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GUIDELINES FOR THE DESIGN OF INTERCHANGES IN URBAN AREAS

(First Revision)

INDIAN ROADS CONGRESS
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GUIDELINES FOR THE DESIGN OF INTERCHANGES IN URBAN AREAS

1 INTRODUCTION

The Guidelines for the design of interchanges in urban areas was first published in 1985. The document helps designers, engineers, planners in developing appropriate solutions to urban traffic problem by designing interchanges for different situations in urban areas to facilitate fast and smooth motorised traffic.

Since last decade, traffic in urban areas has witnessed a significant growth and also its consequences on safety. Furthermore, the National Urban Transport Policy, formulated by the Ministry of Housing and Urban Affairs (MoHUA) emphasizes that our focus should be on movement of people, rather than vehicle alone. Therefore, need for a new comprehensive guideline has arisen so as to include the recent advancement.

Accordingly, the task was assigned to Urban Roads and Street Committee (H-8) of during tenure 2015-18. The H-8 Committee in its meeting held on 20th May, 2015 decided to revise this document to include the recent advancement and make it more comprehensive. Initial draft was prepared by Sub-group headed by Dr. Sewa Ram, Professor, SPA, comprising Ms. Ammu Gopalakrishnan and Dr. Mayank Dubey. This draft was discussed and deliberated at length in numerous meeting of H-8 Committee. Other than H-8 Committee members valuable inputs were received from Ms. Sonal Shah, ITDP; Ms. Aparna Vijaykumar, Mr. Parin Visariya, Mr. Amit Bhatt, WRI and Dr. Sanjay Wakchaure, MoRTH. The H-8 Committee finally approved the draft document in its meeting held on 20th May, 2017 for placing before the HSS Committee.

The composition of the H-8 Committee is given below:

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The Highways Specifications & Standards Committee (HSS) considered and approved the draft document in its meeting held on 23rd June, 2017. The Executive Committee in its meeting held on 13th July, 2017 considered and approved the same document for placing it before the Council. The Council in its 212th meeting held at Udaipur on 14th July, 2017 considered and approved the draft IRC:92 "Guidelines for Traffic Interchanges" (*First Revision*) for printing.

Grade separated intersection or road interchange is fundamentally a crossing of two or more roadways at different levels to meet its prerequisite. Interchanges are predominantly used to carry fast moving motorized traffic, to decongest an at-grade intersection or to segregate the conflicting movements of an intersection, thus improving its operational efficiency.

Type of interchange, shape and pattern of the interchange ramps, planning considerations, geometric design factors, composition of traffic, capacity, speed, right of way, cost, safety, topography, environmental factors etc. varies from site to site. Interchanges, therefore, are necessarily designed individually in light of the above considerations. This publication provides guidelines for planning and developing appropriate designs for interchanges under different situations in urban areas.

2 SCOPE

The revised guidelines are applicable mainly for urban roads. But in some case, non-urban roads also have been included and guidelines may be followed.

3 GLOSSARY OF TERMS

Some of the key terms in planning and design considerations of urban traffic interchanges are given below:

- **Auxiliary Lane or Operational Lane:** An extra lane provided between interchanges, giving motorists more time to merge in or out. The lane is created when an entrance ramp meets the highway, and drops out (“exit only”) with the exit ramp.
- **Braid Interchange:** A design feature where two nearly parallel ramps must cross each other and use a grade separation to avoid weaving or crossing. Most often this occurs when an on-ramp from one nearby interchange is braided to avoid interfering with an off-ramp for the next one. **Fig. 3.1** shows a typical Braid Interchange.
- **Buttonhook Ramp or Hook Ramp:** J-shaped ramp that connects to a parallel or diagonal street or frontage road, which is often well removed from the interchange structure and other ramps. **Fig. 3.2** shows a typical Buttonhook ramp or Hook ramp.
- **Basic Lanes:** The minimum number of lanes designated and maintained over a significant length of route, irrespective of changes in traffic volume and the requirements of lane balance.
- **Candela (cd):** The unit of luminous intensity.
- **Candlepower (cp):** Luminous intensity expressed in Candelas. It is not an indication of total light output.
- **Cloverleaf Interchange:** A form of interchange that provides indirect right-turn movements in all four quadrants by means of loops. Generally used where the turning and weaving volumes are relatively low. This type of interchange eliminates all crossing conflicts found in a diamond interchange but requires more area. The cloverleaf type of interchange can have one or two points of entry and exit on each through roadway. The complete implementation, using eight ramps, is also called a full cloverleaf. **Fig. 3.3** shows typical Cloverleaf interchange.
- **Co-efficient of Utilization (cu):** The ratio of the luminous flux (lumens) from the lantern received on the surface of the roadway to the lumens emitted by the lantern lamp alone.

- **Collector–Distributor Road:** An auxiliary road separated laterally from, but generally parallel to a through road and joining it at a limited number of points. The road serves to collect traffic from and distribute traffic to several local roads.
- **Complete Interchange:** An interchange providing enough ramps to provide access for all possible traffic movements is known as a Complete Interchange. A complete interchange between expressway and any other road (not an expressway) requires at least four ramps. Four ramps are required for each crossing of roads. Thus, complete interchanges between two expressways require at least eight ramps and a five-way complete interchange would require twenty ramps.
- **Design Traffic Volume:** The number of vehicles usually expressed as an hourly volume estimated to use the road or element of the interchange in the design year.
- **Design Year:** Design year is the year for which the interchange is designed to operate acceptably under traffic volumes likely at that time. It is generally 20 years beyond the scheduled year of opening of the interchange.
- **Directional Interchange:** An interchange, generally between two travel lanes, providing direct travel for some or all right turn movements.
- **Diverge:** An area at a split of two carriageways other than an exit.
- **Diamond:** A basic four-ramp interchange between an expressway and a surface road. The four diagonal ramps, one in each quadrant, suggest a diamond shape.
- **Diverging Diamond Interchange:** This is similar to a traditional diamond interchange, except that it uses directional lanes for the non-highway to cross over each other on either side of the highway, altering the direction of travel on the over/underpass through the use of traffic lights. This allows all turns to and from the highway to be made without crossing the opposite direction of travel, increasing the capacity when compared to a typical diamond interchange. **Fig. 3.4** shows a typical Diverging Diamond Interchange.
- **Double Trumpet:** A double-trumpet interchange version can be provided where a toll road meets another toll road or a free highway. They are also useful when most traffic on the terminating highway is going the same direction. The turn that isn't used often would get the slower loop ramp. **Fig. 3.5** shows a typical Double Trumpet Interchange.
- **Entry:** The path where an entry ramp joins a ramp or through carriageway.
- **Exit:** The path where an exit ramp leaves a ramp or through carriageway.
- **Flyover:** A bridge over another road for allowing traffic without interruption with its approaches on both sides is known as Flyover.
- **Frontage Road:** A road contiguous with, and generally parallel to the major road, designed to provide an access and/or a traffic movement for local traffic.

- **Gore:** The area bounded by the edge of two carriageways immediately beyond the divergence of those carriageways.
- **Grade Separation:** The separations of road, rail or any other traffic so that crossing movements which would otherwise conflict are affected at different elevations. (Also refer to “underpass” and “overpass”).
- **Half Diamond Interchange:** An interchange with only two diagonal ramps, one entrance and one exit, in adjacent quadrants. This interchange serves traffic to and from one direction along the expressway, but ignores the other.
- **Interchange:** A grade separation of two or more roads with one or more interconnecting roadways is called as an Interchange.
- **Interchange Spacing:** It is the distance measured along the main roadway between the center lines of the intersecting roadways that maintain ramp access to the through highway.
- **Lantern:** A complete unit consisting of lamp, choke, capacitor together with the parts designed to distribute the light, to position and protect the lamp and to connect the lamp to power supply.
- **Level of Service:** A quality measure describing operational conditions within a traffic stream, generally in terms of such service measures as speed and travel time, freedom to manoeuvre, traffic interruptions, comfort and convenience.
- **Lighting Unit:** Assembly of light pole & lantern.
- **Loop:** A ramp where traffic changes direction by 90° by means of a 270° turn.
- **Lumen:** The unit of luminous flux.
- **Luminance (photometric brightness):** Brightness of any diffusively reflecting surface illuminated at a density of luminous flux.
- **Lux (lx):** SI unit of illumination on a surface of one square meter in area from a uniform source of candela intensity or equal to one lumen per square meter.
- **Luminous Flux:** Total light radiated by a light source as evaluated photo metrically.
- **Maintenance Factor:** Ratio of average illumination on the working area, given by a new installation to that of an installation with decreased effectiveness due to dust, ageing of lamp, etc.
- **Merge:** The area at a junction of two carriageways other than at an entry ramp.
- **Multilevel Interchange:** An interchange with mutually crossing carriageways at three or more different levels.
- **Overpass:** A grade separation where the subject carriageway passes over an intersecting carriageway or railway.

- **Partial Cloverleaf:** Partial cloverleaf or parclos, involve fewer ramps. The popular six-ramp version provides two exit ramps (with left turns at the end) and four entrance ramps (all right turns). Many four-ramp parclos may be called folded diamonds, as they serve the same traffic movements as a conventional diamond.
- **Quadrant:** One of four slices of land created when two roads intersect.
- **Ramp:** Carriageway within an interchange provided for travel between two legs of the intersecting roads.
- **Roundabout Interchange/Bridged Rotary Interchange:** A roundabout interchange is a type of interchange between a controlled access and a minor road. The slip roads to and from the carriageways converge at a single roundabout, which is grade-separated from the carriageway lanes with bridges. **Fig. 3.6** shows a Roundabout or Bridged Rotary Interchange.
- **Service Interchange:** An interchange that does not maintain free-flow through its elements for all major movements.
- **Single Point Urban Interchange (SPUI) or Single-Point Diamond Interchange:** A type of diamond where the diagonal ramps are placed as close as possible parallel to the expressway, so that ramp traffic in effect meets at a single point on the surface road directly below (or above) the expressway. **Fig. 3.7** shows a Single Point Urban or Single Point Diamond Interchange.
- **Slip Ramp:** A diagonal ramp, more properly called a cross connection, which connects with a parallel frontage road.
- **Split-level Diamond Interchange:** This interchange is better known as the 3-level diamond or volleyball interchange. All turning movements are managed in an intermediate square structure connecting the eight ramps. Turning traffic travels around the square in the same direction as a roundabout. Through traffic can proceed on either intersecting road without stopping. **Fig. 3.8** shows a typical Volleyball Interchange.
- **Stack Interchange:** A four-level semi-directional interchange with no loop ramps, typically serving two high-traffic expressways. **Fig. 3.9** shows a typical Stack Interchange.
- **Surface Road:** A surface road allows access by traffic signal or stop sign, or allows turns across opposing traffic.
- **System Interchange:** An interchange that maintains free-flow through its elements for all major movements.
- **Turning Roadway:** A carriageway, usually one-way, at an intersection or interchange for turning vehicles.
- **Trumpet Interchange:** A three-way interchange with no crossing movements, featuring one 270-degree loop ramp opposite the terminating roadway, and

a semi-directional ramp following the loop to the outside. **Fig. 3.10** shows a typical Trumpet Interchange.

- **Underpass:** A grade separation where the subject carriageway passes under an intersecting carriageway or railway.
- **Uninterrupted Flow:** A condition in which a vehicle travelling in a traffic stream is not required to stop or slow down for reasons other than those caused by the presence of other vehicles in that stream.
- **Weaving:** The movement in the same direction of vehicles within two or more traffic streams intersecting at a small angle so that the vehicles in one stream cross other streams gradually.
- **Transit:** The change in travel mode, in which vehicles (including buses, streetcars, and street-running light rail) stop at regular intervals along the roadway to pick up and drop off passengers.

Below **Figs.** from **3.1** to **3.10** shows live examples of diverse types of interchanges across the world.

Fig. 3.1 Braid Interchange

Fig 3.2 Buttonhook Ramp or Hook Ramp

Fig. 3.3 Cloverleaf Interchange

Fig 3.4 Diverging Diamond Interchange

Fig. 3.5 Double Trumpet Interchange

Fig. 3.6 Rotary Interchange

Fig. 3.7 Single Point Urban or Single Point Diamond Interchange

Fig. 3.8 Split-level Diamond Interchange

Fig. 3.9 Stack Interchange

Fig. 3.10 Trumpet Interchange

4 PLANNING CONSIDERATIONS FOR INTERCHANGE

The selection of a particular interchange depends on the following planning considerations. These parameters are discussed in detail in the following sub-sections.

4.1 Land Availability

Approximate land requirements of interchanges are as presented in **Table 4.1**.

Table 4.1 Approximate Land Requirements of Interchanges in Square Meters

	Category	Approximate land required in square meters
1	Trumpet Interchange	44,000
2	Diamond Interchange	28,000
3	Full Cloverleaf	73,000
4	Bridged Rotary	1,80,000

4.2 Interchange Spacing

Interchange spacing is an important consideration in the planning and design of new or modified interchanges. Interchange spacing is the distance measured along the main roadway between the centre lines of the intersecting roadways that maintain ramp access to the through highway. The spacing is intended to minimize the disruption of entering and exiting traffic to the mainline of the highway and to prevent insufficient sign spacing.

In urban areas, there should be a 1.6 km minimum spacing between interchanges to allow sufficient space for entrance and exit manoeuvres. Closer spacing may require the use of collector-distributor roads to remove the merging/diverging and accelerating/decelerating traffic from the expressway. In rural, undeveloped areas, interchanges should be spaced at more than 4.8 km apart.

4.3 Access Control

A proposed new or revised interchange access must connect to an expressway, highway, road, or street. Access control is established to preserve the safety and efficiency of specific road and to preserve the public investment.

The numbers of access points are determined by the:

- Functional classification of interchange
- Characteristics of the traffic
- Current and future land use
- Environment and aesthetics
- Highway design and operation
- Economic considerations

4.4 Landuse

Interchange areas attract almost all types of land development. Each land use type namely; commercial, residential, industrial and recreational etc finds desirable features in interchange locations. Following are the major factors that may influence decisions to locate at an interchange:

(i) The market or demand for the use and the land;
(ii) The physical characteristics of the site including infrastructure; and
(iii) Local objectives as embodied in plans, policies and regulations.

Each potential land use should be considered in terms of these factors.

4.5 Warrants

Interchanges and grade separations occur when two or more roadways required to cross at different levels. In many instances, the decision to provide a grade-separated intersection should be made based on careful consideration of a number of factors. These factors are referred to as warrants and include the following:

4.5.1 *Design Consideration*

Once it is decided to develop routing as an expressway, it should be determined whether each intersecting highway/road will be terminated, rerouted, or provided with a grade separation or interchange. The chief concern is providing continuous flow on the expressway.

4.5.2 *Safety*

The crash reduction benefits of an interchange may warrant its selection particularly on an at-grade intersection prone to accidents.

4.5.3 *Congestion*

An interchange may be warranted where the level of service of an at-grade intersection is unacceptable and the intersection cannot be modified to provide an acceptable level of service.

4.5.4 *Site Topography*

At certain sites, a grade separated intersection may be more feasible than an at-grade intersection due to local topography.

4.5.5 *Traffic Volume*

Interchanges are desirable at cross roads with heavy traffic volumes. The elimination of conflicts due to high crossing volume greatly improves the movement of traffic.

4.5.6 *Road-User Benefits*

When interchanges are designed and operated efficiently, they significantly reduce the travel time and costs when compared to at-grade intersections. Therefore, an interchange is warranted if an analysis reveals that road-user benefits will exceed the costs over the service life of the interchange.

Hence, for a thumb-rule, following postulates can be taken as guiding principle conceptualising a traffic interchange:

- At all crossings of highway of the major hierarchy to be developed as fully access controlled.
- At all major crossings on highways to be developed to expressway standards.
- At the crossing of a major arterial road with another road of similar category carrying heavy traffic.
- When an at-grade intersection fails to cater the volume of traffic resulting in congestion and frequent blockage at the intersection e.g., when total traffic of all the arms of intersection exceeds 10,000 PCU per hour.
- High rate of fatal accidents at an at-grade intersection in spite of other traffic control or improvement measures.
- When the topography is such that interchange is the only alternative that can be constructed economically.

5 TYPES OF INTERCHANGES

Interchanges can be broadly classified as:

- **System interchange:** An interchange that maintains free-flow through its elements for all major movements. System interchanges mainly connects from major road to major road. A major road typically refers to an expressway, major highway or major arterial road that does not contain at-grade intersections.
- **Service interchange:** An interchange that does not maintain free-flow through its elements for all major movements. Service interchanges mainly connects from major road to minor road. A minor road typically refers to a highway, arterial or sub-arterial road that contains at-grade intersection.

Based upon partial and complete grade separation along with number of arms, interchanges can also be classified as:

i. 3-arm Partially Grade Separated
ii. 3-arm Totally Grade Separated
iii. 4-arm Partially Grade Separated
iv. 4-arm Totally Grade Separated

The common geometric configurations of interchanges are the trumpet, diamond, cloverleaf, rotary and directional interchanges. Within each type of interchanges, there can be several variations such as split diamond, partial cloverleaf etc. depending on the ramp arrangements. The broad operational characteristics of each of the common interchange types are brought out in this section.

5.1 Trumpet Interchange

Fig. 5.1, shows a typical 3-leg interchanges which takes the shape of trumpet. This is the simplest interchange form adaptable to 'T' or 'Y' intersections. Of the two right turning movements, one is negotiated by a loop while the other is by a semi-direct connection. Diagonal ramps are provided for left turning movements. There can be several variations of the design depending on the type of connection provided. The type of connection provided for the right turning movements should be based on traffic volumes. The ramps catering for heavy traffic volumes should preferably be provided with direct connections.

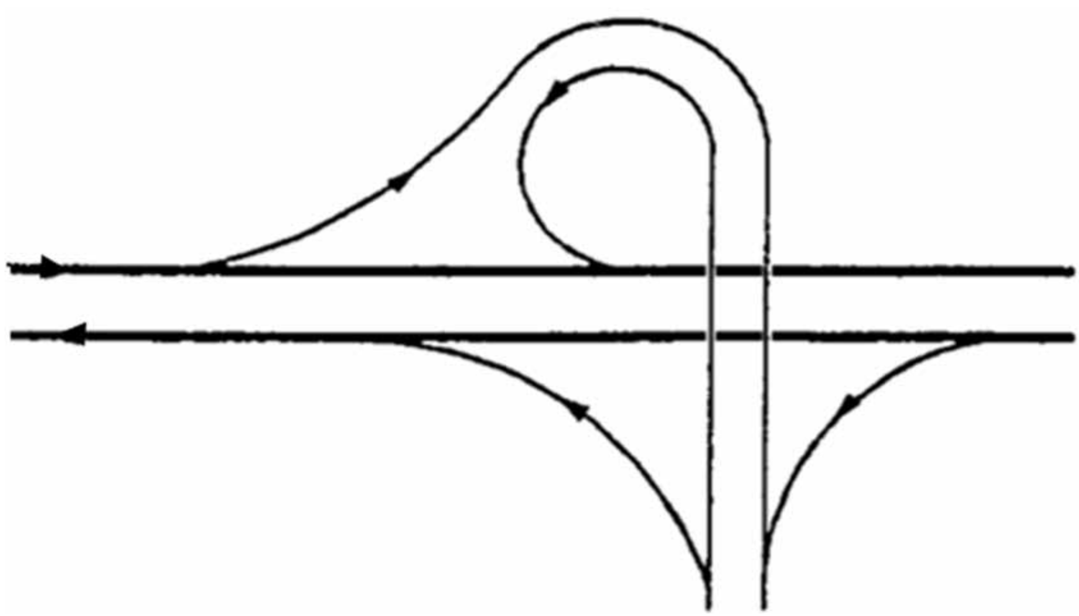

Fig. 5.1 Typical 3-leg Interchange

5.2 Diamond Interchange

Fig. 5.2 shows a typical diamond interchange. Diamond interchange is the simplest of 4-leg interchange designs and is particularly adaptable for major-minor highway intersections. The ramps which provide for one-way movement are usually elongated along the major highway and may be curved or parallel to the major highway. The ramp terminals on the minor road are the at-grade intersections providing for right and left turning movements. These at-grade intersections may be controlled by signals if warranted by traffic volumes or in the absence of adequate sight distance.

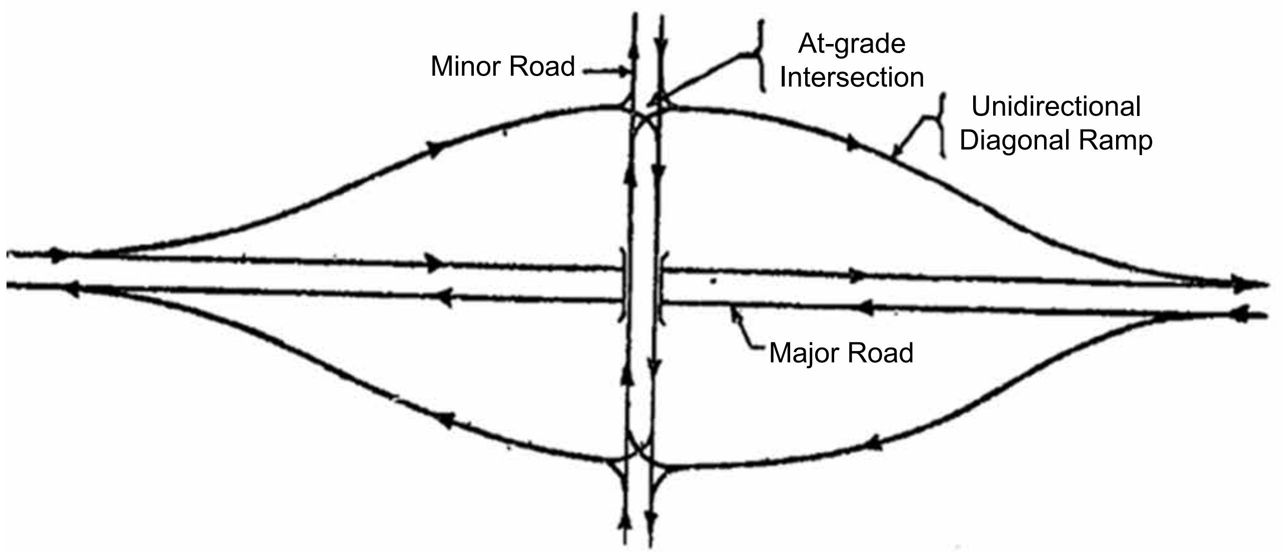

Fig. 5.2 Diamond Interchange

The diamond design requires minimum land, involves only a small extra travel distance for right turning traffic, is the least costly, and will be found ideal for most of the cases both in urban and rural areas. However, this type of interchange has the demerit of limited capacity because of the at-grade terminals on the minor road. The situation can be improved by widening the cross road through the interchange area, or the ramp terminals or both. Further improvements can be effected by having a split diamond or 3-level diamond, but this will involve more than one bridge.

5.3 Cloverleaf Interchange

Fig. 5.3 shows a typical full cloverleaf interchange. The design consists of one loop ramp for right turning traffic and one outer connection for left turning traffic in each quadrant. Vehicles desiring to turn right are required to turn left through about 270 degrees before attaining the desired direction.

This type of interchange provides for continuous movement to all interchanging traffic and is particularly suitable for the crossing of two major roads of equal importance in rural areas. In urban areas, this type of interchange tends to use up too much of costly urban space.

Cloverleaf design involves appreciable extra level distance for the right moving traffic and required a large space. Though all crossing movements conflicts are eliminated, a weaving section is created between the exit and entry points near the structure along each direction of travel on the intersection roads. These weaving sections constitute a critical element in the design, and unless these are designed to have adequate length and capacity, there may be serious loss in capacity besides increased hazards.

In cases where at-grade crossing on one of the roads can be tolerated, full cloverleaf development will not be required. For such cases, partial cloverleaf which is a modification that combines some elements of a diamond interchange with one or more loops to eliminate only the more critical conflicts can be adopted. A number of variations are possible for meeting the different site conditions and traffic distribution. **Fig. 5.4** depicts design of partial cloverleaf.

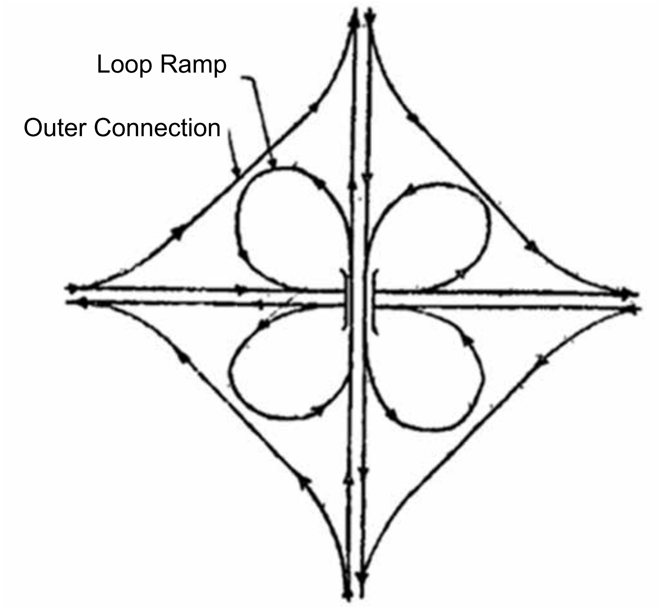

Fig. 5.3 Full Cloverleaf Interchange

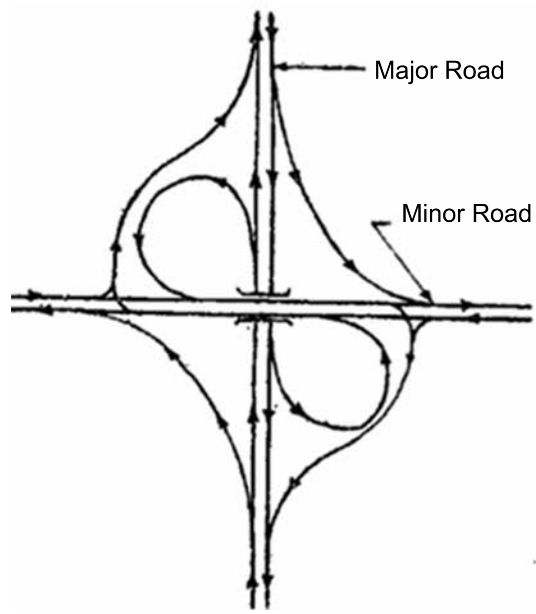

Fig. 5.4 Partial Cloverleaf Interchange

5.4 Rotary Interchange

This type of design is particularly useful where a number of roads intersect at the interchange and in locations where sufficient land is available. It requires that construction of two bridges and generally necessitated more land than for a diamond layout. The main highway goes over or under the rotary intersection and turning movements are accommodated by the diagonal ramps. **Fig. 5.5** shows a typical rotary interchange.

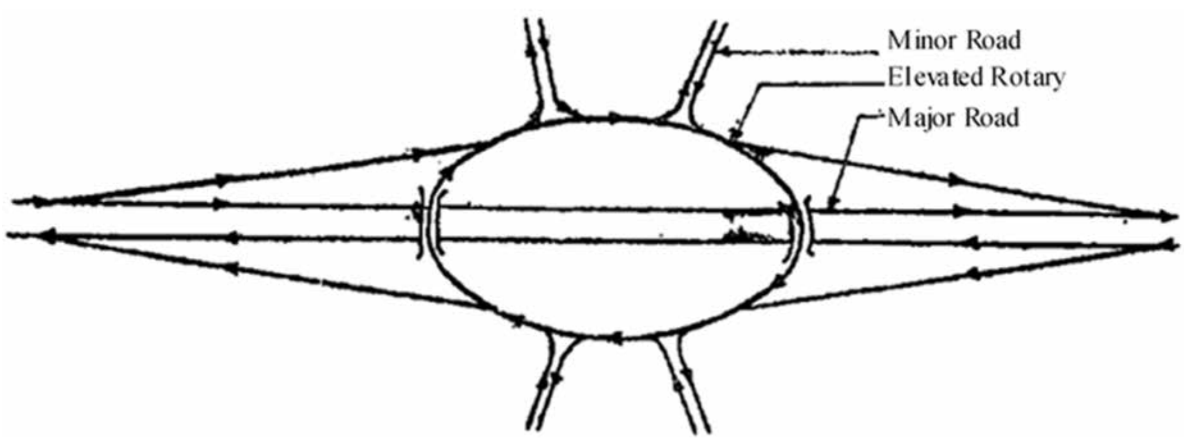

Fig. 5.5 Typical Rotary Interchange

The capacity of a rotary interchange is similar to that of at-grade rotary. High speed operations cannot be maintained on the minor road because of the usually short weaving distances. It can, however, operate satisfactorily at low speeds. Also, this type of design entails only a little additional travel distance for interchanging traffic which is a specific advantage when slow moving traffic is present.

5.5 Directional Interchange

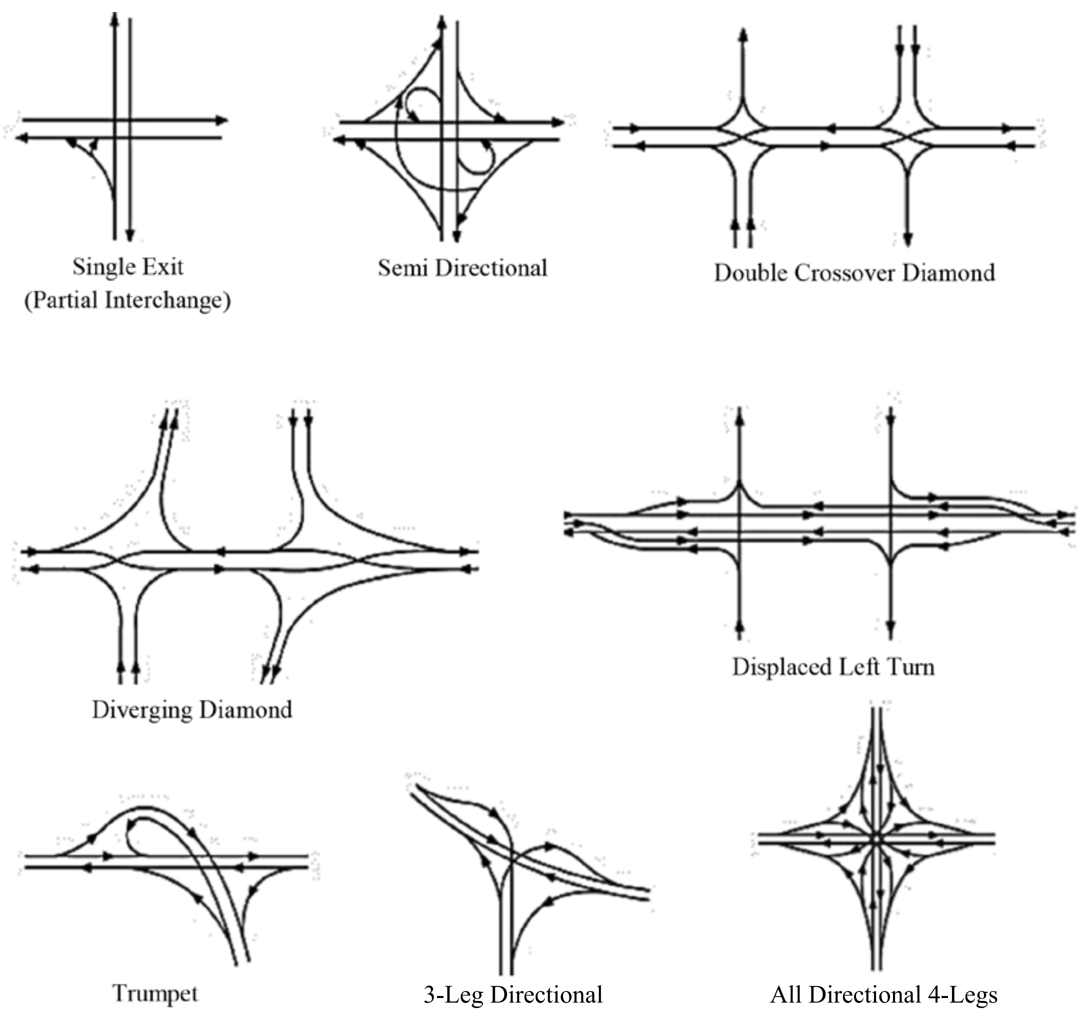

Fig. 5.6 Types of Interchanges

Directional interchanges have ramps for right turning traffic which follow the natural direction of movement. This type of design required more than one structure, or a 3-level structure. Though operationally more efficient than other designs, these generally turn out to be very expensive.

The interchanges illustrated above are common types of 4-leg interchanges. There can be variations depending on the traffic requirement, site conditions etc. Additional layouts of interchange are presented as under **Fig. 5.6** and in **Annexure 1**.

6 GEOMETRIC DESIGN CONSIDERATIONS

6.1 Design Vehicle

Motorized vehicles on road which establish the design characteristics of highways are considered as design vehicles. The design vehicles influence the geometric design of road width, turning radii, sight distance, horizontal and vertical alignments, storage length of auxiliary lanes, acceleration and deceleration lengths etc. The choice of the design vehicle depends on the functional classification of roadway and by the proportions of the various types and sizes of vehicles expected to use the facility. For detailed information on vehicle dimensions and weights, IRC:3 "Dimensions and Weights of Road Design Vehicles" and IRC:SP:41 "Guidelines for the Design of At-Grade Intersections in Rural and Urban Areas" may be referred.

6.2 Ramps

Ramps or pattern of the various turning roadways determine the geometric configuration of the interchanges. The ramps can be broadly classified into the following four basic types, also illustrated in **Fig. 6.1**.

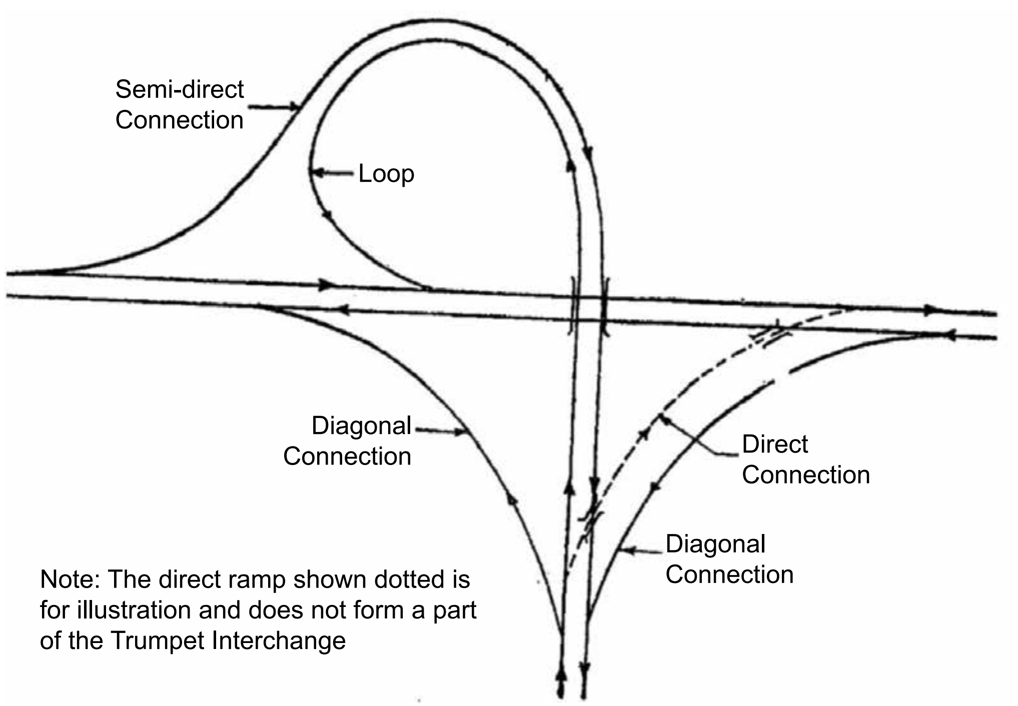

Fig. 6.1 Different Types of Ramps

(i) Left turning roadway referred to as diagonal ramp or outer connection depending on its shape or type of interchange.

(ii) A loop which is a ramp for right turns accomplishes by a left exit and turn to the left through about 270^0.

(iii) Semi-direct connection which is a ramp for right turns accomplished through a partial deviation from the intended path.

(iv) Direct connection which is a ramp for right turns accomplished by a right directional and natural manoeuvre involving least extra travel distance.

6.2.1 Design speed of a ramp should be related to the design speed of the major intersecting highway. Ramp design speeds corresponding to the highway design speeds of 80 and 100 km/h are shown in **Table 6.1**. Design speeds of 80 km/h are applicable to interchanges on urban expressways.

6.2.2 Horizontal curvature of ramps should preferably be of circular curve with transitions at either end. Where this is not feasible, 2-centered compound curves may be employed provided that the radius of any curve is not less than one-half the radius of the preceding curve.

Minimum radius of horizontal curve and sight distance corresponding to the design speeds are also indicated in **Table 6.1**. The sight distance values are for safe stopping conditions and should be ensured both in the horizontal and vertical directions. The sight distance should be measured between two points, one at a height of 1.2 m above the road level representing the driver's eye and the other 0.15 m above the road level denoting the object.

Table 6.1 Speed and Sight Distance along the Straight and Curved Sections of the Ramp

Particulars	Design values for major highway design speed				For loop ramps	
	80 km/h		100 km/h			
	Minimum	Desirable	Minimum	Desirable	Minimum	Desirable
Ramp Design Speed (kmph)	40	50	50	65	30	40
Radius of Curvature (m)	60	90	90	155	30	60
SSD (m)	45	60	60	90	25	45

Notes (i) The major highway design speeds of 80 km/h are appropriate for highways in urban areas.

(ii) The radius of curvature values have been worked out for a maximum super elevation of 7 per cent.

6.2.3 *Sight Distance*

Another element of horizontal alignment is the Sight Distance across the inside of the curves. Because of many variables in alignment, in cross section, and in the number, type and location of potential obstructions, specific study is usually needed for each individual curve. With sight distance for the design speed as a control, the designer should check the actual conditions on each curve and make the appropriate adjustments to provide adequate sight distance. **Figs. 6.2a** to **6.2d** shows the sight distance requirements at exit ramps.

In **Figs. 6.2a** and **6.2b**, the distance X m is based on a minimum of 10 seconds of travel time. In **Figs. 6.2c** and **6.2d**, the distance X m is based on a minimum of 7 seconds of travel time. In **Fig. 6.2d**, sight distances available to the physical nose and beyond are measured in accordance with **Fig. 6.2c**.

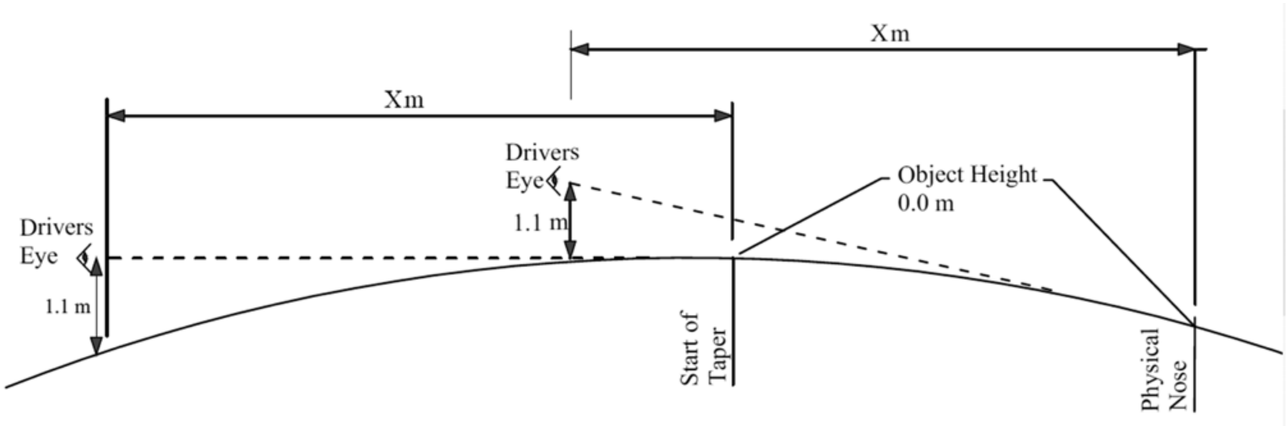

Fig. 6.2a Elevation – Exit Taper

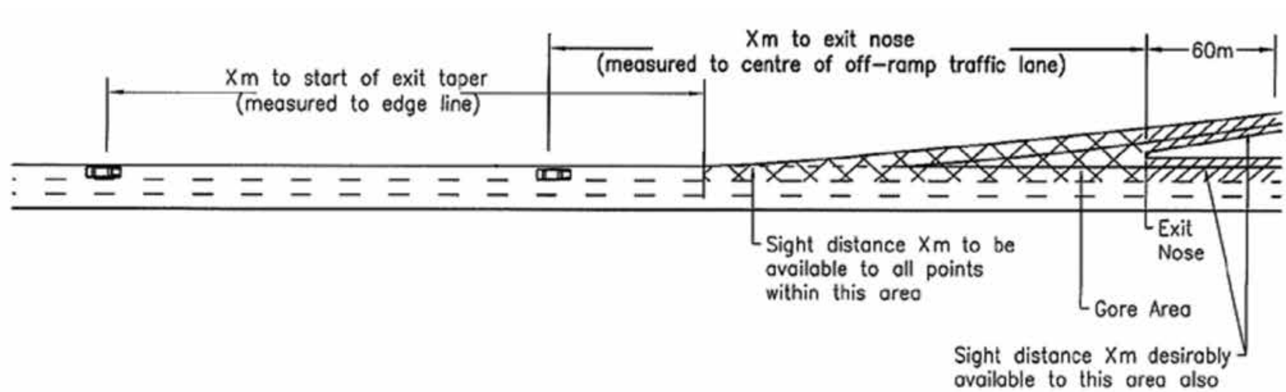

Fig. 6.2b Plan – Exit Taper

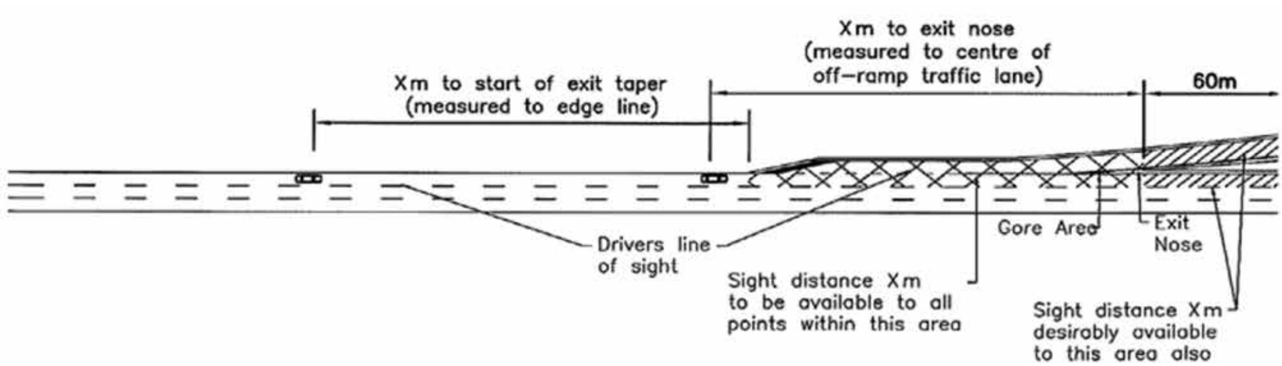

Fig.6.2c Plan – Auxiliary Lane

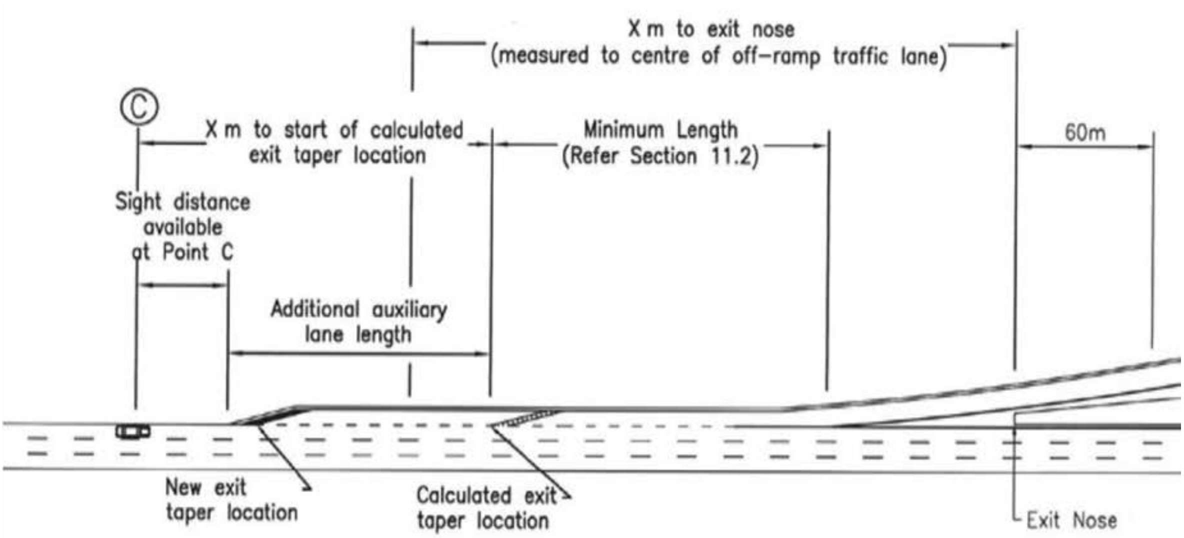

Fig.6.2d Plan – Auxiliary Lane Extension where Sight Distance is Constrained

6.3 Grade and Profile

Ramp profiles usually consist of a section of tangent grade between two vertical curves, valley curve at the lower end and the summit curve at the upper end. The ramp may be for one way or two-way operation. The tangent grades on ramps should be as flat as feasible, and desirably, it should be limited to a maximum of 4 per cent and in no case, should it exceed 6 per cent.

The vertical curves at either end of the ramp should be designed to provide for at least the safe Stopping Sight Distance (SSD) corresponding to the design speed of the ramp. The length of vertical curves for design speeds of 30 to 100 km/h are shown in **Table 6.2**.

Table 6.2 Length of Vertical Curve

Sl. No (1)	Design Speed (kmph) (2)	SSD (m) (3)	Length of Vertical Curve for SSD(m)		Absolute Minimum Length of Vertical Curve(m) (6)
			Summit Curve (4)	Valley Curve (5)	
1	30	30	2.0A(i)	3.5A	15
2	40	45	4.6A	6.6A	20
3	50	60	8.2A	10A	30
4	65	90	18.4A	17.4A	40
5	80	120	32.6A	25.3A	50
6	100	180	73.6A	41.5A	60

Notes: (i) 'A' is the algebraic difference in grades expressed as percentage.

(ii) Where the length given by columns 4 or 5 is less than that given in column 6, the latter value should be adopted.

6.4 Road Cross-Section

The ramp may be for one-way or two-way operation. The two-way, divided type of cross-section should be used with a minimum median width of 1.2 m. The approach width of pavement to be provided for each way will depend on the design hour traffic volume expected to use the ramp. The base capacity and recommended design service volume of urban road sections are given in **Table 6.3**. The minimum width of shoulders should be 2 m of which at least 1 m should be paved. The shoulders should be properly delineated by means of pavement markings. The road markings may be provided as per the guidelines given in IRC:35 "Code of Practice for Road Markings".

Table 6.3 Base Capacity and Recommended Design Service Volume of Urban Road Sections

Sl. No	Type of Carriageway and Road Width	Capacity (PCU/h)	Lane Capacity (PCU/h/lane)
1	Two-lane Undivided (7.0 m)	2400	1200
2	Four-lane Undivided (14.0 m)	5000	1250
3	Four-lane Divided (7.5 m)	5400 (2700)	1350
4	Six-lane Divided (11.0 m)	8400 (4200)	1400
5	Eight-lane Divided (14.0 m)	13600 (6800)	1700
6	Eight-lane Divided Expressway (14.0 m)	9200	2300
7	Ten-lane Divided Urban Road (17.5 m)	10000	2000

Note: The values in parenthesis/brackets represents PCUs per hour per direction.

6.5 Ramp Terminals

Ramp terminal is a portion adjacent to the through travelled way including speed change lanes, tapers and islands. Free-flow type ramp terminals where ramps traffic merges with (entrance terminal) or diverges from (exit terminal) high speed through highway at flat angles should invariably be provided with speed change lanes i.e., acceleration lane at entrance terminal and deceleration lane at exit terminal. The speed change lanes should be carefully sited to ensure that they are not hidden from the view of approaching traffic by horizontal or vertical curves.

6.5.1 *Entrance Terminal*

The entrance terminal should be provided for sufficient length of acceleration lane to enable a driver to increase his speed from that on the turning ramp road-way to that of the operation speed of the highway. It should also provide manoeuvring space so that the driver can watch and take advantage of an opening in the adjacent stream of through traffic and move laterally into it. At the end of the acceleration lane, it is important that there should be no kerb or other obstruction which might be dangerous for a driver to merge with the traffic stream on the near side lane within the length of acceleration lane.

Acceleration lanes are designed in two general forms, namely, the direct taper type and the parallel type. The taper type works on the principle of direct entry at a flat angle and part of the lane is separated from the through pavement of the highway. Though this form is generally preferred by the vehicles, it requires more space with the turning curve located farther away from the edge of the main highway. The parallel type has an additional lane built on the highway itself for speed change purposes. Both types will operate satisfactorily if designed properly, though the direct taper type will be appropriate for most cases.

The length of acceleration lane is governed by the difference between the running speeds of the entrance curve of the ramp and of the highway. **Table 6.4** gives the suggestive lengths for acceleration and deceleration lanes of the interchange. These lengths are particularly influenced by gradient.

6.5.2 *Exit Terminal*

The exit terminal should be provided with sufficient length of deceleration lane to enable vehicles leaving the interchange at high speeds to reduce their speeds to negotiate the turning curve on the exit ramp. Similar to acceleration lane, deceleration lane can be of two forms, namely, direct taper type and parallel type. Recommended minimum and desirable lengths of deceleration lane are also indicated in **Table 6.4**.

Table 6.4 Length of Acceleration/Deceleration lanes

Type of lane	Length including taper(m)	
	Desirable	Minimum
Acceleration lane	250	180
Deceleration lane	120	90

Typical designs for entrance and exit terminal provided with acceleration and deceleration lane respectively are shown in **Fig. 6.3**. It may be noted that the nose separating the through lane from the turning lane is off-set from the edge of the through lane by 2 m to enable an errant vehicle which has inadvertently left the through lane to return with minimum disruption to through traffic. It is important that the “Core” area formed by the edges of the through and the turning lanes immediately beyond the point of divergence should be kept free of all hazardous obstructions so as to provide a clear recovery area for out of control vehicles.

6.6 Geometric Clearance

6.6.1 *Lateral Clearance*

For underpass roadways, desirably the full roadway width at the approaches should be carried through the underpass. This implies that the minimum lateral clearance (i.e. the distance between the extreme edge of the carriageway and the face of nearest support, whether solid abutment pier or column) should equal the normal shoulder width.

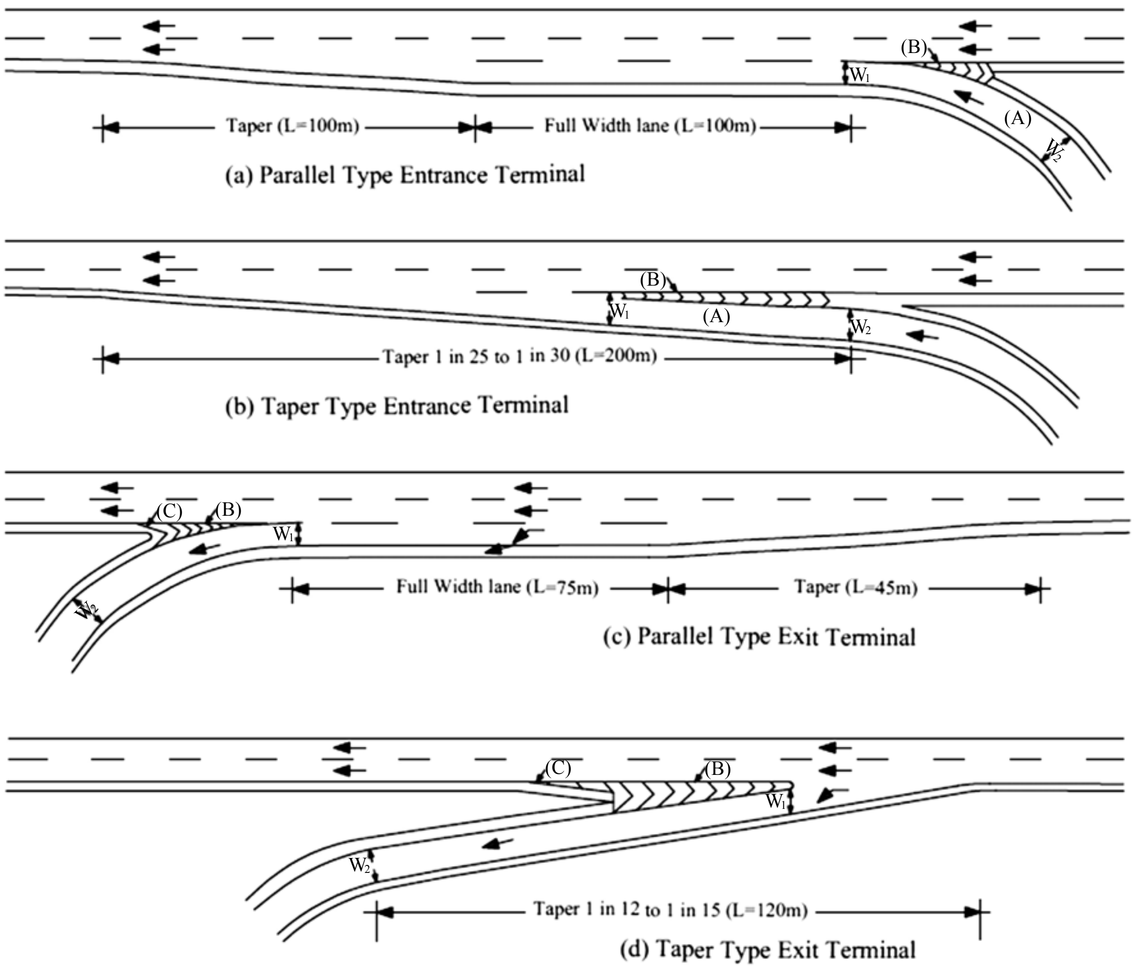

Fig. 6.3 Typical Designs for Entry and Exit Terminals

Notes (i) At locations marked (A) funnel entrance is provided by reducing width of ramp (W_2) to width of lane (W_1)

(ii) The nose area marked (B) should be paved and provided with markings in white paint as indicated.

(iii) At locations marked (C) the through lane should be tapered (1 in 10) for a distance of 20 m)

For overpass structures, the clearances are not that critical as in the case of underpasses since the drivers do not generally get the feeling of constriction. A cross-section with 225 mm wide kerb and open-type parapet will generally be suitable for most cases.

6.6.2 *Vertical Clearance*

Vertical clearance at underpass should be minimum 5.5 m in urban areas, after making allowance for any future raising/strengthening of the underpass roadway.

For more details on clearances, reference may be made to IRC:SP:84 "Manual of Specifications and Standards for four-laning of Highways through Public Private Partnership".

6.7 Super-Elevation on Ramps

To maintain the design speed, highway and ramp curves are usually super elevated to overcome part of the centrifugal force that acts on a vehicle. On interchange ramps the super elevation rate is not as critical as on through pavements since drivers anticipate the sharper curvature and accept operation with higher side friction than on open highway curves. Even so, it is desirable to provide as much super elevation as practicable on ramps, particularly when the curve is sharp and on a down grade. The maximum super elevation desirable 6 per cent but not more than 7 per cent. However, the development of a desirable super elevation without an abrupt change in cross slope at the ramp terminals is often prevented by the sharp curvature and short length of turning roadway. This is compensated by accepting higher side friction factors. The super-elevation rates with varying design speed (kmph) and radius (m) are presented in **Fig. 6.4**.

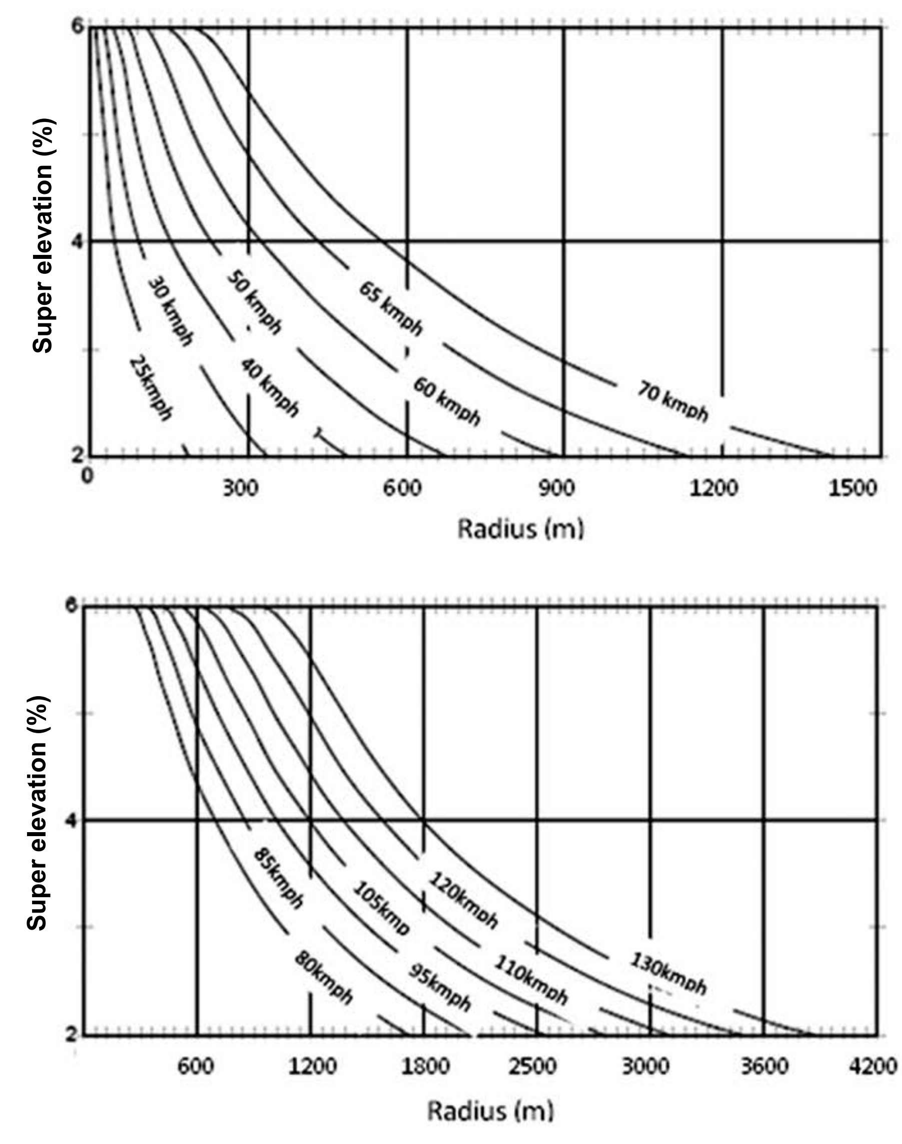

Fig. 6.4 Super-Elevation Rates

6.8 Cross-Section of Major and Minor Road

Traffic passing through an interchange should be accorded the same degree of utility and safety as that given on the approaching highways. The design elements in the intersection area, therefore, should be consistent with those on the approaching highways, even though this may be difficult to attain. Preferably, the geometric design at the highway grade separation should be more liberal than that for the approaching highways to counterbalance any possible sense of restriction caused by the structure. Typical cross sections of urban roads are demonstrated in IRC:86 “Geometric Design Standards for Urban Roads in Plains”.

6.9 Typical Design Challenges at Interchanges

6.9.1 *Sight Distance at Exit Points*

Sight distance is often determined with respect to the gore, which is the area where a ramp diverges from the mainline. Wherever feasible, decision sight distance should be provided to enable drivers approaching expressway exits to see the pavement surface from the painted gore nose to the limit of the paved gore. Proper advance signing of exits is also essential and additional signage is required when it is not possible to obtain the decision sight distance.

6.9.2 *Exit Speed Changes*

The design should provide enough distance to allow safe deceleration from the highway design speed to the design speed of the first exit curve.

6.9.3 *Merges*

The most frequent crash-type at interchanges is the rear-end collision at entrances onto the expressway. This problem can be reduced by providing an acceleration lane of sufficient length with adequate sight distance to allow a merging vehicle to attain speed and find a sufficient gap into which to merge.

6.9.4 *Right Side Entrances and Exits*

Right-side entrances and exits should be avoided as they are contrary to driver expectations and have been associated with higher crash rates.

6.9.5 *Fixed-Object Hazards*

A number of fixed objects may be located within interchanges, such as signs at exit gores or bridge piers and rails. These should be removed wherever possible, placed outside of the recovery area if possible, make breakaway, or shielded with barriers or impact attenuators.

6.9.6 *Wrong-Way Entrances*

In almost all cases, wrong-way manoeuvres originate at interchanges. Some cannot be avoided, but others may result from driver confusion due to poor visibility, deceptive ramp arrangement, or inadequate signing. The interchange design must attempt to minimize wrong-way possibilities. This includes staggering ramp terminals and controlling access in the vicinity of the ramps.

6.9.7 *Excessive Speed on Minor Roadways*

Ramp and merge designs should slow down drivers leaving the high-speed roadway so that they will not exceed the design speed on the secondary road. The section of the secondary road in the interchange area should have a design speed similar to (not faster than) the design of adjoining sections of that road.

6.10 Pier Dimensions and Retaining Walls

The retaining walls shall be designed to withstand earth pressure including any live load surcharge and other loads acting on it, including self-weight, in accordance with the general principles specified for abutments. Stone masonry and plain concrete walls shall be of solid type. Reinforced concrete walls may be of solid, counterfort, buttressed or cellular type.

The geometrical shape (along width of flyover) of the pier should be suitable to enable its adaptation to variable heights where the height of piers is varying as in the approach portion. Vertical shape or some other geometric shape where proportions look pleasing to the eye in spite of change in one dimension (i.e. height) may be adopted. Single circular or oval piers may be suitable where least construction space is to be occupied. They look lighter and less massive.

For more details on piers and retaining walls, reference may be made to IRC:78 “Standard Specifications and Code of Practice for Road Bridges, Section VII-Foundations and Substructures (Revised Edition)”.

6.11 Effectiveness of the Interchange

Measuring the effectiveness of a project’s overall performance depends on the nature or catalyst for the project.

- Accessibility
- Mobility
- Quality of Service
- Reliability
- Safety

6.12 Pavement Selection

Pavement selection is a process to identify the most beneficial type of pavement structure for a given set of traffic, soils, climate, and other factors. It is sometimes as simple as specifying a certain type of pavement on the basis of traffic level, or it may be as complicated as assigning weighing factors to more than a dozen characteristics and evaluating the outcome through a scoring system. Whatever process is used, it should be a rational and explainable methodology in which the effects of different variables on decision making may be determined. Major factors for selecting a pavement are explained here. Further reference may be made to IRC:37 “Tentative Guidelines for the Design of Flexible Pavements”.

7 TRAFFIC CONSIDERATIONS

Following parameters of interchange planning and design are broadly dependent upon observed and anticipated traffic at the proposed location.

7.1 Traffic Studies

Traffic data collection and projections of traffic volumes are basic requirements for planning of road development and management schemes. For detailed planning of an interchange, it is necessary to study in detail the present and expected future traffic characteristics for that location. The surveys that should be carried out are as follows:

a) Road inventory survey
b) Classified traffic volume survey
c) Turning movement count survey
d) Vehicle occupancy survey
e) Roadside origin-destination survey
f) Vehicle speed and delay survey
g) Intersection volume-delay survey

Further reference may be made to IRC:SP:19 “Manual for Survey, Investigation and Preparation of Road Projects” for traffic surveys and analysis.

7.2 Level of Service

Level of Service is defined as a qualitative measure describing operational conditions within a traffic stream, and their perception by drivers/passengers.

Level of Service definition generally describes these conditions in terms of factors such as speed and travel time, freedom to manoeuvre, traffic interruptions, comfort, convenience and safety. Six levels of service are recognized 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.

LOS A - Free flow of traffic.

LOS B - Reasonable free flow; no restrictions on the ability to manoeuvre; minor incidents do not disrupt the flow.

LOS C - Speed is close to free flow speed; slight restriction on the freedom to manoeuvre; queues may form as a result of any obstruction or incident.

LOS D - The speed starts decreasing with increasing traffic flow; density starts increasing; freedom to manoeuvre is restricted; a queue is formed because of minor incidents.

LOS E - Operation of the interchange is near or at capacity; the traffic stream has no usable gap; any disruption results in queuing and operations become extremely volatile.

LOS F- There is a breakdown in flow; the demand exceeds capacity and queues are formed behind breakdown points.

For details, reference may be made to IRC:106 "Guidelines for Capacity of Urban Roads in Plain Areas".

7.3 Weaving Sections - Merging and Diverging Sections

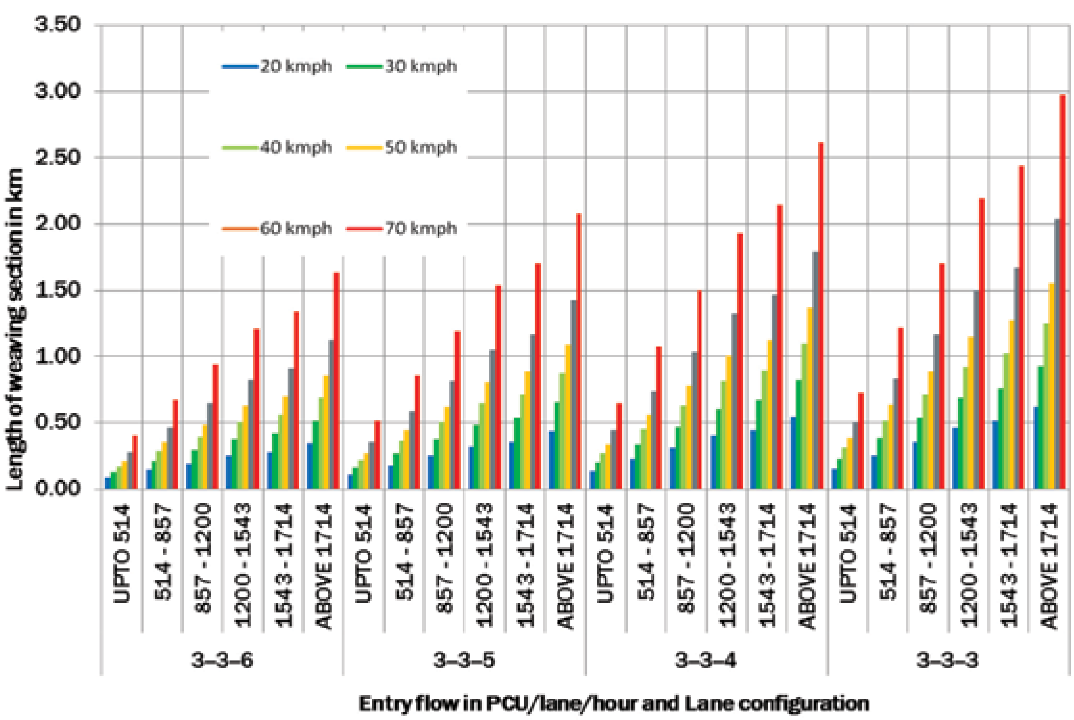

Fig. 7.1 Minimum Weaving Lengths along the Travelled Way for Varying Speeds and Lane Configuration

The movement in the same direction of vehicles within two or more traffic streams intersecting at a small angle so that the vehicles in one stream cross other streams gradually is termed as weaving movements. The road section where the weaving movements takes place are known as the weaving section. In a weaving section, merging and diverging operations take place sequentially with varying desires crossing each other in between. **Fig. 7.1** illustrates the minimum weaving lengths along the travelled way for varying speeds and lane configurations.

The maximum length over which merging and diverging movements are defined is 450 meters. The merging/diverging influence area is reflected by the densities which consists of the right and next-to-right lane; and the acceleration or deceleration lane 450 meters upstream of diverge or downstream of a merge lane. The density reflects the average of all vehicles across all lanes of the segment between the entry and exit points of the segment.

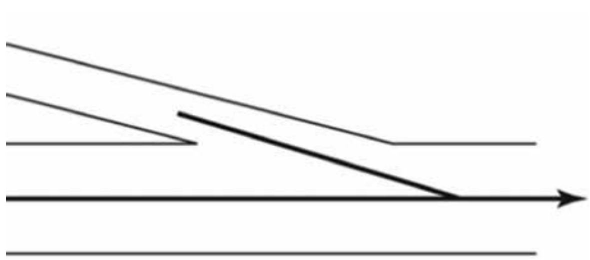

Fig. 7.2a Merging Movements

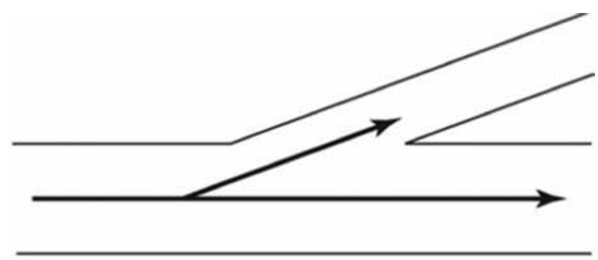

Fig. 7.2b Diverging Movements

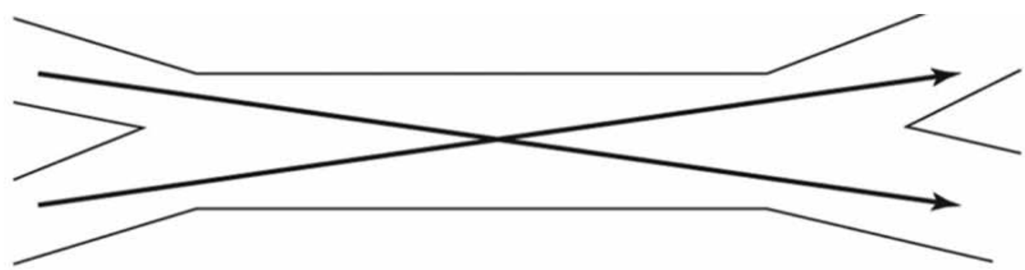

Fig. 7.2c Weaving Movements Across Each Other's Path

7.4 Ramp Metering

Traffic signals which are placed at the expressway on ramps are called ramp meters. The purpose of ramp metering is to reduce congestion or improve merge operations on urban expressways. They control the traffic flow entering the mainline such that the capacity downstream is not exceeded and therefore addresses the problem of congestion on the expressways. Depending on the number of lanes as well as the usage of high occupancy vehicle lanes, the following types of ramp meter are provided:

a) Ramp for Single Occupancy Vehicle (SOV)-A single ramp is used at locations where the peak hour design volume is low, i.e., 720 vehicles per hour or less. It is provided where a High Occupancy Vehicle (HOV) lane is not feasible.

b) Ramp for SOV/HOV-A dual lane ramp meter is provided for peak hour design volume of up to 720 vehicles per hour. When the HOV is greater than or equal to 9 per cent of the total peak hour volume, an HOV lane addition will be warranted.

c) Ramp for 2 SOV- A dual lane ramp meter is provided when the peak hour volume is moderate to high, i.e, it exceeds 720 vehicles per hour.

8 INTERCHANGE SELECTION PARAMETERS

The decision to provide a grade-separated intersection should be made based on careful consideration of a number of factors as discussed in section on “Warrants”. Traffic passing through an interchange should be afforded the same degree of utility and safety as that given on the approaching highways. The design speed, alignment, profile, and cross section in the intersection area, therefore, should be consistent with those on the approaching highways, even though this may be difficult to attain. The presence of the structure itself is somewhat of an obstruction, which should not be augmented by inconsistent designs that might encourage undesirable driver behaviour. Preferably, the geometric design at the highway grade separation should be better than that for the approaching highways to counterbalance any possible sense of restriction caused by abutments, piers, curbs and rails.

A grade separation without interchange ramps may be provided to avoid having interchanges so close to each other that signing and operation would be difficult. This approach eliminates interference with large major road interchanges and increases safety and mobility by concentrating turning traffic at a few points where it is feasible to provide adequate ramp systems. On the other hand, undue concentration of turning movements at one location should be avoided where it would be better to have additional interchanges.

- Lacking a suitable relocation plan for the crossroad, a highway grade separation without ramps may be provided to maintain connectivity of low volume roadways. All users desiring to access one facility from the other are required to use other existing routes. In some instances, these users may have to travel a considerable distance, particularly in rural areas.
- Many times, partial interchanges are constructed initially because the traffic volumes do not support a full interchange or the required right-of-way is not available when the interchange is first constructed. As time passes however, the need for a complete interchange may develop or the right-of-way may be obtained.

Following **Table 8.1** and **Table 8.2** can act as guiding principles for assessing the feasibility of complete interchanges along urban and rural corridors respectively.

Table 8.1 Guiding Principles for Assessing the Feasibility of Complete Interchanges Along Urban Corridor

Road Typology	Collector	Sub-Arterial	Arterial	Expressway
Collector	Highly Not Recommended	Not Recommended	Generally not Recommended	Recommended based on site condition
Sub-Arterial	Not Recommended	Generally not Recommended	Recommended based on site condition	Generally Recommended
Arterial	Generally not Recommended	Recommended based on site condition	Generally Recommended	Recommended
Expressway	Recommended based on site condition	Generally Recommended	Recommended	Highly Recommended

Table 8.2 Guiding Principles for Assessing the Feasibility of Complete Interchanges Along Rural Corridor

Road Typology	ODR/MDR	State Highway	National Highway	Expressway
ODR/MDR	Highly Not Recommended	Not Recommended	Generally not Recommended	Recommended based on site condition
State Highway	Not Recommended	Generally not Recommended	Recommended based on site condition	Generally Recommended
National Highway	Generally not Recommended	Recommended based on site condition	Generally Recommended	Recommended
Expressway	Recommended based on site condition	Generally Recommended	Recommended	Highly Recommended

Selection of the most appropriate type of interchange for the prevailing conditions is an important step in design. The specific form or type of interchange will depend on the physical conditions of the site such as topography, available right-of-way, land-use and developments alongside the intersecting roads, expected volumes of through and turning traffic including their composition, orientation of the intersecting highways, etc.

8.1 Study of the Physical Conditions of the Site should Include:

(i) The topography – this will bring out the roadway that can be made to flyover or run in a subway as also the pattern and possible location of the ramps for maximum economy.

(ii) Location, alignment and design features of the intersecting highways — this will help to identify or distinguish the major highway where free flow type ramp terminals may be necessary. On a highway with frequent at-grade intersections, the ramp terminals should also be at-grade. Similarly, terminals on highways carrying more than 10 per cent slow traffic (i.e. carts, bicycles, etc.) should be at grade.

(iii) Roadside developments — the design should be conducive to provide access to roadside properties and connection to existing access roads. This may call for construction of frontage road or collector roads with connection to the highway at appropriate points.

(iv) Practicability of maintaining traffic during construction — this is important where the intersecting roads are existing roads. When the fly-over structure is under construction, it should be possible to provide for at-grade connections to all traffic movements.

(v) Flexibility for future adjustment and stage development — this should include a study of the design vis-a-vis the planned developments in the adjoining area, augmentation of services and other improvements.

8.2 Lane Balance

To realize efficient traffic operation through and beyond an interchange, there should be a balance in the number of traffic lanes on the expressway and ramps. Design traffic volumes and a capacity analysis determine the basic number of lanes to be used on the highway and the minimum number of lanes on the ramps. The basic number of lanes should be established for a substantial length of expressway and should not be changed through pairs of interchanges, simply because there are substantial volumes of traffic entering and leaving the expressway. In other words, there should be continuity in the basic number of lanes.

After the basic number of lanes is determined for each roadway, the balance in the number of lanes should be checked on the basis of the following principles:

(i) At entrances, the number of lanes beyond the merging of two traffic streams should not be less than the sum of all traffic lanes on the merging roadways minus one, but may be equal to the sum of all traffic lanes on the merging roadway.

(ii) At exits, the number of diverging lanes on the highway should be equal to the number of lanes on the highway beyond the exit, plus the number of lanes on the exit, minus one. Exceptions to this principle occur at cloverleaf loop-ramp exits that follow a loop-ramp entrance and at exits between closely spaced interchanges. In these cases, the auxiliary lane may be dropped in a single-lane exit with the number of lanes on the approach roadway being equal to the number of through lanes beyond the exit plus the lane on the exit.

(iii) The travel way of the highway should be reduced by not more than one traffic lane at a time.

Typical examples of lane balance are shown in **Fig. 8.1**.

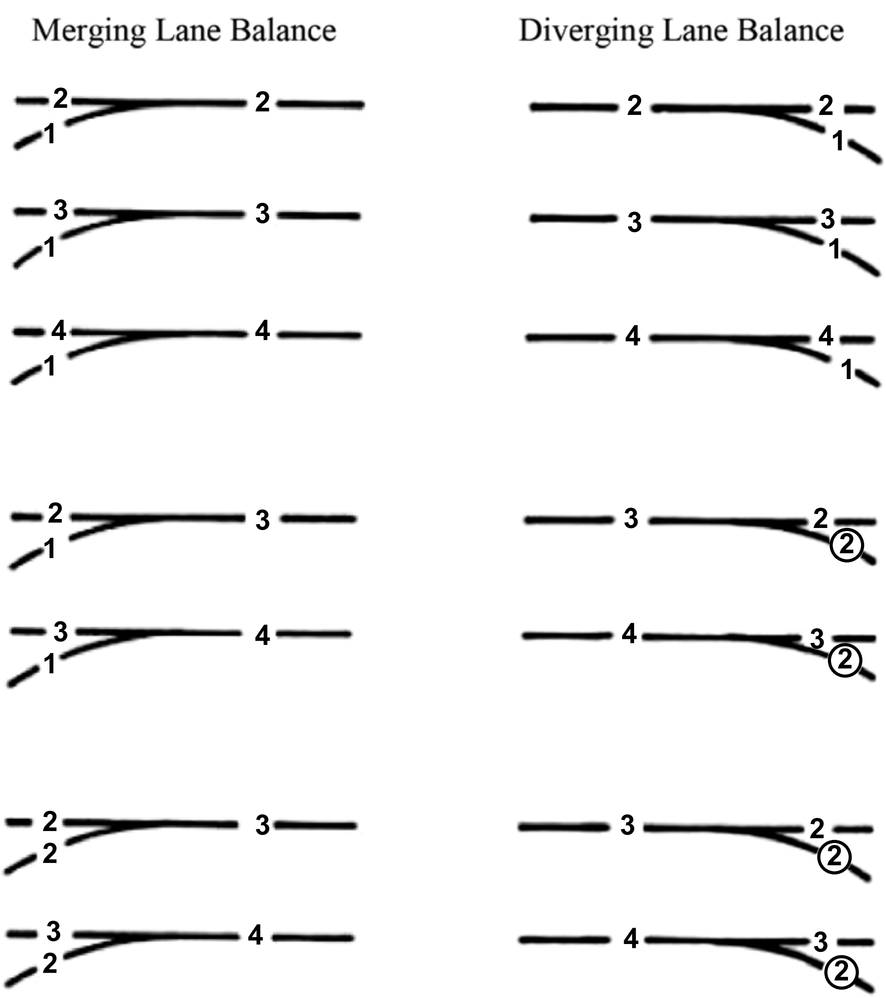

Fig. 8.1 Typical Examples of Merging and Diverging Lane Balance

9 SAFETY CONSIDERATIONS FOR NON-MOTORIZED TRANSPORT (NMT)

Integration of bicycles into multi-modal transport chains, particularly with public transport (PT) modes, contributes to a more efficient and environmentally sustainable transport system. A well-integrated bus-bike system increases bus ridership levels. The common safety issues for an NMT network are:

- Insufficient Lighting
- Lengthy crossing distances
- Discontinuous facilities
- Unmarked crossings
- Free-flowing entry and exit ramps
- Poor sight distance
- Insufficient Space

The factors of safety considerations of an NMT network in an interchange are:

9.1 Sight lines

Crossings (including driveways) are the most likely place for car-bicycle collisions. Crossings should be carefully designed to reduce the chance of conflict. Driveways should have adequate sight lines to see all traffic on the road. Cycle lanes at intersections and cycle paths where they connect with streets should be carefully designed. Intersections with expressways should be grade-separated. **Fig. 9.1** presents the NMT lane change at exit point of interchange.

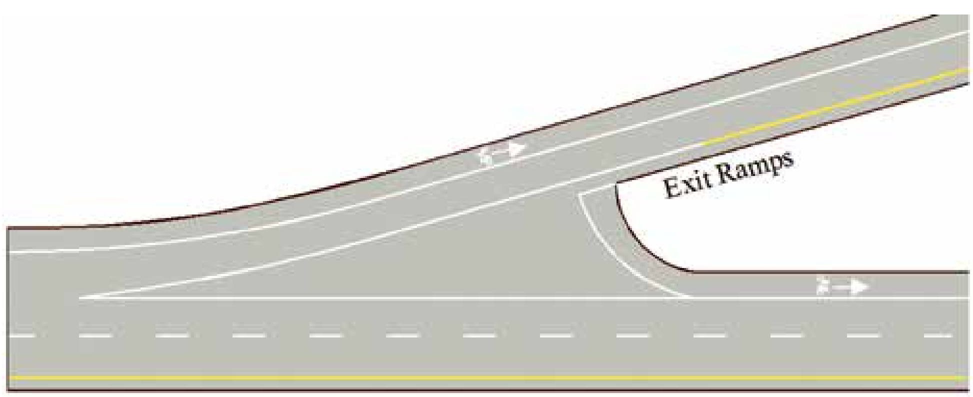

Fig. 9.1 NMT Lane Changing Pattern at the Interchange Exit Lane

9.2 Vertical Separation

The facilities for NMT are to be vertically separated from motor vehicle traffic. When a raised and curb-separated bicycle facility is applied, it is considered part of the street side zone. When the raised and curb-separated bike facility is placed adjacent to motor vehicle traffic, consider using a sloped and mountable curb to enable passing manoeuvres between cyclists. The layout of vertical separation is presented in **Fig. 9.2**.

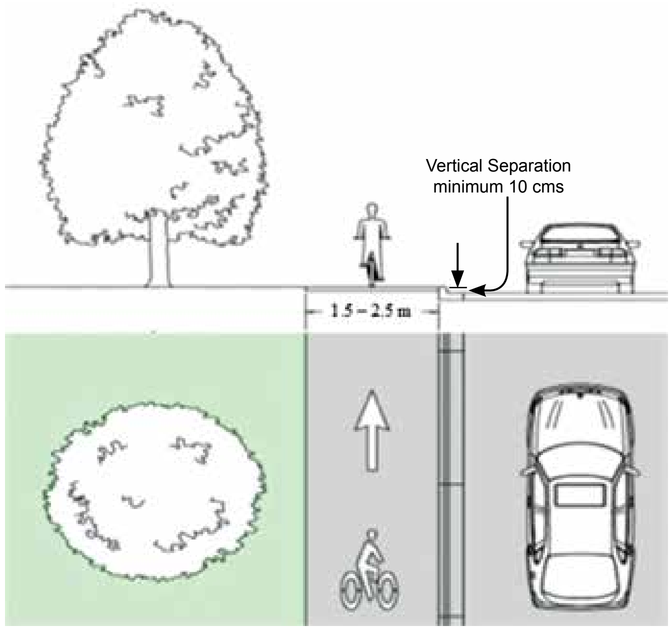

Fig. 9.2 The Vertical Separation

9.3 Horizontal Separation

The dedicated lanes for cyclists and other NMT modes separated or unseparated reduce safety concerns to a considerable level due to zero collision tolerances. The layout of horizontal separation is presented in **Fig. 9.3. Fig. 9.4** shows dedicated bicycle and pedestrian lanes provided for interchange at Vancouver, Canada. **Fig. 9.5** presents dedicated NMT facilities and NMT facilities under the flyover.

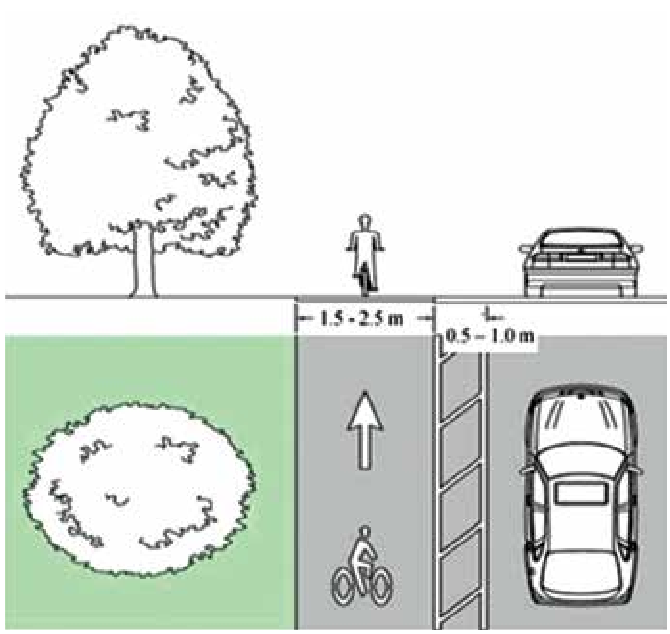

Fig. 9.3 The Horizontal Separation

Fig. 9.4 Example for Dedicated Bicycle/Pedestrian Lanes Provided for Interchange at Vancouver, Canada

9.4 Collision Control

Safety is generally about minimizing or managing conflict between users of a carriageway (whether this is a road or an off-road situation) and needs to consider the design users: age, experience, type of trips and the built environment. This is one reason why the range of users needs to be considered explicitly in infrastructure design. Safety is also about designing for mode dynamics independently of the interaction between users.

9.5 Priority in Traffic

Wherever the points of traffic controls are provided within an interchange, the priority and exclusive green given to the cyclists and other NMT modes can reduce the safety concerns with respect to the head-on collisions.

Fig. 9.5 NMT Facilities (Dedicated & Under Flyovers)

10 MULTIMODAL CONSIDERATION

Multimodal integration helps for accommodating pedestrians, bicyclists, transit, and heavy vehicles at interchange. Benefits of integrating multiple modes at an interchange are:

- Reduced overall right-of-way footprint compared to a conventional diamond interchange
- Two-phase traffic signal control with reduced pedestrian wait time
- Minimized crossing distances
- Simplification of conflicts to one-directional vehicular traffic
- Opportunities for bicycle lanes and multi-use paths through the interchange

Some of the strategic components for multimodal integration at traffic interchange are:

10.1 Right-of-Way

Right-of-way constraints may limit a designer's ability to provide safe movement of vehicles through the crossover or limit the use of alternative design configurations.

10.2 Access Management

Access near an interchange needs to be restricted based on local and state requirements for intersection spacing.

10.3 Design Vehicles

The interchange geometry will need to accommodate transit, emergency vehicles, freight, and potentially oversize and overweight (OSOW) vehicles.

10.4 Pedestrian and Bicycle Accommodation through Interchanges

The pedestrian and bicycle accommodation, such as sidewalks, bicycle lanes, and shoulders, on the minor road should be maintained through the interchange area. If pedestrian and bicycle use is permitted on both roadways, then this principle applies to both facilities.

A fundamental obstacle in developing a traffic interchange form is deciding how to provide for pedestrian and bicycle movements. Some of the challenges for multimodal provisions are uncontrolled turn lanes, some of unfamiliar signal phases etc. The integration of bicycle and pedestrian movements is done by anticipating the desire lines from origin and destination for these modes. Interchanges and other locations with on-ramps and off-ramps can be among the most difficult locations for pedestrians and bicycles to navigate. The combination of high speed merging traffic and crossings by pedestrians and bicyclists creates inherent conflicts and can be very uncomfortable for non-motorized users. Particularly in urban and sub-urban locations where pedestrian and bicycle traffic can be expected to use the roadway, interchange design should account for their needs.

The most important principle in designing interchanges that accommodate pedestrians and bicyclists is to reduce motor vehicle speeds at locations where pedestrians and bicyclists either cross the road, or (as in the case with bicyclists operating on-road) merge with traffic. For this reason, urban interchange design with conventional 90-degree intersections (instead of merge lanes) is preferable for pedestrian and bicycle safety. Interchange designs that enable motor vehicles to maintain speeds above 50 kmph without stopping are not conducive to pedestrian and bicycle access and should be avoided.

10.5 Transit Considerations

Transit can be accommodated in interchanges by providing the bus stops on the interchanges and the passengers which get down on the interchanges should be integrated safely, so that they can safely go out of the interchange or interchanging to the different modes. So, the bus stops should be provided along with the bus lanes and lay bys, so that the stopping of the transit vehicles do not create any congestion on the grade separated interchange. Sometimes the angles for left turn slip lanes are tightened to 55^0 to 60^0 which lead to slower vehicle speeds and creates good visibility to the passengers.

Fig. 10.1 Integration of Pedestrians at Mukarba Chowk Flyover using Elevators and Ramps

11 ILLUMINATION AT INTERCHANGE

An interchange, particularly a complicated one, demands from the driver much more skill and concentration due to continuous change of situations, where it is slowing down at the exit ramps or negotiating the sharp curvatures. In such circumstances visual contact and psycho-physiological conditions are considerably more involved compared with routine driving on a straight road section. More precise and higher quality visual information can be of great importance in meeting the critical needs of such a situation. Thus, lighting at interchanges helps to identify the physical features of the interchange at night and to provide a safe and efficient operational environment.

For details on illumination, reference may be made to IRC:SP:90 "Manual for Grade Separators & Elevated Structures". **Fig. 11.1** shows a visual perception of illumination at interchange.

Fig. 11.1 Visual Perception of Illumination at Interchange

For the sake of uniform illumination levels for Non-Motorized Transport, following suggestions shall be considered:

- The street and footpath or cycle track may be considered together as one element in determining minimum light level and uniformity.
- The contribution of both the pedestrian lighting system and the road lighting system may be considered for calculating light levels and uniformity of the sidewalk or bikeway and the roadway.
- Road lighting may be existing or may be added with the pedestrian lighting
- It may be a part of the same lighting system or a separate lighting system.
- The reduction of veiling glare is beneficial.
- Veiling glare observed by a motorist is mitigated by increasing the luminance of the roadway.

12 NOISE POLLUTION BARRIERS

Noise barriers are used as an effective measure of noise abatement. Different types of "green" noise barriers adapted to the surrounding environment are used. Size and conspicuousness of noise barriers and noise embankments leaves their mark on the environment. An increasing proportion of people's time is spent commuting on highways, and it is therefore an important task to make this time a positive experience through attractive surroundings. Noise screening can constitute an actual physical barrier in a town or housing area. Following principles shall be adhered with while considering noise controlling measures along traffic interchanges:

- Planting of trees and other vegetation so that the noise barrier fits in with its surroundings.

- To allow the noise barrier to bring out the lines and forms of the landscape or town to the roadside.
- Make the noise barrier stand out as a striking and visible addition to its surroundings through a conscious selection of colours and forms.
- Noise barriers constructed could be of different materials, such as steel, brick, concrete, wood and transparent materials.
- The height of a noise screening installation is also important for road users and their possibilities of orientation in the urban area or landscape through which they are passing. Even the erection of a 1.5 m high barrier affects visibility conditions for motorists.

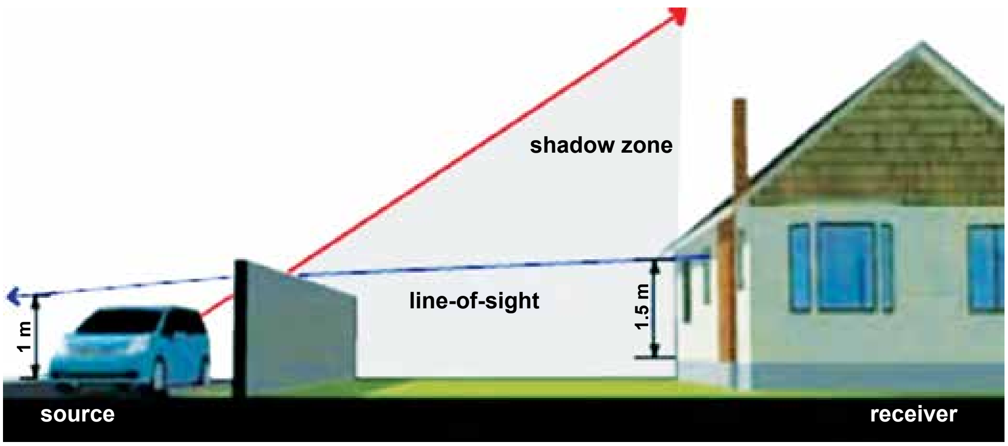

Fig. 12.1 Physical Barrier for Noise Abatement

13 LANDSCAPING AT INTERCHANGE

The unused voids and land shall be utilized for landscaping around the interchange. Landscaping features not only improve the aesthetics but also help in reduction of noise and air pollution, improving microclimate, better heat and light entropy. Although, in general, landscaping improves the overall user experience at interchange but it should never hinder the functioning of interchange. For example, visibility at interchange shall always be maintained and unwanted vegetation shall be trimmed. Similarly, only compatible and suitable vegetation shall be developed. The two aspects discussed are: Planting & Shade.

13.1 Planting

Planting in interchanges should be done as part of a comprehensive landscape and aesthetics plan. The design of the planting must be done so that it achieves the aesthetic goals for the specific corridor and facilitates maintenance of the interchange.

- Planting is most effective in areas of low slope. Planting on the slopes is difficult to maintain and will shade out grass cover, which leads to erosion.
- Planting is most effective when placed in the driver's line of sight and where the background is either sky or light-colored structures.

13.2 Shade

Design solutions must be sensitive to deeply shaded areas and areas that are difficult to access.

- Bridges and tall embankments will shade areas of an interchange, making the establishment of a vegetative cover nearly impossible. These areas should be either eliminated structurally using walls, or surfaced with an appropriate non-living material.
- Shaded areas tend to collect debris, attract graffiti, and are sometimes occupied by transients. These areas should be eliminated structurally if possible. When this is not possible, the views should remain open to allow visual policing.

A paved surface is a better solution than plants where shade from structures prevents vegetation establishment.

Fig. 13.1 Example for Vegetation Under Shaded Structures

13.3 Gores

Gore areas between ramps and weaving lanes often contain crash attenuation barriers that are not particularly attractive. The triangular area between the diverging lanes tends to accumulate trash. Design actions appropriate in these areas are:

- Use colors on pavement that contrast sharply with the driving lane pavement.
- Avoid rough textures that will trap and hold trash and debris.
- Group signs to provide a uniform horizon even if the signs are of different dimensions; such groupings contribute a sense of visual order.

For more details on clearances, reference may be made to IRC:SP:21 “Guidelines on Landscaping and Tree Plantation”.

14 DRAINAGE AT INTERCHANGE

Drainage at road systems and especially at interchanges is a crucial component of planning and design of the facility. The reasons to provide a sound and long-lasting drainage system are:

- To prevent flooding of the road and ponding on the road surface.
- To protect the bearing capacity of the pavement and the sub grade material.
- To avoid the erosion of side slopes.

For more details on drainage, reference may be made to IRC:SP:42 "Guidelines of Road Drainage" and IRC:SP:50 "Guidelines on Urban Drainage".

15 SIGNAGE AND MARKINGS

Suitable road marking and signage shall be posted at convenient and suitable locations to safeguard uninterrupted traffic. The signage may be provided as per the guidelines given in IRC:67 "Code of Practice for Road Signs".

List of some of the essential markings and signage include –

- Directions
- Road side facilities
- Speed limits
- Lane marking and usage
- Overtaking and turning restrictions (if applicable)
- Pedestrian and cycle path (Along and Across)
- Gore area and chevron treatment
- Carriage shyness and travelled way reflectors
- Emergency provisions and contacts

16 CONSTRUCTION AND MAINTENANCE

Projects are planned and carried out using a sequence of activities commonly referred to as the project cycle. There are many ways of defining the steps in the sequence but the following terminologies in road projects are commonly used: - identification, feasibility study and preliminary design, detailed engineering design, commitments and procurement, construction supervision and management, operation and project monitoring evaluation. Details on construction, maintenance and inspection to be referred in IRC:SP:90 "Manual for Grade Separators & Elevated Structures".

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ABBREVIATIONS

cd	Candela
cp	Candlepower
cu	Coefficient of Utilization
HoV	High Occupancy Vehicle
IRC	Indian Roads Congress
km/h	Kilometer Per Hour
LoS	Level of Service
lx	Lux (Unit of Illuminance)
m	Meter
MDR	Major District Road
MoHUA	Ministry of Housing and Urban Affairs
NMT	Non-Motorized Transport
ODR	Other District Road
OSOW	Over Size and Over Weight Vehicles
PCU	Passenger Car Unit
PT	Public Transport
SI	International System of Units (Système International)
SoV	Single Occupancy Vehicle
SP	Special Publication
SPUI	Single Point Urban Interchange
SSD	Stopping Sight Distance

ANNEXURE 1: PROTOTYPE INTERCHANGES

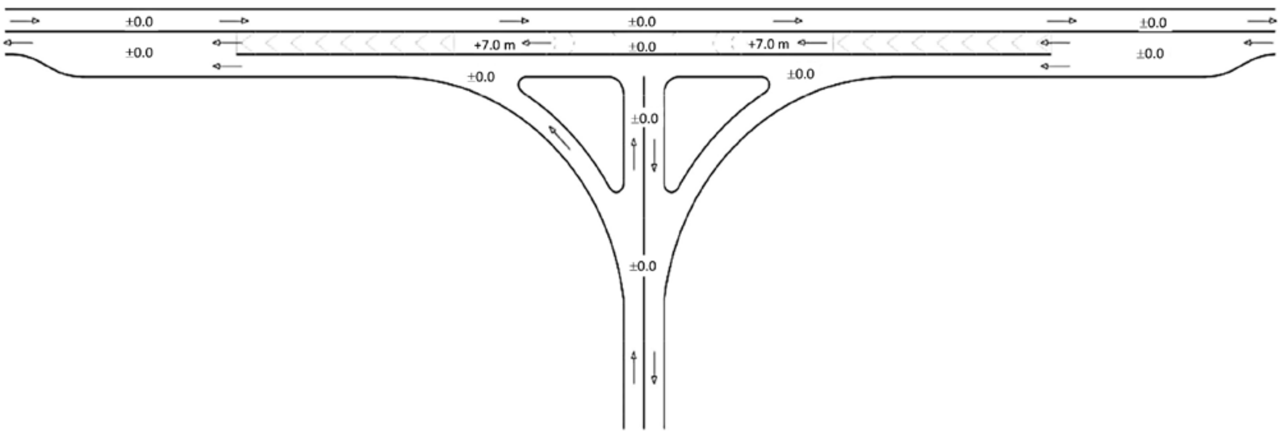

Fig. 1 3-arm Partially Grade Separated Interchange

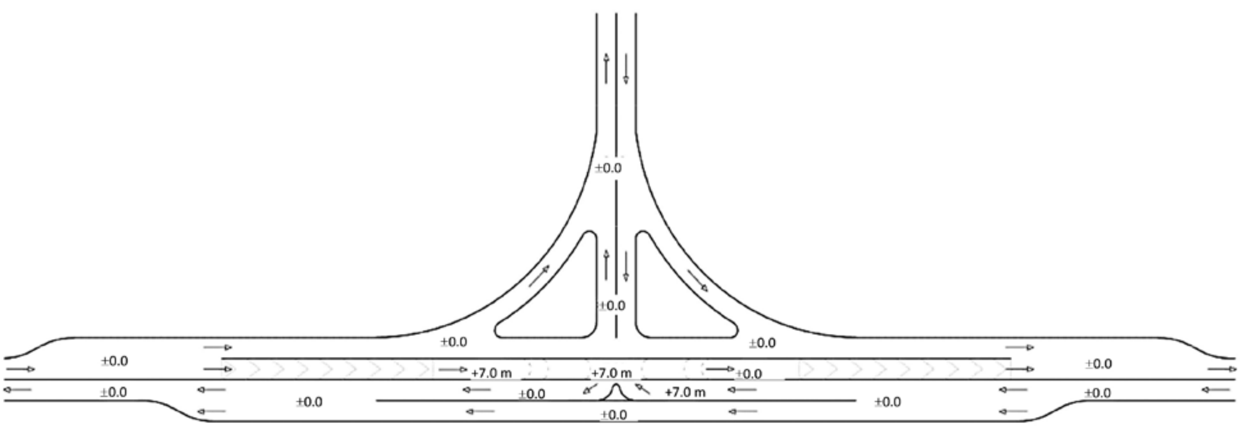

Fig. 2 3-arm Partially Grade Separated Interchange

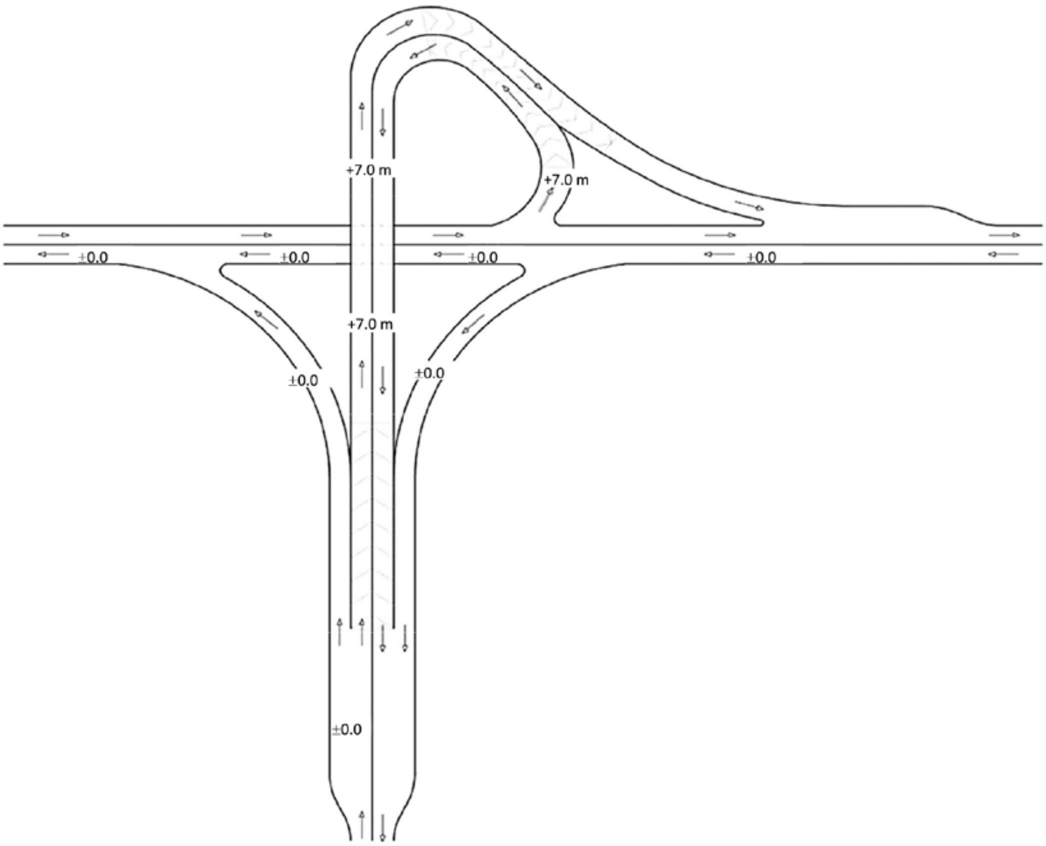

Fig. 3 3-arm Grade Separated/Trumpet Interchange

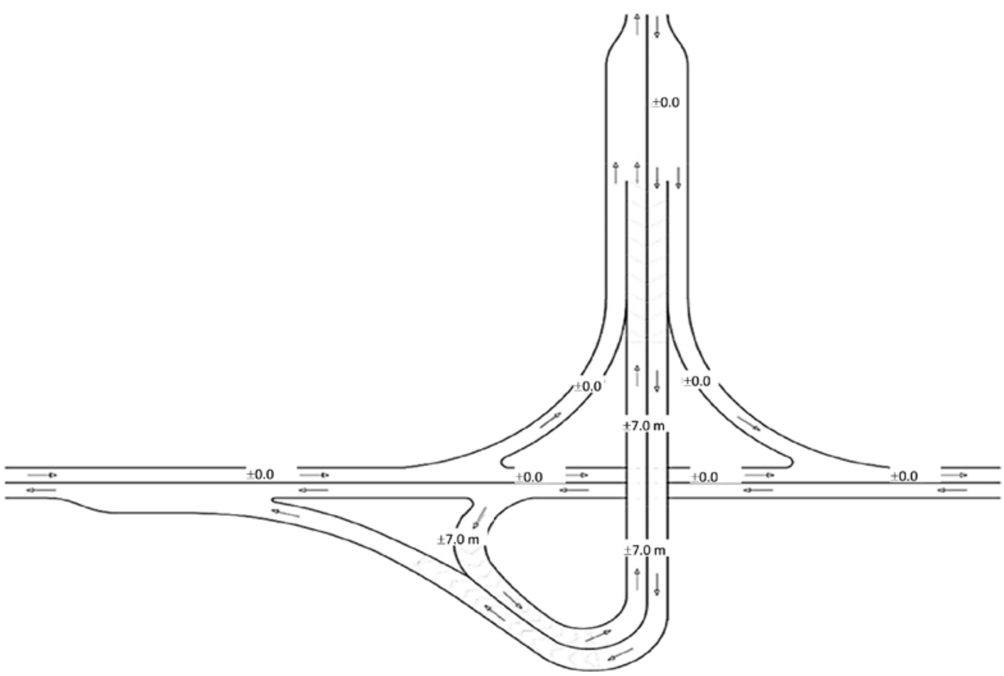

Fig. 4 3-arm Grade Separated Interchange

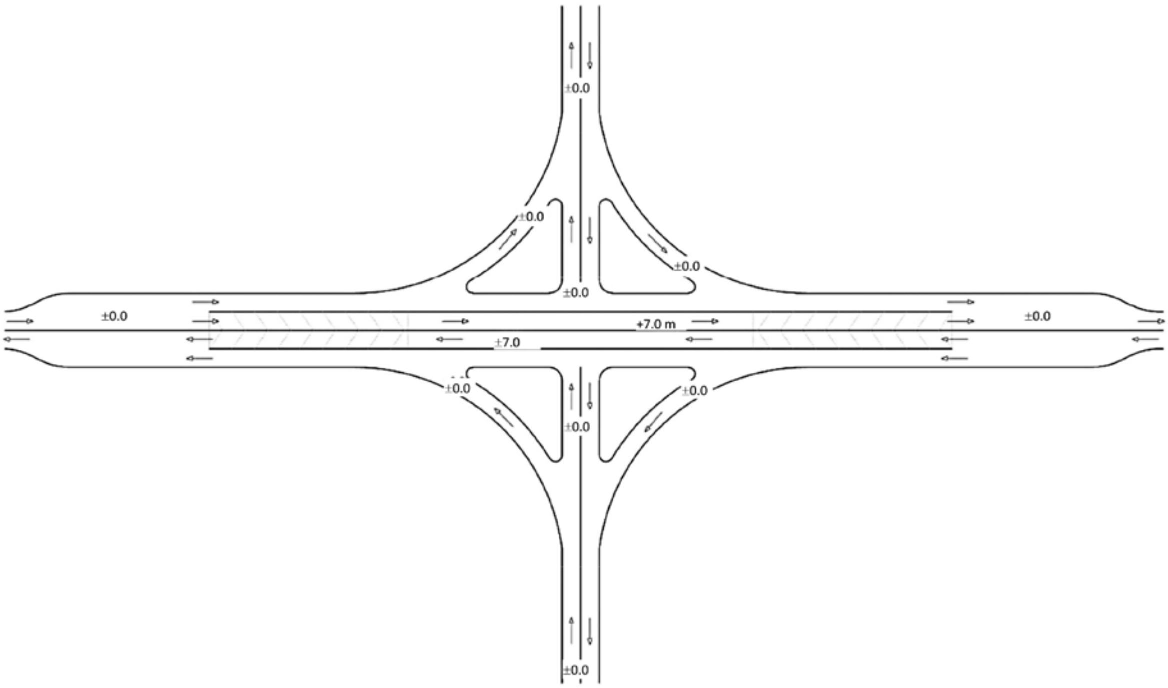

Fig. 5 4-arm Partially Grade Separated Interchange

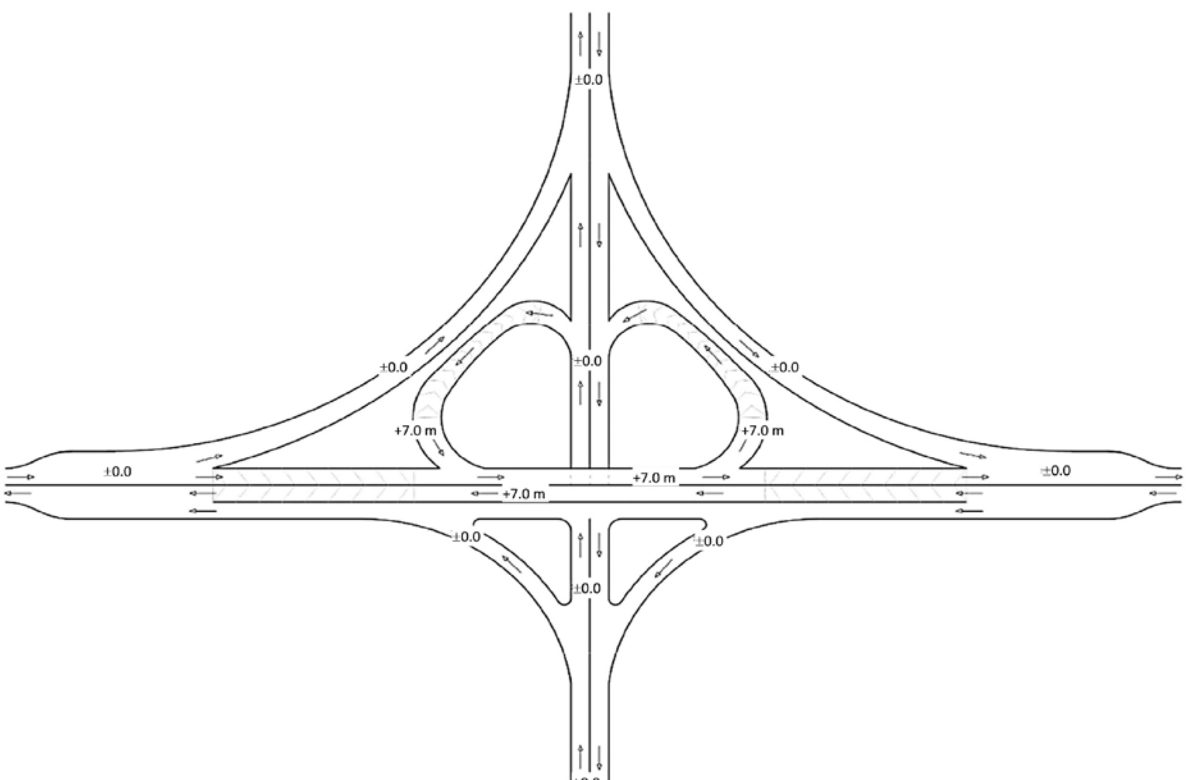

Fig. 6 4-arm Partially Grade Separated/Parclo Interchange

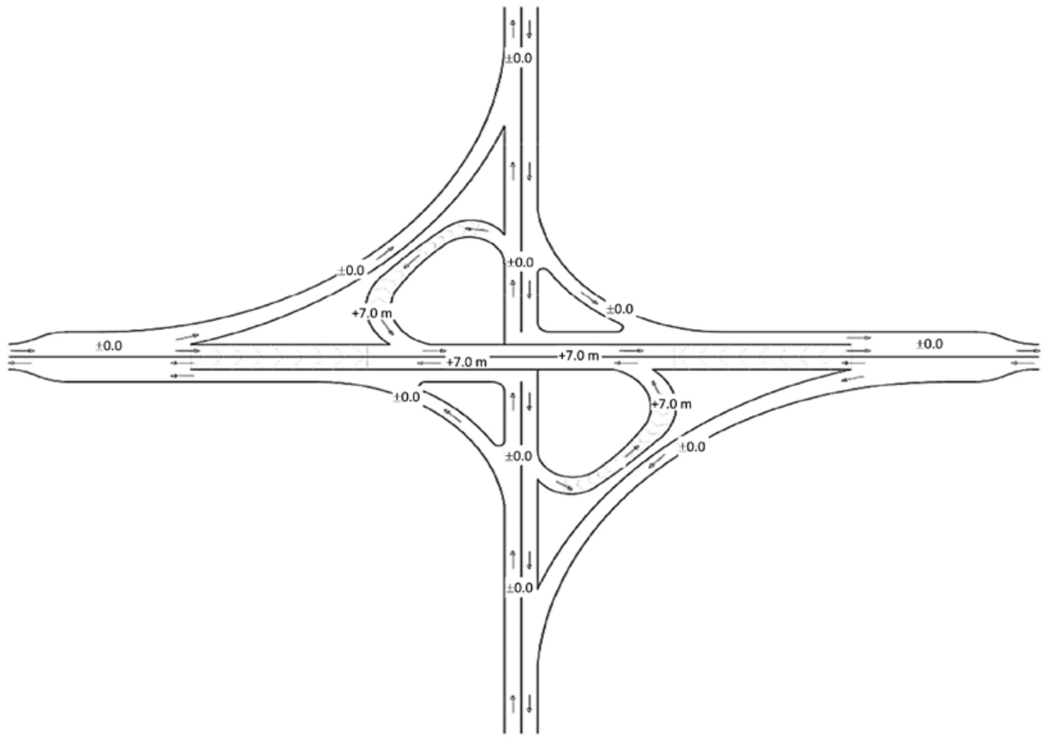

Fig. 7 4-arm Partially Grade Separated Interchange

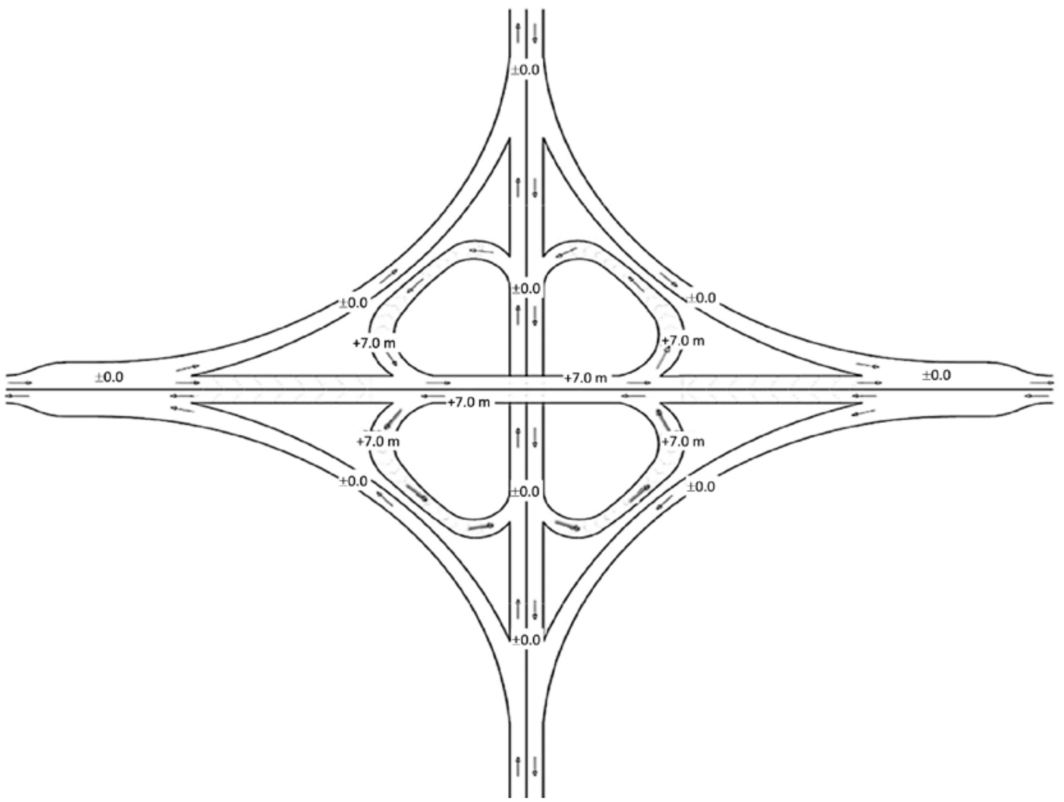

Fig. 8 4-arm Totally Grade Separated/Cloverleaf Interchange

(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the Code/Guidelines/Manual, etc. from the date specified therein)