**SESSION I – INTERSECTIONS AND INTERCHANGES**

**LECTURE I1 - INTERSECTION DESIGN** **Presenter: CD SCOTT**

# 1 INTRODUCTION

Without intersections, a collection of roads would not be a network and, while this would ease the driving task, the choice of destinations would not exist. The objective in providing intersections is thus to enable the driver to move towards a chosen destination by leaving one route in favour of another and being able to do so in safety. Intersection design is aimed at reducing the potential severity of collisions while facilitating and guiding movement through the intersection area.

Particularly in the urban environment, the network stands or falls by the efficiency of its nodes, the intersections. Constraints on capacity are found principally at the intersections because, if signalised, they automatically introduce a reduction in the time in which travel can occur past a point on the road. In the period of time available for flow in a given direction, further reductions in capacity are occasioned by the impedance created by vehicles which wish to turn and are either slow moving or stationary while waiting for a gap in the opposing traffic. The majority of collisions occur at intersections.

In rural areas, intersections are remote from each other and traffic volumes low, so that they have little or no effect on the performance of the network as such. As in the case of urban intersections, rural crashes have a higher frequency at intersections than elsewhere in the network. Because of the higher speed differentials between through- and turning traffic, the consequences of these crashes are more severe. Speed differentials also impinge directly on the selection of sites for rural intersections.

Fundamental issues that the designer must bear in mind when considering the design of an intersection include its form (shape of its skeleton), its spacing from adjacent intersections, its location and topography, visibility and aspects of channelisation and the safe accommodation of all required vehicle movements. This lecture will introduce these issues.

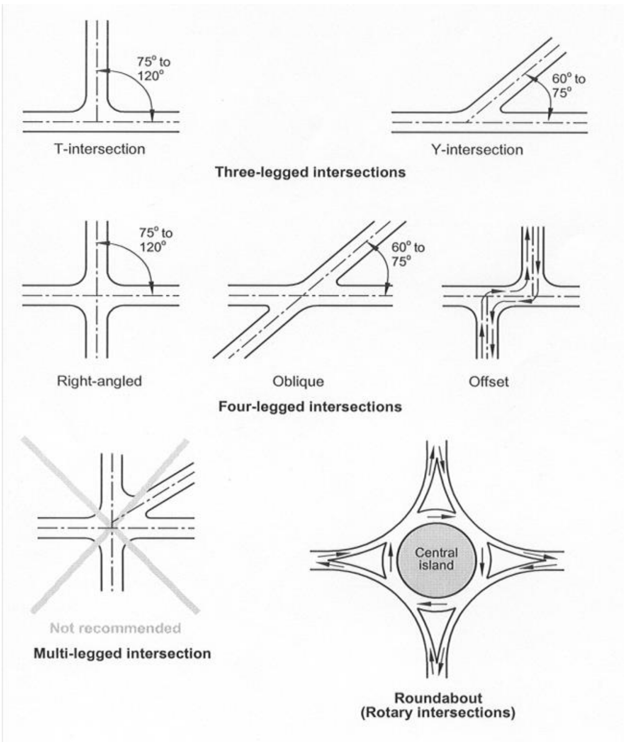
# 2 INTERSECTION FORM

An intersection is created by the crossing or joining of two roads, each approach road being referred to as a leg. (This American nomenclature, generally adopted in South Africa, is different to the British, which would be refer to an “arm”). The number of movements at an intersection has a direct bearing on its safety and capacity so that the three-legged intersection with a maximum of six possible movements and six conflict points is both safer and more efficient than a four-legged intersection with its twelve movements and 24 conflict points.

Five legs result in a possible twenty movements. For an intersection to operate properly, it is necessary to assign priority to various of the movements either permanently by way of a stop condition or temporarily as occurs cyclically with signalisation. This is difficult enough for the designer to do but the poor motorist, who is not blessed with the wisdom of the average designer, has just a few seconds to make up his mind as to who actually has priority. Even if this is done, without near-misses or crashes, the fact of the matter is that the delays involved in clearing a complex intersection would be substantial. In practice, anything more than four legs to an intersection is a recipe for disaster.

Intersection legs should ideally meet at right angles, to afford the driver on the minor approaches the best possible view of the major flow of traffic but a modest skew can be considered if necessary. The absolute maximum range of intersection angles should be 15° off square on one side, and 30° off square on the other. Figure I1.1 illustrates the concept.

If really necessary, the acute angle on the driver's side (right-hand side) of the approaching vehicle may be reduced to a minimum of 60°. This may not be done on the left side of the vehicle because in that position a passenger will obstruct the driver's view to the left. For that reason, the Y- and oblique-intersections shown below with angles of as little as 60° on the left are most undesirable.



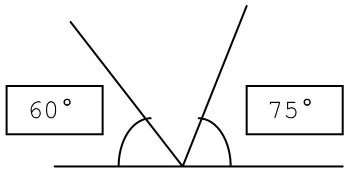




Figure I1.1: Intersection form

The normal forms of intersection are the crossing of two roadways, and the Tee formed where one road terminates at a junction with another which is continuous through the junction. These might occur within a large range of intersection angles. The Y form is undesirable because of the acute angle between the legs of the intersection. A staggered intersection is really just two Tee-intersections on opposite sides of the through road and in close proximity to each other. The direction of the offset should be such that it allows a vehicle which continues on the joining road, from one side of the main road to the other, to do so by first making a right turn and then a left turn. This enables the slow joining-and-turning vehicle to clear the main road most quickly and easily, leaving it freely and unobstructed with a left turn unopposed by oncoming traffic.

Intersection form does not refer to the type of control used. Thus, a mini-roundabout, traffic circle or rotary (which only differ in size) are also described as being three- or four-legged intersections

# 3 INTERSECTION SPACING

Intersection spacing is dependent on the function of the major road which should be the one carrying the greater volume of traffic. Spacing can be anything between 5 km and 20-50 metres, the former being between interchanges on a freeway and the latter being between the two T junctions comprising a staggered intersection.

The inter-related matters of access control and operational efficiency thus become issues to consider. Joubert[1] discusses these matters as they affect the urban arterial and he also comments on the desirability of intersection spacings being such that signal progression becomes possible. In a paper presented at the 2002 SATC, Sampson points to the desirability of a spacing of 800 metres on a Class 2 arterial and 600 metres on a Class 3 road. A national policy document on access control "TRH 26: Road Classification and Access Management Manual" has been compiled, and it deals exhaustively with the matter of intersection spacing.

In terms of the movement function, a network comprises a hierarchy of roads ranging from the freeway (the ultimate vehicle-only route) to the lower-order mixed usage street (corresponding roughly to a residential street). There is also a hierarchy of intersections. The lowest level of intersection is the driveway entrance, and the highest is the interchange. Previously when a 5-level hierarchy was almost universal, the practice was that no street should connect to any other if it was more than one level above or below it in the hierarchy. Currently, classification in urban areas may be less rigid, with less clear guidance on a hierarchical approach to establishing intersections. Urban movement networks are viewed in urban planning circles as comprising vehicle-only, pedestrian-only, and mixed-use routes. It is suggested that a lower order mixed usage street should not connect directly to a vehicle-only route. This is not only in terms of considerations of the efficiency of the vehicle-only route but also to minimise the incidence of rat-running.

## 4 LOCATION OF INTERSECTIONS

Restraints on the location of urban intersections due to cadastral, developmental, and topographic considerations, make things difficult for the designer. Urban design is often more difficult than rural as far as the location of intersections is concerned. In new urban layouts a lot of the restrictions fall away, but infilling and re-development operations often lead to the problem of trying to improve layouts that were adequate in the past, while at the same time creating a layout which is not going to totally disrupt the surrounding area.

Rural intersections are more often influenced by topography alone, and since there is a far greater freedom of choice in the location of the intersections, topographic problems can often be avoided. It remains essential to be aware of what constitutes good or poor location and what actions are required to minimise the consequences of a poor location, if alternative sites are not available.

At any intersection, a vehicle must have sufficient sight distance in which to stop. In addition, there must be sufficient advance warning that a stop is required. This applies principally to the controlled legs of the intersection but must also be allowed for on the through-legs. A momentary lapse of concentration by the driver of a vehicle on a controlled leg, a mechanical malfunction of his vehicle or a lack of manoeuvrability or performance of this vehicle may force a vehicle on the through leg to take some form of avoiding action. This may include coming to a standstill. The ideal location for an intersection thus includes level grades, a $90^o$ angle of intersection and adequate sight distance not only along each leg but also between opposing legs of the intersection (which is of importance to right-turners).

Stopping distance is adversely affected by both gradient and horizontal curvature. A down gradient of 6 % adds roughly 50 % on to the distance required for stopping and drivers seem to experience difficulty in judging the distance required for stopping on downgrades. As a safety measure, intersections should generally not be located where gradients on the through road are steeper than 3 %.

Intersections on curves present a stopping distance problem to vehicles on the through road because the maximum acceptable rate of deceleration is reduced in curves.

Vehicles joining a road on the inside of a curve have the problem that approaching main-road traffic is partially behind them. Apart from the visibility problem with excessive head-turning that this entails, the line of sight may fall outside the road reserve, creating a problem in ensuring that the sight triangle is kept clear of obstructions. The proud homeowner would probably greet the wielder of the chainsaw with a shotgun if the latter were even to look at the former’s great oak tree.

Drivers on the intersecting leg on the outside of the curve generally have excellent visibility in that approaching vehicles are partly in front of them and they have a height advantage created by the superelevation. They do however have to negotiate negative superelevation while turning onto the through road. This should not be a problem for passenger cars, but trucks with high loads are at risk during such a manoeuvre. Tight curves are basically not the place for intersections. Practical experience shows that intersections on a curve with a superelevation greater than 6 % do not function adequately, and the superelevation should for preference not be more than about 4 %.

If an intersection must be placed on a curve, the designer will have particular problems. The major complication is the sharp change in gradient that can occur on the intersecting road in negotiating the superelevation of the through road, while a secondary complication is the additional stopping distance requirement of the through road.

Crashes at rural intersections typically occur with high speed differentials, and there is much energy in the form of momentum that has to be dissipated. One or both of the vehicles involved could, and often do, leave the road. It is therefore unwise to locate intersections on high fills.

The crossroad ramp terminals of a narrow diamond interchange, as discussed in a subsequent lecture, are common examples of intersections on high fills, which also have sight-distance problems. The balustrades of the overpass bridge tend to reduce the visibility of vehicles approaching from the right, perhaps below a sight-distance already limited by a crest curve over the freeway. The positions of such intersections may be fixed for other reasons, and if they can not be moved, they call for extremely careful design.

The alignment of a proposed road may cross an existing road at a very flat angle, which would create problems of visibility. The crossing point is then not a good site for the intersection, and the crossing road should be relocated in the vicinity of the intersection to achieve an acceptable angle of skew. The options would be either to introduce an S-bend and create a crossing with acceptable visibility and crossing angle, or else to design a staggered crossing. The latter can only be done if the direction of the staggered offset allows "crossing" by joining the main road with a right turn and departing with a left turn, as set out above.

## 5 SIGHT DISTANCE

Discussion of the location of intersections stated the need for vehicles to be able to stop, either for a traffic control device or under emergency circumstances. Vehicles must also be able to negotiate the intersection safely, observing special intersection road markings such as those creating dedicated turn lanes. Drivers must be able to detect and assess gaps in opposing or conflicting traffic flows if the intersection is to operate safely. Three forms of sight distance apply, these being stopping sight distance, decision sight distance and intersection sight distance.

Stopping sight distance has already been discussed and this will not be repeated other than to stress that a sight distance read off a table in terms of a given design speed must be adjusted to allow for any special circumstances applying at the intersection, such as gradient, horizontal curvature and super-elevation. Superelevation can also affect the available sight distance

### 5.1 Decision sight distance

Decision sight distance is not generally applied to all intersections, but it can be essential where layouts are unusual or unexpected, or where an approach to the junction might allow an approach at excessive speed (no tight bend to regulate speed). The decision required of a driver may be that he has to stop or divert from his approach path in response to a road marking. If stopping is then required, this decision sight distance will differ from normal stopping sight distance because in the former case, the object height is taken as zero (effectively the height of the paint marking above the road surface). If the design speed of the road is 120 km/h, the stopping distance provided should be 210 metres with relatively little likelihood of the driver being able to perceive, much less interpret, a road marking at that range. Advance warning markings are thus required. The rationale behind what could be considered an excessive provision of sight distance is that the only limitation on the driver seeing the sign and responding to it should be his own capabilities and physical limitations and not an artificial limitation imposed by the geometric design of the intersection.

### 5.2 Intersection sight distance

Intersection sight distance (sometimes referred to as Shoulder Sight Distance) is a distance measured along the centreline of the through road. The requirement is based on the ability of a driver on the intersecting road to complete a manoeuvre in safety even though a through-road vehicle could come into sight just as the manoeuvre commences.

Recent research has proposed a change in our approach to this particular topic. The traditional FHWA models are discussed below, but the new SANRAL document has switched to the Fitzpatrick approach. Fitzpatrick[3] et al have suggested that, as in the case of the stopping sight distance model, the FHWA approach is unsuitable. They suggest that the more logical approach is first to establish what the major movement is that must be accommodated, and then to establish what the design vehicle for this particular movement is. Thereafter, consider what the gap acceptance of the driver in question is likely to be. The design vehicle features in their approach because of its effect on gap acceptance. The driver of your average Ferrari is likely to be prepared to accept a smaller gap than the poor individual who has to insert 22 m of semi-trailer plus trailer into the traffic stream. However, the method reverts to the familiar “sight distance” concept, by converting the time-gap back to distance, according to the relevant speed. It remains a more logical and satisfactory approach than the blanket application of standard distances for a given design speed because it does allow for several site-specific considerations such as the road width, gradients and vehicle types.

To revert to the tried-and-true FHWA model, six combinations of circumstances are possible. The driver can either turn to the left or to the right or proceed across the through road and opposing vehicles can come either from the left or the right. The left turn with the opposing vehicle also coming from the left is irrelevant. Proceeding across the intersection with the opposing vehicle coming from the left is more critical than when it is coming from the right, because of the greater distance that has to be travelled before the crossing vehicle can be considered safe. The left turn in advance of a vehicle from the right is marginally more critical than a right turn in advance of a vehicle from the left, because of the tighter radius and correspondingly slower turn to the left which translates into a higher speed differential on entry to the through road.

There are thus two critical cases and both have to be considered. The more critical of the two is adopted for design purposes.

(a) Straight through with opposing vehicle from left

It is assumed that the opposing vehicle will be travelling at the design speed of the through road. The crossing vehicle will commence its movement two seconds after the driver has satisfied himself that the gap presented is safe. The distance that it has to travel to reach safety is the sum of the distance from the stop line to the edge of the through road, the width of the through road and the length of the crossing vehicle (to clear the through road).

(b) Left turn in advance of opposing vehicle from right

The opposing vehicle is assumed once again to be travelling at the design speed of the through road. Ideally, the driver of the turning vehicle should judge the required gap on the basis of his being able to accelerate to the design speed of the road and achieve the condition of being two seconds or more ahead of the opposing vehicle at the end of the manoeuvre. For design purposes, particularly under limiting conditions of topography, this can be difficult to achieve and a more stringent set of circumstances have to be assumed, namely that the driver on the through road, on perceiving that the turning vehicle does not intend waiting for him, should decelerate gently - that is without braking - while the turning vehicle is applying fairly robust acceleration. The end result should be that the two vehicles end up with a two second headway, or more, and at a common speed which will be less than the design speed.

The values of intersection sight distance quoted in TRH17 are based on the vehicle on the crossing road travelling straight across the intersection. In rural areas, intersections are, more often than not, three-legged so that the values of required sight distance are not always appropriate to the circumstances and the designer would be well-advised to check what is actually being provided.

A substantial gradient, i.e. more than 3 %, will require the designer to treat the intersection as a special case. When, for example, the driver coming from the side road is faced with an upgrade to the right on the through road, he will probably find that the opposing car travelling from left to right will be travelling slower than that from right to left. The latter opposing vehicle may present more of a problem than the former in the case of a straight crossing movement in spite of the lesser distance to be covered before safety is achieved. In the same way, a left turn would be in the face of a vehicle that, without braking, would not decelerate at all, while the turning vehicle's ability to accelerate would be vastly enhanced. Conversely, a right turn will be accompanied by a far lower rate of acceleration up the gradient, but the opposing vehicle from the left will slow rapidly and easily against the gradient. To sum up, the intersection sight distance has to be checked for both directions of travel along the through road with separate calculations and for the crossing movement.

Intersection sight distance is measured along the centreline of the through road and is based on a driver eye height of 1,05 metres for passenger cars and 1,80 metres in the case of trucks with an object height of 1,3 metres.

### 5.3 The sight triangle

The sight triangle is the area bounded by the centre lines of the through road and the crossing road, and the line of sight for the minimum required sight distance. This area must be clear of any obstruction to sight at all times and should thus for preference be incorporated within the road reserve. The form of priority control, yield or stop, dictates the extent of the sight triangle and which of the combinations of manoeuvres should be selected as being critical.

(a) Stop control requires a line of sight commencing at a point on the centreline of the side road and, in the rural environment, 5 metres back from the edge of the through carriageway. The Red Book recommends that, for urban intersections, this distance can be reduced to 2,5 m. This value is a compromise between the typically narrower road reserves in urban areas and the need to provide space for a pedestrian crosswalk beyond the stop line. The line of sight terminates on the centreline of the through road. The critical manoeuvre is typically a straight crossing in the path of a vehicle approaching from the left assuming level grades on both roads. Other possibilities for the critical manoeuvre must also be checked.

(b) Yield control In the rural environment assumes that the vehicle on the crossing road will be approaching the intersection at 60 km/h and hence needing 45 metres to come to a stop.

It is unlikely that a sight triangle of this extent of would be available in urban areas. The Red Book therefore suggests that a vehicle approaching on the minor leg would be travelling at 30 km/h with the driver already preparing to stop. The need for reaction time thus falls away and a distance of 10 m would be required to bring the vehicle to a standstill. Although not explicitly stated in the Red Book, it should be assumed that the vehicle would be stopped at a point 2,5 m back from the edge of the through carriageway. This suggests that the sight triangle should commence at a point 12,5 m from the carriageway edge.

The line of sight terminates on the centreline of the through road. The critical manoeuvre is the left turn with the vehicle on the through road slowing to match speeds.

## 6 CHANNELISATION

Intersections, at their simplest, are a crossing of two roads with circular curves joining their edges to accommodate the turning radius of the design vehicle. The outline of each approach thus forms what is commonly described as a bellmouth. Complex traffic situations often require channelisation, which is accomplished by the use of islands.

High traffic volumes may require that turning movements be provided with refuge areas where they approach conflict points and need to be taken out of the main traffic stream. Pedestrians may also require refuge areas within the intersection area. An awkward angle of skew could lead to an intersection layout with large surfaced areas on which the required travel path is not always clear. Traffic movement can then best be ordered by being channelled along appropriate paths by islands. Typical channelising layouts are illustrated in Figure I1.2.

Kerbed Islands are, in themselves, a hazard. (Painted islands are often ignored and are generally ineffective channelising tools). Since safety is a prime concern in geometric design, the introduction of such hazards must be well motivated and carefully implemented. The cardinal principle that is adopted by all designers is:

ANY HAZARD INTRODUCED MUST BE LESS THAN THE HAZARD IT REPLACES

Channelisation is introduced for one or more of the following reasons:

- ❑ separation of conflicts;
- ❑ control of angle of conflict, merge or diverge;
- ❑ reduction of excessive pavement area;
- ❑ regulation of traffic and indication of the proper use of the intersection, including speed control by bending, funnelling or narrowing and the prevention of illegal or improper manoeuvres;
- ❑ arrangement to favour a predominant turning movement;
- ❑ protection of pedestrians;
- ❑ protection and storage of turning vehicles; and
- ❑ location of traffic control devices.

It is better to have few, relatively large islands than to have a driver trying to pick his way through an archipelago of small and correspondingly less visible islands while surrounded by a host of drivers who are obviously totally familiar with the environment and apparently imbued with only the most malevolent of intentions.

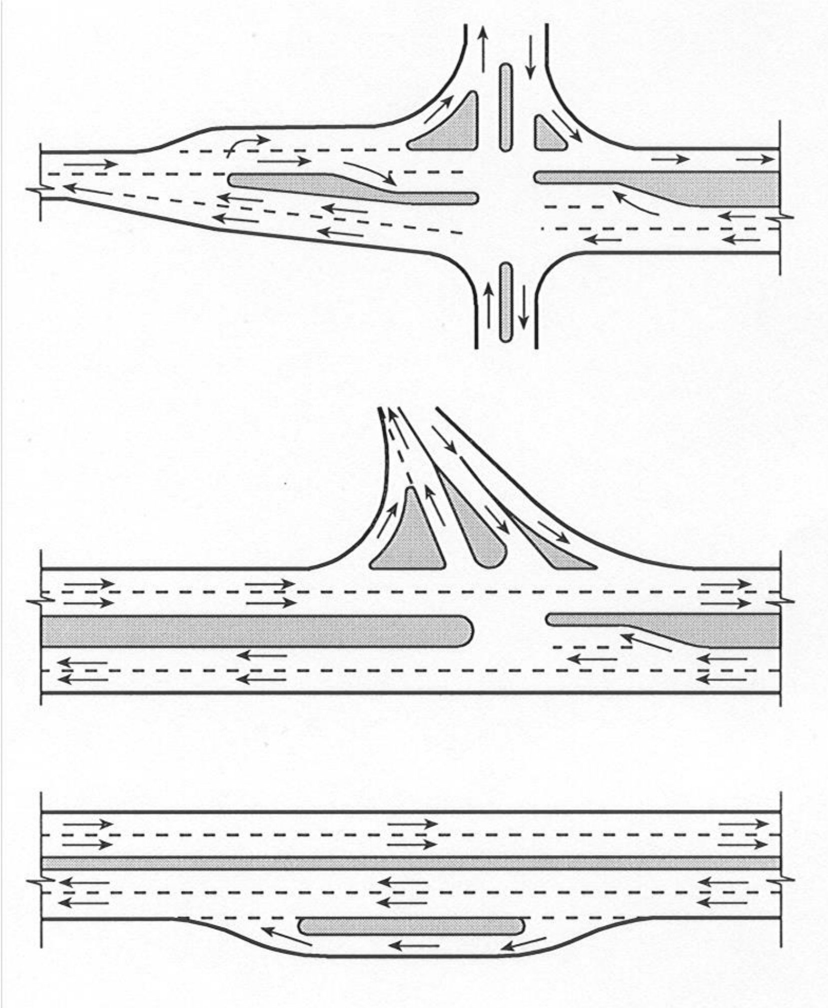


**Figure I1.2: Typical channelising islands**

## 7 INTERSECTION ELEMENTS

Being a node in a larger system which is the network as a whole, the intersection is a local sub-system. It accepts input in the form of three or more streams of vehicles arriving from various origins in a certain sequence at differing volumes and speeds and then processes these streams to deliver an output of the same vehicles, recombined as different streams each with its own composition, volume and range of speeds and all headed towards one of the possible destinations.

The designer's task is to ensure that the process within the sub-system is safe, economic both in direct cost and time and matching the tempo required by the system as a whole to ensure that localised congestion does not occur. To achieve this condition a repertoire of elements can be employed, as discussed below.

The selection of elements and their dimensions depends on the function of the network links served by the intersection, the volume of vehicles to be processed, and the distribution of turning movements required to reconstitute arriving streams into departing streams. The restraints that have to be considered are the limitations of the drivers as data processing and reactive entities, and the characteristics of their vehicles in terms of physical dimensions and operational behaviour. The elements to be discussed here are turning radii, turning roadways, auxiliary lanes and tapers, and islands.

### 7.1 Turning radii

As previously discussed, every vehicle type has a certain minimum radius of turn that it can accomplish. These minimum radii can be used only at very low speeds, and it is generally not advisable to use them in an intersection if congestion is to be avoided.

The selection of radii is based firstly on the turning paths of the vehicles and may be influenced by the desired travel speed. Typical turning speeds lie in the range of 20 to 30 km/h suggesting radii of 10 to 25 metres, but a value often adopted for main road intersections is 15 metres edge radius.

No vehicle can change instantaneously from a straight-line path to a pure circular path. The path followed is a transitional spiral followed by a distance along the circle, followed in turn by a transitional spiral back to straight line travel. Driver guidance is best done with the delineation of the roadway edges following closely along the path that the vehicle can actually follow. This is achieved by using a compound curve, often in the form of a three-centre curve. Ratios between successive curves of 2:1:4 or 3:1:3 are often employed. The radius of the central curve can be close to the minimum turning radius for the design vehicle, while the transitions are taken care of by the larger outer radii. In contrast, a single-radius curve would have to have a significantly larger radius. The compound curve approach is particularly useful in the case of angles of skew greater than $90^o$ where a large and unused surfaced area would result from using a simple curve.

The final shape of the roadway edge can be tested by the use of turn-path templates to ensure that the edge-line is constantly at the same distance from the path of the inside rear wheel of the design vehicle for the selected minimum radius. To make life easier, the template can also be electronic. Draughting is largely CAD-based, and software such as Auto-Turn is very handy. Such a program can also track a Boeing 747 (the vehicle overhang in this case, not surprisingly, being described by the wingtips)

It must always be remembered trucks must have access to all areas of even the most densely developed low-cost residential area with narrow streets, for purposes of refuse removal and fire-fighting.

### 7.2 Turning roadways

Turning roadways are generally used when large volumes of turning traffic demand special treatment. They are then removed from the main intersection area, its conflicts and its control. A simple bell-mouth with a large radius appropriate to the traffic flow would result in a large unused blacktop area with wasteful construction costs. The lack of guidance on the large unsurfaced area could lead to travel paths unanticipated by other drivers, and result in collisions. The solution is to provide a separate turning roadway, “outside” an island. Relatively large radii are used, typically 25 metres.

The width of the turning roadway is a function of

- its chosen radius
- the selected “traffic condition”
- the selected “operating condition”

Three traffic conditions cover the spectrum encountered:

Condition A: Insufficient SU vehicles to influence design
Condition B: Sufficient SU vehicles to influence design
Condition C: Sufficient WB-50 vehicles to influence design

There are also three operating conditions

Case 1: One-way one-lane with no provision for passing stalled vehicles.
Case 2: One-way one-lane with provision for passing stalled vehicles.
Case 3: Two-lane one-way operation

Because of the short length of turning roadways and the likelihood of SU vehicles in the stream it is usual to design for Condition B Case 1 in which case widths vary from 5,4 metres for an inner radius of 15 metres to 4,5 metres for a 150-metre inner radius.

The short length of turning roadways also makes it difficult if not impossible to achieve anything more than nominal superelevation. Speeds are however low, under which circumstances drivers are prepared to accept higher side thrusts than would be comfortable on a long curve at high speed. Normally, superelevation is thus limited to matching the grading of the edges of the through and crossing road, but every effort must be made to have the cross-fall in the right direction to assist turning.

Table I1.1 on the next page sets out the widths of turning roadway needed for a range of radii, traffic conditions and operating conditions.

| Table I1.1: Turning Roadway Widths (m) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Radius on inner edge (m)** | **Case I** | | | **Case II** | | | **Case III** | | |
| | **Design Traffic Condition** | | | | | | | | |
| | **A** | **B** | **C** | **A** | **B** | **C** | **A** | **B** | **C** |
| 15 | 5,4 | 5,4 | 6,9 | 6,9 | 7,5 | 8,7 | 9,3 | 10,5 | 12,6 |
| 25 | 4,8 | 5,1 | 5,7 | 6,3 | 6,9 | 8,1 | 8,7 | 9,9 | 11,1 |
| 30 | 4,5 | 4,8 | 5,4 | 6,0 | 6,6 | 7,5 | 8,4 | 9,3 | 10,5 |
| 50 | 4,2 | 4,8 | 5,1 | 5,7 | 6,3 | 7,2 | 8,1 | 9,0 | 9,9 |
| 75 | 3,9 | 4,8 | 4,8 | 5,7 | 6,3 | 6,9 | 8,1 | 8,7 | 9,3 |
| 100 | 3,9 | 4,5 | 4,8 | 5,4 | 6,0 | 6,6 | 7,8 | 8,4 | 0,0 |
| 125 | 3,7 | 4,5 | 4,8 | 5,4 | 6,0 | 6,6 | 7,8 | 8,4 | 8,7 |
| 150 | 3,7 | 4,5 | 4,5 | 5,4 | 6,0 | 6,6 | 7,8 | 8,4 | 8,7 |
| Tangent | 3,7 | 4,5 | 4,5 | 5,1 | 5,7 | 6,3 | 7,5 | 8,1 | 8,1 |
| **Width modification appropriate to edge treatment** | | | | | | | | | |
| Mountable kerb | None | | | None | | | None | | |
| Barrier kerb one side | Add 0,3 m | | | None | | | Add 0,3 m | | |
| Barrier kerb both sides | Add 0,6 m | | | Add 0,3 m | | | Add 0,6 m | | |
| Stabilised shoulder one or both sides | Condition B & C lane widths on tangent may be reduced to 3,7 m for 1,2 m or wider shoulder | | | Deduct shoulder width; minimum width as for Case I | | | Deduct 0,6 m where shoulder is 1,2 m or wider | | |

### 7.3 Tapers and auxiliary lanes

**7.3.1: The Need:** The principal contributor to the risk of head-to-tail collisions at intersections is the large speed difference between turning and through vehicles. Apart from safety considerations, a high volume of turning vehicles can present substantial impedance to other traffic, and this leads to inefficient utilisation of the intersection. For both reasons, it is often necessary to separate turning vehicles from through traffic and this is achieved by provision of auxiliary lanes.

Auxiliary lanes also provide a clear space in which turning vehicles can decelerate from or accelerate to the operating speed of the through movements in safety. They provide a refuge and storage for vehicles waiting for gaps in opposing traffic prior to completing the turn. Through-vehicles do not have to wait for a stopped leading vehicle to find an acceptable gap.

Another reason to provide auxiliary lanes is to increase the capacity for through-traffic at a junction. If there is signalisation, that means there is only a fraction of the flow time available on the individual links, for movement through the intersection. As a super-simplification, with green time on one approach being, say, 30 out of 60 seconds, the flow rate through the intersection for the duration of the green signal must be double that on the approach leg, in order to maintain the same average flow rate. Of course, under “green wave” conditions and if the capacity of the approach road is not more than half used, everybody would get through the green signal without he need for auxiliary lanes. However, in more typical conditions, the additional capacity of auxiliary lanes will be required. Auxiliary lanes assist in matching the capacity of the intersection to that of its approaches.

**7.3.2 The Design:** Deceleration lanes commence with a tapered section. The length of taper is such that vehicles can traverse a reverse curve path close to the speed of the through traffic, with deceleration commencing only when the slowing vehicle clear of the through traffic. The radii of curvature of the path may be approximated by those appropriate for a superelevation of 2 % followed by a negative superelevation of 2 %. The corresponding taper rate would thus vary from 1:15 for 60 km/h to 1:27 for 120 km/h. The length of the remainder of the deceleration lane is based on a comfortable deceleration rate which is half that used in the calculation of stopping sight distance. Vehicle storage must also be allowed for if queueing will occur Where a gradient is involved, the length of lane has to be lengthened or may be shortened depending on whether the gradient is negative or positive respectively.

It may be noted that these taper rates are flatter than those for high-speed freeway exits, because the freeway exit does not have to allow for the reverse-curve movement required here.

The taper rate for acceleration lane termini lies in the range of 1:35 to 1:50 and this is based on the need to find a gap into which the accelerating vehicle can merge. Acceleration is assumed to be at a rate of 1,5 $m/s^2$ and, because of the restriction on space in the urban environment, it is assumed that acceleration continues to take place on the taper, which is thus included in the overall length of the acceleration lane.

Note that tapers which force vehicles into a certain path (e.g. where a lane is dropped) are known as “active” tapers, while those that permit a change of path (where a lane is added, say) are known as “passive” tapers.

**Table I1.2: Taper Rates**

| **Design speed (km/h)** | **30** | **40** | **50** | **60** | **80** | **100** |
|---|---|---|---|---|---|---|
| Passive tapers | | | | | | |
| Taper rate (1 in) | 5 | 8 | 10 | 15 | 20 | 25 |
| Active tapers | | | | | | |
| Taper rate (1 in) for painted line taper | 20 | 23 | 25 | 35 | 40 | 45 |
| Taper rate (1 in) for kerbed taper | 10 | 13 | 15 | 20 | 25 | 30 |

## 7.4 Islands

Channelisation requires islands, which provide areas within the carriageway that are not intended for use by vehicles. Islands may be painted on the road surface, they may be level with or depressed below the road surface, raised and kerbed, grassed or landscaped. They may be roughly triangular in shape or long, and the circular island is a special case, found as mini-circles or roundabouts.

The type of island treatment depends on its function. Pedestrian refuges should be raised and kerbed but with provision for wheelchairs and prams by means of depressed kerb sections and ramps. In rural areas, level or depressed islands are preferred because pedestrian volumes are low, thus not requiring protection by kerbs, and kerbing represents an unnecessary hazard.

On unlit roads it is difficult to see a raised island because of the dazzle created by oncoming headlights. Islands should be not smaller than about 5 $m^2$, to enhance their visibility and to make them effective in guiding traffic. The nose should have a radius of not less than 0,6 m. For visibility, the approach end of a kerbed island may be painted with contrasting black and white markings or fitted with reflective devices.

Islands are offset from the edge of the travelled lane to reduce the probability of their being struck. On high-speed roads and in a rural environment, an island adjacent to a through lane is typically offset by the full shoulder width plus a further 1,0 m at the nose. In urban areas, it is frequently not possible to provide this extent of space and a lesser offset has to be accepted.

Median islands (and outer separators) occur along the length of a road. Median islands serve to separate opposing streams of traffic and can be used effectively to reduce the nuisance and hazard of approaching headlights, by means of plantings or the placing of glare screens. As a safety measure they greatly reduce the likelihood of head-on collisions. Outer separators that create adjacent frontage roads are used relatively seldom. They tend to find application where a road serves a dual function as in the case of an urban arterial being taken through a shopping area. The former demands high speed and minimal interruption whereas the latter functions at very low speeds, has pedestrian traffic and vehicles manoeuvring in and out of parking bays.

The width of the median island in an intersection area can vary between wide limits. If its function is exclusively channelisation, a width of as little 0,6 m could be contemplated, although this width does not permit the placing of any warning sign other than perhaps a narrow chevron post.. Pedestrians require a median that is 2,0 to 3,0 m wide. Ideally, the median should be wide enough to accommodate a full lane width for right-turning vehicles in addition to providing refuge for pedestrians. This would suggest a width of 5,0 to 6,0 m. The latter width would also provide refuge for a light vehicle either crossing or turning right onto the through road from a side road.

Refuge for a crossing truck would require a median of the order of 9-12 m. It would be difficult to provide refuge for articulated vehicles because a semi-trailer can be 17 m long, or up to 22 m in the case of a combination vehicle.

Very wide medians are sometimes provided on rural roads to allow for the addition of further lanes at a later stage. However, rural divided roads can become suburban arterials, in time, Such wide medians frequently give rise to operational difficulties, creating long travel paths for crossing, and problems of signal phasing and delay when the junction eventually requires signalisation. It is thus generally better for traffic to avoid very wide medians, and to allow for extra lanes to be added along the outer edges of a road instead. Harwood et al[4] point this out in a counter-argument to the Green Book's enthusiasm about the landscaping opportunities offered by medians that are 18 and more metres wide. Where this wide-median signal problem arises, it probably has to be treated as two very closely-spaced intersections.