGARA V.B.	203.61	145.13	0	0	0	5.41	**150.54**	**154.12**
12	BHEEMANAKUPPE RAMSAGARA	56.44	32.19	0	0	0	0	**32.19**	**40.27**
	Total	9802.53	4538.62	231.73	108.22	43.76	351.38	**5273.71**	**4043 .27**

The total not notified area is equal to 789.88 acres which we need to deduct from residential land to arrive at notified residential area falling in the project area. Thus the residential area within the site comes to about 3748.74 acres.

The total project area comes to 4483.83 acres compared to 4043.27 acres as per revenue records and notification by BDA.

Figure 7: Map Showing Existing Landuse of the Site



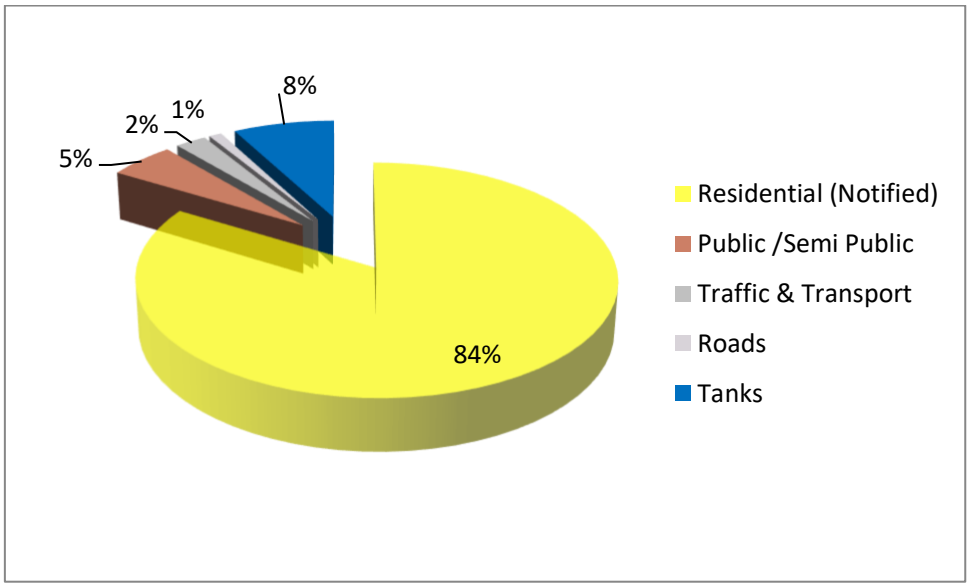
The gross landuse statement for the site is given below:

Table 3: Gross Existing Landuse Statement for the Site

Land Use	Area
Residential (Total)	4538.62
Residential (Not Notified)	789.88
Residential (Notified)	3748.74
Public /Semi Public	231.73
Traffic & Transport	108.22
Roads	43.76
Tanks	351.38
Total	**4483.83**

The percentage distribution of landuse is also given below:

Table 4: Chart Showing Percentage Distribution of Existing Landuse



2.8 SITE CONSTRAINTS

The project site is faced with various constraints which are bought out below.

- Project site is not contiguous. The Industrial area at the centre, the numerous not notified land parcels within the site boundary make the site disjointed and difficult for layout planning. In fact, the northern half above the industrial zone is virtually cut off from the southern half of the site due to such exclusions of land, industrial zone and other topographical features such as water tank.

- Site is longitudinally trisected. The Major Arterial Road passes longitudinally at the centre of the site. A little to the east the High Tension line crosses the site longitudinally. Both of these features divide the side into three distinct parts hampering an integrated and uniform layout.
- NICE Road which passes near the east boundary of the site. Being an access controlled Toll way, the connectivity to the site from NICE Road is currently not there acting as a constraint for the development of site.
- Infrastructure Provision for the township and its access by the not notified area will presenta contentious issue for cost sharing and revenue. A separate mechanism to charge the not notified area needs to be developed for provision and access of the township infrastructure e.g. betterment levy, one-time development charges etc.

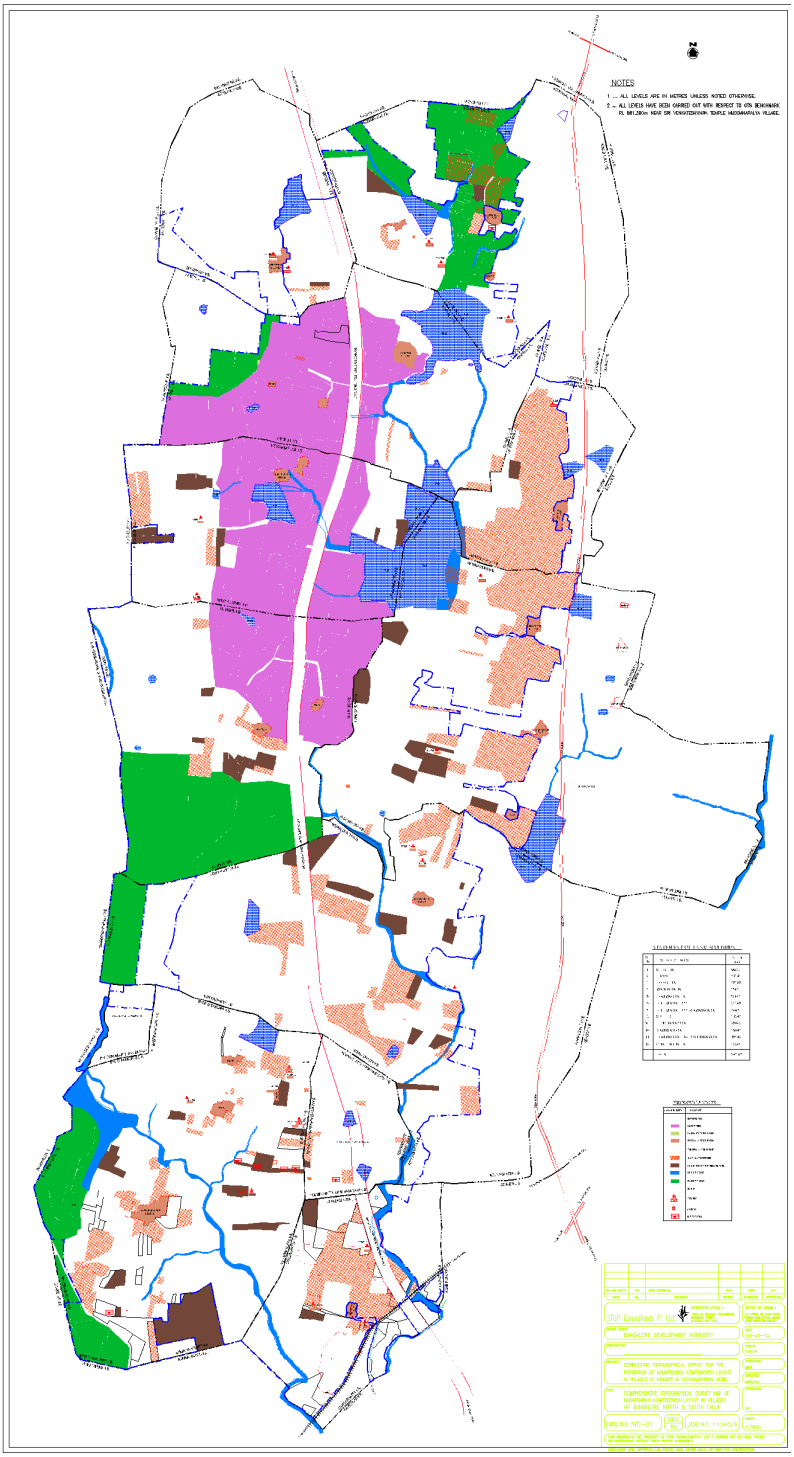


Figure 8: Map Showing All Constraints within the Site Boundary (Exclusions from Site Planning Area)

2.9 SITE POTENTIAL

The site has much potential which are listed below point wise:

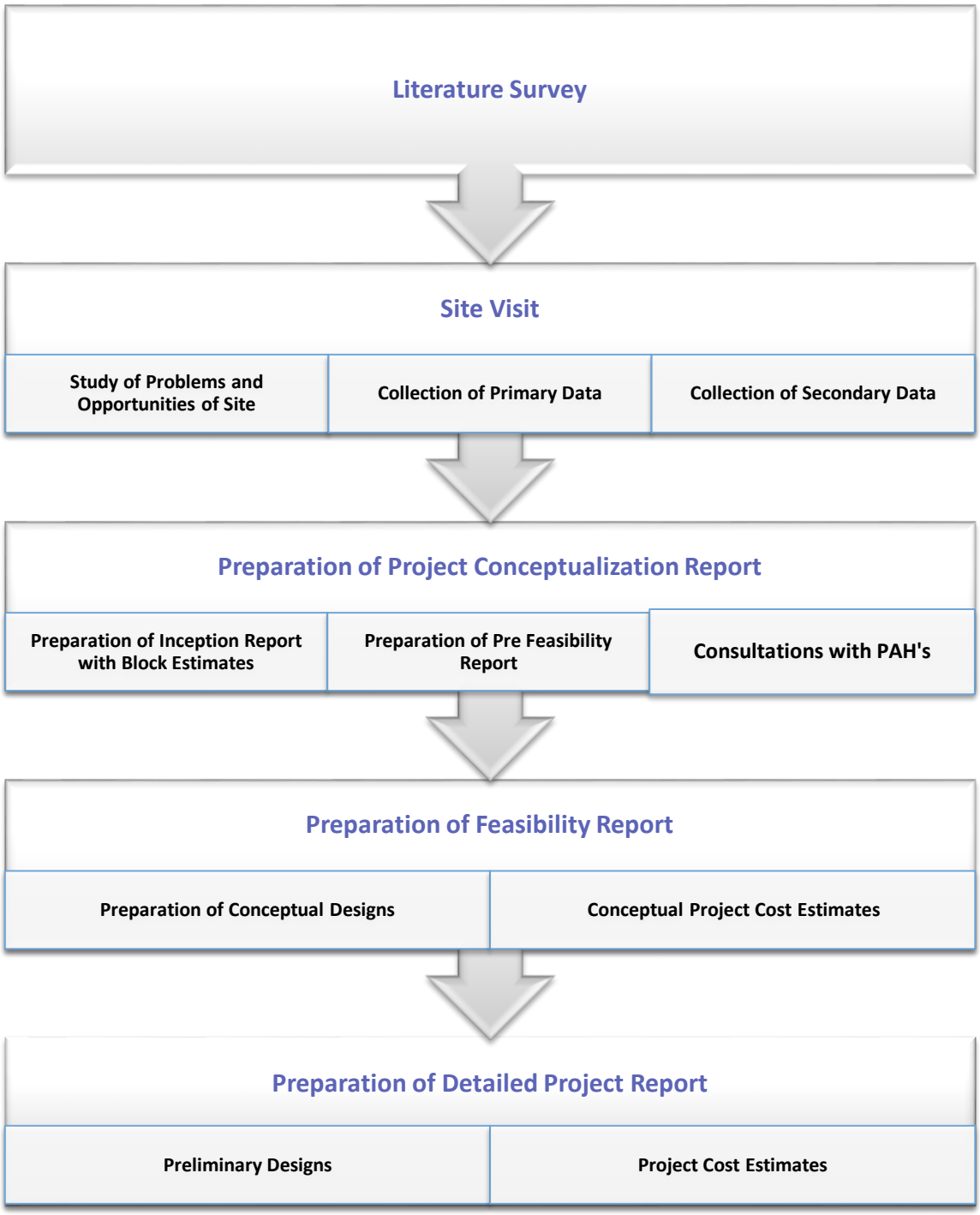
- The site has a large area, irrespective of the site being not contiguous, allows for a holistic development with the provision of internationally benchmarked infrastructure services.
- Presence of numerous water tanks and forest within the site area provides the site with opportunities to create natural design elements and spaces.
- The Major Arterial Road offers a wide area of the site with potential frontages which could be exploited commercially.

3 DETAILED ASSIGNMENT METHODOLOGY

3.1 PROJECT INITIATION

The project initiation stage involves the initial interactions, workshops with the authority to understand the project scope and the client viewpoint regarding the development. Team mobilization, resource mobilizations and methodologies for carrying out the assignment to its logical end are deliberated and frozen. Data required to fulfil the methodological inputs are listed to be collected.

The proposed methodology enables systematic planning, organizing and managing resources to meet the project objectives and bring about the successful completion of the project. The project methodology has been presented below:



In continuation to proposed aforesaid methodology, consultant has dividedthe consultancy services into following tasks but not limited to the following:

- Detailed reconnaissance.
- Review of all available reports and published information.
- Traffic studies including traffic surveys and demand forecasting.
- Inventory and condition survey of the road, if exist.

- Inventory and condition survey for bridges and culverts, if exist.
- Detailed topographical survey.
- Pavement investigations, if exist.
- Sub grade characteristics and strength of other materials for construction.
- Hydraulic & hydrologic investigations.
- Geotechnical investigations.
- Project costing and prioritization of segments.
- Preliminary engineering design and preparation of detailed project report.

3.2 RECONNAISSANCE

The available topographic maps, Coastal Zone Management Plans, GT sheets and photographs have been reviewed. Reconnaissance surveys have been carried to outline the procedure for the detailed investigations, to follow, identifying following:

- Topographic and physical features of the project and surrounding region, including environmental features.
- Traffic pattern and homogenous links.
- Preliminary inventory of pavement, carriageway type, bridges and structures, intersections, urban/congested areas.
- Requirements for conducting supplementary investigations.
- Extent of land available and additional requirements for widening.

3.3 DATA COLLECTION

Available data on the project road and socio-economic conditions of the project region has been collected from different organisations and reviewed. Then need to collect new and complementary data has been defined. This data includes inter alia:

a.) Physical characteristics and natural resources

- Location and Regional Setting
- Topography
- Climate
- Geology and Hydrology
- Inventory and condition reports of road, bridges and structures
- Affected structures and trees

- Traffic data - classified volume counts, turning movement counts, vehicle loading patterns
- Location of utility services
- Availability of construction-materials
- Details of sanctioned/ongoing works
- Survey and evaluation of locally available construction materials
- Type of Project clearances involved for implementation of project

b.) Demography & Economy

c.) Master Plan, Regional Plans

- Zoning
- Building Byelaws

d.) Socio Economic Profile

- Income
- Employment

e.) Real Estate Profile

- Residential
- Commercial
- Retail
- Hospitality

3.3.1 SURVEYS AND INVESTIGATIONS

3.3.1.1 INVENTORY & CONDITION SURVEY

An inventory of the project road has been carried out through dimensional measurement andvisual inspection. Features like chainage, terrain and land-use, railway crossings, utilities etc., have beenrecorded. Whereas visual condition survey was also carried out to obtain information on visual deficiencies and ongoing / recent improvements.

3.3.1.2 TOPOGRAPHIC SURVEYS

The topographical surveys have been carried out to capture the essential road, and ground features along the alignment in order to design and construct proposed project road. The

spot level data from the topographic surveys is available in (x, y, z) format. The output is available in WGS84-43N co-ordinate system.

3.3.1.2.1 BENCHMARKS

- Primary control points have been fixed with the help of DGPS along selected alignment (2 points at every 5 kms).
- Traversing was carried out with the help of total station.
- GTS bench marks have been shifted at every 200m c/c along the selected alignment.

3.3.1.2.2 LEVELING

This survey involves picking up of all surface features including but not limited to existing carriagewayand shoulder edges, ground features,drain top, drain bottom, foot paths, etc. for the specified corridor width of 40mts. The survey also covers major and important features, if any, within 10mts of the RoW. At important road junctions and railway crossings, small streams and nalas survey extend up to 250 mts. on either side. Total stations were used for this purpose.

3.3.1.2.3 MANMADE FEATURES

Location of any sort of manmade feature (over or/and under the ground) like structures, OFC lines, signal lines, sewer line, water line, telephone poles, electric poles, high-tension lines, fence line, boundary walls, bore wells, hand pumps etc. have also been collected through Total station. At locations where HT lines cross the project corridor the height of crossing of the lines for the entire Right of Way width was also captured. The details are presented below.

Ch. From	Ch. To	Features affected
0	650	26 STRUCTURES
650	700	FENCING
750	800	POWER LINE, FENCING
800	850	STRUCTURE
850	900	STRUCTURE, POWER LINE
950	1000	FENCING, C WALL
1050	1100	POWER LINE
1300	1350	FENCING
2250	2300	POWER LINE

2300	2350	FENCING
2350	2400	HTL, POWER LINE,FENCING, CULVERT
2600	2650	FENCING
4650	4700	POWER LINE, DRAIN LINE
4700	4750	FENCING, POWER LINE
4750	4800	FENCING, POWER LINE
4800	4850	FENCING, POWER LINE
4850	4900	FENCING, POWER LINE
4900	4950	2 STRUCTURES,FENCING, POWER LINE
4950	5000	FENCING, POWER LINE
5000	5050	C WALL, FENCING
5050	5100	FENCING
5100	5150	FENCING, POWER LINE
5600	5650	FENCING
5700	5750	FENCING, POWER LINE
5750	5800	FENCING
5800	5850	POWER LINE
6250	6300	FENCING
6300	6350	FENCING
6650	6700	STRUCTURE, POWER LINE, WATER TANK
7000	7050	FENCING
7050	7100	FENCING
7100	7150	FENCING
7150	7200	FENCING
7200	7250	FENCING
7350	7400	POWER LINE,FENCING, WATER TANK,STRUCTURE
7400	7450	STRUCTURE, WATER TANK, POWER LINE
7450	7500	FENCING
7500	7550	FENCING
7700	7750	POWER LINE, FENCING
7800	7850	DRAIN LINE, FENCING
8000	8050	FENCING
8050	8100	DRAIN LINE, FENCING

8100	8150	POWER LINE
8150	8200	POWER LINE
8700	8750	HTL
9200	9250	FENCING
9300	9350	FENCING, BUILDING
9350	9400	3 STRUCTURES, WATER TANK
9400	9450	POWER LINE,FENCING, STRUCTURE
9500	9550	HTL
9650	9700	POWER LINE
9700	9750	DRAIN LINE
9900	9950	POWER LINE
10200	10250	COMPOUND WALL,STRUCTURE
10300	10350	COMPOUND WALL
10350	10400	CULVERT
10450	10500	WATER TANK
10500	10770	3 STRUCTURES

3.3.1.2.4 TREES

Location of individual tree having girth width of more than 0.3m coming within the proposed right of way.

There are about 578 trees having girth width of more than 0.3m coming within the proposed right of way.

3.3.1.3 GEO-TECHNICAL INVESTIGATIONS AND SUB-SOIL EXPLORATION

Geo-technical investigations and sub-surface explorationshave been carried out for the proposed bridges / road over bridges/ tunnels/viaducts/interchangesetc., along high embankments and any other location as necessary for properdesign of the works and relevant laboratory tests were alsoconducted and results are presented below.

Location	**Soil Classification**		**Modified Compaction Characteristics**		**Soaked CBR Value (%)**
	I.S.	**H.R.B.**	**OMC (%)**	**MDD (g/cc)**	
1	SC	A-2-4(0)	12.2	2.04	8.0
3	SC	A-5(2)	13.7	1.94	6.0
10	SC	A-2-4(0)	10.7	2.02	9.0

14	SC	A-2-6(1)	11.5	1.99	9.0
21	SC	A-6(4)	14.2	1.92	4.0

Based on Report on the C.B.R. and Compaction Test performed at proposed Nadaprabhu Kempegowda Layout, the average 4 day C.B.R. value along the major arterial is determined as 7%.

3.3.1.4 MATERIAL INVESTIGATION

Material investigations for the project road werepursued with the following broadobjectives:

- Assessing the quantity, quality, suitability and costs of available construction materials for various road and structure works, commensurate with their specification requirements. Preparation of item wise specifications based on test results and other design requirements.
- Determining suitability of available soil and materials along the proposed alignment corridor for their probable use as sub-grade or other construction purposes.

Sources of construction material are identified along with their quantity and suitability for construction and presented below. Suitable excavated material along the proposed alignment will be used for embankment, sub-grade & other construction purposes.

Sr. No.	Construction Material	Source Identified	Location from Project Site
1	Aggregates	Bidadi (Mathurayaswamy Crusher, Chowdeshwari Crusher)	30 kms
2	Manufacture Sand	Bidadi (Mathurayaswamy Crusher, Chowdeshwari Crusher)	30 kms
3	River Sand	Maddur, Malavalli	120 kms
4	Bitumen	Mangalore Refineries	380 kms
5	Murum	Excavated material	-
		Bidadi & Magadi Road	30 kms

3.3.1.5 HYDRAULIC AND HYDROLOGIC INVESTIGATIONS

The hydrological and hydraulic studies were also carried out in accordance with IRC Special Publication No. 13 (“Guidelines for the Design of Small Bridges and Culverts”) and IRC: 5-

1998 ("Standard Specifications & Code of Practice for Road Bridges, Section I General Feature of Design").

A desk study of available data on topography (topographic maps), storm duration, rainfall statistics, top soil characteristics, vegetation cover etc. was carried out so as to assess the catchments areas and hydraulic parameters for all existing and proposed drainage provisions. The findings of the desk study were further supplemented and augmented by a reconnaissance.

Hydraulic & Hydrologic investigations and design of CD works ad Road-side Drains are detailed out in subsequent chapter of this report.

4 TRAFFIC SURVEYS, ANALYSIS & FORECASTING

4.1 GENERAL

This chapter discusses past planning studies carried out for Bengaluru & its impact on development of Major Arterial Road. Chapter also present travel demand forecasting on Major Arterial Road.

Following are planning & policy documents which impact the road network:

- Comprehensive Traffic & Transport Plan for Bangalore (CTTP, 2007).
- Bangalore Master Plan – 2015, Volume I – Vision Document.

4.2 PAST PLANNING STUDIES

4.2.1 COMPREHENSIVE TRAFFIC AND TRANSPORATION PLAN FOR BENGALURU

A comprehensive Traffic and Transportation Plan for Bengaluru was prepared by the Karnataka Urban Infrastructure Development and Finance Corporation to study the transportation characteristics of the entire Bangaluru Metropolitan Region and to provide Long Range planning for Transportation for the horizon period of 2025. The CTTP study forms an important part in the development of the transport proposals for Bangaluru. Hence this chapter highlights and brings out the salient features of the CTTP study.

The objectives of the study were following:

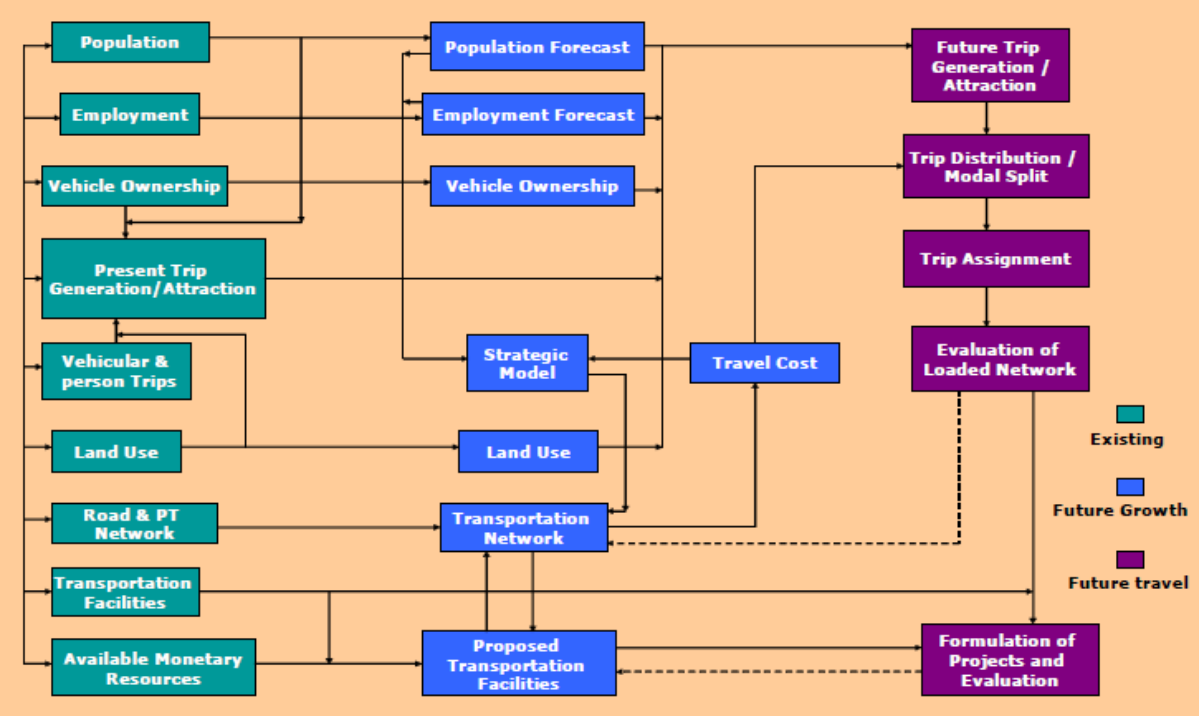
- Identify travel pattern of residents of the local planning area of Bengaluru which is co-terminus with the territorial jurisdiction of Bengaluru Development Authority (BDA);
- Select, develop and operationalise an Urban Transport Planning model using state of the art modeling techniques and software package, appropriate to the conditions and planning needs of the study area;
- Assess the relevance of the existing strategy, identify the consequences of pursuing alternative transportation strategies and recommend / update a long – term comprehensive transportation strategy for the study area up to 2025 (2015 and 2025);

- Identify for all modes, a phased program of appropriate and affordable investments and policy proposals; and also integration of various modes of mass transits.
- Help strengthen transport planning skills, and transfer all data, planning model/tools and knowledge obtained through the study to KUIDFC and other agencies such as BDA, BMTC, KSRTC, South Western Railway, BMRTL, Traffic Police, etc.
- Strategize transport policy as an integrate part of urban planning
- Recommend institutional mechanism for inter-agency co-ordination
- Assess existing infrastructure and forecast requirement - short term and long term.

In this regard, following activities had been performed:

- Collection of household, land use, and travel demand data;
- Development and operation of an urban transport model;
- Formulation of transport strategy and institutional mechanism;
- Identification of a phased program of transport investments and management proposals; and
- Training and knowledge transfer to the concerned agencies.

The adopted study methodology to achieve the set objectives and scope is given below.



Major Arterial Road is accorded Highest Priority in Comprehensive Traffic & Transportation Plan (CTTP) and Master Plan – 2015 prepared for Bangalore with provision of High Capacity BRT System and Cycle Tracks.

Major Arterial Roadwill be further connected with 15m/18m/24m/30m wide east west RMP connectors at 6 locations to improve the accessibility from local streets.

A traditional four stage travel demand modelling approach was adopted in the study. Trip generation, trip distribution, mode-split and assignment models were developed after thorough validation of the demand matrices assessed from HIS and other surveys/ studies. Six purposes (Home based work office, home based work industry, home based work others, home based education, home based others and non-home based) and seven modes (Sub-urban train, metro, bus, auto, taxi, car and two-wheeler) are considered. The region Traffic Analysis Zones (TAZs) for travel demand analysis. The software used for travel demand modelling and network analysis is Equilibria Multimodal Equilibrium (EMME), which is used in more than 70 cities across the world.

Travel demand analysis is carried out for the base year (2005) using the data analysed from the primary and secondary studies to establish the following:

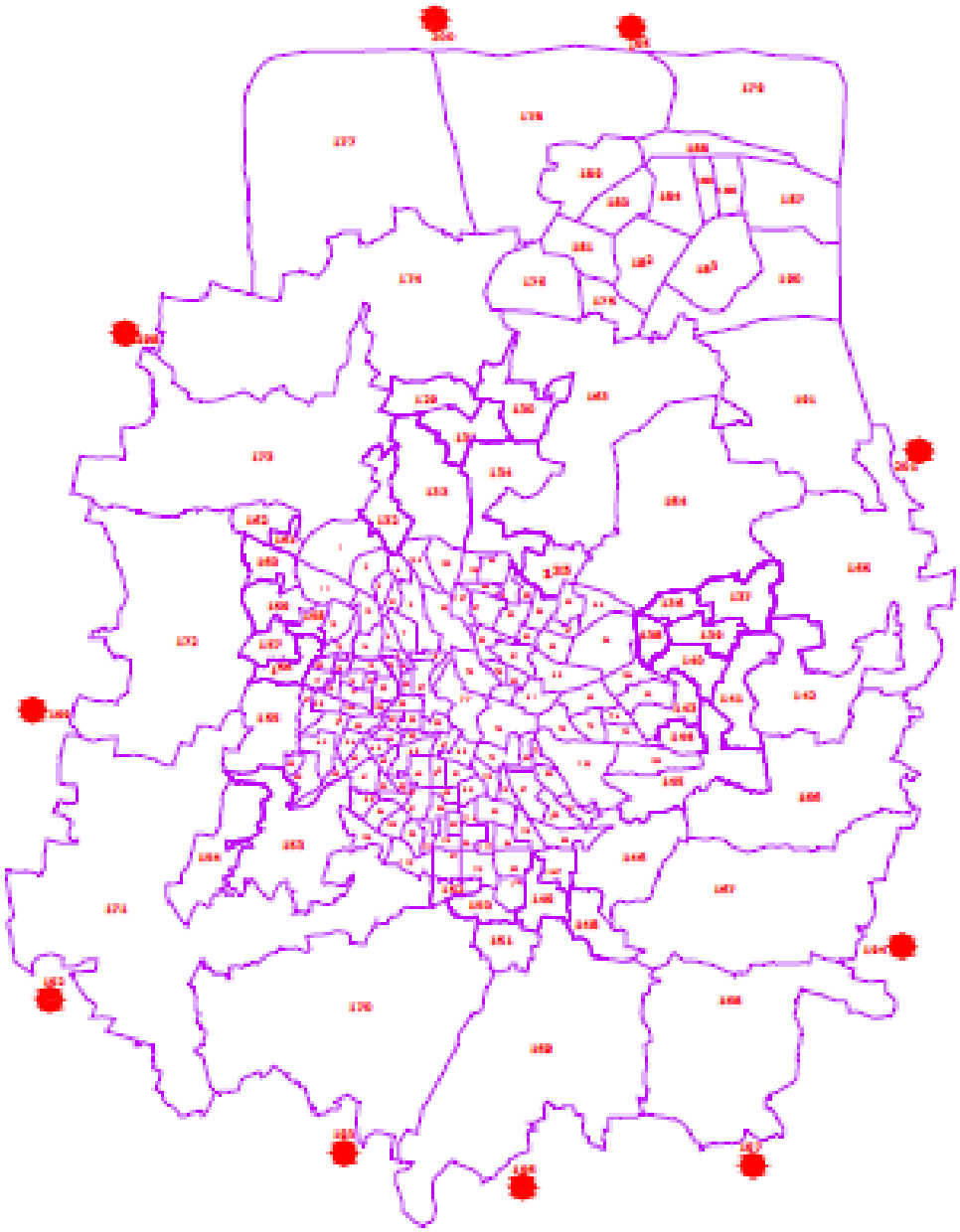
- Travel characteristics;
- Socio-economic characteristics;
- Performance of the existing transportation system; and
- Calibration and validation of the travel demand models.

For analysis of travel demand, the day is divided into four time period, two peak periods (morning, 6:00 to 11:00 hrs. and evening, 17:00 to 23:00 hrs) and two off-peak periods (day time off-peak, 11:00 to 17:00 hrs and night time off-peak, 23:00 to 6:00 hrs).

Travel demand models are developed for the two peak periods i.e. morning and evening. Daily travel demand is assessed using Home Interview Survey (HIS) and other primary surveys. The morning peak period models were used in the analysis of alternative growth scenarios, identification of transport network requirements and the assessment of alternative transportation strategies. The morning peak period was chosen because the heaviest peak hour demands on the public transport systems occur at that time three progressive traffic zone definitions were established which were used for different purposes at various stages of data base development and analysis. The base year transport networks are prepared using the digitised detailed road network inventory and independent data collection on suburban rail system from railway authorities and bus routing and schedule information provided by the bus operators. Socio economic parameters for the 2005 base year are established for the different zoning system using the

2001 population census data adjusted to the 2005 base year, for expansion of the sample home interview surveys

Figure 9: Map Showing Zoning as per CTTP 2005



Trip end, trip distribution models have been developed for six purposes –

- home based work office;
- home based work industry;
- home based work others;
- home based education;
- home based others; and

- non home based.

For each purpose, mode-choice models are developed considering car/two wheeler (private vehicle modes), auto/taxi (IPT modes), bus/train/metro (public transport) modes. Using the primary survey data from road network inventory, speed-flow surveys, intersection flow-delay surveys, workplace surveys, secondary studies, assignment models/parameters are developed/ compiled. Further validation of travel demand, models is carried out to ensure the ability of the travel demand models to replicate the travel pattern of the base year.

The travel demand models are used for the estimation of passenger travel demand and assessment of transport network requirement for various horizon years. These models provide the basis for internal travel demand only. The external travel demand (passenger and goods vehicles) has been estimated separately by applying growth factors based on historical data and assessment of economic growth forecasts of external catchment area.

4.2.1.1 LONG TERM TRANSPORTATION STRATEGIES

Each of the scenarios was analyzed by a separately established model with the land use distributions being the major discriminating variable. Based on the controlling population and employment levels discussed earlier, population and employment distributions were allocated to each of the traffic zones. Individual traffic forecasts were generated by trip purpose and by trip mode. These forecasts were aggregated for vehicles (private vehicles, IPT modes and goods vehicles) on a PCU (passenger car unit) basis and for public transport on a person trip basis. The internal demand has been estimated using identical trip generation and distribution criteria including uniform trip time distributions and mode choice relationships. Mode choice at this phase was largely governed by mode choice/trip distances relationships for each trip purpose, based on the observed data for 2005. In effect, this maintained the predominant public transport mode of travel since the private car has currently a very small component of travel market and opportunities to expand the road capacity in existing urban areas are very limited.

Rigorous analysis of outputs from the model after following the above procedure has been carried out and scenario-wise and mode-wise person trips and mode split for horizon year.

4.3 TRAVEL DEMAND ANALYSIS &FORECASTING

Transportation forecasting is the process of estimating the number of vehicles or people that will use a specific transportation facility in the future. For instance, a forecast may estimate the number of vehicles on a planned road or bridge, the ridership on a railway line, the number of passengers visiting an airport. Traffic forecasting begins with the collection of data on current traffic. This traffic data is combined with other known data, such as population, employment, trip rates, travel costs, etc., to develop a traffic demand model for the current situation.

A thorough understanding of existing travel pattern is necessary for identifying and analyzing existing traffic related problems or projecting future traffic on a link. Detailed data on current travel pattern and traffic volumes are needed also for developing travel forecasting/prediction models. The prediction of future travel demand is an essential task of the long-range transportation planning process for determining strategies for accommodating future needs.

The transportation planning process relies on travel demand forecasting, which involves predicting the impacts that various policies and programs will have on travel in the urban area. The forecasting process also provides detailed information, such as traffic volumes, bus patronage, and turning movements, to be used by engineers and planners in their designs. A travel demand forecast might include the number of cars on a future freeway or the number of passengers on a new express bus service.

There are several different techniques for travel demand forecasting from which to choose, depending on the requirements of the analysis. These techniques differ in complexity, cost, level of effort, sophistication and accuracy, but each has its place in travel forecasting. The most popular and the traditional method for travel demand forecasting is the 4 - step Transportation Model. However this model is generally used for a city or a part of the city town with multiples links and nodes. The various options of models for forecasting are given below:

- Static Models: Static models reflect traffic volumes on the basis of link flows. Such models do not attempt any route assignment, and hence are only applicable for small networks where no change in traffic flows will result from a proposed scheme;

- Assignment Models: Assignment Models which allocate demand matrices through traffic networks, thereby replicating route choice by vehicles for each origin-destination pair; and
- Variable Demand Models: Variable Demand Models, which replicate demand responses where they might be expected as a result of a scheme, for example in larger towns and cities with congested road networks. These demand responses considered here comprise changes in trip rates, choice of destination and travel mode.

There are different levels of planning directed to different types of problems. The terminology for these levels of planning and analysis varies according to the context. For example, the expressions 'micro', 'meso', and 'macro' are sometimes used to describe the level of detail or the size of an area used for an analysis. Similarly, the expressions 'site specific', 'corridor', and 'areawide' or 'metropolitan' are used to describe variations in the scope of a problem.

The approach and techniques for analyzing and forecasting travel would vary according to the level of analysis. Even for a particular level of analysis, the techniques may have to be adjusted to match the constraints of available data and manpower.

4.4 OBJECTIVES & APPROACH TO STUDY

The objective of the study was to determine travel demand forecasting for the Major Arterial Road. The Major Arterial Road does not exist as of today and hence it presents a difficulty as to the technique and methodology to be adopted for the forecasting.

The Major Arterial Road is an arterial corridor which shall cater primarily to the internal traffic needs of the residents and as well as to inter regional travel in near future especially from Magadi Road & Mysuru Road.

Though transport modelling is an option and also one of the most accurate methods for the traffic forecasting, it is one of the most detailed, data driven and time consuming methods. Since the study scope is limited to the traffic forecasts of Major Arterial Road only, a specific study based on existing traffic patterns and travel preferences have been utilised for the study.

4.5 MEASURING EXISTING TRAVEL

Detailed information on existing travel is needed for two purposes –

- Analysing existing problems, and
- Developing mathematical models for forecasting travel.

A variety of surveys can be performed for gathering information related to existing travel demand. However, travel surveys are expensive, and, therefore, care must be taken to identify the types of information that really would be useful for specific purposes, and then the most suitable procedures should be selected for gathering the information. Sampling techniques are useful, and adequate time and care must be devoted to developing sampling procedures. There are several different types of survey techniques, some of which are suitable for automobile travel, some for transit travel, and some for general passenger movement. Survey procedures for freight vehicles and commodity movements may be very different in certain respects from those of passenger travel

Since travel demand varies during a given year according to the season (or month of year) and day of week, a decision must be made carefully to select a specific time frame or reference for surveys. For urban transportation studies it is a common practice to develop travel demand information for an average weekday in the 'autumn/winter' season.

4.5.1 ORIGIN DESTINATION SURVEY

The origins and destinations of trips along with some other characteristics such as trip purpose and mode of travel can be determined in different ways:

- Home interviews (for internal travel).
- Roadside interviews at cordon stations (for external-internal and through trips).
- On-board survey on transit vehicles.

4.5.2 TRAFFIC VOLUME AND PASSENGER COUNTS

For determining the use of various roadway facilities and assessing their level of service, vehicle counts are taken at selected locations along roadways. Short-count techniques are useful provided appropriate expansion factors are developed based on previous or ongoing research on fluctuations of traffic by hour, by weekday, and by month.

For urban transportation studies 'screen lines' and 'cut-lines' are established in the study area to select traffic count locations and take counts in an organized manner so that the

major travel movements can be measured and analysed. These counts are also used for checking the results of travel forecasting models. Similarly traffic counts are taken at special traffic generators such as an airport and a large college/university to capture their unique travel generating characteristics.

4.6 ZONING

Traffic analysis zones are geographic areas dividing the planning region into relatively similar areas of land use and land activity. Zones represent the origins and destinations of travel activity within the region - every household, place of employment, shopping centre, and other activity are first aggregated into zones and then further simplified into a single node called a centroid.

TAZs serve as the primary unit of analysis in a travel demand forecasting model. TAZ's are generally defined based on administrative and road or physical boundaries; however, there are many other considerations which must be factored while delineating the traffic zones.

- Network compatibility
    - Existing and planned transportation facilities; and
    - Centroid connector loadings.
- Boundary compatibility:
    - Physical geography;
    - Census geography;
    - Political geography;
    - Planning District/Sector boundaries; and
    - Irregular zone geography.
- Socioeconomic data (existing and future):
    - Homogeneous land uses, where feasible;
    - Special generators;
    - Trips per zone; and
    - Developments of regional impact.
- Access:
    - Transit access; and
    - Freight/intermodal facilities
- Other considerations:
    - Zone size and intrazonal trips; and

- Internal versus external zones

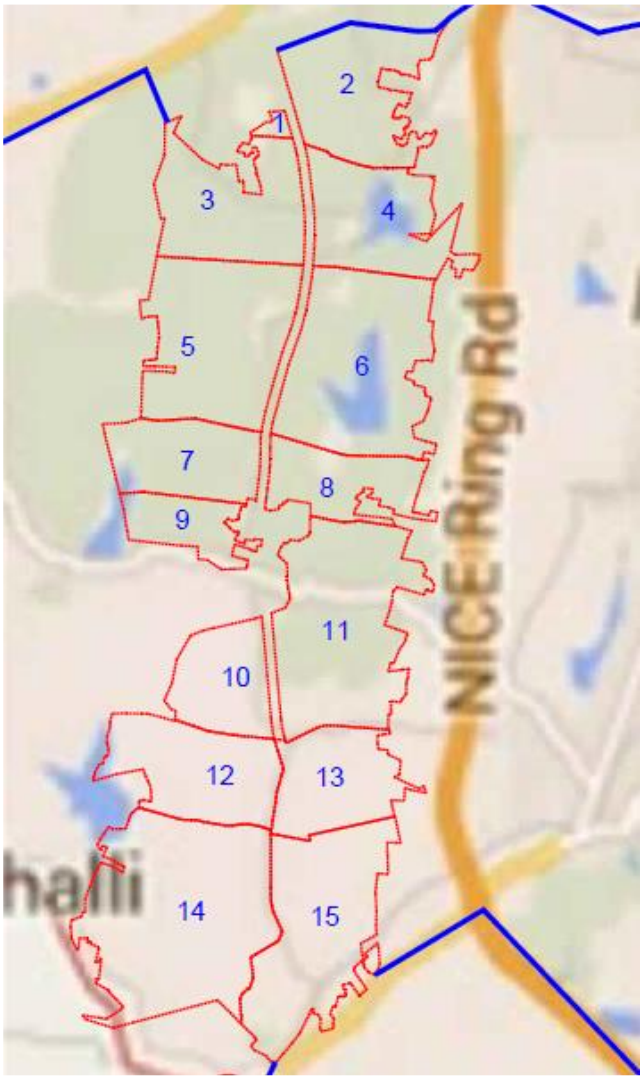
Zoning for Major Arterial Road:

The zoning exercise i.e. delineating the zone boundaries is done based on the following available boundaries to form homogenous zones as required by the study objective

- Available Census/Election Ward Boundaries
- Geometry and Alignment of the Major Arterial Road

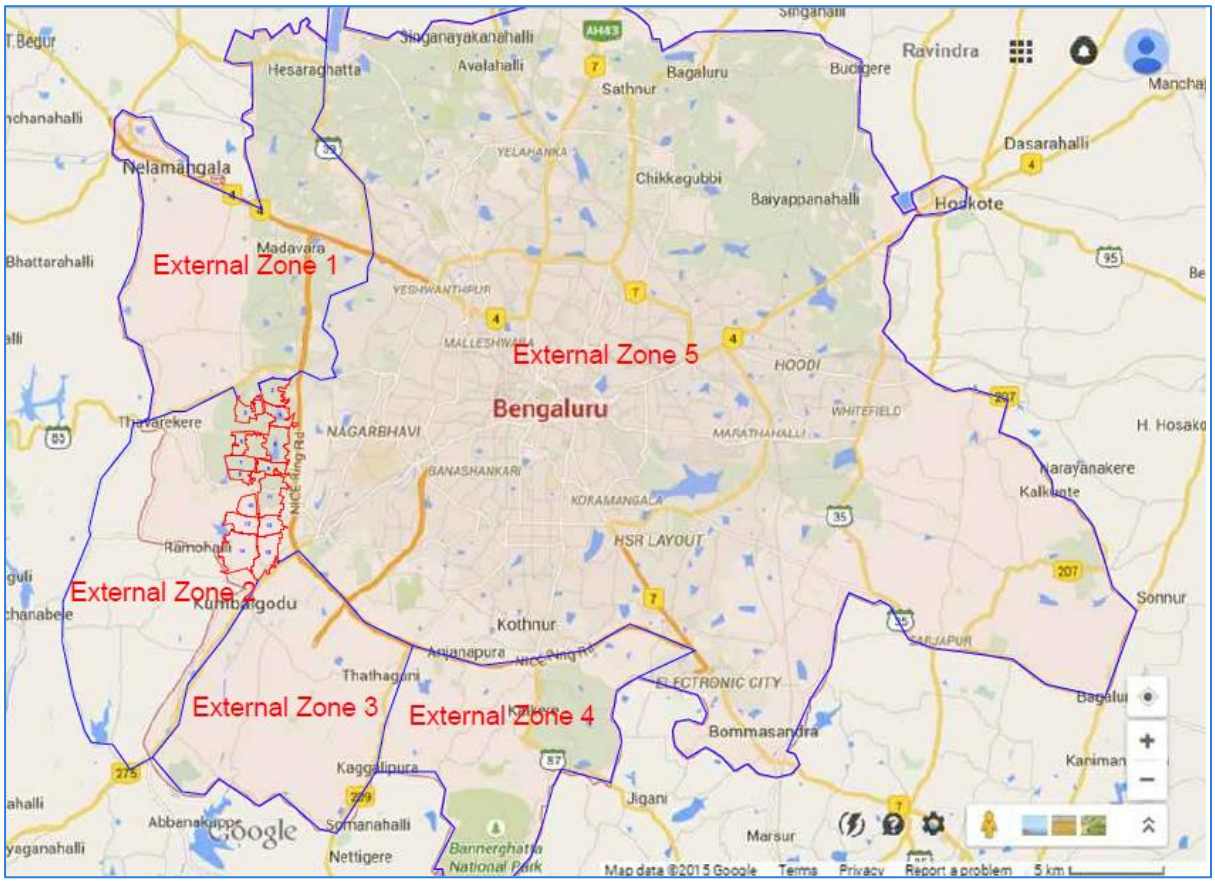
For the analysis of travel pattern within the Study Area and travel demand modelling, entire Kempegowda Layout is divided into 15Internal Traffic Analysis Zones (TAZ). In addition to these internal TAZs, the external area has been divided into 5 External Traffic Analysis Zones (TAZs). Thus the total TAZs for the travel demand analysis works out to 20. The boundaries of the internal zones coincide with the block boundaries. Some of the blocks have been clubbed together to form a zone. The map showing the zones is given below.

Figure 10: Map Showing Traffic Analysis Zones within the Study Area



Whereas for distribution of employment trips, employment centres are clubbed into 5 external zones as presented below.

Figure 11: Map Showing Traffic Analysis Zones outside the Study Area



4.7 POTENTIAL EMPLOYMENT ATTRACTION PLACES

4.7.1 WITHIN INTERNAL INFLUENCE ZONES

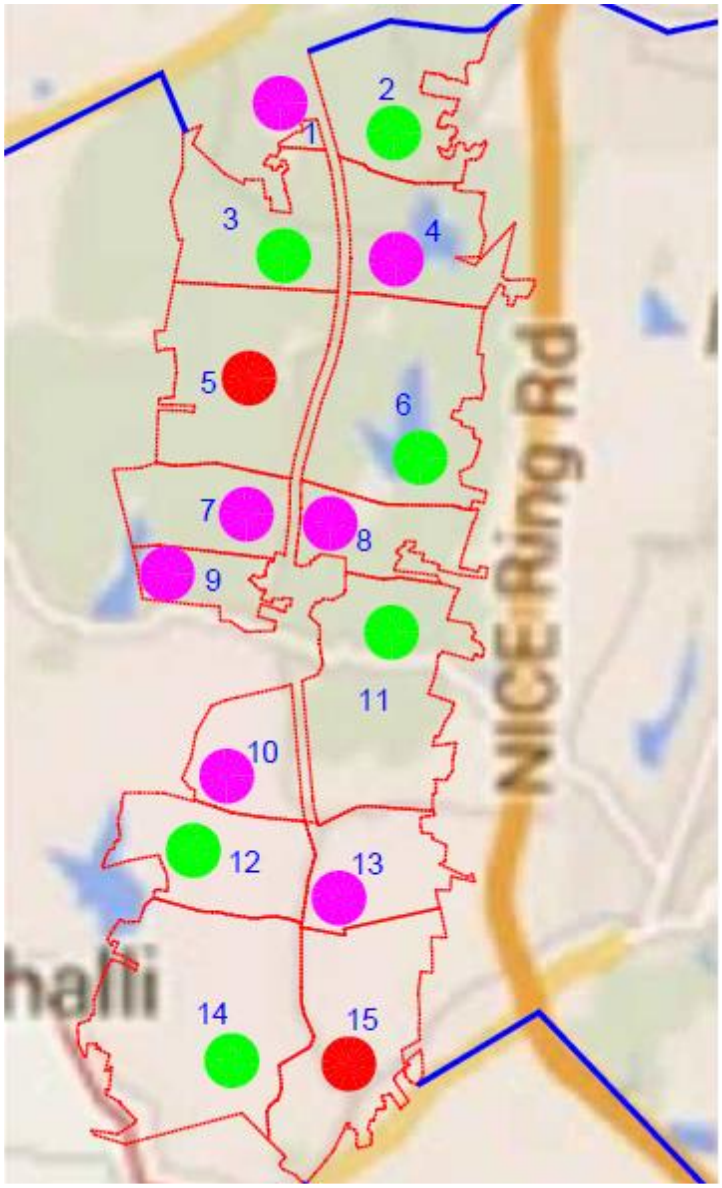
Kempegowda layout and its adjacent major establishment under KIADB in-house scattered commercial and retail centres and will attract employment as presented below.

Table 5: Zone-wise Employment Details

Zone No.	Employment Attraction	
	Kempegowda Layout	Other Establishment
1	379	0
2	11805	0
3	1517	9739
4	2231	4248
5	6150	29218

Zone No.	Employment Attraction	
	Kempegowda Layout	Other Establishment
6	7237	12743
7	5702	0
8	3934	0
9	5702	0
10	9249	0
11	14703	0
12	11663	0
13	3679	0
14	12148	0
15	31885	0

Figure 12: Map Showing Employment Centres within Internal Influence Zones



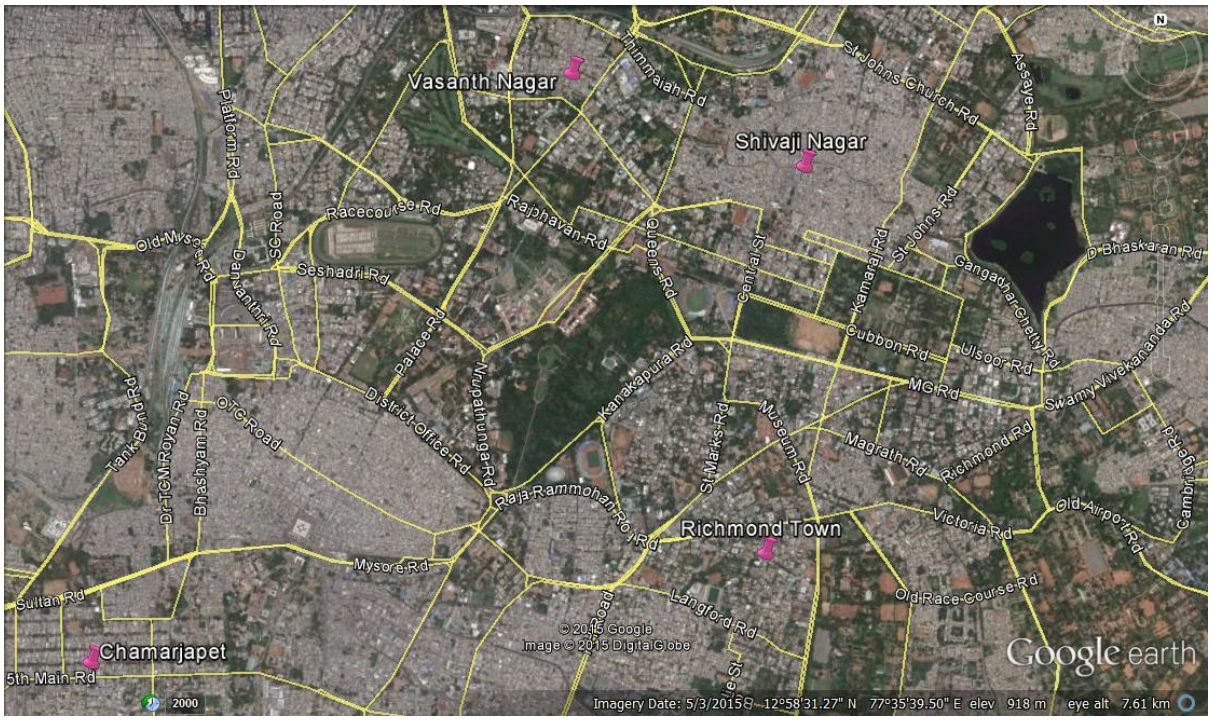
Red dots indicate employment population in excess of 30,000 and Magenta dots indicate employment population in range of 10,000 to 30,000. Whereas Green dots indicate employment population below 10,000.

In Zone 15, large area within Kempegowda layout is designated for commercial and retail establishments, i.e. about 1,25,769.17 sq.m.

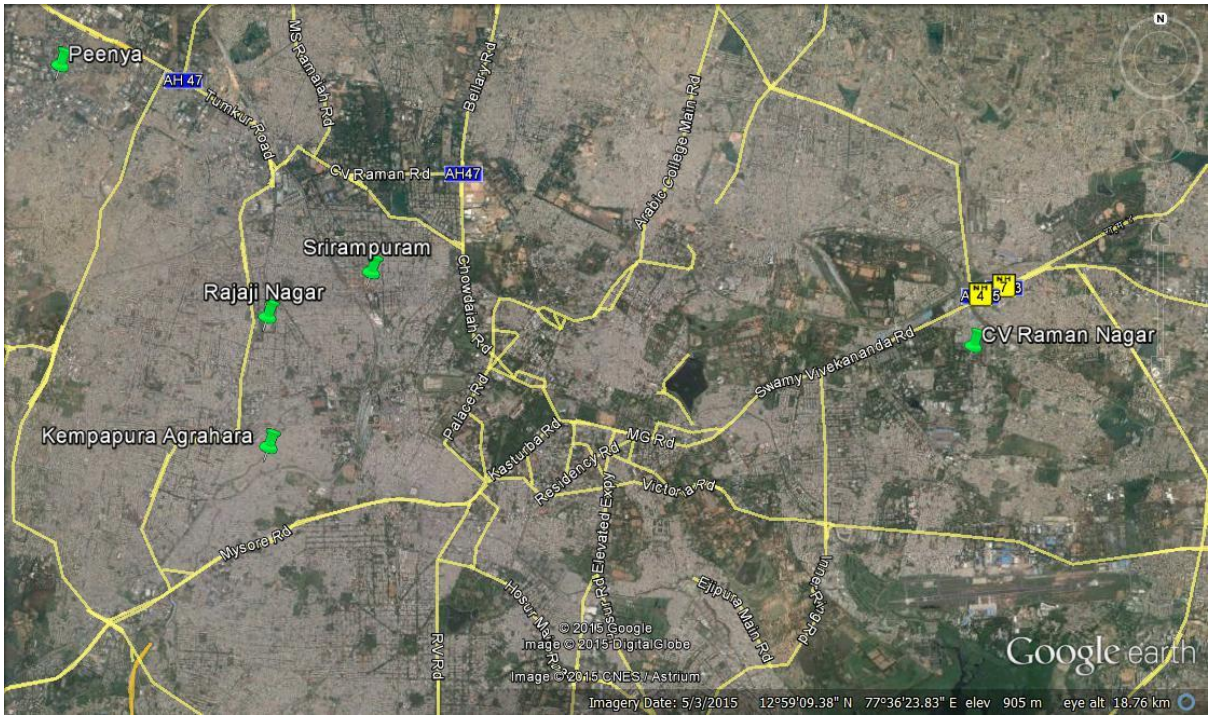
In Zone 5, though less area within Kempegowda layout is designated for commercial and retail establishments, other commercial and retail establishment of KIABD outside Kempegowda layout make it one of the major employment population zone within the study area.

4.7.2 WITHIN EXTERNAL INFLUENCE ZONES

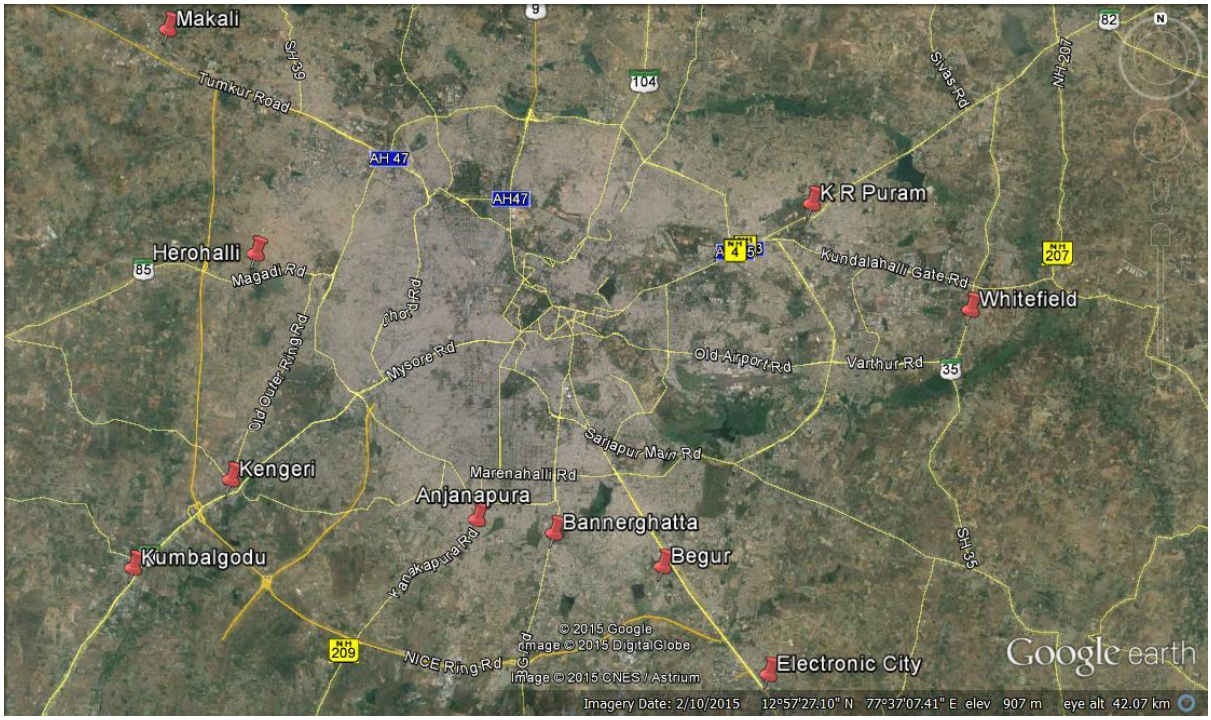
Bengaluru in-house business and commercial centres like Rickmond Town, Vasant Nagar, Shivaji Nagar and Chamarjapet which attract employment within the heart of the city.



There are few industrial or working class developments exist like Peenya, Kempapura Agrahara, Rajajinagar, Srirampuram and CV Raman Nagar in the outskirt of the city within the municipal limits.



Also beyond the municipal limits of the city in the west, strong industrial spaces like Makali, Herohalli and Kumbalgodu exist. In the south and in the east, spaces whose urban development is organized only along the large industrial corridors – Kengeri – Mysore Road, Anjanapura – Kanakapura Road and Bannerghatta Road, Begur – Hosur Road & KR Puram North – Old Madras Road. In the South & East, more or less organized spaces which host IT activities: Whitefield and Electronic City.



Part of Kempegowda layout is located in Kengeri Planning District, a green hinterland of Bengaluru which includes major economic corridor of Mysore Road with very few scattered commercial and industrial developments. Planning recommendations are made to designate Mysore Road & Nagarbavi Road is Mutation Corridors to allow industries, offices and public infrastructure for the plots facing roads, strengthening the pockets of industrial uses occurring of Mysore Road through the Industrial Zone and encourage development in the west part of Uttarahalli Road bordered by the valley on the west as an extension of the satellite town by delineating a Sub Central Business Area Zone.

Part of Kempegowda layout is also located in Herohalli Planning District, which is located along the State Highway Magadi Road (SH-17E) to the south of Peenya Industrial Area and to the east of Rajaji Nagar. The north-east part is an industrial area, containing Peenya Industrial Area IVth Stage and its extension, including services and housing for the industrial workers. Planning recommendations are made to maintain the development of the industrial areas (Peenya, Byrashwara, Doddanna, etc.).

Hence for distribution of employment trips, employment centres are clubbed into 5 external zones, i.e.

1) North zone – Herohalli, Makali & Peenya.

2) West zone – Magadi & Ramanagara.

3) South zone – Kumbalgodu & Kengeri.

4) South East zone – Anjanapura, Bannerghatta, Begur, Electronic City.

5) Bangalore Central & East zone – Rickmond Town, Vasant Nagar, Shivaji Nagar, Chamarjapet, Kempapura Agrahara, Rajaji Nagar, Srirampuram, CV Raman Nagar, K R Puram & Whitefield.

4.8 TRAVEL DEMAND MODELLING FOR KEMPEGOWDA LAYOUT

The travel demand modeling process consists of development of formulae (or models), enabling forecast of travel demand and development of alternative strategies for handling this demand. It is not just one model, but a series of inter-linked and interrelated models of varying levels of complexity, dealing with different facets of travel demand. Through these models, the transportation study process as a whole is checked and calibrated before it is used for future travel predictions. India is one of the developing countries having heterogeneous type of vehicles on roads varying from slow moving vehicles such as cycles

to fast moving two-wheelers, cars, buses, trucks etc. It is necessary to select appropriate travel demand software which can model multi modal transport system.

An integrated landuse transportation model is required to enable estimation of future travel demand which will help in identifying transport requirements. A number of sub-models are developed as follows:

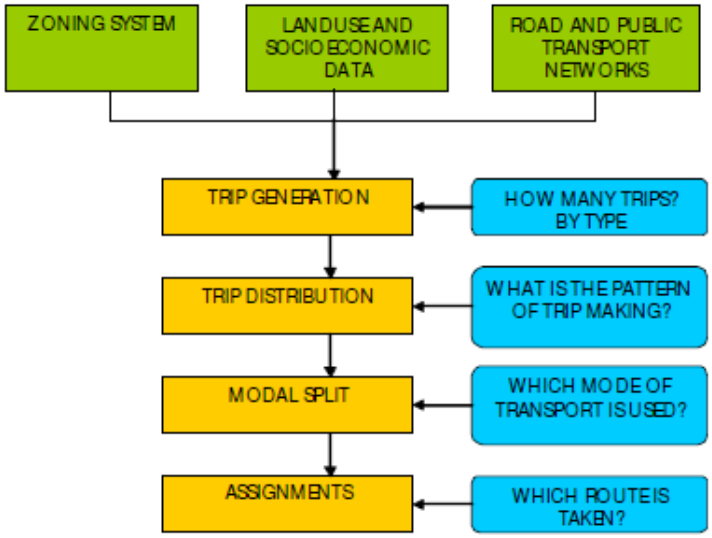
- Trip end model
- Trip distribution model
- Modal split model
- Assignment model

The normal and easily available landuse variables at zonal levels such as population and employment have been made use of in transport demand analysis. The following input requirement is established:

- Location of developments as envisaged by master plan policies such as denseresidential developments, SEZ etc.
- Landuse Parameters by traffic zones such as Population, Employment, SchoolEnrolment
- Road and Public transport network
- Travel patterns in form of origin and destination matrices by mode of travel andpurpose of the trip

The concept of land use transport model is to distribute population and employment so as to minimise the total travel demand. The model is run for various combinations of horizon year, land use and transport network scenarios. The horizon year land use and trip distribution generated by the most combination is then adopted for further stages of transport planning process.

The model developed is a traditional four-stage integrated landuse transport transportation model, as illustrated below.



- Generation and attraction models calculate trips generated and attracted by eachzone, by purpose and vehicle availability group;
- Distribution models distribute trips generated into the possible destinations andprovide all modes matrices;
- Modal choice models split total travel demand matrices by mode;
- Assignment models represent the last stage of the model, build paths, assignorigin / destination (OD) matrices, and finally provide loaded networks for averagehour and global AM peak hour. A standard average hour factor of 7% is applied tothe daily OD matrices for hourly highway and public transport (PT) assignment.

In this regard, zone wise population and employment details are gathered and presented below.

Table 6: Zone-wise Population and Employment Details

Zone No.	Expected Population	Expected Employment
1	12419	379
2	17097	11805
3	75084	11257
4	54869	6479
5	104916	35368
6	60178	19980
7	17265	5702
8	18587	3934
9	17265	5702
10	43776	9249
11	47495	14703
12	48014	11663
13	23447	3679

Zone No.	Expected Population	Expected Employment
14	265691	12148
15	50100	31885

Following assumptions are made to determine the expected number of daily working trips and peak hour working trips:

- Per capita motorized trip rate – 1.3 (As per Study on Traffic & Transportation Policies and Strategies in Urban Areas in India, Ministry of Urban Development, 2008)
- Employment & Recreation Trips – 60% of total trips (CTTP, 2007)
- Peak hour trips – 10% (As per IRC: 106 – 1990)
- Employment Attraction within Kempegowda from Internal Zones – 50% of total employment attraction
- Employment Attraction within Kempegowda from External Zones - 50% of total employment attraction
- Internal to internal trips and vice versa:
    - North bound – 38% (through MAR)
    - South bound – 62% (through MAR)
- Internal to external trips and vice versa:
    - North bound – 20% (through MAR)
    - West bound – 5% (Through MAR)
    - South bound – 20% (Through MAR)
    - South East bound – 15% (Through MAR)
    - Bangalore Central & East bound – 40% (Through RMP roads proposed across East West)
- Modal Trip Shares (CTTP, 2007):
    - Two Wheeler – 28.9%
    - Car – 6.4%
    - IPT – 10.8%
    - PT – 53.9%
- Average Occupancy Rates (CTTP, 2007)
    - Two Wheeler – 1.58
    - Car – 2.59
    - IPT – 2.49
    - PT – 45

- PCU Conversion Factors (IRC: 106 – 1990):
  - Two Wheeler – 0.75
  - Car – 1.0
  - IPT – 2.0
  - PT – 3.7

Upon consideration of expected population&employment and based on aforesaid assumptions, north bound and south bound peak direction peak hour travel demand is determined and presented below:

Table 7: North Bound & South Bound Travel Demand

Sr. No.	Particulars	Travel Demand (Peak Hour PCUs)
1	Peak Direction (North Bound C/W)	6366
2	Peak Direction (South Bound C/W)	7800

4.9 TRAFFIC SURVEYS AND ANALYSIS

4.9.1 SURVEY PLAN

Traffic surveys were planned to be conducted on the competing routes to determine the traffic flow, expected diversion and further forecast the traffic flow for future years on the Major Arterial Road.

4.9.2 VEHICLE CLASSIFICATION SYSTEM

The traffic on the Project corridor is characterized by a high degree of motorised vehicles which consist of passenger vehicles such as cars, two wheelers (scooters/motor cycles) and buses; and commercial vehicles such as light commercial vehicles (LCV's) and trucks.

The following vehicle classification system was adopted for the counts.

Fast Passenger Vehicles

- 2-wheeler (Scooter/motor Cycle)
- Car / Jeep / Taxi
- Mini Bus
- Govt. Bus (Standard)
- Private Bus (Standard)

Fast Commercial Vehicles

- Mini Light Commercial Vehicle (Mini LCV)
- Standard Light Commercial Vehicle (LCV)
- Truck - 2 Axle
- Truck - 3 Axle
- Truck - Multi-Axle
- Truck – Multi-Axle (More than 6 axles)

4.9.3 SURVEY DATA ANALYSIS & FINDINGS

The collected traffic data has been analyzed to obtain information on peak hour traffic and composition of vehicles. This information is further used for estimating traffic projections on the project corridor.

Various vehicle types having different sizes and characteristics were converted into Equivalent Passenger Car Units. The Passenger Car Unit (PCU) factors recommended by Indian Road Congress in "Guidelines for Capacity of Urban Roads in Plain Areas" (IRC-106-1990) have been adopted and are presented below.

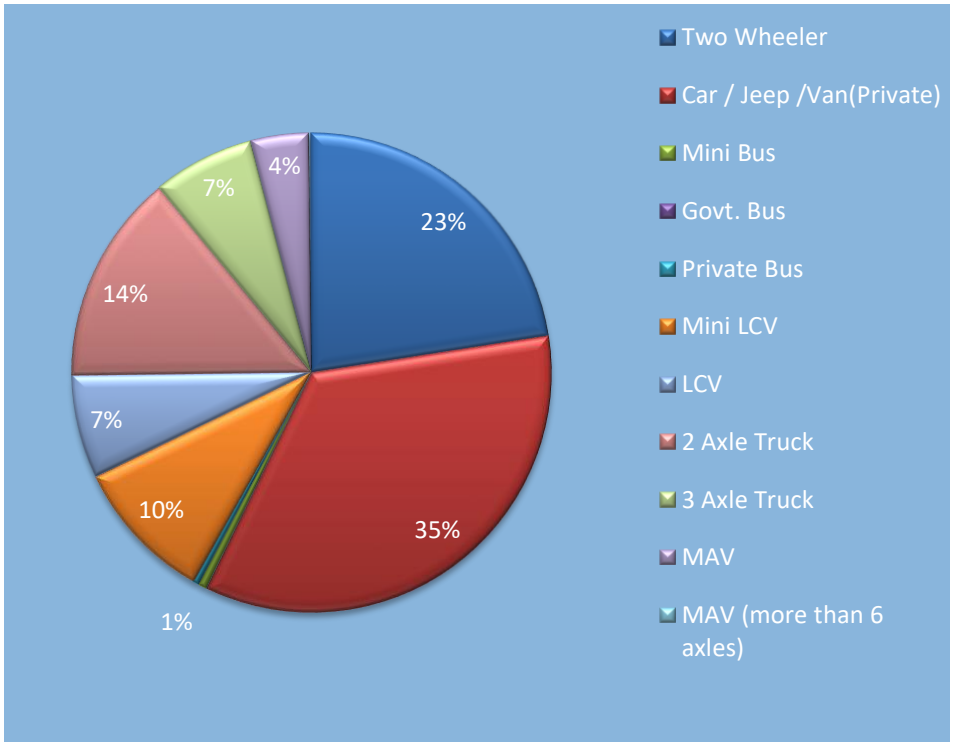
Table 8: PCU Factors

Sl. No.	Vehicle Type	PCU Factor (% composition of vehicle type)	
		5%	10% and above
1	Two Wheeler	0.5	0.75
2	Car / Jeep / Taxi	1.0	1.0
3	Mini Bus	1.5	1.0
4	Private Bus	2.2	3.7
5	Mini LCV	1.4	2.0
6	LCV	1.4	2.0
7	Truck 2-Axle	2.2	3.7
8	Truck 3-Axle	2.2	3.7
9	MAV	2.2	3.7

(Source: IRC: 106-1990)

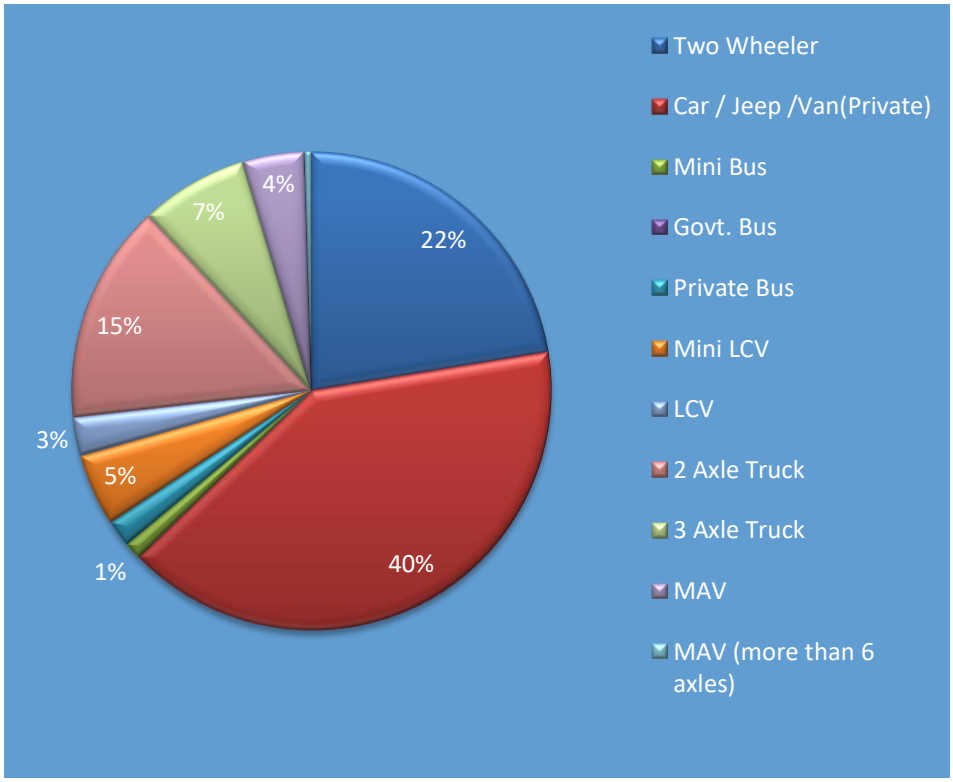
Vehicle Composition:

1) Morning Peak: From Mysore Road to Magadi Road



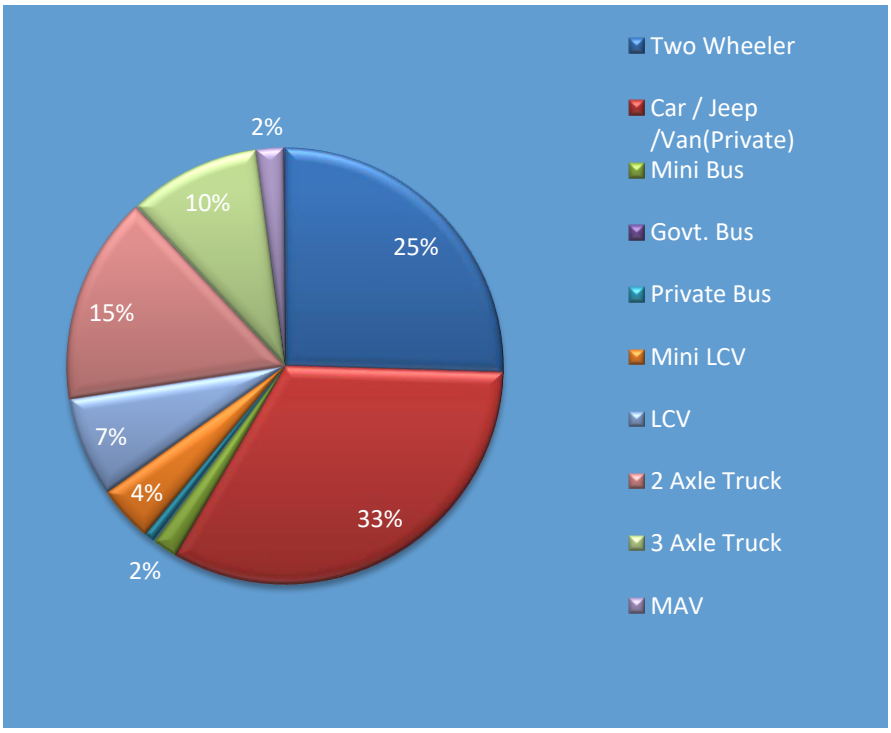
Inference: The share of Car / Jeep / Van is predominant followed by the shares of T Wheeler, Mini LCV & 2 Axle Trucks. Whereas the share of passenger vehicle and goods vehicle is about 58% and 42% respectively.

2) Evening Peak: From Mysore Road to Magadi Road



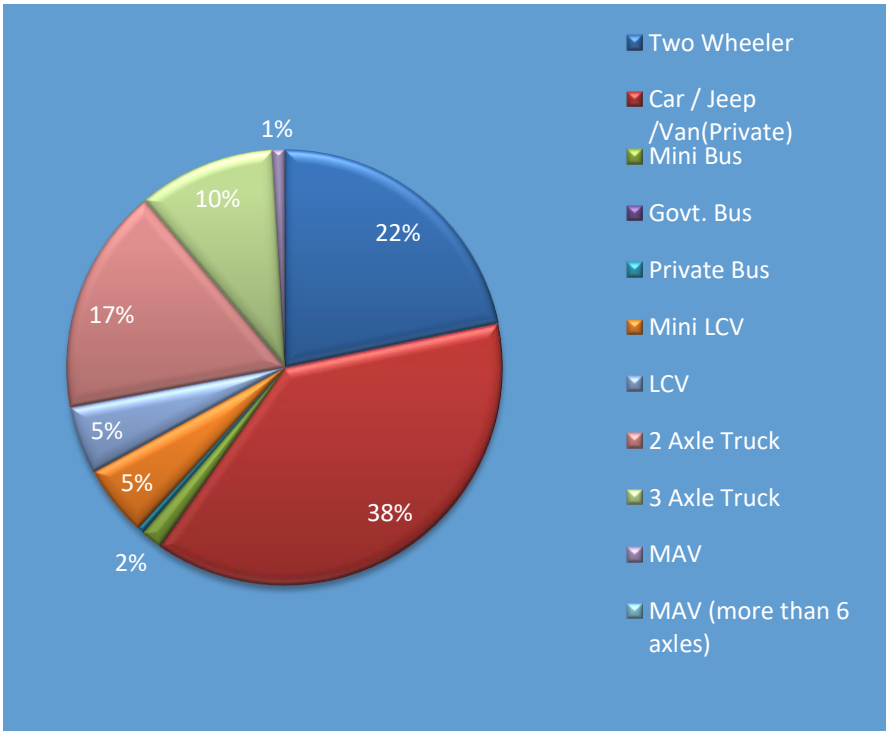
Inference: The share of Car / Jeep / Van is predominant followed by the shares of T Wheeler, Mini LCV & 2 Axle Trucks. Whereas the share of passenger vehicle and goods vehicle is about 66% and 34% respectively.

3) Morning Peak: From Magadi Road to Mysore Road



Inference: The share of Car / Jeep / Van is predominant followed by the shares of T Wheeler, Mini LCV & 2 Axle Trucks. Whereas the share of passenger vehicle and goods vehicle is about 61% and 39% respectively.

4) Evening Peak: From Magadi Road to Mysore Road



Inference: The share of Car / Jeep / Van is predominant followed by the shares of T Wheeler, Mini LCV & 2 Axle Trucks. Whereas the share of passenger vehicle and goods vehicle is about 62% and 38% respectively.

Peak Hour Traffic:

Mysore Road to Magadi Road: *Peak hour traffic in morning and evening peak are observed as 1261 PCU/hr and 1397 PCU/hr respectively.*

Magadi Road to Mysore Road: *Peak hour traffic in morning and evening peak are observed as 1372 PCU/hr and 1312 PCU/hr respectively.*

4.10 DIVERSION ANALYSIS

Diversion analysis was carried out to determine the divertible traffic from competing routes to Major Arterial Road. In case of project corridor only one major competing route is available, i.e. NICE Ring Road, on which classified traffic counts and OD surveys were also conducted and analysed.

In order to determine expected diversion of traffic from competing route to project corridor, the criterion adopted is generalized cost (GC), which is dictated by the road configuration and condition, type of vehicle and its journey speed, route distance and any tolling that may apply on a specific route. GC is computed using following formula:

GC = (VOTT or VOCT) * TT + TC

Where,

VOTT = Value of travel time
VOCT = Value of commodity time
TT = Travel Time
TC = Travel Cost

Comprehensive Traffic & Transportation Plan for Bengaluru, prepared by RITES Limited in 2007 has presented unit values of VOTT and VOC for each vehicle type are based on extensive study for base year model calibration and are based on 2005 price levels. These values have been brought to price levels of 2015 by applying annual average growth of WPI values since 2005 as presented below.

Whereas IRC: SP: 30-2009, Manual on Economic Evaluation of Highway Projects, published by Indian Roads Congress, presented unit values of VOC & VOCT for heavy vehicles are

based on Updated Road User Cost Study (RUCS) and also based on March, 2009 price levels. The value been brought to price level of 2015 by applying annual average growth of WPI values since 2009 as presented below.

Table 9: Wholesale Price Index (WPI) Values since 2005 (base year 2004)

Year	2005-06	2006-07	2007-08	2008-09	2009-2010
WPI	104.47	111.35	116.63	126.02	130.81
% Growth		6.59	4.74	8.05	3.80

Year	2010-11	2011-12	2012-13	2013-14	
WPI	143.32	156.13	167.62	177.64	
% Growth	9.56	8.94	7.36	5.98	
% Average Growth Since 2005					6.88
% Average Growth Since 2009					7.13

Source: Website of Office of Economic Advisor (www.eaindustry.gov.in), as available on 12th June 2015.

Travel Time Cost component of GC is quantified with unit value of travel time (VOTT) and value of commodity time (VOCT) given in CTTP for Bengaluru and IRC: SP: 30-2009 as presented below.

Table 10: VOTT and VOCT by Vehicle Type (2015 price levels)

Serial Number	Vehicle Type	VOTT / VOCT (Rs. /Veh hr.)
2	Car	108.66
3	PT	31.74
4	LCV	7.32
5	Truck	22.42
6	MAV	41.95

Source: Table 6 & Table 7 of IRC: SP: 30-2009

Travel time (TT) has been estimated from the journey speeds which is further derived from Speed Flow Equations presented in Annex B of IRC: SP: 30- 2009 with peak hour traffic as

10% of daily traffic for two lane carriageway and four lane divided carriageway, i.e. 10,000 PCU & 20,000 PCU respectively. The derived values of journey speeds are presented below.

Table 11: Journey Speed by Section & Vehicle Type

Serial Number	Lane Configuration	Journey Speed (Km/hr)				
		Car	Bus	LCV	Truck	MAV
1	Two Lane with Earthen Shoulders	68.18	59.56	61.40	51.00	42.81
2	Four Lane with Paved Shoulders	85.27	67.71	62.01	55.03	46.23
3	Six Lane with Paved Shoulders	85.27	67.71	62.01	55.03	46.23

Travel Cost (TC) component of GC is quantified in terms of Vehicle Operating Cost (VOC), which is the product of VOC per km and distance to be travelled. Vehicle operating costs on six lane project highway will be less due to short route distance, better riding quality and less congestion.

Following assumptions have been made to extract the unit VOC values for each vehicle type:

1. VOC values are adopted considering free traffic flow conditions.
2. Project corridor and competing route in Karnataka are in rolling terrain.
3. Lane configuration and pavement condition in terms of Roughness (mm/km) on the project corridor and competing route are assumed as follows:
    - Magadi Road – 2 lane undivided with 2500 mm /km roughness
    - NICE Ring Road – 6 lane divided with 2000 mm /km roughness
    - Mysore Road – 4 lane divided with 2500 mm /km roughness
    - Major Arterial Road – 6 lane divided with 2000 mm /km roughness

Estimated values of GC on project routes and competing routes for passenger and goods vehicle is presented below:

Table 12: Generalised Cost on Project Route & Competing Route

Route	Route Details	Trip GC (Rs.)				
		Car	Buses	LCV	Truck	MAV
Competing	*Magadi Road – NICE Road – Mysore Road*	200.96	622.67	351.98	421.22	619.26
Project	*Major Arterial Road*	126.51	409.02	183.77	213.20	346.15

It may be noted that significant reduction, of about 40% to 100%, in GC is estimated on Major Arterial Road as compared to Magadi Road – NICE Road – Mysore Road route due to reduction in travel time, travel distance and absence of toll plaza.

Through O-D pattern observed on NICE Ring Road, it is concluded that the contribution of Magadi, Mysore and Westerlypart of Study Area bound traffic is about 50% and remaining contribution from North & South of Bengaluru. Hence with significant reduction of generalised cost while travelling on Major Arterial Road than NICE Ring Road, Magadi & Mysore bound traffic will surely divert on Major Arterial Road and rest will continue using NICE Ring Road.

Therefore, it is concluded that the 50% of projected traffic on NICE Ring Road will be diverted onto Major Arterial Road.

4.11 TRAFFIC PROJECTIONS ON MAJOR ARTERIAL ROAD

Projected Peak Hour Traffic, considering travel demand from study area and expected traffic diversion from competing route is projected for the cardinal years and presented below considering the growth rate as 2.5% per annum (CTTP, 2007).

Table 13: Projected Peak Hour Traffic on MAR

Sr. No.	Particulars	Travel Demand (Peak Hour PCUs)
1	North Bound (Through Traffic)	1144
	Peak Direction (North Bound C/W)	6366
	Peak Direction (North Bound C/W)	**7510**
2	South Bound (Through Traffic)	1124
	Peak Direction (South Bound C/W)	7800
	Peak Direction (South Bound C/W)	**8924**

4.12 RECOMMENDED LANE CONFIGURATION FOR DESIGN TRAFFIC

4.12.1 RECOMMENDED DESIGN SERVICE VOLUMES AND LANE CONFIGURATION

Capacity standards are fixed normally in relation to the Level of Service (LOS) adopted for the design. Level of Service (LOS) is defined as the quantitative measure describing operational conditions within a traffic stream, and their perception by drivers / passengers. Level of Service definition generally describes these conditions in terms of factors such as speed and travel time, freedom to manoeuvre, traffic interruptions, comfort, convenience and safety. Six levels of service are recognised commonly, designated from A to F, with Level of Service A representing the best operating conditions (i.e. free flow) and Level of Service F the worst (i.e. forced of break-down flow). It is recommended that normally LOS C be adopted for design of urban roads (IRC: 106-1990). At this level, volume of traffic will be

around 0.7 times the maximum capacity and this is taken as the "design services volume" for the purpose of adopting design values.

For the Major Arterial Road under consideration, being an **Arterial**, design service volumes for different lane configuration are given below.

Table 14: Recommended Design Service Volumes (PCU per hour)

Type of Carriageway	Total Design Service Volume (Arterial)
2-lane (One-Way)	2400
2-lane (Two-Way)	1500
3-lane (One-Way)	3600
4-lane Undivided (Two-Way)	3000
4-lane Divided (Two-Way)	3600
6-lane Undivided (Two-Way)	4800
6-lane Divided (Two-Way)	5400
8-lane Divided (Two-Way)	7200

It can be seen that, for one way roads, design service volume for LOS C shall be 1200 PCU/hr/lane and same has been adopted for deciding the lane configuration of MAR. Corresponding maximum capacity with V/C ratio of 0.7 shall be 1715 PCU/hr/lane.

Based on aforesaid recommended design service volume and projected peak hour travel demand on Major Arterial Road, recommendations are made for lane configuration and presented below.

Table 15: Recommended Lane Configuration

Description	Recommended Lane Configuration
North Bound Main C/W	6 + 6
South Bound Main C/W	6 + 6
Service Roads	2 + 2

4.12.2 RECOMMENDED LANE CONFIGURATION FOR PHASE 1

Since the project road will be developed in phased manner, Phase 1 of project road development shall include 3 lane carriageway on either side with 2 lane carriageway of service roads on either end of the Right of Way.

4.12.3 POSSIBLE RESTRAINTS WITH 45M RIGHT OF WAY

However, due to restricting Right of Way (ROW) to 45m in future as decided by Bangalore Development Authority, several possible restraints will occur such as:

- Level of Service C with V/C ratio of less than or equal to 0.7 will be maintained till the year 2022.
- Beyond 2022, Level of Service (LOS) shall start reducing from C to E. This representing operating conditions when traffic volumes or at or close to the capacity level. The vehicular speeds will be reduced to low, average value being one-third the free flow speed, i.e. vehicular speeds will be reduced to 20% to 50% less as compared to LOS "C", wherein freedom to manoeuvre within the traffic stream is extremely difficult. Comfort and convenience shall be extremely poor, and driver frustration is generally high. Operations at this level are usually unstable, because small increases in flow of minor disturbances within the traffic stream will cause breakdowns. This will further add to increase in air & noise pollution.

In this situation, practical capacities can be improved through application of traffic engineering techniques besides better enforcement.

4.13 WARRANTS FOR INTERCHANGES AND GRADE SEPARATIONS

An interchange can be useful and an adaptable solution for many intersection problems either by reducing existing traffic bottlenecks or by improving safety. However, high cost of constructing an interchange limits its use to those cases where additional expenditure can be justified. The following six conditions, or warrants, should be considered when determining if an interchange is justified at a particular site (AASHTO, 2001):

- Design designation
- Reduction of bottlenecks or spot congestion
- Safety improvement
- Site topography
- Road user benefits
- Traffic volume warrant
- Eliminate a railroad-highway grade crossing
- Provide access to mass transit stations within the confines of a major arterial.

A traffic volume warrant for grade separated interchange treatment would be the most tangible of any grade-separated warrant. Although a specific volume of traffic at an intersection cannot be completely rationalized as a warrant for an interchange, it is an important guide. However, volumes in excess of the capacity of an at-grade intersection would certainly be a warrant. Interchanges are desirable at cross streets with heavy traffic volumes because the elimination of conflicts due to high crossing volume greatly improves the movement of traffic.

4.13.1 INTERNATIONAL NORMS

An FHWA- sponsored report on access management, suggested grade separated interchanges along 'standard arterials' under the following circumstances:

- Suburban – arterials carrying more than 20,000 vpd crossing arterials carrying more than 10,000 vpd; and
- Rural – arterials carrying more than 5,000 vpd crossing arterials carrying more than 3,000 vpd

Minimum spacing of arterial interchanges is determined by weaving volumes, ability to sign, signal progression, and lengths of speed change lanes. As a general rule of thumb for minimum interchange spacing is 1.5 km in urban areas (AASHTO, 2001 & HDM, 2001).

4.13.2 INDIAN NORMS

As per IRC: 92, an interchange may be justified in following scenarios:

- At the crossing of a major arterial road with another road of similar category carrying heavy traffic.
- When an at grade intersection fails to handle the volume of traffic resulting in serious congestion and frequent choking of the intersection. This situation may arise when the total traffic of all the arms of the intersection is in excess of 10,000 PCUs per hour.

The project road is connected in north & south with Magadi Road at Ch. 0+000 and Mysuru Road at Ch. 10+770 respectively. Both of these roads are of similar category carrying heavy traffic. Hence suitable grade separator is proposed at these locations.

Also to identify locations for grade separator on intermediate crossing, vehicular traffic approaching major road crossings is estimated and presented below.

Table 16: Vehicular Traffic Approaching Major Road Crossings

Sr. No.	Major Crossing at Ch.	Vehicles per Day (VPD)		Peak Hour approaching volume (PCUs)
		Major Arterial Road	Cross Road	
1	1+640	1,14,291	30,458	11,824
2	2+780	1,14,291	47,492	12,790
3	5+505	1,14,291	43,556	12,554
4	7+895	1,40,035	36,480	13,301
5	9+400	1,40,035	61,526	14,696

At aforesaid locations, vehicles per day on major arterial road is exceeding 20,000 vpd and cross road traffic exceeding 10,000 vpdwithapproaching peak hour vehicular traffic is exceeding 10,000 PCUs with average spacing of 1.5 km, vehicular grade separators are proposed at these locations.

5 DESIGN OF ROAD ELEMENTS

Based on project requirements, design standards & design of various road elements has been presented in subsequent part of this chapter.

5.1 DESIGN STANDARDS FOR ROAD WORKS

Proposed Major Arterial Road is considered as ***Arterial***, which is primarily for through traffic, usually on a continuous route. This shall carry significant intra-urban travel such as between central business district and outlying residential areas or between major suburban centres.

Suggestive geometric design standards and design elements for the project road under consideration are referred from following list of IRC codes, Code of Practice for Design of Urban Roads (Part 1, 2, 3 & 4) published by Ministry of Urban Development (MoUD) and Street Design Guidelines published by UTTIPEC, New Delhi and presented below.

Code No.	Title of the Publication.
IRC:3-1983	Dimensions & Weights of Road Design Vehicles (First Revision).
IRC:7-1971	Recommended Practice for Numbering Bridges and culverts (First Revision)
IRC:11-1962	Recommended Practice for the Design and Layout of Cycle Tracks.
IRC:29-1988	Specification for Bituminous Concrete (Asphaltic Concrete) for Road Pavement (First Revision)
IRC:32-1969	Standard for Vertical and Horizontal Clearances of Overhead Electric Power and telecommunication Lines as Related to Roads.
IRC:35-1970	Code of Practice for Road Markings (with Paints)
IRC:37-2012	Guidelines for the Designs of Flexible Pavements
IRC:38-1988	Guidelines for Design on Horizontal Curves for Highways and Design Tables (First Revision)
IRC:52-1981	Recommendations About the Alignment Survey and geometric Design of Hill Roads (First Revision)
IRC:54-1974	Lateral and vertical Clearances at Underpasses for Vehicular Traffic.
IRC:56-1974	Recommended Practice for Treatment of Embankment Slopes for Erosion Control.
IRC:58-2002	Guidelines for the Design of Rigid Pavements for Highways

IRC:62-1976	Guidelines for Control of Access on Highways.
IRC:67-2010	Code of Practice for Road Signs.
IRC:70-1977	Guidelines on Regulation and Control of Mixed Traffic in Urban Areas.
IRC:75-1979	Guidelines for the Design of High Embankments.
IRC:86-1983	Geometric Design Standard for Urban Roads in Plains.
IRC:87-1984	Guidelines for the Design & Erection of False work for Road Bridges.
IRC:92-1986	Guidelines for the Design of Inter-changes in Urban Areas.
IRC:93-1985	Guidelines on Design and Installation of Road Traffic Signals.
IRC:94-1986	Specification for Dense Bituminous Macadam.
IRC:95-1987	Specification for Semi-Dense Bituminous Concrete.
IRC:98-1988	Guidelines on Accommodation of Underground Utility Services Along and Across Roads in urban Areas.
IRC:99-1988	Tentative Guidelines on the Provision of Speed Breakers for Control of Vehicular Speeds on Minor Roads.
IRC:103-1988	Guidelines for Pedestrian Facilities.
IRC:106-1990	Guidelines for Capacity of Urban Roads in Plain Areas.
IRC:107-1992	Tentative Specifications for Bitumen Mastic Wearing courses.
IRC:109-1997	Guidelines for Wet Mix Macadam.

Code No.	Title of the Publication.
IRC: SP:12-1973	Tentative Recommendations on the Provision of Parking Spaces for Urban Areas
IRC: SP:19-2001	Manual for Survey, Investigation and Preparation of Road Projects.
IRC: SP:23-1983	Vertical Curves for Highways.
IRC: SP:30	Manual on Economic Evaluation of Highway Projects in India
IRC: SP:31-1992	New Traffic Signs.
IRC: SP:32-1988	Road Safety for Children (5-12 Years Old).
IRC: SP:41-1994	Guidelines on Design of At-Grade Intersections in Rural & Urban Areas
IRC: SP:42-1994	Guidelines on Road Drainage.
IRC: SP:49-1988	Guidelines for the Use of Dry Lean Concrete as Sub-base for Rigid Pavement
IRC: SP:50- 1999	Guidelines on Urban Drainage
IRC: SP:63-2004	Guidelines for the Use of Interlocking Concrete Block Pavement
IRC: SP:90-2010	Manual for Grade Separators and Elevated Structures

1) Classification of Road	:	Arterial
2) Design Speed	:	80 Kmph (Main Carriageways)
	:	40 Kmph (Service Roads)
3) Land Width	:	45m
4) Cross Sectional Elements	:	
Carriageway width		
Main Carriageway (MCW)	:	2 x 10.0m
Service Roads (SR)	:	2 x 7.00m
Median	:	1 x 3.00m
Space between MCW & SR	:	2 x 28.00m
Cycle Track	:	2 x 2.00m
Footpath	:	2 x 2.00m
5) Kerb	:	Barrier type
6) Camber		
Carriageway	:	2.0%
Paved footpath	:	2.5%
7) Safe stopping sight distance	:	120m
8) Horizontal Alignment:		
Superelevation	:	$e = \frac{v^2}{225R}$ subject to maximum of 4%
Transition Curve	:	Larger value obtained amongst consideration of rate of change of centrifugal acceleration & rate of change of super-elevation

Set-back distance	:	4m (for combination of design speed of 100 Kmph, radius of horizontal curve more than 500m and safe stopping sight distance of 120m).

9) Vertical Alignment:

Minimum gradient	:	0.5% (to facilitate drainage)
Maximum gradient	:	4% (for flyovers)
	:	6% (for service / slip roads)
Minimum length of curve	:	50m

10) Co-ordination of Horizontal Curve & Vertical Alignments: The vertical and horizontal curves shall coincide as far as possible and their length more orless equal. It not feasible, the horizontal curve may be longer than the vertical curve. Sharphorizontal curves at or near the apex of pronounced vertical curves shall be avoided.

11) Intersection design: The at-grade intersections shall be designed to enable efficiency of operation, safety, speed, cost ofoperation and capacity. Junctions where the traffic volume is heavy and the delays and loss caused justifies a grade separator, such proposal shall be made.

12) Railway Crossing: It is proposed to build railway over bridge (ROB) at 1 railway crossing.

13) Additional Features

Acceleration & Deceleration lane	:	
Width	:	3.0m minimum
Length	:	50.0m minimum
Taper	:	1 in 15 beyond design length
Pedestrian / Cattle Underpasses	:	
Width	:	6.0m minimum
Vertical Clearance	:	3.0m minimum

At grade Intersection	:	As per IRC: SP: 41
Rotary Intersection	:	With ICD as 27.8m and width of weaving and non-weaving section as 10.0m.
Grade Separated Intersection	:	As per IRC: 92& IRC: SP:90
14) Utilities	:	To be accommodated in utility ducts running both side of carriageway with intermediate connections. Whereas sewer lines shall be laid separately underneath service roads.
15) Traffic control devices	:	As per relevant code of practice.

5.2 BRT SERVICE DESIGN CONCEPT

The design approach was based on 3 key factors. These are:

- Kind of BRT system best suited for application.
- The character and location of bus lanes on the corridor.
- Kind of bus stations required and their ideal location.

5.2.1 BUS LANE TYPE AND LOCATION

Location of bus lanes can either be on kerb side which is traditionally used in India or in centre of the ROW which has been adopted in other countries. The following table list the rationale and criteria for selecting side or central bus lanes.

Table 17: Rationale and Criteria for Selecting Side or Central Bus Lanes

Sr. No.	Central Bus Lane	Curb – Side Bus Lane	Applicability with MAR of NPKL
1	Excessive side entries for vehicles into service lanes or individual plots.	Limited access to service lanes or widely spaced entry points into adjacent area.	**With limited access to service lanes and widely spaced entry points, curb side bus lane is preferable.**

Sr. No.	Central Bus Lane	Curb – Side Bus Lane	Applicability with MAR of NPKL
2	Closely spaced traffic lights for vehicles may be combined with bus shelters.	Traffic lights at larger intervals.	**With limited access to service roads and signal free corridor, curb side bus lane is preferable.**
3	Higher volume of two wheelers and three wheelers	Lower volume of two wheelers and three wheelers	**With designated parking space for three wheelers beside service road and restricted entry of two wheelers into bus lane by provision of separator and enforcement, curb side bus lane is preferable.**

BRTS ensures bus priority through segregation of bus services from other traffic. At mid-block this is achieved through segregation of bus lanes. Kerb side lanes may not be possible where access to property needs to be achieved as they may be blocked by the segregation. Although in case of curb side bus lanes at least 50% of the commuters have to cross all motorized lanes. This requires longer safe pedestrian crossing time which may increase accidents and increase signal cycle time adversely affecting the motorized vehicles flow.

In case of Major Arterial Road in NPKL, with provision of service roads on either side and pedestrian grade separator at bus stop locations, uninterrupted flow for other motorized vehicles can be achieved by provision of curb side bus lanes.

With consideration of rationale discussed above and provision of pedestrian underpasses at mid-block bus stops, curb side bus lane found preferable and recommended for implementation.

5.2.2 SUCCESSFUL KERBSIDE BRT EXAMPLE IN INDIA– BHOPAL BRT

The city has started the system in 2013 and now counts with 1 bus priority corridor consisting of 24 kilometres and benefiting 70,000 passengers every day with station spacing of about 600m (www.brtdata.org).

5.2.3 SUCCESSFUL KERBSIDE BRT EXAMPLE IN ASIA – HANGZHOU BRT

The city has started the system in 2006 and now counts with 3 bus priority corridors consisting of 55 kilometres and benefiting 260,000 passengers every day with station spacing of about 1500m. The average operational speed of the system is 18.0 km/h (www.brtdata.org).

5.2.4 SUCCESSFUL KERBSIDE BRT EXAMPLE IN WORLD – NEW YORK BRT

The city has started the system in 2008 and now counts with 6 bus priority corridors consisting of 80 kilometres and benefiting 199,566 passengers every day. The average operational speed of the system is 16.4 km/h(www.brtdata.org).

Select Bus Service is New York City's version of Bus Rapid Transit: an improved bus service that offers fast, frequent, and reliable service on high-ridership bus routes. Completed in much less time and at much lower cost than subways—which take years to construct and require expensive up-front infrastructure and equipment—Select Bus Service offers a more immediate improvement to New York City’s transit network benefitting the entire city through improved mobility, cleaner air, reduced greenhouse gas emissions, and reduced congestion.

Designed to provide rail-like service, Select Bus Service uses techniques and technologies such as dedicated bus lanes, off-board fare collection and transit signal priority to improve the quality and performance of transit and, in turn, to improve mobility and access in the neighbourhoods that it serves.

Select Bus Service projects are also designed to make bus service easier to use, through features like bus bulbs, and high quality passenger information and overall attention to pedestrian and vehicular safety. Select Bus Service features can also be applied individually in locations not appropriate for the full Select Bus Service treatment.

Enhanced road markings increase the visibility of bus lanes. Many bus lanes are coloured with dark red terra cotta paint, and all bus lanes include white BUS ONLY markings. The red treatment has been shown to help make sure motorists are aware of the bus lane, and do not drive or park in the lane during restricted hours.

Bus lane cameras are used to enforce bus lane rules on selected streets around the city; cameras may only be used on specific corridors authorized by the New York State Legislature. All potential camera violations are reviewed by a DOT employee before being issued, to ensure that a violation took place. On all corridors, DOT works closely with the New York Police Department to enforce bus lane rules. All bus lane violations are adjudicated by the Department of Finance, not by DOT.

5.2.5 IMPROVING EFFECTIVENESS OF KERBSIDE BRT

The effective of kerbside BRT system can be improved by means of:

- Introducing physical barrier between bus lanes and other motorized lanes.
- Enforcement by camera and contra-flow lanes.
- Introducing Transit Signal Priority through:
    - Green Extension
    - Red Truncation (Early Green)

6 HYDRAULIC DESIGN

6.1 CRITERIA FOR HYDRAULIC DESIGN

All the storm water drainage system is designed as per the norms of CPHEEO/IRC SP 13 as presented below.

6.1.1 RETURN PERIOD

The city is getting urbanized at a very fast pace with mixed nature of development (Central and comparatively high period area). Therefore, considering the importance of area, moderate to flat slopes, the return period of 2 years is adopted.

6.1.2 ESTIMATION OF STORM WATER RUNOFF

The Rational Method

The entire precipitation over drainage district does not reach the draining sewer. The characteristics of drainage such as imperviousness, topography including depressions and duration of precipitation etc., from which fraction of the total precipitation, which will reach to the sewer, has to be determined. This fraction is known as co-efficient of runoff which will be determined for each drainage district depending on its characteristic. The run off reaching the drains is given by the expression as per CPHEEO manual:

Storm Water Runoff Reaching the Drain is given by Theoretical Expression (Q th), As per CPHEEO manual

Q =10 C i A

Where, Q - Runoff (m3/hr).

C - Coefficient of runoff

i - Intensity of rainfall (mm/hour)

A - Area of drainage in Hectares

As per IRC-SP-13 Para 4.7:

Q = 0.028 P A Ic

Where

Q = Max Runoff in cum/sec

P = the co-efficient of Runoff

Ic = the intensity of Rainfall in Cm/hr.

A = Area of drainage district in hectares

6.1.3 STORM FREQUENCY

As per Clause 3.3.1.2 on page 41 of CPHEEO manual, the frequency of storm for which drains are to be designed depends on the importance of the drainage area.

(a) Residential Area

Peripheral Area	-	Twice a year
Central and comparatively high period area	-	Once a year
(b) Commercial and high Priced Area	-	Once in two years

As the newly developing area in high priced one, frequency of once in two years is adopted.

6.1.4 INTENSITY OF PRECIPITATION

As per Clause 3.3.1.3 of CPHEO manual, the intensity of rainfall decreases with duration. Analysis of the observed data on intensity duration of rainfall of past records over a period of 31 years in the area is necessary to arrive at a fair estimate of intensity duration for given frequencies.

The relation between Intensity of rainfall (i) and Time of concentration(t) is given by equation,

I= (a/ t^n)

Rainfall data collected for 31 years from IMD Bangalore are based on instantaneous cumulative rainfall, recorded at automatic rainfall gauges, equipped with pen recorders at Bangalore. Based on these rainfall data and for storm frequency of once in two years, duration – intensity values are calculated by interpolation and these values are plotted on a graph and best-fit curve is drawn against the plotted graph. From this best-fit curve, the relationship between 'time to concentration (tc)'in minutes and intensity of rainfall (i)'in mm/hr., may be expressed by a suitable mathematical formula, which is as under:

$$I = 223.9324^{-0.4488}$$

Where, a= 223.9324, n= -0.4488

6.1.5 TIME OF CONCENTRATION

Time of Concentration is the time required for rainwater to flow over the ground surface from extreme point of the drainage basin and reach to the point under consideration.

As per IRC-SP-13 Para 4.7, the time of concentration for a stream is given by

$tc = (0.87 \times L^3 / H)\ 0.345$

Where

tc = time of concentration in hours

L = length of stream in km

H = fall in stream bed from the farthest point to the disposal point in m

It is the time required for the rainwater to flow over the ground surface from the extreme point of the drainage basin and reach the point under consideration. Time of concentration (tc) for a given storm water drain is calculated by considering inlet time and time of travel.

6.1.6 IMPERVIOUSNESS

The portion of the rainfall reaching the drains is dependent on the imperviousness and the shape of the tributary area.

As per Clause 3.3.1.5 on page no 43 of CPHEEO manual provides the following criteria for adoption of percentage of Imperviousness:

Table 18: Criteria for Adoption of Percentage of Imperviousness

SL. No.	Type of Area	Percentage of Imperviousness
1.	Commercial and Industrial	70 to 90
2.	Residential (a) High Density	60 to 75
	(b) Low Density	35 to 60
3.	Parks and undeveloped area	10 to 20

Considering the speed of development, the higher values will be adopted.

The weighted average imperviousness of the drainage basin for the flow concentrating at a point will be calculated using the following formula:

$$I = \frac{A_1 I_1 + A_2 I_2 + A_3 I_3 + ...}{A_1 + A_2 + A_3 + ...}$$

Where,

A1, A2, A3	=	Drainage Areas tributary to the section under consideration
I1, I2, I3	=	Imperviousness of the respective area and
I	=	Weighted Average Imperviousness of the total drainage basin

The Weighted Average runoff co-efficient for rectangular areas, of length four times the width as well as for sector shaped areas with varying percentages of impervious surface for different time of concentration are given in Clause 3.9.1 on page no 3-7 of CPHEEO manual Table 3.6.

6.1.7 DESIGN OF SURFACE DRAINS – SECTIONS

Carrying capacity of the nallas at different chainage and sections are calculated using manning's Flow-Friction formula given in para 3.4.2 of CPHEEO manual, which is as under:

V = (1/n) R ½2/3 S ½ and

Q = A x V

Where;

V	=	Velocity o flow in m/sec.
n	=	Manning's co-efficient of roughness
R	=	Hydraulic radius in m,
S	=	Slope of hydraulic gradient
Q	=	Discharge/carrying capacity in m^3/sec
A	=	Cross sectional area of storm sewer/nallah in sq.m.

6.1.8 PERMISSIBLE VELOCITIES

The minimum velocity in the drains shall generally be 0.60 m/sec and the maximum permissible velocity for RCC and/or masonry drains with concrete bed is up to 6 m/sec (IRC SP 42). Some have been adopted for the designs.

6.1.9 ROUGHNESS COEFFICIENTS FOR DIFFERENT DRAIN TYPE

Table 19: The Coefficient of Roughness for Different Types of Drains

Drain Type	Description	Manning's 'n'
1	Natural drain, meandering-with vegetation	0.035
2	Natural drain, largely straight-without vegetation	0.03
3	BB/Stone masonry walls natural bed	0.025
4	BB/Stone masonry walls with pointing and stone paving bed	0.02
5	BB/Stone masonry walls-concrete bed or concrete walls with stone paving bed	0.018
6	PCC/RCC walls, concrete bed	0.015
7	RCC pipe drain	0.013

6.2 DESIGN OF CULVERT / MINOR BRIDGES

Based on aforesaid design criterions, hydraulic design is carried out for individual nallah crossing locations and results are presented below. Major Arterial Road crossing over existing pond at Ch. 9+270, hence major bridge (CD-9) of adequate width and length is proposed. Also Major Arterial Road crossing over existing storm water drainage network at Ch. 9+800, hence major bridge (CD-10) of adequate width and length is proposed.

Table 20: Design of Culvert / Major Bridges

Structure no.	Svy No.	Width (m)	Chainage (m)	As per Design	Proposed Structure	Final Proposed Arrangement
CD-1	Sy No.102/1	55.8+55	1910	4 m X 2.4 m	Culvert	2 x 2m x 3m
CD-2	Sy No.67	54.0+55	2810	6.5m x 1.4 m	Culvert	2 x 3.25m x 2m
CD-3	Sy No.58	52.8+55	3090	6.5m x 1.4 m	Culvert	2 x 3.25m x 2m
CD-4	Sy No.46	48.5+55	4040	5 m x 2.4 m	Culvert	2 x 2.5m x 3m
CD-5	Sy No.2	125.0+55	5110	6.5m x 2.4 m	Culvert	2 x 3.25m x 3m
CD-6	Sy No.48	66.7+55	5600	8 m x 2.4 m	Culvert	2x2.60 m x3m + 1x2.8mx3m
CD-7	Sy No.52/3	46.7+55	5980	8 m x 2.4 m	Culvert	2x2.60 m x3m + 1x2.8mx3m
CD-8	Sy No.22	45+55	6590	6.5m x1.4 m	Culvert	2 x 3.25m x 2m
CD-9	-	160	9190-9350	160m x 2.4m	Major Bridge	8 x 20m x 3.0m
CD-10	-	300	9650-9950	300m x 2.4m	Major Road	15 x 20m x 3.0m

Figure 13: Location of CD-1 on Google Imagery

Figure 14: Location of CD-2 & CD-3 on Google Imagery

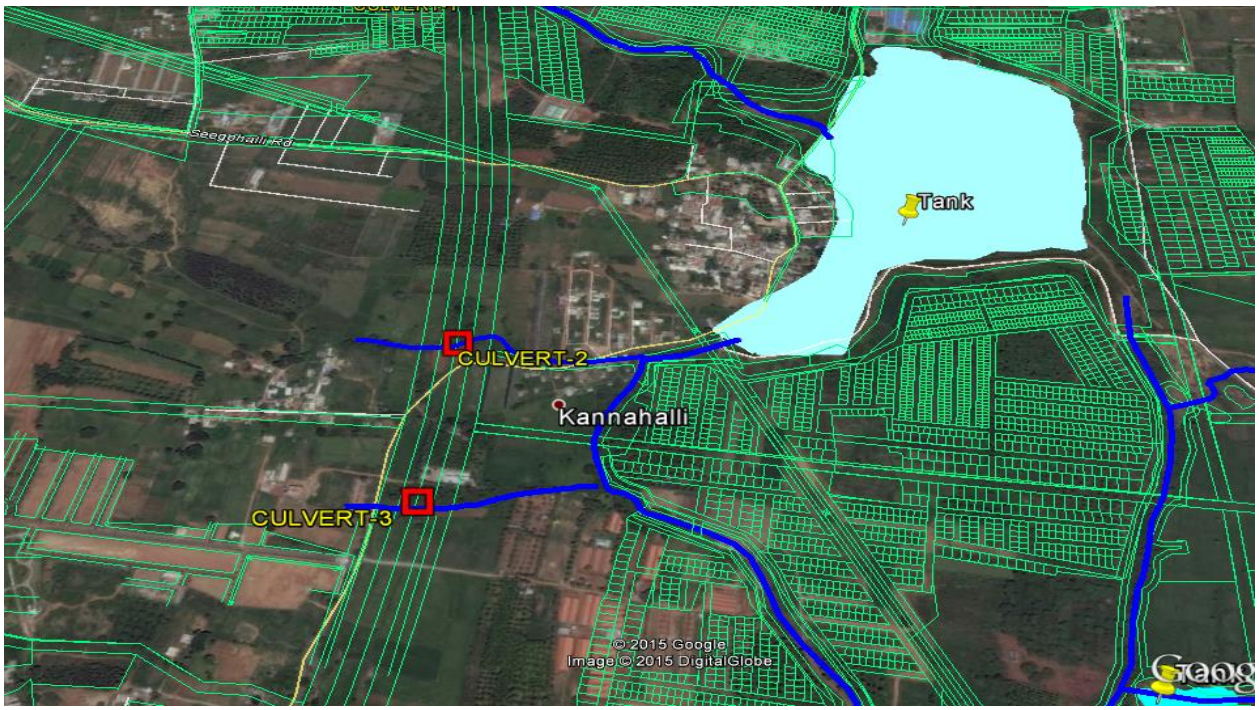


Figure 15: Location of CD-4 on Google Imagery

Figure 16: Location of CD-5, CD-6 & CD-7 on Google Imagery

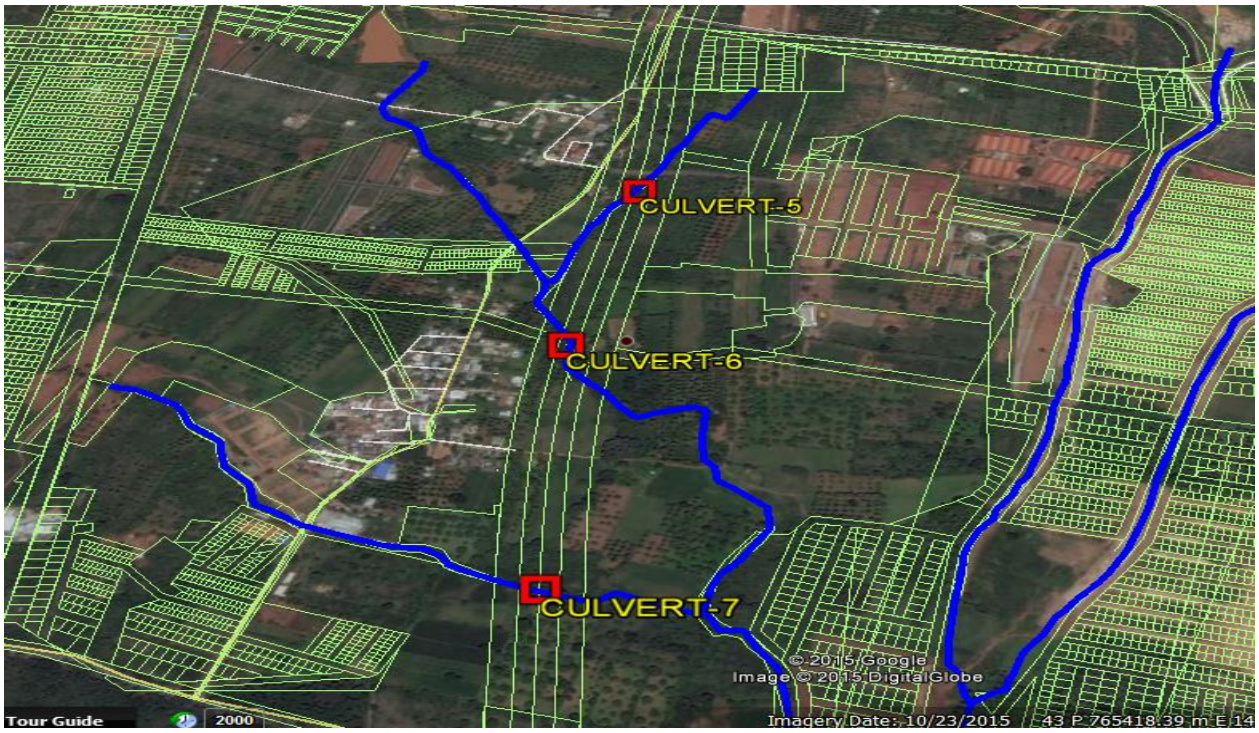
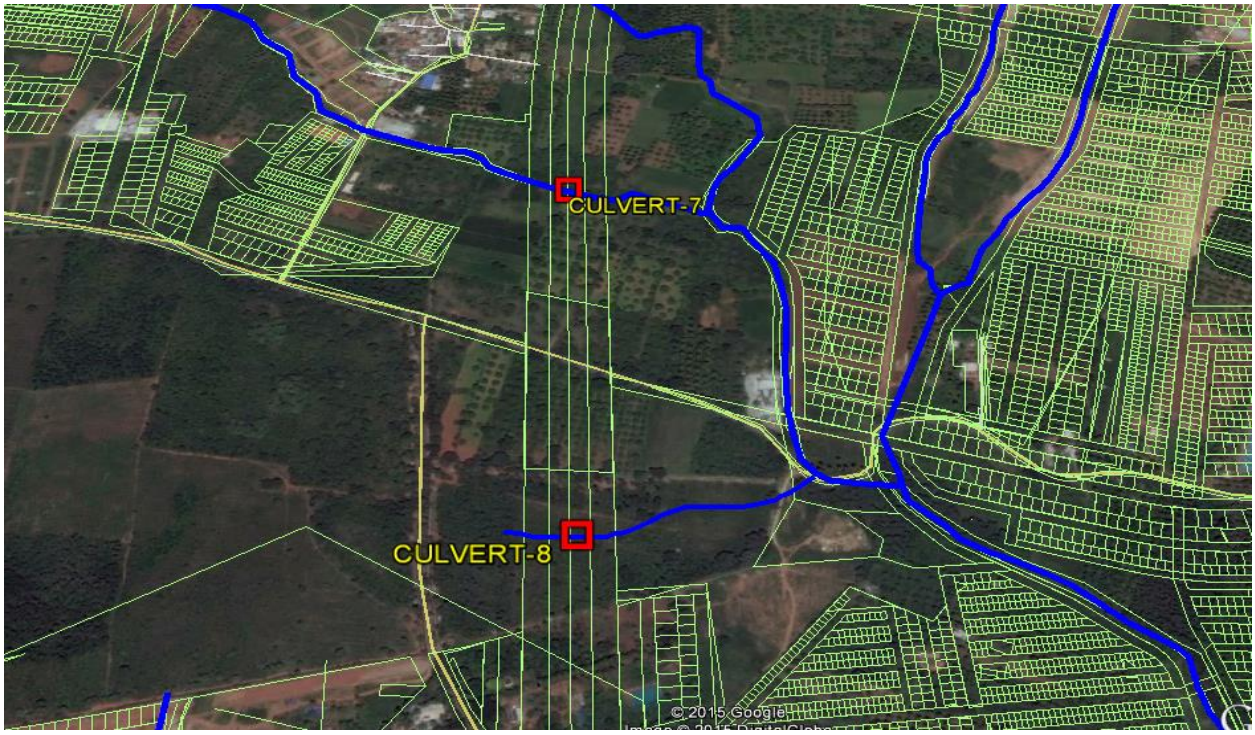


Figure 17: Location of CD-8 on Google Imagery


CULVERT-7
CULVERT-8
© 2015 Google

6.3 CATCHMENT AREA CALCULATIONS

Drain No	Catchment	Total Catchment Area	Actual Area	Distance Of Farthest Point	GL Of Farthest Point	Level Of Catch Basin	Available Slope	Inlet Time (min)	Flow Time (min)	Time Of Concentration tc(min)	Effective Rainfall Intensity I (mm/hr)	Coefficient of Runoff C	Q =10 CIA (cum/sec)	Q Cumulative (cum/sec)
						CD-1								
Drain no-5	CA-1	292820.950	175692.570	295.280	852.000	840.216	25.06	4.94		4.936	109.382	0.55	4.76	4.76
Drain no-5/1	CA-2	350781.250	210468.750	426.630	857.500	837.579	21.42	6.17		6.168	98.969	0.55	3.18	3.18
Drain no-5/2	CA-3	433564.990	260138.994	595.320	842.000	829.235	46.64	10.76	3.201	13.958	68.598	0.59	2.92	10.86
						CD-2								
Drain no-7	CA-4	356140.942	213684.565	454.520	855.500	833.100	20.291	6.343		6.343	97.734	0.51	2.98	2.98
						CD-3								
	CA-5	163526.410	98115.846	278.380	844.000	830.100	20.027	4.327		4.327	116.039	0.55	1.74	1.74
						CD-4								
Drain no-11	CA-6	1361244.681	816746.809	708.900	865.000	843.000	32.223	10.672		10.672	77.381	0.56	9.77	9.77
	CA-7	1174408.010	704644.806	418.600	831.000	821.321	43.248	7.967	45.333	53.300	37.598	0.79	5.81	15.59
						CD-5								
Drain no-16	CA-8	330854.842	198512.905	491.600	829.000	812.529	29.846	7.817		7.817	88.985	0.55	2.70	2.70
	CA-9	873835.744	524301.447	1048.370	849.500	815.400	30.744	14.166		14.166	68.145	0.59	5.86	5.86
						CD-6								
Drain no-16	CA-10	230835.205	138501.123	213.600	805.000	799.538	39.107	4.565	21.663	26.229	51.686	0.69	1.37	9.93
						CD-7								
Drain no-16/2	CA-11	475886.496	285531.898	354.710	830.500	812.700	19.928	5.204		5.204	106.810	0.55	4.66	4.66
						CD-8								
	CA-12	283273.915	169964.349	240.000	820.000	808.100	20.168	3.870		3.870	121.996	0.55	3.17	3.17

6.4 HYDRAULIC DESIGN CALCULATIONS

Sr No	culvert no	From Catch Basin	To Catch Basin	Length (m)	Invert Level at Upstream side (m)	Invert Level at Downstream side (m)	Slope Adopted (1/S)	Slope PROVIDED (1/S)	Manning's n	Proposed Section Size				Avg C/S Area (Sqm)	Perimeter (m)	Velocity (V Proposed) (m/s)	Discharge (Q) Proposed (cum/sec)	Discharge (Q) Existing (cum/sec)	% Full (Q Actual / Designed)	Adequacy
										Width at Upstream side (m)	Width at Downstream side (m)	Depth at Upstream side (m)	Depth at Downstream side (m)							
(Drain-5)		CB-1	CB-2	710.731	840.216	829.235	65	300	0.018	4	4	2.40	2.40	9.6	8.80	3.4	32.63	4.76	15%	**OK**
(Drain-5/1)		CB-2	CB-3	695.709	837.579	829.235	83	250	0.018	4	4	2.40	2.40	9.60	8.80	3.7	35.75	3.18	9%	**OK**
(Drain-5/2)	**CD-1**	CB-3	CB-4	744.617	829.235	822.452	110	250	0.018	4	4	2.40	2.40	9.60	8.80	3.7	35.75	10.86	30%	**OK**
Drain no-7	**CD-2**	CB-5	CB-6	463.760	833.100	830.036	151	500	0.018	6.5	6.5	1.40	1.40	9.10	9.30	2.4	22.28	2.98	13%	**OK**
	CD-3	CB-7	CB-8	346.970	830.100	828.670	243	500	0.018	6.5	6.5	1.40	1.40	9.10	9.30	2.4	22.28	1.74	8%	**OK**
		CB-9	CB-10	1360.000	840.600	821.000	69	400	0.018	5	5	2.40	2.40	12.00	9.80	3.2	38.15	9.77	26%	**OK**
Drain no-11	**CD-4**	CB-10	CB-11	612.849	821.321	809.442	52	500	0.018	5	5	2.40	2.40	12.00	9.80	2.8	34.12	15.59	46%	**OK**
Drain no-16	**CD-5**	CB-12	CB-13	574.800	812.529	799.538	44	500	0.018	6.5	6.5	2.40	2.40	15.60	11.30	3.1	48.05	2.70	6%	**OK**
		CB-14	CB-13	649.900	815.400	799.538	41	500	0.018	6.5	6.5	2.40	2.40	15.60	11.30	3.1	48.05	5.86	12%	**OK**
Drain no-16	**CD-6**	CB-13	CB-15	246.800	799.538	791.583	31	500	0.018	8	8	2.40	2.40	19.20	12.80	3.3	62.51	9.93	16%	**OK**
Drain no-16/2	**CD-7**	CB-16	CB-15	749.670	812.700	791.583	36	500	0.018	8	8	2.40	2.40	19.20	12.80	3.3	62.51	4.66	7%	**OK**
	CD-8	CB-17	CB-18	422.000	808.100	789.000	22	500	0.018	6.5	6.5	1.40	1.40	9.10	9.30	2.4	22.28	3.17	14%	**OK**

6.5 HYDRAULIC DESIGN CALCULATIONS FOR ROADSIDE DRAINAGE SYSTEMS – CATCH BASIN TABLE

Label	Elevation (Ground) (m)	Elevation (Invert) (m)	Local CA (ha)	Structure Type
CB-1	763	762.2	1.188	Box Structure
CB-2	763	762.2	1.22	Box Structure
CB-3	832.94	832.14	0.391	Box Structure

Label	Elevation (Ground) (m)	Elevation (Invert) (m)	Local CA (ha)	Structure Type
CB-4	832.94	832.14	0.386	Box Structure
CB-5	831.31	830.51	0.369	Box Structure
CB-6	831.31	830.51	0.35	Box Structure
CB-7	858.35	857.55	1.039	Box Structure
CB-8	854.73	853.93	1.036	Box Structure
CB-9	850.83	850.03	1.352	Box Structure
CB-10	858.35	857.55	0.812	Box Structure
CB-11	866.5	865.7	0.787	Box Structure
CB-12	841.66	840.86	0.672	Box Structure
CB-13	835.5	834.7	0.825	Box Structure
CB-14	841.66	840.86	0.926	Box Structure
CB-15	834.07	833.27	0.336	Box Structure
CB-16	834.07	833.27	0.758	Box Structure
CB-17	824.75	823.95	0.663	Box Structure
CB-18	821.92	821.12	0.552	Box Structure
CB-19	830.73	829.93	1.381	Box Structure
CB-20	830.73	829.93	1.275	Box Structure
CB-21	807.87	807.07	1.143	Box Structure
CB-22	803.24	802.44	1.027	Box Structure
CB-23	804.82	804.02	0.703	Box Structure
CB-24	804.82	804.02	0.819	Box Structure
CB-25	810.4	809.6	0.802	Box Structure
CB-26	810.4	809.6	0.913	Box Structure
CB-27	809.21	808.41	0.827	Box Structure
CB-28	807.92	807.12	0.941	Box Structure
CB-29	801.42	800.62	0.661	Box Structure
CB-30	801.42	800.62	1.457	Box Structure
CB-31	783.93	783.13	1.077	Box Structure
CB-32	772.32	771.52	0.761	Box Structure
CB-33	764.61	763.81	0.146	Box Structure
CB-34	801.42	800.62	0.677	Box Structure
CB-35	810.4	809.6	0.816	Box Structure
CB-36	809.21	808.41	0.796	Box Structure
CB-37	807.92	807.12	0.893	Box Structure
CB-38	821.92	821.12	0.543	Box Structure
CB-39	834.07	833.27	0.833	Box Structure
CB-40	824.75	823.95	0.724	Box Structure
CB-41	858.35	857.55	0.847	Box Structure
CB-42	866.5	865.7	0.815	Box Structure
CB-43	858.35	857.55	1.065	Box Structure
CB-44	854.73	853.93	1.067	Box Structure
CB-45	850.83	850.03	1.464	Box Structure

Label	Elevation (Ground) (m)	Elevation (Invert) (m)	Local CA (ha)	Structure Type
CB-46	841.66	840.86	0.694	Box Structure
CB-47	835.5	834.7	0.742	Box Structure
CB-48	841.66	840.86	0.923	Box Structure
CB-49	834.07	833.27	0.333	Box Structure
CB-50	830.73	829.93	1.202	Box Structure
CB-51	830.73	829.93	1.287	Box Structure
CB-52	808.56	807.76	1.407	Box Structure
CB-53	802.93	802.13	1.032	Box Structure
CB-54	810.4	809.6	0.805	Box Structure
CB-55	772.32	771.52	0.723	Box Structure
CB-56	764.61	763.81	0.159	Box Structure
CB-57	801.42	800.62	1.476	Box Structure
CB-58	783.93	783.13	1.06	Box Structure
CB-59	804.82	804.02	0.716	Box Structure
CB-60	804.82	804.02	0.706	Box Structure

6.6 HYDRAULIC DESIGN CALCULATIONS FOR ROADSIDE DRAINAGE SYSTEMS – CONDUIT TABLE

Label	Start Node	Stop Node	Length (Scaled) (m)	Elevation Ground (Start) (m)	Elevation Ground (Stop) (m)	Invert (Upstream) (m)	Invert (Downstream) (m)	Width (m)	Depth (m)	Slope (1/S)	Velocity (Average) (m/s)	Conduit Shape	Material	Capacity (Full Flow) (m^3/s)	Manning's n
CO-1	CB-1	OF-1	404.2	763	763.01	762.2	761.8	0.8	0.8	1000	0.84	Box Pipe	Concrete	0.49	0.014
CO-2	CB-2	OF-2	417.3	763	763.01	762.2	761.78	0.8	0.8	1000	0.85	Box Pipe	Concrete	0.49	0.014
CO-3	CB-3	OF-3	131.1	832.94	829.39	832.14	828.59	0.8	0.8	37	1.9	Box Pipe	Concrete	2.57	0.014
CO-4	CB-4	OF-4	138.4	832.94	829.39	832.14	828.59	0.8	0.8	39	1.86	Box Pipe	Concrete	2.51	0.014
CO-5	CB-5	OF-5	125.6	831.31	829.39	830.51	828.59	0.8	0.8	65	1.55	Box Pipe	Concrete	1.93	0.014
CO-6	CB-6	OF-6	119.8	831.31	829.39	830.51	828.59	0.8	0.8	62	1.54	Box Pipe	Concrete	1.98	0.014
CO-7	CB-7	CB-8	421.5	858.35	854.73	857.55	853.93	0.8	0.8	117	1.8	Box Pipe	Concrete	1.45	0.014
CO-8	CB-8	CB-9	425.2	854.73	850.83	853.93	850.03	0.8	0.8	109	2.1	Box Pipe	Concrete	1.5	0.014
CO-9	CB-9	OF-7	469.4	850.83	834.25	850.03	833.45	0.8	0.8	28	3.75	Box Pipe	Concrete	2.94	0.014
CO-10	CB-10	OF-8	291.1	858.35	853.43	857.55	852.63	0.8	0.8	59	2.1	Box Pipe	Concrete	2.03	0.014
CO-11	CB-11	OF-9	270.7	866.5	853.43	865.7	852.63	0.8	0.8	21	2.93	Box Pipe	Concrete	3.44	0.014
CO-12	CB-12	CB-13	264.6	841.66	835.5	840.86	834.7	0.8	0.8	43	2.19	Box Pipe	Concrete	2.39	0.014
CO-13	CB-13	OF-10	301.8	835.5	834.25	834.7	833.45	0.8	0.8	241	1.49	Box Pipe	Concrete	1.01	0.014
CO-14	CB-14	OF-11	326.4	841.66	832.94	840.86	832.14	0.8	0.8	37	2.55	Box Pipe	Concrete	2.56	0.014
CO-15	CB-15	OF-12	114.9	834.07	831.31	833.27	830.51	0.8	0.8	42	1.73	Box Pipe	Concrete	2.42	0.014

Label	Start Node	Stop Node	Length (Scaled) (m)	Elevation Ground (Start) (m)	Elevation Ground (Stop) (m)	Invert (Upstream) (m)	Invert (Downstream) (m)	Width (m)	Depth (m)	Slope (1/S)	Velocity (Average) (m/s)	Conduit Shape	Material	Capacity (Full Flow) (m^3/s)	Manning's n
CO-16	CB-16	CB-17	313.3	834.07	824.75	833.27	823.95	0.8	0.8	34	2.47	Box Pipe	Concrete	2.7	0.014
CO-17	CB-17	OF-13	291.1	824.75	816.47	823.95	815.67	0.8	0.8	35	2.88	Box Pipe	Concrete	2.64	0.014
CO-18	CB-18	OF-14	220.4	821.92	816.47	821.12	815.67	0.8	0.8	40	2.09	Box Pipe	Concrete	2.46	0.014
CO-19	CB-19	OF-15	575.2	830.73	821.92	829.93	821.12	0.8	0.8	65	2.4	Box Pipe	Concrete	1.93	0.014
CO-20	CB-20	OF-16	518.2	830.73	807.87	829.93	807.07	0.8	0.8	23	3.36	Box Pipe	Concrete	3.28	0.014
CO-21	CB-21	OF-17	433.7	807.87	803.24	807.07	802.44	0.8	0.8	94	1.99	Box Pipe	Concrete	1.61	0.014
CO-22	CB-22	OF-18	394.4	803.24	799.48	802.44	798.68	0.8	0.8	105	1.86	Box Pipe	Concrete	1.53	0.014
CO-23	CB-23	OF-19	280.1	804.82	799.48	804.02	798.68	0.8	0.8	52	2.08	Box Pipe	Concrete	2.16	0.014
CO-24	CB-24	OF-20	319.1	804.82	802.27	804.02	801.47	0.8	0.8	125	1.63	Box Pipe	Concrete	1.4	0.014
CO-25	CB-25	OF-21	331	810.4	802.27	809.6	801.47	0.8	0.8	41	2.36	Box Pipe	Concrete	2.45	0.014
CO-26	CB-26	CB-27	344.1	810.4	809.21	809.6	808.41	0.8	0.8	289	1.25	Box Pipe	Concrete	0.92	0.014
CO-27	CB-27	CB-28	329.2	809.21	807.92	808.41	807.12	0.8	0.8	255	1.45	Box Pipe	Concrete	0.98	0.014
CO-28	CB-28	OF-22	322.2	807.92	797.09	807.12	796.29	0.8	0.8	30	3.38	Box Pipe	Concrete	2.87	0.014
CO-29	CB-29	OF-23	233.2	801.42	797.09	800.62	796.29	0.8	0.8	54	2.02	Box Pipe	Concrete	2.13	0.014
CO-30	CB-30	CB-31	598	801.42	783.93	800.62	783.13	0.8	0.8	34	3.05	Box Pipe	Concrete	2.67	0.014
CO-31	CB-31	OF-24	426.7	783.93	771.32	783.13	770.52	0.8	0.8	34	3.42	Box Pipe	Concrete	2.69	0.014
CO-32	CB-32	CB-33	262.7	772.32	764.61	771.52	763.81	0.8	0.8	34	2.46	Box Pipe	Concrete	2.68	0.014
CO-33	CB-33	OF-25	44.8	764.61	763.15	763.81	762.35	0.8	0.8	31	2.62	Box Pipe	Concrete	2.82	0.014
CO-34	CB-34	OF-26	232.6	801.42	797.09	800.62	796.29	0.8	0.8	54	2.04	Box Pipe	Concrete	2.13	0.014
CO-35	CB-35	CB-36	344.4	810.4	809.21	809.6	808.41	0.8	0.8	289	1.21	Box Pipe	Concrete	0.92	0.014
CO-36	CB-36	CB-37	329.2	809.21	807.92	808.41	807.12	0.8	0.8	255	1.42	Box Pipe	Concrete	0.98	0.014
CO-37	CB-37	OF-27	318.8	807.92	797.09	807.12	796.29	0.8	0.8	29	3.31	Box Pipe	Concrete	2.88	0.014
CO-38	CB-38	OF-28	211.2	821.92	816.47	821.12	815.67	0.8	0.8	39	2.1	Box Pipe	Concrete	2.51	0.014
CO-39	CB-39	CB-40	313.9	834.07	824.75	833.27	823.95	0.8	0.8	34	2.55	Box Pipe	Concrete	2.69	0.014
CO-40	CB-40	OF-29	295.4	824.75	816.47	823.95	815.67	0.8	0.8	36	2.96	Box Pipe	Concrete	2.62	0.014
CO-41	CB-41	OF-30	291.7	858.35	853.43	857.55	852.63	0.8	0.8	59	2.12	Box Pipe	Concrete	2.03	0.014
CO-42	CB-42	OF-31	281.9	866.5	853.43	865.7	852.63	0.8	0.8	22	2.93	Box Pipe	Concrete	3.37	0.014
CO-43	CB-43	CB-44	423.1	858.35	854.73	857.55	853.93	0.8	0.8	117	1.81	Box Pipe	Concrete	1.45	0.014
CO-44	CB-44	CB-45	421.2	854.73	850.83	853.93	850.03	0.8	0.8	108	2.12	Box Pipe	Concrete	1.5	0.014
CO-45	CB-45	OF-32	496.2	850.83	834.25	850.03	833.45	0.8	0.8	30	3.73	Box Pipe	Concrete	2.86	0.014
CO-46	CB-46	CB-47	267.3	841.66	835.5	840.86	834.7	0.8	0.8	43	2.21	Box Pipe	Concrete	2.37	0.014
CO-47	CB-47	OF-33	290.2	835.5	834.25	834.7	833.45	0.8	0.8	232	1.49	Box Pipe	Concrete	1.03	0.014
CO-48	CB-48	OF-34	338.6	841.66	832.94	840.86	832.14	0.8	0.8	39	2.52	Box Pipe	Concrete	2.51	0.014
CO-49	CB-49	OF-35	113.7	834.07	831.31	833.27	830.51	0.8	0.8	41	1.74	Box Pipe	Concrete	2.44	0.014
CO-50	CB-50	OF-36	459	830.73	808.56	829.93	807.76	0.8	0.8	21	3.39	Box Pipe	Concrete	3.44	0.014
CO-51	CB-51	OF-37	582.2	830.73	821.92	829.93	821.12	0.8	0.8	66	2.34	Box Pipe	Concrete	1.92	0.014
CO-52	CB-52	OF-38	520.9	808.56	802.93	807.76	802.13	0.8	0.8	93	2.13	Box Pipe	Concrete	1.63	0.014
CO-53	CB-53	OF-39	361.5	802.93	799.48	802.13	798.68	0.8	0.8	105	1.86	Box Pipe	Concrete	1.53	0.014
CO-54	CB-54	OF-40	331.3	810.4	802.27	809.6	801.47	0.8	0.8	41	2.37	Box Pipe	Concrete	2.45	0.014
CO-55	CB-55	CB-56	250.2	772.32	764.61	771.52	763.81	0.8	0.8	32	2.46	Box Pipe	Concrete	2.74	0.014

Label	Start Node	Stop Node	Length (Scaled) (m)	Elevation Ground (Start) (m)	Elevation Ground (Stop) (m)	Invert (Upstream) (m)	Invert (Downstream) (m)	Width (m)	Depth (m)	Slope (1/S)	Velocity (Average) (m/s)	Conduit Shape	Material	Capacity (Full Flow) (m^3/s)	Manning's n
CO-56	CB-56	OF-41	51.2	764.61	763.15	763.81	762.35	0.8	0.8	35	2.48	Box Pipe	Concrete	2.64	0.014
CO-57	CB-57	CB-58	596.5	801.42	783.93	800.62	783.13	0.8	0.8	34	3.06	Box Pipe	Concrete	2.68	0.014
CO-58	CB-58	OF-42	431.3	783.93	771.32	783.13	770.52	0.8	0.8	34	3.41	Box Pipe	Concrete	2.67	0.014
CO-59	CB-59	OF-43	318.2	804.82	802.27	804.02	801.47	0.8	0.8	125	1.56	Box Pipe	Concrete	1.4	0.014
CO-60	CB-60	OF-44	277.1	804.82	799.48	804.02	798.68	0.8	0.8	52	2.09	Box Pipe	Concrete	2.17	0.014

6.7 HYDRAULIC DESIGN CALCULATIONS FOR ROADSIDE DRAINAGE SYSTEMS – CATCHMENT TABLE

Label	Rational C	Catchment CA (ha)	Time of Concentration (min)	Outflow Node	Catchment Intensity (mm/h)	Catchment Rational Flow (m^3/s)
CM-1	1	1.188	5	CB-1	109	0.36
CM-2	1	1.22	5	CB-2	109	0.37
CM-3	1	0.391	5	CB-3	109	0.12
CM-4	1	0.386	5	CB-4	109	0.12
CM-5	1	0.369	5	CB-5	109	0.11
CM-6	1	0.35	5	CB-6	109	0.11
CM-7	1	1.039	5	CB-7	109	0.31
CM-8	1	1.036	5	CB-8	109	0.31
CM-9	1	1.352	5	CB-9	109	0.41
CM-10	1	0.812	5	CB-10	109	0.25
CM-11	1	0.787	5	CB-11	109	0.24
CM-12	1	0.672	5	CB-12	109	0.2
CM-13	1	0.825	5	CB-13	109	0.25
CM-14	1	0.926	5	CB-14	109	0.28
CM-15	1	0.336	5	CB-15	109	0.1
CM-16	1	0.758	5	CB-16	109	0.23
CM-17	1	0.663	5	CB-17	109	0.2
CM-18	1	0.552	5	CB-18	109	0.17
CM-19	1	1.381	5	CB-19	109	0.42
CM-20	1	1.275	5	CB-20	109	0.39
CM-21	1	1.143	5	CB-21	109	0.35
CM-22	1	1.027	5	CB-22	109	0.31
CM-23	1	0.703	5	CB-23	109	0.21
CM-24	1	0.819	5	CB-24	109	0.25
CM-25	1	0.802	5	CB-25	109	0.24
CM-26	1	0.913	5	CB-26	109	0.28

Label	Rational C	Catchment CA (ha)	Time of Concentration (min)	Outflow Node	Catchment Intensity (mm/h)	Catchment Rational Flow (m^3/s)
CM-27	1	0.827	5	CB-27	109	0.25
CM-28	1	0.941	5	CB-28	109	0.28
CM-29	1	0.661	5	CB-29	109	0.2
CM-30	1	1.457	5	CB-30	109	0.44
CM-31	1	1.077	5	CB-31	109	0.33
CM-32	1	0.761	5	CB-32	109	0.23
CM-33	1	0.146	5	CB-33	109	0.04
CM-34	1	0.677	5	CB-34	109	0.21
CM-35	1	0.816	5	CB-35	109	0.25
CM-36	1	0.796	5	CB-36	109	0.24
CM-37	1	0.893	5	CB-37	109	0.27
CM-38	1	0.543	5	CB-38	109	0.16
CM-39	1	0.833	5	CB-39	109	0.25
CM-40	1	0.724	5	CB-40	109	0.22
CM-41	1	0.847	5	CB-41	109	0.26
CM-42	1	0.815	5	CB-42	109	0.25
CM-43	1	1.065	5	CB-43	109	0.32
CM-44	1	1.067	5	CB-44	109	0.32
CM-45	1	1.464	5	CB-45	109	0.44
CM-46	1	0.694	5	CB-46	109	0.21
CM-47	1	0.742	5	CB-47	109	0.22
CM-48	1	0.923	5	CB-48	109	0.28
CM-49	1	0.333	5	CB-49	109	0.1
CM-50	1	1.202	5	CB-50	109	0.36
CM-51	1	1.287	5	CB-51	109	0.39
CM-52	1	1.407	5	CB-52	109	0.43
CM-53	1	1.032	5	CB-53	109	0.31
CM-54	1	0.805	5	CB-54	109	0.24
CM-55	1	0.723	5	CB-55	109	0.22
CM-56	1	0.159	5	CB-56	109	0.05
CM-57	1	1.476	5	CB-57	109	0.45
CM-58	1	1.06	5	CB-58	109	0.32
CM-59	1	0.716	5	CB-59	109	0.22
CM-60	1	0.706	5	CB-60	109	0.21

6.8 HYDRAULIC DESIGN CALCULATIONS FOR ROADSIDE DRAINAGE SYSTEMS – OUTFALL TABLE

Label	Elevation (Ground) (m)	Elevation (Invert) (m)	Boundary Condition Type
OF-1	763.01	761.8	Free Outfall
OF-2	763.01	761.78	Free Outfall
OF-3	829.39	828.59	Free Outfall
OF-4	829.39	828.59	Free Outfall
OF-5	829.39	828.59	Free Outfall
OF-6	829.39	828.59	Free Outfall
OF-7	834.25	833.45	Free Outfall
OF-8	853.43	852.63	Free Outfall
OF-9	853.43	852.63	Free Outfall
OF-10	834.25	833.45	Free Outfall
OF-11	832.94	832.14	Free Outfall
OF-12	831.31	830.51	Free Outfall
OF-13	816.47	815.67	Free Outfall
OF-14	816.47	815.67	Free Outfall
OF-15	821.92	821.12	Free Outfall
OF-16	807.87	807.07	Free Outfall
OF-17	803.24	802.44	Free Outfall
OF-18	799.48	798.68	Free Outfall
OF-19	799.48	798.68	Free Outfall
OF-20	802.27	801.47	Free Outfall
OF-21	802.27	801.47	Free Outfall
OF-22	797.09	796.29	Free Outfall
OF-23	797.09	796.29	Free Outfall
OF-24	771.32	770.52	Free Outfall
OF-25	763.15	762.35	Free Outfall
OF-26	797.09	796.29	Free Outfall
OF-27	797.09	796.29	Free Outfall
OF-28	816.47	815.67	Free Outfall
OF-29	816.47	815.67	Free Outfall
OF-30	853.43	852.63	Free Outfall
OF-31	853.43	852.63	Free Outfall
OF-32	834.25	833.45	Free Outfall
OF-33	834.25	833.45	Free Outfall
OF-34	832.94	832.14	Free Outfall
OF-35	831.31	830.51	Free Outfall
OF-36	808.56	807.76	Free Outfall
OF-37	821.92	821.12	Free Outfall

Label	Elevation (Ground) (m)	Elevation (Invert) (m)	Boundary Condition Type
OF-38	802.93	802.13	Free Outfall
OF-39	799.48	798.68	Free Outfall
OF-40	802.27	801.47	Free Outfall
OF-41	763.15	762.35	Free Outfall
OF-42	771.32	770.52	Free Outfall
OF-43	802.27	801.47	Free Outfall
OF-44	799.48	798.68	Free Outfall

7 DESIGN OF STRUCTURES

7.1 DESIGN BASIS

The intent of this chapter is to identify and record all the pertinent input requirements, analysis & design criteria for structural design of the proposed structures. It is aimed at formulating the basis of the structural analysis, design & detailing work that the Structural Engineer is planning in delivering the structural scheme. The scheme will be compatible with the overall project, satisfy the functional needs, at the same time conforming to the Indian Road Congress and Bureau of Indian Standards and other applicable norms to achieve safe, stable, strong and yet optimally economical structures.

7.2 AIM OF DESIGN

The structural design aim to achieve:

- Structural & functional integrity.
- Desirable Structural performance under characteristic service design loads.
- Resistance to loads due to natural phenomena i.e. wind and earthquakes.
- Structural durability & maintainability.

Design Standards- the latest guidelines circulars of MORT&H and relevant publications of the IRC and BIS are invariably be followed. For aspects not covered by IRC and BIS, international standard practices, such as, British and American Standards have been adopted.

The span arrangement and the geometric of the structural components of the new bridges have been selected in such a way that the new structures do not adversely affect the existing bridges and at the same time these are aesthetically pleasing, giving better riding qualities and are most suitable and cost effective.

7.3 TYPES OF STRUCTURES

The main structures expected are of following type:

Cross Drainage (CD) structures- The cross drainage structures are classified as culvertsand major bridges depending upto the length of structure as per IRC standards. Structures up to 6m length

fall into the category of culverts, more than 6m and up to 60m in length as minor bridges and beyond this as major bridges.

For box culverts standard drawings of MORT&H are adopted. The bridge spans are provided as per standard details of MORT&H and abutment & piers are designed as per IRC loadings.

Flyovers - Grades of Concrete for superstructures will be as per MORT&H Specifications and IRC Standards. The Minimum grade shall be M40 for PSC and M30 T-Beam slab respectively. For substructures and foundations, the concrete grade will not be lower than M30 except for well stoning and bottom plug where M25 concrete will be used. For PCC substructures M20 grade will be adopted.

Road over Bridges –ROB will be required at railway line crossing. The clearances from the railway structures will be followed as per Railway requirement. The locations of piers and abutments will be finalized as per Railway requirements. The design of bridge will be in structural steel as per Railway requirement. The structural design will be done as per IRC codes.

The cross drainage and flyover structures will be mainly R.C.C . all the loads will be considered as per IRC codes. The deck slab will be designed using grillage analysis. A computer model of the structural frame will be generated for carrying out computer analysis for the effects of vertical and lateral load that are likely to be imposed on the structure.

Road over bridge will have structural steel superstructure with piers and abutment of RCC. A three dimensional model of the structure is generated and all loads are applied and the analysis and design carried out on computer.

7.4 LOADS CONSIDERED

Following loads areconsidered in general:

- Dead load
- Live load
- Wind load
- Seismic load
- Impact load
- Loads due to water currents
- Longitudinal forces
- Centrifugal forces

- Buoyancy
- Earth pressure
- Temperature
- Deformation stresses
- Secondary stresses
- Erection loads
- Vehicle collision loads

7.5 METHODOLOGY OF DESIGN

The structure is analyzed using STAAD-Pro v8i software. STAAD-Pro v8i have been thoroughly tested, validated and recognized internationally by several organizations and are well suited for the analysis.

Design of different structural elements is carried out using In-house developed spreadsheets. Foundation is designed as per the reference bore-logs samples recorded nearby.All structures are checked for stability considering sliding, overturning, buoyancy effects.

7.6 REFERENCE CODES

Design of all proposed structures is in accordance with the provisions of the following:

IRC codes:

- IRC:5-1998 Section 1, General Features of Design
- IRC: 6-2000 Section II, loads and Stresses
- IRC: 18-2000 Design Criteria for Prestressed Concrete Road Bridges
- IRC:21-2000 Section III, Cement Concrete (Plain and Reinforced)
- IRC: 22-1986 Section IV Composite construction for Road Bridges (Ist Revision)
- IRC: 78-2000 Section VII, Foundations and Substructure
- IRC: 83-1999 Section IX, (Part-1) Metallic Bearings
- IRC: 83-1987 Section IX, (Part-II), Elastomeric Bearings
- IRC:89-1997 Guidelines for Design and Construction of River Training and Control Works for Road Bridges (1st Revision

Whenever IRC codes are silent, relevant BIS codes are followed. In case where even BIS

codes are silent, other suitable international codes are adopted.

IS Codes

IS:456	Code of Practice for Plain and Reinforced Concrete-Based essentially on CP-110
IS:800	Code of Practice for General Construction in Steel
IS:875	Code of Practice for Design Loads Parts 1,2,3,4 & 5 (Other than Earthquake) for Building and Structures
IS:1080	Design and construction of shallow foundations in soils(other than Raft, Ring & Shell)
IS:1343	Code of Practice for Prestressed Concrete-Based essentially on CP-110
IS:1364	Hexagon Head Bolts, Screws & nuts of product grades A&B part 1.
(Part 1)	Hexagon Head Bolts(size range M1.6 to M64)
IS: 1489	Specifications for Portland Pozzolana Cement (flyash Based)
(Part 1)	
IS:1786	Specs. for High Strength Deformed steel bars and wires for concrete reinforcement
IS :1893	Criteria for Earthquake Resistant Design of structures
IS:1904	Design and Construction of Foundation in Soils: General Requirements
IS:1905	Code of Practice for Structural Use of Un-Reinforced Masonry
IS :2062	Specifications for Weld able structure steel
IS:2502	Code of Practice for Bending and Fixing of Bars for Concrete Reinforcement
IS :2950	Designs and Construction of Raft Foundations
IS:4000	Code of Practice for High Strength Bolts in Steel Structures
IS:4326	Code of Practice for Earthquake Resistant Design and Construction of Buildings
IS:4923	Hollow Steel sections for structural use-specification
IS:2062	Steel for General Structural Purposes-specifications
IS:8009	Calculation of Settlement of shallow foundations
IS:8112	Specification for 43 Grade Ordinary Portland cement
IS:8500	Structural Steel-Micro alloyed(Medium and high strength qualities)
IS:9103	Specifications for Admixtures for Concrete
IS:12070	Code of Practice for Design and Construction of Shallow Foundations on Rocks
IS:12269	Specifications for 53 Grade Ordinary Portland Cement
IS:14268	Uncoated stress Relived Low relaxation seven-ply Strands for Pre Stressed Concrete

7.7 MATERIALS OF CONSTRUCTION

7.7.1 CONCRETE

Concrete of Grade ranging from M:25 have been used in RCC structural members.

Concrete Mix M15 has been used in filling, plum concrete, leveling courses and other non-structural items.

Density of reinforced concrete is assumed as 25.00 KN/cu.m

Minimum cement content, water cement ratio etc. shall conform to IS 456:2000 code provisions for durability and strength criteria.

7.7.2 CEMENT

Ordinary Portland Cement of grade 43 or higher confirming to IS 8112 and IS 12269 is specified for concrete grades ranging from M:25.

7.7.3 AGGREGATES

The sizes of coarse aggregates confirm to IS 383.Nominal maximum size of coarse aggregate be 20 mm, suitably graded as per the requirement of mix design.

The fine aggregates confirm to the specifications of IS 383.

7.7.4 WATER

Water used for construction shall comply with IS 456:2000.

7.7.5 REINFORCEMENT

High yield strength deformed bars conforming to IS 1786 with fy = 415/500 N/ sq.mm has been used.

7.7.6 STRUCTURAL STEEL

Structural steel work, if any, shall conform to IS 226 and IS 2062 for Indian steel sections.

7.7.7 PRESTRESSING STEEL

Prestressing steel shall confirm to IS 14268 class 2 low relaxation uncoated stress relieved strand.

7.7.8 BEARINGS

Elastomeric bearings for all the bridges apart from ROB have been provided. POT/PTFE bearing have been adopted for the flyover.

7.7.9 CRASH GUARD

Reinforced concrete Crash barrier in M 40 grade concrete will be provided.

7.7.10 EXPANSION JOINTS

Strip seal expansion joint is proposed for all bridges.

7.7.11 WEARING COURSE

Asphaltic concrete wearing course, 62 mm thick, will be provided. It will comprise of 12mm thick mastic coating with 50mm thick asphaltic concrete overlay.

7.7.12 APPROACH SLAB

Reinforced concreteapproach slabs, 3.5 m long and 300 mm thick, in M30 grade concrete at either end of the bridge, will be provided, with one end supported on the reinforced concrete bracket projecting from the dirt wall and the other end resting over the soil, in accordance with the guidelines issued by MORT&H.

7.7.13 DRAINAGE SPOUTS

Drainage spouts will be provided in accordance with MORT&H standard drawings.

7.8 RECOMMENDATION FOR STRUCURES

Since entire alignment lies in open land and rolling terrain and in order to ensure that the drainage pattern of the area does not get affected by construction of proposed road and based on inventory survey of waste water streams across the project road; recommendations for the major structures for new construction have been made and presented below. Pedestrian grade separators will also be provided at bus stop locations.

Table 21: Detailed Statement of Major Structures

Sr. No.	Chainage	Type of Structure
1	0+000	Flyover
2	1+640	Flyover

3	1+910	Culvert
4	2+810	Culvert
5	2+935	Flyover
6	3+090	Culvert
7	4+040	Culvert
8	5+110	Culvert
9	5+505	Flyover
10	5+600	Culvert
11	5+980	Culvert
12	6+590	Culvert
13	7+895	Flyover
14	9+270	Major Bridge
15	9+400	Flyover
16	9+800	Major Bridge
17	10+365	Underground Tunnels
18	10+770	

8 PAVEMENT DESIGN

8.1 GENERAL

The major arterial of NPKL is an entirely new alignment. Pavement option study has been carried out to make analysis of different pavement alternatives to provide a basis for selection of the most advantageous solution considering all costs occurring during the life of the pavement, viz. construction costs and routine & periodic maintenance costs.

8.2 PAVEMENT OPTIONS & DESIGN METHODS

Two types of pavement options are considered, i.e. flexible pavement & rigid pavement. The principal methods of pavement design for new carriageway are based on IRC: 37 for flexible pavement and IRC: 58 for rigid pavement.

8.3 SOIL INVESTIGATIONS

For pavement design, the subgrade strength is to be assessed in terms of CBR of subgrade soil in both fill and cut sections at the most critical moisture conditions likely to occur in-situ.

Based on Report on the C.B.R. and Compaction Test performed at proposed Nadaprabhu Kempegowda Layout, the average 4 day C.B.R. value along the major arterial is determined as 7%. Hence the design CBR is considered as 7% for further design.

8.4 FLEXIBLE PAVEMENT DESIGN

Design of flexible pavement has been carried out in accordance to IRC: 37 with consideration of following:

1) Traffic – As determined in earlier chapter of traffic forecasting, initial traffic in terms of number of commercial vehicles of about 1,120 are expected to ply on average day in 2018 from Kempegowda Layout. Whereas diverted commercial vehicles of about 750 are expected to ply on average day in 2018.

2) Growth Rate – Kempegowda layout is projected to grow at the rate of 14% by 2025. However for diverted traffic and after 2025, a marginal growth rate of 2.5% will be observed.

3) Design Life – Pavement design life is considered as 20 years.

4) Vehicle Damage Factor – For expected commercial vehicles per day is more than 1500 & with plain area under consideration, VDF value of 4.5 has been adopted.

5) Lane Distribution Factor – Lane distribution factor for the dual three-lane carriageway is considered as 60%.

6) Directional Distribution Factor – Directional distribution factor is assumed as half of the sum in both directions, i.e. 50%.

Based on aforesaid input parameter, design traffic is computed in terms of the cumulative number of standard axles (in the lane carrying maximum volume) to be carried during the design life of the road and arrived as 38.46 MSA.

Hence for design traffic of 40 MSA and design CBR of 8%, following composition has been proposed for flexible pavement:

- 500mm Subgrade with CBR of 7%
- 230mm of GSB
- 250mm of WMM
- 70mm of DBM
- 40mm of BC

8.5 RIGID PAVEMENT DESIGN

Design of rigid pavement has been carried out in accordance to IRC: 58 with consideration of following:

1) Wheel Load – This shall be the maximum wheel load of the predominant heavy vehicle. Considering the fact that predominant heavy vehicle being used is with standard axle with dual wheel with legal axle load limit as 10.2 tonnes, hence wheel load is adopted as 5100 kg. Subsequently type pressure of 8 kg/cm^2 has been adopted for analysis.

2) Design Period – Design period is considered as 30 years.

3) Temperature Differential – Temperature differential between the top and bottom of concrete pavement is considered as 11^0c for Bangalore (Study of temperature differential in different concrete slabs of varying slab thickness in different regions, European Journal of Applied Engineering and Scientific Research, 2015, 4 (2):35-43).
4) Characteristics of Subgrade & Sub-base - Corresponding value of K with respect to design CBR of 8% is considered as 4.8 kg/cm^2/cm.

   Dry lean concrete (DLC) sub-base of 100mm is proposed beneath cement concrete pavement. Hence effective K value over 100mm DLC is considered as 20.8 kg/cm^2/cm.

   Also to facilitate the quick disposal of water that is likely to enter the subgrade, a drainage layer of 150mm thick GSB is proposed over subgrade.

5) Characteristics of Concrete – A 28 days' flexural strength of 40 kg/cm^2 has been adopted for the design of pavement quality concrete (PQC).

6) Modulus of Elasticity, Poisson's Ratio & Coefficient of Thermal Expansion – The adopted values are as follows:

Modulus of Elasticity	:	3 x 10^5 kg/cm^2
Poisson's Ratio	:	0.15
Coefficient of Thermal Expansion	:	10 x 10^{-6} per ^{0}c

Based on aforesaid input parameters & trial design thickness of pavement slab as 220mm, combine induced stresses due to temperature & flexural stress due to highest wheel load has been calculated and found less than flexural strength of concrete.

Corner stress also calculated and found less than flexural strength of concrete.

Hence following pavement composition has been proposed for rigid pavement:

- 500mm Subgrade with CBR of 6%
- 150mm GSB
- 100mm DLC
- 220mm PQC

8.6 LIFE CYCLE COST ANALYSIS

Life cycle cost analysis (LCCA) is carried out to quantify the long term financial implications of initial pavement decisions. It involves estimation of capital costs (i.e. construction, maintenance cost, PMC and contingencies) and comparison of annual streams of capital costs for the analysis period and estimation of Net Present Worth (NPW) on the basis of discounted cash flow (DCF) technique.

The initial construction cost of main carriageway per km for both the flexible and rigid pavements have been worked out at current price level of 2015 as follows:

1) Flexible Pavement: Rs. 4,68,20,442/-
2) Rigid Pavement: Rs. 5,04,32,632/-

Also routine & periodic maintenance strategy has been developed as per guidelines stipulated in "Guidelines for Maintenance Management of Primary, Secondary & Urban Roads" published by MORT&H and considered as follows:

1) Routine maintenance: 0.5% of the construction cost per year.
2) Periodic maintenance: 3% of the construction cost every seventh year.

Analysis period is considered as 30 years. The annual streams of initial construction and maintenance have been computed over the analysis period and results are assessed in terms of Present Worth (PW) by applying discounted cash flow (DCF) technique and results are presented in table below.

Table 22: Results of Life Cycle Cost Analysis

Alternatives	Flexible Pavement	Rigid Pavement
Present Worth (PW), Rs. Crores	7.72	6.18

It may be seen from the results that the value of Present Worth for flexible pavement is morethan that of rigid pavement.

There really are manyto prefer an HMA pavement including: smoothness, quiet, stage construction, ease of maintenance, speed of construction, least user delay cost, ease of repair of utility cuts, no cure time and recyclability.

Considering stage construction, since the pavement section will be built in several stages over a period of time, flexible pavement is preferred to rigid pavement and recommended for implementation.

9 COST ESTIMATES

9.1 ESTIMATION OF QUANTITIES

In general, the work is to be executed as per technical specifications contained in "Specifications for Road and Bridge Works" (Latest Revision) issued by MORT&H with suitable modifications depending on the project requirements.

The quantities of major items of work have been estimated on the basis of topographic surveys, detailed designs and typical details presented in Drawing Volume. The quantities of the following major items of works have been estimated separately:

- Site Clearance
- Earthwork
- Pavement
- Median, Cycle Track & Footpath
- Drainage & Protective Works
- Flyovers& Interchanges
- Bridges, Cross Drainage (CD) Works & Utility Ducts
- Road Appurtenances & Safety Works

9.1.1 SITE CLEARANCE

Site clearance quantity is estimated based on overall area required for construction of project road. It includes necessary clearing & grubbing, dismantling of existing pavement and disposal of cleared material, etc.

9.1.2 EARTHWORK

Quantities of earthwork in excavation & Embankment are estimated based on output derived from AutoCAD Civil 3D 2014.

9.1.3 PAVEMENT

The new bituminous pavement work includes Bituminous Concrete (BC), Semi Dense Bituminous Concrete (SDBC), Dense Bituminous Macadam (DBM), Wet Mix Macadam (WMM) and Granular Sub Base (GSB) over prepared subgrade of 500mm & embankment.

9.1.4 MEDIAN, CYCLE TRACK & FOOTPATH

Quantities for items such as kerb stones, median filling, plain cement concrete, heavy duty paver blacks, coloured asphaltfor cycle track are also included.

9.1.5 DRAINAGE & PROTECTIVE WORKS

Roadside Lined covered drains are proposed and quantities are calculated as per design and drawings.

9.1.6 FLYOVERS& INTERCHANGES

The constructions of new flyovers and interchanges are assessed on proposed length and the appropriate work items are included.

9.1.7 BRIDGES, CROSS DRAINAGE WORKS & UTILITY DUCTS

The constructions of new bridges, culverts and utility ducts are assessed on proposed length and the appropriate work items are included. The quantities of items like RCC & PCC work of bridges, culverts & utility ducts are calculated based on standard design and drawings published by MORT&H. Depth of pile foundation for bridges, flyovers and interchanges have been ascertained based on locally available information and same shall be verified in due course with BDA. Hence cost variation of +/- 10-15% is expected in construction cost of bridges, flyovers and interchanges.

9.1.8 ROAD APPURTENANCES AND SAFETY WORKS

Provisions for road safety measures such as road signs, markings, MS raling, street lighting, street-scaping items, etc. have been made as required.

9.1.9 LANDSCAPING

Landscaping within the medianhas been considered on the basis of standard requirements.

9.1.10 TREE REPLANTATION

There are about 578 trees coming within the proposed right of way.Hence replantation will be carried out at identified location for about 2 times of trees being cut or as per the state government rules & regulations and considered in estimates.

9.1.11 STRUCTURES

There are about 42 structures coming within the proposed right of way. However the Resettlement and Rehabilitation (RR) of the project affected people shall be as per state government rules and regulations.

9.1.12 UTILITY SHIFTING

There are about 3 high tension lines crossing the project highway along with crossing of low voltage lines at various locations. Required provision is made in estimate for shifting / raising the high tension and low tension power lines.

9.2 RATES

The item rates given in Schedule of Rates for the year 2016-17 in PW, P & IWTD, Bangalore Circle and Schedule of Rates of Electrical Works for the year 2014-15 in K.P.W.D. Buildings Circle, Bangalore are used. For items whose rates are not available in any of the DSR, prevailing market rates are used. For items whose combined rate is not available in DSR, Rate analysis is carried out and final rates are derived.

9.3 ESTIMATION OF PROJECT COST

The project cost estimate for road and structural works have been prepared for various project components and presented below.

Table 23: Cost Estimates for Project Components

Sr. No.	Particular	Cost in Rs. Cr.
1	Site Clearance & Embankment Work	32.29
2	Pavement Work, Road Side Drain & Utility Duct	243.64
3	Electrification Works	3.03
4	Road Furniture Works	1.10
5	Culverts & Minor Bridges	71.35
6	Tunnel Intersection by BMRCL	93.14
7	Flyovers (5 No's)	153.28
8	Pedestrian Underpass	41.98
9	Footpath Works	2.78
10	Cycle Track	6.30
11	Flyover at Magadi Road	28.08
12	Landscaping Works	11.70
13	Utility Shifting	5.0
14	Miscellaneous	0.22
	TOTAL COST IN RS. CRORES	**693.89**

10 DEVELOPMENT PHASING

There are primarily two factors which would generally determine the magnitude and spatial extent of occupancy of plots in Nadaprabhu Kempegowda Layout.

- Share of NPKL in Yearly growth of population and resulting housing demand of Bengaluru city as whole.
- Order of construction completion, marketing and sale of Plots.

Bengaluru's population in 2001 and 2011 is 56.86 Lakhs and 84.74 Lakhs respectively. The decadal growth in population of 27.88 Lakhs is observed between 2001-2011. Expecting that same decadal growth will continue till the year 2041, based on arithmetic increase, the average yearly increase in population shall be 2.79 Lakh persons broadly. Out of this yearly growth of population, taking into account the increase of population due to natural births, we can consider that around 30% of such population may look at Nadaprabhu Kempegowda layout as a housing option. Considering a household size of 4.5, the number of tenements required to house this growing population ranges from 18000 - 20000 per year. Though there are many factors that influence the choice of housing by the migrant population, for simplification we have assumed as above. NPKL is one of the largest layouts being developed in the next 10 years in Bengaluru and we assume it shall command a majority share of the housing supply.

Nadaprabhu Kempegowda Layout is being developed in phases and the occupancy of the layout is dependent on the completion of the phases as well as marketing and sale of completed developments. Plots in subsequent phases may be sold one after or may be sold simultaneously, based on the marketing strategies. Based on aforesaid range of maximum household increase per year, the development trend of Nadaprabhu Kempegowda Layout is established in terms of occupancy spread of projected population and employment from date of completion of infrastructure works for following scenarios and presented below.

Scenario 1: Occupancy trend based on simultaneous sale and occupancy of all phases of work.

Scenario 2: Occupancy trend based on phase by phase sale and occupancy of plots.

Scenario 1	Scenario 2
Infra Completion Year	Infra Completion Year

Sr. No.	2016	2017	2018	2016	2017	2018
2016	20%	-	-	30%	-	-
2017	15%	20%	-	40%	-	-
2018	15%	15%	5%	30%	10%	-
2019	10%	15%	10%	-	35%	-
2020	10%	10%	15%	-	35%	-
2021	10%	10%	15%	-	20%	15%
2022	10%	15%	10%	-	-	35%
2023	10%	10%	10%	-	-	35%
2024	-	5%	20%	-	-	15%
2025	-	-	15%	-	-	-

Based on aforesaid occupancy spread of projected population and employment, following peak hour approaching traffic projections in PCUs is determined at major junctions for Scenario 1.

	Junction 1	Junction 2	Junction 3	Junction 4	Junction 5
2016	2,038	2,341	2,408	2,058	1,901
2017	3,430	3,851	3,854	3,387	3,089
2018	4,698	5,265	5,234	4,701	4,383
2019	5,912	6,549	6,465	6,046	5,862
2020	7,002	7,736	7,628	7,377	7,449
2021	8,094	8,925	8,793	8,710	9,038
2022	9,311	10,212	10,027	10,058	10,520
2023	10,305	11,303	11,094	11,205	11,806
2024	10,966	11,936	11,699	12,209	13,264
2025	11,306	12,276	12,039	12,820	14,220

Whereas for Scenario 2, following peak hour approaching traffic projections in PCUs is determined.

	Junction 1	Junction 2	Junction 3	Junction 4	Junction 5
2016	2,347	2,802	2,902	2,230	2,142
2017	3,620	4,681	4,914	3,544	3,142
2018	5,030	6,491	6,768	4,945	4,296
2019	6,630	7,898	7,976	6,407	5,715
2020	8,231	9,306	9,185	7,870	7,135
2021	9,460	10,426	10,191	9,293	8,878
2022	10,192	11,158	10,923	10,660	11,050
2023	10,925	11,891	11,656	12,028	13,223
2024	11,264	12,230	11,995	12,638	14,178
2025	11,307	12,273	12,038	12,681	14,221

It can be seen that the projected peak hour approaching traffic of 10,000 PCU which warrant grade separated facility will reach at major junctions beyond 2021 for both the scenarios. With expected completion of project by end of 2017 (i.e. 18 months starting from mid of 2016) and requirement of grade separated facilityat major junctions beyond 2021; the entire projectis proposed to be developed in 2 phases as summarized below:

1) **Phase 1 (Immediate Phase - 2017)** - Provision for Pavement Works, utility duct, service road, bus bays, three lanes main carriageway with median, road side drains, Electrification Works, Road Furniture Works, Underground Tunnels on Mysore Road; culverts and major bridges.

2) **Phase 2** – Development of Pedestrian Underpasses, Intermediate Vehicular Flyovers and Major Flyover on Magadi Road, Cycle Track, Landscaping Works, Utility Shifting Works

Table 24: Phase-wise Cost Estimates

Sr. No.	Phase	Cost Estimate (Rs. Crores)	Cumulative Costing (Rs. Crores)
1	Phase 1 (Immediate – 2017)	**444.78**	**444.78**
2	Phase 2	**249.12**	**693.89**