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Note: *Sections 7 and 8 of this article refer to an early version of aaSIDRA. Improvements recommended in this paper were implemented in aaSIDRA soon after the publication of this paper.*

THREE-LANING A TWO-LANE ROUNDABOUT - THE OUTCOMES!

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1. INTRODUCTION

In 1995, VicRoads, the State Road Authority, was faced with a decision to upgrade an existing highly congested two-lane roundabout by either converting to traffic signals or by adding additional lanes to the roundabout. The existing roundabout, which had signalised metering on one approach, was characterised by extensive queuing and delays (up to 10 mins) in both peak periods, with highly unstable and unpredictable traffic flow conditions.

Capacity analysis of roundabouts is still in its infancy, and is somewhat unreliable. The various analyses showed that the roundabout was likely to perform better than signals, but there were many doubts as to what would happen if the three-lane roundabout option was implemented.

The results have been surprising, with the roundabout operating in excess of expectations with generally minimal queuing and delay, in spite of increased levels of demand.

The site was subjected to extensive before and after survey and analyses to allow measurement and analysis of gap acceptance, lane discipline, as well as queuing and delays.

The paper presents some of the background to the decision. There is also discussion on the "transferability" of the results. The paper describes the technical assessments, design considerations, capacity analyses, other deliberations, and "before & after" analyses for a project which resulted in the conversion of a two lane roundabout to a three lane roundabout. It also re-analyses the "after" data in light of the unforeseen substantial redistribution and increase of traffic which took place on completion of the project.

The results break new ground in roundabout capacity analysis. The “before” roundabout was one of a number of intersections used to calibrate the SIDRA roundabout model in Version 4.13. The “after” results will be used for further calibration of the SIDRA intersection capacity model, and this is reported in the paper.

2. THE SITE

The Fitzsimons Lane/Porter Street roundabout is located in the fast growing outer suburbs of Melbourne, Australia. Fitzsimons Lane is a 4-lane divided primary arterial road which is one of the few crossings of the Yarra River in the region. It carries about 45,000

vehicles per day (vpd) north of the roundabout. South of the roundabout (Williamsons Road) is also a 4-lane divided primary arterial road carrying about 35,000 vpd. Porter Street on the east approach and Anderson Street on the west approach are generally two-lane roads but have local widening on the approaches and departures from the roundabout and carry about 12,000 vpd (east) and 10,000 vpd (west). High proportions of traffic on the east and north approaches turn right at the intersection, and this was the prime factor in the initial treatment of the intersection some 20 years ago being a roundabout rather than traffic signals.

3. THE PROBLEM

In morning and afternoon peak periods, there were rapidly increasing delays occurring in the peak travel directions. In the AM peak "Rolling" queues on the northern approach were often over 1 km, with delays of up to 10 minutes. On the eastern approach, while queues were shorter, the delays were very high at around 5 min. In 1990 a set of pedestrian operated traffic signals was installed on the northern leg about 50 m north of the roundabout, and these were used for "metering" approach flows to provide gaps for traffic from the east. The meter detector is located about 90 m from the stop line. The meter had the effect of reducing delays on the eastern approach to a maximum of about 3 min.

4. ALTERNATIVE TREATMENT OPTIONS

Three-LANE ROUNDABOUT - OPTION 1

The two-lane roundabout could have been modified to increase the capacity by constructing additional lanes on the approach and departures of Fitzsimons Lane, Williamsons Road and the approach in Porter Street. No land acquisition was required as the diameter of the central island could be reduced to enable a third circulating lane to be constructed. As a consequence, the design speed of through movements would increase, however these speeds would still be acceptable (50km/h for Fitzsimons Lane/Williamsons Road and 45km/h for Porter Street/Anderson Street).

Early SIDRA analysis indicated that the degree of saturation would reduce from above 1.0 (growing queues at the height of the peak) to about 0.77 in the morning peak (30%) and from above 1.0 to 0.75 in the evening peak (43%).

Pedestrian numbers at this site are not high, however their movements around the proposed three-lane roundabout may have become more difficult due to the additional lanes. The pedestrian crossing in Fitzsimons Lane would have been retained because of the continuing requirement to provide traffic metering to minimise delays to Porter Street traffic in the AM peak.

It was expected that there would be a small increase in crash frequency at the intersection due to an increase in vehicle speeds, but not to the same extent as those expected if the intersection was signalised.

ESTIMATED (and actual) COST = $500,000

THREE-LANE ROUNDABOUT - OPTION 2

That proposal differed from Option 1 in that Porter Street would not be widened to three lanes.

The degree of saturation for the intersection was calculated to still be in excess of 1.0 (in Porter Street) in the morning peak and 0.65 in the evening. This was unsatisfactory, and therefore not pursued.

PRELIMINARY COST = $350,000

SIGNALISED INTERSECTION

The proposed layout is shown in Figure 1. Extensive roadworks would have been required to remove the existing roundabout and construct a conventional intersection. Analysis of the intersection determined that three through lanes would be required in Fitzsimons Lane/Williamsons Road with a double right turn lane on the Fitzsimons Lane (north) approach. Porter Street required two through lanes and a double right turn lane, whilst Anderson Street needed two through lanes and only a single right turn lane.
The signal operation would have had all right turns fully controlled with the exception of Anderson Street. SIDRA analysis based on a cycle time of 110 seconds indicated degrees of saturation of 0.90 in the morning peak and 0.93 in the evening. The cycle time was comparable to the signals at Williamsons Road/Foote Street intersection (700m to the south) to ensure adequate signal linking for traffic on Williamsons Road.

It was expected that the number of accidents would most likely increase with this alternative because of the higher speeds compared to a roundabout. Pedestrian movements would have become easier because all approaches are controlled.

ESTIMATED COST = $750,000

5. ADOPTED ROUNDABOUT

The adopted scheme consisted of three-lane approaches on all but the western approach, and three circulating lanes - except for the northern segment which would only be a single lane. "Alberta" linemarkings were used to obtain the desired lane discipline. The final plan is as shown in Figure 2.

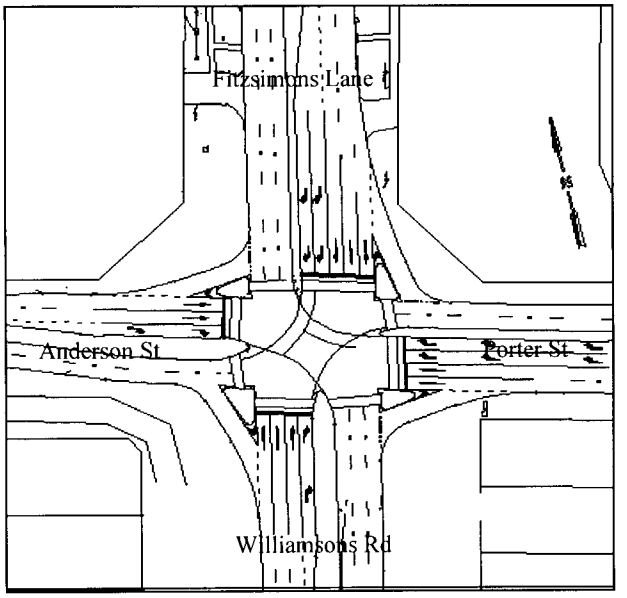

Figure 1 : Signalised Option

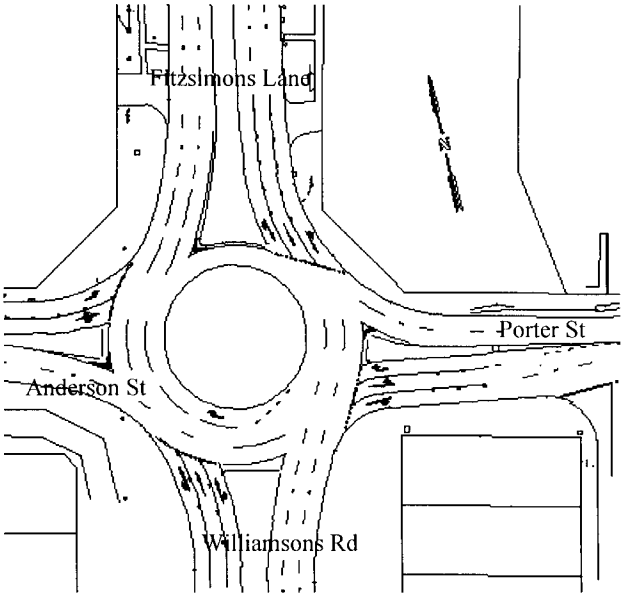

Figure 2 : Adopted Three-Lane Roundabout Option

6. BEFORE & AFTER SURVEYS AND ANALYSES

SURVEYS

The performance of a dynamic system such as a roundabout is characterised by many interactive variables, making analysis a complex task. In order to conduct a meaningful analysis of traffic conditions, individual parameters such as vehicle queues and in-vehicle travel times were surveyed and then cross checked against manual counts and observations.

In addition to the data collection surveys, portions of the survey period were captured on video to allow later analysis of the gap acceptance behaviour.

The methodology adopted for the before and after surveys is summarised below.

In-vehicle travel time surveys

In-vehicle travel time and delay surveys were conducted for each entry lane of all approaches to the roundabout separately. The sets of data recorded were:

- Time vehicle passed fixed survey point (defined by VicRoads);
- Time vehicle joined back of queue;

- Time vehicle reached the holding bar (yield line) of the roundabout; and
- Time vehicle crossed the holding bar (yield line) and entered the roundabout.

Two instrumented vehicles were used to achieve the observations with circuits at around 15 minute intervals.

Manual counts

The manual counts consisted of:

- static queue lengths recorded by roadside observers every 5 minutes;
- turning movement and manual classification counts on each entry lane for all approaches in 15 minute intervals; and
- arrival (demand) flow rates on each approach in 15 minute intervals.

The arrival (demand) flow rates were conducted behind the back of queue on the approaches with large delays to test the difference between arrival rates and actual roundabout entry flow rates. During the after surveys, arrival (demand) flow rates were assumed to be the same as the roundabout entry flow rates during the after surveys, as vehicle queues were minimal.

BEFORE SURVEY RESULTS - THE "PROBLEM"

The results of the before surveys showed extensive queuing and delays for peak direction traffic. Analysis of the "before study" data confirmed anecdotal evidence and field observations that the two-lane roundabout was not performing successfully under heavy flow conditions. The geographic location of the roundabout on the urban fringe north-east of the Melbourne CBD means that the northern and eastern approaches experience heavy traffic flows in the AM period, with heavy flow shifting to the southern and western approaches in the PM period.

Fitzsimons Lane

In the AM period, the northern approach (Fitzsimons Lane) highlighted the magnitude of the overall problem faced at the roundabout. Manual counts of static queue lengths showed vehicle queues of up to 1km at 7:15am, increasing to almost 2km by 7:30am. Due to Fitzsimons Lane's priority over the eastern approach, the long queue lengths were not reflected in the delay times (about 3-5 minutes from back of queue). Queues and delays in the PM period were both low.

Porter Street

Average queue lengths were in the order of 100m in the AM and PM periods, however delays of up to 15 minutes were recorded in the AM period and up to 21 minutes in the PM period.

Williamsons Road

Queue lengths and delays in the AM period were low but PM period surveys showed queues that extended back to the preceding intersection (Foote Street, 700m south). Delays of up to 10 minutes were recorded.

Anderson Street

Anderson Street experienced delays in the PM peak of up to 9 minutes due to the constant stream of traffic entering the roundabout from the southern approach. Queue lengths were about 500m.

The results in terms of delays are shown in Table 1, and the traffic counts in Figures 3 and 4.

AFTER SURVEY RESULTS

The results are also summarised in Table 1 and Figure 3 and 4.

Observations showed the roundabout to be performing better than anticipated except Porter Street in the AM peak. The continuing delays on Porter Street related to two factors - significantly increased traffic on the northern leg, and underutilisation of the left lane on the northern leg. Other queue lengths were less than 100m and delays were generally less than 1 minute.

The most important outcome was the unpredicted changes in traffic volumes during both peaks. While some redistribution of traffic was anticipated, an important outcome was the unexpected magnitude of the increase in traffic volumes during both peak periods.

	Before		After	
Av Max Delays:	AM (s)	PM (s)	AM (s)	PM (s)
Fitzsimons Lane	240	15	10	4
Porter Street	480	300	150	20
Williamsons Road	45	375	10	8
Anderson Street	15	300	6	70

Table 1: Averaged Highest Delays (across lanes)

CHANGES IN TRAFFIC PATTERNS

The total number of vehicles per hour using the intersection grew from 4520 to 5320 per hour (18%) in the AM peak, and from 4130 to 5180 per hour (25%) in the PM peak.

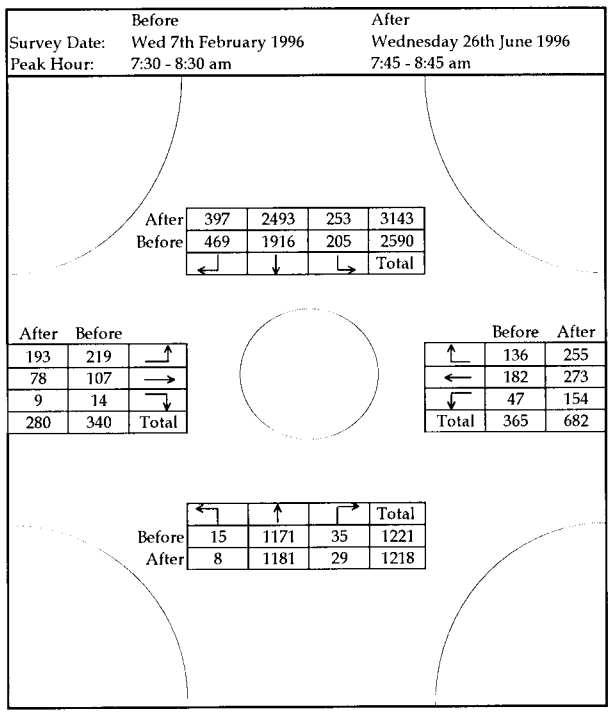

Figure 3 : AM Period Approach Volumes

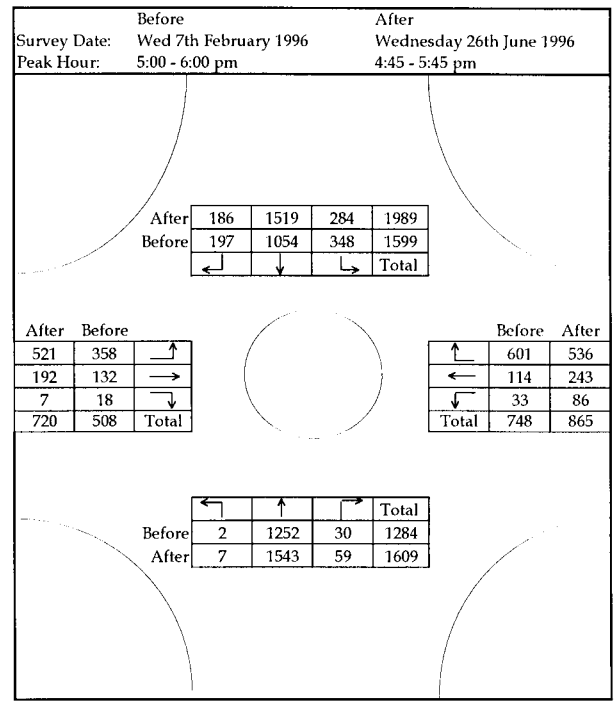

Figure 4 : PM Period Approach Volumes

The other significant outcome was that the delays on the east leg (Porter Street) were not reduced as much as expected. This occurred because of the imbalance in lane usage on the very heavily trafficked but undelayed northern approach. Left lane usage was only about 20% of that in the other two lanes. Except when the northern approach was interrupted by the meter signals, traffic was virtually undelayed hence there was no incentive for drivers to use the outer lane.

7. ANALYSIS OF THE CHANGED CONDITIONS

A major change has been observed and recorded in the "after" traffic volumes. We know the outcome for the roundabout, but not what it would have been for the signals. To test the impact had the increase in traffic been predicted, SIDRA analysis of the signals option has been carried out using the "after" data and this shows that the intersection would have been over-saturated in the AM, and near saturation in the PM.

SIDRA Version 4.13 had a considerable number of changes from previous versions of SIDRA in the roundabout analysis area. A major change was to limit the "intra-bunch headway" to 1.2 seconds due to previous problems of capacity over-prediction. Our

analysis of volumes recorded at or near capacity suggests that this change may now lead to an under-prediction of capacity where there are three circulating lanes. This is not surprising as the distribution of headways across three lanes for an entering platoon from a three-lane approach is likely to include some very small headways.

8. FURTHER WORK

The surveys and analyses indicate that there is a need to further calibrate the SIDRA model for capacity predictions for three-lane roundabouts.

The video data recorded for both before and after conditions will allow researchers to further analyse gap acceptance behaviour.

9. CONCLUSIONS

The conclusions which can be drawn from the analyses in the study include:

- the three-laning of a two-lane roundabout led (as expected and indicated by SIDRA analysis) to a substantial increase in traffic capacity;
- the distribution of traffic across lanes on a multi-lane approach is critical to the entry capacity on the next entry leg;
- entry capacity is highly dependent on the ratio of the single lane circulating flow from an opposite leg to the multi-entry flow on the adjacent upstream leg;
- there is a need to refine the SIDRA model in the capacity prediction area for three-lane roundabouts in light of the additional data now available;
- in practice, it will probably be necessary to use metering signals on multi-lane legs with heavy (unbalanced) approach flows to create gaps in downstream circulating flows, but also to create more even traffic distribution across the approach lanes;
- the exercise has demonstrated the need for extra care when predicting traffic conditions after a significant capacity change at a bottleneck on congested road networks.

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