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MINISTRY OF URBAN DEVELOPMENT
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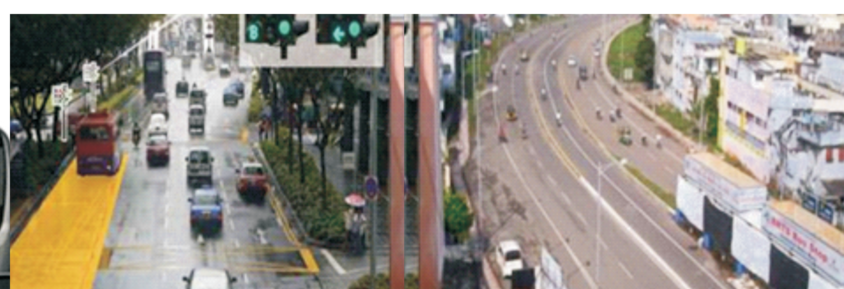
Development of Toolkit under the "Sustainable Urban Transport Project"

Urban Road Traffic System

(Planning, Design and Evaluation)

www.moud.gov.in

December 2013



www.iutindia.org

The Institute of Urban Transport (India) is a premier professional non-profit making organization under the purview of the Ministry of Urban Development, Government of India (MoUD). The National Urban Transport Policy (NUTP), 2006 has empowered IUT to serve as a National Level Facility for continuous advice and guidance on the principles of sustainable urban transport. The objective of the Institute is to promote, encourage and coordinate the state of the art of urban transport including planning, development, operation, education, research and management at the national level.

The Institute has been nominated as the project monitoring unit for Component 1A of the SUTP. IUT is responsible for overseeing the preparation of the training modules, subject toolkits and conduct of training of 1000 city officials in urban transport.

The Ministry of Urban Development (MoUD), Government of India (GoI) has initiated the Sustainable Urban Transport Project (SUTP) with support of Global Environment Facility (GEF) and the World Bank to foster a long-term partnership between GoI and state/local governments in the implementation of a greener environment under the ambit of the NUTP. The aim of the project is to achieve a paradigm shift in India's urban transport systems in favor of sustainable development. The MoUD is the nodal agency for the implementation of the project, to be implemented over a four-year period starting from May, 2010 to 30 November 2014. Project cost is Rs. 14,161.55 Million. The project's development objective (PDO) is to promote environmentally sustainable urban transport in India and to improve the usage of environment-friendly transport modes through demonstration projects in selected cities.

National Institute of Technology, Warangal was established *in 1959* and it is the first in the chain of 30 NITs (formerly known as RECs) in the country. It is the Institute of National Importance, enacted by the Parliament. The Institute currently has thirteen academic departments with advanced research centres and 100 laboratories with state of art facilities. The institute is involved in Research and Development, Industrial consultancy, Continuing education programmes. According to NASSCOM Data Quest Survey, NITW clinches the 13th rank among the technical institutes in the country. NITW is first institute in the country to start post graduate program in Transportation with the assistance of UNESCO. NITW is the brain behind the preparation of comprehensive traffic and transportation plans for Hyderabad and Mumbai cities. In the past 30 years centre for transportation has produced 30 Ph.D.s, over 400 post graduate dissertations and has undertaken consultancy works to the tune of Rs.15 Crores.

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Preface

Government of India has initiated the Sustainable Urban Transport Project (SUTP) with support from Global Environment Facility (GEF), World Bank and UNDP. The primary objective of SUTP is to facilitate urban transport infrastructure in a sustainable environment and under the ambit of National Urban Transport Policy (NUTP).

Component 1A of GEF-SUTP project aims at capacity building amongst practitioners in the field of sustainable urban transport. The objective of the initiative is to create an enabling institutional framework for sustainable urban transport in India. This is to be accomplished by enhancing the capacity of policymakers, planners, researchers, executive agencies, service providers, managers and other professionals involved in urban transport to plan, implement, operate and manage sustainable urban transport.

To achieve the objectives of Component 1A, as part of the program 5 sub-components have been identified which include the following:

- Sub-Component 1 – Institutional capacity development, focusing on strengthening of Institute of Urban transport (IUT)
- Sub-Component 2 – Individual capacity development
- Sub-Component 3 – Preparation of manuals and toolkits
- Sub-Component 4 – Promotion, awareness and dissemination of information to expand and enhance the impact of GEF-SUTP
- Sub-Component 5 – Technical assistance to cities to address emerging issues encountered during project implementation.

Sub-Component 3 aims at providing step by step guidance to cities and other concerned authorities to enable them to plan and implement projects related to urban transport and also facilitate public decision makers and transport planners/ engineers in overseeing urban transport projects. It will include briefly the concept behind the subject of the tool kit, applicable planning standards and norms (most up to-date version to be used) and reference to a code of practice where necessary. The toolkits are as follows:

1. Land use transport Integration
2. Urban Travel Demand Modelling
3. Transport Demand Management
4. ITS for Traffic Management System
5. Public Transport Accessibility
6. Urban Road Safety & Safety Audits
7. Planning, Design and Evaluation of Urban Road Traffic systems
8. Finance and Financial Analysis
9. Environmental Analysis/SEA & SIA
10. Social Impact Assessment and R &R plan

The present toolkit would deal with the subject of **“Urban Road Traffic Systems (URTS)”**. The aim of this toolkit is guiding the city officials with tools and techniques for appropriate URTS for a given urban area with specific objectives as follows:

- Planning network of roads and other elements of the road network for evolving urban centres
- Designing new facilities as well as evaluating the old facilities as per the Standard design procedures
- Evaluating the current service levels and areas of improvement to reach desirable levels of service in order to achieve sustainable mobility objective
- Need for promoting public transport as well as non-motorized transport to minimize congestion

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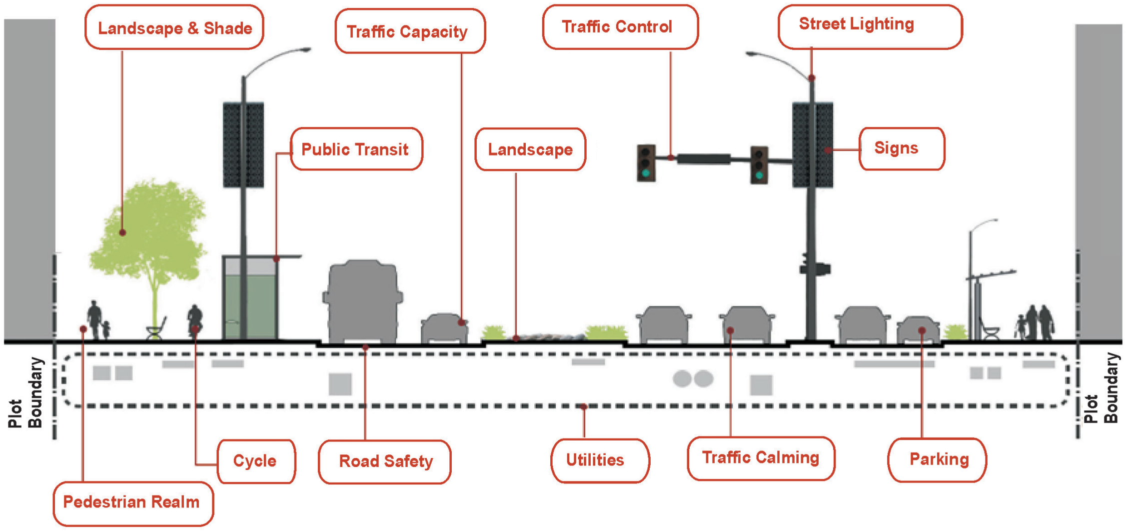
Aim of the Toolkit

Urban Road Traffic Systems (URTS) objectives include planning network of roads and other elements of the road network for evolving urban centres, designing new facilities, evaluating the existing road network and redesigning to meet the demand. This toolkit emphasises need for promoting public transport as well as non-motorized transport to achieve a sustainable urban transport system.

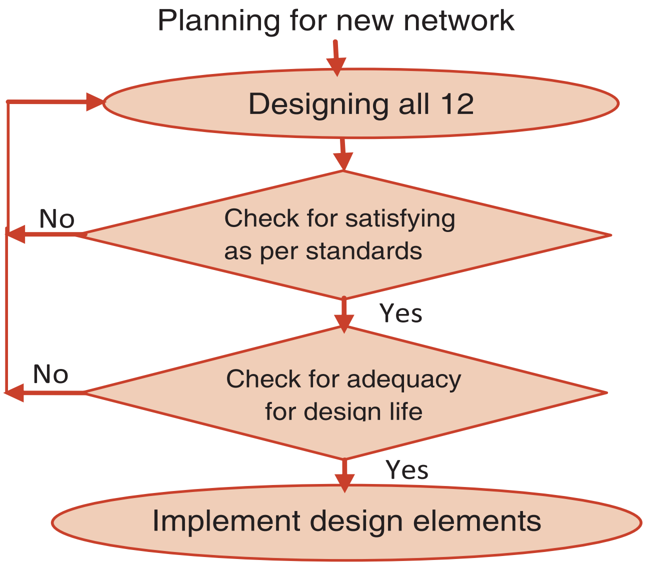
The various elements of urban road network are:

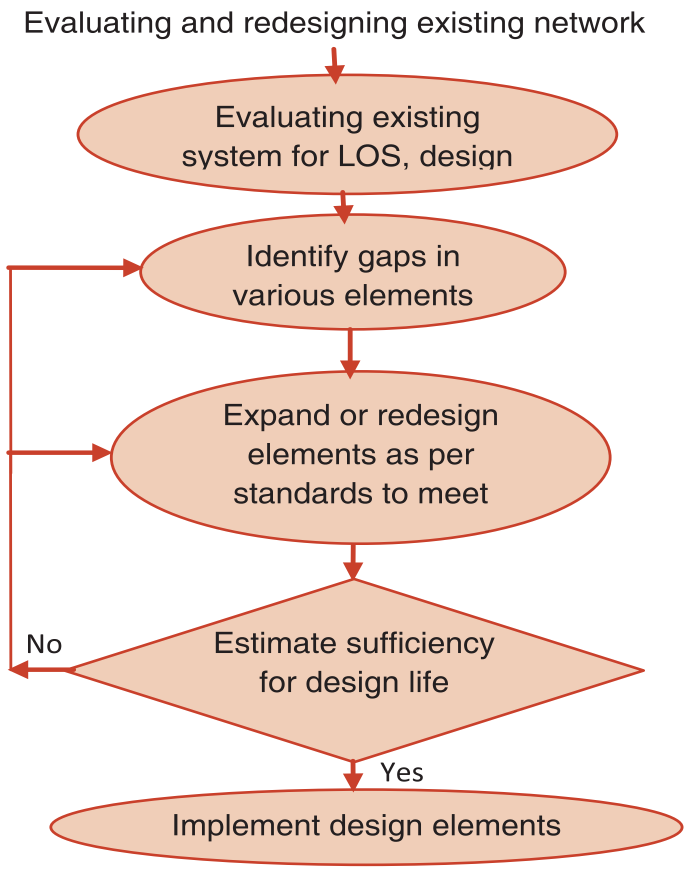
1. Carriageway
2. Cycle tracks
3. Footpaths
4. Service lanes
5. Pedestrian crossings
6. Bus Lanes
7. Bus stops
8. Medians
9. On-street parking
10. Street lighting
11. Intersections
12. Traffic calming elements

A typical cross section of an urban arterial road is shown below:



The activities can be broadly classified into two major sections: Planning new network and Evaluating and redesigning existing as described in the following two flow charts.





A snapshot of different steps to be followed in implementing URTS elements

Step 1: Calculate total Right of Way

- (a) For current demand
- (b) Demand for next design life

Right of way guidelines for different urban roads as per MOUD Guidelines

	Arterial Roads	Sub Arterial Roads	Distributory Roads	Access Roads
Carriageway				
Criteria	50 km/h	50 km/h	>30 km/h & < 50 km/h	>15 km/h & >30 km/h
ROW	50m – 80m	30m – 50m	12m – 30m	6m – 15m
Horizontal curve	30m or more	30m or more	10m or more	5m or more
Gradient	2%	2%		
Number of lanes	Minimum 6 lanes divided (using a raised median);	Minimum 4 lanes divided (using a raised median);	Maximum 4 lanes of 3.0m width each (excluding marking) or 2 lanes of 3.0 to 3.3m width each (excluding marking) with or without an intermittent median	1 to 2 lanes, (undivided); of 2.75 to 3.0m width each
Minimum Width for car lane	3.0 to 3.5m width each	3.0 to 3.5m width each	2 lanes of 3.0 to 3.5m width each	2.75 to 3.0m width each
Minimum Width for bus lane	3.5m –(segregated)	3.5m –(segregated) or painted lane	Mixed traffic	

Step 2: Lanes for vehicular movement

- (a) Minimum 2 lanes each
- (b) Current demand for LOS C
- (c) Future demand/ LOS C: Possible expansion for design life
- (d) Follow LOS C as per IRC standards

Step 3: Cycle track

- (a) Current usage through survey
- (b) Minimum width as per standards
- (c) If demand is more increase width as per need

Guidelines for planning cycle tracks

Facility type	Dimension	Typical Application
1. Buffered Bike Lane	1.5m with the addition of a 0.6m to 0.9m painted buffer. Buffer is typically diagonally hatched to increase visibility	✓ Any location where a bike lane may be considered and sufficient right-of-way exists ✓ Streets with posted travel speeds ≧ 25 mph ✓ Where motor vehicle traffic volumes ≧ 10,000 AADT
2. Raised Cycle Track	1.5m to 2.1m Mountable curb should be 0.45m and have a 4:1 slope edge Special attention needed for drainage to prevent pooling	✓ Streets with multiple lanes and high traffic volumes (≧ 10,000 AADT) ✓ Streets with high travel speeds (≧ 40 mph) ✓ Streets with few intersections and driveway access points One-way or two-way streets
3. Two-Way Cycle Track	3m min. and3.6m preferred width. Can be combined with parking buffer, mountable curb, or physical barrier	✓ Streets with multiple lanes and high traffic volumes (≧ 10,000 AADT) ✓ Streets with high travel speeds (≧ 40 mph) ✓ Streets with few intersections and driveway access points (requires innovative design treatment at intersections) ✓ One-way or two-way streets ✓ On streets where contraflow bike travel is desireable
4. Multi-Use Off-Street Path	3m is the minimum allowed for a two-way shared-use path and is only recommended for low traffic situations. 3.6m or greater is recommended for high-use areas, or in situations with high concentrations of multiple users	✓ Where there are few at-grade crossings such as driveways and alleyways ✓ Where the existing roadway context makes a completely separated bikeway the preferred alternative (i.e. high traffic speeds and volumes in a constrained right-of-way).
5. Bicycle Boulevard	–	✓ Streets with traffic volumes ≦ 3,000 AADT ✓ Streets with posted travel speeds ≦ 25 mph ✓ Along network identified in planning process


Step 4: Footpath

(a) Minimum width as per standards

(b) Increase the width to meet the demand if needed

(c) Follow MOUD/IRC Guidelines

MOUD Guidelines for footpaths

	Arterial Roads	Arterial Roads	Distributor Roads	Access Roads
Pedestrian Paths				
Criteria	50 km/h	50 km/h	30 km/h	15 km/h
	50m – 80m	30m – 50m	12m – 30m	6m – 15m
Gradient	1:20	1:20	1:20	1:20
Sight Distance				
Lane width	1.7 (including curbs) to 5.5m each. However where secondary footpaths are available along service lane, the minimum width of secondary paths can be 1.5m (including curbs)	1.7 (including curbs) to 5m each. (including curbs)	1.5 to 3.0m (including curbs) each	0-2.5m (including curbs) each

Components to be included for making accessible footpaths

Footpath	The minimum clear width should be 1.2m in order to accommodate wheelchair users. Comfortable minimum width is 1.8m. The footpath surface should be even and without any irregularities. The use of guiding and warning blocks should be used.
Paving	The use of guiding and warning blocks should be used along the footpath
Road Markings	It is essential to designate areas in parking lots to make it comply with accessibility standards.
Road Signs	All signs should be visible, clear and consistent. All accessible places should be clearly identified by the International Accessibility Symbol. They should be in contrasting colours. Also, for the visually impaired it is essential to use Braille.
Audible Signals	The use of audible signals or auditory signals is beneficial to the visually impaired to cross a road with minimum or no assistance. Also called a pedestrian access system, it is mountable onto signal poles at crossings and a push button system makes its use easier. It also gives an audible alert signal to Vehicle Users about Pedestrian Crossings.

Step 5: Street vendors along footpath

(a) Minimum width as per IRC standards

(b) Check for sufficiency at major urban corridors and increase if needed

Step 6: Bus lanes

Minimum 1 lane for buses as per IRC standards. The minimum bus lane width should be 3.2m where there are dividers or barriers and 3.0m lane width is required where there are no dividers or barriers.

Step7: Calculate remaining width of right of way:

X = Total right of way - cycle track - foot path- width for street vendors - Bus lane - Service lane

Step 8: Calculate number of lanes for current traffic as per LOS C:

Y= Remaining width after number of lanes for moving traffic = X - Number of lanes for both directional traffic

Step 9: Check for median width

(a) Minimum median width as per standards

(b) Y > Width as per standard

(c) Check for additional lanes needed for the design life, assuming the annual growth of vehicular flows@ 2%, 2.5%, and 3%.

(d) If required increase the right of way accordingly

Step 10: Intersections

(a) Determine the turning movements on all legs of intersection:

Straight, Left, and Right

(b) Select appropriate junction as per norms

Criteria for selection of various intersections types and respective criteria

Type of Intersection	Angle of intersection	Criteria	
3 leg Unsignalized intersection	60 to 120 degrees	Volumes are light	>500 veh/hr Channelize the traffic
4 leg Unsignalized intersection	60 to 120 degrees	Volumes are light on minor road	Higher traffic volume on major road
Multileg Intersection	Multi-leg	Volumes are light and stop control is used for minor road	Higher traffic volume on major road
Signalized intersection	any	Volumes are high and intersection is prone to accidents	If required channelize the traffic
Roundabout	3 leg to multi leg	Where delays are more and traffic volume more than 1500 and less than 5000	Channelization on all approach roads

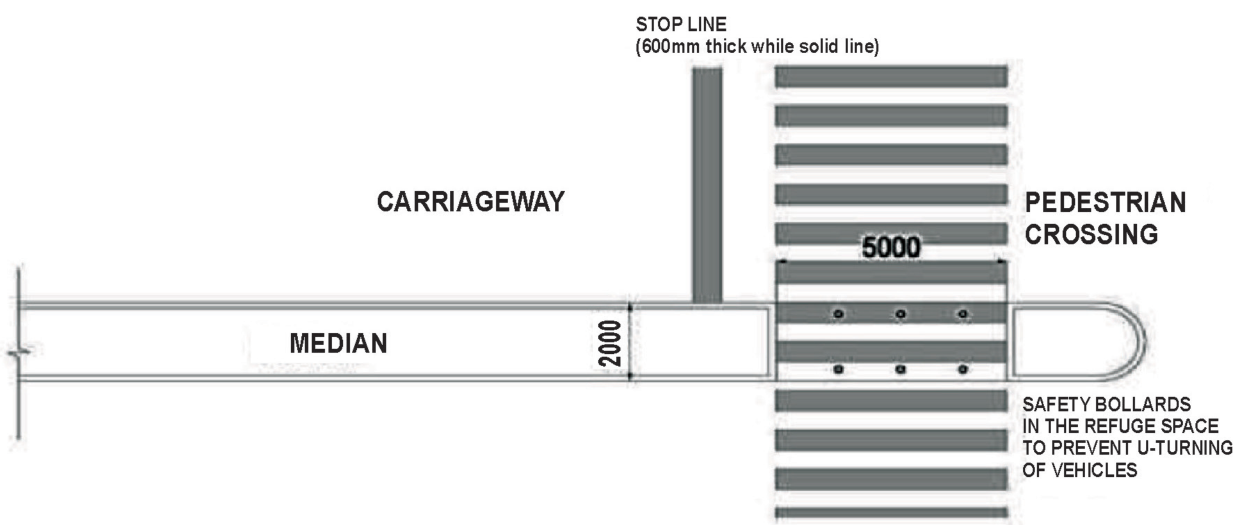
Step 11: Pedestrian Crossings

(a) Provide at least 500m apart on stretches

(b) Pelican signal where heavy pedestrian flow exists

(c) Provide all red period to meet the pedestrian flow at signals

Gap in median at pedestrian crossings (MOUD code of practice: Intersections)



Step 12: On-street parking

(a) Estimate current demand through surveys

(b) Based on demand, decide about type of parking: Parallel, Angular etc.

(c) Mark entry/exit points of parking lots

(d) Calculate LOS for moving traffic during peak hour if parking is full on the road side.

(e) If required ban parking only during peak hour or totally along the stretch

(f) If not able to meet the demand, suggest off-street parking

Step 13: Signs and Markings

(a) Identify all vulnerable areas along the network: Horizontal and Vertical curves, Narrow road sections if any, near bus stops, Pedestrian crossings, School zones etc.

(b) Provide appropriate sign boards as per standards

(c) Markings: Lane markings, Kerb markings, Zebra markings, Centre line marking etc.

Step 14: Street lighting

(a) Calculate the “lux” needed.

(b) Estimate the existing value of “lux” along the road

(c) Change spacing of street light pole positions if needed

(d) Check for sufficiency of lighting for pedestrians and cycle tracks

Chapter 1:

Introduction

1.1 Background

India is experiencing rapid urbanization over the years. The preference towards urban areas is due to the improved opportunities in terms of commercial activity, employment, health, education etc. This shift could be observed from the gradual changes in census data over the previous century as presented in Table 1.1.

Table 1.1: Growth of Population 1901–2011

Year	Total	Rural	Urban	% urban population
1901	238,396,327	212,544,454	25,851,873	10.84
1911	252,093,390	226,151,757	25,941,633	10.29
1921	251,321,213	223,235,043	28,086,170	11.18
1931	278,977,238	245,521,249	33,455,989	11.99
1941	318,660,580	274,507,283	44,153,297	13.86
1951	361,088,090	298,644,381	62,443,709	17.29
1961	439,234,771	360,298,168	78,936,603	17.97
1971	548,159,652	439,045,675	109,113,977	19.91
1981	683,329,097	523,866,550	159,462,547	23.34
1991	846,427,039	628,691,676	217,611,012	25.71
2001	1,028,737,436	742,490,639	286,119,689	27.81
2011	1,210,193,422	833,087,662	377,105,760	31.16

It may be noted that the urban population as percentage of total population has increased from 10.8% in 1901 to 27.81% in 2001. The latest census data in 2011 indicates that growth in urban population has further risen

to 31.16%. A close examination of census data during the previous decade, 2001-2011, reveals that ***for the first time*** the net additional urban population (90,986,071) has surpassed the net additional rural population (90,597,023). It is expected that this trend will get continued in the future.

The demographers predict that by the year 2030 nearly 40% of the total population will be residing in urban areas. The existing transportation facilities are not satisfying the current travel demand in majority of urban areas, which implies that by the year 2030 the whole transportation system could be in gridlock (as shown in Photo 1.1) if the appropriate actions are not initiated to handle the situation. That shows there is an urgent need for developing better transportation infrastructure to contain the gap between the future anticipated travel demand and infrastructure supply.

Photo 1.1: Congested form of traffic in an urban area indicating gridlock

Creating transportation infrastructure is a lumpy activity, involving huge physical activity and also requires large amounts of resources necessitating better planning strategies.

The policy/decision makers in India mostly adopted the option of creating the infrastructure supply after the demand has materialized. That means by the time the construction is completed there is hardly a remarkable improvement in the quality of service, in addition to the temporary inconvenience caused during construction of new facilities along the existing corridors.

Many researchers have pointed out that the urban areas in India suffer from inadequacies in infrastructural facilities. These infrastructural deficiencies are impacting the growth of the nation. Transportation facilities are no exception. Thus the initiatives undertaken by the Ministry of Urban Development towards “Sustainable Urban Transport Project” is an appropriate strategy. There is an urgent need to provide required transport infrastructure


capacity ahead of growth in demand. So the future travel demand must be anticipated and properly estimated and infrastructure must be designed for that demand.

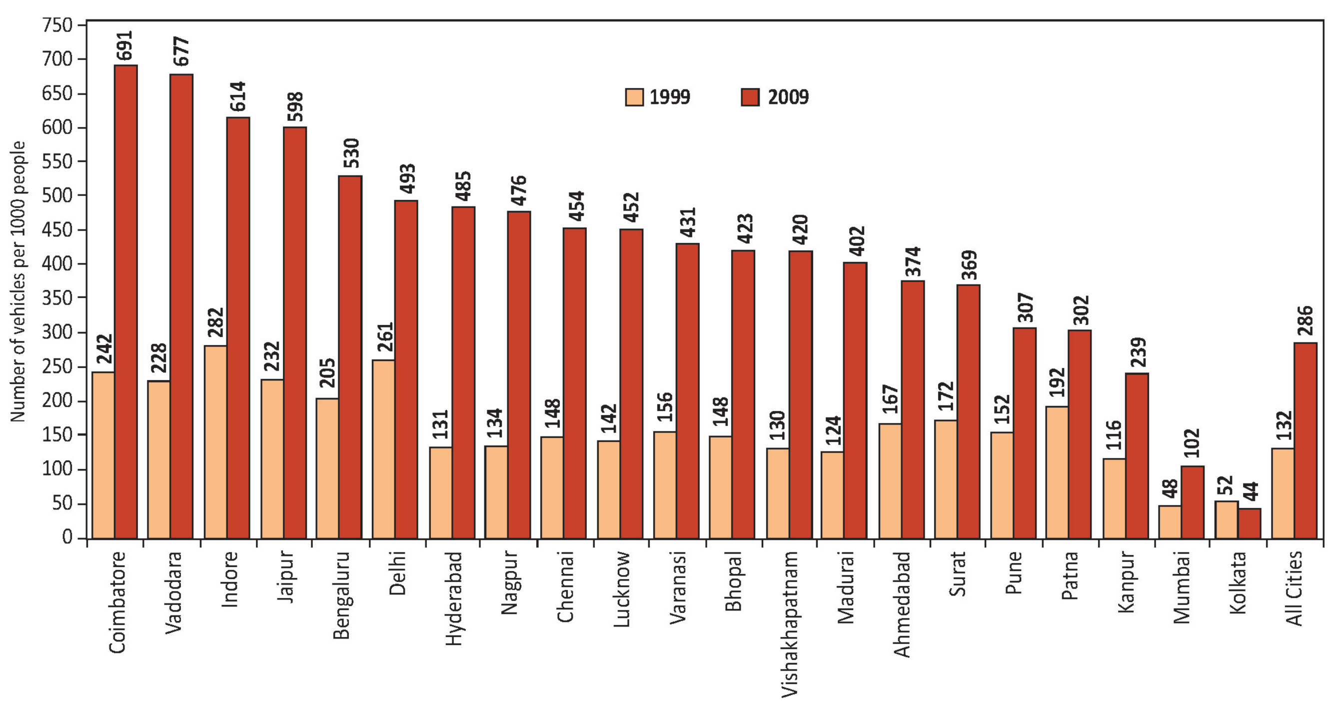
This calls for the trivial question "Is it necessary to spend so much of resources for urban transport infrastructure?" and the straight answer would be a "yes", because of the large contribution of urban society towards the national wealth. This fact could be observed on the basis of the contribution of urban areas to GDP of the nation. A mere 31% of the population is contributing to nearly 70% of the GDP, as can be seen in Table 1.2.

Table 1.2: Contribution of GDP by Urban areas

Year	Percentage of Urban contribution
1990	46
2001	54
2008	58
2011	70

This growth in urban GDP resulted in increased income levels and hence rises in the vehicle ownership which in turn contributes to a drop in the level of service of urban transport facilities. This is reflected by increased congestions, accidents, levels of pollution and decreased operational speeds in all the metropolitan areas. The change in vehicle ownership rates from 1999 to 2009 in some of the selected cities is shown in the Figure 1.1 below.

Figure 1.1: Change in vehicular ownership rates across different cities (1999-2009)



Urban road traffic system mainly comprises network of roads, facilities for Non Motorised Vehicles (NMV) and pedestrian facilities. The network of roads includes arterial, collector and local streets.

The transport related activities comprising planning, design, operation, management and control of traffic and maintenance are vested with different departments. The field personnel lack opportunities to update their knowledge base with the advances in their respective fields of specialization.

Traffic system planning and management is directly related to the total travel demand generated in urban areas. This total travel demand is a function of urban resident population, visiting population, vehicular ownership rate and intensity of different land-uses in urban areas. It may be noticed that the ownership of vehicles is exponentially rising in all urban centers of India.

In order to provide a reasonable quality of service to the road users, adequate funding to maintain the existing traffic system infrastructure as well as to upgrade and augment additional traffic system infrastructure to meet the ever increasing demand in urban areas is necessary. The current funding mechanism is really adhoc and requires a relook to garner additional resources. Innovative strategies need to be adopted in this direction.

The Government of India (GoI) has initiated the Sustainable Urban Transport Project (SUTP) with the support from Global Environment Facility (GEF), United Nations Development Programme (UNDP) and the World Bank. The objective of the project is to facilitate the provision of urban transport infrastructure and services in a manner that is consistent with sustainable environmental considerations and the National Urban Transport Policy (NUTP) of GoI. The Ministry of Urban Development (MoUD) has been appointed as the nodal agency for implementation of the project. One of the components of the SUTP aims at 'National Capacity Development in Urban Transport'. This is targeted through multiple strategies, one of them being 'Selection and preparation of toolkits' for capacity building of local field officials, who deal with urban traffic and transportation problems. A total of 10 toolkits were awarded to different teaching and research institutions in India. These toolkits initiated by the ministry of urban development will be immensely helpful in their day to day activity of urban transportation professionals.

In this connection NIT Warangal is involved in the development of toolkit entitled, "Urban Road Traffic System", (merging the originally proposed two toolkits namely Analysis of Urban Traffic Systems and Urban Traffic System Design and Evaluation).

1.2 Aim of the toolkit

The toolkit on Urban Road Traffic Systems (URTS) presented in this report is aimed at helping the city officials involved in planning, implementing and managing URTS to achieve sustainable and efficient mobility levels for individual cities. The toolkit will provide guidance to the city officials on:

- How to plan appropriate URTS measures for a given city
- How to implement the selected components of URTS
- How to monitor and evaluate the impact of the URTS measures after implementation by conducting before and after studies


1.3 Intended Users

This toolkit helps to enhance the capacity of the city officials to plan and implement URTS measures that help to achieve the overall sustainability of transport system in urban areas. With the help of the toolkit, the city officials would also get equipped to effectively engage and monitor the work carried out by consulting agencies, which would be typically involved in the detailed design of the TDM measures. Following agencies / personnel can use this toolkit:

- Urban local bodies
- City/regional planning and development authorities
- Special agencies constituted to plan and implement transport sector infrastructure and services
- Traffic police

1.4 Focus / Scope of the Toolkit

- The URTS toolkit helps in planning the network of roads and other elements of road network for evolving urban centres
- Evaluating the existing URTS network for the current service levels and areas of improvement to reach desirable levels of service in order to achieve sustainable mobility plan
- Designing new facilities as well as evaluating the existing facilities as per the Standard design procedures
- URTS also addresses issues relating to promotion of public as well as non motorized transport to minimize congestion, parking needs as well as reduce the impact of pollution and accidents

The scope of the toolkit is limited to URTS measures to be implemented by the city level agencies. This toolkit does not provide detailed instructions of design for a specific URTS issue to be followed by the city level official. This toolkit mainly guides city officials in pursuing with the consultants what they really intend to achieve and obtain detailed designs for implementing different components of URTS.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Chapter 2:

Urban Road Traffic System

Urban Road Traffic System (URTS) at macro level comprises of Road Network, Pedestrian facilities, Cycle tracks, facilities for Public Transport, Parking and Street lighting.

A traffic system in an urban area is a set of interrelated components that perform a number of functions in order to achieve mobility and accessibility. System design and evaluation is the application of scientific approach to the solution of complex problems to achieve better mobility and accessibility for which the system is planned or designed. Even though the system is well designed, a number of situations will arise which require management and control of different components of the system.

The personnel involved in traffic control need to understand the existing status of road network by analyzing the data received from field studies and then decide strategic response across the range of traffic control strategies available to manage the situation. Thus URTS mainly focuses in planning, design and evaluation of various elements of urban road transport network, which will lead to the effective implementation of Comprehensive Mobility Plans (CMPs) for a given urban area. CMP is broadly divided into 5 major tasks.

- Identification of the scope of CMP
- Data Collection and Analysis of existing Traffic and Transport Environment
- Development of Integrated Urban Land Use and Transport Strategy
- Development of Urban Mobility Plans
- Preparation of Implementation Program

Different activities of each task are detailed in the flowchart given in Figure 2.1. Table 2.1 presents details regarding major tasks of CMP vis-a-vis with other transport developmental plans. It may be noted from Table 2.1 that CMP is much more comprehensive than other transportation studies.

Figure 2.1: Detailed task list for preparing CMP for an urban area

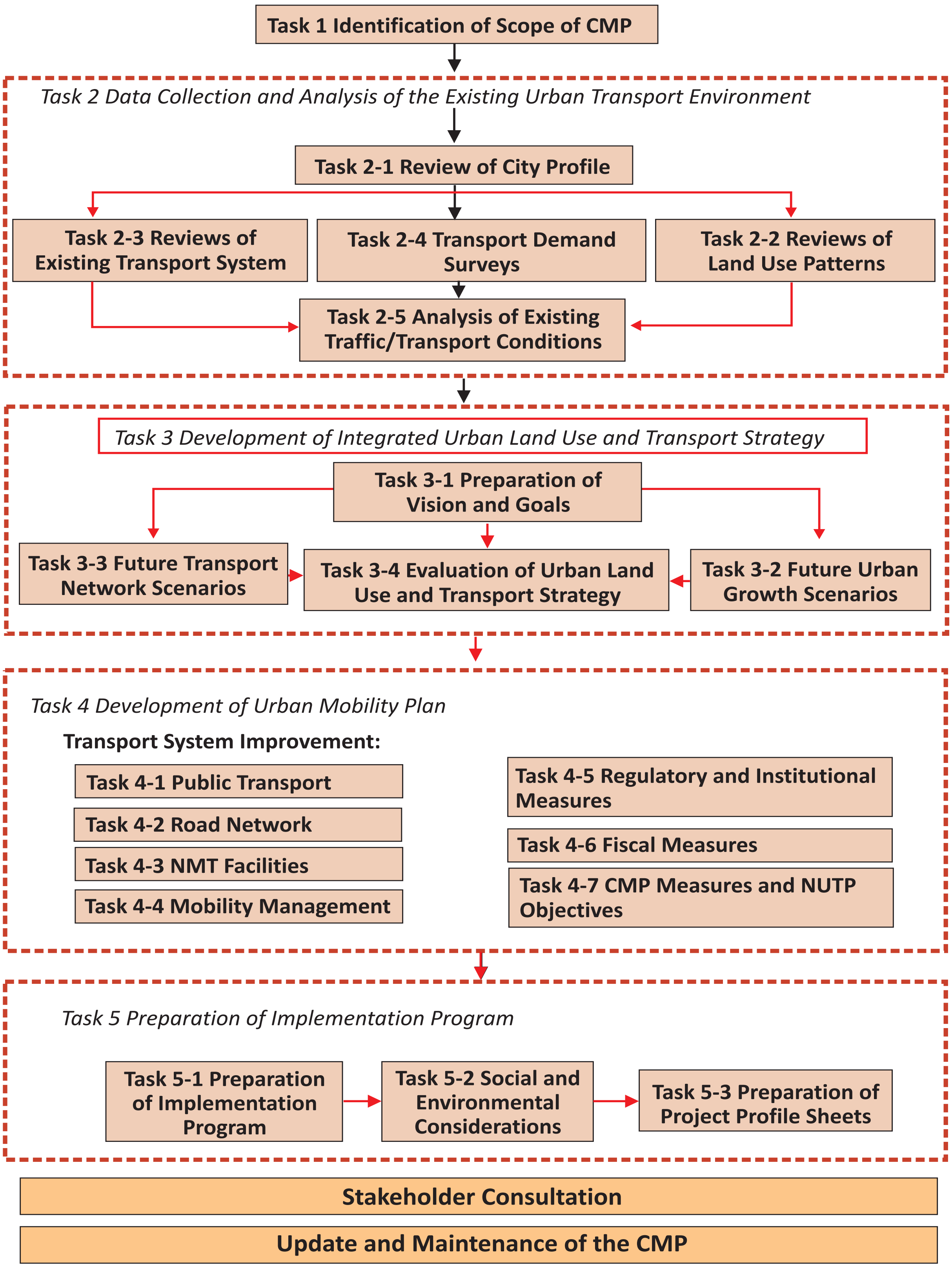


Table 2.1: Comparing major tasks of CMP and other existing transport plans

Major Tasks Existing	Existing CDP	Existing Master Plan	Existing CTTS	CMP
Review of Existing Transport System	#		#	#
Transport Demand Survey			#	#
Review of Land Use Plan		#		#
Analysis of Urban Transport Situations			#	#
Preparation of Future Land Use Scenario		#		#
Future Transport Network Scenario				#
Transport Demand Forecast Model			#	#
Network Evaluation				#
Preparation of Mobility Framework				#
Formulation of Urban Transport Measures	#	#	#	#
Social and Environmental Impact Assessment				#
Institutional Scheme for Project Implementation				#
Preparation of Implementation Programs	#		#	#
Stakeholder Consultation	#	#	#	#
Periodical Update and Maintenance		#		#

The checklist presented in Table 2.1 will help the urban transport professionals to evaluate various features of CMP.

Table 2.2: Checklist for evaluating CMP

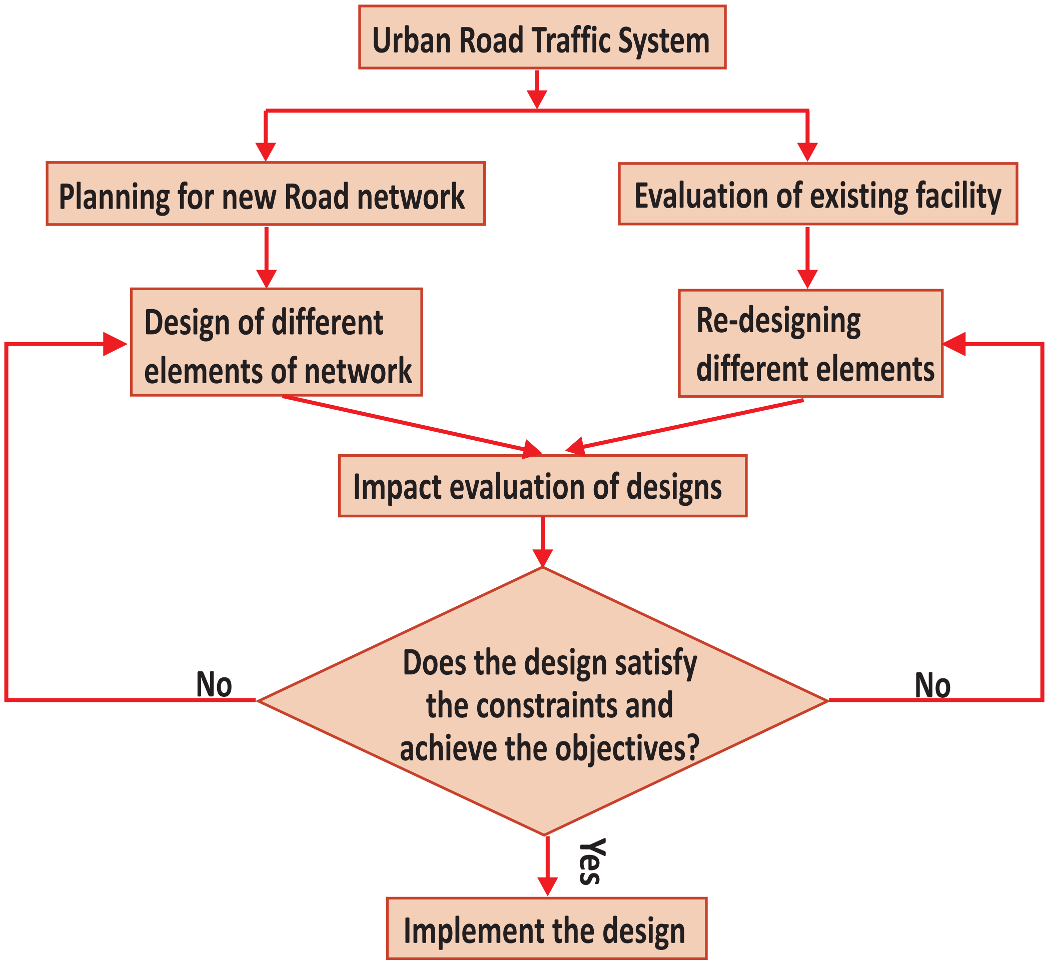
Questions	YES	PARTIALLY	NONE
Scope of CMP			
• Are the target areas and planning horizons clearly identified?			
Existing Land Use Plan			
• Does the CMP fully review the existing land use plans?			
• Have land use issues in relation to mobility improvement been identified?			
Existing Transport System			
• Does the CMP review the existing reports, plans and proposals?			
• Does the CMP review and summarise the existing transport infrastructure?			
• Does the CMP review and summarise the existing public transport system?			
• Does the CMP review the institutional and financial situation of the transport sector?			
• Does the CMP review environmental and social conditions?			
Existing Transport Demand			
• Have the necessary data for existing transport demand been collected, based on the specified formats?			
• Has the base-year transport demand model been developed with the proper methodology?			
• Does the base-year transport demand model estimate traffic volumes with a high correlation to observed traffic volumes?			
Analysis of the Existing Traffic/Transport Environment			
• Does the CMP show adequately traffic characteristics?			
• Has an analysis of the road network been carried out, based on the results of a base-year transport demand model?			
• Have specific issues for the city been identified, based on comparative analyses with data from other cities?			
• Have issues with the existing traffic/transport environment been addressed, with reference to compiled information and data?			
Land Use Scenarios			

• For cities with a Master Plan: Has the land use scenarios assumed in the CMP reflected the growth pattern indicated in the Master Plan?			
• For cities without a Master Plan: Have realistic and feasible land use scenarios been developed, considering the existing situation?			
Transport Network Scenarios			
• Have realistic and feasible transport network scenarios been developed?			
Evaluation of Strategic Land Use and Transport Patterns			
• Is there appropriate consistency between the model and future transport network/land use scenarios?			
• Has each scenario been evaluated and compared with the indicators?			
• Has the network evaluation been conducted with scenarios based on the proposed measures?			
Mobility Framework			
• Does the mobility framework properly describe the future mobility strategy?			
• Does the mobility framework focus on integration of transport development and land use planning?			
• Have the mobility framework and associated proposed measures been revised, based on the results of the network evaluation?			
• Does the mobility framework include consideration of non-motorized transport (NMT)?			
Mobility Improvement Measures			
• Are the proposed urban transport measures based on the mobility framework?			
• Does the CMP avoid overemphasizing road improvement measures?			
• Have sufficient public transport measures been included?			
• Have sufficient traffic management measures been included?			
• Have the social and environmental consideration been addressed appropriately?			
Implementation Program			
• Has the project long list been prepared?			
• Have the identified priority projects been selected applying clear and reasonable criteria?			
• Have the feasible financing options for the priority measures been indicated?			
• Has an implementation program been developed?			

2.1 Steps in the development of Urban Road Traffic System (URTS)

The 3-step process of URTS includes Planning, Evaluation and Design of various geometrical elements of Urban Road Traffic System and the same is presented in the flowchart below in Figure 2.2.

Figure 2.2: Urban Road Traffic System: Planning, Design and Evaluation



Three main activities of URTS are:

- Planning for new Road Network
- Evaluation of an Existing facility
- Designing / Re-designing of different elements as per prevailing standards

For the purpose of assessing the needs for CMPs urban areas are divided into 6 categories based on population as shown in Table 2.3.

Table 2.3: City categories based on population

City Category	Category-1	Category-2	Category-3	Category-4	Category-5	Category-6
City Population in lakhs	< 5	5-10	10-20	20-40	40-80	> 80

The type of road network, density and length of different categories of urban roads may vary for each city category. City planners/officials need to evaluate the adequacy of urban road network accordingly.

The street network in an urban area is normally classified on the basis of the function it serves. Thus the road network in India is classified into Arterial, Sub-arterial, Collector and Local Streets. Different countries follow different classification. Table-2.4 presents the classification followed in different countries.

Table 2.4: Urban road classification in different countries

INDIA		U.S.A	Australia	Malaysia
I.R.C-86-1983	MOUD Urban Road Manual	AASHTO	AustRoads	
Arterial roads	Arterial roads	Principal arterial	Arterial roads	Expressway
Sub-arterial roads	Sub-arterial roads	Minor arterial	Sub-arterial roads	Arterial
Collector streets	Distributor/Collector Roads	Collector streets	Collector streets	Collector
Local streets	Access streets	Local roads and streets	Access streets	Local street

The major function of each category of road as per IRC-86: 1983 is presented in Table 2.5 and Figure 2.3 below. The plans and cross sections of different categories of roads are presented in Figure 2.4(a) and 2.4(b). Figure 2.5 presents ideal urban arterial cross-section.

Table 2.5: Functional classification in India

Classification	Function	Criteria
Arterial	main movement	high mobility, limited access
Sub arterial	interconnects principal arterials	moderate mobility, limited access
Collectors	connects local roads to arterials/Sub arterials	moderate access, moderate mobility
Local roads / streets	permits access to abutting land	high access, limited mobility

Figure 2.3: Schematic diagram showing Urban street network

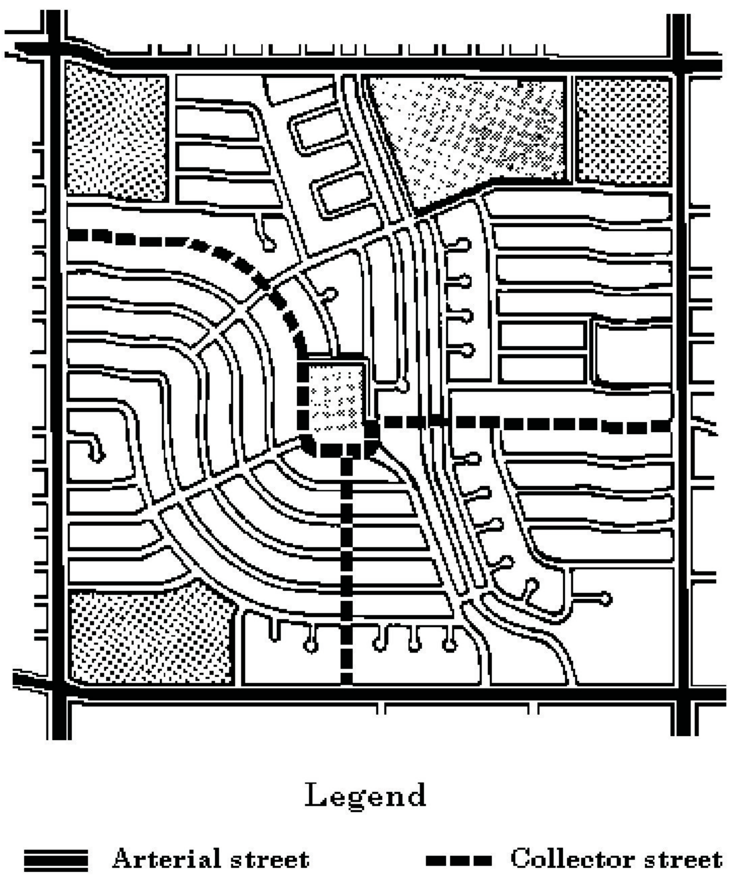


Figure 2.4(a): Typical plan view and cross sections of Urban Arterial, Collector and Local streets (widths in meters)

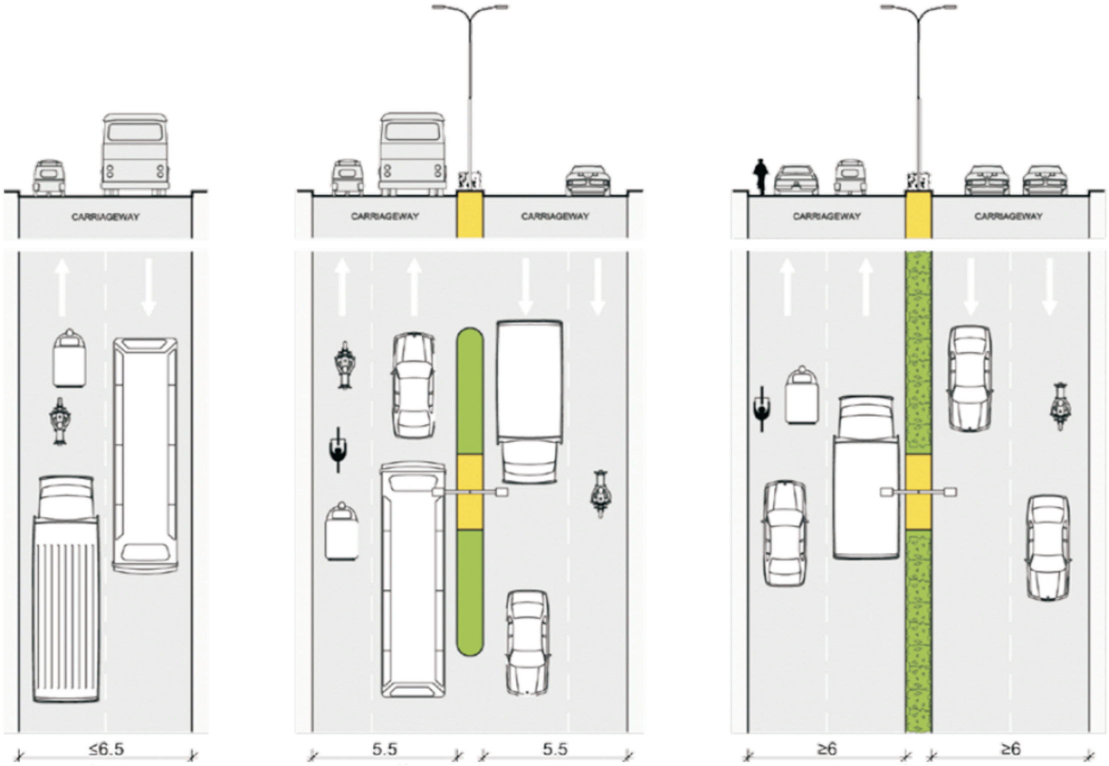
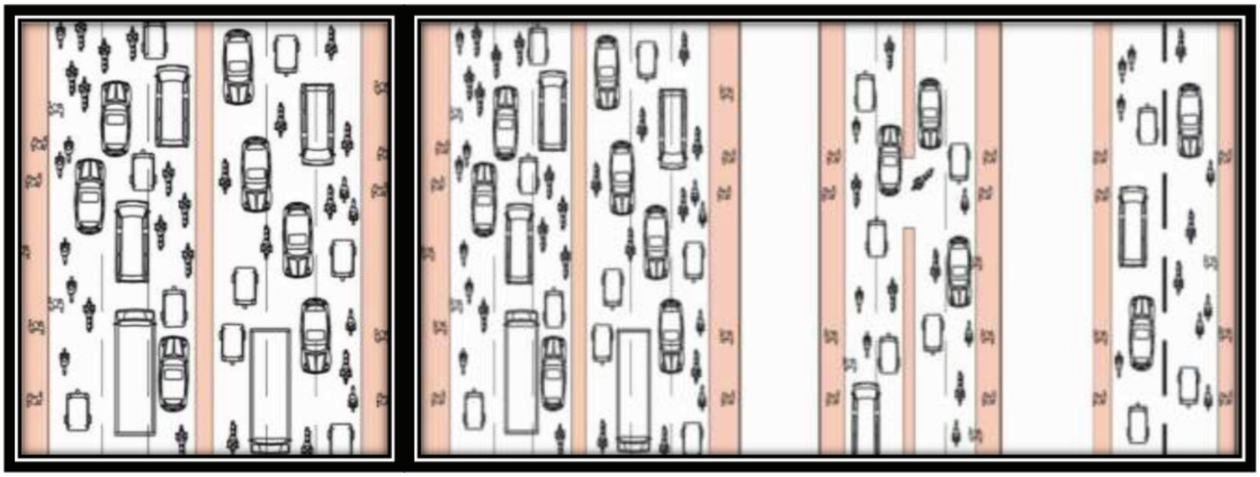


Figure2.4(b): Typical plan view and cross sections of Urban Arterial, Sub arterial, Collector and Access streets



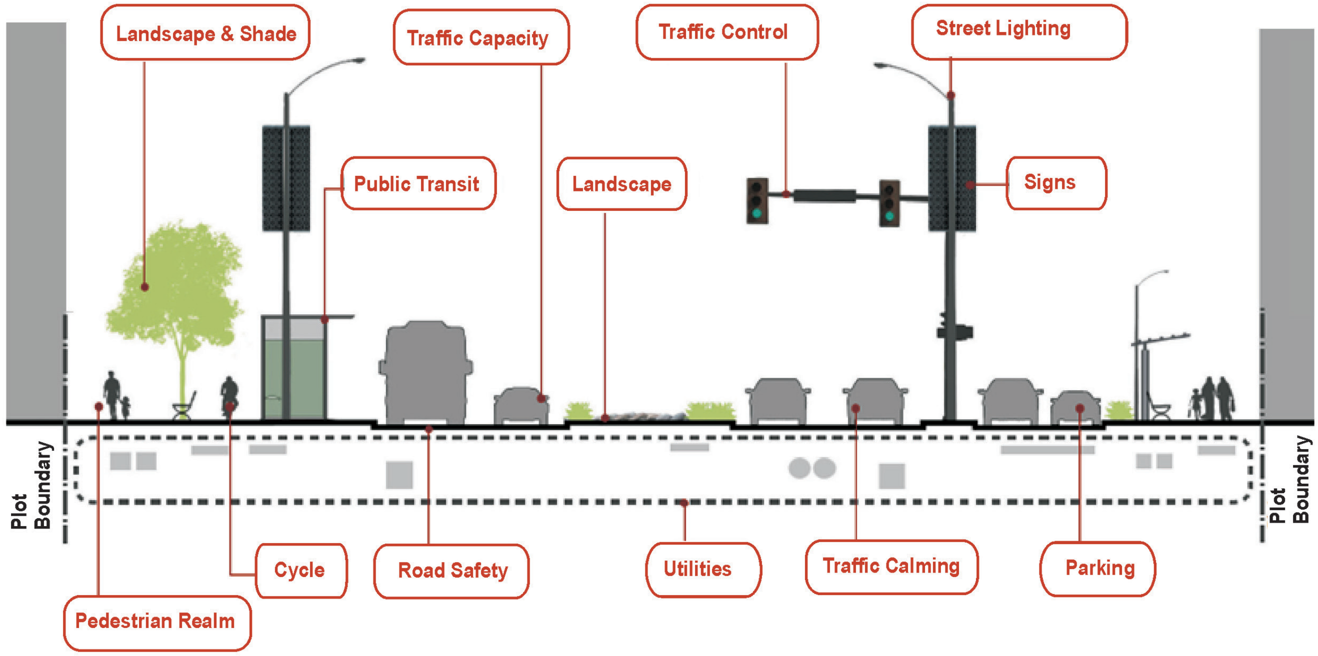
Arterial (ROW-50m to 80m) 50km/h

Sub Arterial (ROW-30m to 50m) 50km/h

Distibutor (ROW-12m to 30m) 30km/h

Access (ROW-6m to 14m) 15km/h

Fig 2.5: Ideal urban arterial cross-section



In any given city, city officials need to take stock of the existing situation on the following items in order to assess the sufficiency / deficiency of the network at the macro level.

- Population of the city
- Length of different categories of roads
- Density of each category of roads
- Availability of footpaths
- Facilities for NMV

If the city is experiencing mobility problems / bottle-necks at some locations or during some time periods of the day, a comprehensive evaluation needs to be undertaken at macro level of the city. Even though commuters are not experiencing congestion or interruptions to movements during peak hours currently, the level of service (LOS) enjoyed by them may not be as per the established design criteria. Hence comprehensive evaluation needs to be undertaken. This analysis helps in identifying locations in urban road network where improvements are needed so as to keep the LOS as per the design. However the adequacy of the network for the future (5 – 10 years) should also be assessed since implementation of infrastructure improvement plans is lumpy in nature requiring huge quantity of material and financial resources. Table 2.6 will provide rough guidelines on share of different categories of road network based on population of the city. These are approximate values based on different master plans.

Table 2.6: Guidelines for desired density of road network based on population

City Category	City Population in lakhs	Road density as percentage of urban area	Desired percentage of each category of road			
			Arterial	Sub-arterial	Collector	Local
Category-1	< 5	8	5 – 10		90 - 95	
Category-2	5-10	10	10 - 15		85 - 90	
Category-3	10-20	12	10 - 20		80 - 90	
Category-4	20-40	14	15 - 20		80 - 85	
Category-5	40-80	16	20 - 25		75 - 80	
Category-6	> 80	20	25 - 30		70 - 75	

In order to evaluate at macro level, data regarding the outline of road network and inventory of different categories of road network as listed below in Table 2.7 need to be collected in a systematic manner.

Table 2.7: Details of data collection at macro level

Survey Items	Description	Sample Form
Outline of Road Network	In order to provide a comprehensive outline of the city's road network, collect information such as road length, right of way, and roa d density.	Survey Form 1
Inventory of Arterial / Sub Arterial Road Network	Compile inventory of the Arterial / Sub Arterial road network of the city to be used for subsequent development of a transport demand model.	Survey Form 2

Survey forms 1 and 2 are presented in Table 2.8 and Table 2.9 respectively. The PCU factors suggested by IRC and frequently adopted PCU factors by many researchers are included in Table 2.10. It is felt that planning of URTS is influenced by vehicle ownership, population and socio-economic scenario that exist in an urban area. Tables 2.11 and 2.12 provide the format to document this information for an urban area.

Table 2.8: Survey form – 1: Outline of road network

Item	Road category	Metropolitan Area / UDA#	Municipality/ MC area	City Core
Road Length (km)	National Highways			
	State Highways			
	Arterial Roads			
	Sub- Arterial Roads			
	Distributors/ Collector streets and Access streets			
Road Density by Road Type (km/km^2)	Arterial Roads			
	Sub- Arterial Roads			
	Distributors/ Collector streets and Access streets			

UDA – Urban Development Area

Table 2.9: Survey Form – 2: Inventory of Arterial road network

Name of Road	Section		Length (km)	Right of Way (m)	Width of Carriage way (m)	No of Lanes	Width of Footpath (m)		Width of Cycle track (m)		Traffic Volume (PCU * /Day)	Parking regulations along roadway	Abutting Land use	Road Surface (G/F/P)#	Remarks Encroachment/ Existence of roadway hazards
	FROM	TO					Left	Right	Left	Right					

#G - Good / F - Fair / P - Poor

Table 2.10: Preferred PCU conversion factors over IRC values

*Description	Cycle	Pedal rickshaw	Two wheeler	Four wheeler	Auto rickshaw	Tempo	Mini-bus	Bus	Light truck	Heavy truck
PCU factor: IRC	0.4	1.5	0.5	1	1.2	1.4	-	2.2	1.4	2.2
PCU factor: Preferred	0.2	1	0.2	1	0.8	1.2	2	2.2	2	3

Table 2.11: Vehicle ownership data

	Total in Metropolitan Area / UDA	Total in Municipality Area	Zone 1	Zone 2	Zone 3	Zone 4.....
Number of Registered Vehicles by Type						
Passenger Vehicle						
Small Passenger Vehicle						
Small Truck						
Heavy Truck						
Auto Rickshaws						
Cycle Rickshaws						
Buses						
Mini Bus						
Motorcycles (two wheeler)						
Number of households having Bicycle						
Number of households having Scooter, Motorcycle, Moped						
Number of households having Car, Jeep, Van						
Number of Licensed Drivers						

Table 2.12: Population and social-economic information (which is the basis for vehicle ownership)

	Total in Metropolitan Area / UDA	Total in Municipality Area	Zone 1	Zone 2	Zone 3	Zone 4....
Population						
Number and size of Household						
Population Growth Trend						
Population Density						
Number of Workers by Category						
Main Workers						
Cultivator						
Agriculture						
Labour						
Household Industry						
Others						
Marginal Workers						
Non Workers						
Average Personal Income						
Average Household Income						

Chapter 3:

Evaluation of Sufficiency of Urban Road Network

Collection and analysis of above data will help city officials to examine the sufficiency of urban road network in a given city at macro level and the data could be studied under the following 6 steps.

3.1 Step 1: Define the Land Use and Urban Design Context

The classification and ultimate design of any urban road network is expected to reflect the existing and expected future patterns of land use. That context should be considered from the broadest, area-wide perspective down to the details of the immediately adjacent land uses.

The following questions regarding the existing and future land use environment around the urban area should be addressed:

- What are the characteristics of the area, land use mix and density?
- Are there any other existing development policies that cover the area?

3.2 Step 2: Define the Transportation Context

The transportation assessment should consider both the existing and expected future conditions of the overall transportation network relative to the potential future growth scenario. The ultimate design should reflect the entire context, rather than that related strictly to capacity on a given segment.

The following issues should be considered:

- How does the street currently function? What are the characteristics of traffic flow like volume, composition and Speeds?
- What is the LOS for vehicles, Cyclists, and pedestrians?
- What are the current design features, including number of lanes, sidewalk availability, bicycle amenities, traffic control features etc.?

- Are there any programmed or planned transportation projects in the area that would affect this street segment?

3.3 Step 3: Identify Deficiencies in the existing road network

Once the land use and transportation contexts are defined and understood from an area-wide perspective, the design team should be able to identify and describe any deficiencies that could/should be addressed by the project. This step should address all of the modes and also the relationship between the transportation and the land use contexts.

In this sense the following questions must be answered:

- Are there gaps in the bicycle or pedestrian network near or along the street segment?
- Are there gaps in the overall street network (this includes the amount of connectivity in the area, as well as any obvious capacity issues on other segments in the area)?
- Are there any inconsistencies between the existing land use and the existing or planned street network?

3.4 Step 4: Future Objectives

This step synthesizes the information from the previous steps into defined objectives for the road/street project. The objectives could be derived from the plans and/or policies for the area around the street, as well as the previously identified list of deficiencies. The objectives for the street will form the basis for the classification and ultimate design.

The following issues should be considered in defining the objectives:

- What conditions are expected to stay the same (or what conditions should stay the same)?
- Why and how would the community and the users like the street and the neighbourhood to change?
- Given this, what conditions are likely to change as a result of this street classification (how will the street classification and design support the stakeholders' expectations)?

The stakeholder's response may be given adequate importance in the revised street classification.

3.5 Step 5: Recommend Street Typology and Test Initial Cross-Section

The plan/design team should recommend the appropriate street typology, based on the previous steps. The rationale behind that classification should be documented. This step should also include a recommendation for any necessary adjustments to the land use plan/policy and/or transportation plan for that area. Since the

street type and the ultimate design are defined, in part, according to the land use context, subsequent land use decisions are expected to recognize and support the agreed-upon street type and design.

The initial cross-section should be defined based on the recommended street typology, keeping in mind that some typologies allow more than one option. Once the preferred option is identified, the ideal cross-section will typically include the design features and ideal dimensions specified for that street type.

The initial cross-section is then tested against the land use and transportation contexts and the defined objectives for the road/street project. At this point, any constraints to provision of the initial, ideal cross-section should also be identified, including:

- Constrained right-of way,
- Existing structures,
- Existing trees or other environmental features,
- Topography, and
- Location and number of driveways.

Many of these constraints will have been considered in earlier steps, but this step should clearly identify which constraints may prohibit use of the cross-section defined initially.

3.6 Step 6: Describe Tradeoffs and Select Cross-Section

The method of evaluating the tradeoffs is left open to the design team, as long as the method / discussion / analysis are documented. This step serves as a reminder that all users should receive equal consideration in the design process. It also provides accountability and direction for future growth opportunities.

Once the tradeoffs are evaluated, the team should be able to develop a refined (or more than one alternative) cross-section and suggested design treatments. The culmination of all of the previous steps, including any additional stakeholder input, should provide enough rationale to select the alternative that best matches the context and future expectations relative to the street project under consideration.

For evaluation of urban transport systems, typical issues such as congestion, coverage of public transport, parking, safety etc. need to be studied and the same are detailed in Table 3.1. The summary of measures suggested by National Urban Transport Policy (NUTP) is included in Table 3.2.

Table 3.1: Typical Urban Transport Issues

Issue	Comments
Traffic Congestion	
❖ Is congestion city-wide	
❖ Is congestion along major roads	
❖ Is congestion city-wide/along major roads only during peak hours	
The probable reasons for congestion:	
✓Due to narrow streets	
✓Due to waiting or parked vehicles	
✓Due to slow vehicles (Bicycle, Cycle Rickshaw, Auto Rickshaw, Two wheeler)	
✓Due to junctions spacing and control	
✓Due to interruptions from bus stops	
✓Due to high pedestrian activity	
Condition of Public Transportation System	
❖ Insufficiency of Public Transportation	
❖ Insufficiency of Bus Routes (i.e. bus routes are far from residence/commercial area)	
❖ Insufficiency of Buses	
❖ Poor condition of Bus systems	
❖ Proliferation of Disorganized Private Bus Services (including mini buses)	
❖ Low Profitability of Bus Operators	
Parking	
❖ Major Streets are too Narrow for Parking	
❖ Problems Caused by Parking of Private Vehicles	
❖ Problems Caused by Parking/Waiting of Rickshaws and Auto-Rickshaws	
❖ Lack of Parking Areas at Station/Bus Terminals	
❖ Lack of Land for Off-Street Parking Lots	
❖ Lack of Regulations for Parking Measures	
❖ Lack of Parking Policy and Guidelines	
Enforcement Measures	
❖ Enforcement of Illegal Traffic Movements or Over Speeding	
❖ Enforcement of Illegal Traffic Parking	
❖ Enforcement of Unlicensed Private Vehicle Motorists	
❖ Enforcement of Illegal Bus/Para-Transit Operators	
❖ Lack of Resources for Enforcement (Road Transport Authorities, traffic police and equipment)	


Planning and Implementation Capacity	
❖ Guidance for Making City Transport Policy/Plans	
❖ City Master Plans Do Not Reflect Actual Situation on the Ground	
❖ Lack of Sufficient Urban Transport Planners within the City Government	
❖ City Officials Dealing with Transport Planning Lack Experience or Training	
❖ Lack of Data Collection Capability e.g. Periodical Traffic Surveys	
❖ Lack of Financial Resources to Implement Planned Transportation Projects	
Traffic Safety (Major Accident Types)	
❖ Vehicle-Vehicle Accidents	
❖ Accidents Involving Pedestrians	
❖ Accidents Involving Cyclists	
❖ Accidents Involving Auto/Cycle Rickshaws	
Transit Quality	
❖ Number of transfers	
❖ Accessibility of transit stops to prominent locations	
❖ Reliability of adherence to time table	
❖ Quality and accessibility of Information	
❖ Comfort and convenience during transit	
❖ Safety and Security	

Table 3.2: Summary of mobility improvement measures in relation to NUTP

NUTP Objectives	Proposed Mobility Improvement Measures
Priority for Pedestrians	✓ Pedestrian paths are recommended in all residential and commercial areas and on major corridors. ✓ Pedestrian crossings are proposed in all commercial areas and school zones. ✓ Pedestrian underpasses are recommended at critical locations.
Priority for Non-motorized Vehicles	✓ Recommended bicycle tracks on major corridors and in school zones. ✓ Bicycle parking is recommended for offices, railway stations, schools and all markets and shopping centres. ✓ Rickshaw stands are proposed at critical locations.
Priority for Public Transport	✓ Development of an MRT system is proposed. ✓ Recommended improvements to existing bus services and necessary regulatory/institutional changes.

Parking	✓ On-street parking facilities are proposed for critical locations. Recommended regulatory changes in building permits to secure parking demand. ✓ Construction of off-street parking is proposed for several locations, and a funding mechanism is developed including the possibility of private sector participation. ✓ Changes in parking tariff policy are proposed to optimize the use of existing off-street parking facilities.
Integration of Land Use and Transport Planning	✓ A preferred urban growth scenario is recommended in the CMP document and its compatibility with the Master Plan is analyzed. ✓ Land use control principles to minimize the mobility requirement are presented. ✓ Proposed MRT corridors with feeder modes of transport cover major residential, commercial and industrial areas in metropolitan areas. ✓ High-density residential and commercial development around proposed MRT stations is recommended.
Equitable Allocation of Road Space	✓ MRT corridors and bus priority lanes are proposed. Pedestrian and NMV lanes are recommended.
Integrated Public Transport Systems	✓ Recommended that inter-city bus terminals be moved to peripheral areas of the city and integrated with inner-city bus services. ✓ Intermodal (taxi/rickshaw stands, vehicle, NMV parking, and bus-loading/unloading) facilities are proposed at MRT stations.
Introduction of Para transit Services	✓ Recommended the introduction of par transit services to supplement the existing/new public transport services.
Freight Traffic	✓ Truck terminals proposed.
Improvement	✓ Entry restrictions for heavy vehicles during peak hours recommended.

Chapter 4:

Different Elements of Urban Road Network

Streets need to be designed for all users not just for motorized traffic alone. 16 elements make up a street.

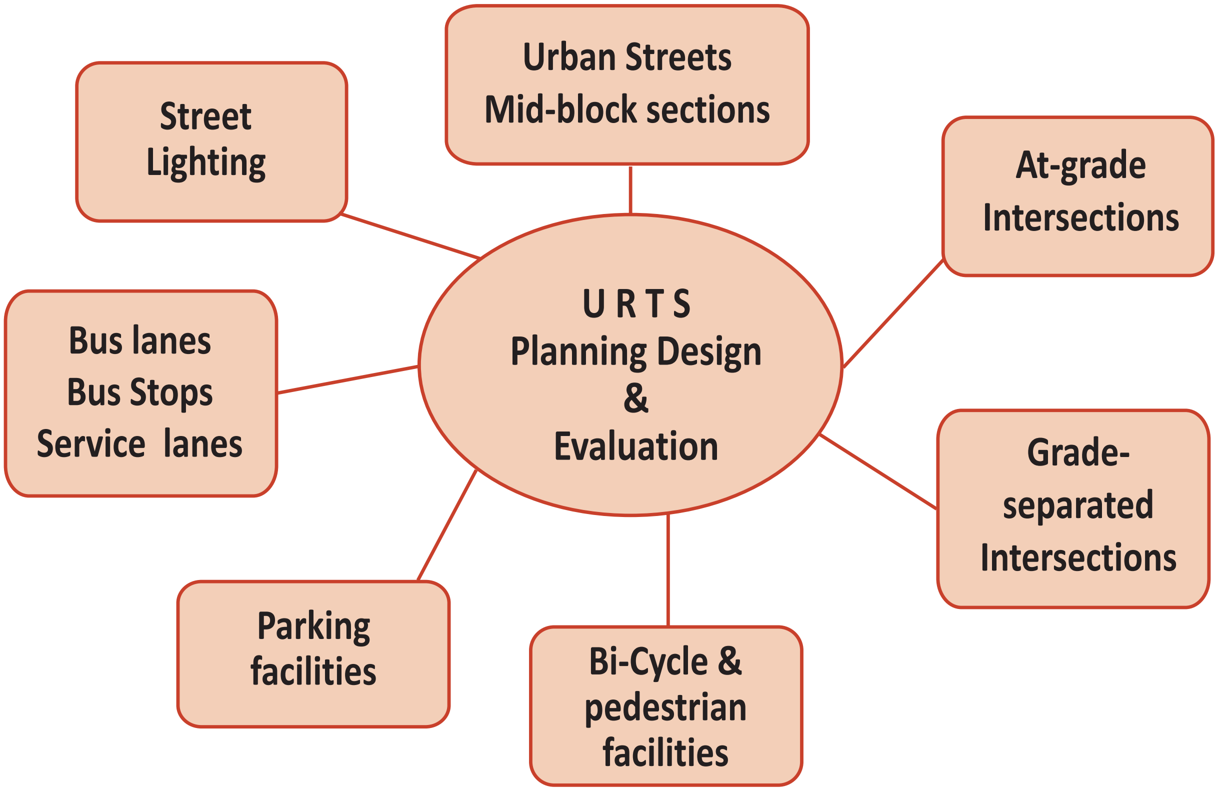
All 16 elements are as below.

1. Carriageway
2. Bus Lanes
3. Cycle tracks
4. Footpaths
5. Service lanes
6. Bus stops
7. Pedestrian crossings
8. Medians and pedestrian refuges
9. On-street parking
10. Street lighting
11. Landscaping
12. Spaces for street vending
13. Street furniture and amenities
14. Road intersections
15. Traffic calming elements
16. Other underground utilities

However for the purpose of this toolkit, the following important elements are discussed in detail. URTS for an urban area is presented in Figure 4.1

- ✓ Carriageway
- ✓ Road intersections
- ✓ Bus Lanes
- ✓ Cycle tracks
- ✓ Footpaths
- ✓ Service lanes
- ✓ Bus stops
- ✓ Pedestrian crossings
- ✓ On-street parking
- ✓ Street lighting

Figure 4.1: Components of URTS



4.1 Geometric Design of Urban Streets

The design of street network mainly consists of two components:

- ✓ Mid-block sections
- ✓ Intersections.

This section mainly focuses on Mid-block or tangent sections of urban road network.

Design of Mid-block sections include width of the lane, number of lanes, Horizontal and Vertical alignment.

The lane width depends upon the physical dimensions of design vehicle. Table 4.1(a) and 4.1(b) provides the same information as per IRC, MOUD, and AASHTO guidelines.


Table 4.1(a): Recommended Lane Widths as per IRC and AASHTO Guidelines

Type of Road	I.R.C-86-1983	Type of Road	AASHTO
	Road Width (meters)		Lane Width (meters)
Single lane without kerbs	3.5	Freeway	3.6
2-lane without kerbs	7	Ramps	3.6-9.2
2-lane with kerbs	7.5	Arterial	3.0-3.6
3-lane with or without kerbs	10.5/11.0	Collector	3.0-3.6
4-lane with or without kerbs	14	Local	2.7-3.6
6-lane with or without kerbs	21		

Table 4.1(b): Recommended Lane Widths as per MOUD Guidelines

	Arterial Roads	Sub Arterial Roads	Distributory Roads	Access Roads
Carriageway				
Criteria	50 km/h	50 km/h	>30 km/h & < 50 km/h	>15 km/h & >30 km/h
ROW	50m – 80m	30m – 50m	12m – 30m	6m – 15m
Horizontal curve	30m or more	30m or more	10m or more	5m or more
Gradient	2%	2%		
Number of lanes	Minimum 6 lanes divided (using a raised median);	Minimum 4 lanes divided (using a raised median);	Maximum 4 lanes of 3.0m width each (excluding marking) or 2 lanes of 3.0 to 3.3m width each (excluding marking) with or without an intermittent median	1 to 2 lanes, (undivided); of 2.75 to 3.0m width each
Minimum Width for car lane	3.0 to 3.5m width each	3.0 to 3.5m width each	2 lanes of 3.0 to 3.5m width each	2.75 to 3.0m width each
Minimum Width for bus lane	3.5m –(segregated)	3.5m –(segregated) or painted lane	Mixed traffic	

Number of lanes for a given type of road depends on design traffic volume, design speed and freedom of manoeuvrability to be provided to the road user. The city engineer or planner needs to organise in collecting and checking information on different items in order to plan and evaluate urban road carriageway. The checklist as shown in Table 4.2 needs to be pursued at all critical locations on all corridors involving arterial as well as sub-arterial roads by city officials for proper planning and evaluation concerning to different elements of urban carriageway. The field observers are requested to assess each item and respond as yes or no. The response YES is considered as 1 and NO is considered 0. Depending upon the total number of YES (1s), a scale has been created to provide some rationale to understand and categorise the functioning of existing facility. Five different ratings (5 - Very good, 4 - Good, 3 - Satisfactory, 2 - Poor, 1 - Very Poor) are included based on total number of positive responses (YES). Geometrical Elements, which receive Poor and very poor rating are to be addressed on priority to improve the situation.

Table 4.2: Checklist for evaluating carriageway

<table>
<tr><th>S.No.</th><th colspan="3">Item</th><th>Comment (Yes:1; No:0)</th></tr>
<tr><td rowspan="7">1</td><td colspan="4">Part A</td></tr>
<tr><td colspan="2">Location Details:
Direction (From -To):
Date and Time:</td><td colspan="2">Land Width (m):
Lane Width (m):</td></tr>
<tr><td rowspan="4">What is the road category? (Arterial/ Sub-Arterial/ Collector / Local)</td><td>Arterial</td><td>For through traffic</td><td rowspan="4"></td></tr>
<tr><td>Sub-Arterial</td><td>Lower level of mobility</td></tr>
<tr><td>Collector</td><td>Link between local to arterial/sub-arterial</td></tr>
<tr><td>Local</td><td>Access to property</td></tr>
<tr><td colspan="4" style="display:none"></td></tr>
<tr><td>2</td><td colspan="3">Carriageway width and number of lanes on left hand side</td><td></td></tr>
<tr><td>3</td><td colspan="3">Carriageway width and number of lanes on right hand side</td><td></td></tr>
<tr><td colspan="5">Part B</td></tr>
<tr><td>4</td><td colspan="3">Is the land width in specified limits?
(Arterial: 50-60m; Sub-arterial: 30-40m; Collector 20-30m; Local: 20-30m)</td><td>Yes/No</td></tr>
<tr><td>5</td><td colspan="3">Is the carriageway divided?</td><td>Yes/No</td></tr>
<tr><td>6</td><td colspan="3">Are there any kerbs?</td><td>Yes/No</td></tr>
<tr><td>7</td><td colspan="3">What is the width of lane? (Recommended: 3.0-3.5m)</td><td>Yes/No</td></tr>
<tr><td>8</td><td colspan="3">What is the width of median in meters? (Minimum: 1.2m)</td><td>Yes/No</td></tr>
<tr><td>9</td><td colspan="3">Is the peak hour traffic (PCU/h) on left hand side is less than values given as per Table 19 for a given road section?</td><td>Yes/No</td></tr>
</table>


10	Is the peak hour traffic (PCU/h) on right hand side is less than values given as per Table 19 for a given road section?	Yes/No
11	Is there lane marking to demarcate the lanes?	Yes / No
12	Is the carriageway demarcated for 2 wheeler / 4 wheeler lanes?	Yes / No
13	Does the carriageway have good riding surface?	Yes / No
14	Does the carriageway have a constant/fixed width throughout?	Yes / No
15	Is there any separate cycle track	Yes / No
16	Is there any separate footpath	Yes / No
17	Is there a proper/safe super-elevation at horizontal curves?	Yes / No
18	Are there any speed breakers/ humps on the carriageway?	Yes / No
19	Is there any railing / curb / crash barrier at the edge of carriageway?	Yes / No
20	Is there a clear marking defining the edge of carriageway in case there is no kerb?	Yes / No
21	Are there pedestrian crossing points on carriageway?	Yes / No
22	Are there warning signs at sufficient distance in advance wherever there are at grade pedestrian crossings / cross streets?	Yes / No
23	Are the direction, warning and regulator signs at visible heights?	Yes / No
24	Is there on street parking facility by the side of carriageway to accommodate breakdown vehicles?	Yes / No
25	Is there a good regulation to identify traffic violators?	Yes / No
26	Are there any bus bays at bus stops	Yes / No
27	Is a separate bus lane provided?	Yes / No
28	Is the carriageway widened at horizontal curves	Yes / No

Range	Rating (Verbal)	Rating (Numerical)
>21	Very good	5
16-20	Good	4
11-15	Satisfactory	3
6-10	Poor	2
0-5	Very Poor	1

The suggested capacity values for urban roads as per IRC are presented in Table 4.3.

Table 4.3: Tentative capacities of urban roads

Number of traffic lanes and width	Traffic flow	Capacity in PCU/hour		
		Arterial	Sub-Arterial	Collector and local streets
2-lane	divided	2400	1900	1400
	undivided	1500	1200	900
3-lane	divided	3600	2900	2200
4-lane	divided	3600	2900	--
	undivided	3000	2400	--
6-lane	divided	5400	4300	--
	undivided	4800	3800	--
8-lane	divided	7200	--	--

4.2 Design Vehicle

For the purpose of geometric design, the design vehicle should be one with dimensions and minimum turning radius larger than those of almost all vehicles in its class. The dimensions of some design vehicles within these general classes given by AASHTO are presented in Table 4.4.

Table 4.4: Design Vehicle dimension (AASHTO)

Design Vehicle		Dimension in metre						Turning Radius (m)
Type	Symbol	Wheel Base	Overall		Overall Length	Overall Width	Height	
			Front	Rear				
Passenger Car	P	3.4	0.9	1.5	5.8	2.1	1.3	7.3
Single Unit Truck	SU	6.1	1.2	1.8	9.1	2.6	4.1	12.8
Truck Combination	WB-50	7.9	0.9	0.6	16.7	2.6	4.1	13.7

A standard Truck / Bus is used as a design vehicle for the purpose of selecting lane width in India. The passenger car should be used for speed-related standards and the bus for standards relating to manoeuvrability, typically at intersections. The following limiting dimensions for different categories of vehicles as specified in IRC-3:1983 for designing various elements of geometric design of urban roads is presented in Table 4.5(a). Non-motorized vehicle dimensions and characteristics of different vehicle-types as per MOUD code of practice: cross section, are provided in Table 4.5(b) and 4.5(c).

Table 4.5(a): Design Vehicles' Dimensions

Authority	Maximum Width (m)	Maximum Height (m)	Maximum length (m)				
			Passenger Car	Single Unit Truck	Semi Trailer	Truck trailer	Single Unit Bus
IRC - 3 (1983)	2.5	3.8 to 4.2 (Truck/Bus) 4.75 (Double Decker Bus)	-	11	16	18	12
AASHTO	2.6	4.1	5.8	9.1	15.2 - 16.7	19.9	18.3
U.K.	2.5	4.57 (bus)	5.5	11	13	18	

Table 4.5(b): Non-motorized vehicles' (NMV) Dimensions (MOUD Code of Practice: Cross Section)

NMV	a Length (mm)	b Height (mm)	c Width with rider (mm)	d Handle bar width (mm)	e Wheel size (dia. in mm)
Adult Touring Bike	1800-1950	990-1200	750	500-600	560-710
Adult Touring Bike with goods (milk cans or gas cylinders)	1800-1950	990-1200	850-950	500-600	560-710
Passenger Rickshaw	2000-2200	990-1200	900-1000	9500-600	560-710
Goods Rickshaw	2000-2400	990-1200	1000-12200	500-600	560-710
Goods Rickshaw	2400-2600	990-1200	1200-1400	500-600	560-710

Table 4.5(c): Characteristics of different vehicle-types (MOUD Code of Practice: Cross Section)

Characteristics\Type of Vehicle	Cycle	2 wheeler	3 wheeler	Car	Bus
Length (m)	2	2	1.7	4	10.5
Width (m)	0.6	0.7	1.5	2	2.5
Max. desired speed (m/s)	10	40	30	45	60
Max. acceleration (m/s^2)	1.5	1.5	1.5	3	3
Normal deceleration (m/s^2)	2.5	2.5	2.5	4	6
Max. deceleration (m/s^2)	6	5	5	6	6
Give way time (s)	5	30	30	30	30

4.3 Design speed

Speed is a primary factor in all modes of transportation, and is an important factor in the geometric design of roads. The speed of vehicles on a road depends on capabilities of the drivers and characteristics of the vehicles. Design Speed as per classification of roads is shown in Table 4.6.

Table 4.6: Design Speeds for different categories of urban roads

I.R.C-86-1983		Code of Practice Cross section (MOUD)		AASHTO	
Classification of Road	Design Speed Kmph	Classification of Road	Design Speed Kmph	Classification of road	Design Speed Kmph
Arterial	80	Arterial	50	Parkways and rural roads	100
Sub-arterial	60	Sub-arterial	50	Arterial and some sub-arterial roads	80
Collector street	50	Distributor/ Collector street	30	some sub-arterial roads and major collector roads	60
Local street	30	Access street	15	minor collector roads and access streets	50

Urban roads in India have heterogeneous traffic, with different types of motorised vehicles sharing right of way with pedestrians and cyclists as shown in Photo - 4.1.

Photo 4.1: Mixed traffic in urban areas of India

4.4 Design Hourly Volume (DHV)

The traffic patterns on any road show considerable variation in traffic volume during different hours of the day and different days of the year. It is difficult to determine which of these hourly traffic volumes should be used for design. The design hourly volume is frequently assumed to be the 30th highest hourly volume of the future year chosen for design, i.e. the hourly volume exceeded during only 29 hours of that year. The design hourly volume is expressed as a percentage of the ADT and typically varies from 12 to 18%. A value of 15% is thus normally assumed unless actual traffic counts suggest a different percentage. In the absence of the traffic survey data, the hourly traffic used in design is the 30th highest hourly volume of the year, abbreviated, as 30HV. The design hourly volume, abbreviated DHV is the 30HV of the future year chosen for design. The design hour is a combination of two distinctly different sets of circumstances, i.e. the morning and the afternoon peak in the case of commuter routes. Furthermore, the peak period may have a duration that is longer (or shorter) than 60 minutes and contain within itself a shorter period (typically 15 minutes) with very intense traffic flows. This peak hour factor is used in determining the DHV as equal to four times the peak 15 minutes traffic. The schedule to collect traffic volume data on urban road sections is included in Table 4.7.

Table 4.7: Traffic volume count surveys (Mid-block)

Location:	Section (To/From):	Date/Month/Year
Count Station No.	Direction:	Day:
	Road Name & No.	

Time	Fast moving						PCU Fast moving	Slow moving		PCU slow moving	Total	
	Bus	Truck	LCV	Car	2-wheeler	3-wheeler		Cycle	Other SMV		Number	PCU
7 am												
8 am												
9 am												
10 am												
6 pm												
7 pm												
8 pm												
9 pm												


4.5 Number of Lanes to accommodate DHV:

The number of lanes needed for an arterial road depends on design volume and the capacity of the lane. The capacity of a lane is defined as the maximum number of vehicles that can pass a point in an hour. At this flow rate the freedom enjoyed by the individual road user is comparatively less. Urban roads are normally designed for level of service C. Thus it is imperative to understand and analyse the levels of service and the corresponding service volume for different categories of roads. Capacity and service volume standards are normally provided in terms of passenger car units (PCU) in India. The traffic stream in India consists of a variety of vehicles whose physical and operational performance characteristics vary widely. For the purposes of design and evaluation of urban road sections all the vehicles in the traffic stream need to be converted in to equivalent passenger car stream. IRC-86: 1983 provides these conversion factors shown in the Table 4.8. A closer examination of the conversion factors indicates that there is variation across different countries.

Table 4.8: PCU conversion factors adopted in different countries

Vehicle Type	I.R.C-86 (1983)	USA (AASHTO)	UK	Malaysia (1989)	China (2003)
Passenger car, tempo, auto-rickshaw, Jeep, van or agricultural tractor	1	1	1	1	1
Bus	3	3.5	2.5	2.8	2
agricultural tractor-trailer		3.5	2.9		
Medium Lorries / Truck	3		1.9	2.5	1.5
Heavy Lorries		3.5		3	3
Motor-cycle / scooter	0.5	0.5	0.4	0.75	0.5
Bi-cycle	0.5	0.2			0.5
Cycle-rickshaw	1.5				
Horse-drawn vehicle	4				
Bullock-cart	8				
Hand-cart	6				

These capacity standards are originally developed in USA and the conversion factors are determined on the basis of extensive field studies and simulation experiments. The traffic stream in USA mainly consists of passenger cars (80 - 85%), and the remaining 15% is shared by buses and trucks. Thus converting 15 to 20% of traffic stream into equivalent passenger car stream is relatively simple.

Mixed stream operations on Indian roads are depicted in Photo 4.2 below.

Photo 4.2: Mixed stream operations on Indian roads

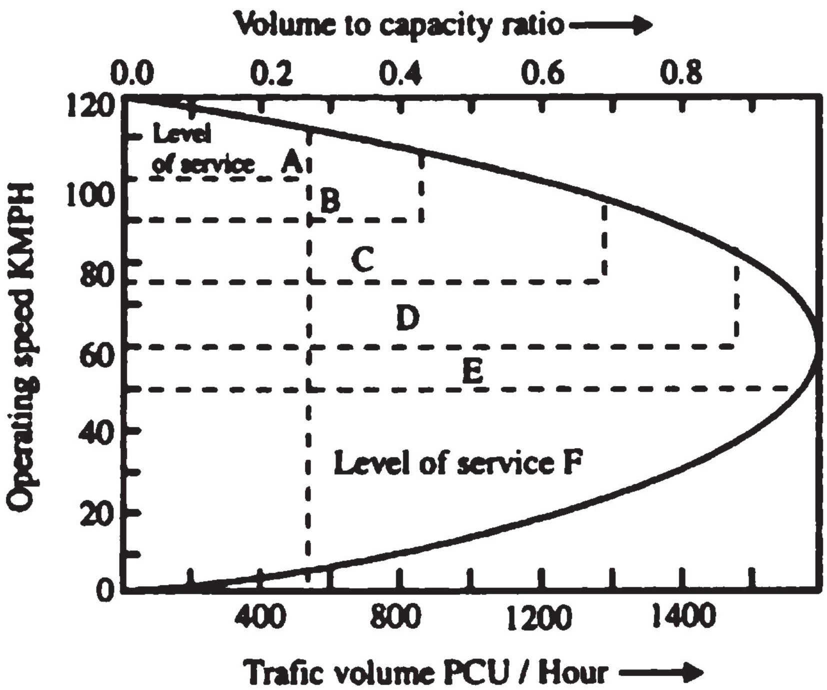
In India the traffic stream mainly consists of motorised two-wheelers (35–45%) and six or seven different categories of other vehicles constitute the remaining 55%. Passenger cars as a percentage of traffic streams may not exceed 15–20% in most of the urban centres. This percentage may slightly be higher at 30% in six or seven metropolitan cities. Thus converting 60–70% of the traffic stream into passenger cars is posing a serious problem in India. Currently this issue is taken as a priority research activity by Central Road Research Institute (CRRI, New Delhi).

The urban road capacity values as suggested by IRC for the purpose of designing number of lanes are presented in Table 4.3. However correction need to be applied to get the service volumes corresponding to LOS C as presented in Table 4.9 or as given in Figure 4.2.

Table 4.9: The relation between V/C and LOS

V/C ratio	LOS
0.0-0.35	A
0.35-0.50	B
0.50-0.70	C
0.70-0.85	D
0.85-1.00	E
>1.00	F

Figure 4.2: Speed - Flow Relationship



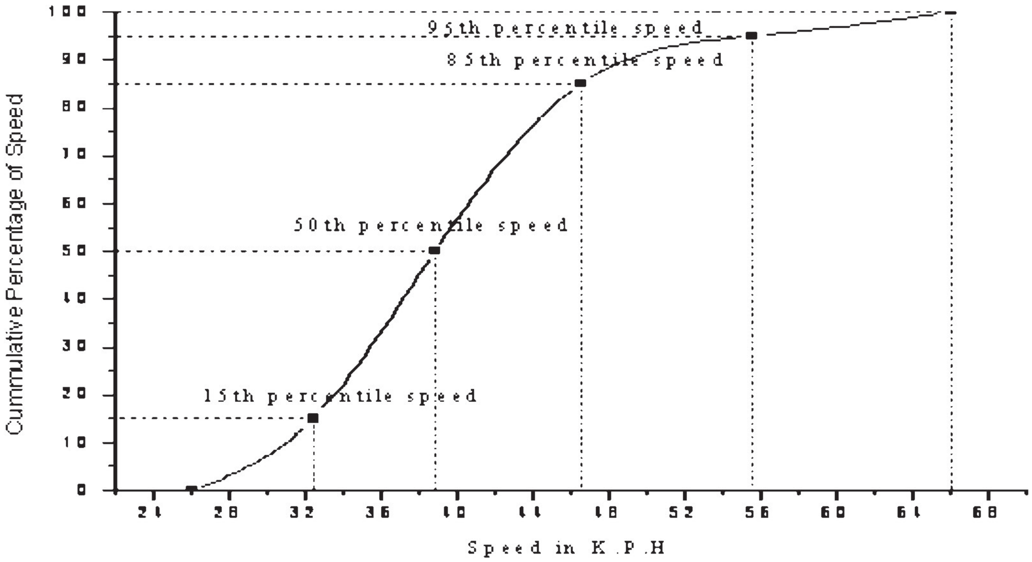
The information presented above helps the field personnel to plan mid-block sections as per IRC guidelines in practice. For the purpose of evaluation of mid-block sections the procedure to be followed by the field personnel is detailed below.

- Collection of traffic volume data
- Finding the 30th Highest hourly volume
- Free speed data of traffic stream
- Estimation of Capacity and Service Volumes

Design Hourly Volume (DHV) calculated and the service volume at L.O.S. – C help in determining the number of lanes. If the existing number of lanes is equal or more, it may be interpreted that the design is adequate. Otherwise additional lanes need to be added.

From the free speed data, a cumulative frequency curve is plotted and 98th percentile is calculated. Sometimes 95th percentile speed is considered instead of 98th percentile speed as shown in Figure 4.3. This speed value is compared with design speed. If the design speed is more than this value no steps needed to control the speeds. Otherwise speed limit signs need to be erected indicating 85th percentile speed as the speed limit.

Figure 4.3: Cumulative frequency of free speed data



While evaluating the existing road networks the availability of these Sight distances are to be analysed and if the values fall short of the required values, sign boards are to be erected to indicate the limiting speeds as shown in Photo 4.3.

Photo 4.3: Regulatory sign showing Speed limit

4.6 Horizontal Alignment

Horizontal alignment, which comprises a series of intersecting tangents and circular curves (with or without transition curve) is a most important feature affecting the safety, efficiency and cost of a road. Generally, vehicle operating speeds decrease as the overall horizontal curvature increases; thus road user costs are affected by the bendiness of a road. Thus the limiting element/factor will be the minimum radius of curvature of the horizontal curve as given in Table 4.10.

Table 4.10: Minimum radius of horizontal curve for different speeds & super-elevations

Design Speed Km/hr	Minimum Radius (metre) when super-elevation is limited to	
	7 percent	4 percent
30	30	40
50	90	105
60	130	150
80	230	265

This will help the field officials in designing horizontal curves at new locations. For an existing horizontal curve, calculate the permissible operating speed from the radius and super-elevation data. If this speed is less than the design speed, regulatory signs for speed limit should be erected as shown in Photo 4.3.

4.7 Vertical Alignment

The terrain of the traversed land influences the design of the roadway. Terrain is generally classified into three categories: level, rolling, and mountainous. Like horizontal alignment, vertical alignment consists of tangent sections and curves. Vertical curves are classified into Summit curves and Valley curves. Suggested lengths of vertical curve for a given design speed are based on sight distance for crest vertical curves and on headlight sight distance for sag vertical curves. A typical vertical alignment is shown in Photo 4.4.

In addition to sight distance, the designer is to also consider appearance and riding comfort when selecting a length of vertical curve. Long vertical curves give a more pleasant appearance and provide a smoother ride than short vertical curves. This will help in design vertical curves with different input data. For evaluating existing vertical curves the field data on different inputs could be used to determine the operating speeds. If the design speed is less than the operating speed, regulatory signs for speed limit should be erected.

Photo 4.4: A typical Vertical alignment of a road

Table 4.11 shows the various concepts in practice for capacity estimation of the different traffic system element. It covers brief methodology and procedure of the capacity estimation.

Table 4.11: Capacity Practices

Elements	IRC	HCM
Mid Block	IRC-106-1990 The capacity estimation is based on LOS of the midblock. Los can be determined by speed and volume relation of the road section	In HCM the LOS is first determined with help of travel time, speed and delay. Then based on LOS maximum flow for a section i.e. capacity of a section is determined
Un-signalized Intersection	IRC-SP-41 The intersection movements are divided into ranks and lower rank movements are considered in capacity estimation. Potential, movement and shared lane capacities are calculated and critical value is considered as a intersection capacity.	HCM has a full methodology for determining capacity of Un-signalized intersection. Less priority movements are considered in capacity estimation. Based on empirical formulas capacity of different movements is calculated and critical value is considered.
Signalized Intersection	IRC-SP-41 Capacity of signalized intersection is based on saturation flow and effective green time of the intersection. By using formula given in the code capacity can be calculated.	Capacity of signalized intersection using HCM is also based on saturation flow and effective green time. Here saturation floe is calculated based on various factors that affect the same.

Chapter 5:
Intersections

An intersection is defined as the general area where two or more roadways join or cross. Intersection is an integral part of the roadway system as much of the safety, speed, level of service, cost of operation and maintenance as well as capacity depends on its design.

Intersections are required to accommodate the movement of both vehicles and of pedestrians. In both respects, intersections have a lower capacity than the links on either side of them. In consequence, it is the efficiency of the intersections that dictates the efficiency of the network as a whole. Intersections can be broadly categorized into two types.

- At-grade intersections
- Grade separated intersection (interchanges)

Usually interchanges provide an uninterrupted flow with smooth transitions where left or right turns need to be taken without intercepting the opposing or cross traffic. But due to the high cost of constructing the interchanges, most of intersections are at-grade.

The intersection type for a location is determined primarily by the following:

- Number of intersecting legs
- Topography
- Character of the intersecting roads
- Traffic volumes
- Speeds
- Desired type of operation

5.1 At-grade Intersection:

An intersection where two roads/streets cross each other at the same elevation is called At-grade intersection. Each road radiating from the intersection and forming part of it is an intersection leg. Figure 5.1 and 5.2 show

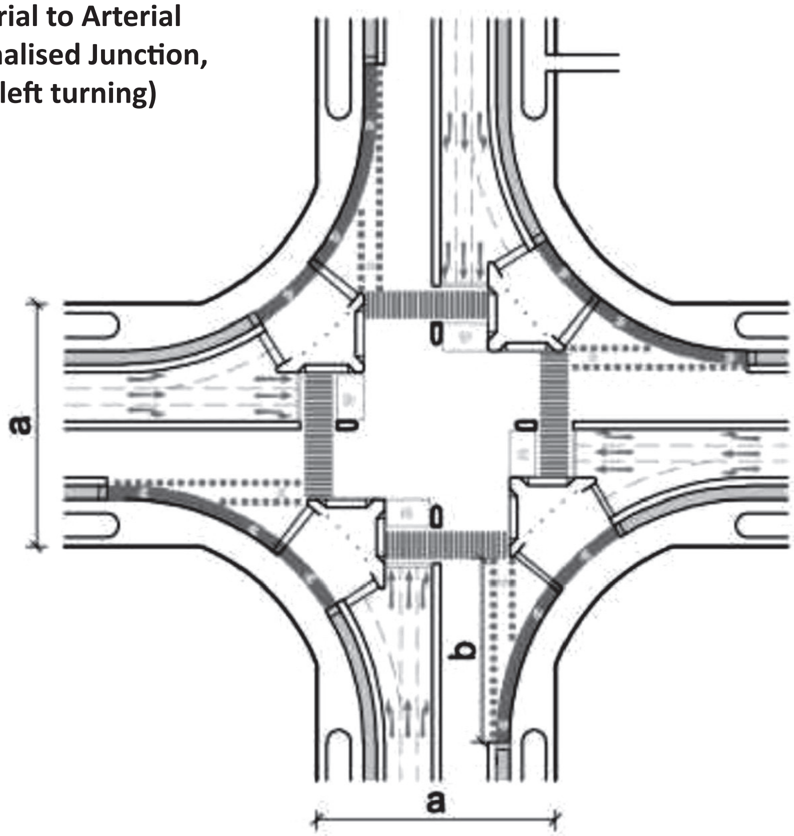
the respective typical sketches of arterial to arterial and arterial to distributor signalised intersection layouts as per MOUD code of practice.

Types of at-grade intersections based on functionality:

- Un-signalized intersection
- Signalized intersection
- Roundabout

Figure 5.1: Signalized intersection: Arterial to Arterial (with pedestrians and cyclist facility)

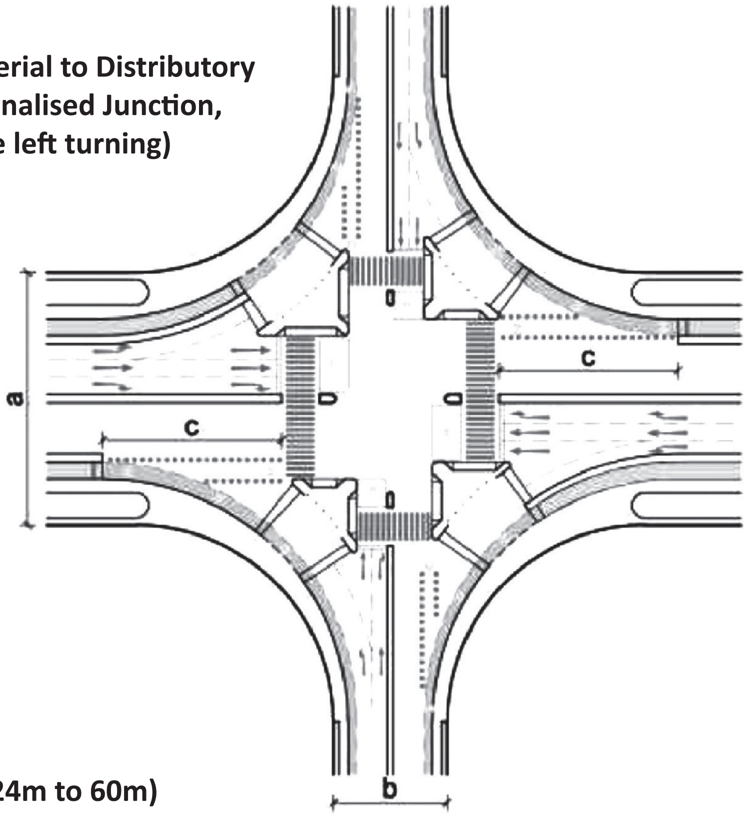
Junction Type: Arterial to Arterial (Signalised Junction, free left turning)



a : Arterial Road (24m to 60m)
b : Length of Cycle Lane leading upto cycle track (minimum 30m)

Figure 5.2: Signalized Intersection - Arterial to Distributor

Junction Type: Arterial to Distributory (Signalised Junction, free left turning)



a : Arterial Road (24m to 60m)
b : Distributory Road (12m to 30m)
b : Offset for Cycle Track start from junction (minimum 30m)

Factors influencing the planning of appropriate intersection are detailed in Table 5.1.

Table 5.1: Checklist for appropriateness of planned intersection type

Issue		Data	Comment
Location Details: Name of the roads meeting at the intersection: Date and Time:			
How many legs are meeting at the intersection?			
Estimate the peak hour traffic volume levels on each leg	Leg 1		
	Leg 2		
	Leg 3		
	Leg 4		
	Leg 5		


Observed delay during peak hour	Leg 1		
	Leg 2		
	Leg 3		
	Leg 4		
	Leg 5		
Type of intersection planned	Channelized Signalized Rotary	As per the standards:	
Is the signal installation at the intersection based on	Vehicular volumes Pedestrian volumes Accident data		

Various issues that concern intersection design are provided in Table 5.2.

Table 5.2: Areas of Concern for Intersection Design

Near Intersection	Existing Intersection
When should another intersection's design or operation affect the design or operation of the subject intersection? How should it be treated? When should a neighbouring rail road/highway grade crossing affect the design or operation of the subject intersection? How should it be treated? How to handle overlapping features (e.g., Turn bays) or queue of cars? Interconnection with other signals Utilities Drainage: Type of storm drains/ relationship of drains to curb return	Type of intersection Angle Grade Horizontal curve Distance to driveways Clear zones Sidewalks and pedestrian ramps Landscaping Sight distance Lighting ROW needs for mast arm placement Pedestrian facilities
Signals	**Approach**
Location of controller cabinet Signal head Footings Pedestrian signal and buttons Interconnection with other signals Hardware/Detectors if any	Lane arrangement Turn bays (right or left) Offset left-turn bays Turning radius Medians Pedestrian refuge Channelization Storage on through lanes Signs/ Markings

The major factors influencing selection of type of intersection are discussed in Table 5.3.

Table 5.3: Criteria for selection of various intersections types and respective criteria

Type of Intersection	Angle of intersection	Criteria	
3 leg Unsignalized intersection	60 to 120 degrees	Volumes are light	>500 veh/hr Channelize the traffic
4 leg Unsignalized intersection	60 to 120 degrees	Volumes are light on minor road	Higher traffic volume on major road
Multileg Intersection	Multi-leg	Volumes are light and stop control is used for minor road	Higher traffic volume on major road
Signalized intersection	any	Volumes are high and intersection is prone to accidents	If required channelize the traffic
Roundabout	3 leg to multi leg	Where delays are more and traffic volume more than 1500 and less than 5000	Channelization on all approach roads

If the actual delay at an intersection is more than the control delay for a particular LOS, for which it is designed, then the appropriate measures such as increasing the number of lanes, or prohibiting some movements or diverting some of the movements to some other intersection could be adopted to bring the delay to an acceptable LOS. Different design elements of intersections and corresponding IRC and AASHTO specifications are included in Table 5.4.

Table 5.4: The design elements of Intersection and respective criteria

S.No	Design Elements	IRC-SP 41(1994)	AASHTO(2004)	DMRB
1	Design speed	40% and 60% of approach speed	Speed of adjoining segments of roadway	-
2	Design Traffic Volume	peak hour flows	ADT projected	30th highest hourly flow *DMRB-6.2,(1981)*
3	Radius of curves at intersection	4.5 to 7.3m for passenger cars and 9m to 15m for trucks and buses	Min 15-25 feet	circular corner radius 6m(min) *DMRB- 6.2.6,(1995)*
4	Design Vehicle	single unit trucks	Single-unit Truck / Passenger Car (P)	-
5	Auxiliary Lanes	Length of storage lane is 1.5 times the average number of vehicles that would store in turning lanes at peak hour	storage length of a lane is 150 percent (1.5 times) of the length of the average number of turning vehicles arriving during a single signal cycle in the peak hour	-

In order to analyse the functioning of an intersection, traffic volume data on each leg along turning movements in different time periods of the day need to be collected and analysed. The schedule for collection of the required information is given in Table 5.5.

Table 5.5: Intersection turning movement survey

Location:	**Section (To/From):**		**Date/Month/Year**
Count Station No.	**Direction:**	**Left /Straight / Right**	**Day:**
	Road Name & No.		

Time	Left turns		Straight		Right turn		Total	
	Number	PCU	Number	PCU	Number	PCU	Number	PCU
6 - 7 am								
7 - 8 am								
8 - 9 am								
9 - 10 am								
...								
...								
...								
5 - 6 pm								
6 - 7 pm								
7 - 8 pm								
8 - 9 pm								
...								
...								

5.2 Procedure for calculating Capacity and LOS of Un-signalized Intersection as per Indian Roads Congress (IRC)

IRC does not have any specific code book for capacity analysis of Unsignalized intersections, but in special publication IRC-SP 41 (1994) methodology for the capacity analysis is given.

The method assumes that major street traffic is not affected by minor street flows. The methodology also adjusts for the additional impedance of minor street flows on each other and accounts for the share use of lanes by two or three minor street movements.

Field data requirements for methodology,

- Volume by type of movement for the design hour
- Vehicle classification for the design hour
- Peak hour factor
- Average running speed of traffic on the major street
- Number of lanes on the major and minor street
- Geometric features i.e. channelization, angle of intersection, sight distance, acceleration lanes, corner radii etc.
- Type of control on the major approaches
- Delay data

Procedure

- Calculation of Conflicting volume for each movement on major and minor street (C_v)
- Calculation of the movement capacity (C_m)
- Calculation of the shared lane capacity (C_{SH})

The factors influencing the estimation of LOS for a given un-signalised intersection as per IRC are included in Table 5.6.

Table 5.6: LOS of Un-signalized Intersection as per IRC-SP 41 (1994)

Reserve capacity (pcph)	LOS	Expected delay to minor street traffic
>400	A	Little or no delay
399-300	B	Short traffic delays
299-200	C	Average traffic delays
199-100	D	Long traffic delays
99-0	E	Very long traffic delays
-	F	Stops and starts

As per IRC-SP 41 the design procedure is as follows:

IRC-SP 41 gives the format of data collection. The collected data is used to find out design factors for intersection. Each one is calculated step by step by using charts and formulas given in IRC-SP 41.

1. First design and approach speeds are fixed based on topography and standards.
2. Then radius of curvature is decided based on speeds and design vehicle selected.
3. Also width of turning lane, its radius etc. are determined from design speeds.
4. Based on traffic volumes auxiliary lanes are provided.

The relation between the speed of operation, type of flow, and level of service information is given in Table 5.7.

Table 5.7: LOS based on running speed

LOS	Speed mean / Speed free flow	Flow Condition
A	>0.9	Free flow condition
B	>0.7	A zone of stable flow
C	>0.5	A zone of stable flow exists
D	>0.4	Represent limit of stable flow
E	>0.33	close to the capacity level
F	<0.25	zone of forced or breakdown flow

The LOS is calculated on the basis of average delay experienced by a vehicle according to HCM. These details are included in Table 5.8.

Table 5.8: Control delay for Level of service (HCM, 2000)

Control delay, Secs	LOS
0-10	A
10-15	B
15-25	C
25-35	D
35-50	E
>50	F

The requirements of visibility vary with respect to design speed on major road. In order to ensure safety, these visibility factors need to be adhered. The standards as per IRC are detailed in Table 5.9.

Table 5.9 : Minimum Visibility along Major road (IRC-SP 41(1994)

Design Speed(km/hr)	Minimum Visibility Along Major road(m)
110	270
80	180
65	145
50	110

In order to ensure required mobility along the corridor information about inventory of major intersections, inventory of level crossings, and queue length information need to be collected and analysed. Tables 5.10 to 5.12 provide details with respect to these information. The adequacy of an existing intersection should be evaluated on the basis of details presented in Table 5.13.

Table 5.10: Inventory of major intersections

Name of Intersection	Geometric Characteristics (Shape of intersections, number of lanes, etc.)	Inflow Traffic Volume (PCI/day)	Traffic Control Devices (such as signalized, etc.)	Existance of pedestrian crosswalks	Existence of Traffic Calming Measures (Such as rumble strips, etc.)	Existence of intersection hazards (such as obstructed signals/signs, unregulated intersections that are unsafe for pedestrains, etc.)


Table5.11: Inventory of Level crossings

Location (Street)	TVU	Traffic Volume (vehicle/ day)	Road Width (m)	Number of lanes	Number of Closures per day	Total time of Closures	Average time of Closures	Total number of Stopped Vehicle	Average Number of Stopped vehicles per closures

Table 5.12: Queue length survey

Queue Length Reading in Meters					
Sequence of Reading Reading	Queue Length (m)	(hr.)	Hour (min)	(sec)	Elapse Time (sec)

Table 5.13: Checklist for evaluating the adequacy of existing intersection

S No	Item	Comment (Yes:1, No:0)
1	Is the design criteria for intersections is as per IRC standards	Yes / No
2	In case at-grade intersections are not able to cater to needs of traffic	Yes / No
3	Whether signage of interchange is adequate?	Yes / No
4	Is the intersection control as per IRC guidelines?	Yes / No
5	Do all the intersecting legs have same importance?	Yes / No
6	Is there a facility for pedestrian crossing?	Yes / No
7	Is the zebra crossing wide enough for the waiting pedestrians/ cyclists to cross the intersection?	Yes / No
8	If there is any foot-over bridge or underpass for pedestrians, Is it properly designed as per standards?	Yes / No
9	Are the road markings proper and as per design standards?	Yes / No
10	Is there a special treatment for cyclists?	Yes / No
11	Is there any undesirable delay specifically on one or more legs?	Yes / No
12	Is there a free left turning lane?	Yes / No
13	Does the intersection have the traffic control island at the centre?	Yes / No
14	Are there surveillance cameras to record the defaulters?	Yes / No
15	Is the intersection properly illuminated?	Yes / No
16	Are the intersecting legs channelized?	Yes / No
17	Is free u-turn permitted at intersection?	Yes / No
18	Is there enough space at medians to act as pedestrian / cyclist refuge?	Yes / No
19	Are the lane markings maintained at intersections?	Yes / No
20	Are intersecting legs slightly widened at intersection to accommodate more traffic?	Yes / No
21	Are deceleration lanes present before the intersection?	Yes / No
22	Does the intersection provide adequate sight distance?	Yes / No
23	Does the intersection minimize the points of conflict?	Yes / No
24	Does the intersection minimize the frequency of conflicts?	Yes / No
25	Does the intersection effectively minimize the delays?	Yes / No
26	Is the signal able to clear the traffic on all sides in one cycle?	Yes / No/NA
27	Whether warrants for traffic signal installation are followed?	Yes / No/NA


28	Is the signal timing verified periodically after installation?	Yes / No/NA
29	Are there changes in traffic volumes from the time signal designed?	Yes / No/NA
30	Is there a traffic police to regulate the signal defaulters?	Yes / No/NA
31	Is there proper uninterrupted power supply for the signal lights?	Yes / No/NA
32	Are the signal timings hampering the functioning of adjoining signals?	Yes / No/NA

Range (with signals)	Rating (Verbal)	Rating (Numerical)
>26	Very good	5
20-26	Good	4
14-19	Satisfactory	3
7-13	Poor	2
0-6	Very Poor	1


MIGRATE
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Chapter 6:

Roundabouts

The roundabout is a channelized intersection with one-way traffic flow circulating around a central island. All traffic—through as well as turning—enters this one-way flow. Although usually circular in shape, the central island of a roundabout can be oval or irregularly shaped. A typical rotary intersection and its components are detailed in Figure 6.1.

Roundabouts can be appropriate design alternative to both stop-controlled and signal-controlled intersections, as they have fewer conflict points than traditional intersections (8 versus 32, respectively). At intersections of two-lane streets, roundabouts can usually function with a single circulating lane, making it possible to fit them into most settings. Roundabouts also help in reducing the number of conflicts (change in number of conflicts through introduction of roundabout from 32 to 8 conflicts) at an intersection as depicted in Figures 6.2 and 6.3. An uncontrolled intersection has 32 conflicts against 8 conflicts in a roundabout.

Figure 6.1: Typical Rotary Intersection with various components

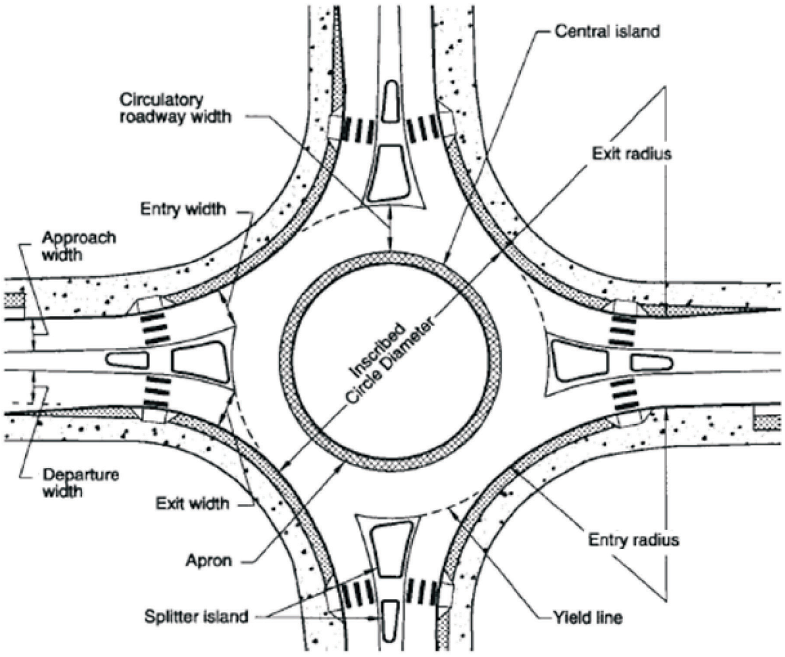


Figure 6.2: A typical un-signalized intersection with 32 conflict points

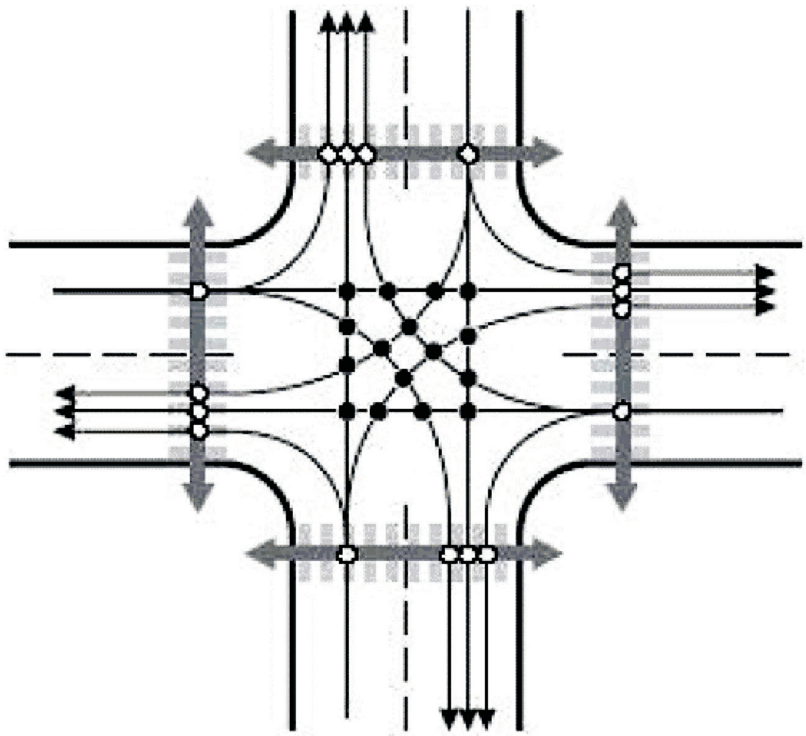
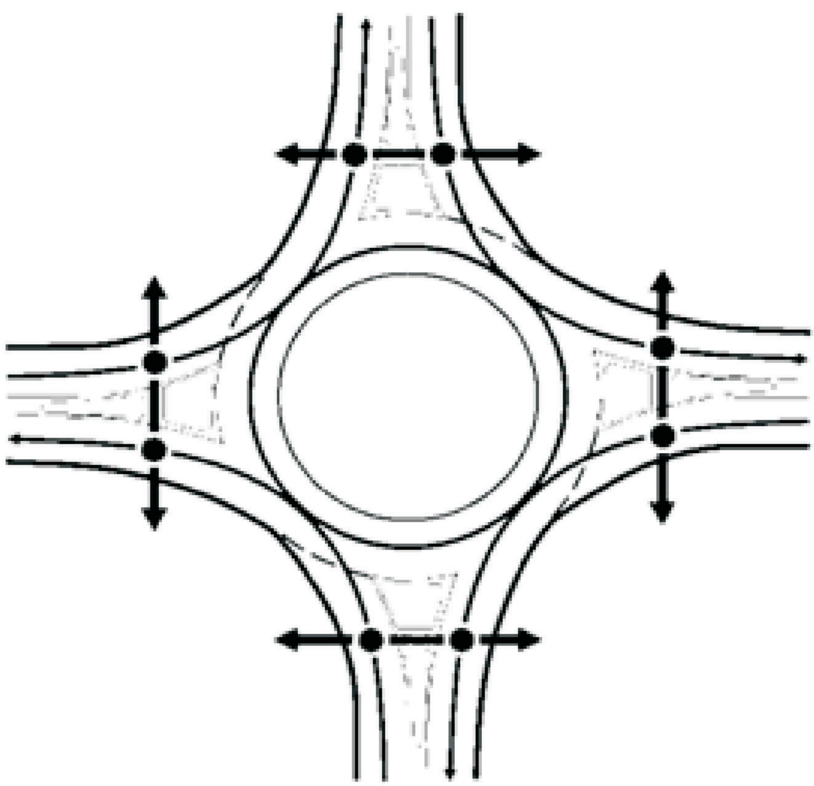


Figure 6.3: Roundabout with 8 conflicting points



These are designed with specific traffic control features. These features include control of all entering traffic, channelized approaches, and appropriate geometric curvature to ensure that travel speeds on the circulatory roadway are typically less than 60 km/h. The various steps in roundabout design are detailed in Figure 6.4 and Photo 6.1 shows a typical roundabout before being converted into an Interchange.

Figure 6.4: Steps in Roundabout design

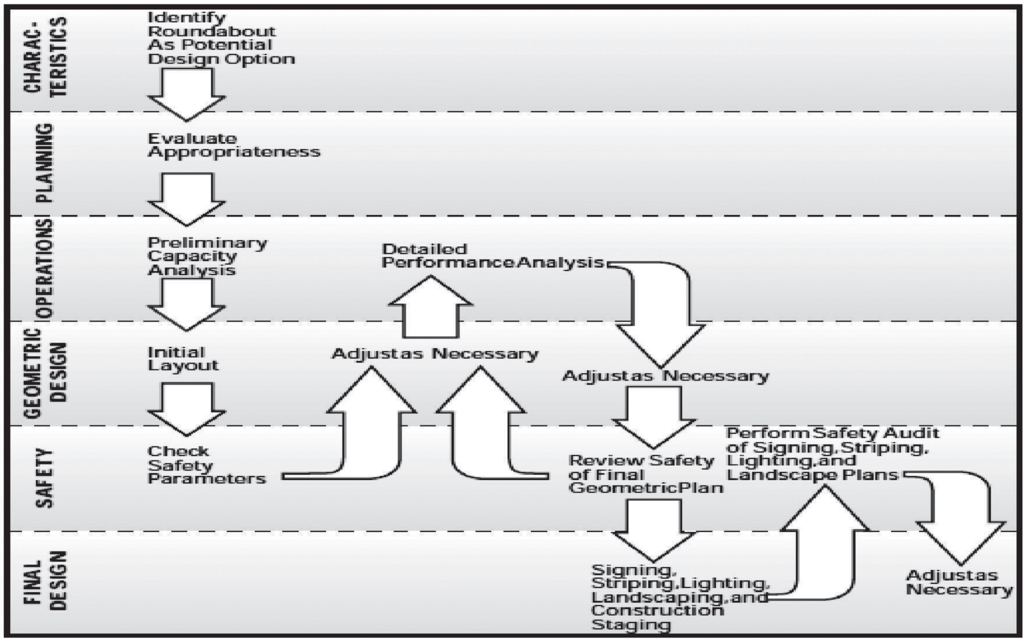


Photo 6.1: Kathipara Junction before the construction of cloverleaf interchange

As per MOUD code of practice: Intersections, the circulatory roadway width should always be at least as wide as the maximum entry width (up to 120 percent of the maximum entry width) and should remain constant throughout the roundabout. Table 6.1and 6.2below provide fundamental elements and minimum recommended circulatory roadway widths for two lane roundabouts where semi-trailer traffic is relatively infrequent.

Table 6.1: Fundamental elements of Roundabouts on urban roads (MOUD code of practice: Intersections)

Design element	Mini	Urban compact	Urban single lane	Urban double lane
Recommended max entry design speed	25 km/h	25 km/h	35 km/h	40 km/h
Max no of entering lanes	1	1	1	2
Inscribed circle diameter	13m to 25m	25m to 30m	30m to 40m	45m to 55m

Table 6.2: Minimum recommended circulatory roadway width for two lane roundabout (MOUD code of practice: Intersections)

Inscribed Circle diameter	Minimum circulatory lane width	Central island diameter
45m	9.8m	25.4m
50m	9.3m	31.4m
55m	9.1m	36.8m
60m	9.1m	41.8m
65m	8.7m	47m
70m	8.7m	52.6m

6.1 Capacity and Los of Roundabout

A roundabout is a form of channelized intersection in which vehicles are guided onto a one-way circulatory road about a central island. The main objective of roundabout design is to secure the safe interchange of traffic between crossing traffic streams with the minimum delay. The operating efficiency of a roundabout depends upon entering drivers accepting headway gaps in the circulating traffic stream.

Factors affecting roundabout approach capacity

The capacity of a roundabout is a function of the capacities of the individual entry arms. The capacity of each arm is defined as the maximum inflow when the traffic flow at the entry is sufficient to cause continuous queuing in its approach road. The main factors influencing entry capacity are the approach half-width, the width and flare of the entry, while the entry angle and radius also have small but significant effects.

1. The conflicting circulating flow and
2. The roundabout's geometric elements.

Roundabouts should be designed to operate at no more than 85 percent of their estimated capacity. Different parameters influencing capacity of roundabout are represented in Figure 6.5.

Procedure for calculating Capacity of roundabout

Indian Road Congress (IRC)

As per IRC-65 (1976) practical capacity of rotary is given by following equation,

$$OP = \frac{280w\left(1+\frac{e}{w}\right)\left(1-\frac{p}{3}\right)}{1+\frac{w}{l}}$$

Where, Qp= practicle capacity of weaving section of rotary in pcu/hr

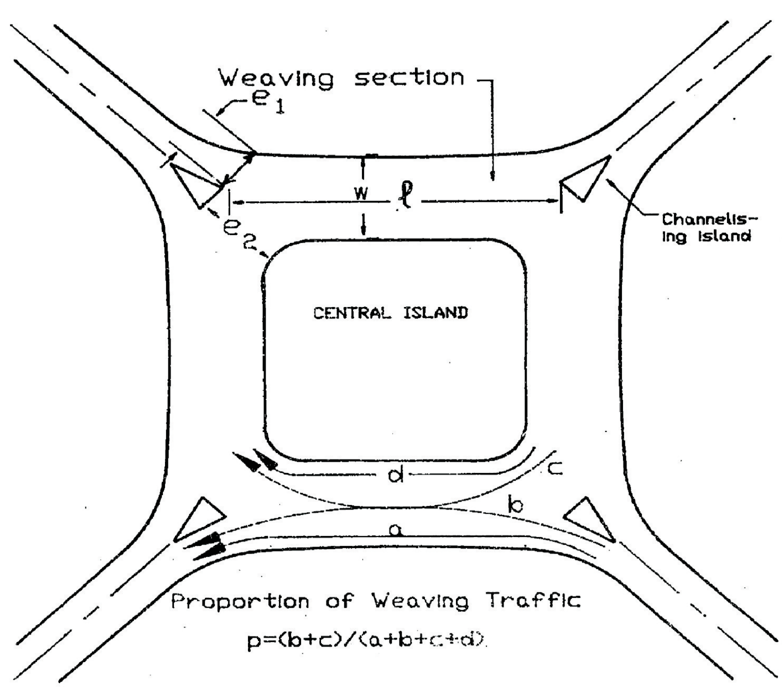
w= width of weaving section in meters (within the range of 6-18m)

e= average entry width in meters (average of 'e_1' and 'e_2', e/w to be within range of 0.4 - 1.0)

l = length of weaving section between the ends of channelizing islands in meters (w/l to be within the range of 0.12 to 0.4)

p= proportion of weaving traffic i.e. ratio of sum of crossing streams to the total traffic on the weaving section. $(P = \frac{b+c}{a+b+c+d}$, range of p being 0.4 to 1.0)

Figure 6.5: Roundabout parameters



The steps required to perform a roundabout analysis

STEP 1: Calculate the traffic from the four approaches negotiating through the roundabout.

STEP 2: Weaving width is calculated.

STEP 3: Weaving length is calculated.

STEP 4: The proportion of weaving traffic to the non-weaving traffic in all the four approaches is calculated.

STEP 5: The highest proportion of weaving traffic to non-weaving traffic will give the minimum capacity.

STEP 6: The capacity of the rotary will be capacity of this weaving section.

In order to achieve effective results in the functioning of roundabout, proper criteria as per IRC standards need to be adhered while designing different elements of roundabout. The same are discussed in Table 6.3.

Table 6.3: Worksheet for designing a Roundabout

Design Data			
Design Class			
Design Year			
Mainline Design Speed (Posted Speed)			
Cross Road Design Speed (Posted Speed)			
Truck Percentage			
	Reference/ Date	**Design Performance Objective**	**Determination**
Design Vehicle Turning Path			
Fatest Vehicle Paths			
Natural Vehicle Paths			
Design Components			
Inscribed Circle Diameter (ICD)			
Approach Alignment			
Entry			
Exit			
Central Island			
Truck Apron			
Super-elevation and Grades			
Clear Zone			


Design Element			
Approach From... [Designer must include a section for each approach]			
Design Vehicle			
R1 - Entry Path Radius Super-elevation Speed (kmph)			
R2 - Circulating Path Radius Cross Slope Speed (kmph)			
R3 - Exist Path Radius Cross Slope Speed (kmph)			
R4 - Left Turn Path Radius Cross Slope Speed (kmph)			
R5 - Right Turn Path Radius Slope Speed (kmph)			
Approach Stopping Sight Distance			
Circulating Stopping Sight Distance			
Exit Stopping Sight Distance			
S1 – Entering Stream Sight Distance			
S2 – Circulating Stream Sight Distance			
Pedestrain Design			
Feature			
Sidewalk Width			
Buffer Width			
Clear Width			
Cross Slope			
Running Slope			
Maximum Vertical Rise			
Grade Break			
Surface Discontinuities			
Curb Flare Slope			
Vertical Clear Area			
Counter Slope			
Landing			
Detectable Warning Surface			
Right-Turn Slip Lane			
Add and Drop or Bypass Lane			
Railroad Crossing			
Bicycles			
Signing and Pavement Marking			
Illumination			
Access, Parking, and Transit Facilities			

After designing roundabouts, there is a necessity to evaluate the functioning of roundabouts to assess the achievements of the objectives set while planning the junction as rotary. The checklist to assess and quantify the effectiveness of roundabout is presented in Table 6.4. The checklist includes about 25 different items. The field observers are requested to assess each item and respond as yes or no. The response YES is considered as 1 and NO is considered as 0. Depending upon the total number of YES (1s), a scale has been created to provide some rationale to understand and categorise the functioning of existing facility. Five different categories (Very good, Good, Satisfactory, Bad, Very bad) are included based on total number of positive responses (YES).

Table 6.4: Checklist for evaluating Roundabout

S No	Item	Comment (Yes:1; No: 0)
Location Details: Name of the roads meeting at the intersection: Date and Time:		
1	Is the roundabout having four or more legs.	Yes / No
2	Does the roundabout solve the problem of intersection delays as a whole?	Yes / No
3	Are the super elevations properly maintained at entry and exit so as not to cause accidents?	Yes / No
4	Is proper super elevation maintained at circulatory portion?	Yes / No
5	Are the entry and exit regions designed with proper channelizing / splitter islands?	Yes / No
6	Does the roundabout cater to the traffic demand?	Yes / No
7	Is the conversion to roundabout solves problems of entry and exit ?	Yes / No
8	Are there proper direction signs at entry / exit / circulatory portion to guide the road user?	Yes / No
9	Is the roundabout designed for the standard design speeds?	Yes / No
10	Is there marked apron on outer portion of central island that is elevated with kerb or railing?	Yes / No
11	Is there enough approach stopping sight distance?	Yes / No
12	Is a footpath/pedestrian facility included in the circulatory roadway portion to reach the central island?	Yes / No
13	Are the at grade pedestrian crossings (zebra crossings) placed well beyond the yield-line?	Yes / No
14	Is there a separate facility for bi-cycles to separate them from the fast moving traffic?	Yes / No


15	Is the riding quality on roundabout good enough?	Yes / No
16	Does the roundabout include a facility to handle the breakdown vehicles either towards the central island or towards the intersecting legs?	Yes / No
17	Is the roundabout design a standard one or a new innovative design created exclusively for the field conditions / restrictions?	Yes / No
18	Is the roundabout properly illuminated for night visibility?	Yes / No
19	Is the roundabout circulatory carriageway more than 2 lanes wide?	Yes / No
20	Is the weaving traffic able to separate itself from the circulatory traffic without much difficulty?	Yes / No
21	Are the departure widths adequately designed so as to clear the departing/approach traffic?	Yes / No
22	Are there speed limit signs boards	Yes / No
23	Are there proper roadway markings showing weaving sections / yield lines / circulatory movement direction?	Yes / No
24	Is the inscribed circle diameter wide enough to provide a comfortable and secure ride?	Yes / No

Range	Rating (Verbal)	Rating (Numerical)
21-24	Very good	5
16-20	Good	4
11-15	Satisfactory	3
6-10	Poor	2
0-5	Very Poor	1

Chapter 7:

Interchanges

An interchange is a road junction that typically uses grade separation, and one or more ramps, to permit traffic on at least one highway to pass through the junction without directly crossing any other traffic stream. It differs from a standard intersection, at which roads cross at grade. Interchanges are almost always used when at least one of the roads is a limited-access divided highway (expressway or freeway), though they may occasionally be used at junctions between two surface streets. Photo 7.1 shows a cloverleaf interchange constructed in place of a roundabout.

Photo 7.1: Kathipara cloverleaf interchange constructed in place of a roundabout

The type and design of grade separations and interchanges are influenced by many factors such as highway classification, character and composition of traffic, design speed and degree of access control. These controls plus signing needs, economics, terrain and right-of-way are of great importance in designing facilities with adequate capacity to safely accommodate traffic demands. Although each interchange presents an individual problem, its design shall be considered in conjunction with adjacent interchanges or grade separations on the project as a whole to provide uniformity and route continuity to avoid confusion in driver expectancy. The design principles of interchange are detailed in Table 7.1.

Table 7.1: Design principles for Interchanges

ACCORDING TO IRC 92-1985	ACCORDING TO AASHTO	UK HIGHWAY AGENCY
Adoptability and atta inability in the particular situation	A uniform pattern of interchange geometric layouts should be maintained	the lane configurations ahead should be made clear to drivers
Impact on access to adjoining properties	Design for a minimum of weaving	A leng th of auxiliary lane may be necessary to provide increased local capacity
Relative operational features and capacity potentials	pattern of exits along the freeway have some degree of uniformity	The signing of intersection and interchanges should give c lear and timely information to drivers
Flexibility for future expansion	Try to have no more than one exit in each direction	Sensitivity testing of differing flow proportions should be undertaken.
An interchange may be justified at the crossing of maj or arterial road carrying heavy traffic.	The signing of each design should be tested	_
Provision of Acceleration and Deceleration lanes	All freeway interchanges with non-access-controlled highways should provide ramps	-
Provision for sufficient carriage way width (at least 5.5m) for ramps so as to facilitate easy overtaking.	Avoid designing ramps for minimum speeds	-
The ramp terminals should be located sufficiently away from the grade separated structure	Potential for stage construction	-

Design Elements for Interchanges

- Design speed: Design speed of ramp should be 80 kmph
- Horizontal curvature of ramps should be circular with transition at either ends.
- Grade and profile should be limited a maximum of 4 percent and in no case should it exceed 6 percent
- Entrance terminal: The minimum and desirable length of acceleration is 180 m and 250m respectively
- Exit terminal: The minimum and desirable deceleration lane is 120m and 90m respectively.
- Weaving section: The recommended desirable and minimum length of weaving section is 300m and 200m respectively.
- Lateral clearance: for under pass roadways the minimum lateral clearance should be equal to normal shoulder width. For overpass roadway a cross section with 225m wide kerb and open type parapet will generally be suitable for most cases.
- Vertical clearance: vertical clearance at underpass should be minimum 5.5m

Following is the **STEP BY STEP PROCEDURE** for selecting the design of grade separated interchanges given by the UK Highway Agency

- Step 1 — **Determine the design year and strategic network**
- Step 2 — **Decide initial strategy for network and junction**
- Step 3 — **Derive hourly traffic flows to be used for design**
- Step 4 — **Confirm nature of vehicular traffic (all-purpose or motorway)**
- Step 5 — **Determine if lane requirements for mainline and connector roads are achievable**
- Step 6 — **Determine if suitable merge/diverge and weaving layouts for the design flows are achievable**
- Step 7 — **Determine if suitable signing/signalizing is possible**
- Step 8 — **Determine if lane drop/gains are satisfactory**
- Step 9 — **Determine if junction spacing is satisfactory**
- Step 10 — **Develop a junction/interchange scheme after previous steps are met**

The detailed checklist for evaluating interchanges can be found in Table 7.2.

Table 7.2: Checklist for evaluating Interchanges

S No	Item	Comment (Yes:1; No: 0)
Location Details: Name of the roads meeting: Date and Time:		
1	Is it designed as full interchange?	Yes / No
2	Does the interchange solve the problem of intersection signal delays as a whole?	Yes / No
3	Are the ramp grades maintained with mild slopes so as not to cause the slowdown of vehicles?	Yes / No
4	Are the approach ramp and terminal ramps designed with proper transition?	Yes / No
5	Does the interchange cater to the traffic demand?	Yes / No
6	Is the construction of interchange minimising problems at approach or terminal ramps?	Yes / No
7	Are there proper direction signs on interchanges to guide the road user?	Yes / No
8	Are the interchanges designed for the standard design speeds?	Yes / No
9	Are there proper crash barriers at the edge of the interchange?	Yes / No
10	Does the interchange include a median separator at the end of approach and terminal ramps?	Yes / No
11	Is NMT requirements taken care of?	Yes / No
12	Does the interchange include a facility to handle the breakdown vehicles?	Yes / No
13	Is the riding quality on interchange good enough?	Yes / No
14	Is the interchange properly illuminated for night visibility?	Yes / No
15	Does the interchange provide safe sight distances?	Yes / No
16	Is the interchange carriageway more than 2 lanes wide?	Yes / No
17	Does the interchange designed with noise barrier?	Yes / No
18	Is the ventilation, air quality, and drainage properly maintained?	Yes / No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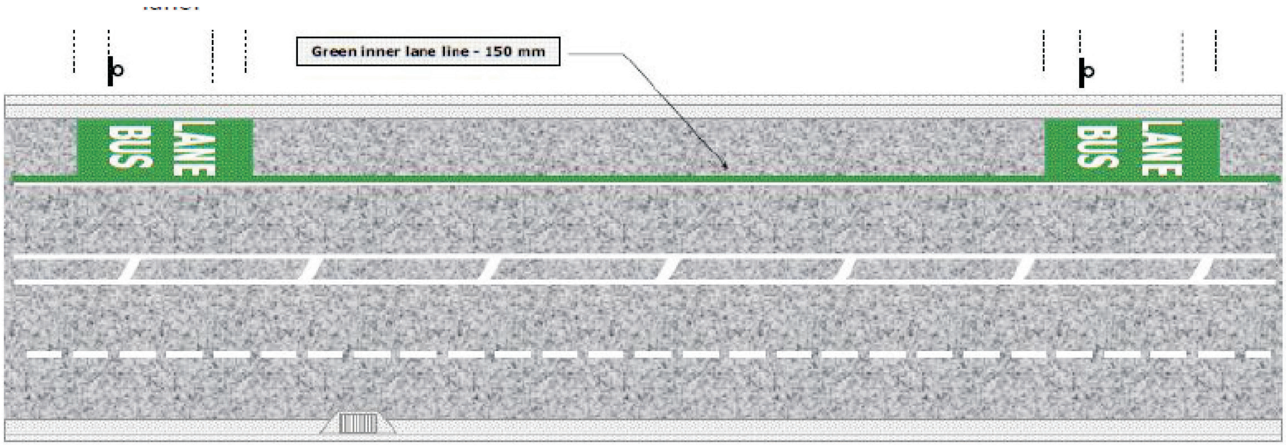
Chapter 8:

Bus Facilities

8.1 Bus Lanes

Bus lanes used in cities are meant for decrease in travel time and increase in schedule adherence. Bus lanes provide benefit to transit vehicles i.e. buses by eliminating their interaction with private vehicles. The buses in mixed traffic lanes near intersections during red signal and merging of the buses after stopping at bus stops/ berths experience more delay. The demarcation of a bus lane is depicted in Fig. 8.1.

Figure 8.1: Demarcation of Bus Lane



By the provision of bus lanes, interaction with other vehicles can be avoided for a maximum of 100m to enter or leave the road at a driveway or intersection. The length of bus lane depends on the red time and bus volume. The minimum bus lane width should be 3.2m where there are dividers or barriers and 3.0m lane width is required where there are no dividers or barriers.

The bus lane can be operated for peak hours or can be shared with other vehicles like cycles, 2-wheelers. The quality of the bus lane can be assessed by the delay to bus fleet and it should not be more than 10% of its travel time. The following checklist in Table 8.1 can be used to assess the quality of a bus lane.

Table 8.1: Checklist for evaluating bus lanes

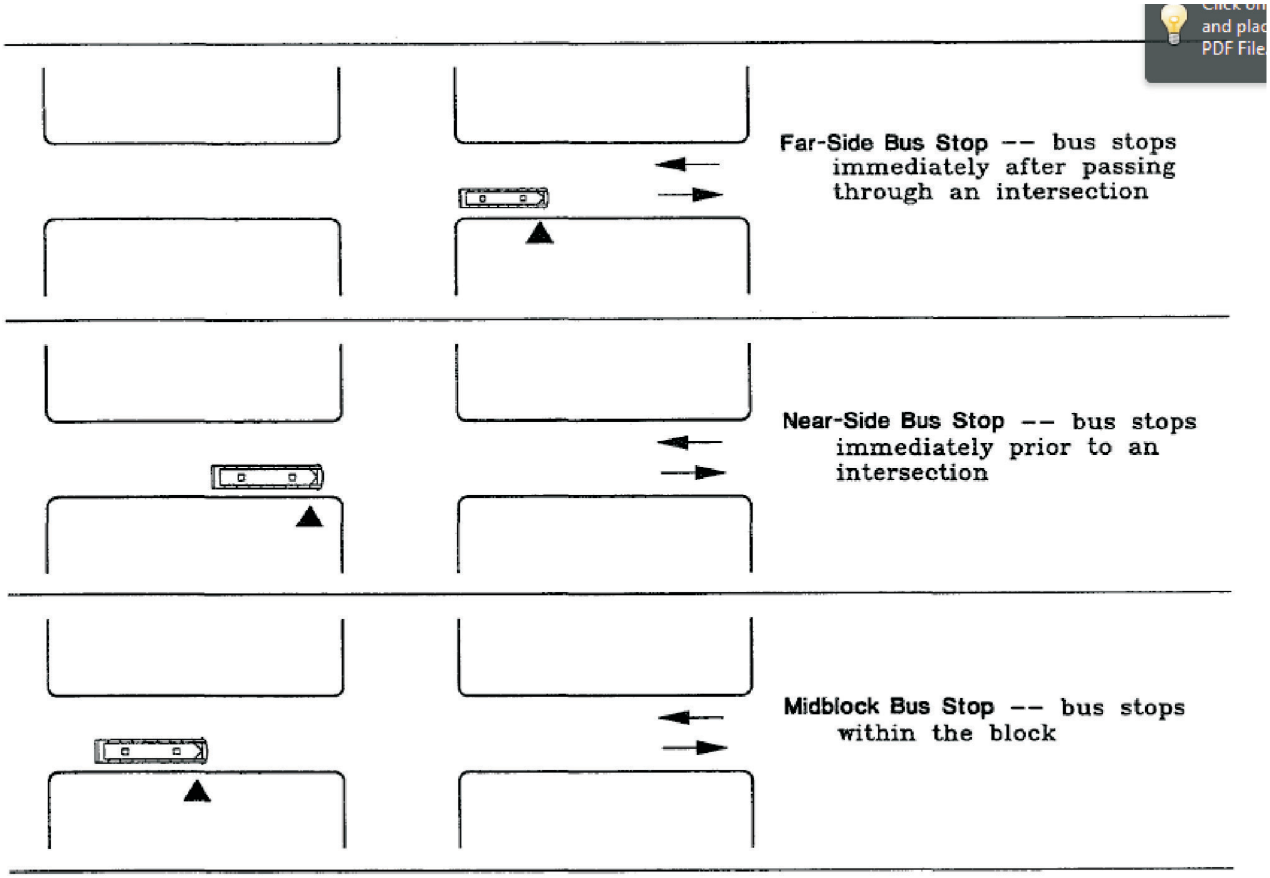
S No	Item	Comment (Yes:1; No: 0)
1	Are there exclusive bus lanes?	Yes / No
2	Are the bus lanes separated from rest of the carriageway?	Yes / No
3	Is the width of bus lane adequate for comfortable bus driving?	Yes / No
4	Is there proper way/chance for buses to move towards the left most lane where the bus stops are located if the bus lane is not separated from the rest of carriageway?	Yes / No
5	Are the bus lanes given priority at intersections?	Yes / No
6	Is there a regulation for other traffic not to enter bus lane?	Yes / No
7	Are the u- turns affecting the bus lane performance at intersections if the bus lanes are not given priority/ exclusive right of way?	Yes / No
8	Are the pedestrians / cyclists given proper facilities to cross the carriageway if there are exclusive bus lanes?	Yes / No
9	Are the bus lanes free from speed breakers (unlike the rest of carriageway for mixed traffic)?	Yes / No

Range	Rating (Verbal)	Rating (Numerical)
>8	Very good	5
7-8	Good	4
5-6	Satisfactory	3
3-4	Poor	2
0-2	Very Poor	1

8.2 Bus Stop

Bus stop is one that serves to community needs safely and comfortably or well connected to neighbourhood and permits efficient and cost effective bus operations. The typical stop types are far side, near side and mid blocks as shown in Figure 8.2.

Figure 8.2: Arrangement of bus stops in an urban area



The following factors should be considered while evaluating a bus stop.

- Traffic control devices (green for buses)
- Spacing between the stops (500 to 1200 feet)
- Accessibility to the stop
- Capacity of the bus stop (based on bus fleet volume)

The inventory of bus operations, maintenance and economic productivity indicators are detailed in Table 8.2 and 8.3. The inventory of major intermodal changes are described in Tables 8.4 and 8.5. The checklist in the Table 8.6 can be used for evaluating a bus stop.

Table 8.2: Inventory of Bus operations, Maintenance and Economic and productivity indicators

Outline of Bus Operation							
Bus Operator:	Type of Operator (Public, Private, or Association of independent drivers)	Number of Bus Vehicles by Vehicle Types	Number of Bus Routes	Operating Vehicle-Distance (Vehicle-km)	Number of Bus Stops	Number of Bus Terminals	Fare Structure

Table 8.3: Inventory of Bus operations, Maintenance and Economic and productivity indicators (2)

Bus Operation and Maintenance			Service period	Typical route speeds	Service reliability	Economic and Productivity Indicators				
Bus Operator	Vehicle loads	Vehicle headways				Passengers per vehicle-hour or vehicle-km	Cost for employees per vehicle-hour or vehicle-km	Cost recovery	Passenger transfers	Passenger comfort and safety

Table 8.4: Inventory of major intermodal interchanges

Name of interchange facilities	Location	Layout and size of facilities	Determination of capacity and geometric characteristics of pedestrian walkways	Number of daily and hourly (peak) passengers	Number of hourly/daily vehicle movements	Number of transport operators housed	Number of loading berths	Ability of loading berths to accept various bus types

Table 8.5: Inventory of major intermodal interchanges (2)

Name of interchange facilities	Number of routes serviced	Condition of waiting areas	Level of passenger convenience and comfort	Existence of passenger amenities	Provision of passenger information (static)	Provision of passenger information (real-time)	Clarity of transfer directions	Directness of required transfer movements	Identification of management authority

Table 8.6: Checklist for Evaluating Bus Stop

S. No	Check		Comment
	Part A		
1	Location details of Bus stops/ Bus bays: Direction: Number of buses during peak hour: Nature of bus stops: With shelter/ Without shelter		
2	What is the bus stop location?	Mid block Near intersection	
Part B			
3	The distance of the bus stop from the intersection? (Desirable 75m)		Yes/No
4	Spacing between consecutive bus stops? (Desirable 400m)		Yes/No
5	During peak hour, Is the bus stop able to meet the demand?		Yes/No
6	Is the bus stop painted with pavement box marking? (2.7X 3m)		Yes/No
7	Does the bus stop has required clearance (Front: 2.7 m; Back: 3.5 m)		Yes/No
8	Is there a separate bus bay?		Yes/No
9	Are there pavement markings for bus stops		Yes/No
10	Whether configuration of bus stop is either side or back to back?		Yes/No
11	Is bus stop properly illuminated for night usage?		Yes/No

Range	Rating (Verbal)	Rating (Numerical)
>7	Very good	5
6-7	Good	4
5	Satisfactory	3
3-4	Poor	2
0-2	Very Poor	1

Chapter 9:

Medians

Medians physically separate opposing traffic streams and help stop vehicles travelling into opposing traffic lanes. Medians can also be used to limit turning options for vehicles, and shift these movements to safer locations. Median barriers are often built on the centre of wide urban multi-lane roads, where they can be used to stop pedestrians crossing the road at unsafe places. Decisions about what type of median/barrier should be used should be based on several factors including: traffic volume, traffic speed, vehicle mix, median width, the number of lanes, road alignment, crash history, and installation and maintenance costs. The following Figure 9.1 depicts the flowchart for the selection of a median. Table 9.1 presents the checklist for evaluating the medians.

Figure 9.1: Median selection flowchart

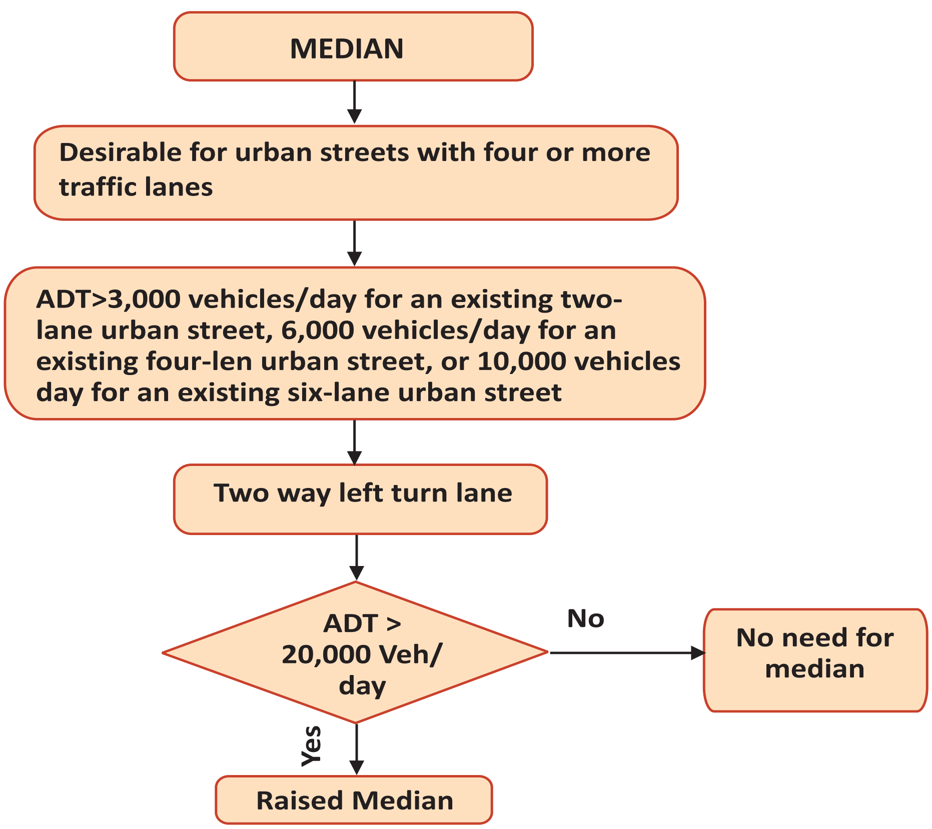


Table 9.1: Checklist for evaluating medians

S. No.	Item	Comments (Yes:1; No: 0)
Location Details: Direction (From-To): Date and Time:		
1	Is there an elevated median?	Yes / No
2	Is the median wide enough to act as A pedestrian refuge at pedestrian crossings?	Yes / No
3	Is the median barricaded to avoid pedestrian crossings?	Yes / No
4	Are there gaps in median at regular intervals to facilitate right / U turns?	Yes / No
5	Are there regular gaps in barricades For the pedestrians to cross the carriageway?	Yes / No
6	Does the median serve the purpose of preventing the headlight glare from the opposing vehicles at night time?	Yes / No
7	Is the median mountable for pedestrians at pedestrian crossings?	Yes / No
8	Is the median aesthetically maintained (with trees/ plants)?	Yes / No
9	Are the medians free from advertisement boards?	Yes / No
10	Is the median height reduced to 150mm at locations when the pedestrian crossings are located	Yes / No

Range	Rating (Verbal)	Rating (Numerical)
>8	Very good	5
7-8	Good	4
5-6	Satisfactory	3
3-4	Poor	2
0-2	Very Poor	1

Chapter 10:

Service Lane / Frontage Road

The service roads are provided parallel to arterials or expressways to serve the accessibility. The primary purpose of service roads is to distribute traffic from the controlled-access arterial to business and residential properties. Service roads segregate the slower-speed local traffic from the higher speed through traffic. Service roads that are not directly adjacent to the higher-class facility are known as detached service roads or backage roads. Delay is the main parameter for evaluating service lane and it depends on number of access points. The checklist for evaluating service lane is given in Table 10.1.

Table 10.1: Checklist for evaluating Service Lane

S. No.	Item	Comment
Part-A		
1	What is the width of separator in metres?	
2	What is the lane width in metres?	
3	What is the spacing between driveways/cross streets?	
4	What is the peak hour traffic volume entering and leaving service road?	
5	What is the cross slope?	
Part-B		
6	Does the service road has good surface?	Yes/No
7	Is there any service/frontage road adjacent to main carriageway?	Yes/No
8	Do they have shoulders?	Yes/No
9	Does it have proper drainage facilities?	Yes/No
10	Are speed change lanes available?	Yes/No
11	Are entry and exit points from main road designed properly?	Yes/No

Range	Rating (Verbal)	Rating (Numerical)
>5	Very good	5
5	Good	4
3-4	Satisfactory	3
2	Poor	2
0-1	Very Poor	1

Chapter 11:
Bi-Cycle Facilities

Roads are meant to facilitate mobility, the movement of people and goods. But many roads have become too congested with traffic and no longer meet their main purpose of improving accessibility. Moreover, most roads have been developed with the motor vehicle as the principal user. To take a more sustainable mobility path, the critical role of non-motorized transport (NMT) needs to be recognized and factored into road infrastructure investments. Walking and cycling are the most natural and energy-efficient way to travel short distances.

The Photo 11.1 below shows the status of a common cyclist in the current traffic scenario.

Photo 11.1: Cyclist sharing the Right of Way with buses

The benefits of non-motorized vehicles are not considered and instead they are not even given a proper place or importance in the traffic streams.

Exclusive bi-cycle lanes are required for the safety of cyclists and to even encourage the bi-cycle culture as they do in some of the European countries like Germany, Netherlands and Belgium etc. Figure11.1 depicts typical bike lane configuration on a roadway. The desirable lane widths for bicycle facilities are presented in Table 11.1. Table 11.2 gives the guidelines for planning bicycle lanes. The bicycle lane has to be properly demarcated and separates from vehicular through appropriate markings. The symbols used for this purpose and necessary treatment at intersections are shown in Figure 11.1 and Table 11.3 respectively.

Figure 11.1: Typical Roadway and Bikelanes

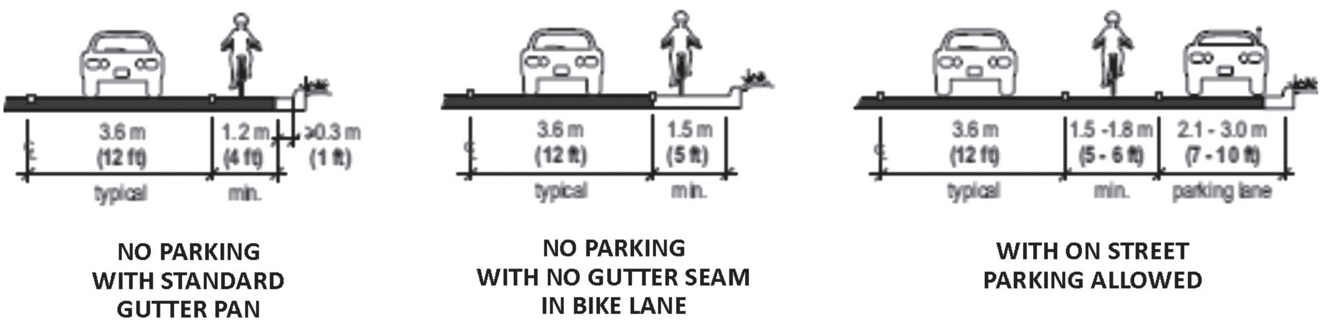


Table 11.1: Minimum and Desirable Lane Width for Bicycle Facility as per IRC 11

	Lane Width (m)					
	Wide Curb Lane	Bicycle Lane	Lane & Parking Stalls	Contra-Flow Lane	HOV/ Bus	Multi-Use Path
Absolute Minimum	4.0	1.2	4.0	1.5	4.3	2.5
Minimum	4.3	1.5	4.0	1.8	4.5	3.0
Desirable	4.5	1.8	4.5	2.0	4.8	4.0

Table 11.2: Guidelines for planning bi-cycle lanes

Facility type	Dimension	Typical Application
1. Buffered Bike Lane	1.5m with the addition of a 0.6m to 0.9m painted buffer. Buffer is typically diagonally hatched to increase visibility	✓ Any location where a bike lane may be considered and sufficient right-of-way exists ✓ Streets with posted travel speeds ≧ 25 mph ✓ Where motor vehicle traffic volumes ≧ 10,000 AADT
2. Raised Cycle Track	✓ 1.5m to 2.1m ✓ Mountable curb should be 0.45m and have a 4:1 slope edge ✓ Special attention needed for drainage to prevent pooling	✓ Streets with multiple lanes and high traffic volumes (≧ 10,000 AADT) ✓ Streets with high travel speeds (≧ 40 mph) ✓ Streets with few intersections and driveway access points ✓ One-way or two-way streets
3. Two-Way Cycle Track	3m min. and3.6m preferred width. Can be combined with parking buffer, mountable curb, or physical barrier	✓ Streets with multiple lanes and high traffic volumes (≧ 10,000 AADT) ✓ Streets with high travel speeds (≧ 40 mph) ✓ Streets with few intersections and driveway access points (requires innovative design treatment at intersections) ✓ One-way or two-way streets ✓ On streets where contraflow bike travel is desireable
4. Multi-Use Off-Street Path	3m is the minimum allowed for a two-way shared-use path and is only recommended for low traffic situations. 3.6m or greater is recommended for high-use areas, or in situations with high concentrations of multiple users	✓ Where there are few at-grade crossings such as driveways and alleyways ✓ Where the existing roadway context makes a completely separated bikeway the preferred alternative (i.e. high traffic speeds and volumes in a constrained right-of-way).
5. Bicycle Boulevard	_	✓ Streets with traffic volumes ≦ 3,000 AADT ✓ Streets with posted travel speeds ≦ 25 mph ✓ Along network identified in planning process

Figure 11.2: Typical Bicycle Lane Symbols

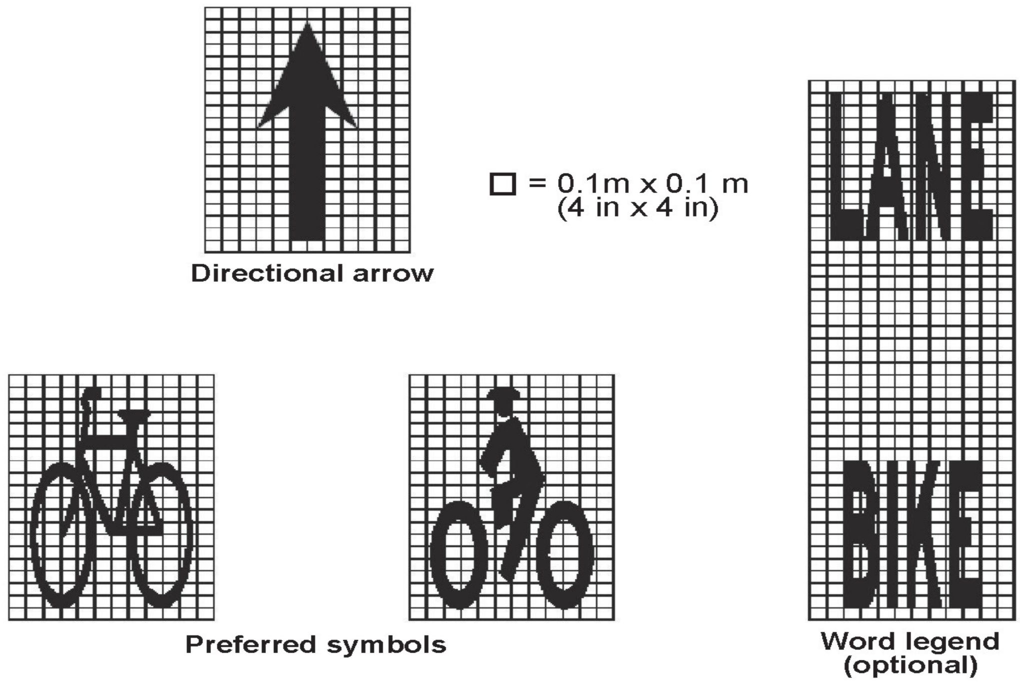


Table 11.3: Treatment at Intersections

At signalized or stop - controlled intersection with turning motor vehicle	The solid striping to the approach should be replaced with a broken line with 0.6-m (2-foot) dots and 1.8-m (6-foot) spaces. The length of the broken line section is usually 15 m to 60 m (50 feet to 200 feet).
At non signalized minor intersections with no stop controls	Solid bike lane striping can continue all the way to the crosswalk on the near side of the intersection if there is a bus stop or high right -turn volume, the 150 -mm (6-inch) solid line should be replaced with a broken li ne with 0.6-m (2-foot) dots and 1.8-m (6-foot) spaces for the length of the bus stop.
Bus stop is located on a far side of the intersection rather than on a near side approach	The solid white line can also be replaced with a broken. Line for a distance of at least 24 m (80 feet) from the crosswalk on the far side of the intersection.
At T -intersections with no painted crosswalks	The bike lane striping on the side across from the T - intersection should continue through the intersection Area with no break
At T - intersections with painted crosswalks	The bike lane Striping on the side across from the T - intersection should be discontinued only at the crosswalks

Photos 11.2 and 11.3 show the practices in some of the countries that encourage cycling. A typical inventory form used for assessing the non-motorised facilities is given in Table 11.4. The checklist for evaluating the adequacy of bicycle facilities is presented in Table 11.5.

Photo 11.2: Exclusive bi-cycle tracks

Photo 11.3: Exclusive bi-cycle tracks are effectively used in many European countries

Table 11.4: Inventory of NMV facilities

Location (Street)	Type of Facility (NMV Path, Overpass, Underpass)	Description	Obstruction (if any)	Existing pavement condition	Adequate drainage facilities	Clear markings	Adequacy of signage/ signaling	Existence of parking restrictions to safeguard pedestrian right-of-way, etc.	Adequacy of NMV and Pedestrian and vehicle Flow Seperation (such as On-street lanes, etc.)

Table 11.5: Checklist to evaluate the adequacy of bi-cycle facilities

S. No.	Item	Comment (Yes:1; No: 0)
Location Details: Direction (From-To): Date and Time:		
1	Is the cycle track separated from carriageway?	Yes / No
2	Is the cycle track independent of pedestrians?	Yes / No
3	Is the cycle track separated from carriagway/ parking area with railing?	Yes / No
4	Is the cycle track separated from footpath with railing?	Yes / No
5	Is the cycle track wide enough for comfortable cycling?	Yes / No
6	Is the cycle track paved?	Yes / No
7	Is the cycle track having a comfortable riding surface?	Yes / No
8	Is the cycle track elevated w.r.t. carriageway?	Yes / No
9	Is there cycle track on both sides of the carriage way?	Yes / No
10	Is the cycle track unobstructed?	Yes / No
11	Is the cycle track continuous to allow reasonable speeds for cyclists?	Yes / No
12	Does the cycle track accommodate the cycle traffic volume?	Yes / No
13	Is there ample street lighting on cycle track?	Yes / No
14	Are the regulatory, warning and direction signs provided on cycle tracks?	Yes / No
15	Are the cyclists given proper importance at intersections?	Yes / No
16	Is the cycle track shaded at intersection points?	Yes / No
17	Are there regulations to avoid motor vehicles from using cycle tracks?	Yes / No
18	Is the bicycle parking facility close to the cycle track?	Yes / No
19	Are the cycle track geometrics properly designed at horizontal curves?	Yes / No
20	Are the cycle track geometrics properly designed at vertical curves?	Yes / No
21	Does the cycle tracks follow desire line pattern?	Yes / No

Range	Rating (Verbal)	Rating (Numerical)
>16	Very good	5
13-16	Good	4
9-12	Satisfactory	3
5-8	Poor	2
0-4	Very Poor	1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Chapter 12:

Pedestrian Facilities

12.1 Footpaths

Conventional traffic/transport studies focused on vehicular movement rather than pedestrians.

Mostly the urban streets are designed for vehicular traffic and not for pedestrians, where only 20 to 30 percent of the population have vehicles and rest make the pedestrian trips for short distances.

The importance of pedestrians in Indian cities has largely been neglected in planning for mobility improvement. Mechanized trips, however, also involve walking as feeder or transfer. A high percentage of trips below 3 to 4 kilometres in urban areas are performed solely by walking or NMVs, such as bicycles and rickshaws and there is an acute need to improve NMT facilities and safety considerations. The following Photo 12.1 depicts typical pedestrian presence on a busy street.

Photo 12.1: Pedestrian movement on a busy street with many educational institutions

Where the pedestrian traffic is more, the motorized vehicles slow down, but when the pedestrian volume is less this is not the case.

At signalized intersections zebra crossings are provided, but at un-signalized intersections or roundabouts the pedestrian crossing facilities are not commonly provided.

Types of pedestrian facilities to be considered include:

- Footpaths (sidewalks)
- Pedestrian crossings
- Pedestrian signals
- Pedestrian over bridges and subways

IRC standards for width of a sidewalk are given in Table 12.1.

Table 12.1: Width of Sidewalk as per IRC standards

Width of side walk (m)	Flow in one direction (persons/hr)	In both directions (persons/hr)
1.5	1200	800
2	2400	1600
2.5	3600	2400
3	4800	3200
4	6000	4000

The pedestrian paths should be continuous as well as segregated unless at stretches where narrow right of way rules out the possibility of segregated paths. At such locations visual continuity should be maintained using texture and pavement markings. Paths should be shaded and space for facilities such as service providers (hawkers), benches, street light poles etc., should be provided outside the pedestrian path, the edge of which needs to be clearly defined. Benches for the disabled as well as the general public should be provided along the pedestrian path. As per the MOUD code of practice, spacing of such facilities should be between 18 to 360m, as per the Table 12.2.

Table 12.2: Cumulative percentage of mobility impaired people observed to be unable to move more than the stated distance in city centres without rest

	18m	68m	137m	180m	360m
Wheelchair Users	0	5	5	60	85
Visually Impaired	0	0	5	50	75
Ambulant Disable with walking aid	10	25	40	80	95
Ambulant Disabled without walking aid	5	15	25	70	80


The recommended guidelines for the pedestrian paths and components to be included for accessible footpaths are provided as per Tables 12.3 and 12.4.

Table 12.3: MOUD Guidelines for pedestrian paths

	Arterial Roads	Arterial Roads	Distributor Roads	Access Roads
Pedestrian Paths				
Criteria	50 km/h	50 km/h	30 km/h	15 km/h
	50m – 80m	30m – 50m	12m – 30m	6m – 15m
Gradient	1:20	1:20	1:20	1:20
Sight Distance				
Lane width	1.7 (including curbs) to 5.5m each. However where secondary footpaths are available along service lane, the minimum width of secondary paths can be 1.5m (including curbs)	1.7 (including curbs) to 5m each. (including curbs)	1.5 to 3.0m (including curbs) each	0-2.5m (including curbs) each

Table12.4: Components to be included for making accessible footpaths

Footpath	The minimum clear width should be 1.2m in order to accommodate wheelchair users. Comfortable minimum width is 1.8m. The footpath surface should be even and without any irregularities. The use of guiding and warning blocks should be used.
Paving	The use of guiding and warning blocks should be used along the footpath
Road Markings	It is essential to designate areas in parking lots to make it comply with accessibility standards.
Road Signs	All signs should be visible, clear and consistent. All accessible places should be clearly identified by the International Accessibility Symbol. They should be in contrasting colours. Also, for the visually impaired it is essential to use braille.
Audible Signals	The use of audible signals or auditory signals is beneficial to the visually impaired to cross a road with minimum or no assistance. Also called a pedestrian access system, it is mountable onto signal poles at crossings and a push button system makes i ts use easier. It also gives an audible alert signal to Vehicle Users about Pedestrian Crossings.

Photo 12.2 shows pedestrians crossing the barricades as proper pedestrian crossings are not provided in the close by area. This is a common sight in Indian cities, but quite risky. Photo 12.3 shows a situation where foot path is used for parking.

Photo 12.2: Pedestrians crossing median barricades

Photo 12.3: Footpaths encroached with parked vehicles

The pedestrian facility design must be an integral part of the urban street design. The inventory of pedestrian facilities can be carried out as per Table 12.5. The adequacy and sufficiency of pedestrian facility system can be checked as per the checklist provided in Table 12.6.

Table 12.5: Inventory of pedestrian facilities

Location (Street)	Type of Facility (Footpath, Overpass, Underpass)	Length (m)	Width of Footpath		Obstruction (if any)	Continuity of the walkway	Existing pavement conditions	Adequate drainage facilities	Clear markings
			Left	Right					

Table 12.6: Checklist for evaluating the adequacy of pedestrian facilities

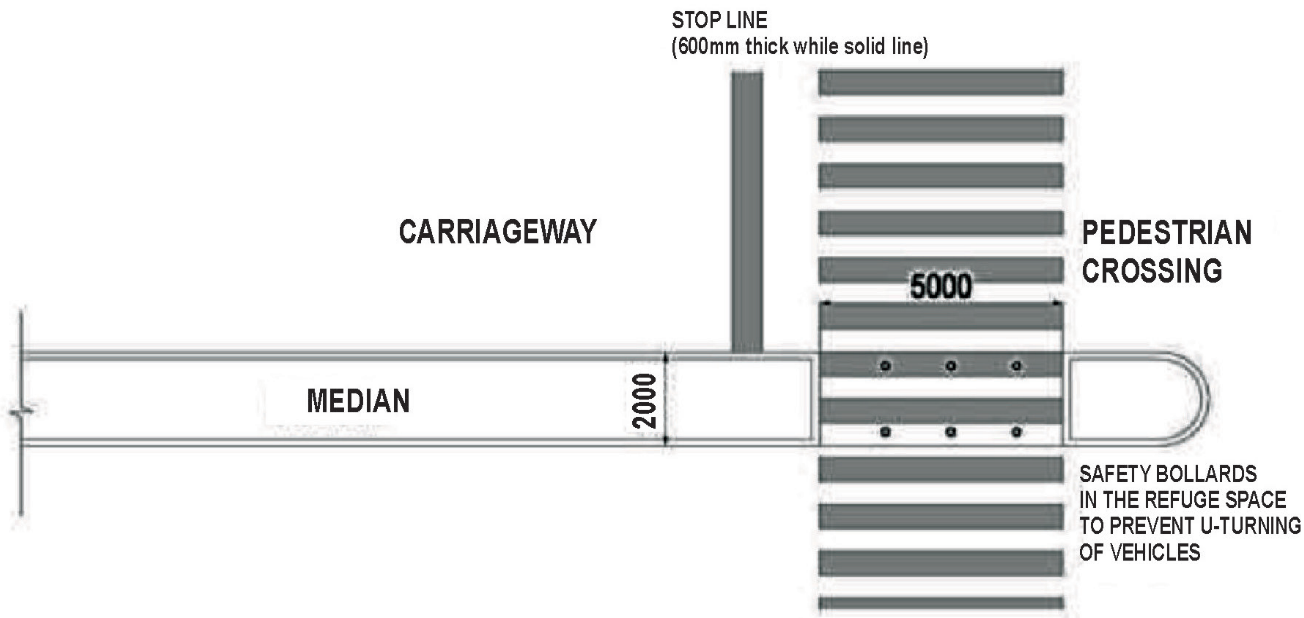
S. No.	Item	Comment (Yes:1; No: 0)
Location Details: Date and Time:		
1	Is the footpath paved?	Yes / No
2	Is the footpath surface smooth?	Yes / No
3	Is the footpath unobstructed & continuous?	Yes / No
4	Is the footpath wide enough for comfortable walk?	Yes / No
5	Is the footpath elevated (over the carriageway) ?	Yes / No
6	Is the footpath curb height mountable?	Yes / No
7	Are there breaks in footpath at property entrance / side streets?	Yes / No
8	Is there a railing / barricade for footpath from carriageway?	Yes / No
9	Is the footpath shaded with trees?	Yes / No
10	Does the footpath accommodate the existing pedestrian traffic?	Yes / No
11	Are there resting places by the side of footpath?	Yes / No
12	Is there a frontage zone between compound wall and footpath?	Yes / No
13	Is the footpath present on both sides of the carriage way?	Yes / No
14	Is the footpath independent of cycle track?	Yes / No
15	Is there ample street lighting for footpaths?	Yes / No
16	Are the footpaths free from regulatory, warning and direction signs?	Yes / No
17	Is the footpath aesthetically designed to encourage pedestrians?	Yes / No
18	Are the footpaths free from street vendors?	Yes / No

Range	Rating (Verbal)	Rating (Numerical)
>15	Very good	5
12-15	Good	4
8-11	Satisfactory	3
5-7	Poor	2
0-4	Very Poor	1

12.2 Pedestrian Crossings

Pedestrian crossings are the places specially marked for the pedestrians to cross the carriageway safely without much interference with the vehicular traffic. The zebra crossings at intersections or at specific locations on the carriageway (mid-block) where there is a higher pedestrian traffic not just helps the pedestrians to cross the street safely but also forewarns the driver to be cautious to avoid unnecessary confusion and thereby avoiding accidents. Foot-over bridges and subways are provided for pedestrians where at grade crossing is not a safe alternative. Fig. 12.1 shows the gap to be provided in medians at pedestrian crossings.

Figure 12.1: Gap in median at pedestrian crossings (MOUD code of practice: Intersections)



A detailed checklist for evaluating pedestrian crossings is given in Table 12.7.

Table 12.7: Checklist for evaluating pedestrian crossings

S. No.	Item	Comment (Yes:1; No: 0)
Location Details: Date and Time:		
1	Are there pedestrian crossings provided at regular intervals on the carriageway as per standards?	Yes / No
2	Are there caution signs for the drivers where there are pedestrian crossings?	Yes / No
3	Are the crosswalks wider than 2 m?	Yes / No
4	Are there foot over bridges/ subways where the at-grade pedestrian crossings cannot be provided?	Yes / No
5	Are the foot over bridges/ subways given priority over at-grade crossing in designing pedestrian crossings?	Yes / No
6	Are there gaps in median barricades at pedestrian crossing?	Yes / No
7	Are there pelican signals at pedestrian crossings?	Yes / No
8	Are the pedestrian crossings given priority at intersections?	Yes / No
9	Are the vehicles regulated not to cross the stop line at intersections to facilitate the pedestrians?	Yes / No
10	Are the medians made wider when they need to act as the pedestrian refuge at pedestrian crossings?	Yes / No

Range	Rating (Verbal)	Rating (Numerical)
>8	Very good	5
7-8	Good	4
5-6	Satisfactory	3
3-4	Poor	2
0-2	Very Poor	1

Chapter 13:

Parking Facilities

Parking is an important consideration for all cities and it is an essential component of the transportation system. One of the problems created by road traffic is parking. There is a great demand for parking space in the CBD and the areas where the activities are concentrated. Well designed and balanced parking controls can maximize the efficiency of road space. Adequate parking supply is needed in cities to encourage retail and commercial activities and to satisfy residential and visitor demands.

The two types of parking available are

1. On-street parking
2. Off-street parking

Typical off-street parking in Kolkata is shown in Photo 13.1.

Photo 13.1: Taxi parking at Howrah railway station–an off-street parking facility

The lack of proper parking facilities often force the vehicle owners to park their vehicles on roads or on the footpaths there by creating additional problems for other vehicles and pedestrians. The general survey forms used for the on-street and off-street parking to estimate the parking demand are given in Tables 13.1 to 13.4. The proposed checklist for evaluating the existing on-street parking facility is given in Table 13.5.

Table 13.1: Inventory of Parking Facilities

Location	Ownership of facility Public/Private/Informal	The number of parking spaces/ vehicle types	Parking Tariff	Occupancy rate during peak hours	Condition of street markings	Type of restriction (e.g. for on-street)

Table 13.2: On Street Parking Inventory Survey Form

Segment

No: Name of Enumerator: Date:

No.	Name of Road	Approx. Length in m	Starting Point (Road Name)	Ending Point (Road Name)	Number of Legal On Street Parking Lot		
					Left	Right	Total
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

Table 13.3: Off Street Parking Inventory Survey Form

Segment No: Name of Enumerator: Date:

Off Street Parking Facility Name: Number of Lots:

Time	Legally Parked Vehicles					Illegally Parked Vehicles					Loading/ Unloading Trucks	Waiting Minibuses
	Cars	Pickups/ Vans	Trucks	M/C	Others	Cars	Pickups/ Vans	Trucks	M/C	Others		

Table 13.4: On Street Parking Demand Survey From

Segment No: Name of Enumerator: Date:

Off Street Parking Facility Name: Number of Lots:

Time	Sides of Road	Legally Parked Vehicles					Illegally Parked Vehicles					Loading/ Unloading Trucks	Waiting Minibuses
		Cars	Pickups/ Vans	Trucks	M/C	Others	Cars	Pickups/ Vans	Trucks	M/C	Others		
	Left Hand												
	Right Hand												
	Left Hand												
	Right Hand												
	Left Hand												
	Right Hand												
	Left Hand												
	Right Hand												

Table 13.5: Checklist for evaluating the adequacy of existing on-street parking facilities

S. No.	Item		Comment
Part A			
Location Details: Direction (From-To): Date and Time:			
1	What is the parking Configuration to kerb line?	Parallel	
		Angular	
		Perpendicular	
2	How many number of vehicles parked per Km. on both sides?		
3	What is the effective loss of carriage way width, (m)		
4	What is the loss of capacity (PCU/hr)		
5	What is number of parking manoeuvre per hour?		
6	What is the width of parking lane in metres?		
Part -B			
7	Is the safety of street system affected?		Yes/No
8	Does this system act as a traffic calming measure?		Yes/No
9	Are there any signages or markings available?		Yes/No
10	Are there any parking restrictions during peak period?		Yes/No
11	Is the number of on -street parking spaces appropriate to encourage use of public transport		Yes/No

Range	Rating (Verbal)	Rating (Numerical)
>4	Very good	5
3-4	Good	4
2-3	Satisfactory	3
1-2	Poor	2
0-1	Very Poor	1

Chapter 14:
Street Lighting

Well-designed street lighting enables motor vehicle drivers, cyclists, and pedestrians to move safely and comfortably by reducing the risk of traffic accidents and improving personal safety. From a traffic safety standpoint, street lighting is especially important in potential conflict points, such as intersections, driveways, and public transport stops. Additionally, lighting helps road users avoid potholes and missing drain covers. It also helps in providing proper visibility of the road when there is glare from headlights of opposing vehicles at night. A well-designed, energy-efficient street lighting system should permit users to travel at night with good visibility, in safety and comfort, while reducing energy use and costs and enhancing the appearance of the neighbourhood. Conversely, poorly designed lighting systems can lead to poor visibility or light pollution, or both. Quite often, street lighting is poorly designed and inadequately maintained (e.g., there are large numbers of burned-out lamps), and uses obsolete lighting technology—thus consuming large amounts of energy and financial resources, while often failing to provide high-quality lighting.

14.1 Lighting Requirements in Streets

When designing or making changes in street lighting it is important to first understand the light requirements of the road. Street lighting in India is classified as per the Indian Standard BIS (1981), based on the traffic density of the road, as shown in Table 14.1. Based on the classification in the code, the local engineer matches the category of road, and designs and provides installation specifications for the street lighting system (Guidelines: Energy Efficient Street Lighting, USAID ECO-III Project, New Delhi).

Table 14.1: Classification of Roads for street lighting (BIS, 1981)

Group	Description
A1	For very important routes with rapid and dense traffic where the only considerations are the safety and speed of the traffic and the comfort of drivers
A2	For main roads with considerable mixed traffic like main city streets, arterial roads, and thoroughfares
B1	For secondary roads with considerable traffic such as local traffic routes, and shopping streets
B2	For secondary roads with light traffic
C	For residential and unclassified roads not included in the previous groups
D	For bridges and flyovers
E	For towns and city centers
F	For roads with special requirements such as roads near airports, and railways

14.2 Lamp Technology

The most important element of the illumination system is the light source. It is the principal determinant of the visual quality, cost, and energy efficiency aspects of the illumination system. An electric light source is a device, which transforms electrical energy, or power (in watts), into visible electromagnetic radiation, or light (lumens). The rate of converting electrical energy into visible light is called “luminous efficacy” and is measured in lumens per watt.

The types of lamps commonly used for street lighting are listed in Table 14.2


Table 14.2: Lamp Technology

Type of Lamp	Luminous Efficacy (lm/W)	Color Rendering Properties	Lamp life in hrs	Remarks
High Pressure Mercury Vapor (MV)	35-65	Fair	10,000-15,000	High energy use, poor lamp life
Metal Halide (MH)	70-130	Excellent	8,000-12,000	High luminous efficacy, poor lamp life
High Pressure Sodium Vapor (HPSV)	50-150	Fair	15,000-24,000	Energy-efficient, poor color rendering
Low Pressure Sodium Vapor	100-190	Very Poor	18,000-24,000	Energy-efficient, very poor color rendering
Low Pressure Mercury Fluorescent Tubular Lamp (T12 &T8)	30-90	Good	5,000-10,000	Poor lamp life, medium energy use, only available in low wattages
Energy-efficient Fluorescent Tubular Lamp (T5)	100-120	Very Good	15,000-20,000	Energy-efficient, long lamp life, only available in low wattages
Light Emitting Diode (LED)	70-160	Good	40,000-90,000	High energy savings, low maintenance, long life, no mercury. High investment cost

14.3 Street Light Poles

Swage (insertion) type steel tubular poles are used for street lighting and the specification for street lighting poles is explained in Indian Standard (BIS, 1981). The optimum mounting height should be chosen by taking into account the light output of the sources, the light distribution of the luminaries, and the geometry of installation. The mounting height should be greater for more powerful lamps, to avoid excessive glare (BIS, 1981). Table 14.3 shows the mounting heights recommended by the Indian Standard.

Table 14.3: Mounting Height of Luminaries (BIS, 1981)

Group	Recommended Mounting Height
A	9 to 10 meters
B	7.5 to 9 meters
Others (roads bordered by trees)	Less than 7.5 meters

14.4 Recommended Level of Illumination

Recommended levels of illumination for street lighting related to groups A1, A2, B1, and B2 are shown in Table 14.4 below.

Table 14.4: Recommended Levels of Illumination (BIS, 1981)

Type of Road	Road Characteristics	Average Level of Illumination on Road Surface in Lux	Ratio of Minimum/ Average Illumination	Type of Luminaries Preferred
A-1	Important traffic routes carrying fast traffic	30	0.4	Cut off
A-2	Main roads carrying mixed traffic like city main roads/streets, arterial roads, throughways	15	0.4	Cut off
B-1	Secondary roads with considerable traffic like local traffic routes, shopping streets	8	0.3	Cut off or semi-cut off
B-2	Secondary roads with light traffic	4	0.3	Cut off or semi-cut off

Table 14.5 describes the various issues to be considered in evaluation of street lighting requirements.

Table 14.5: Checklist for evaluating street lighting

S. No.	Item	Comment (Yes:1; No: 0)
Location Details: Direction (From-To): Date and Time:		
1	Is the street lighting adequate for pedestrians?	Yes / No
2	Is the street lighting adequate for vehicle drivers?	Yes / No
3	Is the street lighting maintained neatly and regularly?	Yes / No
4	Is there a proper electricity connection to provide uninterrupted lighting for the street?	Yes / No
5	Is the street lighting properly designed as per the standards?	Yes / No
6	Are the street lighting issues resolved quickly?	Yes / No
7	Is the pole height suitable for the type of lamp used?	Yes / No
8	Does the street lighting system illuminate the whole carriageway?	Yes / No
9	Are the medians free from lamp posts?	Yes / No
10	Are all lamp posts of same height?	Yes / No
11	Is the effective illumination (lighting) on the carriageway uniformly maintained?	Yes / No
12	Are the tree branches and other lighting obstructions trimmed/eliminated regularly?	Yes / No

Range	Rating (Verbal)	Rating (Numerical)
>10	Very good	5
8-10	Good	4
5-7	Satisfactory	3
3-4	Poor	2
0-2	Very Poor	1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Chapter 15:

Traffic Signs and Road Markings

15.1 Traffic Signage

Signage is a comprehensive system of Regulatory, Informative and Warning messages corresponding to the information for all road user groups. An effective Signage System keeps the road user informed of the following:

1. Important destinations and routes.
2. Unexpected conditions.
3. Traffic laws.
4. Facilities like Public conveniences and Parking areas.

15.1.1 Type of Signage

As per standards like IRC, MUTCD and TCRP, Road Signs have been categorized on the basis of their function, which is to provide messages regarding the regulations, warnings and guidance information for the road user. The categories of the road signage are defined as under:

Regulatory Signage: Regulatory signs indicate requirements, restrictions and prohibitions. These include signs, such as, STOP, GIVE WAY, Speed Limits, No Entry, etc which give notice of right of way, special obligations, prohibitions or restrictions with which the road users must comply. These are installed to give effect to a traffic regulation order or other statutory provision. Regulatory signs either give positive instructions or indicate a prohibition. Signs giving positive instructions are generally circular with a white border and symbol on a blue background. They usually indicate something all drivers must do (e.g. keep left). The exceptions in shape are the octagonal red STOP sign and the triangular GIVE WAY sign. These two signs provide indication about the right of way to drivers. Prohibitory signs, which generally indicate to the drivers what they must not do, are mostly circular and have a red border. The red ring indicates the prohibition; diagonal bars are used only on signs which prohibit a specific manoeuvre, i.e. banned left or right turns or U-turns. These signs need to be complied with and any violation of the rules and regulations conveyed by these signs is a legal offence.

Cautionary/Warning Signs: Warning signs are used to caution and alert the road users to potential danger or existence of certain hazardous conditions either on or adjacent to the roadway so that they take the desired action. These signs indicate a need for special caution by road users and may require a reduction in speed or some other manoeuvre. Some examples of these signs are Hairpin Bend, Narrow Bridge, Gap in Median, School Ahead etc.

Informative / Guide Signs: These signs are used to provide information and to guide road users along routes. The information could include names of places (recreational, tourist, cultural interest area signs and emergency management signs), sites, direction to the destinations, and distance to places, to make the travelling /driving easier, safer and pleasant. Guide signs are essential to direct road users to inform them of intersecting routes, to direct them to cities, towns, villages, or other important destinations, to forests, and historical sites, and generally to give such information as will help them along their way in the most simple and direct manner possible.

15.1.2 Symbols Specifications

- **User Groups -** The Signage System of information is designed keeping in consideration different road user groups. A road user can fall under any of the following categories: Pedestrians, Cycle users or Non-Motorized Vehicle users Motorized Vehicle users, Bus users, Differently-Abled for all the above mentioned groups.

- **Physical Parameters –**

1. **Text Height:** The letter size could be decided with respect to the viewing distance and speed of the vehicle, so as to achieve legibility without signage being too large or obtrusive. In order to determine height of the characters on the basis of viewing distance, the line of sight and the height of the sign from the finished floor level should also be considered. The required height of letter for varying viewing distance is as shown in Table 15.1 and 15.2.

Table 15.1: 'Height' of letter for varying viewing distance

Required viewing Distance (m)	Maximum height of Letter (mm)
2	6
3	12
6	20
8	25
12	40
15	50
25	80
35	100
40	130
50	150

Table 15.2: Acceptable limits for Size of the Letters

Design Speed kmph)	Minimum 'x' Height of the Letters (cms)	Minimum Sighting Distance (m)	Maximum Distance from the Centre Line (m)
45	7.5	45	12
60	10.0	60	16
80	12.5	80	21
90	15.0	90	24
120	20.0	115	32

Letter Height Calculation - The following formula is another method to evaluate the letter height for signage, on the basis of number of words to be displayed, speed of the vehicle and the legibility factor.

Letter Height = (N/3 + 2) f

Where N = Number of words, f = Legibility Factor. Found by dividing vehicle speed in feet per second by 40 (the legibility distance per inch of letter height).

2. **Border:** Each sign shall have a border of the same colour as the legend, at or just inside the edge, unless otherwise specified. The corners of all sign borders shall be rounded.

3. **Diagrammatic Signs/ Symbols:** Symbols used for the signage, unless otherwise stated have been used as prescribed in standards reference – Standard Highway Signs. Direction of the arrows used in the signage can be revised to suit the usage with respect to the lane designation (left/right hand drive).

4. **Colour:** Signage follow colour code on the basis of their typology. Signs shall be provided with retro-reflective sheeting and/or overlay film/screening ink. The mandatory and warning signs shall be provided with white background and red border. The legend/symbol for these signs shall be in black.

The colours chosen for informative or guide signs shall be distinct for different categories of roads. For National Highways, State Highways, Major District Roads and Rural Roads, these signs shall be of green background with white borders, legends and word messages. For Expressways and Urban Roads, these signs shall be of blue background with white border, legends and word messages. Refer to respective sections for more details.

- **Types of Signage -** The Signage System comprises of three internationally accepted categories of signage, on the basis of the user group to be addressed and information to be delivered, represented using three basic geometric shapes.

1. Regulatory Signs: Circle.
2. Warning Signs: Triangle.
3. Informative Sign: Square/Rectangular

- **Mounting -** The Sign boards are mounted on either single poles, double poles, overhead cantilevered/ gantries or on service poles. The mounting type is decided on the basis of the following:
  1. User Group to be addressed
  2. Size of the Signage
  3. Location

15.1.3 Sitting of Signs with respect of the Carriageway

- The Road signs are the means of communication to the road users, especially drivers. Therefore, the signs shall be so placed that the drivers can recognize them easily and in time. Normally the signs shall be placed on the left hand side of the road. For two lane roads, normally the signs may be placed on the left side of the carriageway repeated on the other side of the carriageway if local conditions are such that the signs might not be seen in time by the drivers. For multilane divided roads the signs may be placed on left side of each carriageway. In case of hill roads, the signs shall generally be installed on the valley side of the road, unless traffic and road conditions warrant these to be placed on the hill side.

- On all roads with kerb or without kerb and with shoulder or without shoulder, the extreme edge of the ground mounted sign adjacent to the roadway shall be at a distance of 2 m to 3 m from the carriageway depending upon the local conditions and shall not be less than 600 mm away from kerb line but in no case shall any part of the sign come in the way of vehicular traffic.

- Large guide signs (Gantry mounted signs) should be farther removed preferably 9 m or more from the nearest traffic lane, unless otherwise specified. Lesser clearances, but not generally less than 1.8 m, may be used on connecting roadways or ramps at inter -changes. The minimum lateral offset is intended to keep away trucks and cars that use the shoulders from striking the signs or supports.

- On kerbed roads, the bottom edge of the lowest sign shall not be less than 2m and not more than 2.5m above the kerb. On roads without kerb, the bottom edge of the lowest sign shall not be less than 2m and not more than 2.5m above the crown of the pavement. Where signs are erected above footpaths or in areas likely or intended to be used by pedestrians, minimum headroom of 2.3m is to be provided.


- Where in the opinion of the competent authority a sign would be ineffective if placed on the left hand side shoulder of a road with dual carriageway, it may be placed on the median instead. To improve the visibility of the signs on multi-lane roads, the minimum height of the lower edge of the sign should be kept as 3 m above the highest point of the carriageway.

- The signs shall be so placed that these do not obstruct vehicular traffic on the carriageway, and if placed on the berm /footpath/refuge island, cause least obstruction to pedestrians. The difference in level between the lower edge of the sign and the carriageway shall be as uniform as possible for signs of the same class on the same route.

- From safety and aesthetic standpoints, overhead signs shall be mounted on overhead bridge structures wherever possible. Overhead signs shall provide a vertical clearance of not less than 5.5 m over the entire width of the pavement and shoulders. Where overhead sign supports cannot be placed at a safe distance away from the line of traffic or in an otherwise protected site, they should either be so designed as to minimize the impact forces or protect motorists adequately by a physical barrier or guard rail of suitable design.

15.1.4 Orientation of Signs

- The signs shall normally be placed at right angles to the line of travel of the approaching traffic. Signs relating to parking, however, should be fixed at an angle (approximately) 15 degrees to the carriageway so as to give better visibility.

- Where light reflection from the sign face is encountered to such an extent as to reduce legibility, the sign should be turned slightly away from the road. On horizontal curves, the sign should not be fixed normal to the carriageway but the angle of placement should be determined with regard to the course of the approaching traffic.

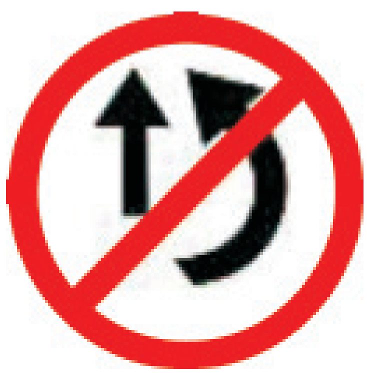
- Sign faces are normally vertical, but on gradients it may be desirable to tilt a sign forward or backward from the vertical to make it normal to the line of sight and improve the viewing angle.

15.1.5 Some Common Traffic Sings Specifications

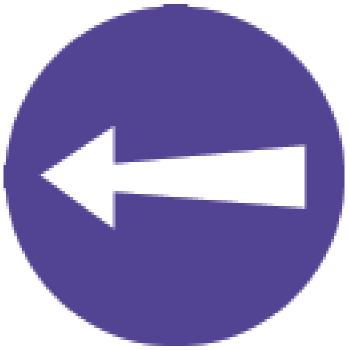
- **REGULATORY SIGNAGE –**

STOP SIGN		Size : 600mm Diameter Background : White Border : Red Symbol / Text : Black
Give Way Sign		Size : 600mm Diameter Background : White Border : Red Symbol / Text : Black
One way		Size : 600mm Diameter Background : White Border : Red Symbol / Text : Black
Vehicles prohibited inboth directions		Size : 600mm Diameter Background : White Border : Red Symbol / Text : Black


All motor vehicles prohibited		Size : 600mm Diameter Background : White Border : Red Symbol / Text : Black
Trucks Prohibited		Size : 600mm Diameter Background : White Border : Red Symbol / Text : Black
Bullock cart & Hand Carts Prohibited		Size : 600mm Diameter Background : White Border : Red Symbol / Text : Black
U-Turn Prohibited		Size : 600mm Diameter Background : White Border : Red Symbol / Text : Black

Pedestrian Prohibited		Size : 600mm Diameter Background : White Border : Red Symbol / Text : Black
Right Turn Prohibited		Size : 600mm Diameter Background : White Border : Red Symbol / Text : Black
Overtaking Prohibited		Size : 600mm Diameter Background : White Border : Red Symbol / Text : Black
Horn Prohibited		Size : 600mm Diameter Background : White Border : Red Symbol / Text : Black


No Parking		Size : 600mm Diameter Background : Blue Border : Red Symbol / Text : Black
No Stopping / Standing		Size : 600mm Diameter Background : Blue Border : Red Symbol / Text : Black
Speed Limit		Size : 600mm Diameter Background : White Border : Red Symbol / Text : Black
Minimum Speed Limit		Size : 600mm Diameter Background : White Border : Red Symbol / Text : Black


Height Limit		Size : 600mm Diameter Background : White Border : Red Symbol / Text : Black
Compulsory Turn Left		Size : 600mm Diameter Background : Blue Border : Blue Symbol / Text : White
Compulsory Keep Left		Size : 600mm Diameter Background : Blue Border : Blue Symbol / Text : White
Compulsory cycletrack/ cycles only		Size : 600mm Diameter Background : Blue Border : Blue Symbol / Text : White


Pedestrians only		Size : 600mm Diameter Background : Blue Border : Blue Symbol / Text : White
Bus way / buses only		Size : 600mm Diameter Background : Blue Border : Blue Symbol / Text : White

- **WARNING SIGNAGES –**

'T' Junctions		Size : 900mm Each Side Background : White Border : Red Symbol / Text : Black
School		Size : 900mm Each Side Background : White Border : Red Symbol / Text : Black

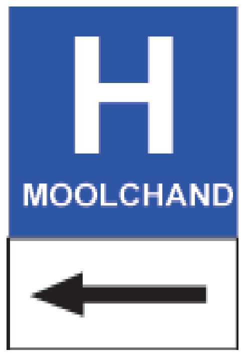
Prohibited Parking in Non-Motorized Lanes		Size -Top: 900mm Each Side Bottom: 900mm x 300mm Background : White Border – Top: Red Bottom: Black – 10mm Symbol / Text : Black
Pedestrian Crossing		Size : 900mm Each Side Background : White Border : Red Symbol / Text : Black

Common Lane for Cyclists and MV		Size : 900mm Each Side Background : White Border : Red Symbol / Text : Black


Merging Traffic		Size : 900mm Each Side Background : White Border : Red Symbol / Text : Black
Bus Lane Split		Size : 900mm Each Side Background : White Border : Red Symbol / Text : Black

- **INFORMATORY SIGNAGES –**

Pedestrian Subway		Size : 450mm x 600mm Background : White Border : Blue Symbol / Text : Black
Petrol Pump		Size : 600mm x 800mm Background : White Border : Blue Symbol / Text - Top: Black Bottom: White


NMV Parking		Size : 600mm 900mm Background -Top: Blue Bottom: White Border : Black (Bottom) Symbol / Text - Top: White Bottom: Black
Hospital		Size : 600mm x 900mm Background -Top: Blue Bottom: White Border : Black (Bottom) Symbol / Text - Top: White Bottom: Black
NMV Track		Size : 600mm x 600mm Background : Blue Border : White Symbol / Text : White
Parking		Size : 600mm x 600mm Background : Blue Border : White Symbol / Text : White


Parking		Size : 600mm x 900mm Background – Top: Blue Bottom: White Border – Top: Blue Bottom: White Symbol / Text – Top: White Bottom: Black
Parking		Size : 600mm x 900mm Background – Top: Blue Bottom: White Border – Top: Blue Bottom: White Symbol / Text – Top: White Bottom: Black
Parking		Size : 600mm x 900mm Background – Top: Blue Bottom: White Border – Top: Blue Bottom: White Symbol / Text – Top: White Bottom: Black
Differently-Abled Environment		Size : 600mm x 600mm Background : Blue Symbol / Text : White

15.2 Road Markings

The essential purpose of road markings is to guide and control traffic on a highway. They supplement the function of traffic signs. The markings serve as a psychological barrier and signify the delineation of traffic path and its lateral clearance from traffic hazards for the safe movement of traffic. Hence they are very important to ensure the safe, smooth and harmonious flow of traffic. Various types of road markings like longitudinal markings, transverse markings, object markings and special markings to warn the driver about the hazardous locations in the road etc. will be discussed below, in detail.

Classification of road markings

The road markings are defined as lines, patterns, words or other devices, except signs, set into applied or attached to the carriageway or kerbs or to objects within or adjacent to the carriageway, for controlling, warning, guiding and informing the users. The road markings are classified as longitudinal markings, transverse markings, object markings, word messages, marking for parking, marking at hazardous locations etc.

Longitudinal markings

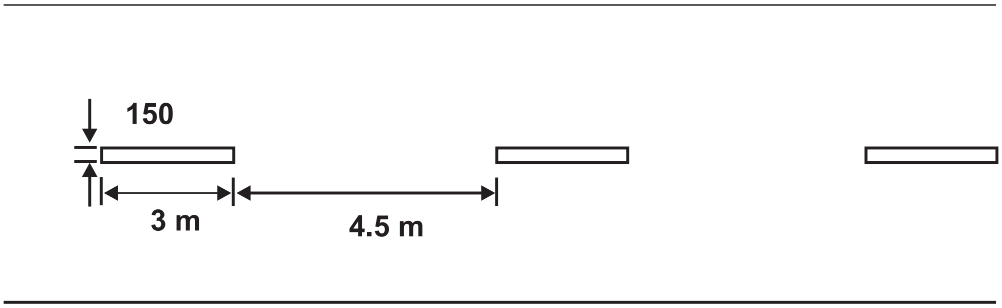
Longitudinal markings are placed along the direction of traffic on the roadway surface, for the purpose of indicating to the driver, his proper position on the roadway. Some of the guiding principles in longitudinal markings are also discussed below.

Longitudinal markings are provided for separating traffic flow in the same direction and the predominant color used is white. Yellow color is used to separate the traffic flow in opposite direction and also to separate the pavement edges. The lines can be either broken, solid or double solid. Broken lines are permissive in character and allows crossing with discretion, if traffic situation permits. Solid lines are restrictive in character and does not allow crossing except for entry or exit from a side road or premises or to avoid a stationary obstruction. Double solid lines indicate severity in restrictions and should not be crossed except in case of emergency. There can also be a combination of solid and broken lines. In such a case, a solid line may be crossed with discretion, if the broken line of the combination is nearer to the direction of travel. Vehicles from the opposite directions are not permitted to cross the line. Different types of longitudinal markings are centre line, traffic lanes, no passing zone, warning lines, border or edge lines, bus lane markings, cycle lane markings.

Centre line

Centre line separates the opposing streams of traffic and facilitates their movements. Usually no centre line is provided for roads having width less than 5 m and for roads having more than four lanes. The centre line may be marked with single broken line, or single solid line, or double broken line, or double solid line depending upon the road and traffic requirements. On urban roads with less than four lanes, the centre line may be single broken line segments of 3 m long and 150 mm wide. The broken lines are placed with 4.5 m gaps (Figure 15.1).


Figure 15.1: Centre line marking for a two lane road



On curves and near intersections, gap shall be reduced to 3 metres. On undivided urban roads with at least two traffic lanes in each direction, the centre line marking may be a single solid line of 150 mm wide as in Figure 15.2, or double solid line of 100 mm wide separated by a space of 100 mm as shown in Figure 15.3.

Figure 15.2: Centre line and lane marking for a four lane road

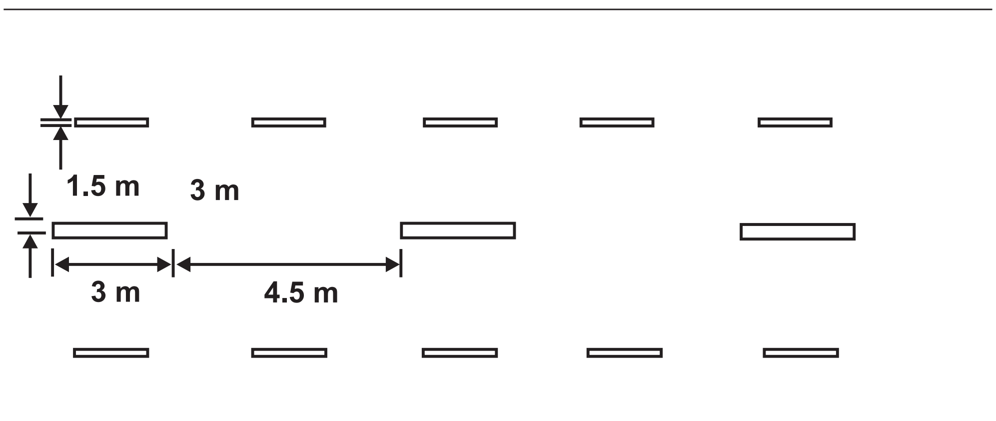
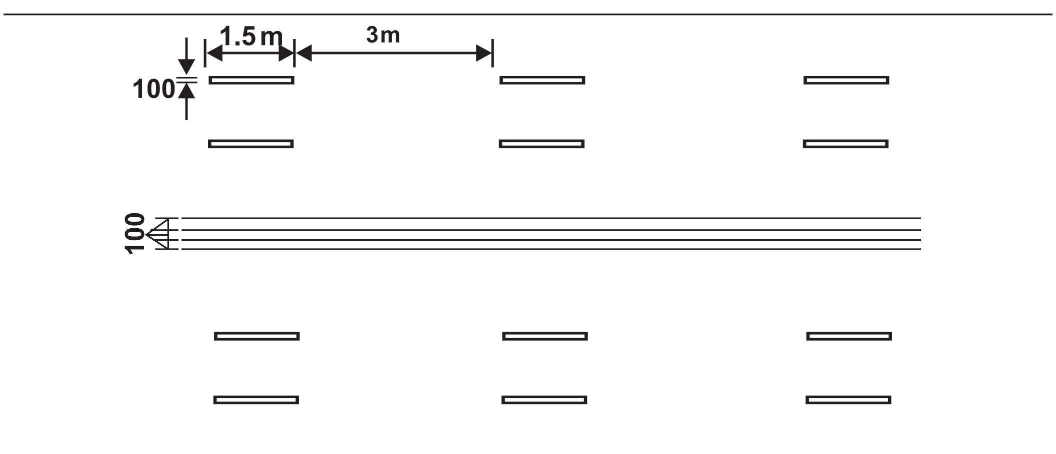
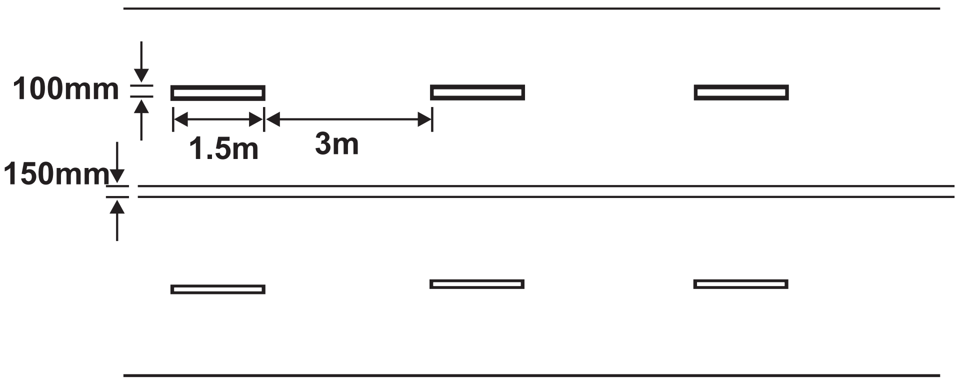


Figure15.3: Double solid line for a two lane road



The centre barrier line marking for four lane road is shown in Figure 15.4.

Figure 15.4: Centre barrier line marking for four lane road



Traffic lane lines

The subdivision of wide carriageways into separate lanes on either side of the carriage way helps the driver to go straight and also curbs the meandering tendency of the driver. At intersections, these traffic lane lines will eliminate confusion and facilitates turning movements. Thus traffic lane markings help in increasing the capacity of the road in addition ensuring more safety. The traffic lane lines are normally single broken lines of 100 mm width. Some examples are shown in Fig. 15.5 and Fig. 15.6.

Figure 15.5: Lane marking for a four lane road with solid barrier line

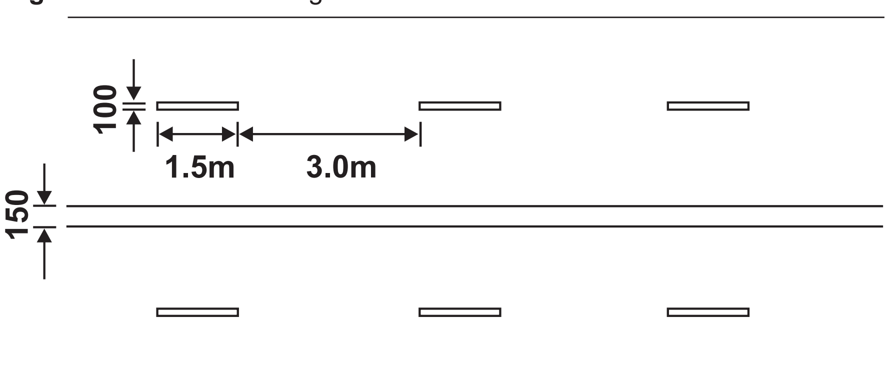
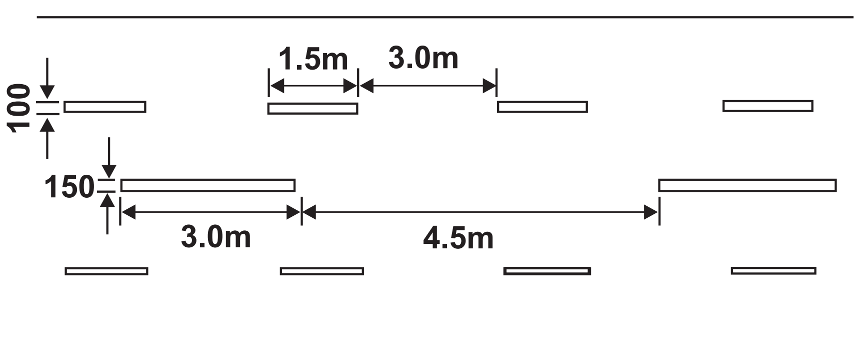


Figure 15.6: Traffic lane marking for a four lane road with broken centre line



Transverse markings

Transverse markings are marked across the direction of traffic. They are marked at intersections etc. The site conditions play a very important role. The type of road marking for a particular intersection depends on several variables such as speed characteristics of traffic, availability of space etc. Stop line markings, markings for pedestrian crossing, direction arrows, etc. are some of the markings on approaches to intersections.

Object markings

Physical obstructions in a carriageway like traffic island or obstructions near carriageway like signal posts, pier etc. cause serious hazard to the flow of traffic and should be adequately marked. They may be marked on the objects adjacent to the carriageway.

The application of road markings is classified under the category of different users. The road space has been divided for different road users depending upon their respective design speeds. The different users of the road space are:-

- Motorized Vehicles (MV)
- Buses
- Cycles
- Pedestrians

The mechanical markers can be used to reduce speed and some of them are listed below:

Cats eye are reflectors which either reflect the light falling on them or can have a blinking mechanism at important locations.

Botts' dots are one type of a mechanical non-reflective raised marker. Generally they are used to mark the edges of traffic lanes, frequently in conjunction with raised reflective markers.

Rumble strips can be a series of simple troughs (typically 1 cm deep and 10 cm wide) that is ground out of the asphalt.

For further details on road markings, users can refer to code of practice on Road Markings issued by Ministry of Urban Development (MOUD).

Table 15.3 presents the checklist for evaluating signs and markings.

Table 15.3: Checklist for evaluating traffic signs and road markings

S. No.	Item	Comment (Yes:1; No: 0)
Location Details: Direction (From-To): Date and Time:		
1	Are the traffic signs available at required places and designed as per MOUD code of practice.	Yes / No
2	Are the traffic signs mounted at the required stopping distance	Yes / No
3	Visibility of traffic signs is good during day and night time conditions	Yes / No
4	Are the traffic signs mounted at required height to be visible from a long distance	Yes / No
5	Are the signs properly readable and retro-reflective in nature	Yes / No
6	Are the road markings properly designed as per code of practice	Yes / No
7	Are the signs and markings visibility is good in adverse weather conditions	Yes / No
8	Are the signs and markings properly maintained over a period of time	Yes / No

Range	Rating (Verbal)	Rating (Numerical)
8	Very good	5
6-7	Good	4
4-5	Satisfactory	3
2-3	Poor	2
0-1	Very Poor	1

Comprehensive checklist for evaluating all the elements of road traffic system simultaneously is presented in Table 15.4.

Table 15.4: Checklist for evaluating all the elements of URTS

S. No.	Item	Yes/No
	A. Function, operating elements and surrounding	
1	Is traffic composition characteristics reflected fully in the design?	
2	Are special measures required for older people, sick people, physically handicapped, hearing-impaired or blind people etc. considered?	
3	Are different road elements of road design done as per function and hierarchy in the network?	
4	Is access to abutting properties appropriate for road safety?	
5	Is stopping sight distance guaranteed along the entire section of corridor?	
	B. Cross section	
1	Is the cross section appropriate to the Design Hourly Volume (DHV) and Road Category?	
2	Is drainage system properly designed?	
3	Is safety guidelines followed if narrowing of the carriageway required due to practical constraints?	
4	Are steps have been taken to ensure that speed limits are obeyed?	
5	Is priority of public transport and its users taken into consideration?	
6	Is slow moving and NMV traffic separated from fast and heavy traffic?	
7	Is the median able to serve its purpose fully?	
8	Is a separating strip required between cycle path and parking strip to ensure safety?	
9	Are proposed signs displayed at bottlenecks?	
10	Do curves with small radii have extra width of the pavement?	
11	Is sight obstructed due to road equipment, parking, buildings etc. given special consideration?	
	C. Intersections	
1	Is proper visibility is maintained at entry/exit locations?	
2	Are traffic signs and markings guide the movements effectively?	
3	Are the auxiliary lanes or tapers for left, right and U-turning movements large enough?	
4	Are the required sight triangles clear of obstructions?	
5	Are type and design of the intersections suitable for the function and traffic volume of the intersecting roads?	
6	Is pedestrian/bi-cyclist routing at intersections adapted to the actual conditions and clearly marked and signposted?	
7	Are all approaches equipped with pedestrian crossings?	
8	Have suitable measures been taken to ensure that speed limits are obeyed?	

9	Are the pedestrian crossings as per the norms?	
10	Are pedestrian crossings clearly marked?	
11	Is each section equipped with signals (including railway structures)?	
12	Are refuges large and wide enough for crossing pedestrians and cyclists to stand and wait?	
13	Are the islands clearly visible and of a suitable design?	
14	Is there a sufficient deflection to ensure an appropriate speed when passing the roundabout?	
	D. Traffic Signals	
1	Is the stopping line correlated with the traffic signal so that the signal can be seen?	
2	Are all turning movements considered in signal design?	
3	Are traffic signals easily recognizable?	
4	Have bicyclists' requirements been considered	
5	Are stop lines for motorists set back for the benefit of bicyclists?	
6	Are all approaches equipped with pedestrian and cycle crossings?	
7	Are exclusive green phases provided for pedestrians and bicyclists where necessary?	
8	Is the green time sufficient for pedestrians to cross the road in one go?	
	E. Public and private services, parking, public transport	
1	Are there major traffic generators such as city hall, churches and cemeteries, hospitals, housing or shopping centres, petrol stations and tourist attractions taking into account?	
2	Are the accesses suitable for the amount of traffic?	
3	Are the dimensions of the parking areas sufficient for parking for passenger vehicles, trucks and buses?	
4	Is the arrangement of parking (parallel, diagonal or perpendicular) along the road sides safe?	
5	Are loading areas provided next to the road at shops and restaurants ?	
	F. Needs of vulnerable Road Users	
1	Are stops easily and safe accessible to pedestrians (combination with pedestrian crossings, crossing help etc.)?	
2	Are the bus stops signposted and detectable by the drivers? Is reconcilability from a longer distance guaranteed?	
	G. At Public transport stops	
1	Are the bus stops situated outside of the carriageway where appropriate?	
2	In the case of bicycle paths: Is cyclist routing safely designed in the area near public transport stops?	
3	Is lighting required? And if so, is it appropriately designed?	
	H. Other needs of Pedestrian	
1	Are areas for waiting pedestrians and cyclists sufficient?	

2	Are the pedestrian crossings located where most required by pedestrian traffic?	
3	Are the pedestrian ways physically separated by kerb stones, barriers or greenery?	
4	Is lighting provided where necessary?	
	I. Bicyclists (only in the case of existing facilities)	
1	Are there separate bicycle facilities?	
2	Have cyclists' requirements been considered (e.g. route across central refuges, bottlenecks)?	
3	Is the visibility for motorised traffic adequate to see cyclists along the road?	
4	Is right of way clearly defined at points where cyclists come into contact with each other or with motorized traffic?	
	J. Traffic Signing, Marking, Lighting	
1	Have appropriate speed limits been signed appropriately (start, end, height, location, usually 50 km/h)?	
2	Is sight obstructed by the traffic or by the signs?	
3	Can the signs be clearly recognized and read (size of signs)?	
4	Is signing logical and consistent? Does it show the right of way clearly?	
5	Is pedestrian/bicyclist routing at intersections adapted to the actual conditions and clearly signposted?	
6	Do the signs have a dimension according to the type of road?	
7	Are the road markings clear and recognizable?	
8	Are the markings appropriate for the function and category of the road?	
9	Are the markings likely to be effective under all expected conditions (day, night, wet, dry, fog, rising and setting sun)?	
	K. Lighting	
1	Is the road sufficiently illuminated?	
2	Is the lighting of special situations (transition zones, changes in cross section) suitably designed?	
3	Does lighting appropriate so that crossing pedestrians are clearly visible?	
4	Is lighting at the intersections appropriate?	

Range	Rating (Verbal)	Rating (Numerical)
>52	Very good	5
40-52	Good	4
27-39	Satisfactory	3
14-26	Poor	2
0-13	Very Poor	1

Chapter 16:

Lessons, Options and Way Forward

In India, there are many cities with a population exceeding 5 million. Here are a few:

- Delhi
- Bombay
- Calcutta
- Madras
- Banglore
- Hyderabad
- Ahmedabad
- Lucknow
- Nagpur, etc.

In almost all the cities, the traffic systems planning and implementation was not taken up at appropriate time. This delay has caused immense mobility problems and the resource needs for implementing urban metro projects which are in different stages of implementation are mind boggling. Thus, the society in any case is incurring huge resources but if these projects were planned and implemented earlier lot of traffic related problems could have been avoided.

For example, in the case of Banglore a final decision to develop urban metro project was taken during 1984, but the actual implementation on the ground took another 15 years. It may be noticed that the original cost of implementing the metro had gone up by several times.

There are more than 40 cities whose population has crossed one million as per 2011 census. These cities will become problematic if timely action is not initiated to develop suitable mass transportation projects. In the absence of such dedicated efforts the problems being faced by the current 10 big cities will get repeated. This situation needs to be avoided. One possible solution is to prepare comprehensive mobility plan and implement them in a time bound manner with a missionary zeal.

This option will minimize the hardships to commuters due to inadequate and incomplete traffic systems infrastructure. In addition, in the present big ten cities new technologies such as ITS, VMS, signal free corridors and incident management system through area traffic control and centralized traffic control through traffic management centres need to be implemented.

Another area of improving the situation is through a serious attempt to contain the demand rather than adding additional traffic infrastructure. This could be achieved through a number of administrative and educative measures such that individual vehicular users will shift to mass transport system.

Some of the measures are:

- Encourage NMT by creating proper footpaths and bi-cycle tracks, etc…
- Attract more users to mass public systems such as metro and bus network. Introduction of Air conditioned Volvo buses in the city of Banglore is a big success. Many cities can emulate this experiment
- Initiate congestion pricing on corridors at least during peak hours

The talent and expertise available in IITs, NITs and some reputed state engineering colleges could be tapped to solve these complex traffic system infrastructure and mobility problems.

To start with, the Ministry of Urban Development may identify 12 -15 institutions in the country and attach 2 or 3 “million plus” cities to be adopted by them.

About 200 to 250 post graduate students and 25 to 30 doctoral students are getting trained in these institutions. These students could take up these live problems for their research work and may be able to suggest innovative and practical solutions.

There is also a need to document success and failures of various strategies adopted in India over a period of time such that the future failure rates could be minimized.

The flow chart given below in Table 16.1 provides some guidelines for undertaking CMPs in million plus cities.


Table 16.1: Steps to be followed in preparing CMP

1	Project name	Development of comprehensive mobility plans (CMP) for the cities with more than one million population (excluding big 10)
2	Problem extent	There are more than 30 such cities in India. In India implementation will take long time. CMPs once prepared could be implemented over a period of 2 to 3 years.
3	Objective of study	Identify the current situation, estimate future traffic needs and develop implementation strategy so that in a time bound manner the mobility issues are resolved.
4	Approach	Population growth, vehicular growth, land use changes during the last decade and future developmental scenario. Identify major centres of traffic generation and attraction.
5	Studies to be conducted	Home interview surveys, other travel desire surveys, parking surveys, speed surveys, intersection surveys, speed and delay along identified corridors.
6	Analysis	Capacity analysis along major routes, trip generation and attraction tables, trip rates for different purposes, modes, time of the day, land use transport impact, parking issues
7	Study duration	18 months
8	Estimated cost for the study	100 Lakhs (approx.)
9	Reports	Inception report, Interim report after data collection at the end of 8 to 9 months. Travel database, implementation strategy, Impact assessment of these changes on travel as well as on Environment.
10	Deliverables	Detailed improvement plans for different links, Public transport routing and scheduling, Intersection improvement plans with complete drawings.
11	Avenues for resource mobilization	Feasibility of cess on establishments employing more than 50 people, insurance agencies, part of traffic fines, feasibility of congestion pricing on major corridors, etc...


STUDY MIGRATE
UBEERICH

Chapter 17:

Planning, Design and Impact Assessment

How can we sustain rapid growth with limited natural resources? How can we spread the ongoing economic and social benefits of regeneration to create broader opportunities? And how can we focus development so that it weathers uncertain futures?

Today's challenges demand coordinated responses. Public agencies require affordable solutions that bring about lasting change for communities. Private sector investors want to create valuable projects with sustained returns.

Economic analysis and planning is at the heart of positive development. Our planners provide joined-up services to support regeneration in cities, towns and rural areas, driving long-term social, economic and environmental sustainability.

As the costs involved in creating traffic infrastructure is so high, we need a detailed planning on how best to utilize the available funds so that the returns to the society would be maximum for the same investment.

Based on the constraints on budgets and new developments in the field of engineering an optimum solution must be arrived at and then implemented after understanding that it satisfies all the conditions.

Impact evaluation of implementation of **BTRAC** project in the city of Banglore is considered for demonstrating this aspect.

BTRAC project was initiated in Banglore for improving the traffic conditions and enhancing the public safety by enforcing the traffic regulations.

The design of the BTRAC project, the cost estimates, available funds and the costs incurred and the (positive) impact of this project on the city as a whole is presented here.

17.1 Impact assessment of B-TRAC project

The city of Banglore is experiencing severe traffic congestion. B-TRAC was envisaged by the Bangalore Traffic Police in order to address the ever growing traffic operational needs of Bangalore City Traffic. The first tranche

of grants was released and Bangalore City Police in turn had signed a Memorandum of Understanding (MOU) with Karnataka Road Development Corporation Limited (KRDCL), a special purpose vehicle to implement the project on its behalf. The details of activities planned and the extent of actual completion of the activities and funds utilized are provided in Table 17.1.

Table 17.1: B-TRAC implementation

Item	Originally planned	Actual completion
Junction improvements	500	46
Signal improvements	129	179
New signal installations	311	193
Road markings	112,500 sq mtr	
Enforcement cameras	At number of important locations	
Surveillance cameras	680	99
Pelican signals	95	16
Resources in Crores	352	124
Variable Message Signs	Implemented at number of locations	
Establishment of TMC (Traffic management centre)	Under execution	

Implementation of B-TRAC project has achieved the following objectives

- Reduction of congestion to the extent of 15-20% at a number of locations
- Average savings in time is to the extent of 15 % at about 80 junctions
- Traffic operating speeds increased from 18 to 23 KMPH along 9 corridors
- The total fines collected in the last 5 years exceeds the money spent on the project

17.2 Impact assessment checklist (Alberta DoT)

Background Information

a) Proposed Development

- ☐ Development name and/or developer
- ☐ Development location
- ☐ Type of development
- ☐ Size of development
- ☐ Staging (by year anticipation)

b) Street

- ☐ Number & Control Section
- ☐ Highway Classification

c) Study Area

- ☐ Key Map
- ☐ Site Plan

Existing Infrastructure & Condition

a) Existing Street Conditions

- ☐ Pavement width
- ☐ Pavment lane markings
- ☐ Right-of-way width
- ☐ Vertical grades
- ☐ Horizontal alignment (i.e. curve radius)
- ☐ Design &/or Posted Speed Limit
- ☐ Locations of speed limit changes
- ☐ Existing illumination in vicinity
- ☐ Traffic control type (Two-way or all-way stop, etc.)
- ☐ Traffic operation signage (i.e. no left-turns, no parking)

b) Existing Intersection Conditions (if applicable)

- ☐ Intersection configuration (including scaled plan)
- ☐ Vertical grades of local/intersection roadway
- ☐ Intersection sight distance
- ☐ Stopping sight distance
- ☐ Existing signal timings
- ☐ Major developments currently using intersection

c) Existing Traffic Conditions

- ☐ Turning Movement Counts (Diagram &/or Table) – AADT
- ☐ Turning Movement Counts (Diagram &/or Table) – AM Peak
- ☐ Turning Movement Counts (Diagram &/or Table) – PM Peak
- ☐ Existing AADT
- ☐ Historical Traffic Growth Rate
- ☐ 5-year Traffic Growth Rate at Intersection
- ☐ 10-year Traffic Growth Rate at Intersection
- ☐ Annual Traffic Growth Rate at Intersection
- ☐ Vehicle composition (% vehicle type) on Intersection

Traffic Projection

a) Existing / Background Traffic

- ☐ AM Peak
- ☐ PM Peak
- ☐ Other (noon, Saturday, etc.)

b) Build Year

i) Projected Background Traffic

- ☐ AM Peak
- ☐ PM Peak
- ☐ Other (noon, Saturday, etc.)

ii) Projected Development Traffic

- ☐ AM Peak
    - ☐ Site Generated
    - ☐ Pass by &/or Internal Trips
    - ☐ Total Trips
- ☐ PM Peak
    - ☐ Site Generated
    - ☐ Pass by &/or Internal Trips
    - ☐ Total Trips
- ☐ Other (noon, Saturday, etc.)
    - ☐ Site Generated
    - ☐ Pass by &/or Internal Trips
    - ☐ Total Trips

iii) Combined (Background + Development) Traffic

- ☐ AM Peak
- ☐ PM Peak
- ☐ Other (noon, Saturday, etc.)

c) Staging Years (If applicable)

i) Projected Background Traffic

- ☐ AM Peak
- ☐ PM Peak
- ☐ Other (noon, Saturday, etc.)

ii) Projected Development Traffic

- ☐ AM Peak
    - ☐ Site Generated
    - ☐ Pass by &/or Internal Trips
    - ☐ Total Trips
- ☐ PM Peak
    - ☐ Site Generated
    - ☐ Pass by &/or Internal Trips
    - ☐ Total Trips
- ☐ Other (noon, Saturday, etc.)
    - ☐ Site Generated
    - ☐ Pass by &/or Internal Trips
    - ☐ Total Trips

iii) Combined (Background + Development) Traffic

- ☐ AM Peak
- ☐ PM Peak
- ☐ Other (noon, Saturday, etc.)

d) 20-Year Horizon

i) Projected Background Traffic

- ☐ AM Peak
- ☐ PM Peak
- ☐ Other (noon, Saturday, etc.)

ii) Projected Development Traffic

- ☐ AM Peak
  - ☐ Site Generated
  - ☐ Pass by &/or Internal Trips
  - ☐ Total Trips
- ☐ PM Peak
  - ☐ Site Generated
  - ☐ Pass by &/or Internal Trips
  - ☐ Total Trips
- ☐ Other (noon, Saturday, etc.)
  - ☐ Site Generated
  - ☐ Pass by &/or Internal Trips
  - ☐ Total Trips

iii) Combined (Background + Development) Traffic

- ☐ AM Peak
- ☐ PM Peak
- ☐ Other (noon, Saturday, etc.)

Analysis

a) Capacity Analysis

i) Required (by intersection, turning movement & peak period)

- ☐ Delay per vehicle (seconds)
- ☐ Level of service (LOS)
- ☐ Left-turn warrant analysis
- ☐ Right-turn warrant analysis

ii) If Applicable

- ☐ LOS on a link (using HCM methodology)
- ☐ Vehicle queuing information

b) Signalization Analysis (If Applicable)

i) Isolated Intersections

- ☐ Signalization Warrant Analysis
- ☐ Signal Timing Optimization
- ☐ Recommended Mitigation

- **ii) Semi-urban/ Urban Intersections**
  - ☐ Signalization Warrant Analysis
  - ☐ Signal Timing Optimization
  - ☐ Signal Coordination Analysis
  - ☐ Recommended Mitigation

c) Illumination (If Applicable)
- ☐ Illumination Warrant Analysis
- ☐ Recommended Mitigation

d) Pedestrians Movements (If Applicable)
- ☐ Pedestrian Warant Analysis
- ☐ Recommended Mitigation

e) Operational Analysis
- ☐ Design vehicle turning movement templates
- ☐ Recommended Mitigation

Conclusion & Recommendations
- ☐ Required intersection improvements
- ☐ Pedestrian Mitigation
- ☐ Illumination Requirements
- ☐ Signalization Conclusions
- ☐ Right-of-way requirements
- ☐ Recommended intersection plan

Chapter 18:

Operation, Maintenance and Evaluation

Traffic systems operation, maintenance and evaluation could be undertaken at 4/5 levels.

- Mid Block level
- Isolated junction level
- Corridor level
- Critical location evaluation
- NMT facilities operation, maintenance and evaluation

In each of these cases a detailed list of each of these facilities need to be first created. Depending upon the purpose for which it is to be redesigned an action plan for each identified facility is to be prepared. A time task to achieve these changes also may be drawn up. In order to achieve all these changes say over a five year period, a schedule for different activities may be prepared. Every year the execution of the plan may be reviewed and if necessary changes in implementing the schedule could be brought in so that all the activities are completed within the time originally envisaged. Every year an impact assessment of these improvements may be undertaken in a systematic manner so that mid course correction if required could be considered. In this correction, it is necessary that a new team or a new organisation may be involved in the impact assessment rather than the same agency/ team implementing the changes for different activities.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Chapter 19:

Planning for the Future

(such as new technologies to overcome obsolescence, changes in policy, etc.)

Currently cities with 5 million and above population are experiencing very acute traffic problems for a number of reasons. The main challenges are:

- Uncontrolled expansion of city limits without proper plans
- Primacy to vehicular movement rather than commuter mobility
- Difficulty in raising adequate resources to upgrade traffic infrastructure
- Unforeseen difficulties in capacity expansion plans due to land acquisition-litigation, resettlement and rehabilitation action plans for land losers

As such if we put aside the large cities with population 5 million and above, all other urban areas could be improved at much lesser cost and the problems stated above are manageable in these cities. If may be noted that Mumbai city alone needs about 1 lakh crores for the next 15 years to solve all mobility problems, where as Banglore needs about 55 thousand crores. Same is the situation in other big cities. As such a new policy initiatives need to be followed to promote million plus cities but with less than 5 million population.

The next preference could be cities with population 5 lakhs to 1 million. Another policy change is to encourage individuals to shift from personalized vehicles to public transport. The commuters' preference to travel by public transport needs to be comprehensively studied and implemented.

The third policy change is to encourage the use of NMT (Non-Motorised Transport) by providing good bi-cycle tracks and foot paths free from hawkers. It may be noted that currently even in big cities a substantial percentage (48-52%) of passengers is travelling by NMT (including intra zonal and inter zonal trips), but commuters are not happy about the facilities. The city planners could aim at 65-70% of total trips to be attracted towards the use of NMT in a period of 5 years.

Another policy change is to collect environmental tax on motorised vehicles which produce emissions. A comprehensive study need to be undertaken to quantify emissions of different categories of vehicles and charges to recover costs associated in damage control.

Charging congestion tax during peak hours on all corridors may dampen the demand for vehicular usage during peak hours.

There is a need to use technology more effectively on the signalized junctions as fully vehicle actuated rather than fixed time signals. In any road section if two or more signals to be designed with in two kilometres they need to be designed as coordinated signals, so that green wave could be achieved in one or if possible in both directions. In such situations in order to get green at subsequent junctions the average speed of operation is to be displayed for the benefit of the commuters.

Chapter 20:

Field Evaluation of Urban Road Traffic System through Checklist:

A Case Study of Kazipet-Warangal Stretch of 16 km

The present report on Evaluation of Urban Road Traffic Systems developed 13 checklists that assist field officials to assess the state of condition for each of the following elements.

- Carriageway
- Intersections
- Roundabouts
- Interchanges
- Bus Lanes
- Bus stops
- Medians
- Service lanes
- Bi-cycle facilities
- Pedestrian Facilities
- Pedestrian crossings
- On-street parking facilities
- Street lighting

This assessment helps the field engineers in developing appropriate improvement strategies and also in evaluating the work of consultants to what extent the improvement has occurred after successful completion of a particular project. Eight checklists among thirteen have been selected in the city of Warangal for a road stretch of about 16 km. The checklists used for this field study are:

- Carriageway
- Intersections
- Roundabouts

- Medians
- Pedestrian Facilities
- Pedestrian crossings
- On-street parking facilities
- Street lighting

For the purpose of this field study, road length of 16 km is divided into two corridors namely Kazipet to Hanamakonda and Hanamakonda to Warangal (Figures 20.1–20.3).

Figure 20.1: Google map of the entire study area from Kazipet to Warangal

Each corridor is further sub-divided into number of sections. For example, corridor 1 Kazipet to Hanamakonda is split into 11 sections, while corridor 2 Hanamakonda to Warangal is divided into 8 sections. Thus the entire stretch of 16 km of Kazipet to Warangal is divided into 19 sections. It may be noted that this stretch is a national highway passing through the city. The carriageway is mostly divided by a median with two lanes for the flow of traffic in each direction.

Figure 20.1: Google map of the corridor 1 of the study area from Kazipet to Hanamakonda

Each checklist as explained previously consists of a number of questions and each question is answered Yes or No. For the purpose of quantification, Yes is considered as 1 and No is considered as 0. The questions are framed in such a manner that Yes indicates the desirable scenario and No indicates the field condition is far from what it should be. Depending upon number of positive responses for each checklist, a five point rating is developed.

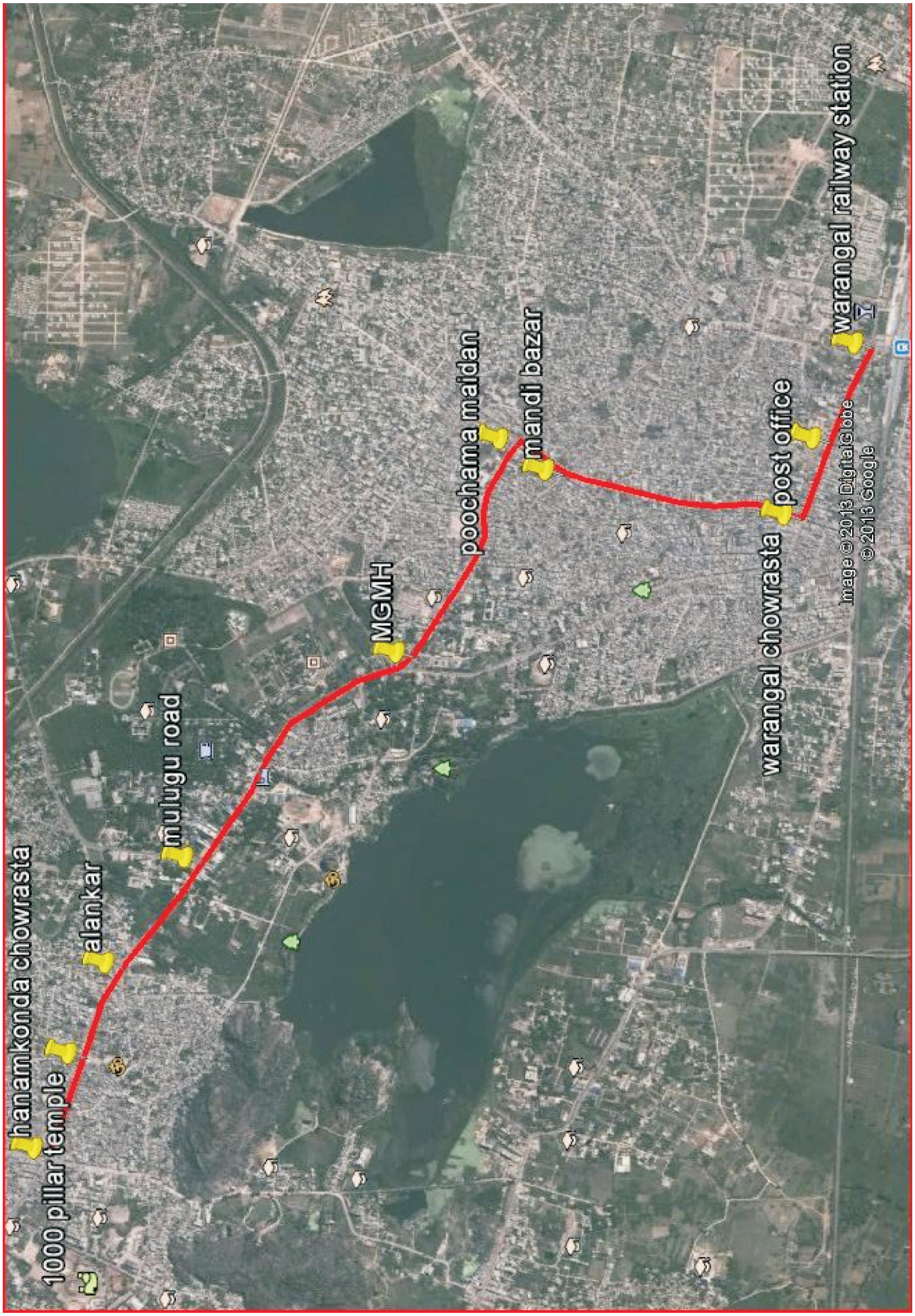

Figure 20.3: Google map of the corridor 2 of study area from Hanamakonda to Warangal

A comprehensive field study of eight checklists for each section and sample analysis of data is presented in Tables 20.1 to 20.6. It may be noted that for each section (sub-part of road length of each corridor), each element is given a rating for all the questions. Table 20.1 to 20.3 provides information on the checklist for evaluation of carriageways, from Kazipet to Hanamakonda, Hanamakonda to Warangal, and Kazipet to Warangal, respectively. It may be noted that for the checklist on carriageway, for different stretches along this corridor, varies from two to three indicating bad to satisfactory. The combined rating for this element on this corridor is 2.54 (Table 201), average of different stretches indicating the field conditions bad to satisfactory. For the same carriageway, the information presented in Table 20.2 for the corridor between Hanamakonda to Warangal is 1.75 indicating very bad to bad. If the information for this element carriageway for the entire stretch of 16 km is combined, the net result is 2.21 indicating bad to worse (Table 20.3). Table 20.4 presents checklist on median across entire road length of 16 km from Kazipet to Warangal. It indicates that median on the whole presents a scenario of satisfactory to good. The information for street lighting is presented in Table 20.5 and the situation on street lighting appears to be varying from satisfactory to good. For all the eight elements, combined rating of each checklist is presented in Table 20.6 for the three sections Kazipet to Hanamakonda, Hanamakonda to Warangal, and Kazipet to Warangal. The results indicate a mixed scenario. In the case of pedestrian crossings on the whole, the situation is bad to very bad and in the case of roundabout intersections, the situation is good. For a given corridor, the overall rating for all the elements are calculated (average rating of all checklists). The results indicate the final rating in the case of all the three stretches, situation is bad to satisfactory. This implies corrective measures need to be taken to improve performance of functioning of all the urban road transport elements.

Table 20.1: Carriageway Evaluation from Kazipet to Hanamakonda

S. No.	Stretch	Rating	Comment
1	Kazipet – Fathimanagar	3	Satisfactory
2	Fathimanagar - 100ft Road	2	Bad
3	100ft Road- Forest Office	2	Bad
4	Forest Office - Collectors Residence	2	Bad
5	Collector's Residence - DIG Bunglow	3	Satisfactory
6	DIG Bunglow - Spencer	3	Satisfactory
7	Spencer - TMC	3	Satisfactory
8	TMC- Ambedkar Statue	3	Satisfactory
9	Ambedkar Statue - Petrol Pump	3	Satisfactory
10	Petrol Pump - Sshoka Hotel	2	Bad
11	Ashoka Hotel - Hanamakonda Chowrasta	2	Bad
	FOR ENTIRE STRETCH	**2.54**	**bad to satisfactory**

Table 20.2: Carriageway Evaluation from Hanamakonda to Warangal

S. No.	Stretch	Rating	Comment
1	Hanamakonda Chowrasta - 1000 pillar Temple	2	Bad
2	1000 pillar Temple - Alankar	2	Bad
3	Alankar - Mulugu Cross Road	2	Bad
4	Mulugu Cross Road - MGMH	3	Satisfactory
5	MGMH - Mandi Bazar	1	very bad
6	Mandi Bazar - Warangal Chowrasta	1	very bad
7	Warangal Chowrasta - Post Office	2	Bad
8	Post Office - Warangal Station	1	very bad
	FOR ENTIRE STRETCH	**1.75**	**very bad to bad**

Table 20.3: Carriageway Evaluation from Kazipet to Warangal

S. No.	Stretch	Rating	Comment
1	Kazipet – Fathimanagar Flyover	3	Satisfactory
2	Fathimanagar – 100ft Road	2	Bad
3	100ft Road – Forest Office	2	Bad
4	Forest Office – Collectors Residence	2	Bad
5	Collector's Residence – DIG Bunglow	3	satisfactory
6	DIG Bunglow – Spencer	3	satisfactory
7	Spencer – TMC	3	satisfactory
8	TMC – Ambedkar Statue	3	satisfactory
9	Ambedkar Statue – Petrol Pump	3	satisfactory
10	Petrol Pump – Ashoka Hotel	2	bad
11	Ashoka Hotel – Hanamakonda Chowrasta	2	bad
12	Hanamakonda Chowrasta – 1000 pillar Temple	2	bad
13	1000 pillar Temple – Alankar	2	bad
14	Alankar – Mulugu Cross Road	2	bad
15	Mulugu Cross Road – MGMH	3	satisfactory
16	MGMH – Mandi Bazar	1	very bad
17	Mandi Bazar – Warangal Chowrasta	1	very bad
18	Warangal Chowrasta – Post Office	2	bad
19	Post Office – Warangal Station	1	very bad
	FOR ENTIRE STRETCH	**2.21**	**bad to satisfactory**


Table 20.4: Median Evaluation from Kazipet to Warangal

S. No.	Stretch	Rating	Comment
1	Kazipet – Fathimanagar Flyover	3	satisfactory
2	Fathimanagar Flyover	5	very good
3	Fathimanagar Flyover – Fathimanagar	4	good
4	Fathimanagar – 100ft Road	3	satisfactory
5	100ft Road – Forest Office	3	satisfactory
6	Forest Office – Collectors Residence	3	satisfactory
7	Collector's Residence – DIG Bunglow	3	satisfactory
8	DIG Bunglow – Spencer	3	satisfactory
9	Spencer – TMC	3	satisfactory
10	TMC– Ambedkar Statue	4	very good
11	Ambedkar Statue – Petrol pump	3	satisfactory
12	Petrol Pump – Ashoka Hotel	3	satisfactory
13	Ashoka Hotel – Hanamakonda Chowrasta	3	satisfactory
14	Hanamakonda Chowrasta – 100 pillar Temple	2	bad
15	1000 pillar Temple – Alankar	3	satisfactory
16	Alankar – Mulugu Cross Road	3	satisfactory
17	Mulugu Cross Road – MGMH	4	good
18	MGMH – Mandi Bazar	2	bad
19	Mandi Bazar – Warangal Chowrasta	4	good
20	Warangal Chowrasta – Post Office	4	good
21	Post Office – Warangal Station	3	Satisfactory
	FOR ENTIRE STRETCH	**3.23**	**satisfactory to good**

Table 20.5: Street lighting Evaluation from Kazipet to Warangal

S. No.	Stretch	Rating	Comment
1	Kazipet – Fathimanagar Flyover	3	satisfactory
2	Fathimanagar Flyover	5	very good
3	Fathimanagar Flyover – Fathimanagar	4	good
4	Fathimanagar – 100ft Road	3	satisfactory
5	100ft Road – Forest Office	3	satisfactory
6	Forest Office – Collectors Residence	3	satisfactory
7	Collector's Residence – DIG Bunglow	3	satisfactory
8	DIG Bunglow – Spencer	3	satisfactory
9	Spencer – TMC	3	satisfactory
10	TMC- Ambedkar Statue	4	very good
11	Ambedkar Statue – Petrol Pump	3	satisfactory
12	Petrol Pump – Ashoka Hotel	3	satisfactory
13	Ashoka Hotel – Hanamakonda Chowrasta	3	satisfactory
14	Hanamakonda Chowrasta - 1000 pillar Temple	2	bad
15	1000 pillar Temple – Alankar	3	satisfactory
16	Alankar – Mulugu Cross Road	3	satisfactory
17	Mulugu Cross Road – MGMH	4	good
18	MGMH – Mandi Bazaar	2	bad
19	Mandi Bazar – Warangal Chowrasta	4	good
20	Warangal Chowrasta – Post Office	4	good
21	Post Office – Warangal Station	3	satisfactory
	FOR ENTIRE STRETCH	**3.23**	**satisfactory to good**


Table 20.6: Evaluation of various elements of Urban Road Traffic System in the study area

Item	Kazipet - Hanamakonda	Hanamakonda - Warangal	Kazipet - Warangal
Carriageway	2.54	1.75	2.21
Intersections	2.6	1.88	2.27
Roundabouts	4.00	3.66	3.88
Pedestrian facilities	2.18	1.37	1.81
Pedestrian crossings	2.75	0.72	1.85
Parking	2.09	1.62	1.89
Street lighting	3.31	3.12	3.23
Overall rating	2.55	2.77	2.16
Inference	Bad to Satisfactory	Bad to Satisfactory	Bad to Satisfactory

Note:5:Very good, 4:good, 3:Satisfactory, 2:Bad, 1:Very bad


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Toolkit on Urban Road Traffic System

Urban Road Traffic System plays a vital role in urban land use transport decision making City's efficiency largely depends upon the effectiveness of its transportation system. Road network constitutes bulk of the Transport infrastructure in most of the urban areas. Road intersections are the critical points which hamper the efficiency of network. In order to achieve sustainable transport development, there is an urgent need to give adequate emphasis to NMV facilities as well as to prioritize Mass Public Transportation systems. This toolkit helps the city officials to guide and assess the activities of consultants in planning a new network and its elements, and evaluating the existing facilities as per the design standards appropriate to India.