

Modern Roundabout Intersections: When To Use Them? A Comparison With Signalized Intersections

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Across the nation, traffic growth and congestion continue to outpace growth in highway capacity. A large amount of this congestion occurs at intersections, rather than along the links between intersections, it is of utmost importance that traffic engineers use every available technique for improving intersection performance and safety. This paper examines the benefits of roundabouts as an alternative to traffic signals in appropriate situations. The differing operational characteristics of roundabouts and traffic signals are compared. Consideration is then given to how traffic engineers can make good use of the differences in roundabout and traffic signal operation to achieve safe and efficient traffic operation, reduce congestion, and mitigate the negative impacts often associated with roadway and highway projects.

Introduction:

The example projects in this paper were specifically chosen to exemplify how the operational characteristics of roundabouts better achieved the project objectives than the signalized alternative. These projects encompass both developing areas and existing infrastructure that needed both capacity and safety improvements.

This paper discusses the performance of roundabouts and compares them to the performance of conventional projects that typically involve signals.

Performance measures are also discussed. These include traffic operations, vehicle safety, residential impacts, business impacts, circulation needs, pedestrian and bicycle connectivity and pedestrian and bicycle safety will be discussed.

This paper and the videoing of signals and roundabouts developed because of a need to communicate technical and analytical conclusions more easily. The goal of this has been to enable elected officials, decision makers, stakeholders, and the public to better understand the operation and benefits of roundabouts.

Visuals that show roundabouts are not from Mars and that they can provide significant benefits in certain situations are extremely effective at reducing anxieties and fears by communicating otherwise difficult technical information in an easily understandable way. This essential part of the process greatly increases the chances that a roundabout will be implemented. However, roundabouts are not a panacea and detailed technical analysis, based on sound engineering principles, is absolutely critical to the success of all roundabout projects.

Balancing Competing Needs

As transportation professionals and traffic engineers, we are responsible for the difficult and challenging task of balancing the competing needs of the various users of the transportation system.

Achieving one goal or objective often conflicts with other objectives. This often leads to the dissatisfaction of individuals or groups, who perceive that their objectives have not been addressed adequately. This results in on-going discussions and arguments on almost all projects and is a problem that is common in all communities across the country.

Signalization: A major objective of Traffic Signal design is to maintain the free flow of traffic. This requires that important design decisions be made in assigning green time to vehicle movements (signal phases). When exclusive phases such as left-turn arrows are added, this generally increases cycle lengths and adds to the overall delay. The green time available in more efficient shorter cycles is often insufficient for traffic needs. Factors such as progression efficiency, pedestrian times and clearance intervals need to be balanced, but this often leads to increased delay. The result is often more lanes, longer cycle lengths and longer queue storage provision. To accommodate these design requirements and to achieve optimal operation, good design practice dictates that we minimize conflict points, reduce turning movements and eliminate business driveways or side streets close to intersections. Also, to achieve optimal performance, conventional design techniques often create unavoidable impacts to adjacent land uses. However, new tools can help us achieve better results when properly applied in appropriate circumstances.

Roundabouts: Excellent traffic operation and exceptional vehicle and pedestrian safety is presently being achieved by U.S. roundabouts, with traffic volumes ranging from 2,500 - 5,000 vehicles per hour. In addition, these projects have minimized negative impacts, such as costly road widening and the need for expensive structures. They also preserved excellent business and side street access, and have minimized residential impacts.

Current U.S. experience with high capacity roundabouts is limited mainly because they are new and un-familiar. Fear and skepticism by both the public and transportation professionals alike is understandable. This is often due to limited knowledge and / or due to bad experiences of older “nonconforming” traffic circles or poorly designed new roundabouts. Overcoming these fears is not easy but is well worth the effort.

Design Methodology Differences and Similarities

Traffic engineers generally think in terms of 90-degree angles, straight lines, hardware and communication requirements when designing traffic signals to help solve traffic congestion problems. Curved lines, round shapes and circles are unfamiliar to many and at first glance roundabouts can look ‘artsy’ and not like an ‘engineered’ solution.

However, roundabout design techniques have many similarities to signal design methods. For example, both roundabout and signal design requires balancing many variables to

achieve an optimal design. Capacity and safety trade-offs are common to both types of intersection.

For roundabouts, design considerations, such as overall size, overall shape, entry angles, entry widths, flare lengths, speed constraint, truck movements, pedestrian and bike accommodation, signing and striping issues, must all be optimized to achieve good designs. To produce good roundabout designs, engineers need to learn new skills and to develop an understanding of a new design methodology. However such skill and understanding is based on principles that are very familiar to U.S. traffic engineers.

The required skill and knowledge takes time and practice to develop. However, instruction and guidance from experienced and expert roundabout designers will greatly speed up this process. In addition, design review by such professionals will ensure that only good designs are produced. The changes required by the review, with the underlying reasons, will provide excellent learning opportunities for the engineers working on the project.

Many traffic and transportation engineers are starting to realize the potential benefits of roundabouts and are seeking opportunities to learn about this new traffic-engineering tool. Many have started designing and implementing roundabouts.

Case Study #1

New Infrastructure: Planned Mixed-Use Development Loveland Colorado,

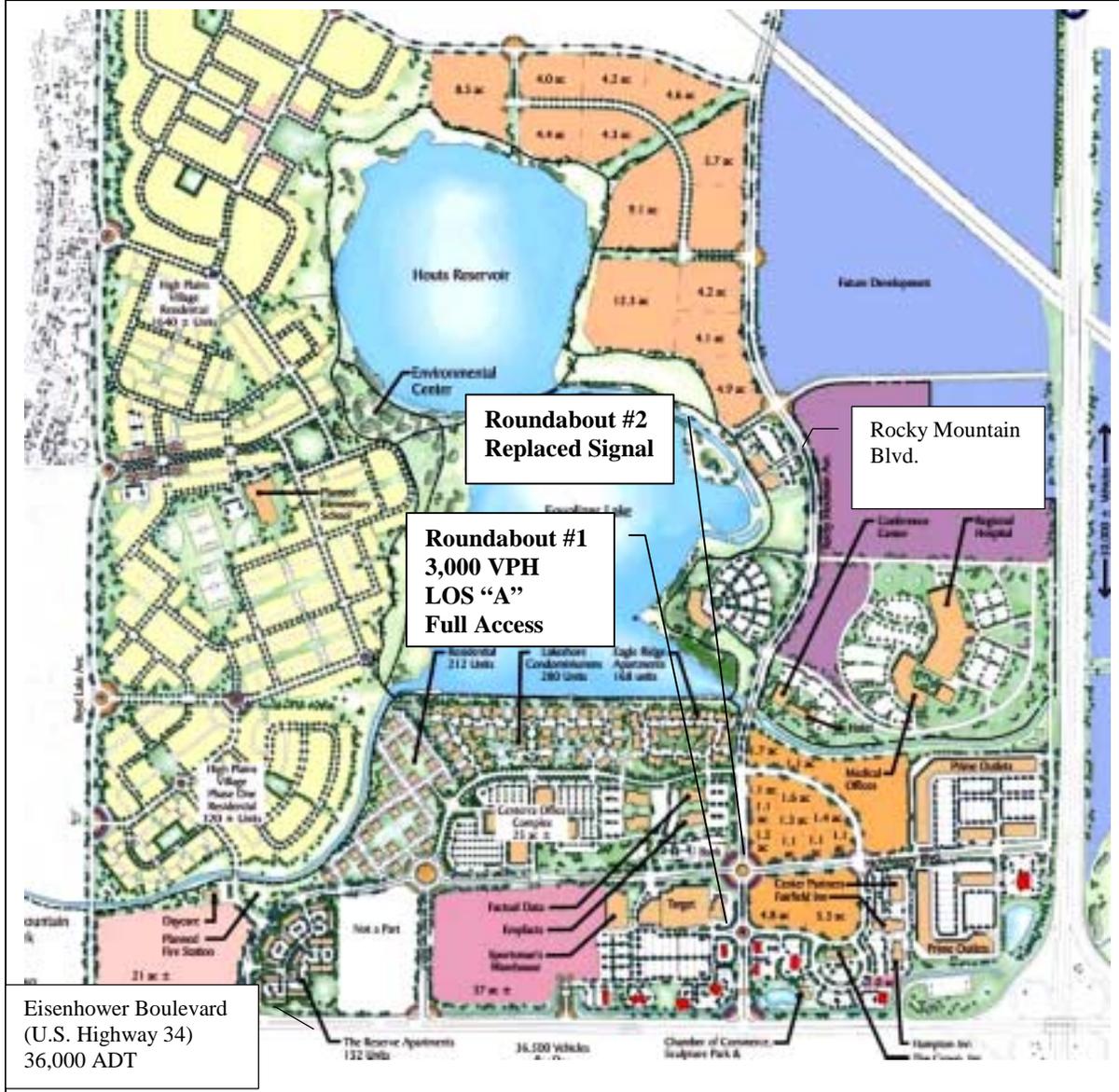
Project Overview

This project is located in the rapidly growing City of Loveland, Colorado (pop. 50,000) located approximately one hour north of Denver along the Front Range. It includes two, two-lane entry roundabouts constructed in August of 1998 as part of a large Mixed Use Development with an 'outlet style' 318k sq. ft. regional shopping mall, a 123k sq. ft. Super Target and other retail uses including 3 fast food and 6 sit down style restaurants, 1500 existing and planned residential units, office, hotel, day care health care uses (Figures 1).

Roundabout #1 is located on a planned major 4-lane Arterial (existing 20,000 ADT), and is located 400 feet from a major signalized intersection at Eisenhower Boulevard (U.S. Highway 34 - 35,000 ADT). The minor legs of the roundabout provide access to a shopping area and to a collector street providing access to a variety of uses including fast food. This roundabout has peak hour design volumes of 4,500 vehicles. It currently carries 3,000 VPH during peak periods and has an overall LOS "A". It has a good safety record with no injury crashes and only 5 Property Damage Only crashes (PDO) since opening in August of 1998. No pedestrian or bicycle crashes have been reported since it opened.

Roundabout #1 has the advantage of providing full access at this location a benefit that was precluded using Traffic Signals because of spacing requirements. In addition, the roundabout facilitated a secondary right/in-right-out access 150' to the south, down stream of roundabout #1.

Figure 1: Major Mixed-Use Development: Loveland, Colorado (Graphic Courtesy of McWhinney Development Corp.)



Photograph A below was taken on the opening day of the Super Target store in 1998. The minimal queues at the roundabouts exemplify their very good operational characteristics and sharply contrast with the considerable queuing at the Traffic Signals, even though

both types of intersection were designed to minimize queues and delays. The heavy left turn demand from Eisenhower Boulevard (at the bottom of Photo “A”) is stacked waiting for the green arrow, while the roundabout shows a much shorter stacking distance under similar traffic conditions.

Photo B below of Roundabout #1 was taken on the busy Friday afternoon of July 12, 2002. It shows the worst-case scenario when a platoon arrives from the two-lane left turn from the traffic Signals on Eisenhower Boulevard (U.S. 34).

However, even with the arrival of this tightly spaced platoon, the delay on this roundabout approach averages approximately 12 seconds per vehicle.

The Wendy’s drive-thru located 100’ west of roundabout #1 (access to Super Target) provides excellent ingress / egress.

The driveway entrance serving a McDonalds / Taco Bell / KFC / Steak House located 125’ east of roundabout #1 also provides excellent ingress / egress.

Photo A: September 15, 1998 opening day of Target



Photo B: July 12, 2002 Roundabout #1



The major benefits gained from the roundabouts at these locations include:

- Full Access (previously denied)
- Improved site circulation
- Higher Capacity
- Improved Safety (5 PDO, 0 injury, 0 pedestrian or bicycle crashes since 1998)

Case Study #2

Existing Roadway: Capacity and Safety Improvement (Adjacent Business Uses) S. Church Street (STH 26): Watertown, Wisconsin

Project Overview

The existing intersection of South Church Street (State Highway 26) and Bernard Street serves as primary access into two 20 - 30 year old shopping centers that include retail, grocery, banking, fast food and other retail uses. The intersection operates poorly at LOS 'F' during peak periods. It also has a very high crash rate of 5 crashes per MEV (105 crashes over 3 years).

The proposed improvement to this intersection is part of a 2.5-mile arterial roadway-widening project (two to four lanes). It extends from the existing downtown area south through the newly expanding areas of the City. Peak hour traffic volumes are approximately 2,300 vehicles. The design-hour volumes of 3,200 vehicles are split 60/40 in favor of the mainline. Trucks are 10% of the total volume. Widening from two to four lanes provides good congestion relief for the mainline roadway (Photo C). However, at the intersection of South Church Street and Bernard Street, the traffic signal alternative only provides a marginal capacity improvement for the large number of left turning vehicles accessing the businesses located off the side streets.

Additionally, both side streets have closely spaced business accesses located within 100' of the mainline (Photos D, E). They currently experience significant delay and congestion and are often blocked by stacking from the signal. The road widening and the enlargement of the existing signalized intersection will shorten the distance between the signal stop lines and the accesses creating more blocking despite the small increase in signal capacity.

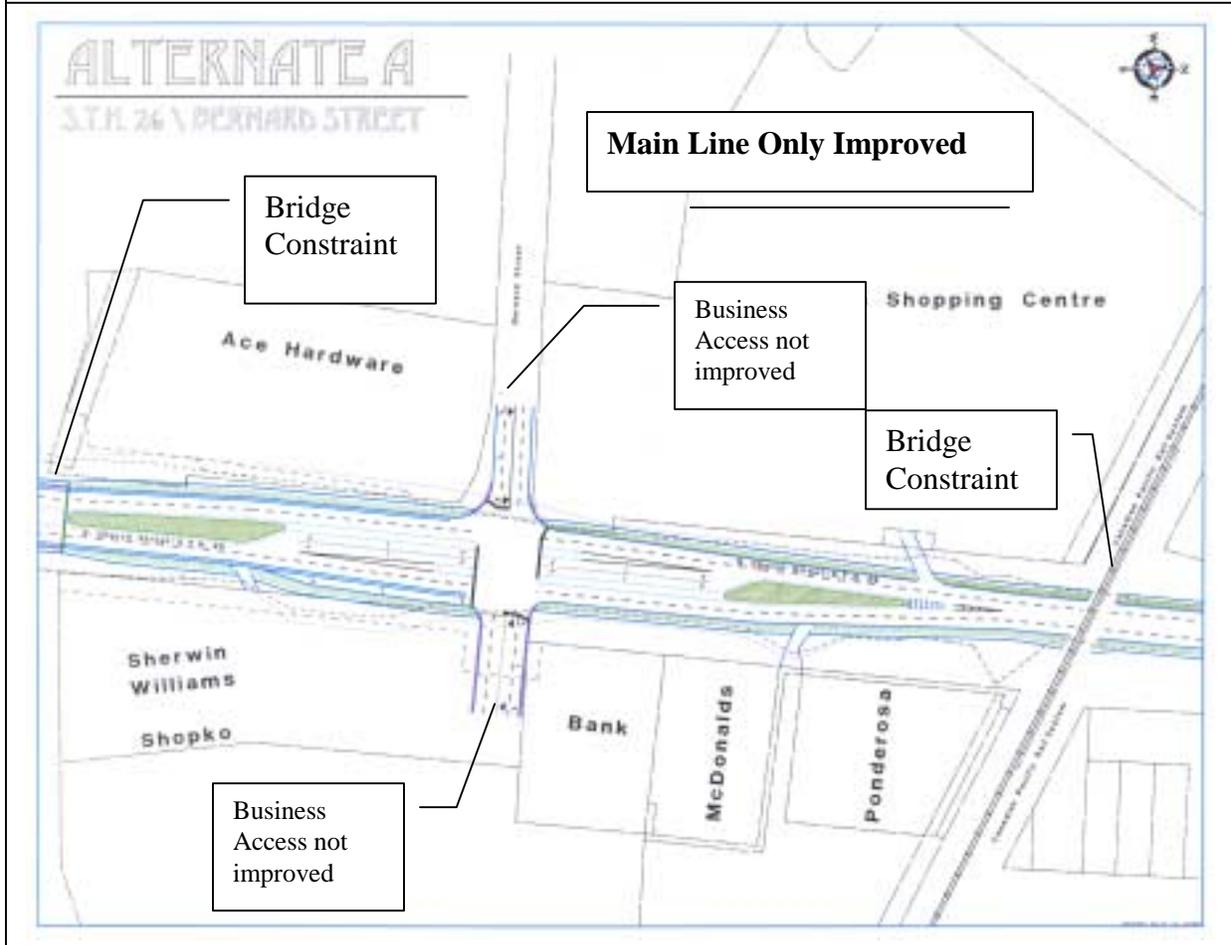
Photo C-E



Design Constraints

The intersection has existing constraints on the main line (STH 26) that include a bridge over the Rock River 550' to the south and an overhead train bridge 775' to the north. These constraints (see Figure 2 below) preclude standard taper lengths and adequate turn lane store storage for left-turning design-year volumes. The signalized alternative "A" shown below provides dual left turn lanes and good thru movement LOS, with reasonable overall average LOS for short term. However, but long-term lefts deteriorate to LOS F, and the existing bridge constraints preclude the ability to achieve recommended taper lengths for lane shifting and provide insufficient left-turn storage lengths. As previously discussed, it also does not provide relief to existing side street congestion, or serve circulation needs for existing business access.

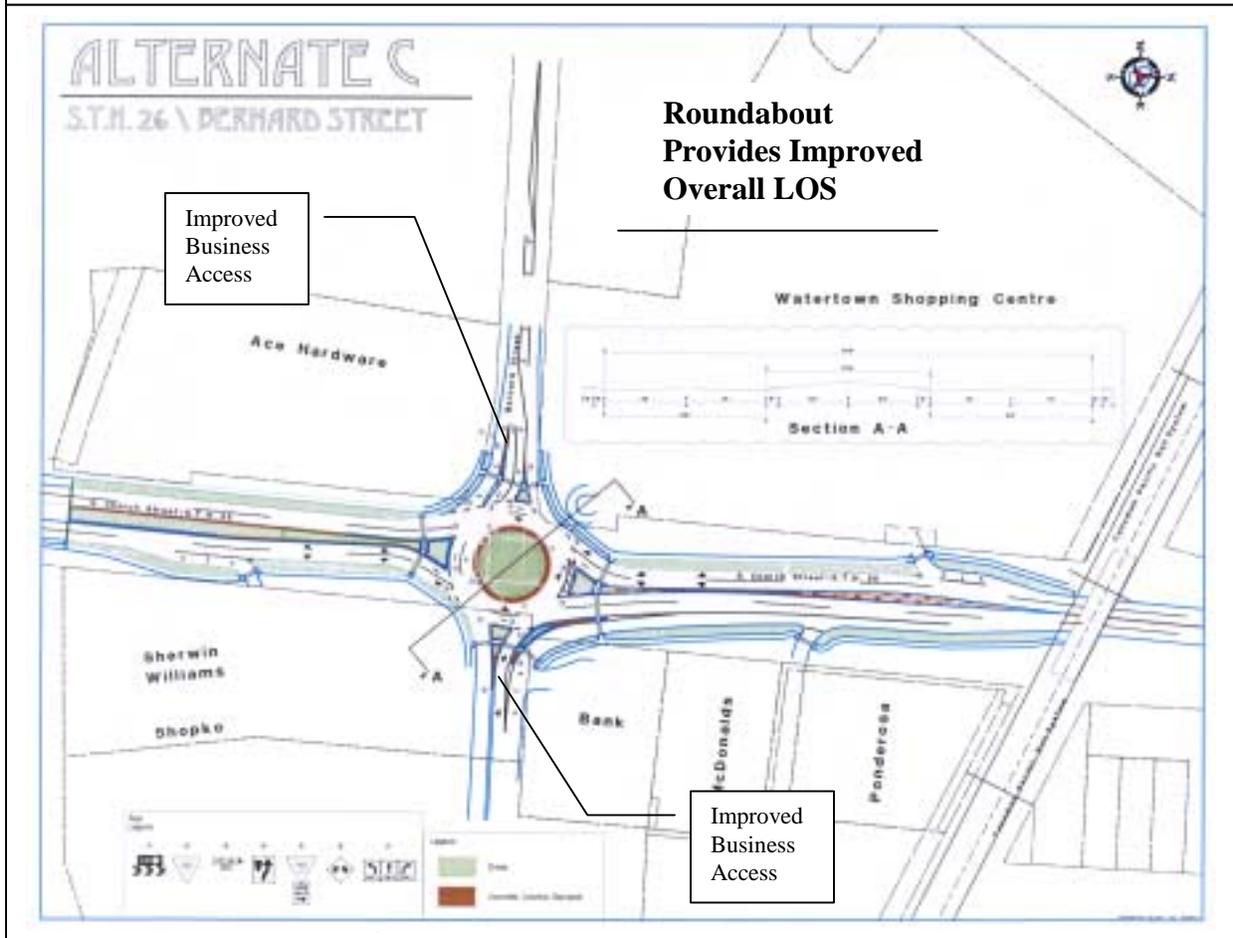
Figure 2: Signal Alternative



The operational characteristics of the roundabout alternative (Figure 3) provide an excellent LOS under existing conditions (LOS A) and future volumes (LOS C). Access to existing businesses is greatly improved, as queuing back and blocking of the access points is reduced or avoided. Pedestrian facilities are also improved, and the overall aesthetics have the potential to enhance the character for this older shopping center area.

The physical constraints that impede optimal operations for the signal alternative are not problems at all for the roundabout. The roundabout alternative can use the space available near the intersection, provide excellent operations, and meet project objectives.

Figure 3: Roundabout Alternative



The major benefits gained from the roundabout include:

- Better overall traffic operations
- Improved business and site circulation
- Improved safety for all modes
- Aesthetic and beautification opportunities (potential gateway)

Case Study Project #4

Existing Roadway: Safety/Capacity Improvements (Adjacent Residential Uses) Thompson Road/Sate Highway 30 Interchange: Madison, Wisconsin

Project Overview

These two intersections operate as a system that serve as an interchange to STH 30. Land-uses served by these intersections are primarily residential, and projected future residential and office development will cause substantial traffic growth at these intersections.

Project objectives include safety and capacity improvements and improvements to pedestrian and bicycle connectivity, while not impacting residential uses near the intersections.

The photo at right (Figure 4) shows the Thompson Road / Commercial Avenue intersection on one side of the bridge with adjacent existing neighborhood and worn paths indicating high pedestrian activity and lack of pedestrian facilities.

The Thompson Road/Commercial Ave. intersection is a two-lane approach, all-way stop-controlled intersection. Significant peak hour delay is occurring with very long wait times common (LOS F). Additionally, a high percentage of injury crashes (67%) are occurring.

The STH 30 off-ramp/Thompson Road intersection shown at right (Figure 5) is a side street stop-controlled “T” intersection and is experiencing significant delay (LOS E-F) and congestion. Also, a relatively high crash rate (1.5 crashes / MEV) with 45% injury crashes is occurring. Solutions for this interchange system of intersections must include both intersections.

Figures 6 and 7 below show the two primary alternatives developed to solve existing peak hour delay and to meet the other project objectives. Project objectives include providing

Figure 4: Homes adjacent to Thompson/Commercial



Figure 5: STH 30 Off-ramp



sufficient capacity for future traffic growth, improving pedestrian and bicycle connectivity, and preserving the livability for the adjacent residential uses. Peak-hour volumes at Thompson/Commercial are 2,100vph and design-hour volumes are 4,400 vph. Peak-hour volumes at the off-ramp intersection are 1,550vph and the design hour volumes are projected to be 2,600vph.

The signal option shown in Figure 6 achieves good existing level-of-service and good operations for the long-range traffic demand. However, the signal alternative requires road widening and moves the road very close to residences requiring the purchase of two homes. Other impacts include shorter residential driveways, and less front yard buffering to traffic. Signalization significantly changes the look and feel of the residential setting. Moreover, the existing bridge abutments preclude achieving desired storage lengths for the north-bound left-turn lane, which will negatively impact future operations.

The alternative of a system of roundabout intersections provides an excellent existing LOS (A), and provides good future LOS (C), with zero negative impacts to the existing homes. Additionally, driveway access is preserved due to the slower entering and exiting speeds at the roundabout. The roundabout provides excellent pedestrian and bicycle connectivity, mobility and safety. In summary, ‘livability’ is protected and enhanced while also achieving excellent traffic operations.

The major benefits gained from the roundabout include:

- Better overall traffic operations
- Reduced Residential Impacts
- Excellent Ped/Bike Connectivity
- Improved Safety
- Aesthetics-Gateway Opportunity
- Enhanced Livability

Figure 6 Signal Alternative

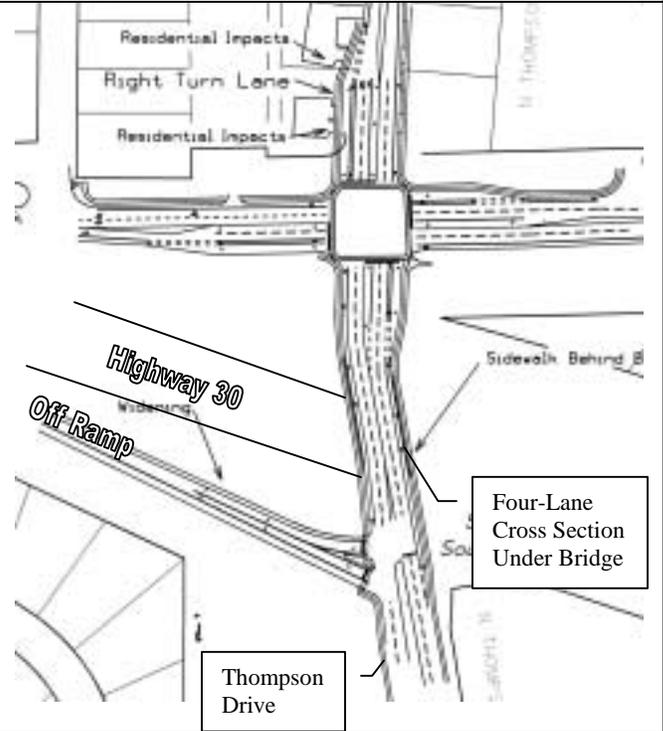
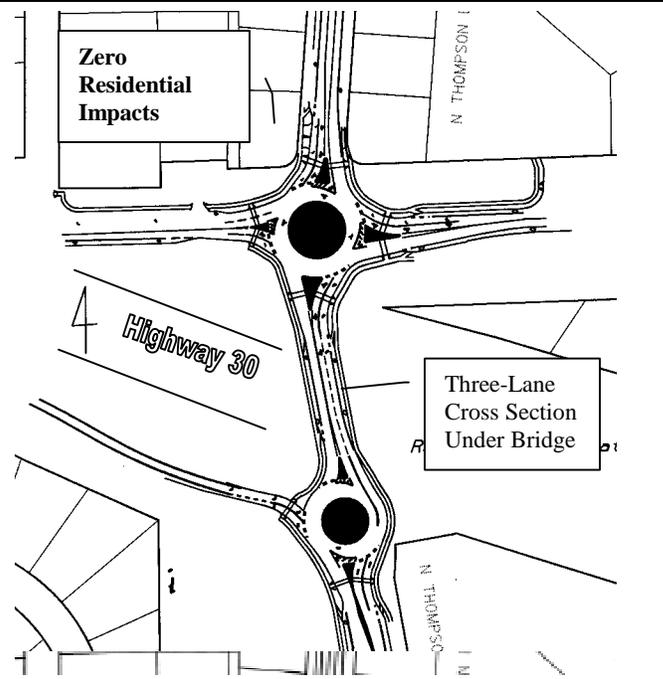


Figure 7: Roundabout Alternative



Case Study Project #5

Existing Roadway: Capacity and Safety Improvement (Adjacent Business Uses)

Interstate 70 / Main-Vail Diamond Interchange

Project Overview

Before the roundabout was constructed in 1995, this diamond interchange at the Main Vail exit from I-70 experienced very serious congestion and long delays at peak hours (Fig. 8). An engineering feasibility study showed the roundabout option would cost \$3M compared to \$20M for a conventional improvement, and provide better LOS. Conventional improvements would have required costly structure and roadway widening, similar to those shown in this photo at right (Fig. 9) of a typical interchange capacity improvement.

Background

Like most projects involving roundabouts there were many opposing opinions and no similar projects anywhere in the U.S. to observe. Vail's tourist economy relies heavily on the ability to get people on/off I-70 efficiently. Consequently, many people feared that visitors and locals alike, unfamiliar with the high capacity roundabout intersection would not be able to adapt to the proposed roundabout (Fig. 10), and it would make a bad situation worse.

The roundabout interchange opened in the fall of 1995, and the first winter ski season received 14 feet of snow, providing a good test for the pair of roundabouts. The congestion and long delays (that typically

Figure 8: Main Vail, 1998 -Typical Congestion
Courtesy Ourston Roundabout Engineering



Figure 9: Typical Interchange Widening with Signal (Ourston Roundabout Engineering)



Figure10: Main Vail Interchange at I-70



occurred during the peak hours of operation before the roundabouts) disappeared.

Both newspapers agreed that the roundabouts worked very well and publicly apologized for their earlier jokes and editorial commentary. Public opinion has been strong each year since it was opened with the project being voted the best public works project for 5 years straight.

Crashes

Since opening in 1995, 1 injury crash and 22 PDO crashes have occurred at the interchange representing an average 50% reduction for all crashes, and 80% reduction in injury crashes from the prior condition. No pedestrian crashes have been reported. One non-injury bicycle crash occurred in June of 2001 involving a right-turning Transit Bus and a thru movement bicyclists. It should be noted that this roundabout interchange experiences substantial bicycle and moderate pedestrian use.

Figure 11: Main Vail - July, 2001



The major benefits gained from the roundabouts include:

- Capacity provided for peak demand tourist seasons and future growth
- Very little off-peak delay
- Preserved good business access near intersection
- Improved safety
- Village look and feel preserved
- Pedestrian connectivity
- Lower cost

Summary

- These five case studies provide examples where roundabouts provide distinct benefits over the signal alternative.
- The roundabouts provided improved traffic operations, safety and fit into the context of the project sites very well.

- The roundabouts mitigated, the negative attributes often associated with our roadway and highway projects. Such as: impacts to business access, residential impacts, costly roadway and structure widening.
- Like all transportation projects roundabouts also require trade-offs and of course there are many situations when signals will simply outperform roundabouts.
- However, roundabouts and signals are not mutually exclusive. In fact, they are compatible and can be used in a ‘systems approach’ to achieve optimal operations.
- Roundabouts are suitable for low, medium, and high volume situations.
- Roundabouts are not a panacea; require the application of thorough traffic engineering principles and sound design techniques to achieve proper operations.

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