SESSION I – INTERSECTIONS AND INTERCHANGES

LECTURE I2 - INTERCHANGE PLANNING & LAYOUT **Presenter : CD SCOTT**

1 INTRODUCTION

The geometric designer who has never had occasion to design an interchange may think that he has somehow been left out of a rather exclusive club. Probably true. There are not that many interchanges in South Africa any way, so that relatively few designers have been afforded the opportunity to exercise this fascinating form of design, which may be described as a three-dimensional jigsaw puzzle.

Interchange design seems to enjoy some mystique which is undeserved. In fact, an interchange is nothing more or less than a rather sophisticated intersection. In certain instances, it becomes a *very* sophisticated intersection, but an intersection it remains, and it is done according to all the basic principles of road design and intersection design.

According to Leisch[1], the very first interchange ever was designed in New Jersey in 1928. The Woodbridge Interchange provided loops for all left turns (right turns in South Africa) and outer connections for all right turns (left turns in South Africa). The resulting layout looked like the four-leaf clover which then gave its name to this interchange type.

Since then many people seem to think that "cloverleaf" is synonymous with "interchange", which, fortunately it is not. The cloverleaf is considered by some to be the least successful of all interchange layouts, having somewhat limited turn capacity and presenting the driver with approximately 30 seconds of driving time around a loop as a replacement for perhaps waiting for the same period at a signal, to turn right. One advantage of the cloverleaf is that if you have missed your left turn, you can replace it by three successive right turns! No other configuration allows this flexibility of decision taking by the driver, but then this "asset" may be offset by the potential weakness of the cloverleaf, which is the weaving that it may generate, depending on the traffic patterns. Another drawback of the cloverleaf is its relatively large territorial needs.

In spite of some bias against the cloverleaf, which South Africa shares with the United States, it is still favourably considered in Europe provided that spatial restrictions do not demand an alternative layout and provided that weaving volumes are not too high. Weaving problems can be alleviated by using the proper layout (with collector-distributor roads) to suit the traffic pattern.

Interchanges fall into two basic categories, namely “Systems Interchanges” which are the junction between two freeways, and “Access Interchanges” where one of the roads is not a freeway. There are various types within each category. This lecture discusses the various types of interchange layout that can be considered and, more importantly, the principles that should be adhered to if a successful interchange layout is to result.

2 THE APPLICATION OF INTERCHANGES

2.1 Control of local access

The spectrum of road functions ranges from accessibility to mobility, and the freeway is at the extreme end of the spectrum. It is concerned purely with mobility and has complete control of access. Access control is one of the prime definitions of a freeway, and access is allowed only at interchanges. If the interchange is with a local road or street, the interchange will serve an access function. Access is then from a local area to the freeway. The crossing road would, or should, be a major road in the local network but the point is that it has at-grade intersections, possibly signalised, along its length. An interchange has “ramps” which link the crossing roads. The start and end of a ramp are known as the “ramp terminals”. In an interchange, the ramp terminals at the crossing road could also be at-grade intersections, hence matching the characteristics of the rest of the route. The ramp terminals with the freeway require high speed, flat angle merging which calls for tapers.

The familiar “diamond” layout is the most often used example of the access interchange, although other access interchange forms will be discussed below.

2.2 Connection between freeways

It is likely, particularly in urban areas, that a freeway will be one link in a system of freeways. Interchanges will then provide the connections between the various freeways and are therefore referred to as “systems interchanges”. Since both the crossing roads through such an interchange are freeways, the terminals at both ends of a systems interchange ramp are high-speed tapers. Freeway speeds and traffic volumes are generally high, so that a common feature of systems interchanges is the “directional ramp” for right turns, and the combination of several of these leads to the multi-level layout known as the directional interchange.

2.3 Spatial versus temporal separation of traffic

Where two heavily trafficked arterials intersect, even the most enterprising exercises in multiphasing, signal synchronisation, use of auxiliary lanes etc may all fail to provide sufficient green time for the number of vehicles that have to traverse the intersection area. Traffic signals provide a separation of traffic streams in time, “temporal separation”. If the time dimension cannot meet the needs for traffic separation, then a physical dimension must come to the rescue by providing a spatial separation of conflicting traffic manoeuvres. The grade separation is the medium whereby that spatial separation is brought about.

If the two arterials are not connected to each other at all but are separated by a bridge structure, the structure provided is referred to as a grade separation. The moment that links between the two arterials are added, the grade separation has been replaced by an interchange.

The statement was made that the interchange is nothing more or less than a sophisticated intersection. Logically then, where a less sophisticated layout becomes inadequate with increasing traffic volumes, recourse should be had to an interchange.

2.4 Topographic considerations

In a previous lecture, some thought was dedicated to the location of intersections and specifically to the places where intersections should not be put. Typically, problems could be generated by putting an intersection on a curve. The standard solution is to shift the intersection, but it can happen that the restraints on the location of both the through and the intersecting roads are so stringent that relocation is not feasible. What then, if the problem is that the logical gradelines of the two roads at the intersection site are separated vertically by several metres?

There is not necessarily only one answer to this problem. The options to be explored include dropping one gradeline into cut, raising the other onto fill or a compromise involving both gradelines. All three of these options may involve regrading over substantial distances with commensurate earthworks costs, apart from any penalties in terms of sight distance that may be involved.

The fourth option is an interchange. If topography is the only reason for the interchange, ie traffic volumes are light and access control is not a restriction, it may be possible to consider the quarter link layout which consists of a grade separation structure and a single two-way ramp with at-grade intersections at both ends. (This is also referred to as a grade-separated intersection by some who feel that a true “interchange” exists only on a freeway).

3 PRINCIPLES OF INTERCHANGE DESIGN

At the outset, one should remember that an interchange, like the cross-section, is not something that is whole and indivisible. It comprises several discrete components. Each need that the interchange has to serve should be considered and the individual interchange component that is required to serve that need should be selected. When all these different components are finally put together, and the resulting layout is revealed in all its glory, one can then say, “I have just invented the diamond interchange (or whatever).”

In the Eighties there was a shift in emphasis towards considering the basic operational principles that govern the selection of interchange type. These principles are based in part on the human factors governing design, as described by Lunenfeld[2]. He discusses the major causes of driver error as being:

- Excessive task demands
- Unusual manoeuvres or task requirements
- Poor sight distance
- Expectancy violations
- Information displays that may be missing, ambiguous, misplaced, obscured or inconspicuous.

Leisch[3] takes the process a step further in discussing operational considerations for systems of interchanges. These, if properly applied, simplify the driving task substantially, and in the process, increase the safety and operational efficiency of the interchanges. He discusses matters (as originally enunciated by his father, the great Jack Leisch) such as:

- System criteria
- Basic number of lanes
- Lane balance and application of auxiliary lanes
- Route continuity
- Interchange considerations
- Appropriate form
- Reduction of weaving
- Operational uniformity
- Left-side entrances and exits
- Single exits per interchange in advance of the cross-road
- Simplified signing
- Ancillary guidelines
- Decision sight distance
- Freeway-ramp speed relationships
- Ramp sequencing /spacing

These form a kind of checklist that the designer should follow in developing his or her interchange layout.

3.1 Basic number of lanes and lane balance

The concept of **basic number of lanes** is simply that there should be a clear indication to the driver that what he/she is driving on is a two or three or more lane carriageway. These basic lanes must continue to exist for a substantial length of freeway. It is possible that a freeway from some outlying area may start off with two basic lanes in each direction. After it has traversed some distance and gone through a number of interchanges, the increase in traffic volume may necessitate an increase to three basic lanes. Still closer to the metropolitan area being accessed by the freeway, three basic lanes may become four. The fact of the matter is that basic lanes would not be picked up or dropped off in willy-nilly fashion.

Lane balance requires that the total number of lanes downstream of an off-ramp (i.e ramp lanes plus freeway lanes) be one more than the number upstream (i.e. freeway lanes only) and the number of lanes downstream of an on-ramp be one less than the total upstream

The designer who creates a lane imbalance, can cause a freeway driver to imagine that he is on a through lane, and then have him carried off inexorably down an off-ramp into the bowels of a suburb that he had no intention of visiting.

An equal total number of lanes in advance of and beyond the nose of an off-ramp is NOT an example of lane balance, rather imbalance. In such a case, the outer lane of the freeway becomes the off-ramp, forcing the unsuspecting driver off the freeway – very angry.

A similar imbalance at the merging end of an on-ramp, has equally undesirable results. In effect, a new outer lane is added to the freeway downstream of the nose. The driver in the outer lane of the freeway who plans to exit at the next off-ramp will suddenly find himself in the central lane of a three-lane carriageway and with a need to execute a lane change before being able to exit.

The principles of lane balance are illustrated in Figure I2.1 below.

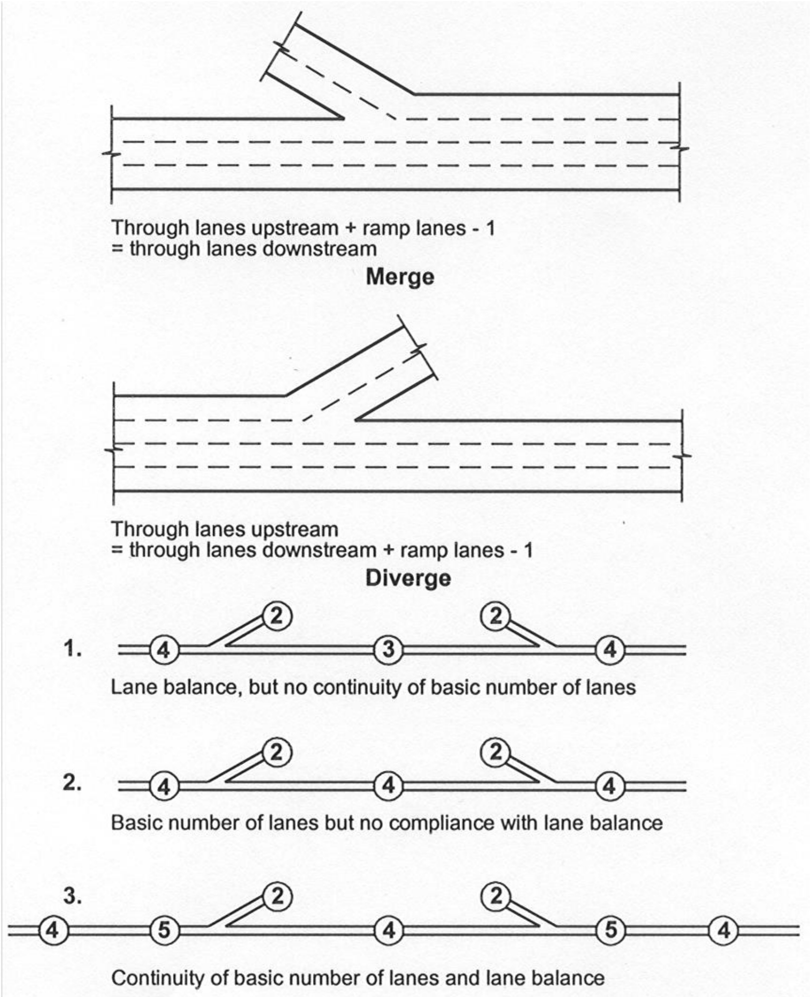


Figure I2.1: Basic number of lanes and lane balance

Both the problems described above can be avoided by lane balance. Application of lane balance in the case of single lane ramps results in that lane which is the outer lane of the freeway in advance of the interchange remaining the outer lane through and beyond the interchange.

Two-lane ramps can be used to decrease or increase the number of basic lanes on the carriageway while maintaining lane balance, if a change in number of freeway lanes is required. (The need for a change in the number of freeway lanes is logically associated with the presence of two-lane ramps which create a major change in freeway traffic volume). Sometimes however it may not be necessary to change the basic number of freeway lanes at the two-lane ramp. This is then done by using relatively short auxiliary lanes at the ramps, leaving the basic lanes intact.

3.2 Route continuity

An unfamiliar driver entering a freeway system say to the north of an urban area and wishing to continue his journey beyond the city towards the south would not be well served if his travel path required picking up a cross-link to another roughly parallel freeway some distance to the east or the west. Logical routes should thus be defined to be continuous or at least provide the illusion of continuity during the planning of the network. (Follow the Route Markers!).

3.3 Appropriate form

Appropriate form relates to the fact that the designer should not decide in advance that the next interchange coming up should be a Par-Clo, say, just to give some variety from the previous three diamonds and then force everything to fit this momentary aberration. Appropriate form relates to the function and movements that the interchange is intended to accommodate and their relative volumes. These aspects of interchange planning are discussed further below but, in the interim, do be aware that it would, for instance, not be appropriate to have a sweeping viaduct carrying a handful of right turning vehicles in one quadrant and to have high volume crawling around a minimum radius loop in another.

Clearly it is necessary to design the components to suit the individual traffic movements and then to assemble these components. This process determines what the form of the interchange is.

Just above, appropriate form was related to function, and this also means that one shouldn't have the function and form of access and systems interchange components mixed up in a single layout. The R21/R24 Interchange at Johannesburg's O R Tambo International Airport is an unfortunate demonstration of such interchange schizophrenia. It is essentially a three-legged systems interchange that, in a very confined space criss-crossed by railway lines, also had to accommodate access legs serving the airport and a local street. Weaving over minuscule distances and other horrors arose as a result, and it is a matter of regret that this Gateway may be the first exposure of foreign tourists to South Africa.

3.4 Reduction of weaving

A potential weakness of the cloverleaf is that it can generate a substantial volume of weaving between loops, which has to take place within a very short distance and often in the relative darkness under the structure. The turbulence created can cause a breakdown of freeway traffic flow affecting even the inner lanes in bad cases. The provision of collector-distributor roads is a major palliative.

Weaving also takes place between interchanges and not just within them. If the interchanges are spaced too closely together, the problem of turbulence can cause the entire freeway operation to hit Level of Service F even if the actual volumes suggest that a far higher LOS should be prevailing.

3.4 Left-side entrances and exits

In the early days of freeways, drivers had difficulty in realising that, if they wanted to exit a freeway with a view to travelling towards the right, it was first necessary to leave the freeway on the left. Similarly, a driver on the crossing road wishing to enter the freeway to travel towards the right, would joyously dive down the first hole that he saw. Very often, this would be the off-ramp and he would find himself confronted by somebody on a reciprocal heading at 120 km/h. Surprise!

Various elaborate schemes were dreamed up to overcome this problem. For example, the Californian Dream Buster; if two successive light beams were broken in the wrong sequence, this would cause dragon’s teeth to emerge from the road surface and blow all four tyres simultaneously. This worked until Caltrans was sued on the grounds of property damage and disregard for the constitutional rights of the driver. Constitutional rights no doubt include committing suicide by killing some one else at the same time. (Isn’t the USA a truly funny place?).

The more practical problems with right-hand exits are:

- ❑ the speed differential that results from having vehicles exiting from what is effectively the fast lane
- ❑ finding the space in the median for including a lane that can climb up and over the opposing carriageway without a major land grab

It was necessary to insist that all exits and entrances be on the left side of the carriageway. Drivers have now got used to this idea and the incidence of wrong-way driving has dropped remarkably over the years. Maybe the drivers that insisted on going the wrong way are now all extinct which is yet another example of genetic selection and Darwinism.

3.5 Single exits per interchange in advance of the interchange

We have already discussed the problems that drivers experience with thinking. In all fairness, when a person is confronted with a multiple-choice decision and has little time to make up his mind, the likelihood of error increases dramatically. We have already commented that the South African driver leaves little margin for error, and, at freeway speeds, errors tend to be fatal. It, therefore, makes sense to expose the driver to a series of two-choice decisions rather than a single multiple-choice situation.

Compound decisions of the form "If I want to leave the freeway somewhere in this area AND turn right, then should I take this ramp or that one just up ahead?" will almost certainly lead to a modest degree of uncertainty and a response which may involve a wild swerve across the bows of a vehicle in the adjacent lane or a rapid stop followed by reversing (quite likely in the fast lane) to the ramp just passed.

What should happen is that the driver is offered a decision tree process:

Do I leave the freeway? Yes or no

If “Yes” which way do I turn after leaving the freeway? Left or right.

The reason for having the exit in advance of the structure relates to visibility, and the fact that a left turn, in any event, is better served by an exit upstream of the crossing road. Seeing the exit ahead of a bridge makes it clear that this not just a grade separation, and the required width of bridge opening is also generally smaller and less costly, with the advance exit.

3.6 Simplified signing

A standard bit of dogma trotted out by older designers is "If you can't sign it - don't design it." Once again, the R21/R24 Interchange serves as an example of insufficient space for timely sequential signage. A reading rate of hundreds of words a minute is required, in addition to hair-trigger reflexes, if you are to find your way around this Spaghetti Junction the first time without getting buried in Benoni as opposed to heading for Pretoria or finding Domestic Arrivals.

The driver, whose only desire is to stay on the road, not get hit by other vehicles, and to end up going in the right direction, simply doesn't have the time to decipher elaborate instructions. Your interchange layout should be such that elaborate instructions aren't called for. It doesn't really matter how much a ramp twists and turns (after the driver is actually on it) in getting from A to B but it does matter that the driver should know comfortably in advance that THIS is the ramp to be taken.

3.7 Ancillary guidelines

These details of design are dealt with in the lecture that follows.

4 DRIVER GUIDANCE

Drivers do get lost on freeway systems. Invariably this is because the system is unfamiliar to them, and they did not do their homework with maps in advance. Unless the freeway signing system actually uses the name of the driver's desired destination, it is not going to offer much help to the unprepared driver either. Unfortunately, though, a directional sign probably just has space for a distant control destination and one or two local destinations plus route numbers. Drivers therefore need to prepare for a journey by establishing which major route (number) they need, with a major destination for that route in mind so they can find it easily.

A driver travelling at high speed in an unfamiliar area, concentrating principally on the quirks and idiosyncrasies of the surrounding driver population could quite easily overlook the odd helpful road sign. Correct interchange design can however offer useful guidance, allow space for clear signage and substantially ease the driving task.

4.1 Target value of interchanges

A bridge crossing over the freeway can be seen from a considerable distance ahead. It offers the driver advance warning of the fact that an interchange may be coming up and he can thus give some attention to his navigational task and be alert for directional signing.

From this point of view, the argument of "Over versus Under" favours the crossing road at an interchange being over the freeway. An operational benefit of this configuration is that the off-ramp has a positive gradient which eases deceleration and the on-ramp a negative gradient assisting the driver to reach the freeway speed more easily. Both ramps could then possibly be shorter than would otherwise be the case, offering the possibility of a saving in construction costs.

Unfortunately, it cannot be regarded as a sine qua non that the crossing road should be over the freeway. The structure imposes a height limitation on loads travelling along the freeway in addition to its substructure presenting a hazard to high volume flows. A need for high fill on the crossing road may cause severe disruption of a local residential street system that is preferably at or close to natural ground level, because of the need to provide access to adjacent stands. There is also a likely sight-distance problem, and a crest vertical curve taking a street over a freeway will probably have to be longer and flatter than is required just for stopping sight distance, because of the need for intersection sight distance at ramp terminals.

4.2 Standardisation of ramp terminal treatment

By consistently placing the noses of off-ramps in advance of structures and the merging ends of on-ramps beyond structures, regardless of the appearance of the rest of the ramp, the driver will be provided with some foreknowledge of what to look for in navigating his way around the system. The phrases “design consistency” and “driver expectation” have frequently been used in these lectures and they apply at least equally to interchanges.

Imagine the unfamiliar driver -because, let’s face it, he’s the person you’re really designing for. He is on the freeway and knows that somewhere soon he has got to get off it. A bridge looms up. “AH! (Sighs of relief off-stage). This must be the place. Now, where is the ramp?” There is no sign of a ramp anywhere. He disappears into the gloom under the structure. Loud cry off-stage, “Daddy! Daddy! There it is!” Sound effects: Screeching tyres followed by brief silence followed by scrunching metal symbolising a semitrailer loaded with steel beams trying to climb over the now-stationary tourist.

Now if that ramp entrance had been **before** the bridge, you wouldn’t be sitting with that multiple fatality on your conscience. The driver would have been warned by the presence of the structure and shortly thereafter would have seen the ramp curving off to the left with a butterfly sign saying “Dis is da place” - or equivalent message and everybody would have been happy.

Of course, the standard “count down” signs placed at 300, 200 and 100 metres before the exit have proved to be a great help, but too often they are flattened or missing.

5 INTERCHANGE LAYOUT

After Woodbridge, an assortment of interchange layouts proliferated, with some “lunatic fringe” layouts also being generated along the way.

Among the lunatic fringe layouts we can include those where the left and right carriageways of the freeway were transposed to allow right-turning drivers a nice short turn to the right out of the fast lane (and into the fast lane of the crossing road), rather than departing from the left side to go on a viaduct over the crossing road and the freeway to finally merge with the crossing road once again from the left. The left-turners, of course, also had to retain their handy short-distance turn so that the transposition of carriageways had to occur within the limits of the interchange area. The two carriageways thus did a sort of vicious barrel-roll around each other to achieve the desired effect. A couple of these were built in the United States but, thankfully, have since been reconstructed.

5.1 Diamond Interchange

The Diamond is perhaps the most frequently occurring layout for access interchanges. It is a simple layout with direct ramps that are relatively safe with proper design. It has stop or signal control at the crossroad ramp terminals and is used to provide access to the freeway. The name derives from its shape as illustrated in Figure I2.2 which is two pages further. Inevitably, several variations of the layout have been developed.

The best known is the **narrow diamond**. This has the crossing road ramp terminals close to the structure in an effort to keep the territorial requirements to a minimum. The main problem that the designer has with the narrow diamond is to ensure that drivers leaving the freeway have sufficient intersection sight distance at the terminal. The problem is that the crossing road is invariably on a crest curve at the ramp terminal, and a good solid bridge balustrade is generally in the sightline.

The **wide diamond** is almost not on our design menu any more. The crossing road terminals are located roughly at the end of the approach fills to the structure, and sight distance is not a problem. Unfortunately, a lot of land is required for the road reserve. The wide diamond seemingly had its origins in the Cloverleaf. The idea was that one would indulge in the favourite pastime of stage construction, which means, effectively, that you just finish something and then you rip it up again to stick on another bit. In this particular case, the designer would put a complete Cloverleaf together on paper and then they would build just be the outer connectors. The crossroad ends of the outer connectors would be swung around to give a square intersection.

The theory was that, when traffic volumes built up, one could go back and stick in the loops and, at the same time, replace the perpendicular ramp terminals with merging ends. Of course, it did happen on occasion that the minimum allowable radius on loop-ramps had been pushed up, so the loops just couldn't get fitted in and we were stuck with large expanses of bird sanctuary that we didn't know what to do with. Wide diamonds are seldom planned now, but the Gauteng Freeway Improvement Scheme of 2008 is certainly adding such loops (e.g. on the N1 at Pretoria).

The **split diamond** arises when the crossing road is actually a one-way pair of streets. The result is two bridges across the freeway about a city block apart. The ramps lie outside the one-way pair and are linked by street sections between the one-way pair. The spilt diamond may have similar problems to the narrow diamond (although its ramps are more commonly close to ground level and the freeway depressed) but with a further complication added. That concerns the routing of traffic leaving the freeway and wanting to turn right: they are automatically confronted by No Entry signs on the right at the first ramp terminal, and much irate hooting if they follow natural instincts.

One almost lunatic-fringe variation of the split diamond is the transposed split diamond, which has the ramps between the crossing roads. This layout is a big No-No. If the ramps can actually be fitted in the available space between the one-way pair, the distance between merging end and nose is very short and weaving becomes a major problem. In the States, they still talk with horror about the so-called scissors ramp. This arose from the ramps actually intersecting before joining the freeway. The accident rates on these were tremendous. The ramp intersections were usually signalised and this was fine for the vehicles for leaving the urban area. It was less fine for the vehicles exiting the freeway. To be confronted with a signal that gives you about 3 to 5 seconds of amber before going resolutely red when you need about 15 seconds to stop is traumatising to say the least.

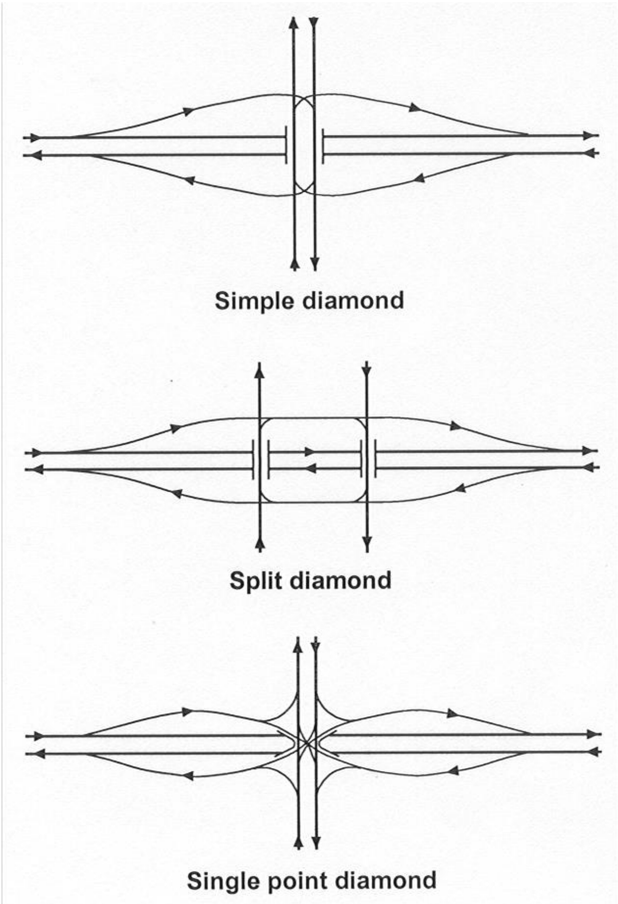
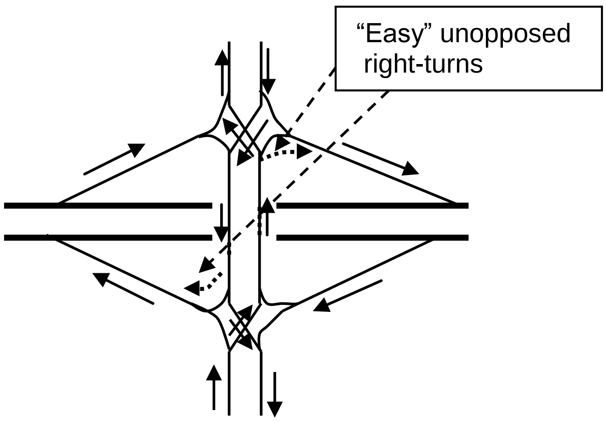


Figure I2.2: The Diamond Interchange

A significant innovation is the **Double Cross-Over Diamond** which may also be termed the "**koeksuster" diamond**. We have already made scathing remarks about transposing the carriageways of freeways at a systems interchange, but this technique can be very effective when applied to the crossroad at a diamond interchange. It is of value only where there are very heavy right turn movements from the crossroad onto the freeway. If the crossroad carriageways are transposed outside the interchange, then the heavy right-turn movement becomes a turn unopposed by oncoming traffic and is similar to an ordinary left –turn. The phasing and timing of signals becomes easier, and capacity is increased.



<u>"Koeksuster" Diamond</u> has only 2 conflict points which are just direct crossings with no turns.

A fairly new development is the Single Point Diamond Interchange, sometimes referred to as the Urban Interchange. (a poor name because any interchange in the urban area could be called an urban Interchange). The big trick about this interchange is that the crossing road ramp terminals are curved inwards to form a single four-legged intersection immediately above or below the structure. Operationally, this is very efficient and the capacity of the SPDI is higher than that of the conventional diamond. If the intersection is below the structure, it would be difficult to fit among bridge piers and the like. Sight distance may also be somewhat problematical.

5.2 Par-Clo Interchange

The Par-Clo derives its name from the fact that it is based on the Cloverleaf but only in part. Hence Partial Cloverleaf and the abbreviation Par-Clo. In its operation, it resembles a distorted diamond, with simple ramps having stop-terminals at the crossroad.

Typically, the Par-Clo comprises two outer connectors and two loop ramps. An outer connector and its accompanying loop ramp are always located in the same quadrant as shown in Figure I2.3.

A Par-Clo interchange as described above will occupy just two of the four quadrants of a road crossing. There may be some choice as to which quadrants will be used for it, and various combinations are possible. The Par-Clo A has both loops in Advance of the structure. ("A" standing for Advance). The Par-Clo B has both loops Beyond the structure. ("B" for Beyond). The third combination is the Par-Clo AB where one loop is in advance and one beyond the structure.

There are two particular reasons for using a Par-Clo type interchange. **Firstly**, it allows an access interchange to be provided when one or two of the quadrants may be unavailable, and a conventional diamond can therefore not be built. This situation could arise due to development, or the presence of a stream or a railway line, say. In South Africa, we often find transportation corridors with a railway line running parallel to a road for several kilometres. If we have to design a freeway running at right angles to that corridor, and provide an interchange, then a conventional diamond interchange would require a three-level arrangement. The "cross-road" alongside the railway might be elevated so that the ramps could pass over the railway line. Then the freeway would have to be raised to a yet higher level so as to pass over the raised cross-road. Three bridges would be required to take the freeway and two ramps over the railway line. It becomes rather impractical. Alternatively, a Par-Clo AB with its loops on the side away from the railway line solves the problem neatly, with just two levels, a structure for the freeway only, and correspondingly less expensive to build.

Secondly, the Par-Clo is very effective in dealing with heavy movements of traffic leaving the freeway to <u>turn right onto the crossroad</u>. A diamond ramp has its capacity constrained by whatever control is applied to its crossing road terminal. High volumes of right turners can become a problem, and if the length of the ramp is insufficient to supply storage space for all the vehicles that want to turn right, you end up with some poor soul being brought to a complete standstill on the freeway, knowing that everybody behind him is travelling at about 140 km/h. This is very nervous making. Providing a loop for this movement makes it possible to convert the right turn into a left turn that can then flow continuously, assuming that a lane has been built on the crossing road to accommodate this. (This is also a practical illustration of cross-section design). Loop ramps almost invariably have a single lane which puts a reasonably high limit on their capacity. This capacity, available for 60 seconds of the minute generally beats the most sophisticated of signal layouts which allow flow for possibly less that 30 seconds of the minute.

Having a loop ramp to serve traffic as it diverges from the freeway is, of course, not without its own problems. Vehicles that have been travelling at high speeds, possibly for a considerable distance suddenly have to be choked down to about 40 km/h and it can be anticipated that some vehicles will not slow down sufficiently in time to negotiate a tight radius loop. A short cross-country trip might then take them onto the next on-ramp, assuming that they don't hit a guardrail first! Visibility and signage are all-important.

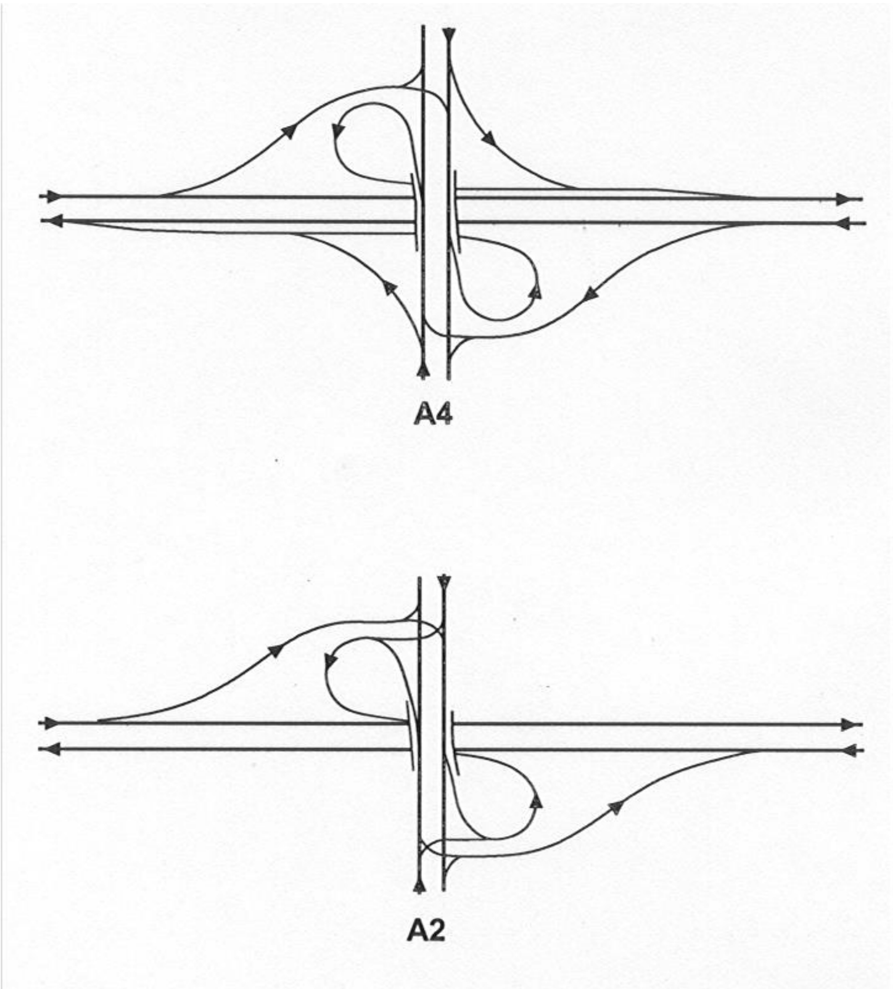


Figure I2.3: Par-Clo interchanges (Type "A")

5.3 Cloverleaf Interchange

The Cloverleaf has certain shortcomings in its large requirement for space and also the weaving movements it generates. The cloverleaf layout is illustrated in Figure I2.4.

It might be possible to reduce the spatial demand by tightening up the loop radii but this soon becomes self-defeating. Tighter loops become operationally inefficient, and the travel time around a small loop is not less than around a large loop because of reduced speed. Even if you do put in a very small loop, the land area required will be determined by the radius and design speed of the adjacent outer connector ramp.

The weaving problem is dealt with by moving it off the freeway. (If the cloverleaf is a systems interchange, off both freeways). Weaving is then made to take place on auxiliary roads known as Collector-Distributor or C-D roads, parallel to the through roads, between the loops.

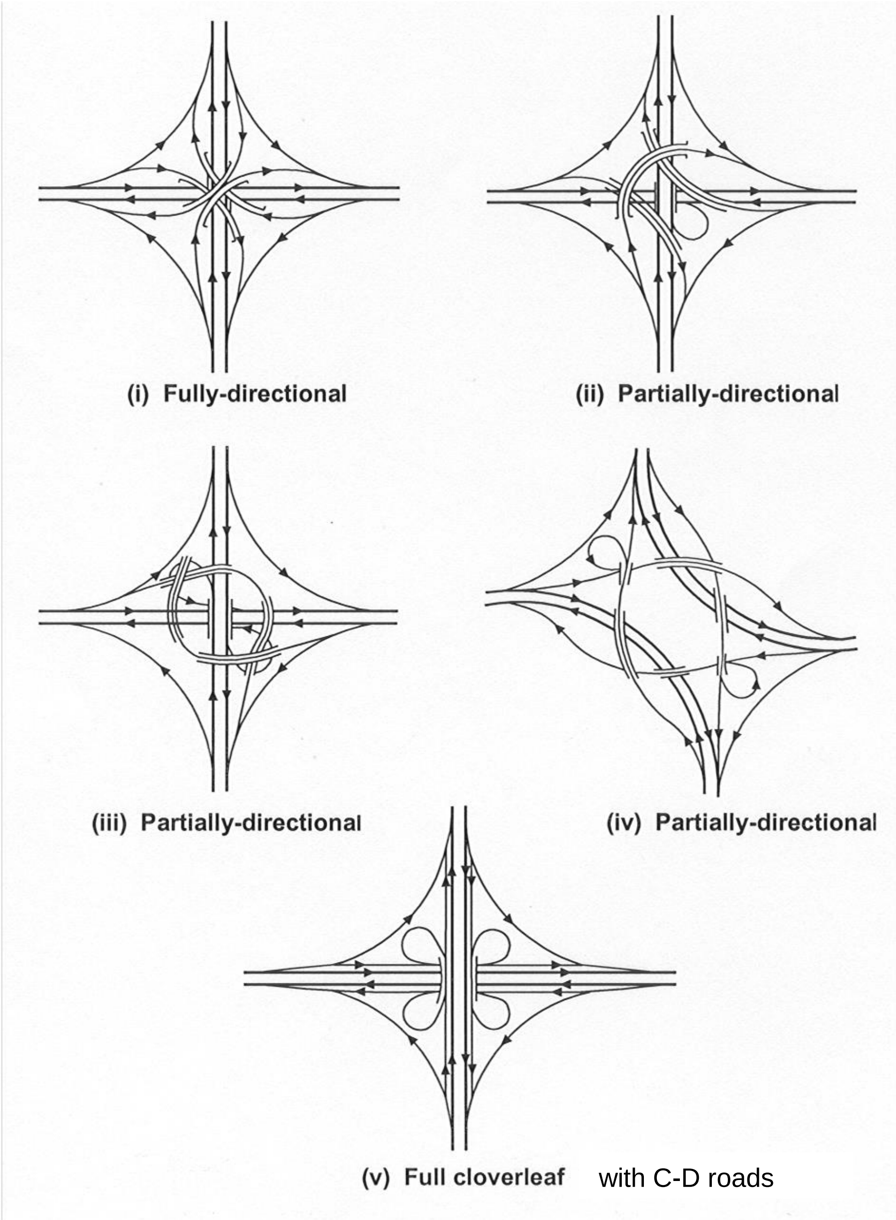


Figure I2.4: Directional and Cloverleaf interchanges

5.4 Directional Interchanges

The Diamond and Par-Clo interchange types are dedicated purely to access. They are typically used to provide local areas with a link to the freeway system, from a local arterial. The Cloverleaf can be either a systems interchange or possibly an access interchange, if one road is an arterial and not a freeway. The Directional Interchange is purely a systems interchange.

The Directional Interchange stems from a time when drivers still expected to be able to exit from the right when they wanted to turn to the right. The medians of both roads had to be very wide to allow for the ramps which climbed up over the opposing carriageway from the median and similarly came back to earth in the median of the crossing road. These ramps were truly directional and, for a long time, ramps which commenced and terminated on the left sides of the linked carriageways were known as being “semi-directional”. This was because the travel path was still approximately through the desired 90^0 rather than the 270^0 of a loop ramp, although not quite as direct as the right-side-to-right-side ramp. Since then, that old-fashioned “truly directional ramp” has fallen into disuse and the previous “semi-directional” ramp is now regarded as the directional ramp. Somewhat idealised directional interchanges are illustrated in Figure I2.4.

The directional ramp is the basis of a directional interchange. A “fully directional” interchange has all movements provided with directional ramps. A “partially directional” interchange has one or more loops for certain movements, in addition to directional ramps for all the other movements. In both cases, all the ramp terminals are high-speed tapers.

The Directional Interchange can climb to great heights both of complexity and altitude. The latter would typically arise in the case where all the right turn ramps and the intersecting roads cross at one point. The need for this is usually due to urban spatial restrictions. Topography invariably dictates which of the freeways and ramps should go over the top. All things being equal, the more heavily trafficked freeway should be kept at ground level and the crossing freeway at the first level up. Assuming that these roads are respectively East-West and North-South, the North to West and South to East ramps could be at the second level with the West to South and East to North at the top level depending which of the turns have the greatest volumes. Threading all these ramps through the maze of piers required to hold everything in place can be quite complex and securing enough headroom between the various decks a major headache.

An alternative layout for the Directional Interchange uses more space by moving the crossing point of the ramps away from where the freeways intersect. This layout reduces the number of levels from four to three but does so at the cost of several bridges and may not always have great merit.

Very often, the right turning movements are not all accommodated by directional ramps and one or two loops could be used in their stead, creating a “partially directional” interchange. The particular combination depends on the traffic volumes to be accommodated. The development of a layout for a directional-type interchange is a prime example of the principle set out early in this lecture, that each need that the interchange has to serve should be considered individually, and a selection made of the interchange component required to serve that need. The process is complicated by topographic aspects, founding conditions for large structures, and their form and dimensions, and each directional interchange design becomes a truly individual exercise.

The British Island-in-the sky layout is another totally different possibility, which also involves an amount of weaving. The major freeway is at ground level and the crossing freeway is two levels up while the ramps all converge on an island on the level in between. The island is, in effect, a rotary intersection.

A Directional Interchange could also be three-legged as opposed to four-legged, for example as a Tee between two freeways, forming what is called a Trumpet interchange.

5.4 Trumpet Interchange

All the interchanges described above are four-legged. The Trumpet, on the other hand is three-legged and its name derives from the overall shape of the interchange. It does not take much imagination to see the bell of a trumpet in the configuration of the right-turning ramps as illustrated in Figure I2.6.

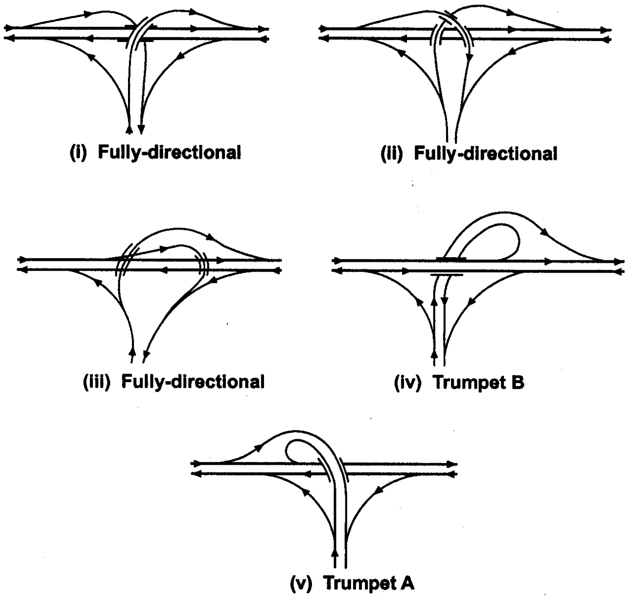


Figure I2.6: Trumpet interchanges

The trumpet has been used both as an access and as a systems interchange but its application these days is limited to systems interchanges. The previous application as an access interchange stemmed from cases of a freeway bypassing a town, with the town requiring freeway access from one side only. As we engineers, subsequently discovered that if you attempt to bypass a development somebody is sure to start developing a township on the other side of the freeway. As a case in point, the area of Pretoria to the east of the Eastern Bypass is a small city in its own right. None of it was there when the bypass was originally built. These days, even if there isn't any development on the other side of the freeway, we bow to the inevitable, accept that one day there will be development there and build a diamond interchange in the first instance.

As in the case of the Par-Clo, Trumpets are divided into Trumpet A and Trumpet B interchanges depending on the location of the loop relative to the structure i.e. in advance of or beyond. The selection of configuration depends on topographic restraints and turning movements to be accommodated. The lesser turning movement usually has to accept the loop ramp.

6 CONCLUSION

Although the various interchange layouts have been discussed in some detail, the really important feature of interchange design is that the expectations of drivers should not be violated and that the series of decisions that they have to take in traversing the interchange area should be as simple as possible. The configuration of ramps that can best accommodate these principles is always the best layout to have. After the event, one can attach a name to the layout that has resulted, but it is extremely unwise to commence with preconceived ideas of what the layout should be and then force everything else to fit.

In line with comment offered in other lectures, interchanges must not only give effect to their function but they must do so in an aesthetically pleasing way. The topography should not be seen as an enemy to be tamed but rather as having best-friend status. A convenient hillside can make it possible for a ramp to gain height over a crossing road without actually leaving ground level. This is not only relaxing for the driver but also reduces scarring of the landscape.

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