Signals and Meters at Roundabouts

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ABSTRACT

With the emergence of the modern roundabout as an effective form of traffic control in the United States, more and more information is needed when situations arise in which additional traffic control is required. The signalization and metering of roundabouts can relieve congestion during peak hours of the day as well as possibly provide safer access for pedestrians and cyclists.

Although the signalization or metering of a roundabout may prove to be effective in solving access and congestion issues, it is not common in the United States and few have been installed. Of the roundabouts where signals or meters have been installed, these were done with little or no formal experience. With that in mind, a need exists for professionals to understand the basics of roundabout signalization and metering.

Several tasks were accomplished to generate a set of guidelines, and upon completing these tasks several options for the signalization and metering of roundabouts were found, including options for means of control, time of operation, and approach control. Unbalanced flow and pedestrians are also discussed, since these have been found to be the reasons for most signalization or metering. Several existing signalized and metered roundabouts are detailed from current literature and survey responses and were compiled in a table as part of the guidelines. Using all of the information from survey responses and literature seven guidelines were established, including the following:

- Observe and obtain data
- Review data
- Identify main concerns
- Choose means of control
- Choose time of operation
- Choose approaches to control

Key words: meters—roundabouts—signals
INTRODUCTION

With the emergence of the modern roundabout as an effective form of traffic control in the United States, more and more information is needed when situations arise in which additional traffic control is required. The signalization and metering of roundabouts can relieve congestion during peak hours of the day as well as possibly provide safer access for pedestrians and cyclists (Robinson 2000).

Signalizing and metering traffic at a roundabout can be considered reverse thinking. Roundabouts are installed to gain greater capacity and lower delays, and an added signal defeats this purpose. It should also be made clear that a signalized or metered roundabout is still far better than a regular signalized intersection. Even with some loss of capacity and greater delays, they still offer the benefits of improved safety over signalized intersections (Baranowski 2004).

There have been several reported cases of roundabout signalization in the United States. In Florida and Utah, pedestrian-actuated traffic signals have been installed, while in Maryland, a metering device is being considered to help ease congestion during certain periods of peak traffic flow (Sides 2000). Although the Florida and Utah locations have worked well, they were installed without a set of general roundabout signalization and metering guidelines. If a set of guidelines were developed, it would help professionals make decisions when considering signalization or metering at a roundabout while still providing the flexibility of good intersection design engineering.

PROBLEM STATEMENT

The signalization or metering of roundabouts may prove to be effective in solving access and congestion issues at roundabouts. Although several roundabouts in the United States have used traffic control signals, and metering is being seriously considered at one site, there is still a need for a set of guidelines to aide in the decision for implementation. Such signalization and metering appears to have fairly widespread use in Europe and Australia.

RESEARCH OBJECTIVES

To develop a set of guidelines applicable to the installation of traffic control signals and meters at roundabouts, several objectives were established. The primary research objectives were the following:

- Obtain general information and methods on the signalization and metering of roundabouts
- Determine locations and features of roundabouts that have traffic signals and meters in the United States, Europe, and Australia
- Determine the reasons for signalization and metering
- Determine locations where signalization and metering have been planned or could help operations
- Highlight the results of traffic signalization and metering and discuss their effectiveness
- Develop a set of guidelines for traffic control signals and meters at a roundabout
- Gain feedback on the developed set of guidelines from known roundabout experts in roundabout design and operations relative to the applicability of the guidelines
- Finalize a set of guidelines applicable to the signalization and metering of roundabouts

SCOPE

The finalized set of guidelines on signalization and metering of roundabout is only applicable to what is known as the modern roundabout and does not consider rotaries or traffic circles. Cases involving
roundabout interchange signal coordination and signalizing for pedestrians were also not considered. Guidelines were based on information from individual case studies, literature, and recommendations from known authorities on the subject.

**RESEARCH METHODOLOGY**

To meet the objectives established and obtain the information needed to complete the research, five steps needed to be completed. The five steps included reviewing the literature, developing a state of the practice survey, developing guidelines, obtaining comments from experts on the developed guidelines, and finalizing a set of guidelines.

**Literature Review**

A literature review of documents relating to the signalization and metering of roundabouts was completing using resources from the library and internet. Approximately seven documents were used in the review, with a vast majority of the documents coming from countries outside of the United States.

**State of the Practice Survey**

A web survey was created to gain information by asking known experts in the field of roundabout design and operation to provide the information listed below relative to traffic signalization at roundabouts.

- Location of existing signalized roundabouts
- Type of signal system in place
- Location of signal system
- Main cause for signalization
- Effect of volume on the decision to signalize
- Effect of the location on the decision to signalize
- Human factors
- The addition of signs and striping with the installation of the signal
- Literature used to make decisions regarding implementation
- Peak hour considerations
- Software used to analyze the roundabout

The web survey was sent to known experts in the field of roundabout design and operations, as well as the Kansas State roundabout listserv. The survey is still available and can be accessed at www.cstevensandcomp.com/roundaboutsurvey.html. Seven surveys were received, including two indicating no experience with signalization or metering, two surveys detailing the same location, and one of the surveys providing great information on two pedestrian signals that were not within the scope of the research. Three sites pertinent to the research were detailed with survey responses and will be described in detail in a later section of this document.

**Developing Guidelines**

After completing the literature review and reviewing all of the survey responses, the information was used to establish a set of guidelines. The guidelines are not technical in nature and should be easily understood by someone not familiar with roundabout signalization and metering. The guidelines are mainly based from reoccurring patterns in literature and survey responses.
Expert Review

Another web-based form was created to obtain comments on the developed guidelines for the signalization and metering of roundabouts. The website address was sent to the survey respondents as well as other experts in roundabout design and operation and can still be found at www.cstevensandcomp.com/rbguidelines.html. Readers can access this page and comment on the guidelines.

Finalize Set of Guidelines

After obtaining comments on the developed set of guidelines, suggestions were used to finalize a set of guidelines for the signalization and metering of roundabouts.

BACKGROUND

Although signalization of a roundabout superficially defeats its intended purpose, there are still several underlying benefits that the geometry of a roundabout provides. The deflection of vehicles due to the presence of the central island and splitter island not only reduces entry speeds, but also eliminates right angle collisions. The FHWA concludes that reduced speeds within the roundabout gives drivers more time to react to possible incidents, reduces crash severity and allows for safer merging, and especially makes the intersection safer for drivers who are unfamiliar with the area (Robinson 2000).

Another key safety element that remains after a roundabout has been signalized is fewer conflict points. A four-leg, single-lane roundabout has eight conflict points, compared to an intersection with four two-lane entering roadways, which has 32 possible conflict points. If a roundabout is metered, it is important to remember that during non-peak times the roundabout still offers all of the benefits discussed in the previous section (Robinson 2000).

Some may ask why put in a roundabout if it is likely to be signalized? The reason is that although a signalized roundabout may not provide the same improved capacity and delay values, it is still safer than a normal signalized intersection. A signal or meter can extend the life of the roundabout while still providing added safety and aesthetic value (Robinson 2000).

Signalization and Metering Options

Once a decision has been made to signalize or meter a roundabout, there are several options. Means of control, time of operation, and approach control are the three most important signalization characteristics. Due to the differences between signalization and metering, these options vary. The different options for signalization and metering are described in Figures 1 and 2 in the form of a flow chart.
Means of Control

The means of control at a signalized or metered roundabout describes how the signal system controls entering and exiting vehicles. There are two main means of control at a signalized or metered roundabout: direct control and indirect control. A direct means of control affects both external and internal approaches, influencing traffic entering the roundabout as well as vehicles leaving from within the roundabout. For a metered approach, a direct means of control usually only affects vehicles entering the roundabout. Indirect control affects external traffic at a distance from the entry point of the roundabout. The circulatory traffic within the roundabout is not affected. Indirect control of vehicles is sometimes established with the addition of pedestrian signals, where crosswalks are at a distance from the roundabout entry (Hallworth 1992).

Time of Operation

The time of operation at a signalized or metered roundabout focuses on the period of time a signal or meter operates. There are two times of operation common at signalized or metered roundabouts: full-time
and part-time. For full-time operation, the installed signals operate permanently and do not turn off during non-peak times. For part-time operation, the installed signal does not operate at all times. The signal is activated by time of day or by detectors. Detectors are usually placed at a distance from the controlled approach on a delay setting to determine when a queue has built up. For a metered approach, the time of operation varies according to queue length and dissipation; once a queue is no longer detected, metering signals will go blank and normal operation will resume (Hallworth 1992).

**Approach Control**

Approach control describes the number of approaches controlled with a signal or meter. There are two main types of approach control: full control and part control. Full approach control oversees all approaches of the roundabout. Part approach control at a signalized or metered roundabout is defined as control of one or more, but not all, legs of a roundabout while remaining approaches operate under right-of-way control. Roundabout metering signals usually control a single lane and are considered part control (Hallworth 1992).

**Reasons to Signalize or Meter a Roundabout**

A problematic roundabout usually falls into two main areas: unbalanced flow and high circulatory speeds. It should also be mentioned that there are several characteristics that each situation may create within a roundabout, such as loss of capacity, delays, elevated numbers of crashes, excessive queues, gap acceptance problems, and circulatory lockup.

**Unbalanced Flow**

Hudaart (1983) details unbalanced flow by stating, “The capacity of roundabouts is particularly limited if traffic flows are unbalanced. This is particularly the case if one entry has very heavy flow and the entry immediately before it on the roundabout has light flow so that the heavy flow proceeds virtually uninterrupted. This produces continuous circulating traffic which therefore prevents traffic entry on subsequent approaches.” Huddart also states that in such situations, “signals can be used to initiate gaps in the traffic flow and hence balance the capacity” (Huddart 1983).

**High Circulatory Speeds**

With the need to weave and merge within a roundabout, sometimes higher than desired speeds can occur within the circulating sections and make it difficult for entering traffic. Another example of high speeds, brought to the author’s attention by Tom Hicks of the Maryland State Highway Administration, is that of roundabouts with elliptical-shaped central islands (Hicks 2004). The discussion resulted in the conclusion that vehicles tend to increase speed on the longer side of the central island, causing incidents as the vehicle meet slower entering traffic on the short sides of the island. Signals can regulate traffic directly, if desired, by placing the signal within the circulating traffic, reducing speeds and allowing for safer and more efficient movement of traffic (Hallworth 1992).

**Benefits of Signal Control**

Although signalization and metering are against the nature of a true roundabout’s purpose, they may provide solutions in such situations, as discussed earlier with unbalanced flows and high circulatory speeds. There are four main benefits to signalizing or metering a roundabouts, including shorter delays, reduced queue lengths, increase in capacity, and safety.
**Shorter Delays**

Delays at non-signalized roundabouts increase due to unbalanced flows or interactions with other intersections. Signals and meters can be used to balance delays and can reduce delays among a coordinated network (Hallworth 1992).

**Reduced Queue Lengths**

With unbalanced flow, queues can become excessive, sometimes backing up into other intersections or roadways. This situation is most likely to take place on frontage road off-ramps. A signal or meter can reduce queues by allowing queued traffic the right-of-way once a critical queue is detected (Hallworth 1992).

**Increase in Capacity**

If an excessive amount of traffic due to growth or new developments is entering a roundabout, traffic may not be able to circulate freely and can sometimes lock up. In situations where traffic is excessive, traffic signals may improve operations. It should also be noted that additional improvements to the roundabout design may be need to supplement the addition of signals (Hallworth 1992).

**Safety**

With the need for weaving and merging within a roundabout, internal circulatory speed can increase and hinder the ability of entering traffic to accept a gap. Traffic signals and meters better regulate the entry and sometimes exit of the roundabout, slowing the speeds of weaving and merging traffic, giving more time for drivers to react, and increasing safety at a roundabout (Hallworth 1992).

**Roundabout Signalization and Metering in Literature**

Several examples of signalization and metering are in the literature, and four are summarized in Table 1.

**Table 1. Signalized and metered roundabouts from literature**

<table>
<thead>
<tr>
<th>Roundabout</th>
<th>Means of control</th>
<th>Time of operation</th>
<th>Approach control</th>
<th>Problem areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Park Square, South Yorkshire, UK (Barnes)</td>
<td>Direct</td>
<td>Full</td>
<td>All</td>
<td>Excessive delays and accidents; high circulatory speeds</td>
</tr>
<tr>
<td>Newbridge, Scotland (Anderson)</td>
<td>Direct</td>
<td>Full</td>
<td>All</td>
<td>Traffic congestion, poor safety, high circulatory speeds, large queue lengths, and delay</td>
</tr>
<tr>
<td>Sheaf Square, South Yorkshire, UK (Barnes)</td>
<td>Indirect</td>
<td>Part</td>
<td>All</td>
<td>Delays due to excessive pedestrian traffic</td>
</tr>
<tr>
<td>Moore Street (Barnes)</td>
<td>Indirect</td>
<td>Metered</td>
<td>All</td>
<td>Unbalanced flow, excessive turning traffic, and delay</td>
</tr>
</tbody>
</table>
Guideline Development

The literature provided a detailed look into the process of signalization and specific triggers for added traffic control. Several themes resounded throughout the literature, including data collection and observations and the three categories of signalization options: means of control, time of operation, and approach control.

KEY FINDINGS

A web survey was created to gain information by polling known experts in the field of roundabout design and operations. Four survey responses detailing three roundabout locations are listed in Table 2.

Table 2. Signalization and metering from survey responses

<table>
<thead>
<tr>
<th>Roundabout</th>
<th>Means of control</th>
<th>Time of operation</th>
<th>Approach control</th>
<th>Problem areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charles Street, MD, USA</td>
<td>Indirect</td>
<td>Full</td>
<td>All</td>
<td>Unbalanced flow</td>
</tr>
<tr>
<td>Clearwater, FL, USA</td>
<td>Indirect</td>
<td>Full</td>
<td>One</td>
<td>Unbalanced flow during spring break</td>
</tr>
<tr>
<td>Penn Inn, Abbot, UK</td>
<td>NA</td>
<td>Full</td>
<td>All</td>
<td>Unbalanced flow and excessive turning movements</td>
</tr>
</tbody>
</table>

Survey Responses

Charles Street at Bellona Avenue, Lutherville, Maryland, USA

A traffic signal was installed at the Charles Street roundabout because “the traffic flow is very unbalanced, with two legs of the roundabout representing over 90% of the flow” (Survey). The two heavy legs are northbound Charles Street and westbound Bellona Avenue. Charles Street did not have to yield the right-of-way very often due to the absence of conflicting flow, resulting in very few gaps in traffic for the westbound movement. A signal existed approximately 600 feet south of this intersection. The timing was changed to add a dummy phase to create artificial gaps for the northbound movement. Roundabout location, human factors, and pedestrians were not issues at this site. No new signing or striping was added, and no literature aided implementation. “We actually just went in the field with the signal technician and played with the timing until we reached the balance we were looking for” (Survey). No special software was used to evaluate signal timing, but aaSIDRA was used to evaluate the roundabout.

Causeway at Coronado at Mandalay, Clearwater Beach, Florida, USA

Information on this location was received from two respondents. The first author provided the following: A metering signal was installed on the main approach of this roundabout to create downstream gaps. The signals were located 150–250 ft upstream of entry and are actuated by a queue detector on the downstream approach. The respondent states: “This is an ambitious topic for which it might be difficult to obtain useful results at this stage. The number of roundabouts that are currently metered directly or with signalized pedestrian crossings is very small. Use of simulation as the sole basis for guidelines, if that is what is being considered, requires accurate modeling of the roundabout itself. Whatever the outcome, these guidelines need to fit in with ongoing operational and accessibility research” (Survey).
The second author also provided detailed information about the signal system: “On occasions there is a massive flow onto the island of Clearwater Beach. As a result of a deficiency of parking paces, congestion starts south of the roundabout continues northward through the roundabout and sometimes almost to the mainland. The roundabout was a vast improvement over the signals. This backup limited access to the roundabout from other legs. Installing metering signals on the causeway approach with queue loops on other approaches enabled the automatic stoppage for traffic from the mainland for 90 seconds wherever the queue conditions were met. It has been a great success. It only works late at night and Saturday lunchtime, Saturday late afternoon” (Survey).

*Penn Inn, Newton Abbot, Devon, UK*

Traffic signals were installed to balance complex turning movements on this overloaded roundabout. The site has recently been improved and updated, but traffic lanes are still not perfect. “Many drivers tend to drift laterally across the lanes” (Survey). The signals are located on all approaches adjacent to the circulatory roadway. The author was not sure of software or literature used to implement signalization.

*No Experience with Signalization*

Of the seven survey responses received, two of them stated that they had no experience with signalization. Three emails outside of the survey were also received expressing their lack of experience with signalized or metered roundabouts.

*Guideline Development*

The information obtained from survey responses present areas of concern at roundabouts, and although detailed information was not received regarding official data collection, observational comments were a standard in all three responses. Information was also given regarding the means of control, time of operation, approach control, and software packages used for analysis.

*An Additional Location Where Signalization and Metering May Improve Operations*

The roundabout at the intersection of Maryland state highway 100 and Snowden River serves both northbound and southbound lefts (see Figure 4). A traffic signal is located just south of the roundabout. When the green releases, vehicles travel towards the roundabout arriving in large platoons and take over the roundabout. Since there are no vehicles coming from the left that would cause entering traffic to yield, the vehicles proceed uninterrupted through the roundabout. This obviously prevents vehicles coming from the ramp of MD 100 from entering the roundabout and has caused a large queue to form that approaches the freeway during the evening peak hour (Niederhauser 2004).
GUIDELINES FOR THE SIGNALIZATION AND METERING OF A ROUNDABOUT

Before presenting the established guidelines for the signalization and metering of roundabouts, it should be mentioned that lack of detailed information and difficulty in obtaining specific information about signalized and metered roundabouts may limit the utility of the guidelines. Due to this, the guidelines are not technical in nature and can only realistically aim to inform engineers of their options and the corresponding process of implementing a signal or meter. Completing this research only leads one to ask, “What’s next?” and “How can these guidelines be improved to be of more use?” More detailed and accurate information is required and could be the next step in terms of research for this topic.

Observe and Obtain Data

Observation of a problematic roundabout will most likely provide much information into what is causing the problem. The following data should be obtained for further analysis:

- Entry and exit volumes
- Circulatory volumes
- Circulatory speeds
- Accident data
- Queue lengths
- Delays
- Headways
- Gap acceptance data

Review the Data

Upon obtaining data and observing the operation of the roundabout in question, it may be appropriate to compare data from previous signalization experiences when facing the decision to implement a signal or
meter. Although not every situation is alike, the following values obtained from the literature can help characterize a problematic roundabout (see Table 3).

Table 3. Values from literature and survey responses for review

<table>
<thead>
<tr>
<th>Roundabout or guidelines</th>
<th>Signal system</th>
<th>Geometry</th>
<th>Volume design/actual (vph)</th>
<th>ADT design/actual</th>
<th>Location of signal</th>
<th>Queue lengths</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clearwater, FL</td>
<td>Traffic Meter</td>
<td>Oval 150/180 m</td>
<td>3,655/ NA</td>
<td>39,500/58,000 during spring break</td>
<td>150 to 250 from entry</td>
<td></td>
<td>12 injuries per year, 3:1 ratio of approaches during peak hour</td>
</tr>
<tr>
<td>Park Square, UK</td>
<td>Signal 200 m across</td>
<td>NA/6500</td>
<td></td>
<td>At entry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Granville Square, UK</td>
<td>Signal Oval 70/30 m</td>
<td>NA/3500-4000</td>
<td></td>
<td>At entry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moore Street, UK</td>
<td>Part-Time Signal</td>
<td>NA/3,300-1800 u-turn</td>
<td></td>
<td>25 m from entry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Newbridge, Scotland</td>
<td>Signal 60 m diameter</td>
<td>NA/60,000</td>
<td></td>
<td>At entry</td>
<td>1.5 km (max)</td>
<td>30 mph</td>
<td></td>
</tr>
</tbody>
</table>

Identify Main Concerns

Upon observing the roundabout, a list of concerns should be established. The following questions can help identify those concerns:

- Is the roundabout suffering from unbalanced flow?
- If the roundabout has unbalanced flow, which approach has the heaviest volume?
- Do all approaches need to be signalized?
- Are there excessive speeds within the circulatory roadway?
- Are there more than a normal or expected number of crashes at this roundabout?
- Are there any geometric restrictions that will influence the placement of the signals?
- Does the roundabout affect, or is it affected by, other nearby signalized intersections or roadways?
- Is there a need to accommodate pedestrian traffic?

Choose Means of Control

Once the main concerns for signalization have been identified, it is time to choose the means of control for the intersection. Direct control is what the name implies; it directly controls traffic at the entry points of a roundabout. Direct control is one of the most common forms of control, and signals are usually placed at roundabout entries to alter the natural progression of a heavy volume that tends to prevent weaker approaches from entering the roundabout. Indirect control is when the signal is placed a distance...
from the entry of the roundabout. Indirect control often utilizes a metering signal, similar to a ramp meter, providing gaps in the traffic stream. In another form of metering control is the presence of an indirect pedestrian signal at a crosswalk. With indirect control, the literature has shown strengthening or widening the yield line is a common practice; this is because vehicles must still yield the right-of-way after moving through the indirect signal.

Choose Signal Operation

Signal operation can come in many forms, including full-time control, part-time control, and metering. Full-time control means that the signal will operate permanently and never switch off. There have been several noted cases of full-time control. In one case, the signal system had set cycle lengths for morning and evening peaks, as well as a cycle length for all other times. Another example of full-time operation is a traffic response control system that operates at different cycle lengths depending on actuated queue measurements. With part-time control, the signal usually only operates during peak periods. Part-time operation is usually the combination of a set period of operation or operation for a period of time due to the detection of excessive queue lengths. Metering of vehicles can also be an effective form of traffic control at problematic roundabouts. A metering signal is usually placed on the approach carrying high volumes that may prevent other vehicles from entering the roundabout. A traffic metering system can help alleviate this problem by detecting excessive queues and activating the signal, stopping traffic on the high-volume approach long enough for some vehicles to escape the impeded approach. Once the queue has dissipated on the impeded approach and is no longer detected, the signal will go blank and the roundabout will revert back to normal operation. This is similar to a ramp metering operation.

Choose Approaches to Signalize

Not all approaches need to be signalized. In many cases, metering one heavily traveled approach can be very effective. When establishing a queue balancing system, it is sometimes necessary to signalize all approaches. A queue balancing system monitors all approaches of the roundabout and uses the input to operate the signal or metering system.

CONCLUSION

After completing this research, one conclusion that can be made is the definite need for more investigation. One problem that seems to be facing engineers, planners, and government officials is the absence of a formal set of values to justify signalization or metering. A table similar to the one presented in the finalized guidelines would be an ideal place to begin. Obtaining more detailed information from the before-state of the signalized or metered roundabout can give engineers more values on which a decision to signalize or meter a roundabout can be based.
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