LECTURE I1– INTERSECTION DESIGN

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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. The majority of collisions occur at intersections.

Introduction

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 impact on the selection of sites for rural intersections.

Fundamental issues that the designer must consider in the design of an intersection include its form, its spacing from adjacent intersections, its location and topography, visibility and aspects of channelisation and the safe accommodation of all required vehicle movements.

Intersection Form

An intersection is created by the crossing or joining of two roads, each approach road being referred to as a leg. 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.

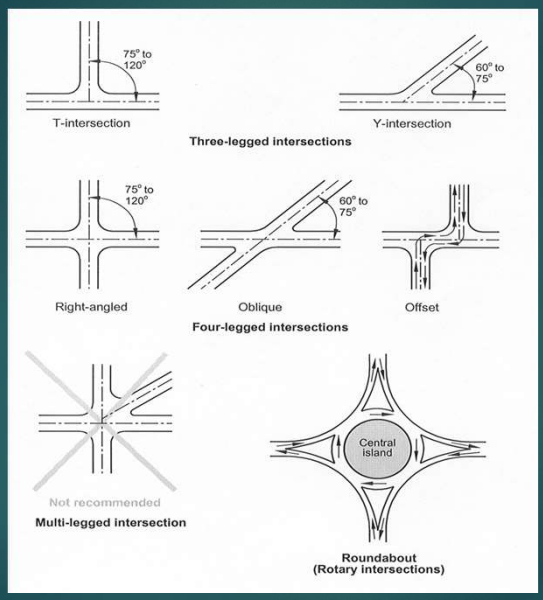
Five legs result in a possible twenty movements. without near-misses or crashes, the fact of the matter is that the delays involved in clearing a complex intersection would be substantial. In practice, anything more than four legs to an intersection is a recipe for disaster.

Intersection Form

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.

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.

Intersection Form



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.

A National policy document, TRH 26 South African Road Classification and Access Management Manual deals exhaustively with the matter of intersection spacing.

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.

The South African Road Classification and Access Management Manual deals with what class of road may or may not join at intersections. In general, roads of more than two levels of class order may not intersect.

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.

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.

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.

Location of Intersections

The ideal location for an intersection thus includes level grades, a 90° 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.

Location of Intersections

Intersections on curves present a stopping distance problem to vehicles on the through road because the maximum acceptable rate of deceleration is reduced on curves. Vehicles joining a road on the inside of a curve have the problem that approaching main-road traffic is partially behind them.

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.

Location of Intersections

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 %.

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.

Location of Intersections

The cross-road ramp terminals of a narrow diamond interchange, as will be 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.

The positions of potentially problematic intersections may be fixed for other reasons, and if they can not be moved, they call for extremely careful design.

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.

Sight Distance

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.

Sight Distance

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.

Sight Distance

The suggested and 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 method reverts to the familiar “sight distance” concept, by converting the time-gap back to distance, according to the relevant speed.

There are two critical cases, and both must be considered. The more critical of the two is adopted for design purposes.

Sight Distance

(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).

Sight Distance

(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.

Sight Distance

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.

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.

Sight Distance

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 maneuvers should be selected as being critical.

Sight Distance

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 cross-walk beyond the stop line.

The line of sight terminates on the centreline of the through road.

Sight Distance

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 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.

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.

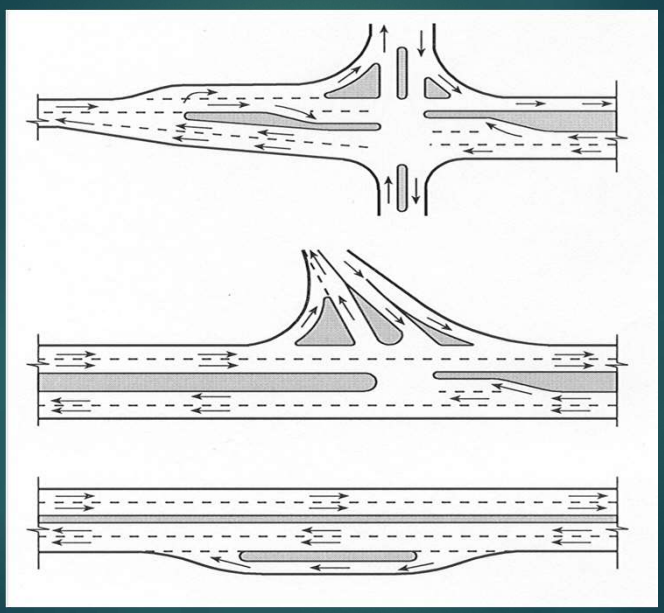
Channelisation

Kerbed Islands are, in themselves, a hazard. The cardinal principle that is adopted by all designers is:

ANY HAZARD INTRODUCED MUST BE LESS THAN THE HAZARD IT REPLACES

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

Channelisation



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 and then processes these streams to deliver an output of the same vehicles, 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.

Intersection Elements

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.

Turning Radii

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.

Intersection Elements

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.

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. Relatively large radii are used, typically 25 metres and more.

Intersection Elements

The width of the turning roadway is a function of :

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

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.

Intersection Elements

Tapers and Auxiliary Lanes

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.

Intersection Elements

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.

Auxiliary lanes commence and end with tapered sections. The length of a deceleration taper is such that vehicles can traverse a reverse curve path close to the speed of the through traffic

Intersection Elements

The typical taper rates vary from 1:15 for 60 km/h to 1:27 for 120 km/h. 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.

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. 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.

Intersection Elements

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.

Intersection Elements

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.