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REPRINT

Not "the greatest new development in traffic engineering since the traffic signal"

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NOTE:

This letter to the editor is related to the intersection analysis methodology used in the SIDRA INTERSECTION software. Since the publication of this letter to the editor, many related aspects of the traffic model have been further developed in later versions of SIDRA INTERSECTION. Though some aspects of this letter to the editor may be outdated, this reprint is provided as a record of important aspects of the SIDRA INTERSECTION software, and in order to promote software assessment and further research.

Not 'the greatest new development in traffic engineering since the traffic signal'

LETTERS to the Editor

Dear Sir,

In a recent issue of the *Road & Transport Research*, an article titled *'The greatest new development in traffic engineering since the traffic signal? '* presented a comparison of delay estimates for a conventional design and a *'Continuous Flow Intersection'* (CFI) design for a signalised intersection (Hutchinson 1994). A more comprehensive article on the *Continuous Flow Intersection*, which appears to be a patented design, was published in the ITE journal (Goldblatt, Mier and Friedman 1994). Hutchinson's T-junction example is useful as a simplified case of the CFI design.

This article presents a brief response to Hutchinson's paper, not based on a systematic study of the subject, but on a quick analytical look at the performance of the CFI design as an interesting academic exercise. For the numerical examples used by Hutchinson, the SIDRA package (Akçelik 1990) has been used to obtain delay estimates for the CFI and two conventional signalised intersection designs as well as a two-lane modern roundabout alternative. The new SIDRA version 4.1 has been employed in this exercise due to its improved performance models including the use of geometric delays. Analyses for signalised intersection cases were carried out with and without pedestrians.

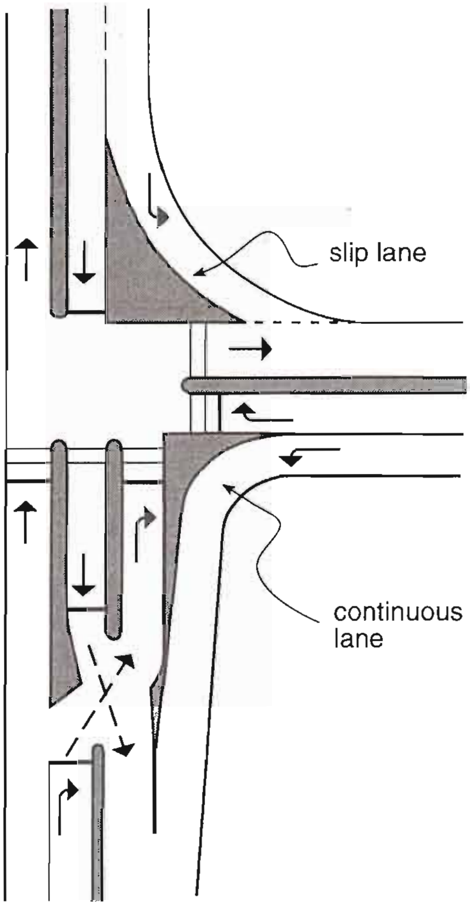


Figure 1

The assumed Continuous Flow Intersection (CFI) design

Data Specifications

Figure 1 shows the assumed CFI design. *Figures 2 and 3* show the intersection geometry pictures generated by SIDRA for the conventional signal design (with pedestrians) and roundabout cases. *Figure 4* shows the phase sequence data for the CFI and conventional signal design cases with pedestrians.

The following assumptions were made in SIDRA analyses (see *Figures 1 to 4*):

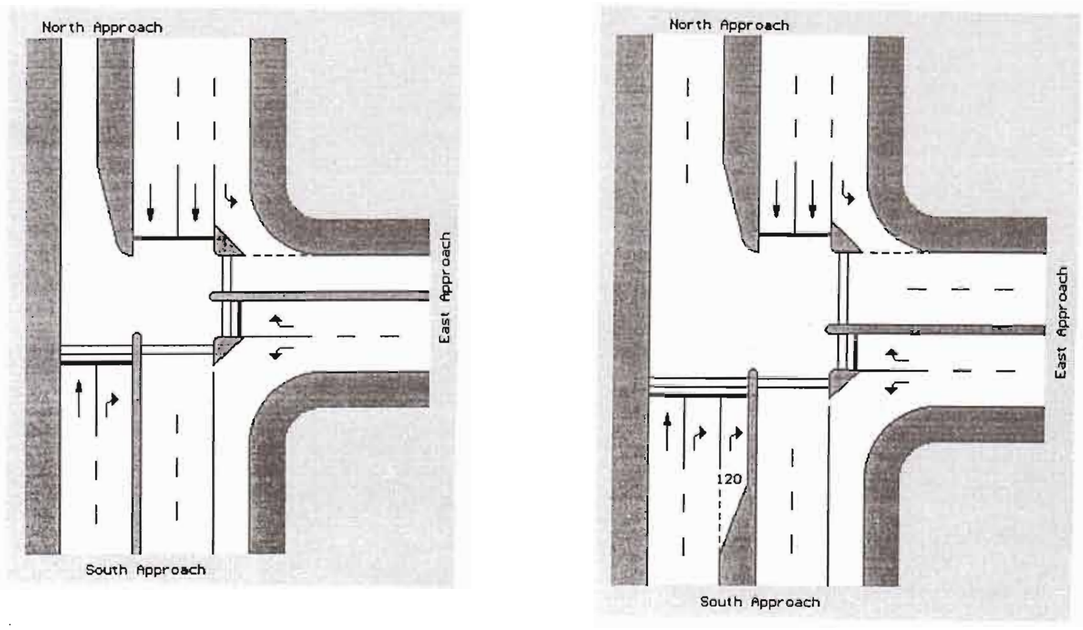


Figure 2

Intersection geometry pictures for the two conventional signalised intersection design cases

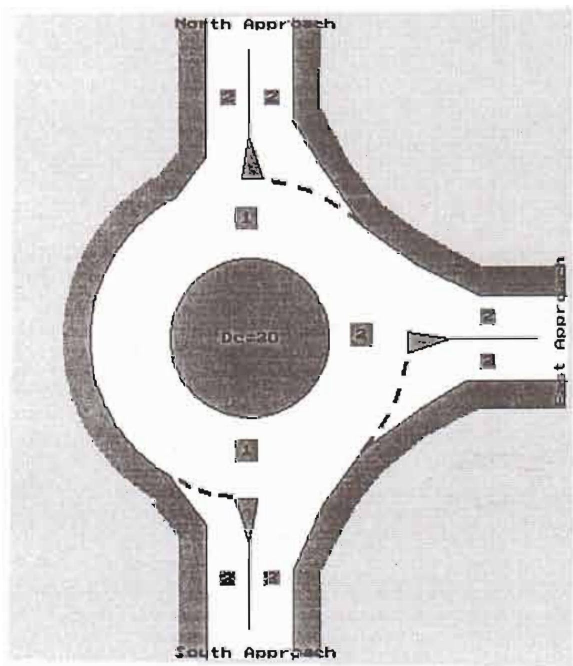
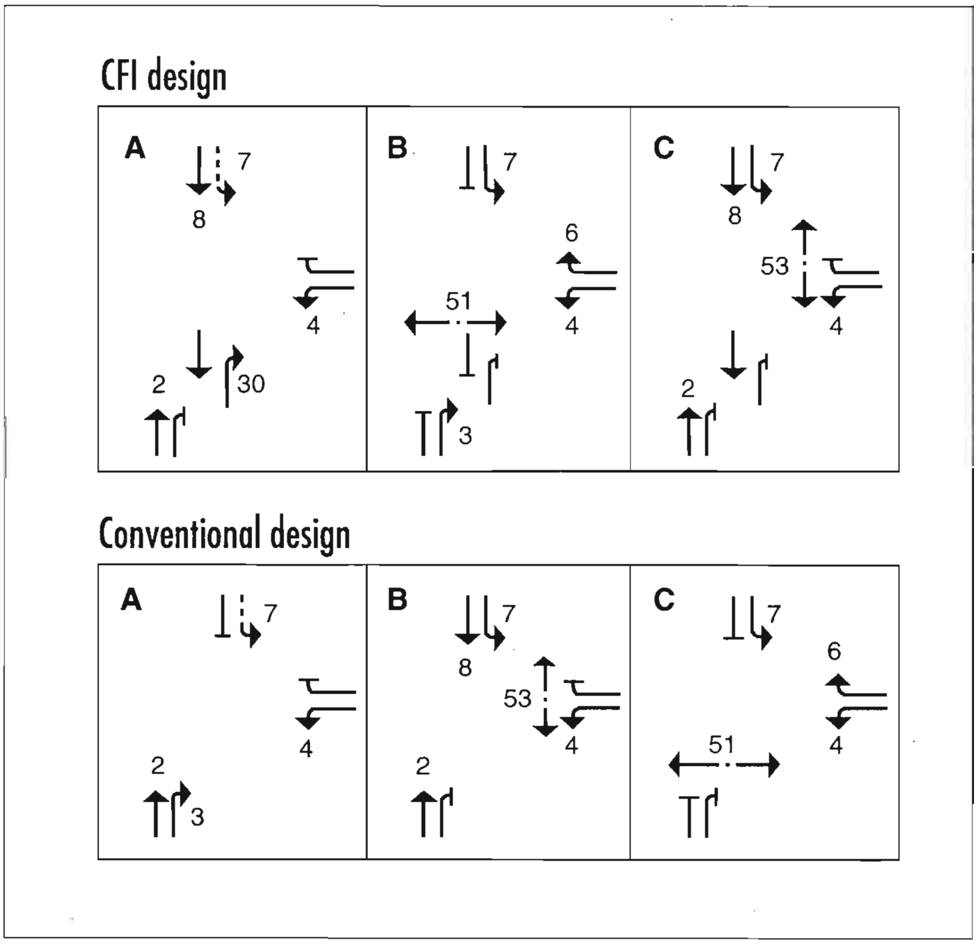


Figure 3

Intersection geometry picture for the roundabout design case

Figure 4

The phase sequences used for the CFI and conventional design cases



(i) In Hutchinson's example, left turns from North and the conflicting right turns from South appear to be given right of way at the same time. This could be correct only if a continuous lane treatment is adopted for the left-turn movement. In the analyses presented here, an exclusive slip lane was specified for left turns from North (left turns give way to right turns from South), and a continuous left-turn lane was specified for the East leg for both the conventional and CFI designs.

(ii) For all signalised intersection cases, all movements are in exclusive lanes (i.e. there are no shared lanes). The through movement from North is allocated one lane in the CFI design and two lanes in the traditional signal design options. For the conventional design option with two right-turn lanes, the second lane is added as a short lane (turn slot) with length 120 m.

(iii) For the roundabout option, a two-lane roundabout with shared lanes on the North (LT, T) and South (T, TR) approaches, and exclusive left and right-turn lanes on the East approach (L, R) has been assumed (L: Left, T: Through, R: Right). SIDRA defaults for all roundabout parameters are used (inscribed diameter = 40 m, circulating road width = 10 m, entry lane width = 4.0 m, variable critical gap and follow-up headways). Numbers of circulating lanes are specified as two for the West leg and one for the South and North legs as dictated by the approach lane disciplines.

(iv) For the CFI design, the downstream storage area was modelled as a diagonal leg (Southeast). The platooned-arrivals model was used for the right-turn movement at the downstream stop line specifying Arrival Type = 1 as most vehicles would arrive at this stop line during the red period. The effect of this is an increased delay compared with the random-arrivals case. Delays to right turns from South for the CFI design were calculated by adding the delays at the upstream and downstream stop lines. The downstream storage area was coded as a full-length lane. The implication of this is discussed in the last section.

(v) For the conventional design, full control was assumed for right turns from South (i.e. there are no filter turns) as they have priority over the slip-lane left turns from North. In the case without pedestrians, the phase sequence for the CFI design is as used by Hutchinson. In the case with pedestrians, pedestrian crossings are assumed in front of the South and East legs. In this case, a third phase is added which is the same as the first phase except that the right-turn movement from the storage area is stopped and the North-South pedestrian movement is given right of way (see Figure *4*). Pedestrians in front of the South approach cross during the second phase.

In the CFI design and the conventional design with one lane for right turns from South, the minimum green times are 11 seconds for the North-South pedestrian movement and 16 seconds for the East-West pedestrian movement. In the conventional design with two lanes for right turns from South, the minimum green times are 14 seconds for the North-South pedestrian movement and 19 seconds for the East-West pedestrian movement.

(vi) Left-turn flow rates are fixed as 300 veh/h from North and 400 veh/h from East for all cases. Through flow from South is fixed as 800 veh/h for all cases. Other flow rates vary as shown in Tables 1 and 2. For the options with pedestrians, all pedestrian movement flows are 150 ped/h.

(vii)For the purpose of time-dependent delay modelling in SIDRA, the peak flow period is specified as 0.5 h and the peak flow rates (veh/h) are used as known (Peak Flow Factor = 1.0). Saturation flows are as used by Hutchinson: through movements 1800 veh/h, left turns: 1500 veh/h, right turns: 1600 veh/h. No saturation flow adjustments are carried out except for the filter-turn phase of slip-lane left turns from North. All intergreen times = lost times = 5 seconds (except the left-turn movement from North which has different values due to two green periods and filter turns, but this does not affect timing calculations since this movement is specified as undetected). The maximum cycle time is specified as 120 seconds and the cycle increment is specified as 5 seconds.

Results

The results shown for all options are summarised in *Tables 1 and 2*. All delays given in these tables include the geometric delays although no attempt has been made to fine-tune the modelling of the CFI design for additional geometric delays experienced by right-turners entering the storage area. It is seen that:

(i) While the CFI design offers some improvement over the conventional design for very heavy right-turns, better results can be achieved by simply adding a turn slot for right turns, a much used practice in Australia.

(ii) The best performance for these examples was offered by the two-lane roundabout option, confirming the general knowledge that roundabouts are good in handling heavy right-turn volumes. However, right turns from the East leg of the roundabout experience long delays (42.6 s) in the case of the last flow pattern *in Table 1*. This is due to the heavy through flow (1000 veh/h) from the adjacent (North) approach, presenting unbalanced flow conditions that reduce the capacity of the East approach.

(iii) Generally, the conventional design gave lower delays to right turns from the South leg, the only exception being the conventional design with a single right-turn lane in the case of very heavy right turn and conflicting through traffic volumes.

(iv) Generally, the CFI design gave higher delays to pedestrians. The existence of pedestrians affected (adversely) the performance of the CFI design more than the traditional design.

Discussion

Goldblatt, et al (1994) stated that New York City was preparing plans for implementing an intersection of this type although their comments indicate that this design is costly, and has human factor problems due to some frightful design features, especially the problems for pedestrians faced with the contra-flow situation.

The analysis of the CFI design must account for extra delays and stops at the downstream storage area for right turns. The available downstream storage space can be a limiting factor for the capacity of the right-turn movement, and therefore a short lane capacity analysis is required. For the CFI design results given in *Tables 1 and 2*, unlimited length has been assumed for the downstream storage area. An estimate of the back of queue for the heavy flow pattern (last pattern in *Table 1*) indicates that the 95th percentile queue for the storage area is about 200 m. A similar amount of queueing space would also be required for the upstream stop-line.

While the CFI design has the advantage of handling very high right-turn flows as dealt with in Hutchinson's examples, it would thus require more space generally, and more queueing space for right-turning traffic because they are stopped twice. If the space were available, effective conventional signal design options such as double or triple right-turn lanes, or the modern roundabout design, could be used with better performance results as seen from the results given in Tables 1 and 2.

Furthermore, the modelling of queue interaction effects of the downstream storage area (causing reductions in the upstream saturation flow) can be significant, and should be modelled carefully for this type of design (not included in the results presented here).

In summary, the *Continuous Flow Intersection* does not appear to fulfil its promise as indicated by much better performance results predicted for adequately-designed conventional signalised intersection and modern roundabout options.

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TABLE 1

Average delays and other results for the conventional and Continuous Flow Intersection (CFI) signal designs and a two-lane roundabout: *the case WITHOUT pedestrians*

Flow rates* (veh/h)	S_R	400	400	600	600
	N_T†	600	1000	600	1000
	E_R	400	400	600	600
Conventional signal design	c	65	90	120 (max)	120 (max)
	X	0.903	0.938	1.053	1.184
	d (INT)	26.0	34.8	75.2	136.2
	d (S_R)	47.0	63.1	113.1	232.3
Conventional signal design (2-lane S_R)	c	55	65	85	110
	X	0.859	0.860	0.938	0.982
	d (INT)	20.8	24.8	35.0	48.8
	d (S_R)	35.0	47.1	50.1	84.4
CFI signal design	c	50	70	75	120 (max)
	X	0.889	0.949	0.952	1.023
	d (INT)	19.6	25.1	32.2	54.0
	d (S_R)	60.3	81.1	87.9	148.1
Roundabout	X	0.561	0.606	0.803	0.850
	d (INT)	13.6	14.7	18.8	22.4
	d (S_R)	15.0	15.0	24.0	24.7

* Other flow rates are fixed: 800 veh/h for Through from South (in one lane except for the roundabout case), 400 veh/h for Left-turn from East (in one lane in all cases), 300 veh/h for Left-turn from North (in one lane in all cases).

† In one lane in the case of the CFI design and in two lanes in the case of the conventional design.

S_R: Right-turn movement from South
N_T: Through movement from North
E_R: Right-turn movement from East
c: Cycle time (seconds)
X: Intersection degree of saturation
d (INT): Average intersection delay (seconds/veh)
d (S_R): Average delay to the right-turn movement from South (seconds/veh)

TABLE 2

Average delays and other results for the conventional and Continuous Flow Intersection (CFI) signal designs: *the case WITH pedestrians*

Flow rates* (veh/h)	S_R	400	600
	N_T†	600	1000
	E_R	400	600
Conventional signal design	c	65	120 (max)
	X	0.903	1.184
	d (VEH)	26.7	136.2
	d (PED)	22.9	35.3
	d (S_R)	47.0	232.3
Conventional signal design (2-lane S_R)	c	60	110
	X	0.860	0.982
	d (VEH)	21.6	48.8
	d (PED)	22.1	30.2
	d (S_R)	36.7	84.4
CFI signal design	c	65	120 (max)
	X	0.855	1.023
	d (VEH)	22.8	56.7
	d (PED)	23.3	40.8
	d (S_R)	82.6	165.0

* All pedestrian flows = 150 ped/h. Vehicle flows are as in *Table 1*.
† In two lanes in the case of the conventional design option.
S_R: Right-turn movement from South
N_T: Through movement from North
E_R: Right-turn movement from East
c: Cycle time (seconds)
X: Intersection degree of saturation
d (VEH): Average intersection delay for vehicles (seconds/veh)
d (PED): Average intersection delay for pedestrians (seconds/ped)
d (S_R): Average delay to the right-turn movement from South (seconds/veh)