

# **Roundabouts with Metering Signals**

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# Roundabouts with Metering Signals

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**Abstract.** A deficiency of roundabouts in urban areas arises when lengthy delays occur on one or more legs of the roundabout. This event occurs when the entering and circulating volumes are not evenly spread, typically during the peak periods when traffic flows have a predominantly directional characteristic. These conditions develop a negative public opinion about roundabouts that ignore the safety and capacity benefits that roundabouts provided for the majority of the day.

Introducing traffic signal control to a roundabout is a technique that can be used to overcome problems associated with uneven traffic flows during peak periods. However, the form of signal control, its operation details and its impact on all road users all need to be considered before it can be adopted for application at a roundabout.

A conceptual analysis model has been developed by Akcelik and Associates Pty Ltd (May 2001) to analysis roundabouts with metering signals. This model was tested using a range of data to verify its operation and to test its robustness.

Using the results obtained from the model, a set of guiding principles was developed for the appropriate use of metering signals at roundabouts.

## **APPLICATIONS OF SIGNALISED ROUNDABOUTS**

The majority of published literature on the subject of signalised roundabouts is based on experience in the United Kingdom where they were adopted initially to control traffic around many of the older larger roundabouts that have existed in towns for many years. The use of full time, total signal control at these roundabouts has been the method used on the majority of these sites.

The trend towards introducing signal control to roundabouts is increasing in the United Kingdom. A survey conducted by the County Surveyors' Society (1997) of 49 road authorities in England found that between 1991 and 1994 the rate of increase of installations of signalised roundabouts was averaging 25% per year compared with only 3% per year for signalised intersections in general. The survey of 161 signalised roundabout sites indicated that 35% of the roundabouts were fully signalised, 36% operated on a part time basis and 34% of signalised roundabouts have some formal pedestrian facilities.

Hallworth (1992) identified six options for introducing signal control to a roundabout (see Table 1). A particular site can be a combination of different device options.

Design Parameter	Option	Description
1. Means of Control	Direct	Signal control of external and internal approaches (i.e. all conflict points are controlled)
	Indirect	External traffic only controlled by signals some distance from the entry point (to meter entry flow); circulating traffic is not controlled and therefore has priority
2. Full / part-time	Full	Signals permanently operating
	Part	Part-time only, switched on by time switch or queue detectors
3. Full / part-control	Full	All approaches with signal control
	Part	One or more approaches remain under priority control

**Table 1 – Types of Signal Control at a Roundabout (Hallworth, 1992)**

In Australia, the practice has been to install signals on one approach of the roundabout to “meter” circulating flow to reduce delays on an opposing leg of the roundabout. This approach operates on a part time basis and is activated by the queue length on the delayed approach reaching a defined critical distance.

In Melbourne, examples of roundabouts with metering signals include:

- Fitzsimons Lane / Porter Street (Templestowe)
- Boundary Road / Governor Road (Mordialloc)
- Nepean Highway / McDonald Street (Mordialloc)
- Nepean Highway / Beach Street (Mordialloc)
- Todd Road / West Gate Freeway Off Ramp (Port Melbourne)
- Sunshine Ave / Melton Hwy (Taylors Lakes)
- Pascoe Vale Rd / Barry Rd (Broadmeadows)
- Dandenong Valley Highway / Thompson Road (Carrum Downs)

An example of a fully controlled roundabout exists in Melbourne at the intersection of Swanston St / Cemetery Rd East / College Crescent.

Elsewhere in the world the use of signal control at roundabouts as an effective form of intersection control appears to be limited given the lack of published experience.

Hallworth (1992) noted the benefits that can be obtained by introducing signal control to roundabouts. These benefits relate to a roundabout with signal control on all approaches, however, the benefits are also applicable to roundabouts with part signal control

	<b>Conventional Roundabout</b>	<b>Signalised Roundabout</b>
<b>Delays</b>	Delays on some approaches can become excessive due to unbalanced flows	Signals can be used to alter the natural priority to provide more balanced delays
<b>Queues</b>	Queues on particular approaches can exceed a critical length.	Signals can monitor the queue lengths and bias the green times so as to reduce the critical queue.
<b>Capacity</b>	The overall roundabout capacity may prove insufficient.	Signals can improve the overall capacity
<b>Safety/Control</b>	The need for weaving and merging can provide difficulties at particular entry approaches	Signals can better regulate traffic patterns, reduce the need for weaving and merging and reduce speeds
<b>Pedestrian Facilities</b>	Lack of control can make it difficult for pedestrians to cross approaches.	Signals can render it safer and more positive.

**Table 2 – Benefits of Introducing Signal Control to Roundabouts (Hallworth, 1992)**

The County Surveyors' Society (1997) in their survey of 49 road authorities in England regarding the installation of signalised roundabouts in their jurisdiction found that the reasons for signalisation varied as follows:

- Queue Control 42%
- Increased Capacity 39%
- Accident reduction 17%
- Links with adjacent signal sites 16%
- Other reasons 13%

It should be noted that the numbers are not exclusive and that in several cases, more than one reason was specified.

In summary, the published literature provided no clear definition of when a roundabout was considered to be inefficient in terms of capacity and performance criteria. The examples contained in published literature regarding the analysis tools available to undertake an evaluation of a signalised roundabout were particular to experiences and sites in the United Kingdom and did not have a direct application for the types of signalised roundabouts in Australia, which are predominantly controlled by metering signals. There has been no published analysis associated with the introduction of metering signals at roundabouts in Australia and it is therefore concluded that any comparison of the before and after situation has only been based on site observations without any predetermined analytical results.

As a result it was identified that there was a need for an analysis tool that to determine the impact of introducing metering signals to improve the performance of roundabouts as well as a set of guiding principles to determine when it is appropriate to use metering signals at roundabouts.

## **AN APPROACH FOR ANALYSING ROUNDABOUTS WITH METERING SIGNALS**

The following approach was adopted for analysing roundabouts with metering signals:

1. Develop a data set of different traffic flow conditions at a study roundabout that would represent conditions requiring the adoption of metering signals.
2. Analyse the data set without the influence of metering signals to determine conditions when metering signals are required.
3. Analyse the data set with the influence of metering signals using different operational designs.
4. Compare the results to determine the improvements in capacity and performance criteria when adopting metering signals and the most efficient operational design.

The results of the analysis were then reviewed with the purpose of developing a set of guiding principles for the appropriate use of metering signals at roundabouts.

This approach is represented by the flow chart presented in Figure 1.

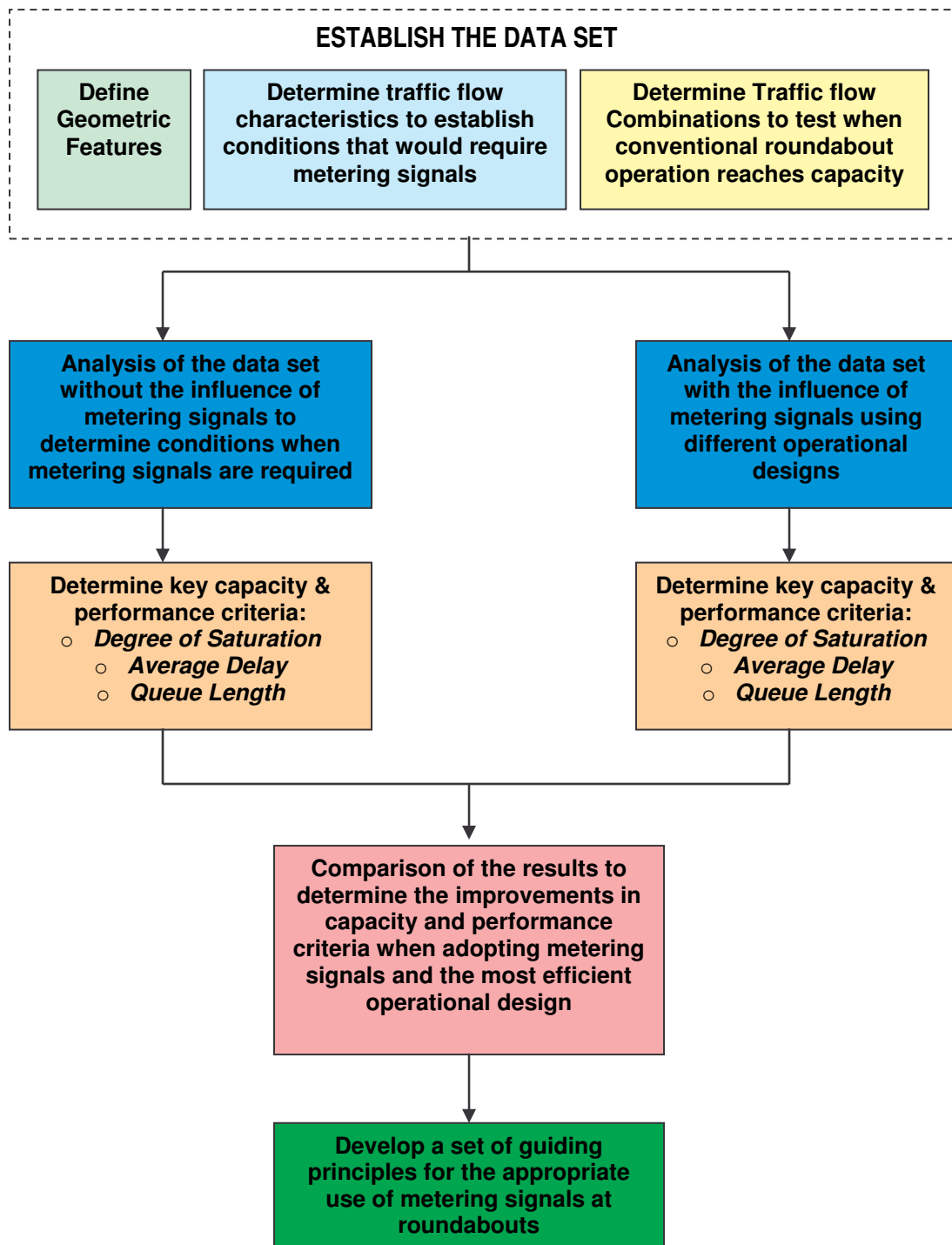
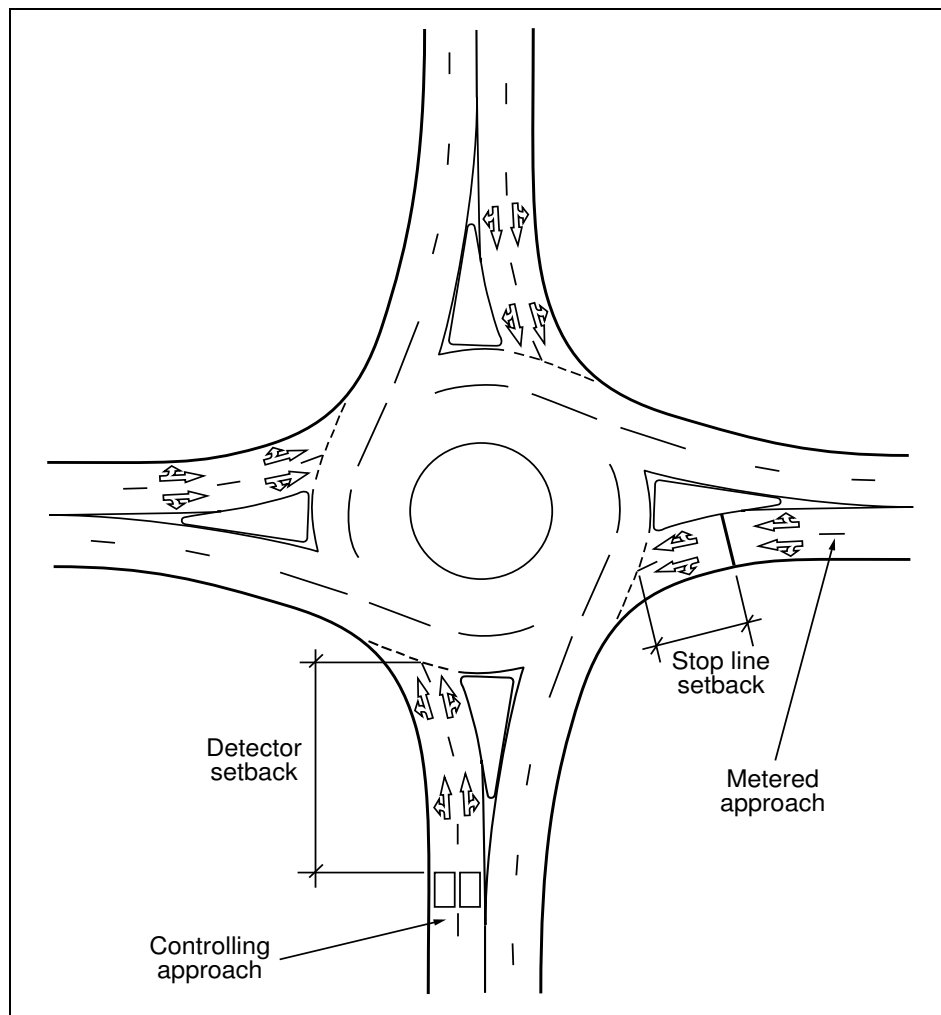


Figure 1 – Study Framework

The analysis of the data set without the influence of metering signals was conducted using an existing commercially available roundabout analysis model called aaSIDRA Version 1.0.4 (Akcelik and Associates Pty Ltd, 2001). The analysis of the data set with the influence of metering signals was conducted using a theoretical analysis model developed by Akcelik and Associates Pty Ltd to analyse the capacity and performance of roundabouts with part-time metering signals. This theoretical model is detailed in a report titled Roundabouts with Metering Signals: Capacity and Performance Analysis, Akcelik and Associates Pty Ltd (May 2001).

Roundabouts with metering signals operate as a two-phase operation. Motorists on one approach of the roundabout either face a red signal and then a green or blank signal depending on the use of the metering signals. This approach is referred to as the “metered approach”. The red signal is activated when the queue on another approach of the roundabout is detected at a critical length. This approach is referred to as the “controlling approach”. These relationships are shown in Figure 2.



**Figure 2 – Metered and controlling approaches, and stop line and detector setback distances for roundabout metering signals (Akcelik and Associates Pty Ltd, May 2001)**

It is acknowledge that a commercially available micro-stimulation computer package could also have been used for the analysis of the roundabout both with and without the influence of metering signals. Given the wide use of aaSIDRA as an analysis tool for roundabouts in Australia, the relative ease of inputting and processing the data, together with the compatibility of the metering signals model, which is to be incorporated into a future version of aaSIDRA, these tools were selected to perform the analysis.

The theoretical analysis model developed by Akcelik and Associates Pty Ltd (May 2001) to analyse the capacity and performance of roundabouts with part-time metering signals was coded into a Microsoft Excel spreadsheet to verify its operation and to test its robustness. This process identified a number of minor issues with the model which were corrected.

### RESULTS OF THE ANALYSIS

When analysing roundabouts without the influence of metering signals the results indicated that there was a narrow area of transition from satisfactory conditions on the controlling approach to where the prescribed performance criteria was exceeded. This transition area in all cases was less than 100 vehicles per hour. Figure 3 indicates the flow conditions on the controlling approach that would benefit by installing metering signals at the roundabout. The grey band indicates the transition zone over which the prescribed performance reached the critical limit specified.

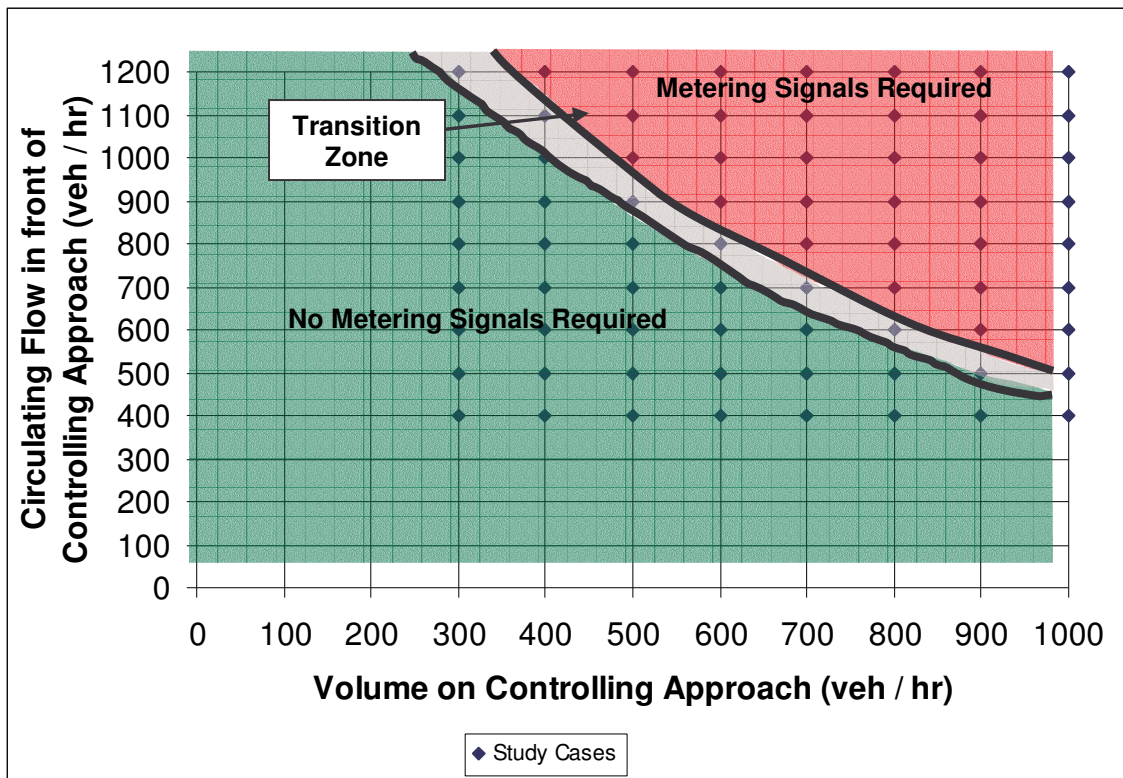


Figure 3 – Flow Conditions on the Controlling Approach that requiring Metering Signals



When analysing roundabouts with the influence of metering signals the results indicated that all adopted operational designs improved the capacity and performance of the controlling approach whilst decreasing the capacity and performance of the metered approach.

Comparing the different operational designs for a roundabout with metering signals the results indicated that:

- Higher minimum blank and red times have a more positive impact on the capacity and performance of the controlling approach than a shorter queue detector setback distance. Therefore, higher cycle times benefit the controlling approach.
- A shorter queue detector setback distance has a lesser impact on the capacity and performance of the metered approach than higher minimum blank and red times. Therefore, lower cycle times benefit the metered approach.
- Smaller minimum red times have a lesser impact on the capacity and performance of the metered approach than higher minimum blank times and larger queue detector setback distances.

In addition, when comparing traffic flows on the metered approach to those on the controlling approach to the roundabout it was identified that there was no identifiable trend between capacity and performance results on the metered approach and the percentage of the circulating flow in front of the controlling approach originating from the metered approach.

### **GUIDING PRINCIPLES FOR APPLYING METERING SIGNALS AT ROUNDABOUTS**

From the results established from the model for analysing roundabouts with metering signals a set of guiding principles of when to signalise roundabouts was developed. These principles focused on capacity and traffic volume warrants for both the controlling and metered approaches. It should be noted that these guidelines are specific to single lane roundabouts that have heavier flows from two legs only.

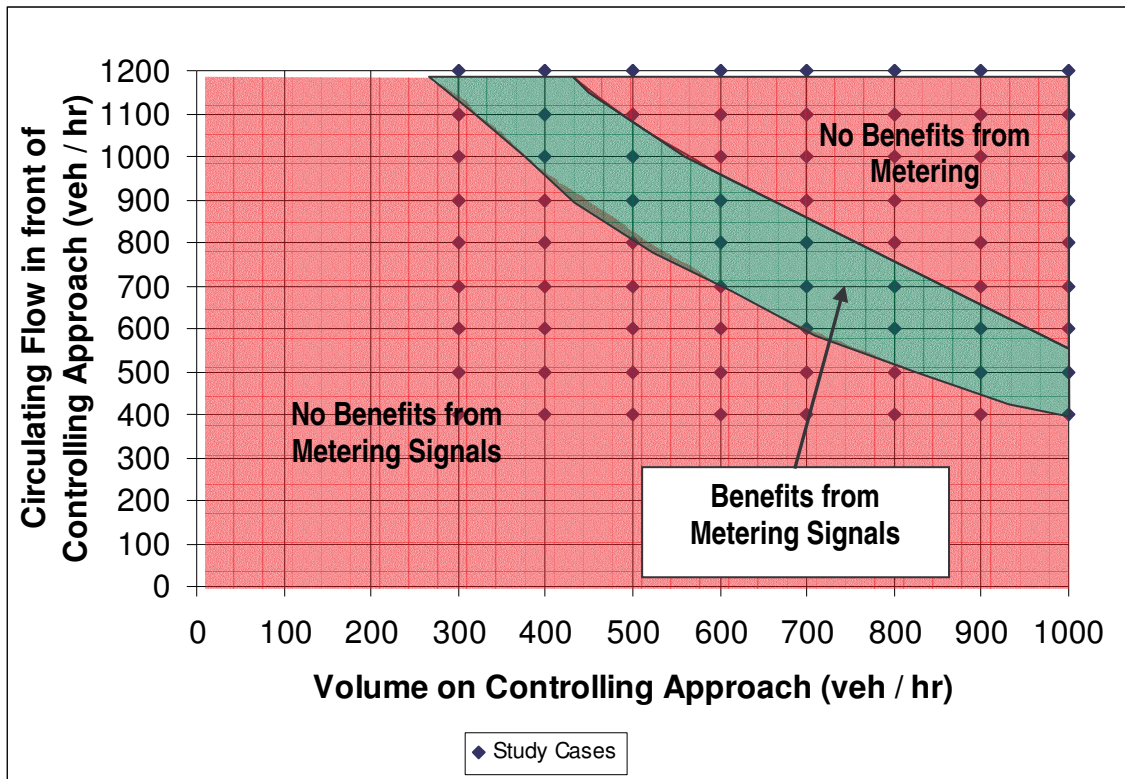
#### **Controlling Approach Guidelines**

The part-time metering signals model indicated that the default operational settings that produced the best overall capacity and performance conditions at a roundabout with metering signals were:

Queue Detector Setback Distance	-	60 metres
Minimum Blank Time	-	20 seconds
Minimum Red Time	-	20 seconds

Reviewing the results obtained from the adoption of the default values at a roundabout with metering signals, the flow conditions on the controlling approach that would benefit by installing metering signals at the roundabout can be more precisely defined as shown in Figure 4.

The green band in Figure 4 indicates the combination of volumes on the controlling approach and those circulating in front of the controlling approach that would benefit from the operation of metering signals based on the established performance criteria.



**Figure 4 – Flow Conditions on the Controlling Approach that would benefit by installing Metering Signals**

The results indicate that metering signals are required at a single lane roundabout when the combined volumes of traffic flow on the delayed (controlling) approach together with the circulating flow in front of the delayed (controlling) approach is between 1300 and 1400 vehicles per hour. The benefits of metering signals begin to decline once the combined volumes of traffic flow on the delayed (controlling) approach together with the circulating flow in front of the delayed (controlling) approach is between 1550 and 1650 vehicles per hour. This result indicates that there is only a small band of combined demand volumes (approximately 250 vehicles per hour) on the controlling approach and those circulating in front of the controlling approach that would benefit from the operation of metering signals.

### **Metered Approach Guidelines**

On the metered approach there needs to be sufficient spare capacity to cater for metering signal operation. It was determined that if the metered approach has a degree of saturation less than 0.6 it is likely to maintain good operating conditions (DoS < 0.85) when metering signals are introduced. Similarly, if the metered approach has a degree of saturation less than 0.7 it is likely to maintain tolerable operating conditions (DoS < 1) when metering signals are introduced.

## CONCLUSIONS

The main conclusions derived from the investigation were:

- With the suggested improvements to the part-time metering signals model developed by Akcelik and Associates Pty Ltd, the results produced were consistent with expectations of the changes in the capacity and performance criteria on the metered and controlling approaches with the introduction of metering signals. As a result, it was concluded that the part-time metering signals model developed by Akcelik and Associates Pty Ltd would be an appropriate tool to analysis the data set with the influence of metering signals using different operational designs. However, although the model produced results that were consistent with expectations, it should be noted that the model must still be validated using field data.
- Higher minimum blank and red times have a more positive impact on the capacity and performance of the controlling approach than a shorter queue detector setback distance. Therefore, higher cycle times benefit the controlling approach.
- The default values of queue detector setback distance of 60 metres, minimum blank time of 20 seconds and a minimum red time of 20 seconds overall produce the best capacity and performance criteria at a roundabout with metering signals.
- Metering signals are required at a single lane roundabout when the combined volumes of traffic flow on the delayed (controlling) approach together with the circulating flow in front of the delayed (controlling) approach is between 1300 and 1400 vehicles per hour.
- The benefits of metering signals at a single lane roundabout begin to decline once the combined volumes of traffic flow on the delayed (controlling) approach together with the circulating flow in front of the delayed (controlling) approach is between 1550 and 1650 vehicles per hour.
- If the metered approach has a degree of saturation less than 0.6 it is likely to maintain good operating conditions ( $DoS < 0.85$ ) when metering signals are introduced.
- If the metered approach has a degree of saturation less than 0.7 it is likely to maintain tolerable operating conditions ( $DoS < 1$ ) when metering signals are introduced.

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