RIGHT TURNS AT INTERSECTIONS: ARE THERE ALTERNATIVES?

R.C. Pyke, J.D. Sampson and K.G. Schmid

Stewart Scott International, P O Box 784506, Sandton, 2146
TTT Africa, P.O.Box 109, Sunninghill, G.D.P.T.R.W, Private Bag X83, Marshalltown, 2107

ABSTRACT

Opposing right turn traffic movements at intersections have a substantial negative impact on both capacity and potential for serious accidents.

This paper discusses alternative intersection layout types, which are aimed at reducing the negative impact of these right turns, by relocating some of the conflict points to areas that are remote from the main intersection. The purpose is to reduce and control the number of conflict points. The different intersection layout types are categorized according to operation.

Typical alternative intersection layout sketches, which are compatible with South African geometric standard requirements, were developed based on current overseas practice. As the issues are capacity and safety at high volume intersections, the study was limited to dual carriage-way roads.

Relevant issues associated with the application of these alternative unconventional intersection types are discussed. These issues include aspects such as sign posting, road markings, potential operational problems, capacity and other factors that should be taken into account when implementing these intersections. Using micro-simulation techniques, the operation of specific intersection types were modeled. By consideration of the operational Level of Service and the cost of construction, the various intersection types were ranked in order of suitability.

1. INTRODUCTION

1.1 Background

Many roads in South Africa are heavily congested, particularly in the urban areas, where large-scale development has occurred without a concomitant increase in road capacity.

Intersections, where vehicles compete for a share of the same road space, often create bottlenecks in the road network and collisions are frequently concentrated at intersections. In South Africa, 49% of all urban accidents occur at intersections, and 61% of these occur at traffic signals. In Johannesburg (1988 to 1995), an average of 14 accidents per annum occurred at signalized intersections and one per annum at un-signalised intersections. 7% of accidents at signalised intersections were right turning in the face of oncoming traffic compared to 4% at unsignalised intersections (Ref. 1).

Of all the conflicting movements, the right-turn movement across the path of oncoming vehicles is generally considered to be one of the most problematic from a capacity and a collision point of view.

The need to manage this right-turn movement safely at at-grade intersections on roads with high traffic volumes has led to the use of two-lane and even three-lane exclusive right-turn lane configurations at intersections. This requires the installation of three-phase traffic signal control, normally with protected right-turns and prohibited permissive right-turns due to poor visibility, despite the negative impact on the intersection capacity due to an increase in lost time.

1.2 Aim of the Paper

Alternative “low cost” (compared to interchanges) intersection layouts, specifically designed to promote safer right-turning movements have been or are being developed in various other countries.

These intersection alternatives are designed to re-locate the problematic right-turn movement to a new location remote from the intersection under consideration, thereby improving the operational aspects of the intersection by:

- Reducing the total number of vehicular conflict points associated with right-turns at the intersection.
- Permitting the use of simpler 2-phase traffic signal control instead of the 3-phase traffic control that would otherwise be required.

This paper explores possible alternative unconventional intersection layouts that could be used locally. The options considered are based to a large extent on overseas experience, and particularly in the United States of America.

The investigation took the form of a literature study and a deliberation of the issues. This was augmented by simulation modelling of those alternative intersection layouts considered as potentially viable in a South African context.

2. ASSESSMENT OF INTERSECTION ALTERNATIVES

2.1 Classification of Possible Alternatives

It is possible to categorize the different unconventional alternatives for performing a right turn movement at an intersection into four basic types, based on:

- whether the relevant turning movement is made before the vehicle reaches the main intersection or after it passes through it; and
- whether the turning movement is made from the right hand traffic lane of the road or from the left hand (kerb) traffic lane.

Using these criteria, the four different alternatives can be classified as follows:

- a right turn movement undertaken upstream of the main intersection:
- a right turn movement undertaken downstream of the main intersection ;
- a left turn movement undertaken upstream of the main intersection , and
- a left turn movement undertaken downstream of the main intersection.

These four options are shown graphically in Figure 2.1, where the vehicle path originates from the left hand side of the drawing and follows the path of the arrows on the diagram.

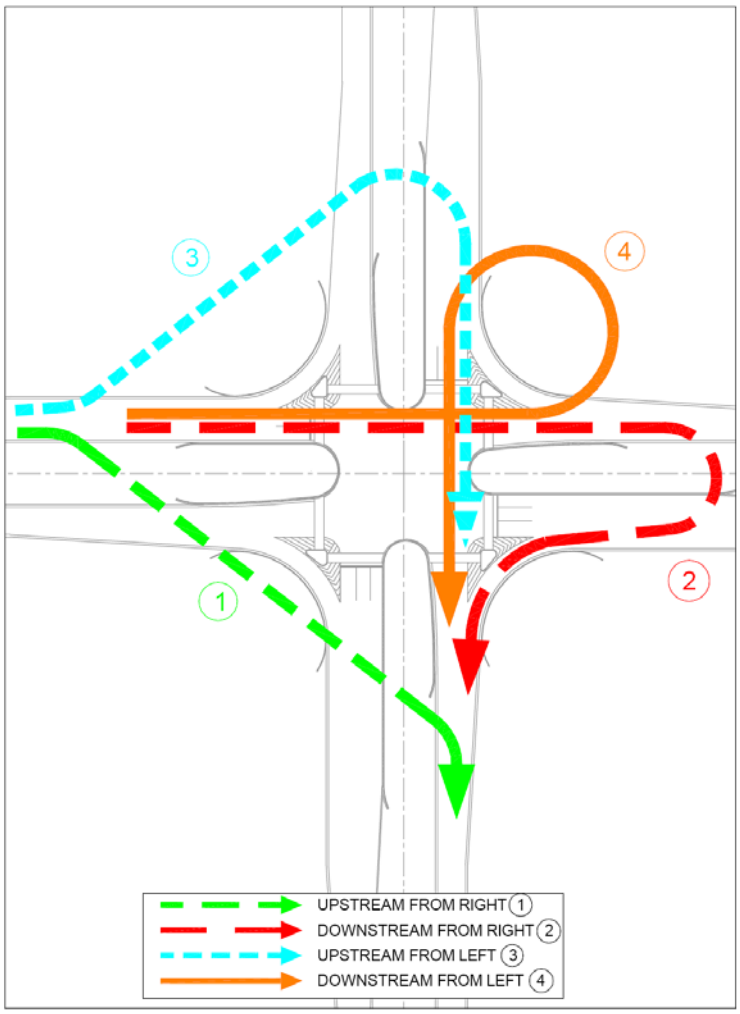

Figure 2.1. Possible Intersection Alternatives.

2.2 Potential Intersection Layouts

A typical layout of a multi-lane dual carriageway intersection with dedicated right turn lanes on all approaches and left turn slip lanes was taken as the point of reference. A series of alternative layouts were drawn to illustrate the four options identified above. For simplicity, these drawings show the alternative right-turn treatment from one approach only. This treatment could be applied to two or even all four approaches to the intersection according to the traffic conditions.

It must be noted that some of these intersection alternatives require that vehicles follow a longer route for the right turn manoeuvre than that at a conventional intersection.

2.2.1 Right Slip Lane Intersection

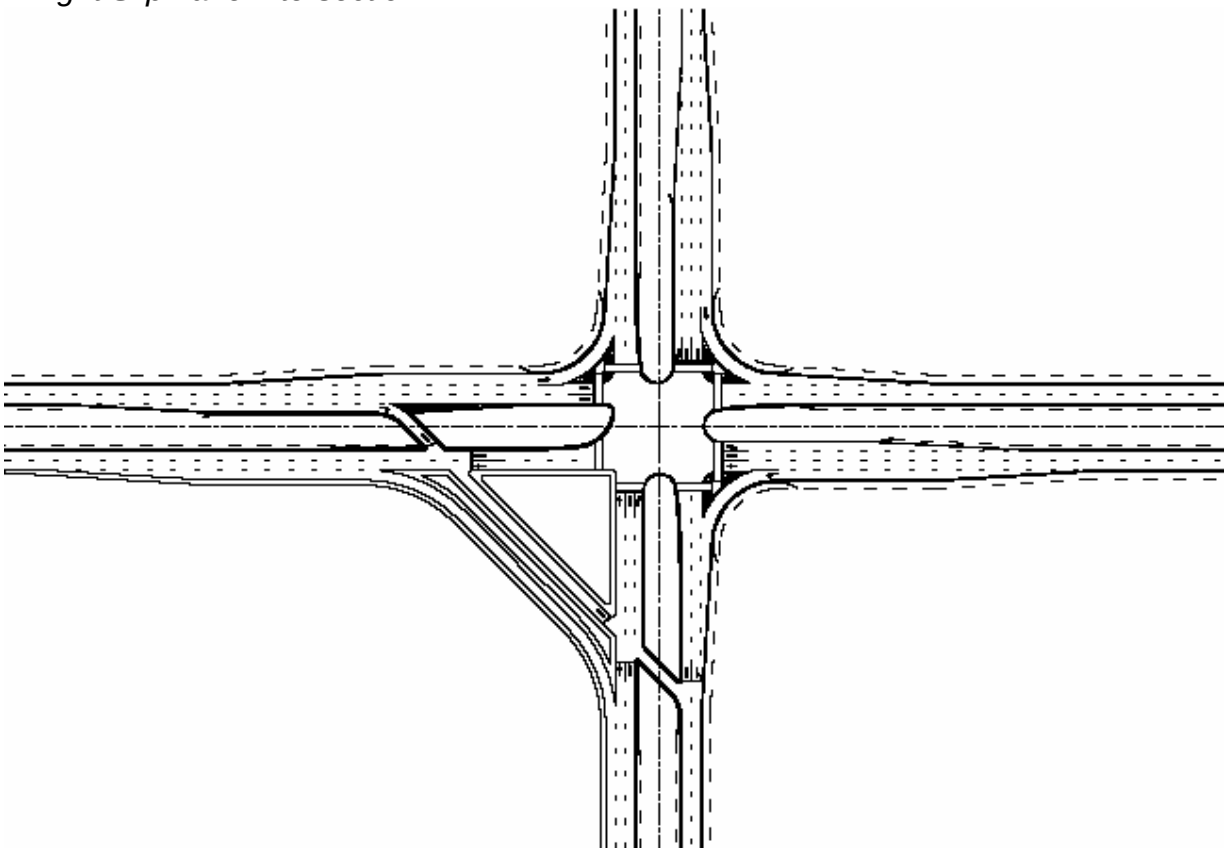

Figure 2.2. Right Slip Lane intersection.

This Figure shows a possible layout for a Right Slip Lane Intersection (with right-turns from the right-hand traffic lane upstream of the intersection). Road marking and road signage for the right turn is conventional and driver confusion is not a major consideration in this type of layout as the right turn is initiated from the normal side of the road. The driver will however need advance warning that the slip lane is for the cross road he/she wishes to turn into.

In this layout the traffic conflict points are located at three separate crossings, each controlled by a two-phase traffic signal (if traffic signals are warranted by traffic volumes). Careful traffic signal phasing and co-ordination is extremely important for the satisfactory operation of this type of intersection.

The provision of adequate storage length for queued vehicles on the slip lane and also on the sections of roadway between the main intersection and both the terminals of the slip road is an important consideration in the design of Right Slip Lane Intersections.

In the case of the Right Slip Lane Intersection, a vehicle undertaking the right-turn manoeuvre follows a shorter path than is the case at a conventional intersection.

2.2.2 Median U-turn Intersection

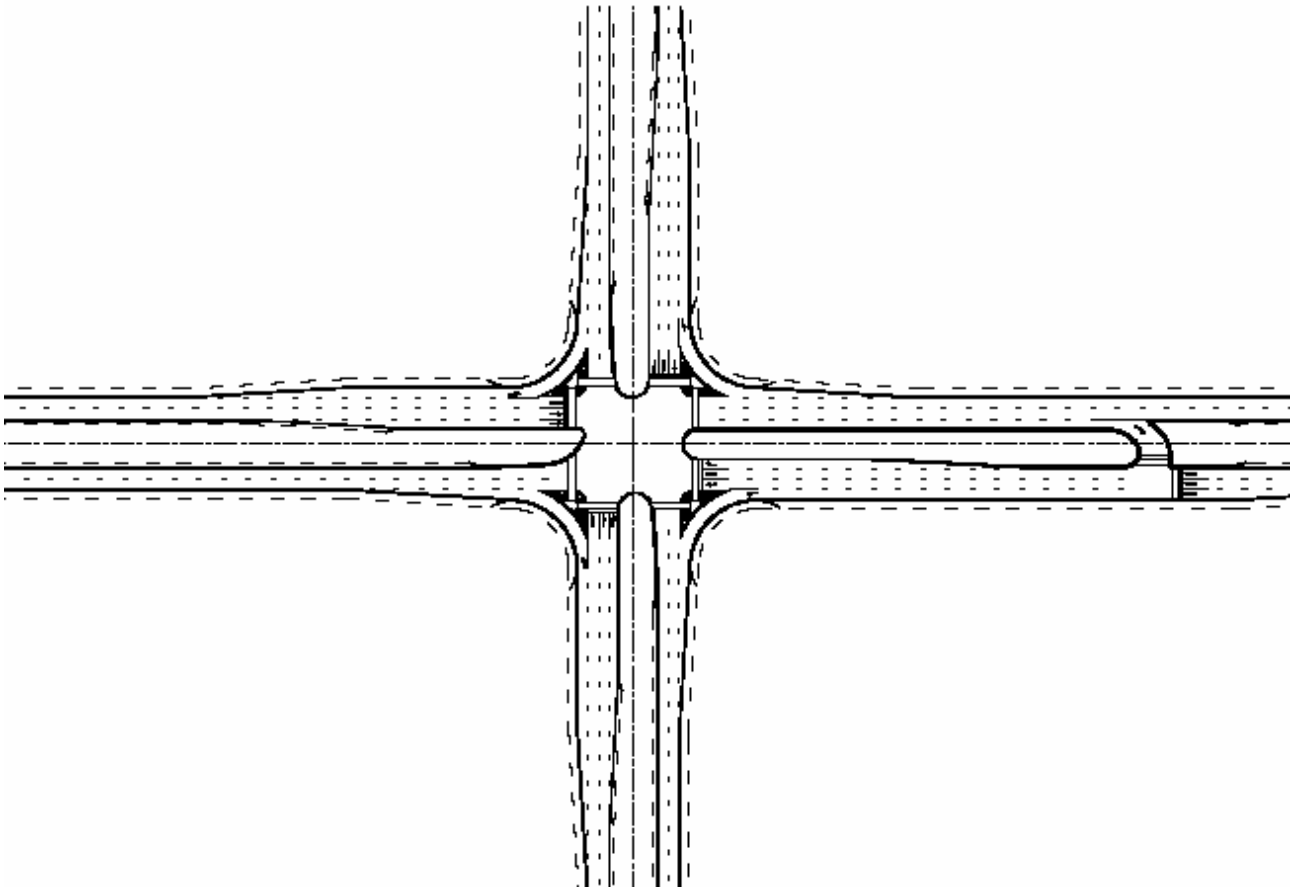

Figure 2.3. Median U-turn intersection.

This Figure shows a possible layout for a Median U-Turn Intersection (with right turns from the right-hand traffic lane downstream of the intersection). Road marking and road signage for the right turn is conventional and driver confusion is not a major consideration in this type of layout as the right turn is initiated from the normal side of the road. However, there is a problem in preventing motorists from turning right at the main intersection, and adequate signing and warnings will need to be provided.

In this layout the traffic conflict points are located at two separate crossing points, each controlled by a two-phase traffic signal (the need for traffic signal control is however determined by the relative traffic volumes). Although important, phasing and traffic signal co-ordination is a simple issue in this type of layout.

There is a need for the provision of adequate storage length for queued vehicles in the dedicated lane for the u-turn movement in order to prevent spill-back across the main intersection. The path of a right-turn manoeuvre at a Median U-turn Intersection is much longer than that at a conventional intersection.

2.2.3 Jug Handle Intersection

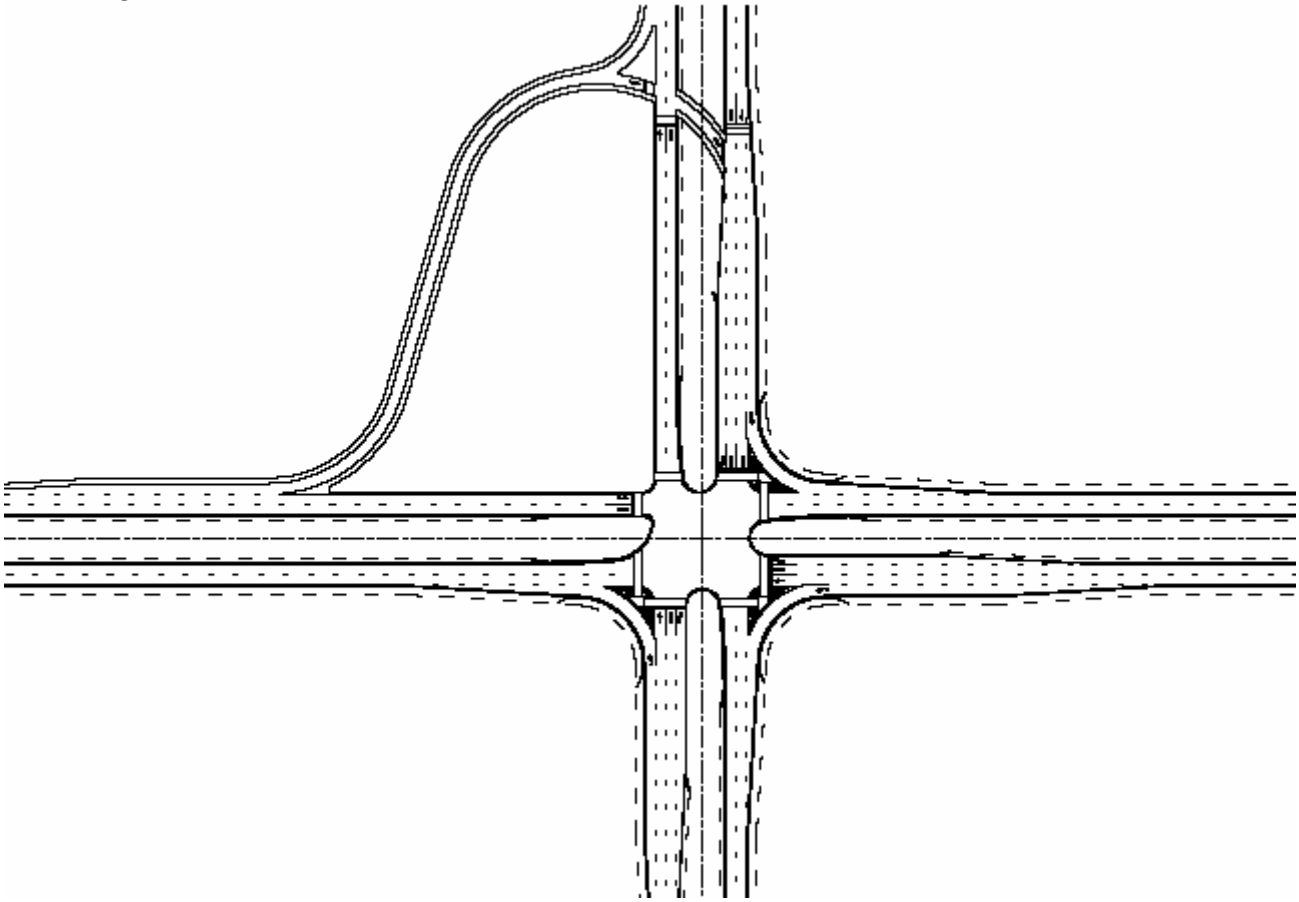

Figure 2.4. Jug Handle intersection.

This Figure shows a possible layout for a Jug Handle Intersection (with right-turns from the left-hand traffic lane upstream of the intersection, combined with conventional left-turns). Driver confusion is a major concern in this type of layout as the turn is made from the left-hand side of the carriageway. Adequate road signage and road marking is required in order to give the driver sufficient warning to allow enough time for the driver to weave to the left side of the road, in order to select the correct lane for the right turn. There is also a problem in preventing motorists from turning right at the main intersection.

In this layout the traffic conflict points are located at three separate crossings, each controlled by a two-phase traffic signal (the need for traffic signal control is however determined by the relative traffic volumes).

There is a need for the provision of adequate storage length for queued vehicles in the jug handle slip lane.

The path of a right-turn manoeuvre at a Jug Handle Intersection is much longer than that at a conventional intersection. Substantial additional land-take may be required, which will be especially problematic and expensive if already fully developed.

2.2.4 At-grade Loop Intersection

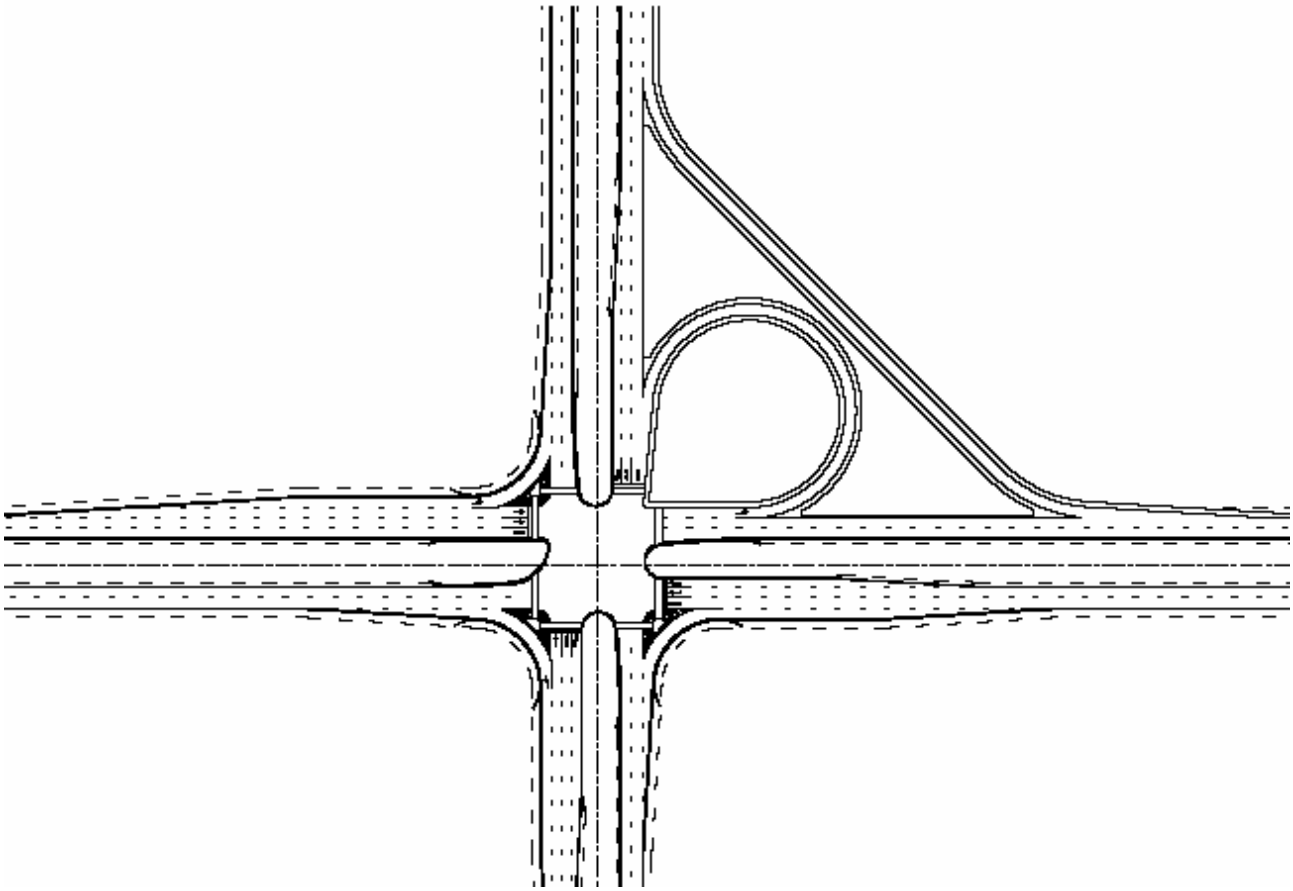

Figure 2.5. At-grade loop intersection.

This Figure shows a possible layout for an At-Grade Loop Intersection (with right-turns from the left-hand traffic lane downstream of the intersection). Driver confusion is a major consideration in this type of layout, as the right turn is initiated from the left-hand side of the carriageway, after the intersection. Adequate road signage and road marking is required in order to give the driver sufficient warning to allow enough time for the driver to weave to the left side of the road, in order to select the correct lane for the right turn. There is again also a problem in preventing motorists from turning right at the main intersection. An additional disadvantage of this layout, is that right turning traffic passes through the intersection twice.

The traffic conflict points are situated at one location, i.e. at the main intersection controlled by a two-phase traffic signal. In addition there is a merging movement at the end of the loop on the intersecting road approach. Traffic signal phasing is simplified in this type of layout.

There is a need for the provision of adequate storage length for queued vehicles in the loop in order to prevent spilling-back of queued vehicles across the main intersection.

The path of a right-turn manoeuvre at an At-grade Loop Intersection is somewhat longer than that at a conventional intersection. Substantial additional land-take may be required for the loop and slip lane, which will be especially problematic and expensive if already fully developed.

2.2.5 Partial Mid block Access Intersection

The accompanying Figure 2.6 shows a typical layout for a partial mid-block access between two conventional intersections. This type of access is generally associated with a large-scale development adjacent to the main road.

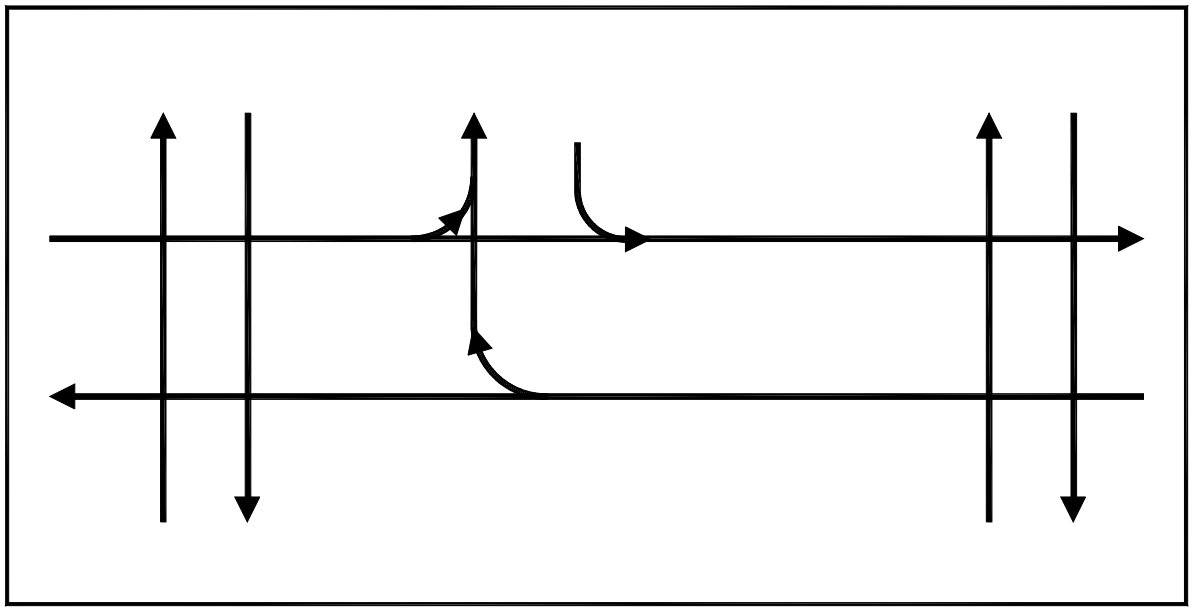

Figure 2.6. Partial Mid-block Access.

Traffic on the major route (traveling from right to left), can access the site using the dedicated right-turn lane through the associated opening in the median. Although possibly motivated by improved accessibility to the development, the partial access can improve capacity at the main intersection downstream of the development if a substantial percentage of the right turning movement has the development as its destination. Partial access should only be considered for large scale developments, where this is a distinct possibility. Each case will however be unique and must therefore be assessed on its merits, including the possible need for signalisation at the partial access.

3. MODELLING

A modeling exercise was undertaken using the AIMSUN micro-simulation model to compare the operation of the different intersection alternatives, using a limited range of traffic flow conditions. The output of the model was compared in terms of cost of modelled delay and estimated cost of construction, and based on this the various intersection alternatives were ranked in terms of relative cost benefit for the traffic flows tested.

Based solely on this assessment, the ranking of the main intersection types in terms of value for money was found to be:

- Median U-turn intersection
- Slip Lane intersection
- Conventional intersection with dual right-turn lanes
- At-grade Loop intersection
- Jug Handle intersection
- Conventional intersection with single right-turn lane

In terms of value for money, the modelling results indicate that the Median U-turn intersection performs significantly better than the other alternative intersection types for the range of traffic conditions tested. The Slip Lane Intersection and the Conventional Intersection with dual right turn lanes were similar in performance, with no significant advantage offered by either design over the other. The At-grade Loop Intersection, the Jug Handle Intersection and the Conventional Intersection with a single right-turn lane fared significantly less favourably than the other alternatives tested.

4. CONCLUSIONS

The following conclusions can be derived from the study:

- Unconventional intersection layouts accommodating displaced right turns have the potential to cause driver confusion unless this issue is carefully addressed at the design stage.
- Unconventional intersections, if considered, should be implemented consistently on a corridor basis and not at isolated intersections. It is imperative that intersections with right turn from right-hand lane and intersections with right turn from left-hand lane should never be mixed in the same corridor as this could result in serious driver confusion. Consistent design along a specific section of roadway will assist in reducing the number of errors of judgement by drivers.
- Careful thought must be given to the provision of adequate road markings and road signage to ensure that the road user can anticipate an early or late right turn manoeuvre timeously. This is particularly relevant where the right turn is made from the left-hand traffic lane, which is contrary to driver expectations, or when the driver cannot see the intersection before making the decision to turn.
- The prevention of conventional right turns at the intersection is a particular geometric and signage challenge, especially where the right turn is executed after the intersection.
- In these unconventional intersections storage length is generally a critical issue and this aspect must be carefully checked when finalizing an intersection layout. The distance between the main intersection and the "cross-over" is a trade-off between spill-back and extra travel distance, and it can be the deciding factor as to whether an alternative right turn type intersection is more suitable than a conventional intersection at a particular location.
- Heavy vehicle turning paths are a critical aspect in the design of unconventional right turn intersections. This is particularly relevant for intersections that require median U-turns.
- Recent research has indicated that median U-turns are a relatively safe manoeuvre.
- The successful operation of many types of unconventional right turn intersections is generally dependent on the efficient co-ordination of adjacent traffic signals.
- Based on the results of the limited modelling exercise undertaken, the median U-turn intersection offers the best value for money and also offers the best operational results in terms of reduction in intersection delays. The relative benefit is however marginal, and possible driver confusion can negate such benefits.
- Detailed site specific analysis should be contemplated prior to the implementation of unconventional intersection types

It must be emphasised that the modelling exercise undertaken as part of this study was severely restricted in extent and used a relatively narrow range of traffic flows. Before implementing any of the unconventional intersection types it is necessary to undertake a detailed study using the specific site conditions to determine its suitability.

5. REFERENCES

[1] Sampson JD and Arnott-Job, P “Traffic Signals: How safe are they?”, ATC 1995.

[2] Hummer J, September, 1998, Unconventional Left-Turn Alternatives for Urban and Suburban Arterials - Part One: - *ITE Journal on the Web*.

[3] Hummer, J, November, 1998: Unconventional Left-Turn Alternatives for Urban and Suburban Arterials - Part Two: - *ITE Journal on the Web*.

[4] Goldblatt, R, Mier, F and Friedman, J, July, 1994: Continuous Flow Intersections: - *ITE Journal*.

[5] Bared, J and Kaisar, E, February, 2002: Median U-Turn Design as an Alternative Treatment for Left Turns at Signalized Intersections: - *ITE Journal*.

[6] American Association of State Highway and Transportation Officials (AASHTO), 2000, *A Policy on Geometric Design of Highways and Streets*. Indirect Left Turns and U-Turns: Washington D.C.

[7] University of Kentucky, June 2004, U-Turns at Signalized Intersections: *Research Report KTC-04-12/SPR 258-03-3F*

[8] Transportation Research Board, 2004, Safety of U-Turns at Unsignalized Median Openings: *TRB NCHRP Report 524, , Washington*.

[9] *United States Department of Transportation, 2005,* Signalized Intersections Information Guide - *FHWA-HRT-04-091 - Federal Highway Administration (FHWA), Washington D.C*

[10] Hummer, J and Reid, J: Unconventional Left-Turn Alternatives for Urban and Suburban Arterials, An Update: - *TRB Circular E-C019*: Urban Street Symposium.

[11] Bared, J, July 2005, A Review of the Signalized Intersections: Information Guide. ITE Journal