Roundabouts Increase Interchange Capacity

DUE TO THE HIGH APPROVAL RATING, 4.4 ON A SCALE OF 5, OF THE FIRST MODERN ROUNDABOUT INTERCHANGE THAT WAS BUILT IN VAIL, COLO., USA, IN 1995, SIMILAR ROUNDABOUTS ARE IN VARIOUS STAGES OF STUDY, APPROVAL AND CONSTRUCTION IN NORTH AMERICA NOW.

BY LEIF OURSTON AND GREGORY A. HALL

A *MODERN ROUNDABOUT* is a circular intersection whose design follows modern roundabout design guidelines (see sidebar on page 35). A *modern roundabout interchange* is a freeway-to-street interchange or a street-to-street interchange that contains at least one modern roundabout.

Flare and *taper* of modern roundabouts create high capacity where it is needed, at ramp and frontage road intersections. Entries to roundabouts are often flared to add lanes, and exits from roundabouts are often tapered to drop lanes. Thus the capacity of large roundabouts nearly equals the capacity of narrow link roads joining them. Unlike interchanges regulated by traffic signals, modern roundabout interchanges do not require long storage and turning lanes over or under the most expensive element of the interchange, the bridge.

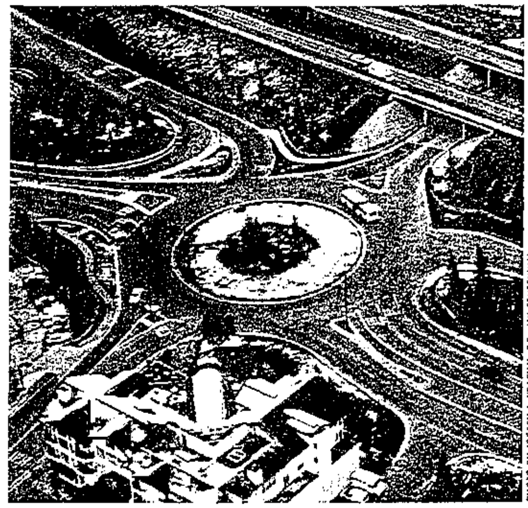


PHOTO BY JOSEPH J. KRACUM, P.E., AK CENTENNIAL

Figure 1. Vail created high capacity at low cost by widening the nodes, not the link joining them.

I-70/VAIL ROAD

The Town of Vail, Colo., USA, built North America's first modern roundabout interchange at I-70/Vail Road in 1995 (Figures 1 and 2). Closely spaced ramp and frontage road intersections, formerly regulated by stop signs, have been replaced by two roundabouts: a five-leg, 120-foot (ft) raindrop-type roundabout north of the freeway and a six-leg, 200-ft roundabout south of the freeway. The two frontage road entries to the south roundabout flare to three lanes at the yield line from two upstream lanes. All other roundabout entries flare to two lanes at the yield line from one upstream lane.

Vail considered various solutions for the interchange over the last decade, as presented in Table 1. Compared with conventional solutions first considered, roundabouts offer superior capacities, levels of service and aesthetics. Costs are similar after inflation is factored in.

BRITISH TECHNOLOGY

The project extended to North America an established British concept, the modern roundabout interchange, which has been the preferred type of freeway-to-street interchange in the United Kingdom over the past three decades. Modern roundabouts have been built away from interchanges in North America since the spring of 1990, when the first ones were built in Las Vegas, Nev., USA.[1]

Since accurate design of entry flares is essential to high-capacity roundabout design, roundabout dimensions at Vail were set using the British computer application RODEL, which facilitates the design of flared entries.[2] After the user inputs his traffic performance objective, in this case an average delay of 30 seconds per vehicle, RODEL lists pairs of entry widths and flare lengths to meet the objective. Using this and other RODEL features, the designer quickly achieves the optimal design. By contrast, the British application ARCADY does not facilitate rapid selection of entry widths and flare lengths, and capacities estimated by the Australian application SIDRA have not been validated by field counts of capacity flows.

Developed by R.B. Crown of Staffordshire County Council, RODEL contains regression equations relating roundabout capacity to six geometric parameters: entry width, length of flare, upstream roadway width, diameter, curb return radius and entry angle. The equations were developed by R.M. Kimber of the British Transport and Road Research Laboratory from track experiments involving 35 geometric variations, and from 11,000 minutes of capacity data taken at 86 public road sites.[3]

The interchange was designed following *Roundabout Design Guidelines*,[4] in which British design guidelines are translated to American transportation terms, with British illustrations mirrored to show right-side driving. *Roundabout Design Guidelines* features modern roundabout interchanges.

LOWER COSTS

Since the 36-ft-wide undercrossing was not widened, the total cost of the project was only $2.8 million. With bridge widening the cost would have been at least $5 million. The project saves the town $85,000 per year on traffic direction officers, whose services are no longer required.

HIGH CAPACITY

Before the roundabout project, the interchange was so overloaded that traffic was redirected to less impacted interchanges. Now traffic is directed toward the interchange, which has ample reserve capacity, as shown in Table 2.

LOW DELAY

Long queues of traffic used to extend back onto the freeway.[5] Now, even under the heaviest traffic, queues rarely exceed 10 vehicles. People used to wait in traffic as long as half an hour on peak ski days just to enter or leave Vail. Frustrating waiting times have been eliminated. Reduced idling time has reduced air pollution and fuel waste.

FEWER CRASHES

The total crash rate for the first year of operation decreased 12 percent, to 22 crashes in the after period from an average of 25 crashes per year in the before period. Injury crashes decreased 40 percent, to three from an average of five, as shown in Table 3. These changes are not statistically significant.

The crash rate for the second six-month winter of operation, which is not tabulated here, was exactly the same as for the first winter of operation, with regard to the total number of crashes and injury crashes, at both the north roundabout and the south roundabout. This is an indication that the crash rate of the remodeled interchange may be fairly stable.

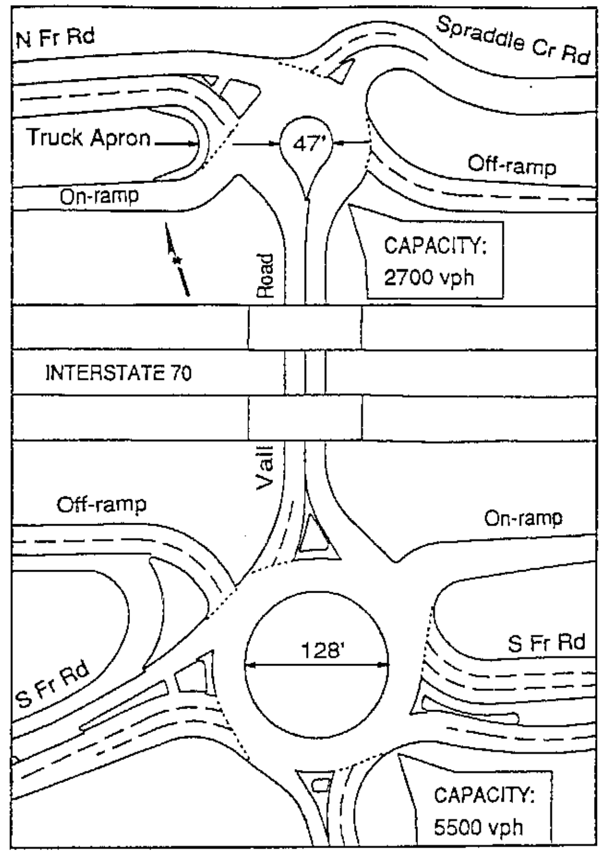


Figure 2. Following British guidelines, lanelines were not painted in the circulatory roadways.

HIGH APPROVAL

A survey of residents' opinions was taken to measure the acceptance of the modern roundabout interchange. The project received an average rating of 4.4 on a scale of 5—a high approval rating for a public works project. In addition to improved traffic performance, residents expressed appreciation of the beautiful entry statement to their world-class resort.

Table 1. Alternatives studied to relieve traffic congestion, south side of I-70/Vail Road.

ACTION	YEAR STUDIED	CAPACITY VEH/HOUR	LEVEL OF SERVICE AM	PM	AVERAGE DELAY (SECONDS)	TRAFFIC CONTROL	COST
New EB ramps one mile west	1988	3875	C	D	36	Signal	1.9 million
Move two ramps two miles east	1990	3875	C	D	38	Manual	1.0 million $125,000/yr
Status quo	1994	3200	D	E	50	Manual	$85,000/yr
Roundabout	1995	5500	A	B	12	Yield	2.8 million

Table 2. Higher capacity.

	Intersection North	Intersection South
Former intersection capacity	1700	3200
Highest roundabout count (veh/hour)	1884	3412
Roundabout capacity (veh/hour)	2700	5500

Table 3. Fewer crashes.

	Average annual crashes			
	Total		Injury	
	North	South	North	South
Before, 1991–94	7	18	3	2
After, 10/95–9/96	2	20	1	2

SUCCESSFUL CONCEPT SPREADS

This low-cost, high-capacity interchange concept has spread across North America, where 21 modern roundabout interchanges are in various stages of study, approval and construction (see Table 4 and check www.west.net/~owendee for updates to this rapidly growing list). In addition, North America's second and third modern roundabout interchanges opened this fall. They are I-70/Chamonix Road, the western entrance to Vail (Figure 3) and at I-70/Avon Road in Avon, Colo., USA (Figure 4), a town nine miles southwest of Vail.

The Avon Road project includes five roundabouts, two at the interchange and three which have replaced heavily impacted traffic signals south of the interchange (Figure 5). Seeing the success of the Vail interchange and wanting to eliminate congestion on their main entry road,

Table 4. Modern roundabout interchanges proposed for North America.

British Columbia	1
California	6
Colorado	2
Kansas	1
Maryland	7
Michigan	2
Utah	1
Wyoming	1
Total Interchanges	21

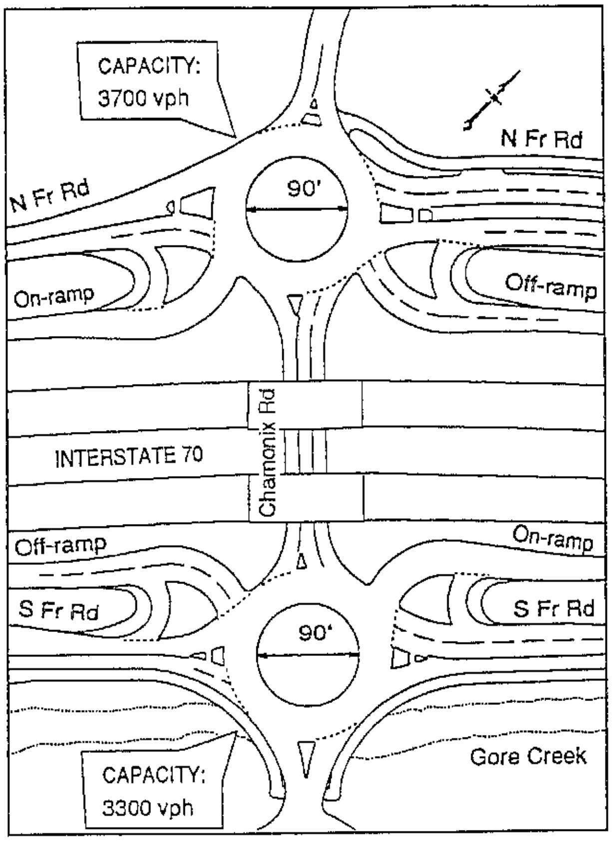


Figure 3. Remodeling of I-70/Chamonix Road created Vail's second modern roundabout interchange this fall.

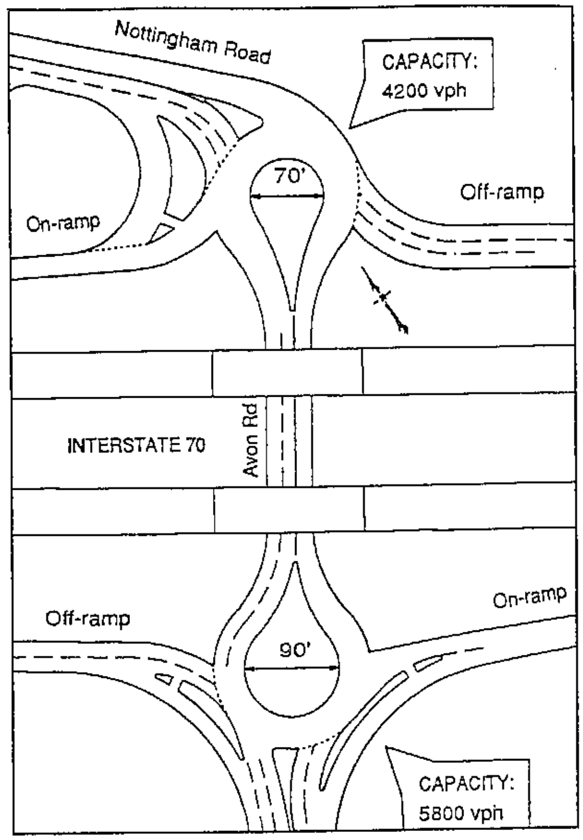


Figure 4. Construction on I-70/Avon Road in Avon, Colo., USA, nine miles southwest of Vail, was completed this fall.

the people of Avon voted two-to-one to increase their own property taxes to pay for the roundabouts. By converting the intersections to modern roundabouts instead of widening the whole road, Avon has built the second wide-node/narrow-link project in North America. I-70/Vail Road is the first.

This Vail Valley has become America's "Roundabout Valley." In a space of nine miles it has nine high-capacity roundabouts, including North America's first three modern roundabout interchanges.

ROUNDABOUTS OR SIGNALS?

Modern roundabouts at freeway-to-street interchanges provide capacity where it is needed, at the ramp and frontage road intersections, while minimizing the number of lanes passing over or under the most expensive part of the interchange, the bridge. By contrast, signalized interchanges require wide bridges for storage and turning lanes. For this reason modern roundabout interchanges are usually much less expensive than signalized interchanges. It costs roughly $2 to $6 million dollars to retrofit an existing interchange with roundabouts. This compares with roughly $10 to $15 million dollars to install signals and widen the bridge. In addition to their cost advantage, modern roundabouts usually cause less delay and fewer crashes than signalized cross intersections.

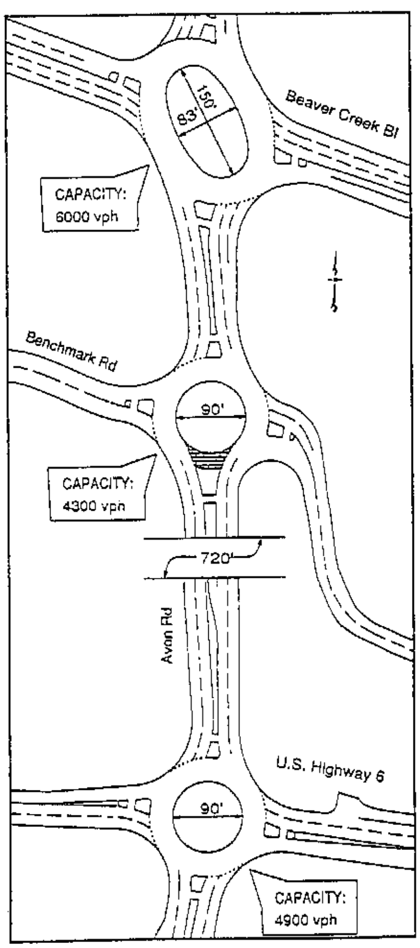


Figure 5. The Avon project removes all three of the Vail Valley's traffic signals and replaces them with high-capacity modern roundabouts.

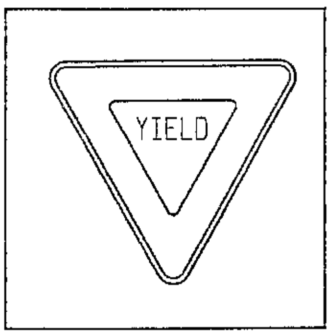
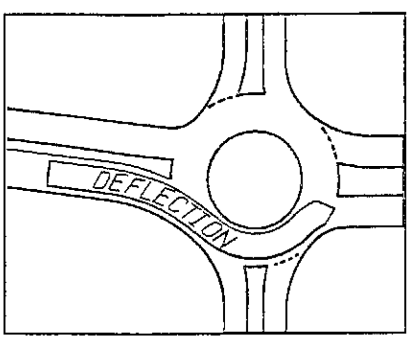
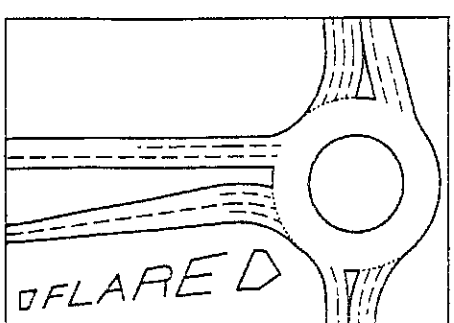
CONCLUSION

Wide-node/narrow-link traffic engineering is cost-effective on most arterial roads, where roundabouts permit the use of fewer lanes between intersections. Avon Road's five-roundabout congestion relief project is a good example of an arterial that will use modern roundabouts at all its major crossings in lieu of full-length road widening. Roundabouts are cost-effective intersections at the ends of tunnels and bridges, where the storage and turning lanes required by traffic signals would be expensive. Modern roundabout interchanges are a special subset of roundabouts at the ends of tunnels and bridges.

North America is beginning to accept the flared-entry roundabout as a normal type of intersection to be considered

WHY ARE MODERN ROUNDABOUTS SO EFFECTIVE AT INTERCHANGES?

Modern roundabout interchanges provide high capacity at ramp and frontage road intersections without wasting bridge width on storage lanes. *Modern roundabouts* conform to design guidelines produced by four decades of research and development in the United Kingdom and other countries. By contrast, *nonconforming traffic circles* do not conform to modern roundabout design guidelines. Yield at entry, deflection, and flare give modern roundabouts big advantages at interchanges.

	MODERN ROUNDABOUT	NONCONFORMING TRAFFIC CIRCLE
YIELD AT ENTRY 	*Entering traffic yields to circulating traffic.* • Circulating traffic always keeps moving. • Works well with very heavy traffic. • No weaving distance necessary. Roundabouts are compact.	*Entering traffic may cut off circulating traffic.* • Circulating traffic comes to a dead stop when the circle fills with entering traffic. • Breaks down with heavy traffic. • Long weaving distances for merging entries cause circles to be large.
DEFLECTION 	*Entering traffic aims at the central island and is deflected slowly around it.* • Slows traffic on fast roads, reducing accidents. • Deflection promotes the yielding process.	*Entering traffic may aim to the right of the central island and proceed straight ahead at speed.* • Causes serious accidents if used on fast roads. • Fast entries defeat the yielding process.
FLARE 	*Upstream roadway often flares at entry, adding lanes.* • Provides high capacity in a compact space. • Permits narrow roads between roundabouts, saving pavement, land, and bridge area.	*Lanes may not be added at entry.* • Provides low capacity even if circle is large. • For high capacity, requires multilane roads between circles, wasting pavement, land, and bridge area.

wherever high capacity at low cost is needed. Vail's success affirms the positive experiences of other countries where the flared-entry roundabout is already widely accepted, both at interchanges and at other high-capacity crossings. ■

References

1. Ourston, Leif, and Joe G. Bared. "Roundabouts: A Direct Way to Highway Safety." *Public Roads*, 59 (Autumn 1995): 41–49.

2. Crown, R.B. "RODEL—An Alternative Approach to Roundabout Design." *Highways and Transportation*, 10 (October 1987): 12–19.

3. Kimber, R.M. *The Traffic Capacity of Roundabouts, LR 942.* Crowthorne, Berkshire, U.K.: Transport and Road Research Laboratory, 1980.

4. Ourston, Leif, and Peter Doctors. *Roundabout Design Guidelines.* Santa Barbara, Calif., 1995.

5. Ourston, Leif, and Peter Doctors. *I-70/Vail Road* (eight-minute video). Santa Barbara, Calif., 1996.

Conversion Factors

To convert from	To	Multiply by
ft	m	0.3048
mi	km	1.6094

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