



RESEARCH

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Toolbox to Evaluate the Impacts of Roundabouts on a
Corridor or Roadway Network

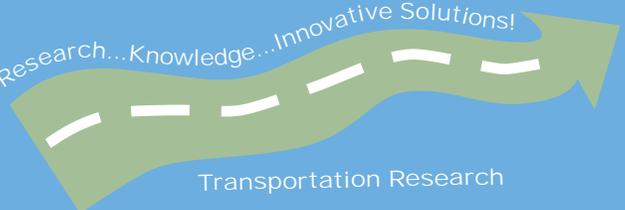


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Toolbox to Evaluate the Impacts of Roundabouts on a Corridor or Roadway Network

Final Report

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Executive Summary

Roundabouts are frequently considered individually to address operational and/or safety needs at an isolated intersection or along a section of a roadway. More often than not, at the project level, little consideration is given to how a roundabout may impact an overall roadway corridor or network. As a result, a roundabout at one intersection may solve safety and operational problems or address other needs, but it may also adversely affect the corridor performance if adjacent intersection traffic control is not also evaluated. Signal timings, phasing and coordination with other signals may be compromised, as platoons dissipate at a roundabout.

The toolbox provides information to assist transportation agencies in considering and integrating roundabouts within corridors or roadway networks. The information was developed by summarizing available information and conducting several evaluations. Common concerns and strategies are presented. Case studies are used to illustrate how other agencies have successfully addressed challenges. The toolbox discusses how roundabouts can be incorporated in comprehensive planning in Section 1 so that they can be considered early in the planning process. The impacts of incorporating a single or series of roundabouts within a corridor on mobility are covered in Section 2. The research team evaluated the impacts of incorporating a roundabout within two signalized corridor using traffic simulation. The impacts on travel time and delay were evaluated. This section also discusses use of roundabouts in various different land use settings. In Section 3, the impact of roundabouts on system-wide mobility is discussed. The experience of several agencies in Wisconsin, Oregon, and Colorado are highlighted. Use of roundabouts in a corridor as part of access management is discussed in Section 4. The impact of roundabouts on other planning considerations is presented in Section 5. This includes a summary of available information about the air quality impacts of roundabouts. Pedestrian and bicylists needs are also discussed in this section. The last section is section 6 which discusses how roundabouts perform in situations where unbalanced flows exist. Since little information is available the team conducted a case study using RODEL and aaSIDRA. Various balanced and unbalanced volumes were evaluated and compared to determine the impact of unbalanced flows on travel time and delay.

Chapter 1

Introduction

Intersections introduce conflict and each time a new intersection is planned and constructed, a new vulnerability, if you will, has been incorporated into the roadway network. Conflict not only introduces potential for crashes, it also initiates delay when turning vehicles impede through traffic. Traffic signals and stop signs are common treatments used to assign right-of-way at intersections and are proven to be compatible with each other within a roadway network. Alternatively, modern roundabouts provide a self-regulating intersection strategy whereby drivers chose their own gaps in the traffic stream; however, questions remain about the compatibility of signalized intersections and roundabouts along the same corridor.

Roundabouts are typically considered individually to address operational and/or safety needs at an isolated intersection or along a section of a roadway. More often than not, at the project level, little consideration is given to how a roundabout may impact an overall roadway corridor or network. As a result, a roundabout at one intersection may solve safety and operational problems or address other needs, but it may also adversely affect the corridor performance if adjacent intersection traffic control is not also evaluated. Signal timings, phasing and coordination with other signals may be compromised, as platoons dissipate at a roundabout.

Newly planned intersections, corridors and roadway networks within future developments or in redevelopment areas are also being evaluated for optimal mobility and safety. On new corridors, roundabouts are being considered more frequently based on the potential benefits including increased safety, increased capacity, improved mobility, reduced roadway widening and intersection footprint, reduced fuel consumption and improved air quality, aesthetics, access management, and traffic calming.

As a result, this “Toolbox to Evaluate the System Impacts of Roundabouts on a Corridor or Roadway Network” was developed to assist transportation agencies with assessing the impacts of roundabouts on a corridor or system in terms of transportation planning, corridor and network mobility, land use, flow conditions, access management, and other planning considerations (i.e. pedestrians, emissions). The Toolbox will allow agencies to consider the “big picture” rather than assessing the safety and/or operational impacts of isolated roundabouts.

Many portions of the toolbox can be applied to isolated roundabouts as well.

The toolbox covers the following general topics:

- Roundabouts in comprehensive planning
- Impact of roundabouts on corridor mobility
- Impact of roundabouts on system-wide mobility
- Roundabout performance with unbalanced traffic flows

- Roundabouts in access management
- Impact of roundabouts on other planning considerations

Chapter 2

Roundabouts in Comprehensive Planning



Figure 2.1 Roundabouts

Table 2.1 Roundabouts in comprehensive planning

Challenges	Strategies
<p>Determining how roundabouts can be addressed in short- and long-range transportation plans</p>	<p>Require consideration of roundabouts as an alternative for all new and major reconstruction of intersections</p> <p>Require roundabouts be considered as an alternative for all new junctions created in new growth areas</p> <p>Preserve an adequate amount of right-of-way at the junctions so that roundabouts can be considered as an option in the future</p> <p>Develop corridor management plans that recognize roundabouts as an effective solution to address safety and mobility challenges</p> <p>Adopt a narrow roads and wide nodes initiative</p> <p>Incorporate roundabouts at major intersections</p> <p>Educate stakeholders</p>
<p>Maintaining consistency in planning and design among neighboring jurisdictions</p>	<p>Collaborate with adjacent jurisdictions on corridor planning efforts to provide consistency</p>

2.1 Incorporating Roundabouts into Short and Long Range Transportation Plans

As roundabouts gradually make their way out of infancy in the US, they are still typically considered and implemented at isolated intersections to address safety, mobility, or aesthetic reasons, or a combination thereof. However, including roundabouts as an intersection strategy in Comprehensive Plans and during the comprehensive planning process encourages agencies to assess the impacts of implementing a roundabout within a system and to evaluate the relationship with signalized and stop controlled intersections. Consideration of roundabouts in the comprehensive planning process may also allow agencies to strategically site roundabouts within existing and new corridors to provide the most efficient and safe roadway network.

Most Comprehensive Plans are updated every 20 years and provide insight on how the community would like to grow over the next few decades considering land use, infrastructure, population, economic growth, community goals, and transportation system needs. This macro level document does not provide details as intricate as what intersection control will be at each intersection, but it does provide the goals of the agency as they relate to how the transportation network can handle the projected growth and what tools and strategies are recommended to address these future needs. Acknowledging roundabouts as a strategy to address safety and mobility sets the stage for future transportation improvements. The comprehensive planning process uses the framework established in the Comprehensive Plan and provides details on how the identified goals for land use planning, systems planning and mobility will be implemented at a project and corridor level.

2.1.1 Existing roadway network

Evaluating roundabout implementation on existing roadway networks will likely be conducted very differently than on a proposed network in a new development. The existing network, corridors and intersections already have physical constraints and established traffic patterns that must be worked around. Whereas, a new development provides a “blank slate” when laying out a roadway network in terms of the number of lanes, access control, and intersection control.

Whether on the existing roadways or in a new development, developers seem to be in the driver’s seat, not the government agencies, when making decisions about locations and treatments for many intersections. Ultimately, the government agency approves these plans, but there seems to be an overwhelming trend to continue using stop control and eventually signalized intersection treatments once a signal is warranted. Integrating roundabouts as a consideration in the planning stage can help agencies reverse this trend and provide agencies with the ability to proactively address safety and mobility.

As with any decision process, several alternatives should be considered and the preferred alternative should be a balance of safety, mobility, and environmental consciousness since by no means is a roundabout the solution for every intersection. Figures 2.2 and 2.3 provide roundabout considerations that can be used during the transportation planning process.

Figure 2.2 emphasizes the goals and questions that can be incorporated into long- or short-range plans. These goals and questions should be reviewed when planning to improve an existing

roadway network. During the transportation planning process the following long range transportation goals are viewed as standard areas that are addressed.

- Improve safety performance
- Minimize ROW and reduce environmental footprint
- Improve capacity and mobility
- Improve access management
- Improve aesthetics

Although roundabouts are not the universal remedy to all intersection problems, they do provide a diverse approach to addressing multiple issues and provide a balance to the transportation network.

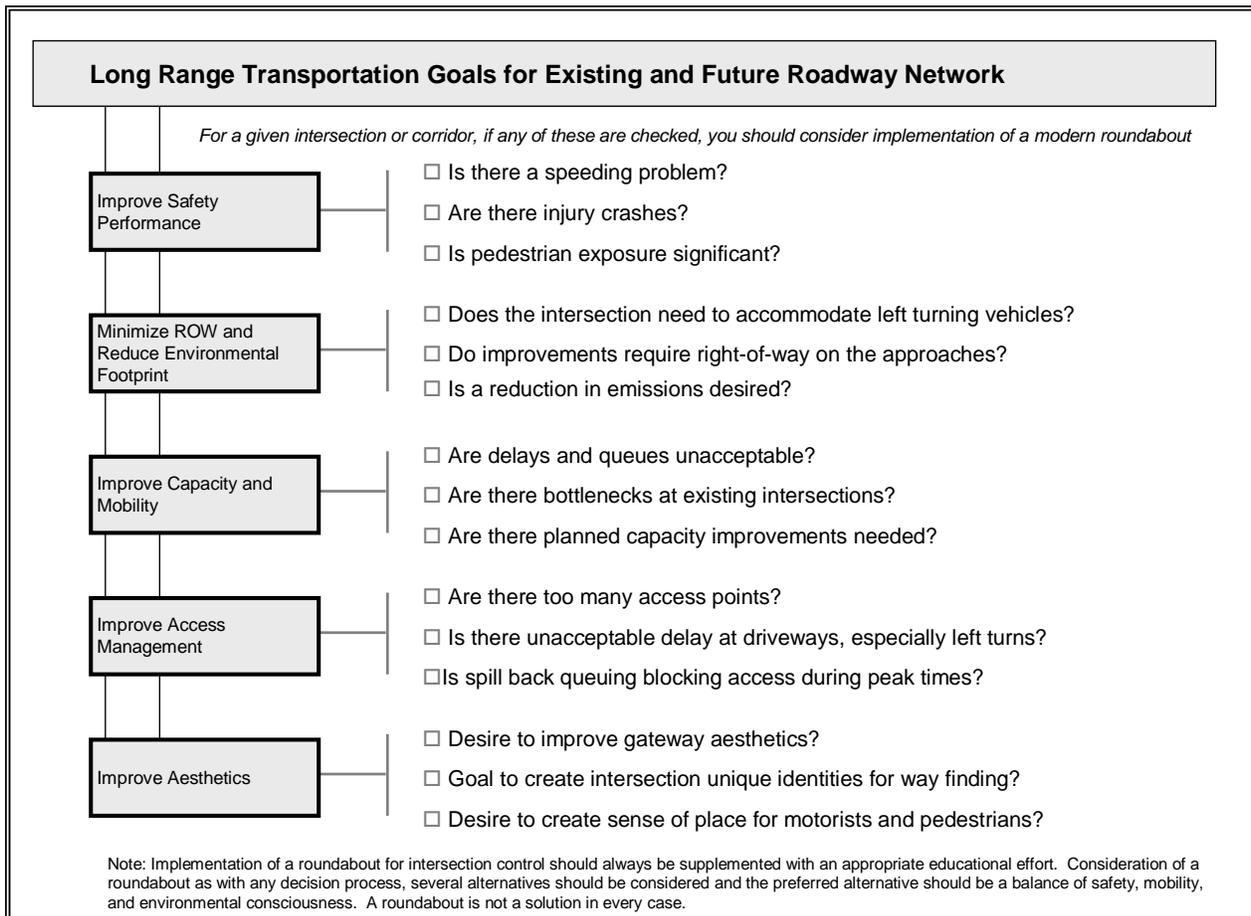


Figure 2.2 Integrating roundabouts in existing roadway networks

2.1.2 Growth—New Development

Figure 2.3 summarizes how roundabouts can compliment new growth areas. New growth areas provide transportation officials with the opportunity to apply proactive solutions to safety and mobility. The areas of consideration for new growth areas are as follows:

- Designing for safety
- Sizing up capacity and right-of-way needs
- Controlling access and serving adjacent land uses
- Ability to accommodate all pedestrians
- Overall aesthetics and user experience

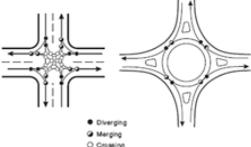
Planning for Roundabouts in New Growth Areas			
CONSIDERATION	TIME FRAME		EXAMPLE
Designing for Safety	<input checked="" type="checkbox"/> Short Term	<input checked="" type="checkbox"/> Full Build Out	 <p>● Diverging ● Merging ○ Crossing</p> <p>Image Source: FHWA, 2000</p>
	<p>Roundabouts reduce conflict points, eliminate head-on and right-angle crash types, and are effective in reducing speeds. Especially in areas of unknown growth potential, roundabouts provide a proactive approach in minimizing safety issues arising from congestion and access.</p>		
Sizing up Capacity and Right-of-Way Needs	<input checked="" type="checkbox"/> Short Term	<input checked="" type="checkbox"/> Full Build Out	 <p>Image Source: Hawkins</p>
	<p>Purchase right-of-way for a multi-lane roundabout (full build scenario). Roundabouts have a proven track record in reducing right-of-way needs as fewer through lanes and turn lane storage are needed due to efficient free flow condition at critical junctions. Design for both single lane and multi-lane roundabout - including striping. Construct the single-lane roundabout and retro-fit for multi-lane in the future (i.e. modifications to center island size, location of splitter island, striping). Single lane roundabouts</p> <p>Modify single-lane roundabout to multi-lane roundabout (i.e. reduce size of center island, pull back splitter islands, adjust striping). Storage for left turn lanes are not needed as roundabout handles left turns with proper lane assignments in advance of the intersection. High right turn movements may require the addition of a free-flow right turn lane, but this should have been considered in original design. Roundabouts with 1-2 and 2-3 circulating lanes (hybrid) are common in areas with dominant turning movements.</p>		
Ability to Accommodate Peak Hour Demands	<input checked="" type="checkbox"/> Short Term	<input checked="" type="checkbox"/> Full Build Out	 <p>Image Source: Isebrands</p>
	<p>Roundabouts handle high percentages of left turns efficiently and are "self regulating". The "self regulating" term refers to drivers being in control of taking gaps they are comfortable with to enter the circulating lane(s) rather than a signal assigning right of way to particular movements with the green, yellow, red indicators of a traffic signal. Not only can roundabouts handle the anticipated peak hours during the day (i.e. morning and afternoon commutes) they can also handle unplanned or special event peaking with the similar efficiency.</p>		
Controlling Access and Serving Adjacent Land Uses	<input checked="" type="checkbox"/> Short Term	<input checked="" type="checkbox"/> Full Build Out	 <p>Image Source: City of Golden, CO</p>
	<p>Raised medians and right-in-right-out movements force left turning movements to the intersection. Roundabouts provide a U-turn for the vehicles requiring a left turn. Roundabouts provide flexibility in intersection design, as no left turn lanes or storage is necessary.</p>		
Ability to Accommodate all Pedestrians	<input checked="" type="checkbox"/> Short Term	<input checked="" type="checkbox"/> Full Build Out	 <p>Image Source: Isebrands</p>
	<p>Roundabouts have lower speeds, provide reduced pedestrian exposure with shorter crossing lengths to the splitter islands (refuge), and pedestrians only cross one direction of traffic at a time.</p>		
Overall Aesthetics and User Experience	<input checked="" type="checkbox"/> Short Term	<input checked="" type="checkbox"/> Full Build Out	 <p>Image Source: Isebrands</p>
	<p>The central islands and splitter islands provide green space for landscaping and art work. It also can provide a gateway to a community or highlight an area of interest, a unique district or development.</p>		

Figure 2.3 Integrating roundabouts in new growth area

2.1.3 Preserve Right-of-Way

Even if a roundabout is not the most feasible option at the time, preserving right-of-way up front can provide more options down the road when conditions change. While existing roadway networks continue to be retrofitted and reconstructed to accommodate increased demand, new growth areas provide an opportunity to layout and space intersections that compliment each other. Open spaces are quickly being swallowed up by development. Development typically occurs in phases and agencies plan and design 20 years into the future; however, traffic volumes can potentially reach the 20 year forecast in 10 years, as we are seeing in some high growth areas. Therefore, the importance of acquiring sufficient right-of-way for roadway corridors and choosing the best intersection design becomes essential, especially in areas with unknown growth potential, where roundabouts provide a proactive approach in minimizing safety issues arising from congestion and access.

The Bend, Oregon Transportation Systems Plan (2000) provides strategies, approaches and standards designed to meet community transportation system needs over the next 20 years. The document not only outlines general solutions, it also identifies critical corridors and more detailed improvements, including intersection strategies. Section 6.5.2.1 states the following:

“At all major intersections, where streets classified as a major collector or arterial meet, additional right-of-way needs to be preserved to accommodate turn lanes or alternative design treatments such as roundabout construction. This additional right-of-way, plus transition from the normal street section, should be delineated in the street standards.”

http://www.ci.bend.or.us/depts/community_development/planning_division/docs/TSP_Chapter_6.pdf

The Larimer County, Colorado Urban Area Street Design Standards (2008) states (Figure 2.4):

“In Loveland (GMA and city limits), on all Arterials and Major Collectors, additional right-of-way may be required at intersections in conformance with Figure 8-16L to accommodate the potential installation of a roundabout in the future.”

http://www.co.larimer.co.us/engineering/GMARdStds/Ch08_04_01_2007.pdf

Figure 2.3 from the standards note that:

“the local entity may require the developer to provide right-of-way for future roundabout locations on Major Collector, or 2, 4, or 6 lane arterials.”

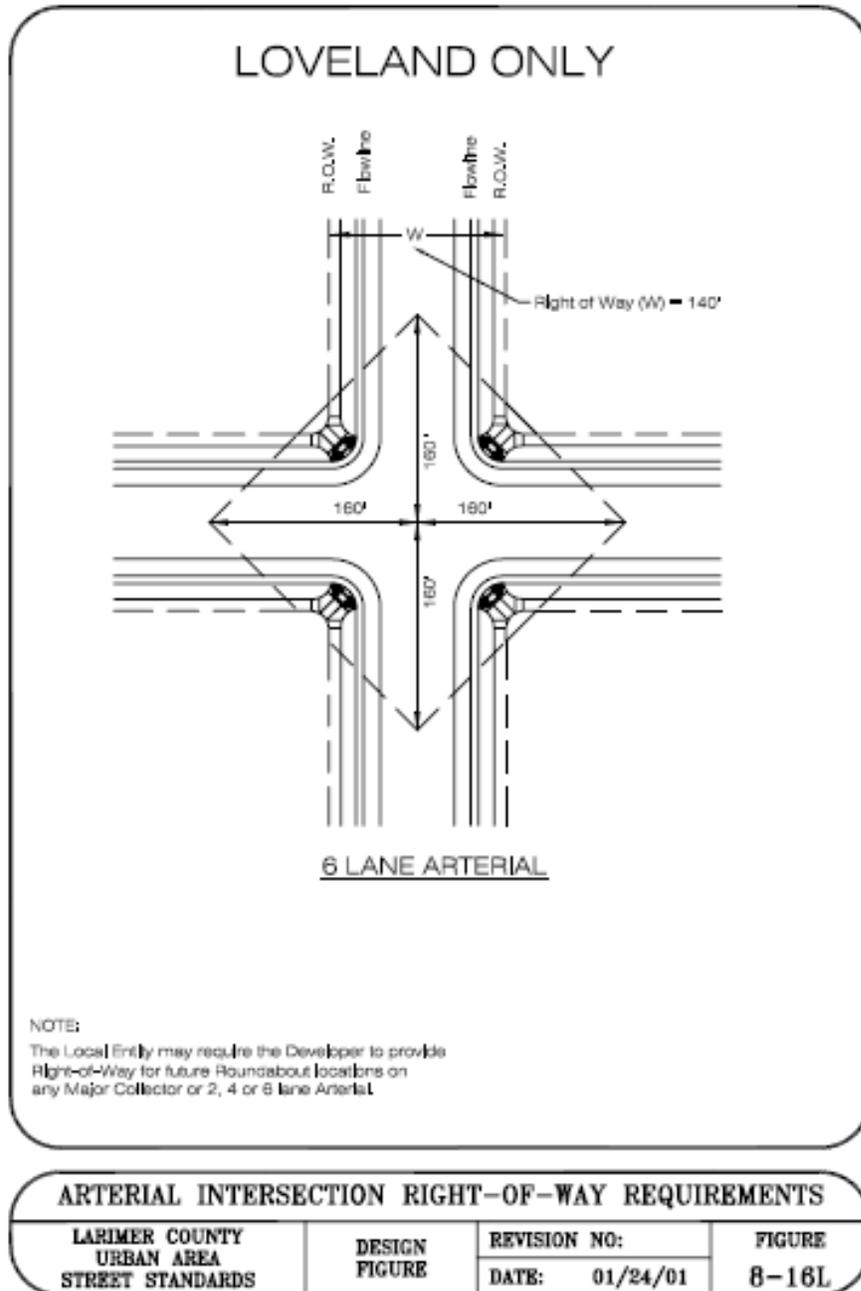


Figure 2.4 Right of way requirements (Larimer County, 2008)

2.1.4 Develop Corridor Management Plans

The Florida Department of Transportation (FDOT) published a document identifying effective strategies for corridor management (2004). Roundabouts are considered a successful strategy in the document for corridor management because of increased safety, increased vehicular capacity, reduced fuel consumption and air quality, lower cost, aesthetics, easy U-turns, and traffic calming.

The Brown County, Wisconsin Planning Commission (BCPC) (Runge, 2005) produced a report that addresses use of roundabouts in a corridor. They suggest consideration of roundabouts at a major intersection as one of the three suggested treatments along arterial street corridors. The report states that the biggest benefits appear to come from using roundabouts at major intersections along a corridor. This report also states that roundabouts, two and three lane streets, and minimal driveway access to the street often cost less because less roadway width and right-of-way are needed. One of the specific benefits indicated by the BCPC is that no electricity or hardware is needed as for traffic signals. Additionally they report that snow removal is more efficient at a roundabout.

A Transportation Network Plan for Middleton, WI (Traffic Associates, 2006) addresses street and intersection modifications due to traffic projections provided by the Madison Metropolitan Planning Organization. Prioritized intersections and corridors within the network are highlighted and solutions to address the traffic increases based on future land use are recommended. Roundabouts are considered for many of the intersection improvements.

Olympia, Washington is exploring a corridor roundabout strategy and integrating them into corridor planning and design. The Thurston Regional Planning Council (TRPC) prepared a report for the Boulevard Road Corridor Study (2006) in Olympia to investigate the potential of roundabouts along Boulevard Road, a major collector within the city's urban growth area, and similar corridors. Minimizing the number of lanes required and maximizing safety and capacity at the intersections is a benefit of roundabouts. This is often referred to as the "wide node, narrow road" concept. Subsequently, an amendment to the existing comprehensive plan was made recommending roundabouts be the preferred alternative at several intersections.

2.1.5 Educate Stakeholders

Educating all stakeholders is paramount to the success of any "new" transportation strategy. Public involvement and education should be on-going and not only for specific projects. Stakeholders include just about everyone – from the engineers and planners to the elected officials to the general public and the traveling public. Roundabout education can be accomplished through many mediums:

- Public service announcements on the public access channel
- Web pages
- Open houses
- Newsletters
- Radio
- Brochures and more

2.1.5.1 Washington County Minnesota Experience in Communicating with the Public

Washington County has recently constructed several roundabouts including one at Radio Drive (CSAH 13) & Bailey Road (CSAH 18) and West Broadway Avenue and Lake Street.

The construction of the roundabout at the Radio Drive and Bailey Road intersection was part of a larger project to expand Radio Drive. Radio Drive was reconstructed as a four lane divided roadway north of Bailey Road and remains a two lane undivided roadway to the south. Bailey Road is a two-lane roadway. Radio Drive and Bailey Road have an AADT of 9,000 and 7,000, respectively. The Radio Drive and the Bailey Road intersection has 1,200 entering vehicles during peak hour. A two-lane roundabout was constructed at the intersection to accommodate future traffic volumes. Construction was completed in 2007. A pedestrian underpass was constructed at the intersection. This is consistent with the county's preference to separate pedestrians from motorists whenever possible.

A roundabout at West Broadway Avenue and Lake Street in Washington County is the second multi-lane roundabout in Washington County and Minnesota. The project was in response to growing traffic, safety, a large number of uncontrolled access points, and a capacity deficient bridge. The roundabout was constructed in 2007 (Washington County, 2006).

The County discussed lessons learned in communicating with the public. They indicated that initially public reaction was negative when drivers were unfamiliar with roundabouts but was usually favorable with drivers who had used roundabouts. Common concerns included (Slagle, 2006):

- drivers were not familiar with roundabouts
- drivers had encountered roundabouts in other areas and felt that they did not work
- crashes would increase
- Minnesotans will never accept roundabouts

The most concerned groups for the Broadway Avenue project were elected officials, business owners who were concerned about access, public safety officials, and pedestrians (Slagle, 2006).

Washington County addressed the need for a public education plan and created "Roundabout-U," a program that helps answer questions about roundabouts for the public. The county is also active in educating the public about roundabouts by having information booths at the local supermarkets, distributing newsletters and appearing on the cable access channel and local new (Washington County, 2008).

Strategies used and lessons learned for public education campaign includes (Slagle, 2006):

- They stressed starting early and acknowledging that much of the public is unfamiliar with roundabouts
- Stress key messages

- Education needs to reach a large audience including local, county, and regional
- Look at efforts used in other areas of the country
- Develop a strategic communication plan
- Target specific audiences
 - Residents
 - Business
 - School districts
 - Public safety
 - Trucking companies
 - Commuters
 - Senior housing
- Evaluate the communications plan

The communication plan was carried using mailings, open houses, public displays, and computer simulations at the local level. They also partnered with the community and obtained business buy-in. At the county level they also used the county fair and educated county employees to act as advocates. Regionally they used newspaper articles, television, the state fair, the Local Road Research Board, and a roundabout conference to communicate their message about roundabouts (Slagle, 2006).

2.1.5.2 Additional Material

It is nearly impossible to get consensus on most issues but having informed consent from the stakeholders is invaluable. Below are examples of educational materials from various agencies. (the following links were valid as of March 2008)

- Washington County, Minnesota has a roundabout public education campaign called “Roundabout U,” where it helps answer questions about roundabouts in the county. http://www.co.washington.mn.us/info_for_residents/transportation_division/roundabout_u/
- Richfield, Minnesota has impressive roundabout public involvement materials for their newest roundabouts on 66th Street. They produced a “Richfield Intersection Improvements Q&A” brochure discussing alternatives and providing the public with a detailed chronology of the intersections with milestone dates for the two projects on 66th Street which encourage public involvement. <http://www.richfieldroundabouts.com/>
- The Iowa Department of Transportation roundabout website also provides resources for the public. <http://www.iowadot.gov/roundabouts/roundabouts.htm>

- Washington State has nearly 100 roundabouts with many more in the planning phases. <http://www.wsdot.wa.gov/Projects/roundabouts/>
- The Arizona DOT conducted a 17 month Needs Based Implementation Plan for a project on State Route 179 where public outreach and a collaborative community based effort was critical and instrumental to the project. <http://www.scenic179.com/NBIP/index.cfm>

2.2 Maintaining Consistency among Neighboring Jurisdictions

Having short and long range plans as well as corridor management plans can encourage collaboration with adjacent jurisdictions. Collaboration on corridor planning provides consistency in design and reinforces driver's expectancy within in a metropolitan area or region. Short and long range plans and corridor management plans provide a blueprint and common goals.

Chapter 3

Impact of Roundabouts on Corridor Mobility



Figure 3.1 Roundabout

Table 3.1 Impacts of roundabouts on corridor mobility

Challenges	Roundabout strategies and benefits
Compatibility with different land uses <ul style="list-style-type: none"> • Access to businesses • Initial construction phase vs. full build out 	<ul style="list-style-type: none"> • Facilitate U-turns to provide safe access (in combination with raised medians and right-in-right-out) • Serve as commercial driveway entrances • Reduce pedestrian exposure to vehicles
Roundabouts at intersections within a signalized corridor or in series <ul style="list-style-type: none"> • Impact on traffic flow and progression • Impact on transit and emergency response 	<ul style="list-style-type: none"> • Reduce travel time • Maximize intersection capacity without adding lanes • Incorporate roundabouts at major intersections

Roundabouts are found in urban (i.e. neighborhoods, commercial areas, school campuses, central business districts) and rural (i.e. high speed undeveloped, crossroads in small towns) areas alike. Roundabouts have commonly been used at isolated intersections. Agencies are less familiar with their use in a corridor. However, roundabouts have been successfully used in corridors both in conjunction with signalized intersections or stop control as well as in a series of roundabouts.

3.1 Use of Roundabouts in a Signalized Corridor

3.1.1 Common Concerns

Roundabouts can be used in conjunction with signals along a corridor. Proponents suggest that corridor travel times may be reduced with the implementation of roundabouts, as flow is more constant and speeds are more consistent. They also suggest that signals tend to create a series of starts and stops and speeding between the intersections to “make the green light”.

However, there is some concern that use of a roundabout in a signalized corridor can disrupt traffic flow. At a signalized intersection, vehicle platoons form. Vehicles arriving downstream in a platoon can better utilize capacity than vehicles arriving randomly. Progression is also difficult without formation of platoons. Additionally, platooning creates a recurring pattern of gaps which traffic on minor streets downstream can utilize to enter the corridor or pass through the intersection (Kansas DOT, 2003).

In contrast, traffic at a roundabout is dispersed randomly. This may be an advantage at a downstream unsignalized intersection where the minor road has a smaller traffic volume (FHWA, 2000). However, the random dispersion of vehicles makes coordination difficult and makes effective utilization of signalized intersection capacity difficult. Additionally, roundabouts function better when vehicles arrive randomly. Platoons of vehicles arriving at a roundabout from an upstream signalized intersection may cause queuing at the roundabout when large groups of vehicle arrive simultaneously.

Roundabouts do have the potential to alleviate congestion at critical intersections (i.e. bottleneck) along a coordinated signal corridor but impacts should be assessed carefully. Impacts are specific to corridor traffic volumes, percent turning vehicles, intersection spacing and vehicle types.

Estimating queue lengths at roundabouts within a corridor is important to understand the upstream and downstream impacts. Acceptable queue lengths and delays can be estimated for various traffic control alternatives (i.e. traffic signal, roundabout, stop control) based on the spacing between intersections and access points between intersections. As a rule of thumb, the 95th-percentile queue from a signalized or stopped controlled intersection should be contained between the intersections (FHWA, 2000). Signalized intersections that are pre-empted to provide priority to emergency vehicles or trains may develop longer queues which could impact operations at a nearby roundabout.

Although roundabouts are often believed to cause less queuing and delay, their impact on a signalized corridor has not been well demonstrated. Only one study was found that evaluated the performance of a roundabout in a signalized intersection corridor. Bared and Edara (2005) used a microscopic simulation program, VISSIM, to evaluate the performance of a roundabout within a coordinated set of signals. They used a corridor with three intersections separated by ¼ mile. Initially they evaluated the corridor with all three intersections signalized and re-coordinated the intersections using TRANSYT-7F. Next, they replaced the middle intersections with a roundabout. Results of the VISSIM analysis indicated that when the system was operating below capacity, the roundabout scenario resulted in less delay. When the corridor approached capacity, they found that the coordinated signals scenario resulted in slightly lower overall delay.

There may also be concern that if drivers perceive that roundabouts along a corridor interfere with traffic flow that vehicles may bypass the corridor and traffic may divert to other roadways causing safety and operational problems on those roadways, however no evidence has been presented to substantiate this concern.

3.1.2 Case Studies

Since little information was available from other sources, the research team evaluated two corridors using VISSIM software to evaluate impacts of a roundabout on a signalized corridor. The analysis compared average corridor travel time, delay, stop time and travel speeds. This analysis was intended to gain insight into the interaction of signals and roundabouts on the same corridor. The following sections provide a summary of the results.

3.1.2.1 US 69/Grand Avenue—Ames, IA

The first case study was US 69 (Grand Ave), a signalized corridor in Ames, Iowa. There are five signalized intersections, shown with blue X's on the aerial in Figure 3.3, along the 1.4 mile section of the corridor used in the analysis. Intersections are spaced at ¼ mile, 1/3 mile, ½ mile, and ¼ mile, respectively. The corridor is a four-lane major collector with an AADT of 17,000. The intersection at 13th Street and Grand Avenue has 2,900 entering vehicles during peak hour and is the most congested intersection along the corridor. No left turn lanes are currently present which causes significant delay. Both a roundabout and addition of left turn lanes were alternatives that have been considered by to improve operations at the intersection. Three alternatives were evaluated in VISSIM for the 13th Street and Grand Avenue intersection, 1) optimized signal timing with existing geometry, 2) a two-lane roundabout, and 3) optimized signal timing with left turn lanes. The existing layout of the intersection as well as a schematic of the roundabout alternative are shown in Figure 3.2.



Figure 3.2 13th Street and Grand Avenue—existing (left) and proposed roundabout (right) (aerial source: Iowa DOT)

The corridor was coded into VISSIM (a microscopic traffic simulation package). Existing vehicle volumes and intersection timing plans were obtained from the City of Ames and used to develop the model. Once the system was calibrated to replicate existing conditions, an attempt was made to optimize signal times and coordinate the system for each alternative. Due to geometry and other constraints, an optimal coordination plan could not be achieved. However,

the best possible progression was sought with the offsets and signal timings. Figure 3.4 shows the results for each alternative during the peak hour by direction. The data show delay and travel time for passenger vehicles which travel through system. Vehicles which turn onto and off the system mid-corridor were not included in the analysis.

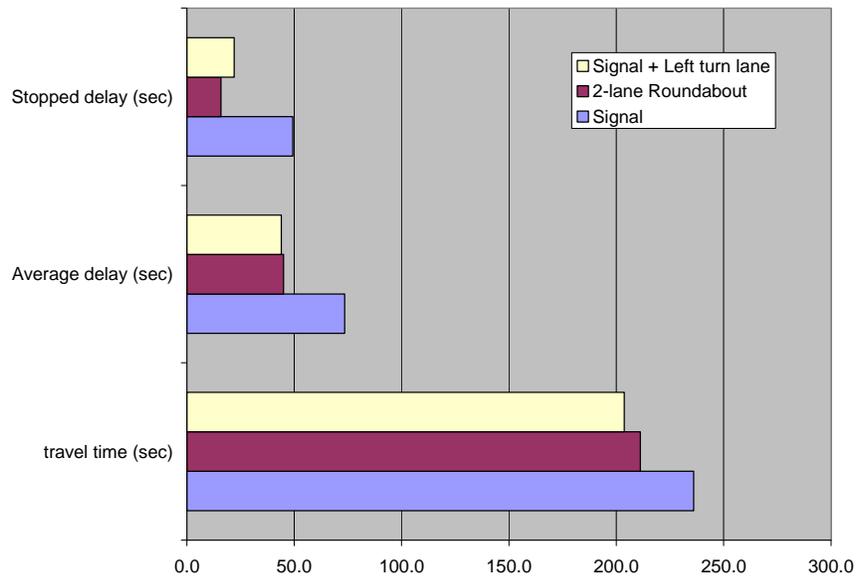
The optimized timing with existing geometry alternative has much higher travel time, stopped delay, and average delay than the other two alternatives. The signal with left turn lanes alternative has slightly more stopped delay for both the northbound and southbound directions of travel than the roundabout alternative. However, the two alternatives have similar amounts of average delay for both directions. The signal with left turn alternative has slightly less average delay for the northbound direction of travel while the roundabout has slightly less for the southbound direction of travel.

As shown in Figure 3.4, the roundabout alternative has the lowest travel time for northbound traffic while the signal with left turn lanes alternative has the lowest travel time for southbound traffic.

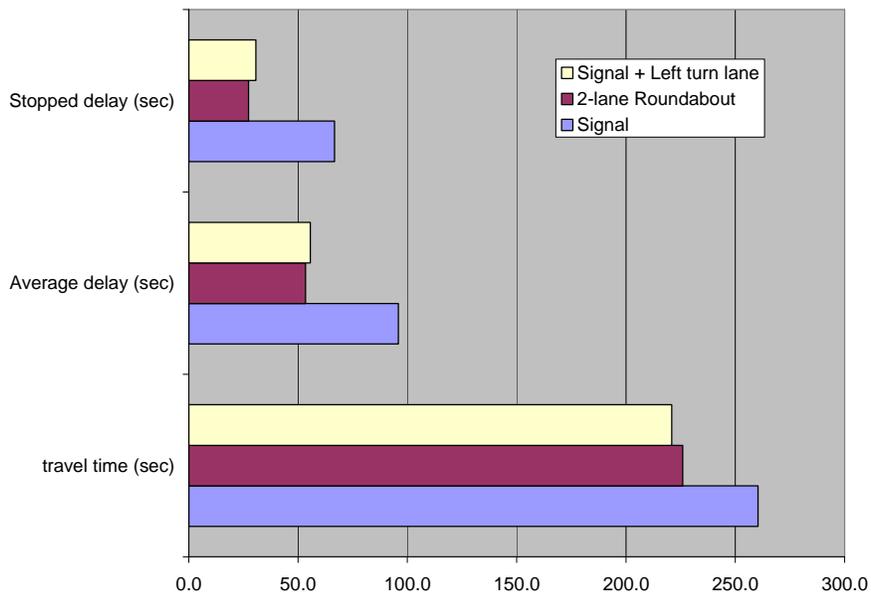
Overall, both the signal with left turn lanes and roundabout alternatives have similar results suggesting that the roundabout does not provide a significant advantage in terms of traffic operations through the corridor. The safety benefits, right of way, and air quality impacts of a roundabout alternative were not considered in the analysis.



Figure 3.3 Signalized corridor image for Grand Avenue in Ames, Iowa (Iowa DOT)



Northbound



Southbound

Figure 3.4 Comparison of alternatives for the Grand Avenue corridor, Ames, IA

3.1.2.2 Radio Drive - Woodbury, MN

A second corridor, Radio Drive/CSAH 13 in Woodbury, Minnesota (MN), which has three major intersections, was evaluated. The corridor has signals for the two northern most

at the southern intersection was constructed as a roundabout in 2007, shown with a blue circle. The intersection spacing between intersections is 0.6 miles between Bailey Rd and Commonwealth Ave and 0.4 miles between Commonwealth Avenue and Lake Road.

Radio Drive is a four lane divided roadway north of Bailey Road and a two lane undivided roadway to the south. Bailey Road is a two-lane roadway. Radio Drive and Bailey Road have an AADT of 9,000 and 7,000, respectively. The Radio Drive and the Bailey Road intersection has 1,200 entering vehicles during peak hour.

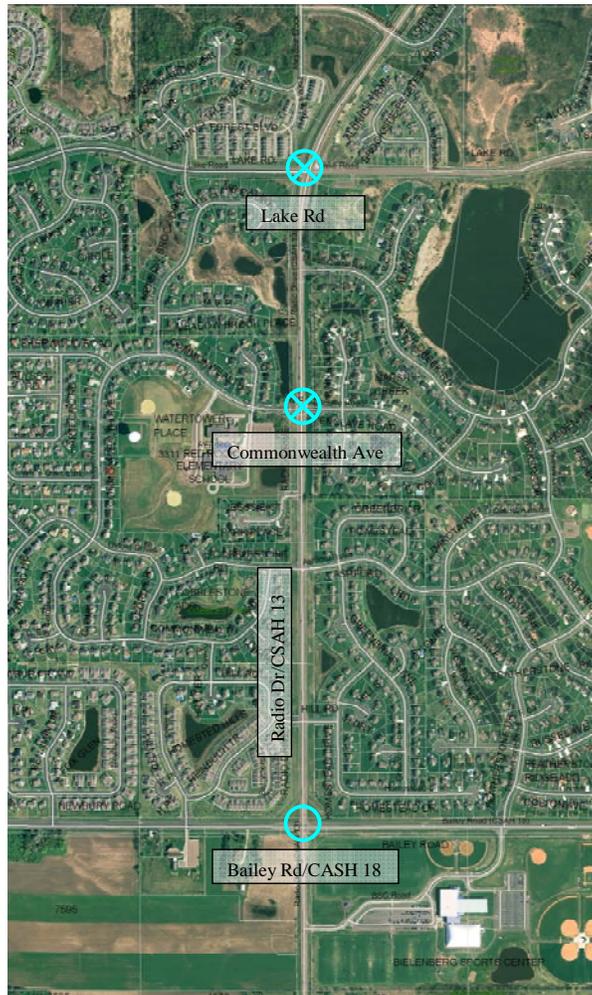
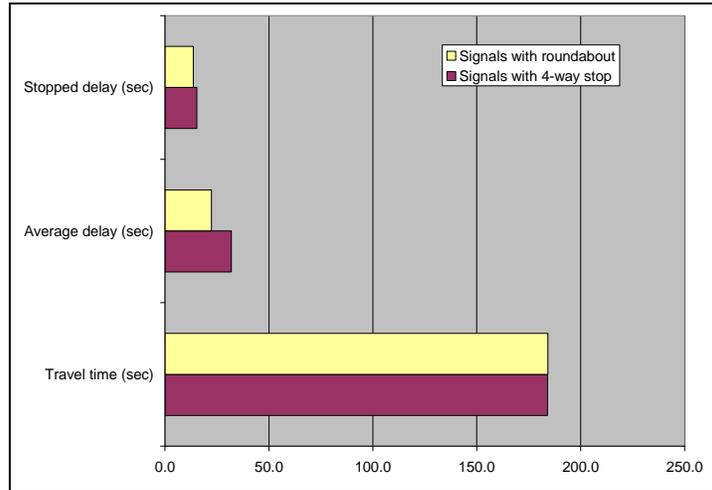


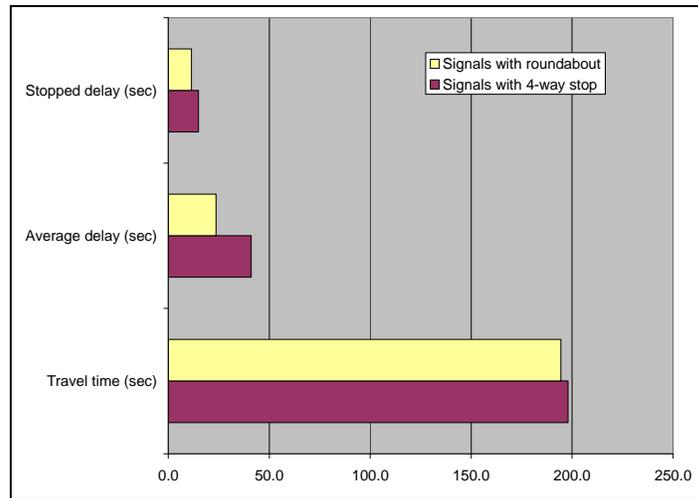
Figure 3.5 Radio Drive, MN Signalized Corridor (City of Woodbury, MN)

Two alternatives were evaluated for the corridor. The two northern intersections are currently signalized. The alternatives considered two options for the third intersection. For the first alternative, the intersection of Bailey Road and Radio Drive was modeled using a four-way stop and for the second alternative the intersection was modeled using a two-lane roundabout. Both alternatives were modeled in VISSIM and results are shown in Figure 3.5. The data show average delay, stopped delay, and travel time for passenger vehicles which travel through system. Vehicles which turn onto and off the system mid-corridor were not included in the analysis.

As shown, there was very little difference in total travel time for both the northbound and southbound corridors between the two alternatives. Average delay was 10 and 17 seconds longer with the four-way stop alternative for both the northbound and southbound directions of travel, respectively, than for the roundabout alternative. Stopped delay was slightly longer for the alternative with the 4-way stop for the northbound and southbound directions than for the roundabout alternative but the differences were minor.



Northbound



Southbound

Figure 3.6 Corridor comparison for Radio Drive, MN

3.1.2.3 Summary

Two corridors were evaluated using VISSIM to determine the impacts of implementing a roundabout and other traffic control or geometric alternatives at one of the intersections along the corridor.

The Grand Avenue Corridor compared two alternatives at an intersection which is third in a series of five signalized intersections in the corridor. The intersection currently has no left turn lanes and experiences significant delay. The two alternatives considered were a two-lane roundabout or addition of left turn lanes with updated signal timing. Both alternatives were significantly better than the existing situation. Results for the Grand Avenue analysis indicate that while the roundabout alternative overall had slightly less average, stopped delay, and travel time than the alternative with optimized signalized timing with addition of left turn lanes, differences between the two alternatives were small. It was concluded that the roundabout did not provide a significant advantage over adding left turn lanes and optimizing signal timing.

The second analysis was Radio Drive which is a corridor which currently has two signalized intersections at the northern most intersections and four-way stop-control at the southern most intersection. The existing scenario was compared with an alternative which incorporated a two-lane roundabout at the southern intersections. The two scenarios were compared. Average and stopped delay were slightly less for the roundabout alternative. However, travel time, was nearly identical for the two scenarios.

Results of the two analyses suggest that use of roundabouts in a corridor with signalized intersections may not have the same benefits that are assumed for use of a roundabout at an isolated intersection.

3.2 Use of Roundabouts in a Series

In addition to use of roundabouts with stop or signal control, roundabouts are also used in series in a corridor. This facilitates U-turns on access restricted roadways (divided roadways with turn restrictions) and allows flexibility in maximizing intersection capacity without the need for excess turn lane storage or additional receiving lanes. This concept is often referred to as the “wide nodes, narrow roads” concept.

3.2.1 Common Concerns

A common concern for use of roundabouts in a series along a corridor is how flow will be impacted. Along a major corridor with signals, an attempt is usually made to coordinate the signals or provide for progression so that large groups of vehicles can proceed through the system without being stopped. A series of roundabouts forces all vehicles to slow at every intersection.

Another concern is possible delay to emergency vehicles, as pre-emption is not possible without a signal. In many jurisdictions, certain corridors use pre-emption at signalized intersections to give priority to emergency vehicles. Pre-emption is intended to aid emergency vehicles in getting through intersections with minimal delay; it does not however give the emergency

vehicle exclusive right-of-way through the intersection whereby they do not have to reduce their speeds before proceeding through an intersection.

3.2.2 Case Studies

Several locations have implemented or will be implementing a series of roundabouts on a corridor as discussed in the following case studies:

3.2.2.1 Existing Locations

3.2.2.1.1 South Golden Road—Golden, CO

South Golden Road in Golden, Colorado is lined with a series of strip malls, grocery stores, fast food restaurants, and other businesses. The ½ mile corridor has an ADT over 20,000. Safety and operations were a dominant concern for the community. The project goals were to

- Reduce speeds,
- Improve aesthetics,
- Improve access for businesses and residential neighborhoods,
- Improve safety, and
- Create a pedestrian friendly environment.

Two alternatives were considered for the corridor, 1) signalized intersections with center medians and restricted left turns and 2) roundabouts at the junctions with center medians to restrict left turns. The City determined that the roundabout alternative provided better access to businesses and was more pedestrian friendly so this alternative was selected (Hartman, 2004). Figure 3.7 shows the corridor before and after construction.



Figure 3.7 South Golden Road in Golden, CO—before (top); after (bottom) (Hartman, 2004)

Traffic operations were compared before and after installation of the roundabouts as well as with the alternative to add a third signal to the corridor. Figures 3.8 and 3.9 show the reduction in travel times and 85th percentile speeds over the ½ mile corridor. As shown in Table 3.4, travel time decreased by 10 seconds. At the same time the 85th percentile speed decreased from 47 to 33 mph. The queues in the parking lots were nearly eliminated because the vehicles did not have to wait to make left turns. Instead, they made right turns and used the roundabouts for U-turns. Safety also improved along the corridor. Prior to construction of the roundabouts, there were 10 injury crashes per year and in the four years after the roundabout was constructed only one injury crash was reported (Hartman, 2004).

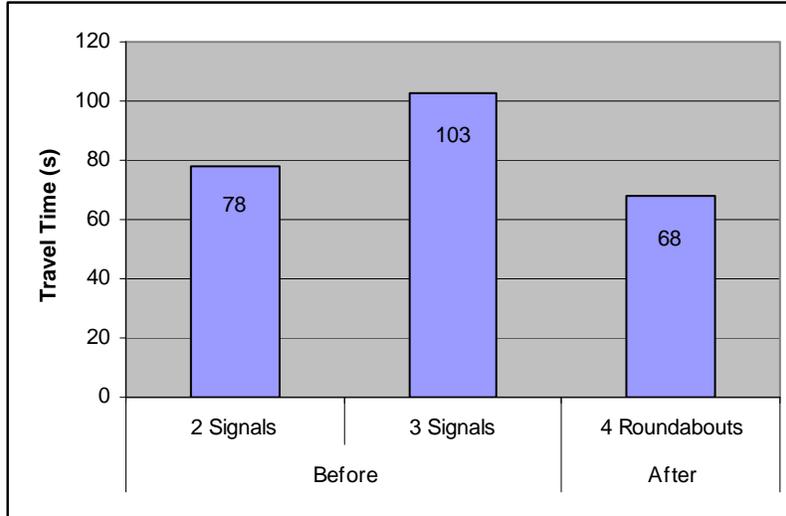


Figure 3.8 South Golden Road travel times before and after roundabout installation

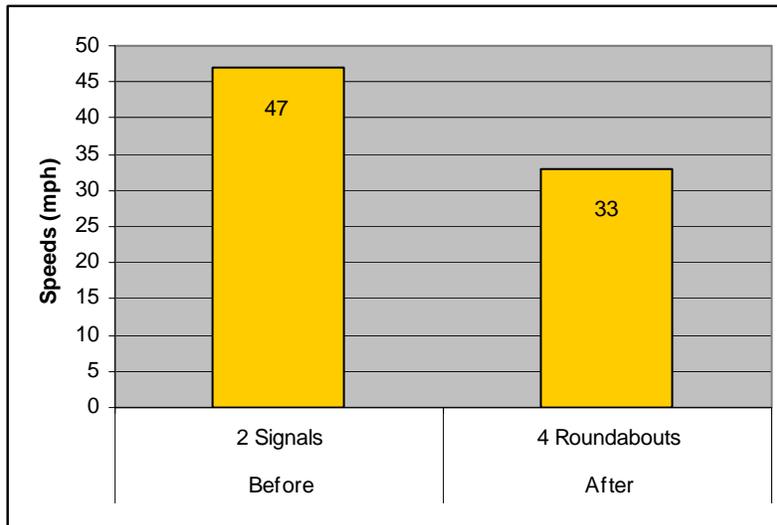


Figure 3.9 South Golden Road 85th percentile speeds before and after roundabout installation

3.2.2.1.2 Lineville Road—Brown County, WI

Lineville Road in the Village of Howard, Wisconsin has five single-lane roundabouts in a one-mile stretch of roadway. Figure 3.11 shows three of the five roundabouts and on Lineville Road. The first two roundabouts at the intersections with Cardinal Lane and Rockwell Road were constructed in 1999 near the school campus. The Velp Avenue/ CTH “HS” roundabout (Figure 3.9) was constructed in 2005. The Belmont/ Carolina Cherry roundabout was constructed in 2006 and the Shopko entrance road roundabout was constructed in 2007.



Figure 3.10 Lineville Road/CTH “G” and Velp Avenue/CTH “HS” Intersection
(Brown County, WI)

The Belmont Road, Cardinal Lane, Rockwell Road and Velp Avenue roundabouts are spaced approximately 700 ft to 1000 ft apart and the Shopko entrance is about 1200 ft from the fourth roundabout.



Figure 3.11 Lineville Road—(from left to right) Belmont Road (prior to roundabout construction) and the Cardinal Lane, Rockwell Road and Velp Avenue Roundabouts
(Microsoft Virtual Earth)

Crash history is shown for two of the intersections in Figure 3.12. Total and injury crashes from 1996 to 2006 are shown for the Cardinal Lane/Lineville and Velp Avenue/Lineville intersections. At the intersection of Cardinal Lane and Lineville, total crashes decreased from 2.8 per year before the roundabout was constructed to 1.7 after. Injury crashes decreased from 2.0 per year before the roundabout to 0.1 after. As indicated, it is difficult to establish whether a reduction in crashes has occurred for Velp Avenue/Lineville at this point.

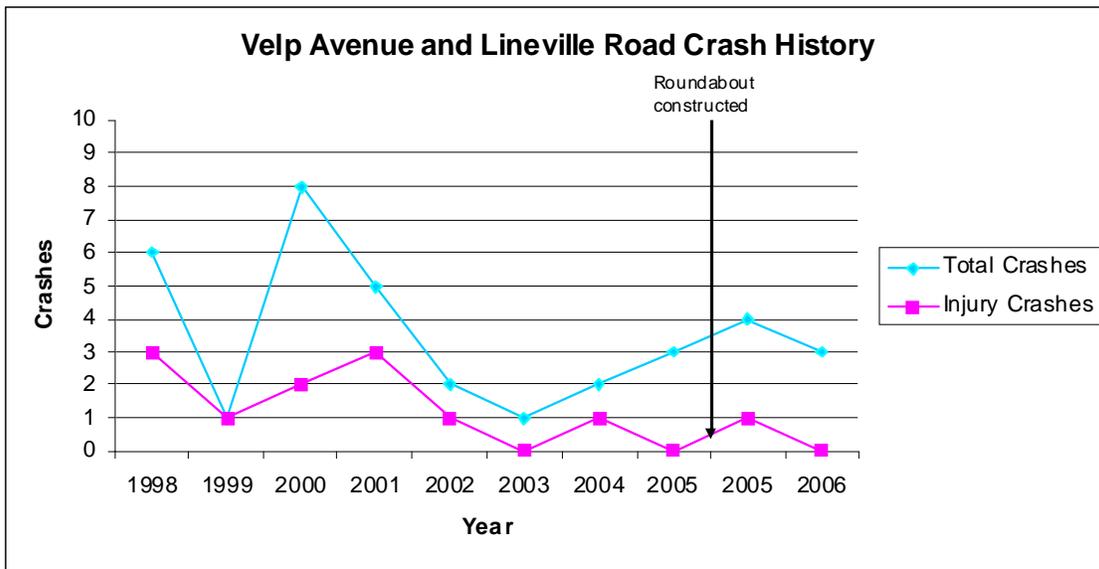
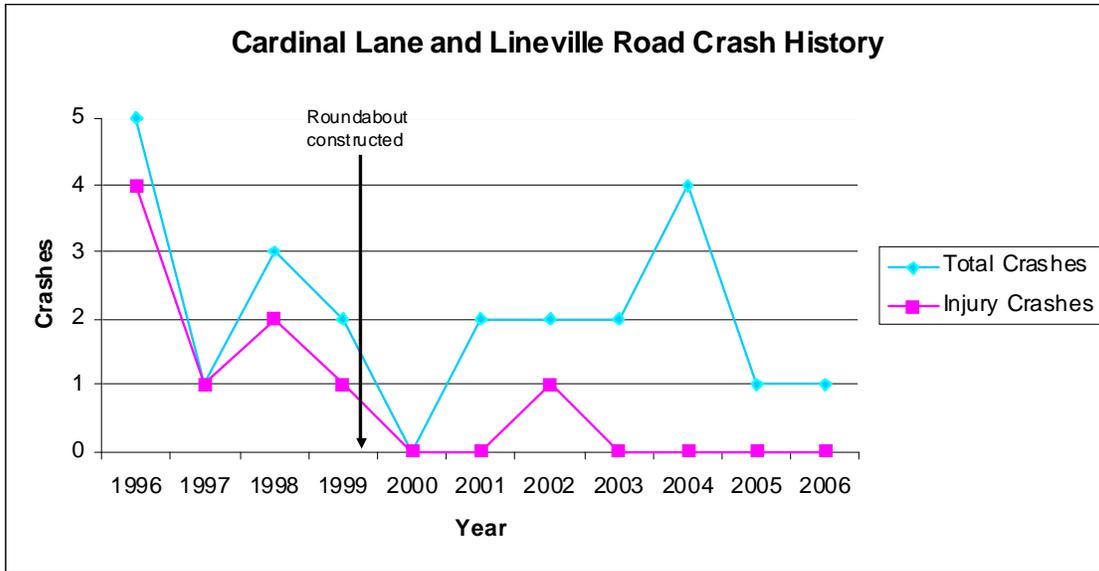


Figure 3.12 Crash history for Lineville Road Corridor (data source: Brown County, 2008)

Although costs for the roundabouts on the Lineville Road corridor were not reported, costs for three other single-lane roundabouts in Brown County were estimated to save the county between \$135,000 and \$255,000 compared to a signalized alternative. Additional information on the Cardinal Lane roundabout, specifically pertaining to the school environment, can be found in Section 3.3.1.

3.2.2.1.3 West 70th Street—Edina, Minnesota

A series of roundabouts was implemented along West 70th Street in Edina, Minnesota. The three roundabouts are near a large retail area (Galleria Shopping Mall) near West 70th Street and

area which was heavily retail. West 70th Street was a four-lane roadway which was reduced to a two-lane roadway in the vicinity of the three roundabouts which were constructed along the corridor. One of the roundabouts is an entrance to Target and the Galleria Shopping Center.

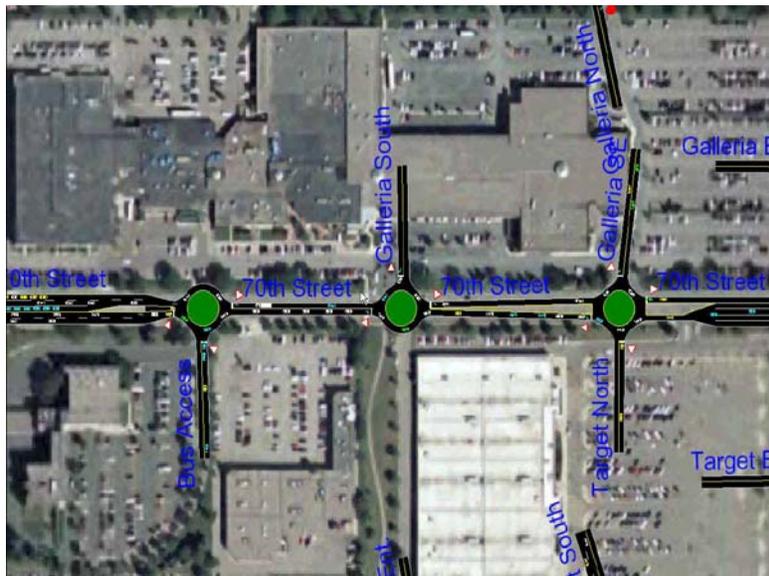


Figure 3.13 Series of Roundabouts along West 70th Street in Edina, MN (Rickart, et al. 2008)



Figure 3.14 Roundabout along West 70th integrated with commercial activity (Rickart, et al. 2008)

Prior to installation of the roundabouts, during peak travel times traffic had a difficult time entering the West 70th Street corridor. There were also concerns about pedestrian and bicyclist safety. The corridor carries about 16,000 vehicles per day and was experiencing delay to side streets along the corridor (SRF, 2006). Other issues raised about the corridor were (City of Edina, 2007):

- high speeds and cut-through traffic on adjacent neighborhood streets due to congestion

along the corridor resulting in the perception that cutting through neighborhoods was a faster alternative to the corridor

- safety concerns for school children
- difficulty in entering the corridor from side streets and driveways
- high speeds along the corridor

Access management and a series of 3 roundabouts were designed and used along the corridor to solve the traffic operation and safety problems. Although the roundabouts have only been open for a short time, the city indicates that vehicle operations have improved from LOS B to F prior to opening to LOS A-D after opening. They also found no reduction or change in access (Rickart, et al. 2008).

The city and design team addressed construction staging, access, and business coordination during construction (Rickart, et al. 2008). They also kept the public informed through public meetings during the alternative selection and design process. During construction they handed out brochures, placed a video on the city website, and attempted to publicize the project. They also were involved in directing traffic when the corridor opened to ensure that drivers understood how to negotiate to roundabouts. They felt that they had maintained consensus through the process with various stakeholder and that the improvements have been accepted by local businesses and the general public. they indicate that the following lessons were learned from the process:

- Include all stakeholders (both business and residents)
- Insure that all design details are reviewed
- Educate stakeholders

3.2.2.2 Locations in Planning and/or Construction

3.2.2.2.1 US 41—Wisconsin

A 60 mile portion of the US 41 expansion in eastern Wisconsin has approximately 45 proposed roundabouts at 13 different interchanges along the corridor. The US 41 corridor serves both local and regional traffic from Chicago to Green Bay.

Figure 3.15 shows the location of the 13 interchanges with proposed roundabouts.

The improved corridor must address the following issues:

- Long-haul truck route
- Potential to be upgraded to interstate standards
- Gateway to Lambeau Field and the Green Bay Packers

- Major crossing of the Lake Butte des Morts/Fox River system
- Access management



Figure 3.15 US 41 Expansion Project in Winnebago and Brown Counties (Google Maps)

The Wisconsin DOT requires that all projects with state funding evaluate a roundabout as an alternative for construction and/or reconstruction. The proposed roundabouts are located in Winnebago County and Brown County. The US 41 feasibility study compared roundabouts with signalized and stop controlled intersections. The proposed roundabouts along this corridor are in close proximity with traffic signals and stop controlled intersections. An extensive traffic analysis micro simulation model, using Paramics, was created to evaluate the intersections and interchange corridors.

3.2.2.2.1 State Route 539 North of Bellingham, WA

A corridor project on State Route 539 between Ten Mile Road and State Route 546 (Badger Road) near Bellingham, WA was slated for safety and capacity improvements. Figure 3.16 shows a project overview. This two-lane narrow roadway is home to over 20,000 AADT and is a freight route. Delays at the county road intersections and crossover crashes were a concern. The state needed an alternative that would address both operations and safety along the corridor as well as at the intersections.



Figure 3.16 State Route 539 Improvement Corridor (WSDOT, 2008)

The corridor is being expanded from a two-lane roadway to a four-lane facility. The state determined that installing barrier median cable would address the cross-over collisions and four roundabouts at critical intersections would effectively reduce delay and increase safety at the major intersections. Figures 3.17 and 3.18 provide conceptual roundabout layouts at the intersections. This project started in spring 2008.

The corridor has an AADT of approximately 20,000 vehicles and is a popular route for large trucks. Traffic had exceeded capacity on the route so the roundabout and expansion was undertaken to increase safety and capacity (WSDOT, 2008).

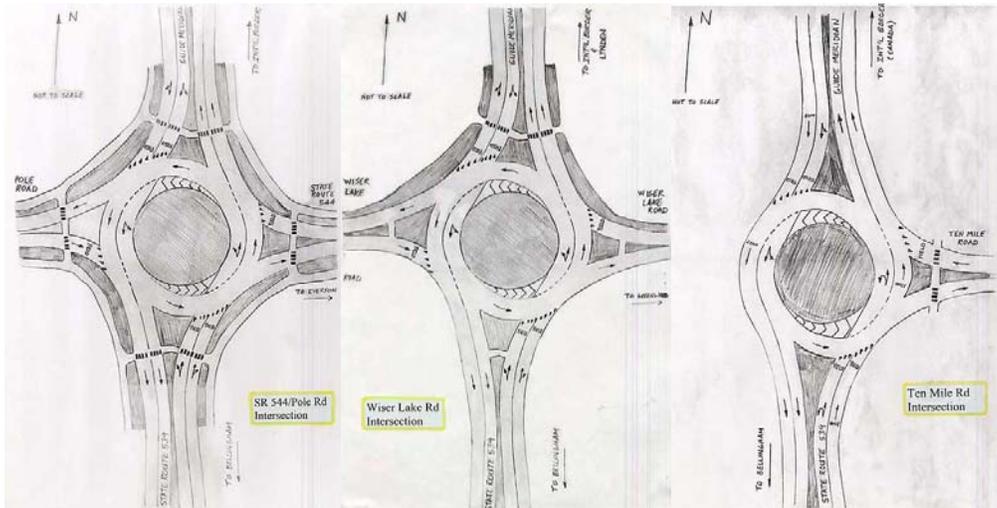


Figure 3.17 Conceptual roundabout layouts for the corridor (WSDOT, 2008)



Figure 3.18 Roundabout design visuals (WSDOT, 2008)

3.2.2.2.2 State Route 179—Sedona, AZ

A nine-mile stretch of State Route 179 (SR 179), from Oak Creek to Sedona, Arizona is being reconstructed to improve safety and mobility while preserving the scenic, aesthetic, historic, and environmental sensitive corridor. Not only is this corridor a tourist route for millions of people each year, it is also a commuter route for this bedroom community. Population in the region is expected to grow by 72% (DMJM Harris:Aecom, 2005)

Figure 3.19 shows the project overview. This two-lane roadway will be re-constructed with a raised median and 11 roundabouts, under two construction projects which started in 2007. Figure 3.20 shows the Preferred Planning Concept for the corridor and Figure 3.21 shows a conceptual layout of a portion of the corridor with a raised median and outside bike path and

According to the AZ DOT, roundabouts were chosen as the preferred alternative based on:

- Sound engineering principles
- Community input
- Access management
- Safety studies
- Research on other tourism communities with roundabouts
- Traffic studies and simulations

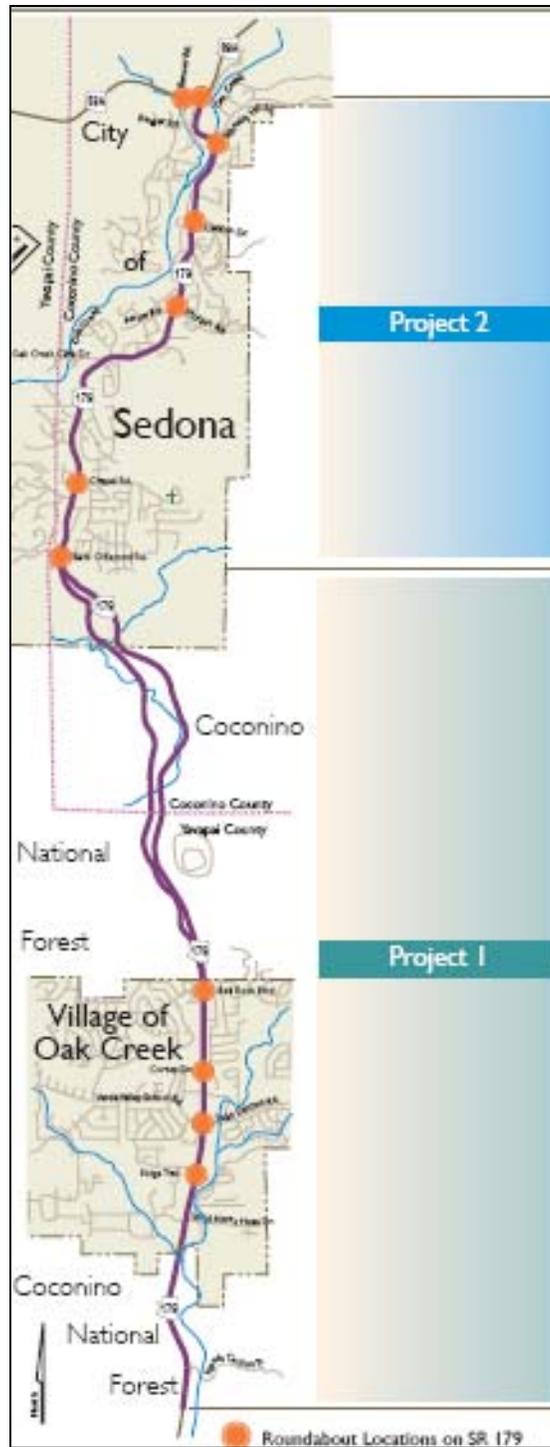


Figure 3.19 State Route 179 Corridor (Arizona DOT, 2007)

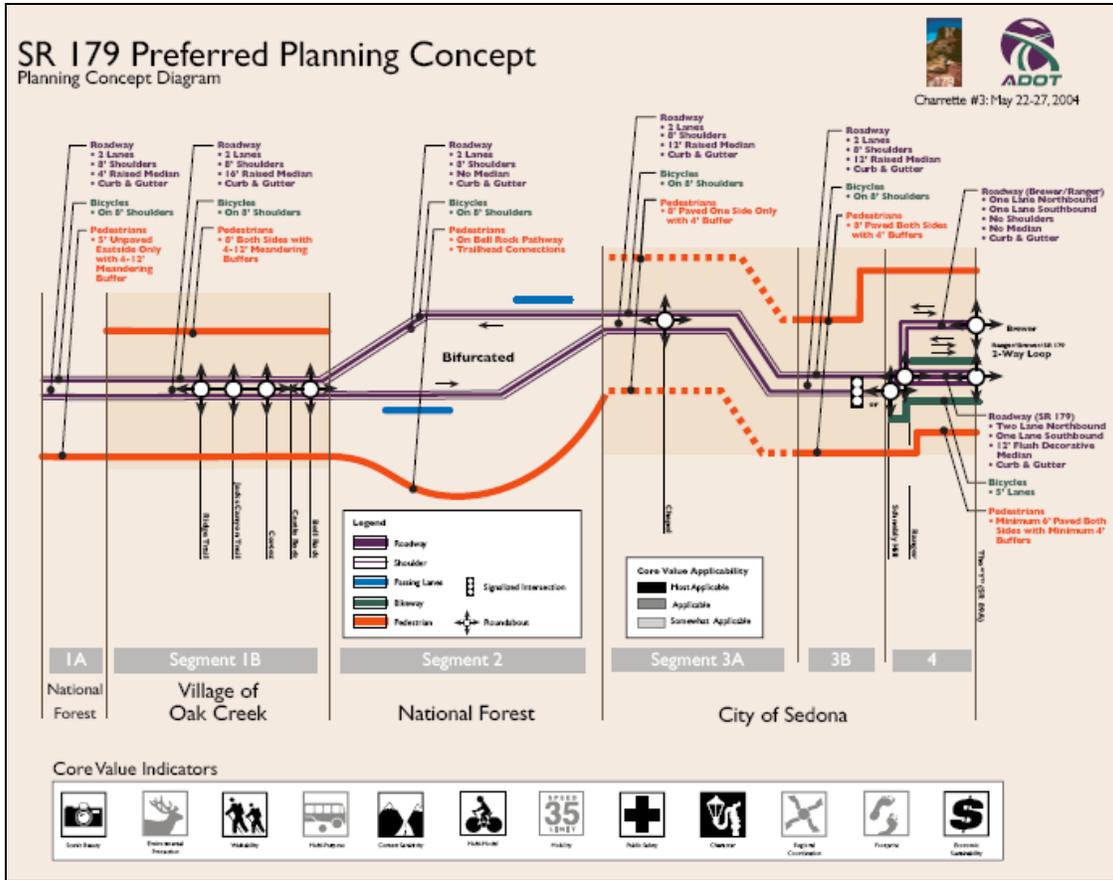


Figure 3.20 Preferred Planning Concept for State Route 179 Corridor (AZ DOT, 2007)



Figure 3.21 Portion of Project 1: State Route 179 Corridor (AZ DOT, 2007)

3.3 Land Use and Roundabout Compatibility

Landowners unfamiliar with roundabouts may have concerns about operations and safety of roundabouts near their properties. For example, business owners are sometimes concerned about having roundabouts placed adjacent to their development. Many believe that access into and out of their property may be negatively affected. The South Golden Road example in Golden, CO is just one example of how roundabouts have enhanced business. See Sections 3.2.2 and 6.3.1. In addition, parents and school administrators may have concerns about child pedestrians crossing roundabouts. Though, roundabouts have been successfully located at intersections adjacent to many types of land uses. They can accommodate a diverse range of traffic volumes, motorized and non-motorized users, as well as geometric configurations.

3.3.1 Roundabouts near Schools

An increasing number of roundabouts are located near schools in the U.S. Nearly 40 roundabouts are in operation near elementary, middle, and high school as well as university campuses. Roundabouts reduce speeds, provide shorter crossing distances, and allow pedestrians to only cross one direction of travel at a time, all of which are beneficial to child pedestrians. Roundabouts do not assign right of way, as a pedestrian phase does at a signal, but does it allows pedestrians to choose a safe gap in traffic as traffic is slowing to enter the roundabout.

3.3.1.1 Case Study—Howard, WI

Lineville Road (also a county road) was a 45mph corridor in Howard, Wisconsin that bordered a middle and elementary school. Even though a 15 mph school speed limit was used in the area, speeding problems existed and the roadway had been designated as hazardous which required the school district to bus kids across the roadway. In addition to existing problems, a high school was planned on the same campus as the existing two schools and was expected to add a substantial amount of additional traffic as well as a number of teen drivers to the mix.



Figure 3.22 Lineville Road/Rockwell Road Roundabout adjacent to Three Schools (Brown County, WI)

Instead of the typical solution which would have been to expand the highway to four lanes with intersection turn lanes and signals, the planning commission decided that roundabouts would slow drivers in the school zone and selected that as an alternative. The county determined that two roundabouts near the schools was the safest alternative and would provide less exposure for child pedestrians. Figure 3.22 shows one of the roundabouts near the school campus.

Initially, residents were concerned about the roundabouts, believing they would cause congestion and would be dangerous to cross. However, since the roundabouts have been in place

- speeds have been reduced significantly, even with the new high school traffic
- injury crashes have been significantly reduced
- congestion has been reduced on the corridor

After installation of the roundabouts, residents changed their minds and were pleased with the project. The sheriff's department was able to remove the hazardous designation allowing children to walk or bike to school (Runge, 2008). They also felt that roundabouts help crossing guards to assist children crossing the street. One crossing guard indicated that the splitter island allowed her to stop one lane of traffic at a time.

3.3.2 Roundabouts in Agricultural Areas

Agencies may be hesitant to implement roundabouts on rural corridors since they are somewhat unexpected. They must also accommodate rural drivers and farm equipment. Reduction in delay is only of minor concern, but the main benefit to roundabouts on a rural corridor is crash reduction. Rural intersections are frequently at the junction of two high speed facilities. FHWA's Roundabouts: An Informational Guide (Robinson et al, 2000) indicates that roundabouts have fewer injury crashes than rural two-way stop-controlled intersections. Figure

stop control intersections.

3.3.2.1 Case Study—Washington County, OR

In 2003, Washington County, Oregon constructed two roundabouts along NW Verboort Road which is a heavily commuted farm-to-market route. The roundabouts had to be constructed to accommodate farm vehicles and minimize the impact to farmland. The two roundabouts have reverse curves on the approaches to the roundabout to assist with reducing speeds and landscaping was used to cut down on headlight glare (Swanson, 2003). Figure 3.24 shows the two roundabouts in Verboort, Oregon.

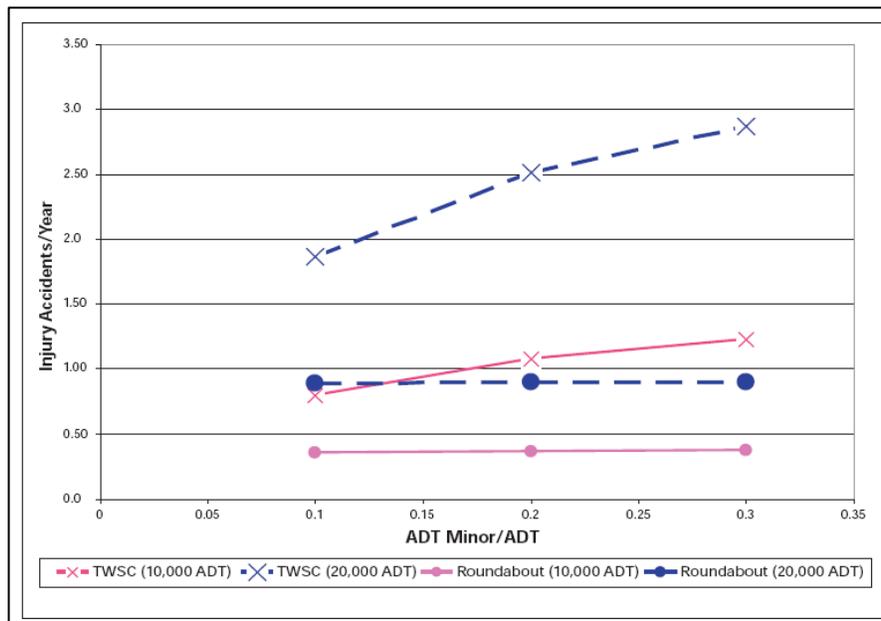


Figure 3.23 Predicted crashes for roundabouts versus two-way stop control (Robinson et al, 2000)



Figure 3.24 Verboort, Oregon Roundabouts (Google Maps)

3.3.3 Roundabouts in Commercial Areas

New commercial developments are also utilizing roundabouts at the entrances to their stores. From intersections near Wal-Mart to Home Depot to lifestyle centers, roundabouts are more widely used in newly developed and re-development commercial areas.

Rocky Mountain Avenue in Loveland, Colorado serves a mixed-use commercial area (i.e. retail, hotels, shopping, medical facilities, an insurance company, fast food). The first two roundabouts on this corridor were constructed in 1998. Figure 3.25 shows the Fox Trail Drive intersection. The corridor now has six two-lane roundabouts. The ADT at the McWhinney Boulevard intersection is over 21,500 vehicles.



Figure 3.25 Rocky Mountain Avenue and Fox Trail Drive intersection (Isebrands)

Richfield, Minnesota constructed a roundabout in 2007 at the 66th Street and 17th Avenue intersection which leads to the Cedar Point retail center. The shopping center includes Target and Home Depot stores, as shown in Figure 3.26.

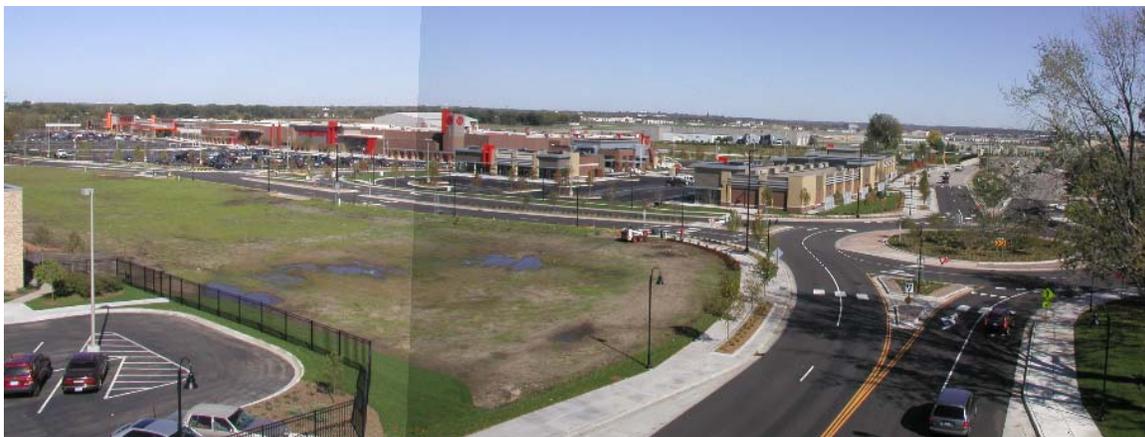


Figure 3.26 Cedar Point Retail Center in Richfield, MN (City of Richfield, MN)

3.3.4 Roundabouts as Community Gateways

The city of Cottage Grove is in the process of constructing roundabouts at the entrance and exit ramps for Trunk Highway 61 at the intersections with West Point Douglas Road/Jamaica Avenue (Figure 3.27 and 3.28). The interchange is a principal connection to the Twin Cities and southeast Minnesota and was experience congestion and safety problems. Traffic was queuing onto the southbound exit ramp of HWY 61 and the city was concerned about safety (City of Cottage Grove, 2008). Additionally, the two intersections were closely spaced and traffic operation problems resulted during peak hours (Bonestroo, 2008). The City decided to go with two roundabouts at the interchanges. The roundabouts are in the landscaping stages. They city developed a website to facilitate public involvement which includes simulation videos that show how traffic would operate with three alternatives: all-way stop control, a traffic signal, and a roundabout.

An interesting aspect of the project is that the city is developing the roundabout as a community gateway. They plan to landscape the roundabout with terraced landforms and vegetation in keeping with the community character. They plan for this to be focal point that symbolizes the entrance to Cottage Grove. Planned completion is Fall 2008.



Figure 3.27 Roundabouts at interchange of TH 61 and Jamaica Avenue (Bonestroo, 2008)



Figure 3.28 Gateway design for Cottage Grove Roundabout
(City of Cottage Grove, 2008)

3.3.5 Roundabouts with Other Land Uses

Roundabouts are compatible with most land uses. Roundabout can also be used to signal to drivers that they are entering an area where the character of the roadway or adjacent land use is changed. The roundabout can delineate the change or act as a gateway between changing environments (KYTC, 2006). The City of De Pere, Wisconsin constructed a roundabout at an intersection in a residential area which also had a few small businesses and a fire station. As shown in Figure 3.27, the roundabout was designed so that the one of fire station's driveways accesses the roundabout. This allows fire trucks to easily enter the intersection (Brown County, 2008).



Figure 3.29 Grant Street/9th Street Roundabout in De Pere, WI with fire station adjacent to roundabout (Brown County, Wisconsin)

Table 3.2 Roundabouts compatibility with land use

Land Use	Location	Example
Residential	West Des Moines, IA	
Commercial-Urban	Golden, CO	
Schools	Lacey, WA	
Agricultural	New Prague, MN	

Image source: N. Hawkins

Image source: City of Golden, CO

Image source: Isebrands

Image source: Isebrands

Chapter 4

Impact of Roundabouts on System-wide Mobility

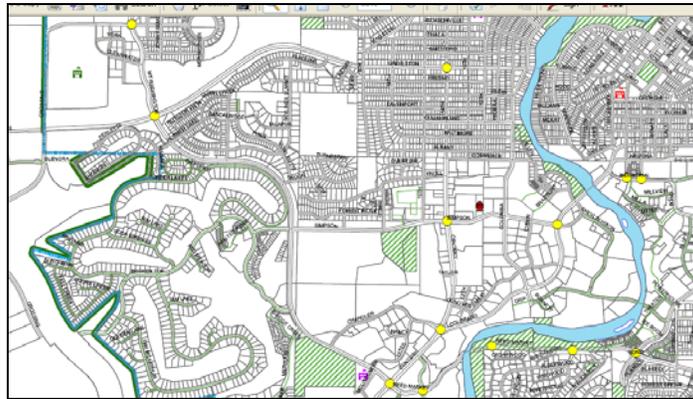


Figure 4.1 Roundabout (City of Bend, OR)

Table 4.1 Impact of roundabouts

Challenges	Roundabout Strategies and Benefits
<ul style="list-style-type: none"> Overall impacts on system-wide mobility • Intersection spacing • Use of parallel corridors to avoid roundabouts • Circulation • Speeds (multi-lane roundabouts) • Accommodation of heavy trucks and large vehicles 	<ul style="list-style-type: none"> • Function as gateway treatments to reduce speeds • Narrower corridors • Provides random release of vehicles, rather than platoons • Regulates traffic entering freeway from entrance ramp • Use of truck aprons to allow for large vehicle movements (may differ for single- and multi-lane roundabouts) • Access management (See Section 6)

4.1 Background

Roundabouts are expected to reduce delay and queuing at isolated intersections, but may impact traffic operations at adjacent intersections or parallel routes with alternative traffic control. Use of a series of roundabouts may also have impacts on system wide flow. The impact is specific to the traffic volumes, intersection spacing and vehicle types.

On a system wide level, it is always important to identify what corridors are the bottlenecks in the network. Some drivers will go out of their way to avoid those corridors and put pressure on other parallel routes, some of which may be at a lower functioning level (i.e. local neighborhood roads) and others may be at a higher functional level (i.e. interstate). It seems that most drivers are interested in getting from point A to point B in the shortest amount of time with minimal amount of idle time. Roundabouts allow drivers to keep moving which has the potential to improve overall circulation in the system.

To date, agencies appear to be comfortable with constructing roundabouts at:

- local-local
- local-collector
- collector-collector intersections

However, there appears to be hesitation in constructing roundabouts at collector-arterial or arterial-arterial intersections.

Furthermore, the traffic generated by private developments has put great stress on our transportation network. Many developers are proposing roundabouts at junctions, but once a roundabout is chosen as a preferred intersection alternative, quality reviews are not always performed. It is important that the design be critically reviewed and inspection is performed during construction, as a poorly designed and/or constructed roundabout can and will negatively influence mobility and safety on the roadway.

Often times when considering enhanced mobility, an emphasis is put on operational characteristics, conversely the safety benefits associated with roundabouts will also provide improved mobility.

4.2 Experience from Other Agencies

4.2.1 Guidance from the Wisconsin DOT

The Wisconsin Department of Transportation (WisDOT, 2005) provides the following information on system consideration of roundabouts:

- Implementing roundabouts along a corridor for the purpose of access management (i.e. exchange left turn conflicts for U-turns at the next roundabout) will likely provide overall network improvements

- Roundabouts incorporated on the arterial network can provide gateways into more dense developments
- Although downstream gaps are shorter due to roundabouts (no platooning), they occur more frequently to allow for vehicles on the side streets to access the roadway
- Bottlenecks within a coordinated network may benefit from a roundabout since they are expected to lower overall system signal cycle length, and reduce delays and queues

Interchange ramp terminals often have a large percentage of left turning traffic and potentially limited queuing storage on the bridges which can cause corridor and intersection congestion. The close proximity of ramp terminal intersections, as well as adjacent intersections and accesses also create challenges in determining the appropriate traffic control. WisDOT (2005) identifies several benefits of roundabouts at ramp terminal intersections including, the intersection sight distance required is typically less and the spacing of vehicles turning on the on-ramp tends to be more random which may be helpful during peak periods.

4.2.2 Case Study—Bend, OR

4.2.2.1 Background

Bend, Oregon has a network of roundabouts on the west side of the city. They have no signals within this network. All arterial/arterial and arterial/collection intersections have roundabouts. The intersection spacing is typically every ½ mile but occasionally every ¼ mile. The roundabouts assist with the circulation by balancing traffic out on the network.

The majority of the roundabouts are single-lane roundabouts with 22 single-lane roundabouts and two multi-lane existing roundabouts. An additional three multi-lane roundabouts will be constructed as a part of the SW Reed Market Street corridor improvements. Eighteen of the roundabouts are on four roadways. Figure 3-1 shows the roundabouts (yellow dot) within the Bend, OR roadway network (City of Bend, 2008). The SW Reed Market Street is a key east-west major arterial in southern Bend, OR. Daily traffic volumes vary from 15,000 to 20,000.

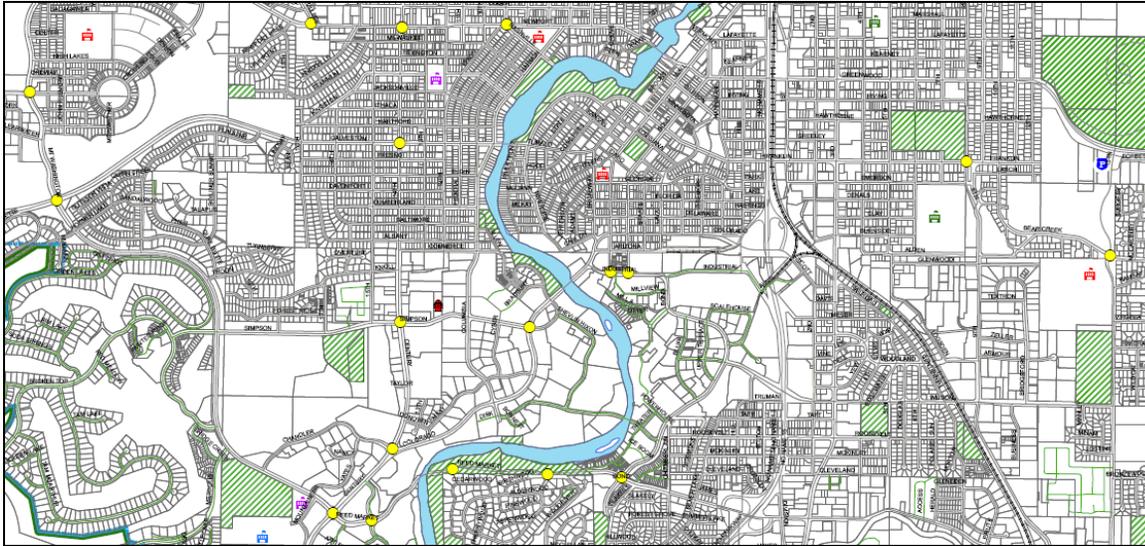


Figure 4.2 Bend, OR roundabouts—yellow dot indicates existing roundabouts (Bend, OR)

4.2.2.2 Strategies and Lessons Learned

The City of Bend benefits from roundabouts in many different ways. Roundabouts are used in periphery areas as traffic transitions into more dense urban areas and to improve circulation on the network.

The following is a list of lessons learned from Bend, OR (Lewis, 2008):

- Design should allow adequate width at the entry for emergency vehicles to pass vehicles that are pulled over – preferred width 20 ft curb to curb
- Traffic signals typically create periods downstream where large gaps are present due to queuing at the signal. Roundabouts tend to create a set of uniform gaps which can make it difficult for vehicles to turn onto or off the main roadway. As a result, consideration should be made for driveway spacings and access policies.
- When accommodating trucks, truck apron height should discourage passenger vehicles and allow for easy maintenance (i.e. plowing); and communication and education with local truck stakeholders should start early in the planning process.
- Trucks should be allowed to use both lanes in a two-lane roundabout to minimize the design footprint.
- Public involvement should continue to be an essential part of each project.

4.2.3 Case Study—Brown County, WI

4.2.3.1 Background

Brown County, WI has 18 single-lane roundabouts and one two-lane roundabouts in the greater Green Bay area. Fourteen of these roundabouts are on the county road system and three are on the state highway system. Additionally, the Wisconsin Department of Transportation (WisDOT) is planning 25 new roundabouts at seven interchanges along US 41 between 2010 and 2015 (See Section 3.2.2.2 for more information on this project.). Figure 4.3 shows the existing and proposed roundabouts in Brown County.

The sheer number of roundabouts has created a network of roundabouts within Brown County and the greater Green Bay area. This roadway network carries both local and regional traffic and has both rural and urban characteristics. Two corridors within the existing network, County Trunk Highway (CTH) “G” and CTH “M” and the proposed roundabouts on the US 41 corridor account for the majority of the roundabouts, however a majority of the remaining roundabouts are tied to these corridors. The spacing of these roundabouts varies from 700 ft to over 1500 ft. Brown County has not experienced problems with circulation or heavy trucks as a result of the increased number of roundabouts on the roadway network.

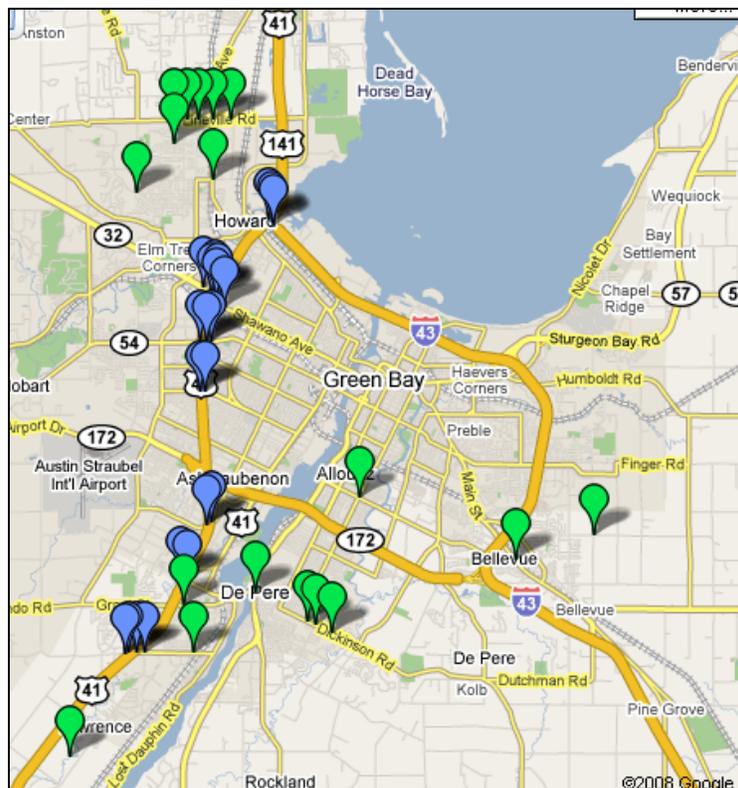


Figure 4.3 Brown County, WI—network of existing maps—green indicates existing roundabouts and blue indicates proposed roundabouts (Google Maps)

The desire for improved safety and the counties preference to construct roundabouts at these intersections were instrumental in developing a network of roundabouts in the Green Bay area. The network has experienced a reduction in the number of crashes with injuries. Prior to the construction of the roundabouts at the 19 intersections (before years vary from 0 to 9), 155 injuries were reported in 300 crashes. Since the roundabouts have opened (after years vary from 0 to 7) 21 injuries have been reported in 69 crashes (Brown County, 2008).

4.2.3.2 Lessons Learned

The following is a list of lessons learned from Brown County (Dantoin, 2008):

- Lighting should be included at the approach crosswalks. Previously the projects only included one mast arm with four lamps in the central island, since it was determined that lighting was needed at the decision point on the approaches.
- Longer splitter islands should be used. They suggest a minimum of 50 feet.
- Signing should be consistent. The signing used in Brown County varies from that used by WisDOT. Citizens have indicated a preference for the Brown County signing.
- The public may oppose roundabouts at the offset but opposition typically lessens as time goes on when the public has more driving experience with roundabouts.

4.2.4 Case Study—Avon, CO

4.2.4.1 Background

Avon, Colorado is a small town of approximately 5,500 regular residents. In the winter, however, Avon becomes the gateway to the Beaver Creek Resort off of Interstate 70, which is approximately two miles south of Avon. The Beaver Creek Ski Resort can handle 26,000 skiers per hour – and the only way to get to Beaver Creek is through Avon. Figure 4.4 shows the I-70 westbound ramp terminal at the Avon.



Figure 4.4 I-70 Exit at Avon, CO (Isebrands)

with ski traffic, which ultimately would back down the ramp terminals and onto I-70 and cause major gridlock within the towns themselves. Avon Road had five signalized intersections leading to Beaver Creek. In 1996 approximately, 11,000 vehicles a day exited I-70 and headed towards Beaver Creek (Brooks, 2008). Congestion, emissions, vehicle and pedestrian safety, and cost were all a concern. The signalized alternatives required multiple turn lanes and widening of the I-70 structures. It was not desired to intermix roundabouts with signalized intersections on this corridor. The intersections on Avon Road are (from I-70) 430 ft, 600 ft, 375 ft and 1,150 ft apart. It was determined that roundabouts were the preferred intersection alternative to address all of the issues identified. In 1997, Avon constructed roundabouts at the I-70 ramp terminals as well as three more roundabouts on Avon Road, the only north-south route through the town.

The roadway network in and around Avon is limited because of the terrain. Avon is located in a valley approximately ½ mile wide. A new interchange and roadway network were constructed as a result of a commercial development on the east side of Avon. The expanded roadway network provided opportunity for more roundabouts. The new William J. Post Boulevard intersections were constructed with five more roundabouts. This roadway is between Highway 6 and I-70 and leads to a big-box retail center (i.e. Wal-Mart and Home Depot). Figure 4.5 shows the existing roundabouts in Avon.

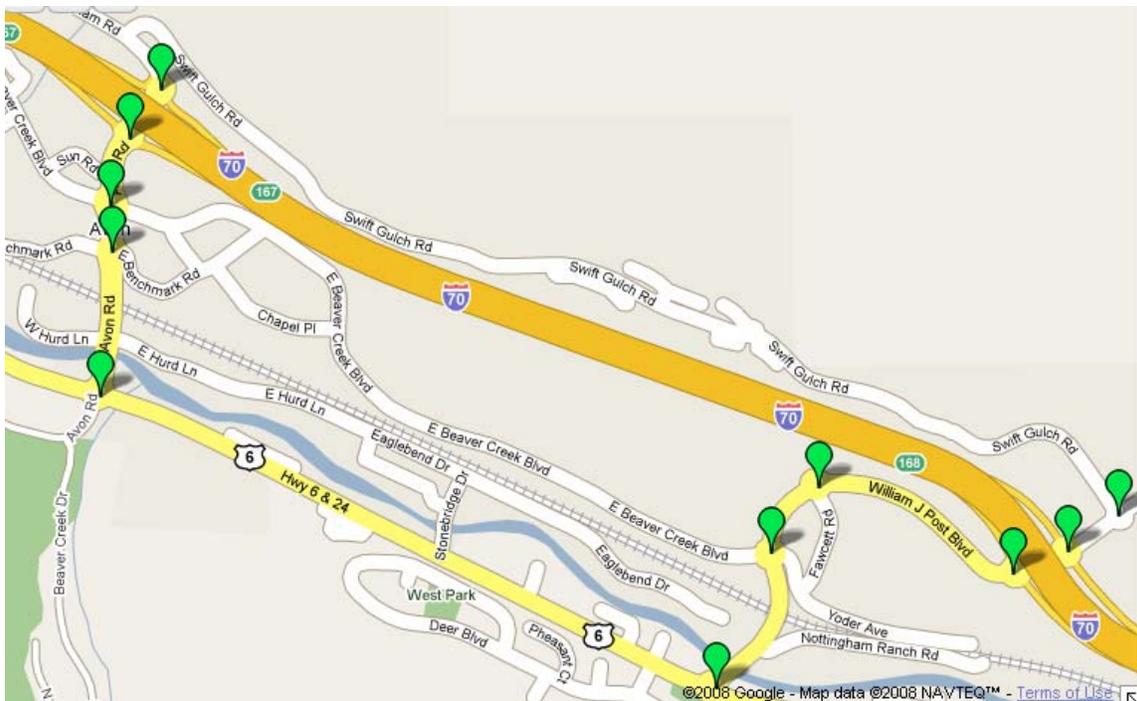


Figure 4.5 Avon, CO—network of existing roundabouts (Google Maps)

4.2.4.2 Strategies and Lessons Learned

The four roundabouts at the two I-70 interchanges and the two roundabouts on Highway 6 are considered community gateways to Avon (Town of Avon, 2006). Avon Road has a narrower footprint because it does not need left and right turn lanes at every intersection

landscaped medians and sidewalks. Additionally, Avon has found that roundabouts provide flexibility even when flows are unbalanced.

Although the roundabouts on Avon road have reduced congestion, there is still concern for vehicle speeds and pedestrian safety for the town. Vehicle speeds are a concern because vehicles can typically travel faster through multi-lane roundabouts because of the larger radius. The town would prefer slower vehicle speeds so people enjoy the amenities of the community in addition to traveling to the Beaver Creek Resort.

The Town of Avon continues to learn from their roundabouts. Over the past decade, the town has made some improvements the roundabouts on Avon Road, including converting a tear drop roundabout to a full access roundabout at the Avon Road and Benchmark Road and adding more visible pedestrian crossings.

The following is a list of lessons learned for the Town of Avon (Brooks, 2008):

- Although the roundabouts on the corridor does reduce speeds, the town would like to reduce the speeds further by narrowing the travel lanes on Avon Road.
- Benchmark Road roundabout was constructed as a tear drop roundabout because there was concern about the steep grade on the south side. It was later realized that this roundabout would better serve the town as a full access roundabout and was converted in 2007.
- It is preferred that the trucks and buses use both lanes in the two-lane roundabouts. The town prefers that the truck aprons were not constructed on this corridor.
- The bus drivers are instructed to use both lanes in a two-lane roundabout rather than using the truck apron. This slows down vehicles and passengers have a smoother ride without the use of a truck apron.
- They have also found that drivers will slow down for pedestrians without “extensive” pedestrian treatments.

4.2.5 Planning Case Study—Chicago, IL

A new urban network was developed for the Chicago Metropolis 2020 by Calthorpe in 2002. The transportation network is comprised of boulevards, throughways, avenues and connectors. It would replace the old grid network made up of arterials spaced one-mile apart. Figure 4.6 shows Calthorpe’s new urban network compared to ‘traditional suburbia’. Transit boulevards are for semi-local traffic and transit, Throughways are limited access roadways for longer trips, Avenues connect commercial destinations and Connectors provide local circulation. Roundabouts and couplets of one-way streets are used throughout. The plan incorporates roundabouts to increase route efficiency and couplets to allow urban development. Avenues intersect Throughways and Boulevards at one-mile spacing and Connector streets would be at 1/8 mile spacing.

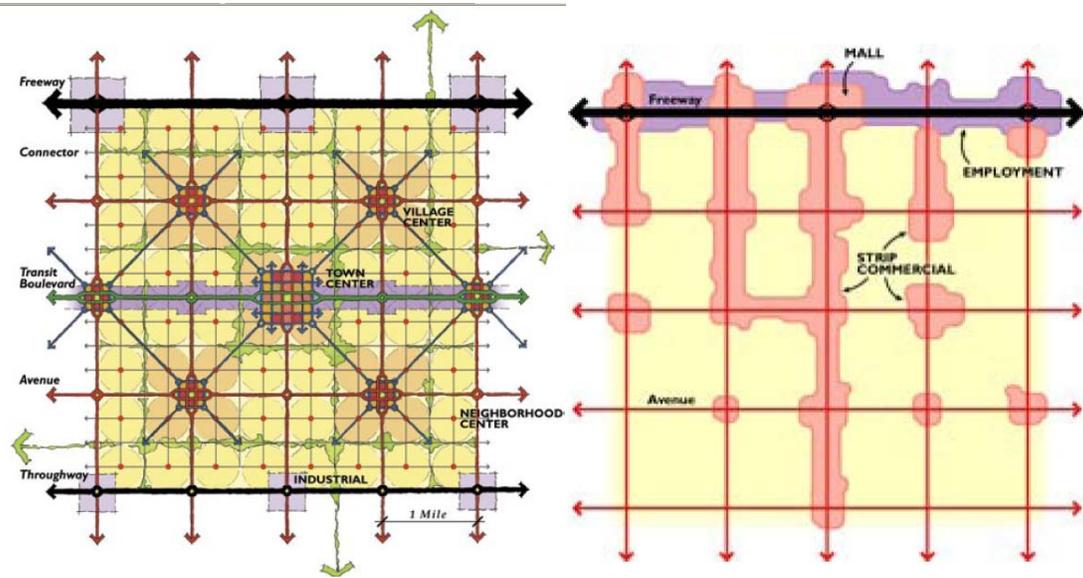


Figure 4.6 New transportation network (left); old grid (right) (Calthorpe, 2002)

Chapter 5 Roundabouts in Access Management



Figure 5.1 Roundabouts (City of Golden, CO)

Table 5.1 Challenges and benefits to roundabouts

Challenge	Roundabout Strategies and Benefits
<p>Impacts to businesses</p> <ul style="list-style-type: none"> • Reduced access • Median closures • On street parking 	<ul style="list-style-type: none"> • U-turns to allow access to businesses • Force turning movements to occur at intersections • Median closures • Reduce queues and delays in parking lots and driveways • Pedestrian exposure reduced • Increased safety with reduced conflict points • Intersection crash types reduced (eliminate head on and right angle) • Fewer thru lanes due to “free flow” at intersections - Road diet (4 lanes to 3 lanes or 2 lanes)
<p>Driveways along the circulatory roadway</p>	<p>Treat as a roadway with splitter island</p>

5.1 Background

Roundabouts are considered a viable option to assist with access management. Generally access management along new corridors is easier to control than existing corridors with established driveways and businesses. Opportunities to revise access control may also be possible as properties redevelop. Access management benefits include improved safety, reduced congestion and delay, improved capacity, more efficient use of land and minimized infrastructure investments (WisDOT, 2005).

Integrating roundabouts into an existing corridor requires consideration for how it will affect business access. With the rapid change of land use in growing and redeveloping areas, it is critical that roadway and intersection designs withstand existing and future traffic volumes and changing land uses. Roundabouts are considered a favorable alternative to assist with access management along existing corridors with established driveways.

Figure 5.2 illustrates the Access vs. Mobility matrix presented in the *FHWA Safety Effectiveness of Highway Design Features, Volume I: Access Control*. Roundabouts can play a role in the effectiveness of access control as well as mobility. Constructing roundabouts along local, collector and minor arterial junctions enables agencies to achieve safe and efficient corridors.

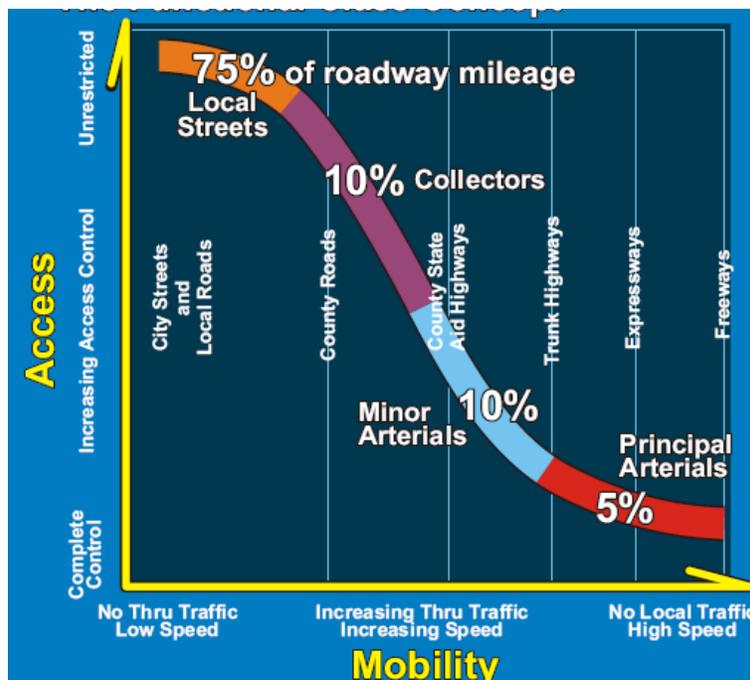


Figure 5.2 Access vs. mobility: The functional class concept (as cited by MnDOT, 1999)

FHWA (2007) produced a toolbox of intersection countermeasures and their potential effectiveness. They suggest the following crash reduction factor (CRF) for all crashes when an intersection is converted to a roundabout depending on the previous control previous control:

- CRF of 18 to 72 when converted to a roundabout from 2-way stop control

- CRF of -3 when converted to a roundabout from 4-way stop control
- CRF of 1 to 67 when converted to a roundabout from a signal

The following crash reduction factors were found for fatal and injury crashes when converting to a roundabout

- CRF of 72 to 87 when converted to a roundabout from 2-way stop control
- CRF of -28 when converted to a roundabout from 4-way stop control
- CRF of 60 to 78 when converted to a roundabout from a signal

5.2 Guidelines for Use of Access Management with Roundabouts

Several access management strategies that compliment roundabout design are:

- Continuous raised medians
- Restricted turning movements
- Right-in-right-out movements
- Use of U-turns

In particular roundabouts complement raised medians. When drivers are prohibited from making a left turn into a business they are forced to pass their destination and make a U-turn. A roundabout facilitates a safe U-turn and which can provide an opportunity to sell access management to business owners (Alternate Street Design, 2008).

The Kansas Department of Transportation (KSDOT, 2003) looks at access management in two ways: access *into* the roundabout and *near* the roundabout. More often than not, driveways with direct access *into* a roundabout are discouraged. However, if there is no other reasonable access point to the property, the driveway should be designed as a leg of the roundabout (WisDOT, 2005). This assures that the appropriate deflection is provided and discourages backing into the circulatory roadway.

Driveways near a roundabout should be located beyond the pedestrian crosswalk (WisDOT, 2005; Kansas DOT, 2003; WashDOT, 2004) and those within the splitter island located within the splitter island will only be provided right-in-right-out access. In this case, a U-turn at the roundabout will be required for any left turning movements. Left turn storage may also be needed for the driveway based on traffic volumes using the driveway. Figure 5.3 provides an example of driveway spacing near a roundabout (Kansas DOT, 2003).

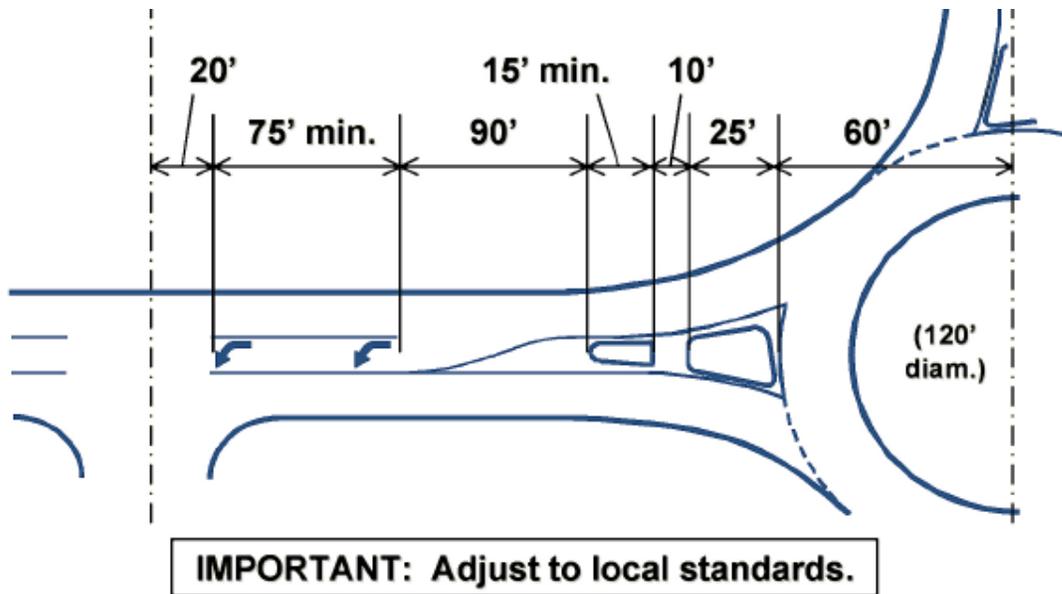


Figure 5.3 Left turn access near a roundabout (KSDOT, 2003)

5.3 Case Study—South Golden Road—Golden, CO

The South Golden Road project in Golden, Colorado is a tremendous example of how business owner concerns were overcome after the installation of two roundabouts on the corridor. The businesses were worried that potential customers would bypass their businesses because of the roundabouts. Concerns were mitigated to the point that the business owners became proactive in getting two additional roundabouts constructed at adjacent intersections, because of the U-turn capabilities of roundabouts. Access management could be applied while providing better access to the businesses with roundabouts at the intersections (Ariniello, 2004). Figure 5.4 shows a 50% reduction in the average access point delays (time it takes to enter the roadway from the driveway/parking lot) after the roundabouts were constructed and a 67% reduction in the maximum access point delays.

The corridor has been a great economic success for the community as well as the businesses. Sales tax revenues increased 60% over a six year period in the area, which far exceeds that for the remainder of the City. Additionally, another 75,000 square feet of retail/office space has been built along the corridor since the roundabouts opened (Ariniello, 2004).

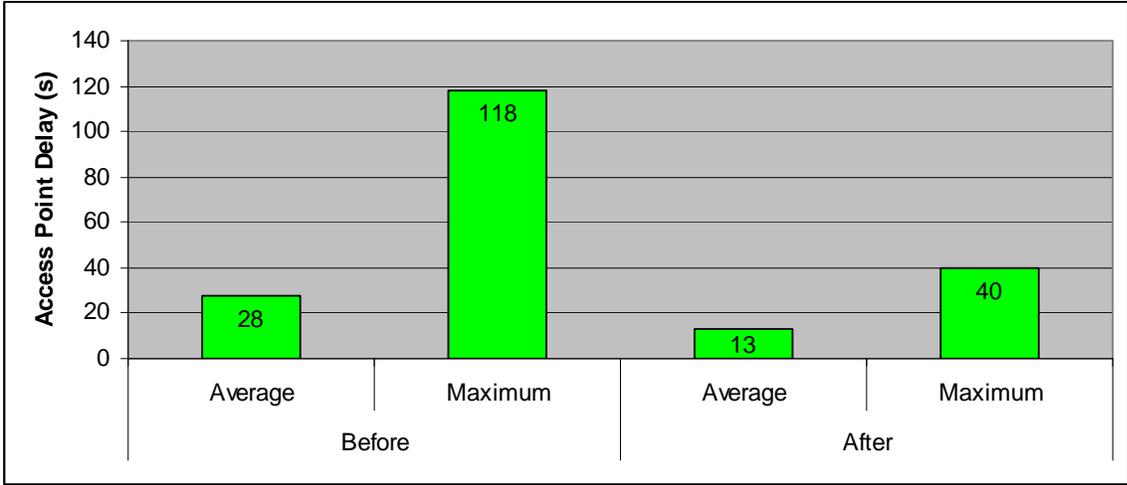


Figure 5.4 South Golden Road access point delay before and after roundabout installation

Chapter 6

Impact of Roundabouts on Other Planning Considerations



Figure 6.1 Roundabout (Isebrands)

Table 6.1 Challenges and benefits of roundabouts

Challenges	Roundabout Strategies and Benefits
Effect on air quality impacts	<ul style="list-style-type: none"> • Potential for reduced transportation related emissions • Evaluate using US emission factors
Non-motorized users	<ul style="list-style-type: none"> • Pedestrian exposure reduced • Increased safety with reduced conflict points and reduced speeds
Impact on community character	<ul style="list-style-type: none"> • Community gateways

Several other considerations often come up in planning a roundabout that go beyond intersection and access control. Environmental impacts, multi-modal accommodations, and aesthetics also require attention when considering a roundabout on a corridor.

6.1 Air Quality Impacts

One implicit benefit attributed to the use of roundabouts over traditional stop or signal control intersections is reduced emissions. Roundabouts are expected to provide smoother flow, reduce idle time, and result in fewer stops which lead to reduced emissions and fuel consumption. As a result, roundabouts are increasingly being included as Congestion Mitigation and Air Quality

(CMAQ) projects.

Air quality benefits of roundabouts, however, have not been completely quantified. The FHWA's *Roundabouts: An Informational Guide* provides minimal information on estimating environmental benefits, though it does caution that models should be calibrated for current U.S. conditions since a number of publications on roundabouts are based on European literature (Robinson et al, 2000).

Roundabouts are expected to reduce emissions as a result of reduced delays and stops; however, roundabouts slow all vehicles to speed ranges where emissions may be higher, while signals stop and delay only a portion of vehicles. Roundabouts may also increase the amount of acceleration and deceleration for all vehicles. Emissions are correlated to these modal events, therefore increases in deceleration and acceleration should be considered in the evaluation of roundabouts. Additionally, studies which evaluate emission reductions due to roundabouts use default values from roundabout design software to calculate delay and emissions rather than using emission factors from the US Environmental Protection Agency's (USEPA) model, MOBILE (CTRF, 2001).

Several studies have indicated that roundabouts produce lower emissions than stop controlled intersections or signalized intersections. The majority have used a traffic analysis package to evaluate impacts and in most cases have relied on the models default emissions. One study used a portable emissions monitor and measured actual emissions before and after roundabouts were implemented. They found that average emissions increased at roundabouts that replaced non-signalized junctions (Hyden and Varhelyi, 2000). The studies are summarized in the following sections.

Mandavilli et al (2003) evaluated three locations in Kansas where a roundabout replaced all-way stop controlled intersections. They video taped the actual intersections to collect traffic variables and then used aaSIDRA to evaluate differences in emissions before and after the roundabouts were installed. The aaSIDRA analysis reported:

- 38% and 45% reduction in carbon monoxide (CO)
- 45% reduction for particulates (PM)
- 55% and 61% reduction in carbon dioxide (CO₂)
- 44% and 51% reduction in nitrogen oxides (NO_x)
- 62% and 68% reduction in hydrocarbons (HC)
- Statistically significant decrease in delay, queuing, and stopping

Varhelyi (2002) evaluated the driving patterns of vehicles before and after implementation of a roundabout at a signalized intersection. This information was used to estimate emissions. Test drivers in an instrumented car followed vehicles and attempted to imitate the vehicle's driving pattern. Emissions and fuel consumption were calculated using emission and fuel consumption factors for specific speed and acceleration based on Swedish values. They found that speeds

decreased by 11 seconds. The number of vehicles stopping decreased from 63 to 26% of the total. Carbon monoxide emissions decreased by 29%, nitrogen oxide emissions decreased by 21%, and fuel consumption decreased by 28% based on the Swedish values.

Bergh et al (2005) evaluated traffic flow for ten northern Virginia signalized intersections and one stop controlled intersections which were determined to be good candidates for a roundabout based on volume and intersection geometry. They evaluated performance for the existing control and then compared that with the hypothetical situation of including a roundabout using aaSIDRA. The analysis was based on data collected during peak periods for two days. They determined that average vehicle delay would be 17 to 92% lower for the roundabout alternative than for signalization. Results also estimated a 16% reduction in fuel consumption.

Hyden and Varhelyi (2000) evaluated speeds and emission before and after installation of small roundabouts in Sweden. Speed profiles were recorded by instrumenting vehicles and using a chase car methodology. Speed was recorded two times per second and average speed profiles developed. Overall they found that roundabouts reduced speeds considerably both at the intersection and on links between roundabouts. Statistically significant reductions in mean speeds were reported at 7 of 10 approaches evaluated. The main factor in speed reduction was the lateral displacement forced by the roundabout.

At non-signalized intersection they found that delay increased for vehicles on the main road and decreased on the minor road after implementation of a roundabout. Since minor street traffic was only 30% of main road traffic, delay increased overall by an average of 0.75 sec/vehicle. At a signalized intersection, delay decreased overall by 11 sec per vehicle and number of vehicles stopping decreased from 63 to 26% after implementation of a roundabout. Emissions were calculated from the speed profiles using a Swedish model that has emissions for different levels of speed and acceleration. Emissions could only be calculated for gasoline passenger vehicles. At the unsignalized intersection CO increased by 6% and NO_x by 4%. At the signalized intersection CO decreased by 29% and NO_x decreased by 21%.

Most of the studies which have evaluated the air quality benefits of roundabouts have used computer models to generate results. One study was found which measured actual on-road emissions for roundabouts. Zuger and Porchet (2001) evaluated four locations in Switzerland which were converted to a roundabout. They instrumented a vehicle with mobile exhaust gas measurement equipment which measured fuel consumption and actual emissions. The test vehicle was driven through each of the five intersections a number of times both before and after implementation of the roundabout. They measured emissions for each approach. They determined that hydrocarbon emissions were too low to be practically compared. They found that speeds and emissions depended on local conditions (amount of traffic, frequency of interruption of traffic number of pedestrians, ratio of traffic density on different branches, etc) and time of day.

The first location was characterized by high traffic density. The intersection was unsignalized with minor approach control before. Installation of a roundabout resulted in a reduction of speed and interruption of previously smooth traffic for the main direction of flow with an improvement in flow for the minor direction of flow. An increase in fuel consumption, CO, NO_x, and CO₂ resulted. The next intersection was also unsignalized with minor approach control. In the main direction of traffic, speeds decreased slightly. Fuel consumption, CO, and

CO₂ increased while NO_x decreased. The authors noted that installation of the roundabout led to braking and acceleration on the main direction when previously flow was at constant speed. The third roundabout was also unsignalized with control in the minor direction. No change in average speed or NO_x was observed while fuel consumption, CO, and CO₂ decreased. The fourth intersection previously had a traffic signal. Average speeds increased. NO_x increased while fuel consumption, CO, and CO₂ decreased.

The authors concluded that the effect of roundabout is different at different times during the day depending on traffic density. In general, they indicated that roundabouts are favorable for emissions when a light-controlled crossing is replaced by roundabout. However, when a signal is replaced by a roundabout, they found unfavorable fuel consumption and emissions. They indicate that roundabouts are likely to have a negative impact when previous smooth flow is replaced by slowing and acceleration and that the effect could be even greater with grade. They also suggested that if traffic flow on the minor street is lower by a factor of 5 to 10 than the main direction, unfavorable effects are expected in terms of speeds and emissions when a roundabout is used.

6.2 Non-motorized Users

6.2.1 General Concerns

The ability of pedestrians to safely cross a roundabout is often a concern when a new roundabout is proposed. Right-of-way is not assigned for pedestrians at roundabouts, as it can be using a pedestrian walk phase at a signal. Drivers may also be unfamiliar with roundabouts and as a result may not be paying attention to pedestrians. Crossing may be difficult for blind or handicapped pedestrians.

Traditionally, no pedestrian indicators are installed at roundabouts to assign right-of-way to pedestrians crossing the intersection as seen at signalized intersections. The U.S. Access Board has issued a DRAFT Public Rights-of-Way Accessibility Guidelines (2005) that requires a pedestrian activated signal on the approaches of multi-lane roundabouts that have accommodations for pedestrians. Additionally, guidelines are proposed regarding the placement of landscaping at roundabouts to aid visually impaired pedestrians in locating cross walks. This will have an impact on how roundabouts handle pedestrians but will not be discussed at length in the document.

Section 7.3 discusses pedestrians in general, use of roundabouts near schools and child pedestrian concerns are provided in Section 3.3.1.

6.2.2 Roundabout Benefits for Pedestrians and Bicyclists

Roundabouts reduce speeds, provide shorter crossing distances, and allow pedestrians to only cross one direction of travel at a time, all of which are beneficial to child pedestrians and bicyclists. Figure 6.2 shows a pedestrian crossing at a roundabout and at a similar intersection with a traditional intersection design. (Brown County, WI). As shown, the crossing distance is reduced and the pedestrian can safely cross in stages with the refuge island.



Figure 6.2 Pedestrian crossing accommodations at the Lineville/Cardinal Roundabout compared (left) to a regular intersection (right) (Brown County, WI)

6.2.3 Case Study—Asheville, NC

College Street in downtown Asheville, North Carolina underwent a road diet. This corridor was a typical traditional intersection with four through lanes and left and right turn lanes at the intersections. Figure 6.3 shows before and after photos of the College Street/Valley Street/Oak Street intersection. Previously, a pedestrian would have to cross six lanes of traffic at the intersection and now the pedestrian crosses only two lanes. The splitter island also provides a refuge prior to crossing the second direction of traffic. Landscaping and bike lanes were also easily added to this corridor as a direct result of reducing the through lanes and eliminating the turn lanes at the intersection.



Figure 6.3 College Street in Asheville, NC: before (left); after (right) (Butzeka)

6.3 Community Character

Some communities may be concerned that roundabouts will take up too much space or be out of context. However, since roundabouts can be designed with aesthetic features and landscaped, they easily are modified to fit within a community’s character.



Figure 6.4 Teardrop Roundabout on the I-70 exit ramp to Avon, CO (Isebrands)

Central islands and extended splitter islands provide a green space for landscaping and/or art work. Landscaping can range from flowers to grasses to trees and shrubs. Art work may portray the community's character and exhibit a sense of place or identity of an area. Figure 6.4 shows flags and evergreen trees in the central island of an Avon, CO roundabout. Installation of landscaping and other rigid objects should meet clear zone requirements, however.

In some areas, roundabouts have been used as a gateway to a community entrance. The roundabout can be designed to fit within the community character and provides a delineation that indicates to drivers that they are entering a new community. A roundabout was used as a gateway into the Hilton Head Plantation (Hilton Head, South Carolina) as an alternative to a signal as shown in Figure 6.5.



Figure 6.5 Roundabout as a gateway in Hilton Head, SC (CTRTR, 2008)

Chapter 7

Roundabout Performance with Unbalanced Traffic Flows



Figure 7.1 Traffic on roundabout (Isebrands)

Table 7.1 Challenges and effectiveness of roundabouts

Challenges	Roundabout Effectiveness
<p>Delays caused to the major route as a result of slowing down and gap availability for the minor route</p>	<ul style="list-style-type: none"> • Roundabouts can be used to accommodate dominant major route turning movements • Drivers choose gaps to enter the intersection at a roundabout rather than being assigned right-of-way by a signal

7.1 Delays on the Major Route and Gap Availability on the Minor Route

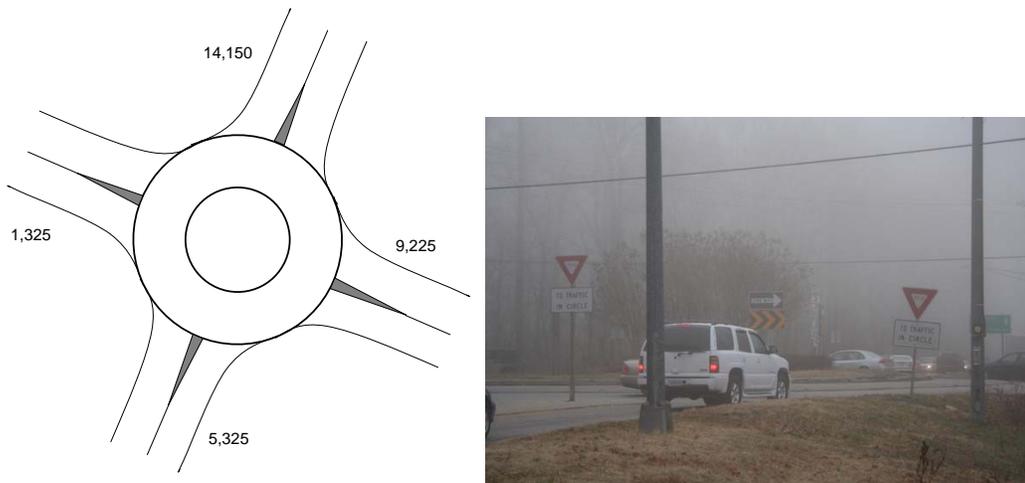
Existing roundabout guidelines caution against the construction of roundabouts at intersections with unbalanced traffic flows; however, roundabouts exist at such locations in the U.S. The concept - unbalanced flows - covers a wide range of volume combinations. Flows may be unbalanced between the major and minor routes or may be unbalanced between all the approaches. The concerns in relation to roundabouts at intersections with unbalanced flows stem from the potential for additional delay on the major road approach for vehicles that may have not had to slow under two-way stop control or actuated signal control conditions. This effect is called reverse priority.

Hyden and Varhelyi (2000) evaluated speeds before and after installation of small roundabouts in Sweden. Speed profiles were recorded by instrumenting vehicles and using a chase car methodology. The research evaluated several different scenarios. They evaluated un-signalized intersections where the minor street made up only 30% of the traffic on the main road. They found roundabouts increased the delay for vehicles on the main road and decreased delay on the minor road. Delay increased overall by an average of 0.75 sec/vehicle.

The individual intersection traffic characteristics will dictate whether a roundabout will operate effectively at an intersection with unbalanced flows. The volume of traffic turning, especially left hand turns, at the intersection will have substantial impact on the operations. The roundabout geometry, namely the number of circulating lanes, also plays a critical role in assessing the success or failure of a roundabout with unbalanced flows, just as signal phasing and actuation can effect the operations at an intersection. Hybrid circulating lane configurations (1/2 lane or 2/3 lane) can provide additional flexibility for roundabout operations when dominant flows are present.

Intersections where one approach has a significant number of left turning traffic may benefit from a roundabout. An example of such a case is the Lothian, Maryland roundabout. This roundabout operates well under unbalanced flow conditions. It is a rural, single-lane roundabout at the intersection of MD 2 and MD 408/MD 422 and is a commuter route south of Annapolis, Maryland. A right turning movement is dominant during the AM peak and this flow reverses during the PM peak with a high left turning movement. AADT for each approach for the construction year (1997) is shown in

Figure 7.2. Due to the low speeds at the roundabout, vehicles on the two minor approaches are easily able to find gaps and enter the circulating lane with the major route traffic.



Source: Traffic Data - Maryland DOT Image Source: Isebrands

Figure 7.2 Unbalanced flows at MD 2 and MD 408/MD 422 Roundabout

Agencies should not exclude roundabouts at intersections with unbalanced flows without conducting an analysis of all possible solutions. Intersection capacity benefits may be more evident for some volume and turning movement combinations than others.

7.2 Sensitivity Analysis—Unbalanced Flows

Little information was available in the literature that discusses whether and under what circumstances roundabouts can handle unbalanced flows. As a result, the research team conducted a sensitivity analysis at an intersection in Ames, IA (US 69/Grand Avenue and 13th Street) that evaluated how well unbalanced flows were handled at an intersection using two alternatives. The first alternative was a traffic signal with left turn lanes present at the intersection. The second alternative was to use a roundabout. The intersections were analyzed in isolation using RODEL (Issue 1.07) and aaSIDRA (Version 2.1) software for the roundabouts and aaSIDRA for the signalized intersection.

This analysis provided insight into various flow conditions during a peak hour and the resulting roundabout and signalized intersection operations, specifically delay and queues. The models were calibrated with existing conditions and then volumes were varied to reflect different scenarios from balanced to unbalanced flow. Fourteen scenarios were modeled as shown in Table 7.2. A total of eight scenarios were evaluated with different volumes assuming that 10% of vehicles at each approach turned left, 10% turned right, and the rest were through vehicles. Six scenarios with varying volumes were evaluated assuming that 25% of vehicles at each approach turned left, 10% turned right, and the remaining were through vehicles. The circulating plus entering volumes varied between 900 and 2000 vehicles for each approach which are within an appropriate range for a two-lane roundabout.

Table 7.2 Volume scenarios

		10% Left Turns				25% Left Turns			
		NB	SB	EB	WB	NB	SB	EB	WB
Volumes ↓ Unbalanced	Balanced	1000	1000	1000	1000	700	700	700	700
		700	700	700	700	1200	1000	500	600
		1000	1000	500	900	1000	500	400	800
		1200	1000	500	600	1000	500	400	400
		1000	500	400	800	1200	1000	200	300
		1000	500	400	400	1500	1200	200	300
		1200	1000	200	300				
		1500	1200	200	300				

RODEL and aaSIDRA were used to analyze the different scenarios. The performance metrics were average approach delay and 95% back of queues. (The 95% back of queue is the number of vehicles in queue that only occurs 5% of the time during the analysis period.) Figure 7.3 shows the simple geometry used for the analysis. The roundabout was analyzed with a 180 ft diameter, two 17 ft circulating lanes, one thru-left lane and one thru-right lane. The signalized intersection was analyzed with a 150 ft left turn lane, one thru lane and one thru-right lane.

The signal timings for the signalized intersection were optimized using the software for each scenario. As a result, cycle lengths varied from 40 to 112 seconds for the 10% left turn scenarios and 35 to 112 seconds for the 25% left turn scenarios. Changes in volumes by approach and the percentage of left turns requires significant modifications to the signal timings, as well as the length of the left turn lane (or number of turn lanes).

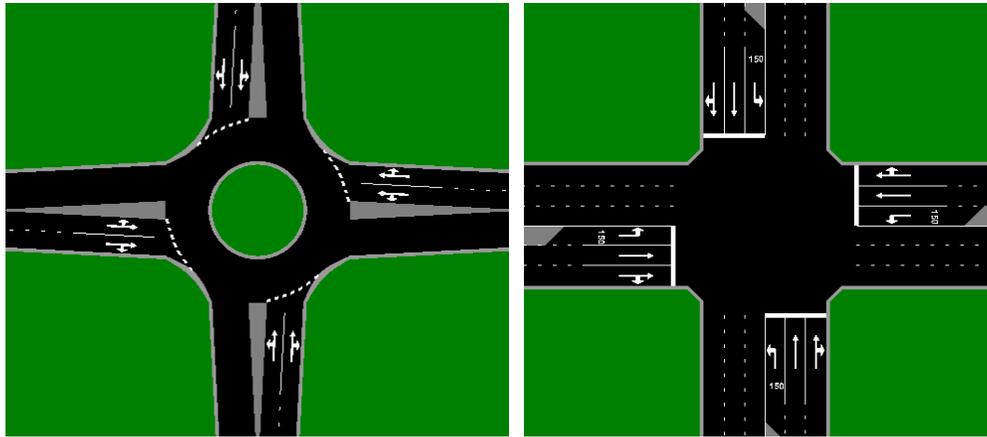


Figure 7.3 Intersection layouts—roundabout (left); signalized intersection (right) (aaSIDRA)

The RODEL and aaSIDRA results for the roundabout approach delays and 95% back of queues were similar. RODEL had an average of 2 seconds less delay than aaSIDRA for the 10% left turn scenarios and 5 seconds less delay for the 25% left turn scenarios. RODEL reported an average of 2 less vehicles in queue than aaSIDRA for all the scenarios.

7.2.1 Results

Delays at the roundabout were considerably less than the signalized intersection, regardless of whether the volumes were balanced or unbalanced. Figure 7.3 shows graphs of average delay and 95% back of queue for each of the scenarios. The scenarios with balanced flows had similar delays and queues, but how often does an intersection have completely balanced flows – not too often.

The unbalanced flows at the roundabout result in average delays for all the approaches within 4 seconds of each other. The smaller, minor approach volumes at the roundabout did not have a great impact on the major approaches for an intersection with 10% and 25% left turns (both with 10% right turns). The signalized intersections show a much higher variability in delay between approaches and scenarios.

The 95% back of queues for the extreme cases of balanced vs. unbalanced flows had 9 and 10 vehicles queues, respectively, however the unbalanced scenario produced an 8 vehicles to 9 vehicles higher vehicle queues for the major routes than the minor route. Figure 7.4 shows the graphs of the 95% back of queues for each scenario. Similar to the delays, the signalized intersection alternatives have significantly higher number vehicles in queue.

7.2.2 Conclusions

As was shown by this sensitivity analysis, the roundabout performed substantially better than the optimized signal during the peak hour at this isolated intersection with 10% and 25% left turns. Roundabouts should not be ruled out as a viable alternative at an intersection with unbalanced flows. Intersections should be evaluated to consider all solutions, including roundabouts, when addressing safety and operations for both existing and new intersections.

This analysis did not address the potential delay to traffic on the major or minor routes during off-peak periods due to the roundabout (i.e. all traffic having to reduce speeds at the intersection); however, it is known that the safety implications of roundabouts (i.e. near elimination of right-angle, high-speed crashes) should be a part of the balanced intersection analysis for all hours of the day. Additionally, the analysis also could not consider effects such as platooning as it was evaluated in isolation. However, the results suggest that roundabouts can be effectively used in situations where unbalanced flow exists and a signal would have been the alternative traffic control. The analysis also did not address the situation where a roundabout would replace 2-way stop control. In all cases, each potential alternative should be evaluated for the existing situation before selecting the best alternative.

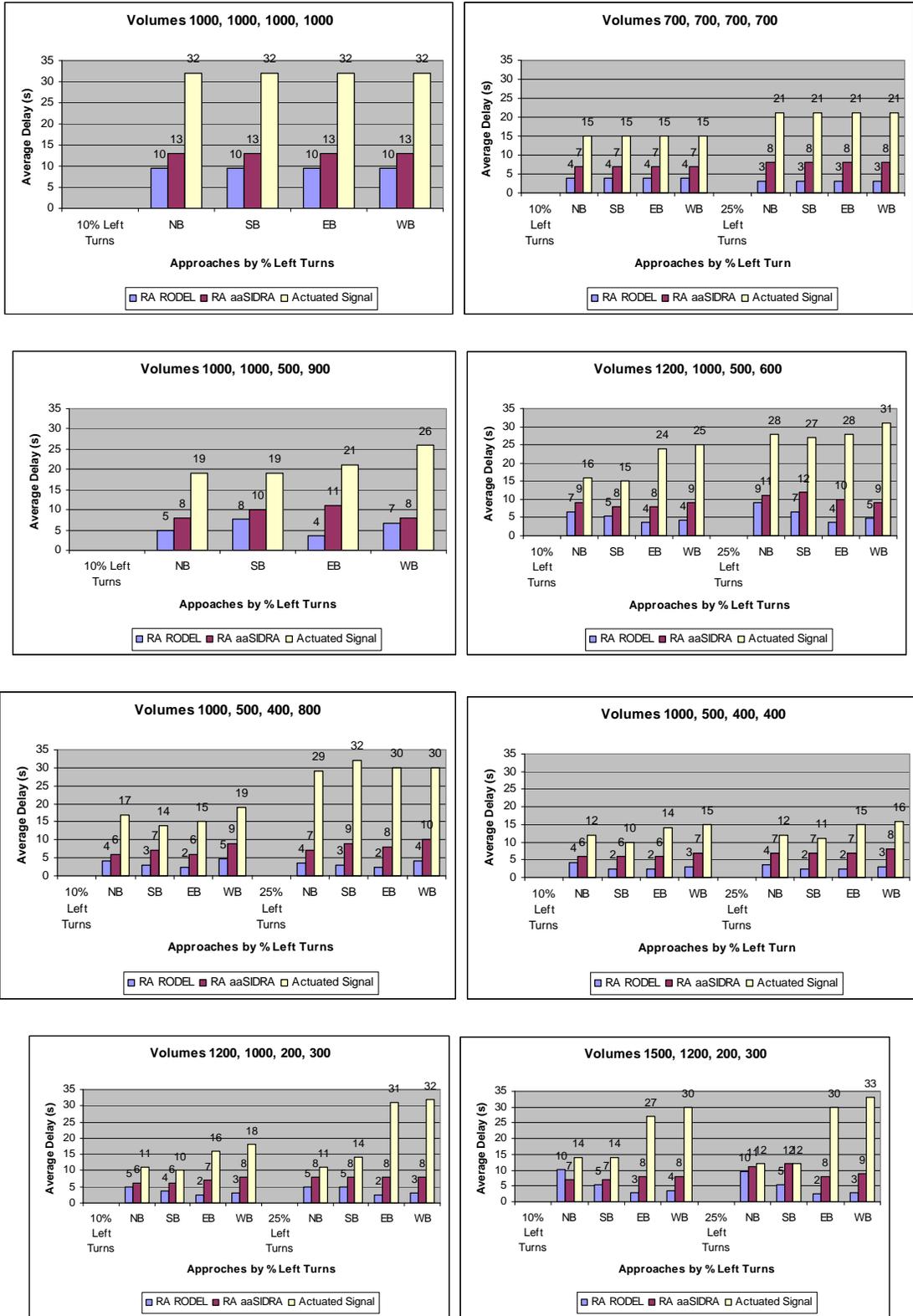


Figure 7.4 Average delay by volume scenario and left turn percentage

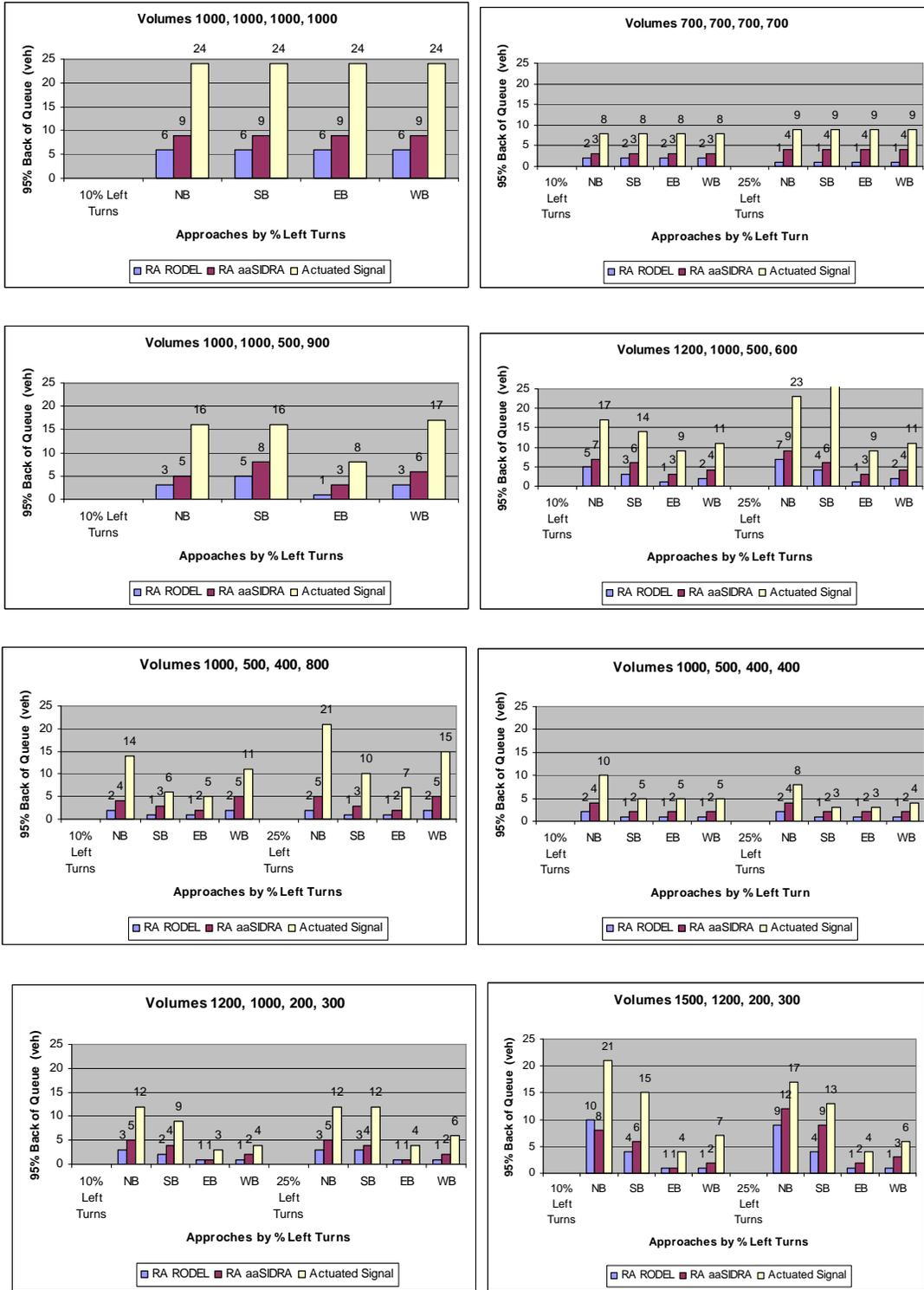


Figure 7.5 95% Back of queue by volume scenario and left turn percentage

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