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GUIDELINES FOR CAPACITY OF URBAN ROADS IN PLAIN AREAS

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1. BACKGROUND

1.1. Capacity analysis is fundamental to planning, design and operation of roads. Among other things, it provides the basis for determining the number of traffic lanes to be provided for different road sections having regard to volume, composition, and other parameters of traffic. Alternatively, for an existing road network, the capacity analysis provides a means of assessing the traffic carrying ability of the number of traffic lanes provided for a given road link under the prevailing roadway and traffic conditions. Capacity standards can therefore help in rational evaluation of the investments needed for further road construction and improvements.

1.2. Initially, tentative capacity values for urban roads between junctions were recommended by the Indian Roads Congress in IRC : 86-1983. Since these recommendations were not based on actual data under Indian conditions, the formulation of realistic and appropriate capacity standards for urban roads was long felt to be a critical need by the practising engineers.

1.3. In the last few years, further studies on this subject have been carried out in the country which have improved the state of knowledge and yielded relevant data regarding urban road capacity. Based on that, it has been possible for the Traffic Engineering Committee of the IRC to come up with these fresh guidelines for general use.

1.4. These guidelines were considered by the Traffic Engineering Committee (personnel given below) in their meeting held at New Delhi on the 27th March, 1990 and approved subject to further amendments to the guidelines to be carried out by Sub-group comprising Shri R.P. Sikka, Convenor and Shri M.K. Bhalla, Dr. A.C. Sarna, Dr. L.R. Kadiyali and Dr. P.K. Sikdar as members. The modified guidelines finalised by the above Sub-group on behalf of the Traffic Engineering Committee was placed before the Highways Specifications & Standards Committee.

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1.5. The modified draft was subsequently considered and approved by Highways Specifications and Standards Committee, the Executive Committee and the Council of the IRC at their meetings held on the 16th April, 1990, 20th March, 1990 and the 29th April, 1990 respectively.

2. SCOPE

2.1. The guidelines contained in this publication are applicable essentially to mid-block sections of urban roads, i.e. road lengths between junctions. The guidelines will also apply to roads in suburban areas. However, these are not directly relevant to urban expressways.

2.2. For the design of various other geometric features of urban road sections, including guidelines for determining the capacity of sidewalks and cycle tracks in urban areas, it is recommended that IRC : 86-1983 "Geometric Design Standards for Urban Roads in Plains", IRC : 69-1977 "Space Standards for Roads in Urban Areas", and IRC : 103-1988 "Guidelines for Pedestrian Facilities" may be referred to.

3. CLASSIFICATION OF URBAN ROADS

3.1. Roads in urban areas can be classified either on the basis of the number of lanes provided within an undivided/divided cross-section, or in accordance with their functions in the total urban road network.

3.2. An undivided urban road is one which permits traffic flow in both directions without segregating the directional movements by means of some physical divider, such as a central verge or median. A divided urban road, on the other hand, is one where the traffic in two directions moves in segregated lanes because of the presence of a physical divider. Undivided urban roads are termed as 2-lane undivided, 4-lane undivided or 6-lane undivided depending upon the number of lanes available for the use of traffic. Similarly, the divided roads are known as 4-lane divided, 6-lane divided or 8-lane divided urban roads in accordance with the number of traffic lanes available.

3.3. Functional classification of urban roads is based on the hierarchy of the urban roads in the total urban road network. Besides the Freeways and Expressways, urban roads can be classified into the following four main categories :

- Arterial
- Sub-arterial
- Collector Street
- Local Street

3.4. Definitions of each of the above categories are as under :

(i) **Arterial** : A general term denoting a street primarily for through traffic, usually on a continuous route.

(ii) **Sub-arterial** : A general term denoting a street primarily for through traffic usually on a continuous route but offering somewhat lower level of traffic mobility than the arterial.

(iii) **Collector Street** : A street for collecting and distributing traffic from and to local streets and also for providing access to arterial streets.

(iv) **Local Street** : A street primarily for access to residence, business or other abutting property.

3.5. Functions of different categories of urban roads (as reproduced from IRC : 86-1983) are given below :

(i) **Arterials** : This system of streets, alongwith expressways where they exist, serves as the principal network for through traffic flows. Significant intra-urban travel such as between central business district and outlying residential areas or between major suburban centres takes place on this system. Arterials should be coordinated with existing and proposed expressway systems to provide for distribution and collection of through traffic to and from sub-arterial and collector street systems. Continuity is essential for arterials also to ensure efficient movement of through traffic. A properly developed and designated arterial street system would help to identify residential neighbourhoods, industrial sites and commercial areas. These streets may generally be spaced at less than 1.5 km in highly developed central business areas and at 8 km or more in sparsely developed urban fringes. The arterials are generally divided highways with full or partial access. Parking, loading and unloading activities are usually restricted and regulated. Pedestrians are allowed to cross only at intersections.

(ii) **Sub-arterials** : These are functionally similar to arterials but with somewhat lower level of travel mobility. Their spacing may vary from about 0.5 km in the central business district to 3-5 km in the sub-urban fringes.

(iii) **Collector Streets** : The function of collector streets is to collect traffic from local streets and feed it to the arterial and sub-arterial streets or vice-versa. These may be located in residential neighbourhoods, business areas and industrial areas. Normally, full access is allowed on these streets from abutting properties. There are few parking restrictions except during the peak hours.

(iv) **Local Streets** : These are intended primarily to provide access to abutting property and normally do not carry large volumes of traffic. Majority of trips in urban areas either originate from or terminate on these streets. Local streets may be residential, commercial or industrial, depending on the predominant use of the adjoining land. They allow unrestricted parking and pedestrian movements.

4. CAPACITY-RELATED DEFINITIONS

4.1. An understanding of concept of highway capacity is facilitated through a clear definition of certain terms.

4.2. **Speed** is the rate of motion of individual vehicles of a traffic stream. It is measured in metres per second, or more generally as kilometres per hour. Two types of speed measurements are commonly used in traffic flow analysis; viz. (i) Time mean speed and (ii) Space mean speed. For the purpose of these guidelines, the speed measure used is "Space mean speed".

4.3. **Time Mean Speed** is the mean speed of vehicles observed at a point on the road over a period of time. It is the mean spot speed.

4.4. **Space Mean Speed** is the mean speed of vehicles in a traffic stream at any instant of time over a certain length (space) of road. In other words, this is average speed based on the average travel time of vehicles to traverse a known segment of roadway. It is slightly less in value than the time mean speed.

4.5. **Volume (or flow)** is the number of vehicles at a given point on the road during a designated time interval. Since roads have a certain width and a number of lanes are accommodated in that width, flow is always expressed in relation to the given width (i.e. per lane or per two lanes etc.). The time unit selected is an hour or a day. ADT is the Average Daily Traffic when measurements are taken for a few days. AADT is the Annual Average Daily Traffic when measurements are taken for 365 days of the year and averaged out.

4.6. **Density (or concentration)** is the number of vehicles occupying a unit length of road at an instant of time. The unit length is generally one kilometre. Density is expressed in relation to the width of the road (i.e. per lane or per two lanes etc.). When vehicles are in a jammed condition, the density is maximum. It is then termed as the jamming density.

4.7. **Capacity** is defined as the maximum hourly volume (vehicles per hour) at which vehicles can reasonably be expected to traverse a point or uniform section of a lane or roadway during a given time period under the prevailing roadway, traffic and control conditions.

4.8. **Design Service Volume** is defined as the maximum hourly volume at which vehicles can reasonably be expected to traverse a point or uniform section of a lane or roadway during a given time period under the prevailing roadway, traffic and control conditions while maintaining a designated level of service.

4.9. **Peak Hour Factor** is defined as the traffic volume during peak hour expressed as a percentage of the AADT. The peak hour volume in this case is taken as the highest hourly volume based on actual traffic counts.

5. LEVEL OF SERVICE (LOS)

5.1. Capacity standards are fixed normally in relation to the Level of Service (LOS) adopted for the design. Level of Service is defined as a qualitative measure describing operational conditions within a traffic stream, and their perception by drivers/passengers.

5.2. Level of Service definition generally describes these conditions in terms of factors such as speed and travel time, freedom to manoeuvre, traffic interruptions, comfort, convenience and safety. Six levels of service are recognised commonly, designated from A to F, with Level of Service A representing the best operating condition (i.e. free flow) and Level of Service F the worst (i.e. forced or break-down flow). On urban roads, the Level of Service is affected strongly by factors like the heterogeneity of traffic, speed regulations, frequency of intersections, presence of bus stops, on-street parking, roadside commercial activities, pedestrian volumes etc. This renders the Level of Service concept for urban roads somewhat different than the rural roads.

5.3. Fig. 1 shows the various levels of service in the form of indicative volume-flow relationship for urban conditions. Each of the levels can be described broadly as under

Level of Service A : Represents a condition of free flow with average travel speeds usually about 90 per cent of the free-flow speed for the arterial class. Individual users are virtually unaffected by the presence of others in the traffic stream. Freedom to select desired speeds and to manoeuvre within the traffic stream is high. The general level of comfort and convenience provided to the road users is excellent.

Level of Service B : Represents a zone of stable flow, with the drivers still having reasonable freedom to select their desired speed and manoeuvre within the traffic stream. Average travel speeds are usually about 70 per cent of the free flow speed for the arterial class.

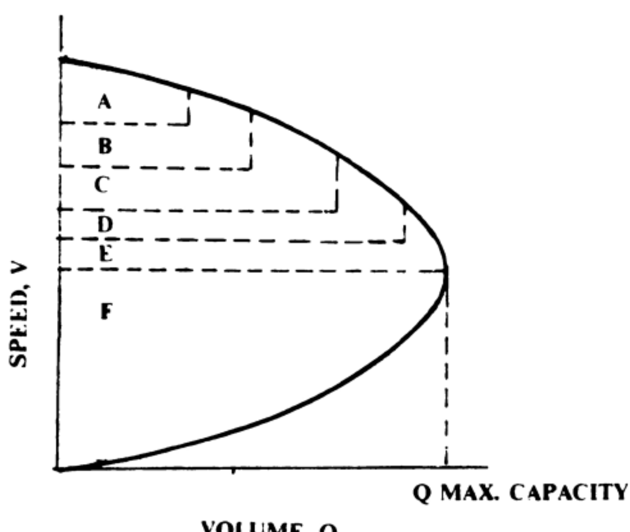

Fig 1. Speed,volume curve showing levels of service

Level of comfort and convenience provided is somewhat less than Level of Service A, because the presence of other vehicles in the traffic stream begins to affect individual behaviour.

Level of Service C : This also is a zone of stable flow, but marks the beginning of the range of flow in which the operation of individual users becomes significantly affected by interactions with others in the traffic stream. The selection of speed is now affected by the presence of others, and manoeuvring within the traffic stream requires substantial vigilance on the part of the user. The general level of comfort and convenience declines noticeably at this level. Average travel speeds are about 50 per cent of the average free flow speed.

Level of Service D: Represents the limit of stable flow, with conditions approaching close to unstable flow. Due to high density, the drivers are severely restricted in their freedom to select desired speed and manoeuvre within the traffic stream. The general level of comfort and convenience is poor. Small increases in traffic flow will usually cause operational problems at this level. Average travel speeds are about 40 per cent of free flow speed.

Level of Service E : Represents operating conditions when traffic volumes are at or close to the capacity level. The speeds are reduced to a low, but relatively uniform value, average value being one-third the free flow speed. Freedom to manoeuvre within the traffic stream is extremely difficult, and is generally accomplished ley forcing a vehicle to give way to accommodate such manoeuvres. Comfort and convenience are extremely poor, and driver frustration is generally high. Operations at this level are usually unstable, because small increases in flow or minor disturbances within the traffic stream will cause breakdowns.

Level of Service F : Represents zone of forced or breakdown flow. This condition occurs when the amount of traffic approaching a point exceeds the amount which can pass it. Queues form behind such locations. Operations within the queue are characterised by stop-and-go waves, which are extremely unstable. Vehicles may progress at a reasonable speed for several hundred metres and may then be required to stop in a cyclic fashion. Due to high volumes, break-down occurs, and long queues and delays result. The average travel speeds are between 25 per cent and 33 per cent of free flow speed.

6. DESIGN CRITERIA FOR URBAN ROADS

6.1. Unlike rural roads, the hourly variation of traffic on urban roads has at least two distinct peaks, viz. during the morning and evening hours of the day. Further, traffic fluctuates more on urban roads than on rural roads. The urban peak hour traffic constitutes about 8-10 per cent of the total daily traffic depending on various factors including the importance of the road in the network. During peak times, unidirectional traffic is also observed on several roads in urban areas. These factors coupled with other urban characteristics make it necessary to design the urban roads on the basis of peak hour traffic rather than average daily traffic (ADT) as in the case of rural roads.

6.2. On two-way undivided roads, the traffic carrying capacity is relatively independent of the directional distribution of traffic and design is based on two-way total flows. On dual or divided carriageways, the capacity is dependent on directional split of traffic flow and the design should therefore be based on peak hour traffic in the busier direction of travel. To determine the peak hour factor, it is usual to conduct traffic counts for 16-hour day (6 A.M. to 10. P.M.) in order to capture all the peaks.

6.3. While applying the design criteria, the past and present traffic counts and considerations of future development of urban area must be kept in view. Estimation of future traffic volumes may be done either on basis of projection of current volumes related to past trends, or using results of transportation studies considering the changes in land use and socio-economic factors. The future traffic volumes should be projected upto the end of design life of the road. A design period of 15-20 years should be adopted for arterials and sub-arterials, and 10-15 years for collector and local streets.

7. PASSENGER CAR UNITS

7.1. Urban roads are characterised by mixed traffic conditions, resulting in complex interaction between various kinds of vehicles. To cater to this, it is usual to express the capacity of urban roads in terms of a common unit. The unit generally employed is the 'Passenger Car Unit, (PCU), and each vehicle type is converted into equivalent PCUs based on their relative interference value.

7.2. The equivalent PCUs of different vehicle categories do not remain constant under all circumstances. Rather, these are a function of the physical dimensions and operational speeds of respective vehicle classes. In urban situations, the speed differential amongst different vehicle classes is generally low, and as such the PCU factors are predominantly a function of the physical dimensions of the various vehicles. Nonetheless, the relative PCU of a particular vehicle type will be affected to a certain extent by increase in its proportion in the total traffic. Considering all these factors, the conversion factors as shown in Table 1 are recommended for adoption.

TABLE 1. RECOMMENDED PCU FACTORS FOR VARIOUS TYPES OF VEHICLES ON URBAN ROADS

Vehicle Type	Equivalent PCU Factors	
	Percentage composition of Vehicle type in traffic stream	
	5%	10% and above
Fast Vehicles		
1. Two wheelers Motor cycle or scooter etc.	0.5	0.75
2. Passenger car, pick-up van	1.0	1.0
3. Auto-rickshaw	1.2	2.0
4. Light commercial vehicle	1.4	2.0
5. Truck or Bus	2.2	3.7
6. Agricultural Tractor Trailer	4.0	5.0
Slow Vehicles		
7. Cycle	0.4	0.5
8. Cycle rickshaw	1.5	2.0
9. Tonga (Horse drawn vehicle)	1.5	2.0
10. Hand cart	2.0	3.0

8. RECOMMENDED DESIGN SERVICE VOLUMES

8.1. Considering the need for smooth traffic flow, it is not advisable to design the road cross-sections for traffic volumes equal to the maximum capacity which will become available normally at LOS E. At that LOS, the speeds are rather low and freedom to manoeuvre within the traffic stream is very much restricted. Besides, even a small increase in traffic at that traffic volume would lead to forced flow situation and breakdowns within the traffic stream. On the other hand, adoption of a higher level of service like A or B, although enabling near free flow conditions would mean lower design service volumes necessitating higher number of traffic lanes to carry a specified traffic volume with implicit higher facility cost. As a compromise solution, it is recommended that normally LOS C be adopted for design of urban roads. At this level, volume of traffic will be around 0.70 times the maximum capacity and this is taken as the "design services volume" for the purpose of adopting design values.

8.2. Capacity of urban roads is also a function of the roadside fringe conditions, e.g. parking, extent of commercial activities, frontage access etc. For purpose of recommendations given furtheron, the following fringe conditions are assumed :

(a) Arterials : No frontage access, no standing vehicles, very little cross traffic

(b) Sub-arterials : Frontage development, side roads, bus stops, no standing vehicles, waiting restrictions.

(c) Collectors : Free frontage access, parked vehicles, bus stops, no waiting restrictions.

8.3. Design service volumes for different categories of urban roads corresponding to above referred conditions are given in Table 2.

TABLE 2. RECOMMENDED DESIGN SERVICE VOLUMES (PCUs PER HOUR)

S. No.	Type of carriageway	Total Design Service Volumes for Different Categories of Urban Roads		
		Arterial*	Sub-arterial**	Collector***
1.	2-Lane (One-Way)	2400	1900	1400
2.	2-Lane (Two-Way)	1500	1200	900
3.	3-Lane (One-Way)	3600	2900	2200
4.	4-Lane Undivided (Two-Way)	3000	2400	1800
5.	4-Lane Divided (Two-Way)	3600	2900	—
6.	6-Lane Undivided (Two-Way)	4800	3800	—
7.	6-Lane Divided (Two-Way)	5400	4300	—
8.	8-Lane Divided (Two-Way)	7200	—	—

* : Roads with no frontage access, no standing vehicles, very little cross traffic.

** : Roads with frontage access but no standing vehicles and high capacity intersections.

*** : Roads with free frontage access, parked vehicles and heavy cross traffic.

8.4. Design service volumes as given in Table 2 assume that the functional classification of roads into arterial, sub-arterial and collector categories, strictly conforms to the fringe conditions indicated in Clause 8.2 above. Where, however, the fringe conditions do not conform to the stated assumptions, the design service volumes may be modified in accordance with the prevailing conditions. In other words, where a road is functionally arterial road, but prevailing fringe conditions correspond to 'sub-arterial' or 'collector', the values indicated for the latter will apply, and vice-versa.

9. MEASURES FOR IMPROVING THE CAPACITY OF URBAN ROADS

9.1. In the event of traffic on a road section exceeding the design service volume at the desired level of service, the operating conditions will deteriorate. If so, the available practical capacities can be improved through application of traffic engineering techniques besides better enforcement.

9.2. Some of the measures that could be considered for enhancement of capacity are as under :

(i) Prohibiting on-street parking of vehicles, and simultaneously developing off-street parking facilities;

(ii) Segregating the bi-directional traffic flow through central verge/median;

(iii) Provision of segregated right-of-way for slow moving vehicles such as animal drawn carts, rickshaws/tongas etc.;

(iv) Imposing restrictions on the movement of animal drawn/other slow moving vehicles, and/or heavy commercial vehicles on busy arterial/sub-arterials during selected periods, specially the peak hours;

(v) Reduction of roadside friction through control of abutting land-use and roadside commercial activity;

(vi) Provision of adequate facilities for pedestrians and cycles;

(vii) Banning certain conflicting movements at major intersections, particularly during peak hours;

(viii) Controlling the cross traffic and side-street traffic by regulating the gaps in medians; and

(ix) Improving traffic discipline such as proper lane use and correct overtaking, through appropriate road markings, education and publicity.