WIDE NODES AND NARROW ROADS

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Paper presented to the
Transportation Research Board
72nd Annual Meeting
January 10-14, 1993
Washington, D.C.

ABSTRACT

Compared to typically wide American arterials which intersect at signalized cross intersections, a roundabout-based road system, like the system of main roads in the United Kingdom, uses wide "nodes" (roundabouts) and narrow "roads" (links), for an overall saving of pavement, bridge area, and land. An important economic advantage of modern roundabouts is to save money between roundabouts by using narrower road links.

The difference between modern roundabouts and nonconforming traffic circles is in the guidelines they follow. Modern roundabouts follow modern guidelines; nonconforming traffic circles do not. Among other features, modern guidelines recommend yield at entry, deflection, and flare, characteristics that give the modern roundabout great safety and high capacity in a compact space.

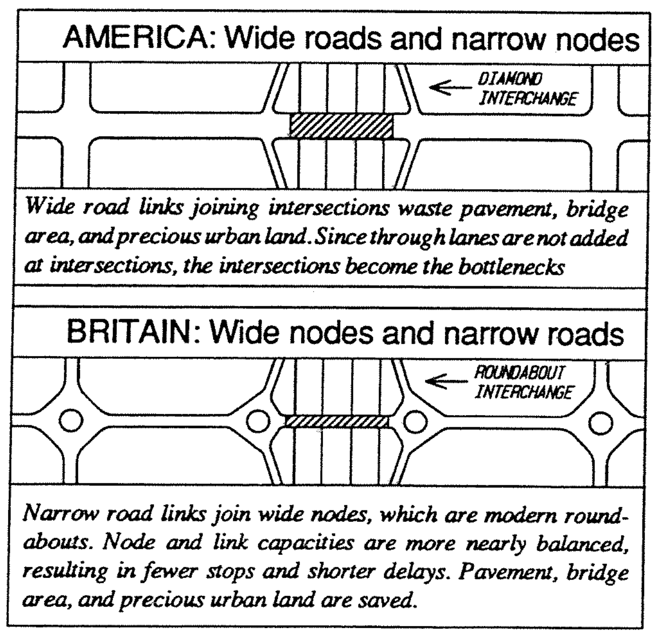
The effect of modern roundabouts on highway engineering is revolutionary as they proliferate from country to country. Four states are funding modern roundabout work here. Seven modern roundabout interchanges have been proposed, and the Federal Highway Administration has approved one of them.

Freeway-to-street interchanges are the most cost effective place to use modern roundabouts because their potentially "narrow roads" include expensive bridges. If additional capacity is needed at ramp and frontage road intersections, it is often far less expensive to convert those intersections to high capacity modern roundabouts than to widen an undercrossing or overcrossing or to build loop ramps.

MODERN ROUNDABOUTS REDUCE THE COST OF MAIN ROADS

Much has been said about the value of modern roundabouts to reduce road user costs, the costs of accidents, delay, and fuel waste. Often overlooked is the important capital cost saving contribution of roundabouts: Roundabouts allow the use of narrower link roads joining them, for an overall reduction of pavement, land, and bridge area in the road system (Figures 1, 2, and 3).

The wide-nodes-and-narrow-roads planning principle refers to the use of wide roundabout intersections (nodes) joined by narrow links (roads). With roundabouts, node capacity approaches link capacity partly because the number of lanes in the roundabout is usually greater than the number of lanes moving in each direction on the link.



Wide road links joining intersections waste pavement, bridge area, and precious urban land. Since through lanes are not added at intersections, the intersections become the bottlenecks

Narrow road links join wide nodes, which are modern roundabouts. Node and link capacities are more nearly balanced, resulting in fewer stops and shorter delays. Pavement, bridge area, and precious urban land are saved.

Figure 1

Figure 2

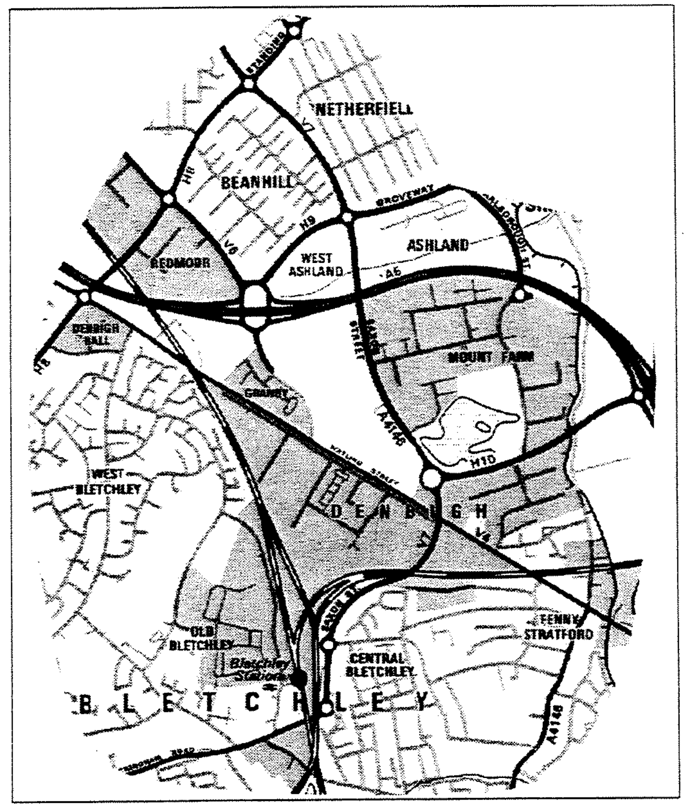


Figure 3

British roads use modern roundabouts at most important at-grade crossings and freeway-to-street interchanges. New towns of Warrington (left) and Milton K[illegible]es are shown above.

For example, a one-lane approach usually flares out to two or three lanes at the roundabout, and a two-lane approach usually flares out to three or four lanes (Figures 4, 5, and 15). Roundabout capacity is further increased by use of right turn bypass lanes, lanes that enable drivers requiring the first available exit to bypass the roundabout altogether (Figures 5, 10, 15, 17, and 18).

Figure 4

A wide four-lane node makes possible a narrow road having two lanes in each direction, for an overall savings of pavement, land, and bridge area.

But before explaining how wide nodes permit the use of narrow roads, it is first necessary to answer the question:

WHAT IS A MODERN ROUNDABOUT?

Circular intersections fall into two categories: Modern roundabouts and nonconforming traffic circles. Modern roundabouts conform to one of a few sets of foreign guidelines that are patterned after British guidelines. By contrast, nonconforming traffic circles do not conform to the guidelines for modern roundabouts.

If you live in North America, most of the circular intersections that you are likely to have driven are nonconforming traffic circles. For example, all but four of the circular intersections in the United States, all of the circular intersections in Canada, Mexico, Belgium, and

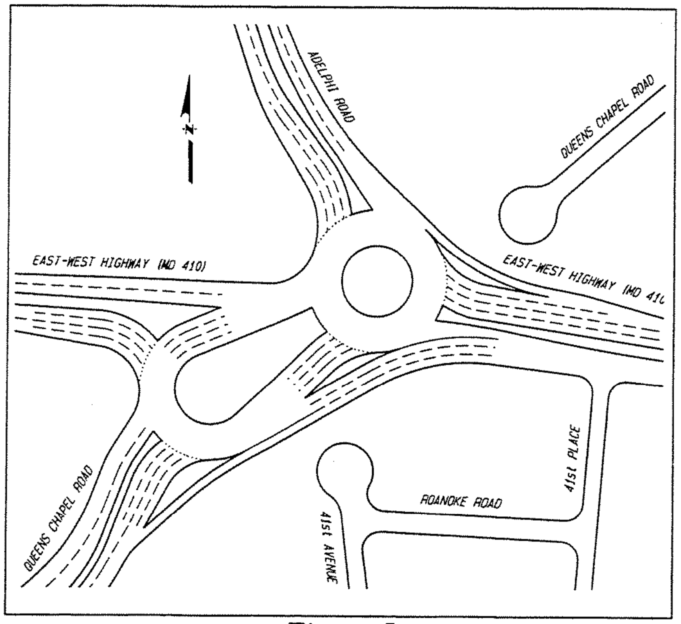


Figure 5

College Park Roundabout, College Park, MD. ICD=200', each end. 2010 DHV=7000 vph. A double roundabout proposed to relieve congestion at a complex intersection. Modern roundabout design uses many entry lanes, multiple central islands, and bypass lanes to increase capacity as necessary. Designer, Ourston.

Italy, and many of the older French circular intersections are nonconforming traffic circles. Generally, they handle light flows of traffic satisfactorily, but they fail as traffic demand approaches capacity.

By contrast, modern roundabouts can carry more traffic than any other type of at-grade intersection. The highest capacities, of around 8,000 vehicles per hour, are achieved by wide entries, bypass lanes, and double roundabouts (Figure 5). In the United Kingdom, at locations which require high capacity, the modern roundabout is the intersection of choice. For example, almost all British freeway-to-street interchanges are based on the modern roundabout (Figure 6), and the first intersection at the end of a freeway in Britain is usually a modern roundabout.

Superior Performance of Modern Roundabouts

It is not possible to list all the guidelines of modern roundabout design here, but among other features, modern roundabouts have two fundamental design elements: *Yield at entry* and *deflection* of the vehicle path (Figure 7). A third fundamental feature, entry *flare*, is essential for high capacity. It is found in many, but not all, modern roundabouts. In lieu of YIELD signs, one or more entries to some modern roundabouts are regulated by traffic signals.

The three fundamental differences give modern roundabouts important advantages over nonconforming traffic circles.

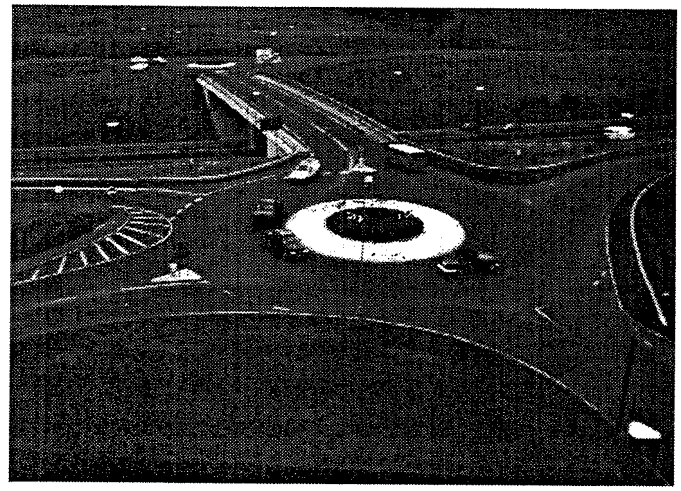


Figure 6

Wide nodes and narrow roads save the most money at interchanges. Wide nodes permit the road between them, which contains an expensive bridge, to be narrow. Two lanes always moving on the structure do the work of four stopped half the time at red lights.

Yield at Entry

At modern roundabouts entering traffic yields the right of way to circulating traffic. Since entry is by gap acceptance, not by weaving, long weaving sections between entries and exits are no longer required.

For this reason modern roundabouts are compact. Modern roundabouts with raised central islands fit into an inscribed circle of 100 to 300 feet in diameter. Miniroundabouts—having traversable central islands, either flat or in the shape of a dome up to five inches high—fit into the smallest intersections. Being compact, modern roundabouts are a type of intersection that can be used almost anywhere.

By contrast, conventional weaving entry rotaries are often 400 feet or more in diameter, limiting their application to a few rural and suburban sites. Their large radii encourage high speed.

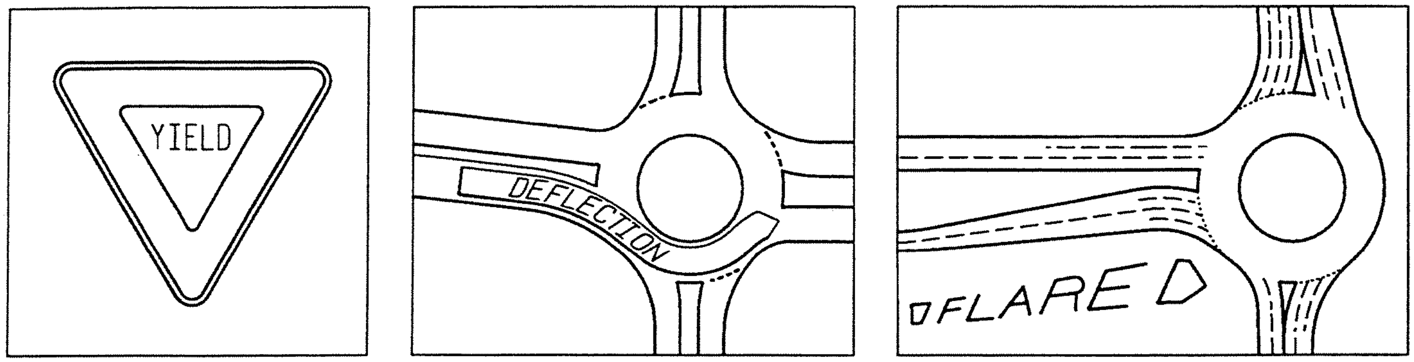


Figure 7: The three main features that distinguish modern roundabouts from nonconforming traffic circles are: yield at entry, deflection, and flare.

Deflection

The entry geometry of modern roundabouts deflects traffic through an arc whose radius is no longer than 328 feet (100 meters). By contrast, conventional traffic circles often have tangential entries which allow traffic to enter in a straight line at speed. Deflection of the vehicle path slows traffic, thus contributing to the good safety record of the modern roundabout. Entry deflection also reinforces the yielding process.

Flare

The entries to modern roundabouts often flare out from one lane on the approach road to two or three lanes at the yield line, or from two approach road lanes to three or four lanes at the yield line. Flare is the characteristic that gives the modern roundabout its great capacity in a compact space. By contrast, nonconforming traffic circles do not have flared entries.

Common Deviations of Nonconforming Traffic Circles

Most traffic circles in this country are one-off designs that do not conform to any guidelines. As such, they deviate from modern roundabout guidelines in ways that are unique to each site. Some of the more common deviations are:

1. Parking in the circle.
2. STOP signs regulating the entries.
3. No regulation of the entries.
4. Crosswalks leading to the central island.
5. Lane lines in the circle.
6. Channelization which causes circulating drivers to leave the circle before their desired exit.
7. Too wide or too narrow circulatory roadway width.
8. YIELD signs but no yield lines.
9. Inadequate sight distance.
10. Inadequate signing and lighting.

The Daytona Beach roundabout (Figure 8) illustrates the importance of deflection. Constructed in 1949 with YIELD signs added later, this old circle is three-fourths modern and one-fourth old. The three approaches that have adequate deflection logged zero, one, and four

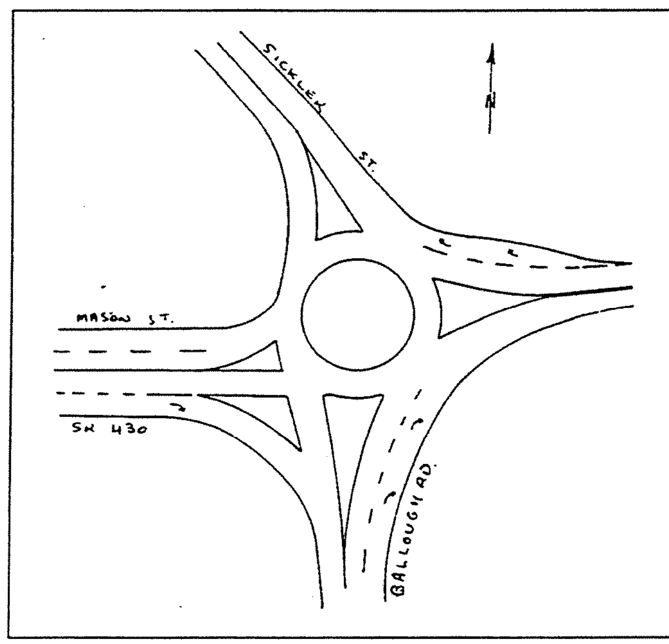


Figure 8

Daytona Beach Traffic Circle, Daytona Beach, FL. ICD=110'. PHV=2800 vph. Designer, unknown. Submitted by Wallwork.

accidents over the past four years. By contrast, the west approach, which has no deflection, was the site of seventeen accidents during the same period. The circle compares the benefits of modern design with old design at one location.

WIDE NODES PERMIT NARROW ROADS

Independence of link and node size

Roundabouts and the links joining them are sized independently. Links and nodes are designed just large enough so that the nodes have adequate capacity regardless of link width, and the links have adequate capacity regardless of node diameter. Link and roundabout sizes are blended by flaring the roundabout entry to add lanes just before the roundabout and by tapering the exit to drop a lane just after the roundabout (Figure 9).

Within modern roundabouts, since there are usually no lane lines, almost all of the merging is done at low speed just after entry, as three or four vehicles entering side-by-side at a multiple lane entry immediately move into a staggered single file type of alignment, with the front right corner of each vehicle just behind the left rear corner of the vehicle ahead of it. Within two or three car lengths of entry they are in single file or, rarely, in a double widely separated file. By the time they reach the exit they are usually in a single file. Merging at low speed shortly after entry is a safe, normal part of the operation of modern roundabouts. Since there are no lane lines, the transition does not seem or feel like merging.

By contrast, to drop though lanes after a cross intersection would require a high- or medium-speed merger, a dangerous maneuver, and an annoying one to impose on motorists if the number of lanes would spread out a short distance away at a traffic signal. The number of lanes on a link on conventional American roads is therefore determined by the requirements for

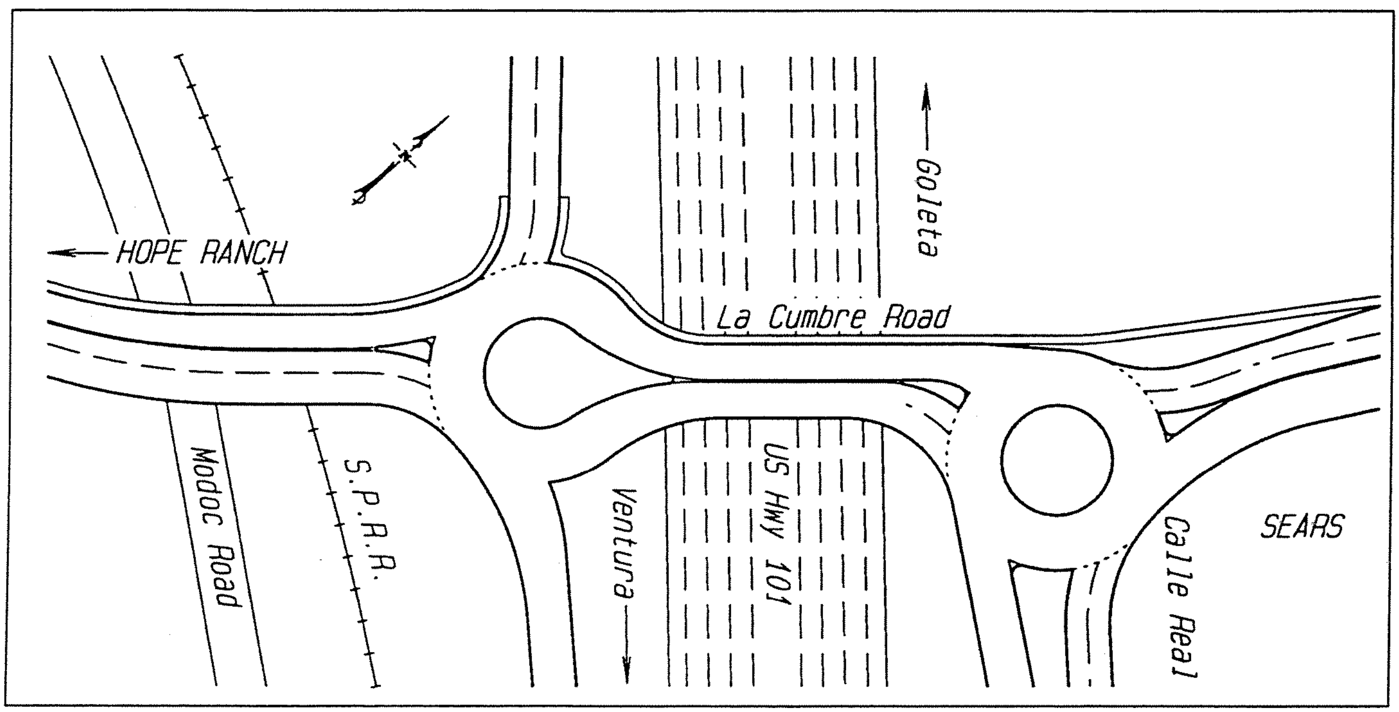


Figure 9

La Cumbre Road/U.S. Highway 101, Santa Barbara, CA. ICD=120'. DHV=2660 vph, north roundabout, 2600 vph, south roundabout. A modern raindrop interchange, the design is under environmental review by the Santa Barbara County Association of Governments as an alternative to the State's proposed widening. It would cost much less, would reduce delay, accidents, fuel waste, and emissions, and would not require additional right of way. Designer, Doctors.

intersection capacity. Very often the capacity of a link far exceeds the flow of traffic on it. Inefficient traffic control at the nodes may cause long queues, giving the impression of very heavy traffic, while the actual flow of traffic through the link is quite low.

Sizing a link which joins a pair of modern roundabouts

The open road capacity of a link is about 1700 vehicles per lane-hour. If the unidirectional flow of traffic on the link will not exceed 1700 vehicles per hour, one lane in that direction may be all that is needed. If the flow falls between 1700 and 3400 vehicles per hour, two lanes are needed. Left turn lanes are not needed unless there are minor T-intersections and cross intersections between the major roundabout intersections. In any case, broad medians which would shadow double left turn lanes are not needed. Roundabouts cater to left turns without any specially assigned left turn lanes on the approaches.

In America, most four-lane roads and many six-lane roads do not carry more than 1700 vehicles per hour in one direction. Some of these roads would provide better service as two-lane roads with wide nodes. The links would be easier for pedestrians and side street traffic to cross, and the modern roundabouts would be safer and more efficient than signalized cross intersections.

Sizing a modern roundabout

Roundabout capacity is determined by six geometric parameters: entry width, upstream half-width (the width of the side of the link road carrying traffic toward the roundabout before it begins to flare out at the entry), length of flare, roundabout inscribed circle diameter (the outer diameter), entry angle, and the radius of the curb return at entry. Roundabout capacity is increased through use of wider entries (up to four lanes), longer flares, and bypass lanes. Additional capacity can be gained, if necessary, by splitting one four-leg roundabout into two three-leg roundabouts. This technique is especially useful if a heavy left turning flow can be eliminated from the circulating flow in front of a critical entry. By applying these techniques as necessary, a modern four-leg roundabout or double roundabout of about 250 feet inscribed circle diameter can be designed so that its capacity exceeds 8,000 passenger car units per hour. Depending on entry geometry and on the circulating flow of vehicles in front of the yield line, the capacity of a four-lane entry to a modern roundabout ranges from zero passenger car units per hour, with heavy circulating flow, to about 4,000 passenger car units per hour, with negligible circulating flow.

The capacity of modern roundabouts can be estimated to within about 15% by use of one of two programs from the United Kingdom, ARCADY and Rodel. Both programs are based on the same primary research, and although each program offers different features, insofar as their output overlaps, their estimates of capacity, delay, and queue lengths are equal. The license for each program costs about $1800 in America.

The knowledge of how to use modern roundabouts and narrow road links to economical advantage would have little importance to American highway engineers if modern roundabouts were strictly a British phenomenon, or if they were not recognized by state highway departments or by the Federal Highway Administration. Fortunately, things have changed from just a few years ago, and the modern roundabout revolution has spread to several countries, including our own.

ROUNDABOUT REVOLUTION COMES TO AMERICA

Proliferation of Modern Roundabouts Overseas

Because of their success and popularity, modern roundabouts are proliferating in about a dozen countries, including most British influenced countries like Australia, New Zealand, Ireland, South Africa, Barbados, and Bermuda, as well as France, Switzerland, Norway, Denmark, Sweden, Germany, Spain, Portugal, the Netherlands, and finally, the United States. For example:

- In France, since 1984 there has been an explosion in the population of roundabouts in many French towns. Roughly one thousand roundabouts were built in France in 1991.
- In Melbourne, Australia, there are about 1600 modern roundabouts, a density of one roundabout per 1800 residents. This represents and increase of about 700 roundabouts over the past seven years.

- In Switzerland, since 1987 when the yield at entry rule was adopted, the number of roundabouts has increased to about 100 from about 20.
- In Norway, YIELD signs were installed at all roundabouts beginning in 1985. The number of roundabouts there increased to about 600 by 1992 from around 50 in 1985. Roughly 100 roundabouts are built in Norway each year. Recently some signalized intersections have been converted to modern roundabouts.

Wide Nodes Planned and Proposed for the United States

Only four modern roundabouts have been built in the United States, two in Las Vegas in the spring of 1990, one in Gainesville in the spring of 1992, and one in Santa Barbara in November of 1992 (Figures 10, 11, 12, and 13).

Las Vegas, Gainesville, and Santa Barbara are pleased with their modern roundabouts. Contrary to the fears of skeptics who worried that Americans would not be able to drive modern roundabouts safely, there has only been one accident at a modern American roundabout since the first ones were built here three years ago.

In addition to these first modern American roundabouts, four states are now funding modern roundabout work.

GLOSSARY

DHV Future design hour volume, vehicles/hour.
PHV Present peak hour volume, vehicles/hour.
ICD Inscribed circle diameter; the outer diameter.

California

District 7 of the California Department of Transportation, which includes Ventura and Los Angeles Counties, has funded roundabout projects since 1987. Their first proposed project was the Ojai roundabout, which would have replaced a signalized Y-intersection. That project was withdrawn because of organized opposition.

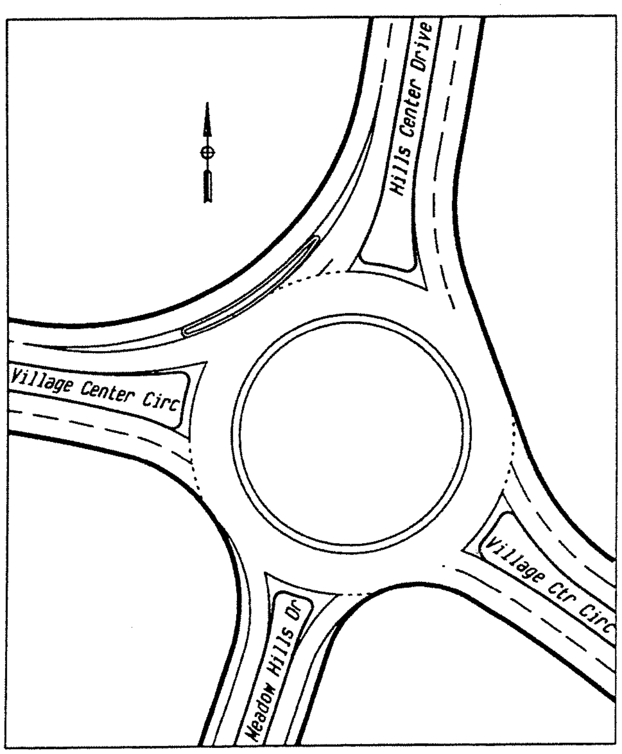


Figure 10, North Roundabout

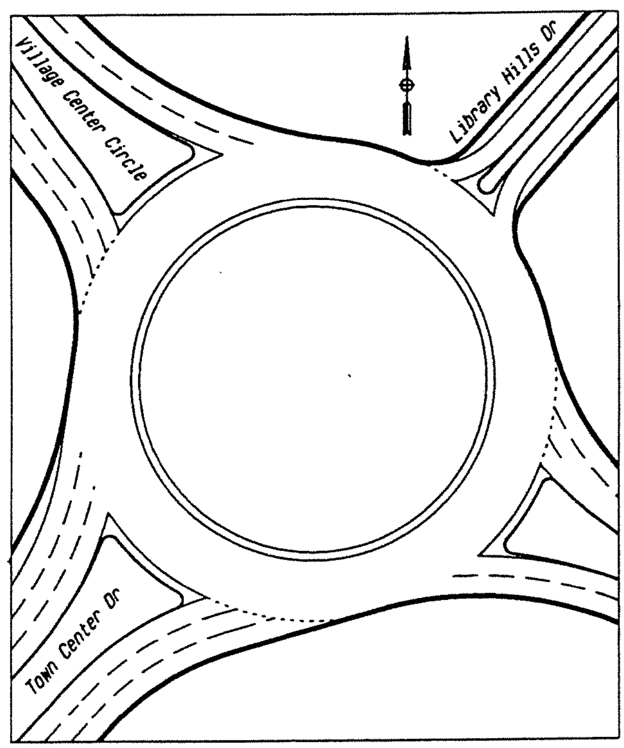


Figure 11, South Roundabout

North Roundabout (ICD=200'. DHV=3000 vph) and South Roundabout (ICD=300'. DHV=6000 vph), Las Vegas, NV. Constructed in spring of 1990, these two roundabouts are the first modern roundabouts in North America. Located at the end of the Summerlin Parkway, they are the focus of the community of Summerlin, a development which will one day have a population equal to that of present day Las Vegas. Designers, Ourston, Sprague, and O'Brien.

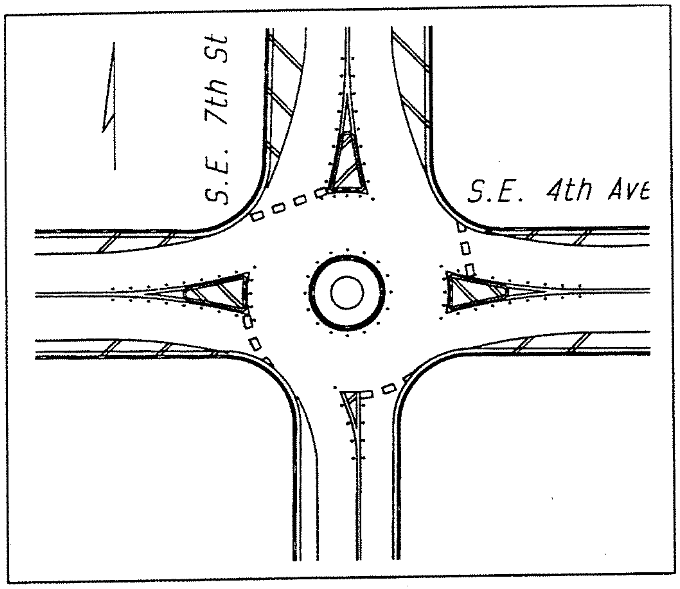


Figure 12

Gainesville Roundabout, Gainesville, FL. ICD=58'. PHV=500 vph. Constructed in April, 1992, this is the first modern American roundabout to replace a traffic signal. Because of its success, Gainesville is looking for other signals to replace with modern roundabouts. Designers, Kanely and Mann.

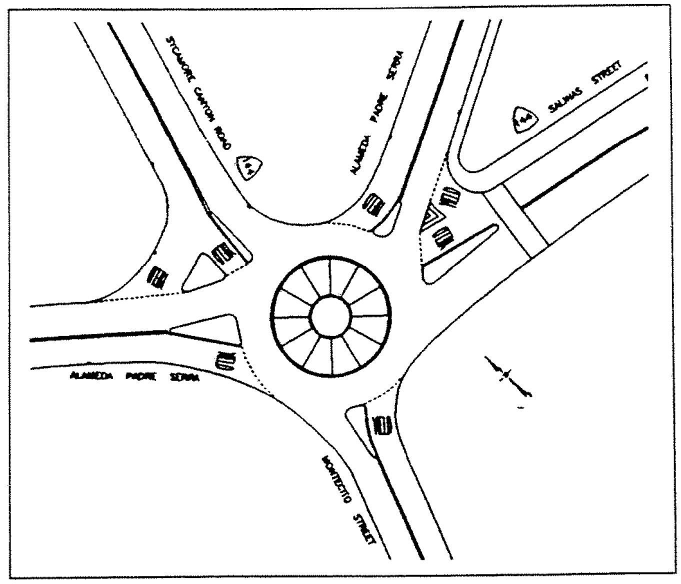


Figure 13

Five Points Roundabout, Santa Barbara, CA. ICD=86'. PHV=1500 vph. Working only one week in November, City of Santa Barbara maintenance crews replaced a 5-way STOP sign controlled intersection with the first modern roundabout on the California state highway system. Carrying a peak hour volume of 1500 vph, the Five Points roundabout is now the busiest of the four modern roundabouts in the United States. Peak hour queues, formerly up to thirty vehicles long, are now zero to four vehicles long. The learning process was easy and swift for most drivers; there have been no reported accidents. Designer, Doctors.

Now the Long Beach roundabout, to replace a large nonconforming traffic circle at the intersection of two state highways, is under construction (Figure 15).

District 7 has retained the author to study the feasibility of using modern roundabouts to solve safety and capacity problems at five sites. Caltrans has also commissioned the translation of the British roundabout design guidelines, and they have authorized a before-and-after study of the Long Beach roundabout. They have retained DKS Associates to study the feasibility of roundabouts at several sites.

Maryland

Since August of 1991 Maryland has funded feasibility studies of roundabouts at about a dozen sites. They have produced an eight-minute video, "Modern Roundabouts," to bring the concept to the public. (Call 410 787-5879 to request your copy.) A Roundabout Task Force, composed of state highway officials and traffic engineers of metropolitan counties, meets monthly to propose and discuss sites for modern roundabouts. Two roundabouts are in final design, and one, the Lisbon roundabout, will be built this spring (Figure 16).

Florida

The Florida Department of Transportation has sponsored several pedestrian safety and roundabout design courses by Michael Wallwork, Traffic Operations Engineer, and Dan Burton, Pedestrian-Bicycle Coordinator. Teaching techniques influenced by Wallwork's native Australia, the team has reached hundreds of engineers across Florida and other states. The team's most recent course, in Vermont, persuaded the governor that roundabouts have a future there.

Wallwork has written two papers on roundabouts, one of them for the *Compendium* of the 1990 annual ITE meeting, and he has written to *ITE Journal* on roundabouts. He has written parts of Florida DOT's Urban Mobility *Technical Assistance Manual* and *Pedestrian Safety Plan*, in which he recommends roundabouts to improve capacity and safety.

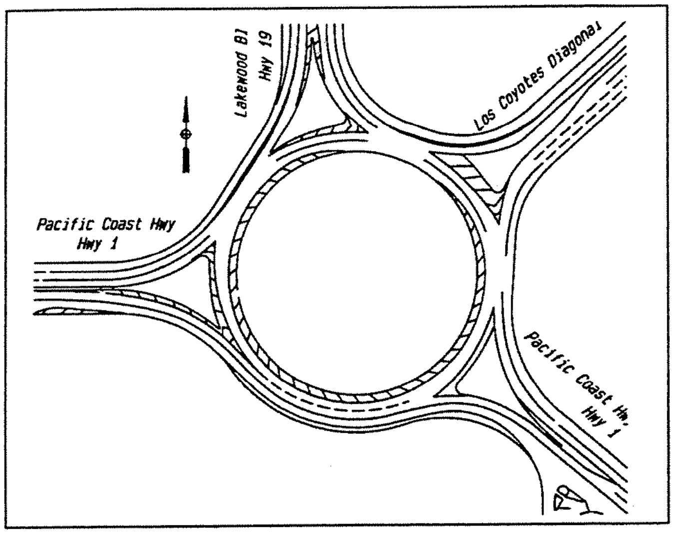


Figure 14, old Long Beach traffic circle

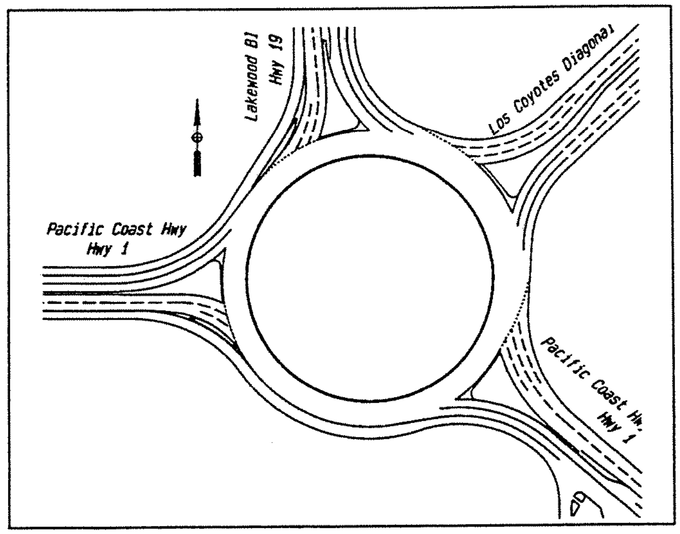


Figure 15, new Long Beach roundabout

Long Beach Roundabout, Long Beach, CA. ICD=470'. PHV=6000 vph. Now under construction, the modern roundabout will replace the old Long Beach traffic circle. Mainly a signing and striping job, the project will not change the outside curblines or the central island. Confusion, anxiety, and accidents will be reduced when the two uncontrolled Pacific Coast Highway entries are regulated by YIELD signs. To reduce congestion, all entries will be widened to three or four lanes by narrowing the splitter islands. As the busiest modern U.S. roundabout likely to be built any time soon, the outcome of this project will influence the course of the roundabout revolution in America. Designers, Ourston and Burnside.

Vermont

This summer Montpelier, the capital of Vermont, will install a modern roundabout as a demonstration project one block from the state house. Federal STP (Surface Transportation Program) grants have been awarded for traffic calming studies in Montpelier and Brattleboro. The studies will consider roundabouts, which improve safety and capacity while calming traffic.

MODERN ROUNDABOUT INTERCHANGES COST LESS

The desire to save money by use of wide nodes and narrow roads has motivated proposals for seven modern roundabout interchanges.

1. The Federal Highway Administration has approved a diamond interchange which will use modern roundabouts at the ramp intersections of Interstate 95 (the Capital Beltway)/Ritchie Marlboro Road (Figure 17). The Maryland State highway Administration selected this design as their preferred alternative. A conventional

FOR MORE INFORMATION, CALL THE DESIGNERS

Burnside, John H., Caltrans District 4. 510 286-5233.

Doctors, Peter L, Penfield & Smith, Santa Barbara, CA. 805 963-9532.

Kanely, Brian D., City of Gainesville, Gainesville, FL. 904 334-2130.

Hendershot, Denise, Rodgers & Associates, Rockville, MD. 301 948-4700.

Mann, Philip R., City of Gainesville, Gainesville, FL. 904 334-2130.

Myers, Edward J., Hurst-Rosche Engineers, Cockeysville, MD. 410 683-1683.

O'Brien, Andrew, Andrew O'Brien & Associates Pty. Ltd., Camberwell, Victoria, Australia. 01161-3-882-9955.

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Sprague, Ben R., Pentacore Engineering, Las Vegas, NV. 702 258-0115.

Wallwork, Michael J., Florida DOT, Jacksonville, FL. 904 685-4069.

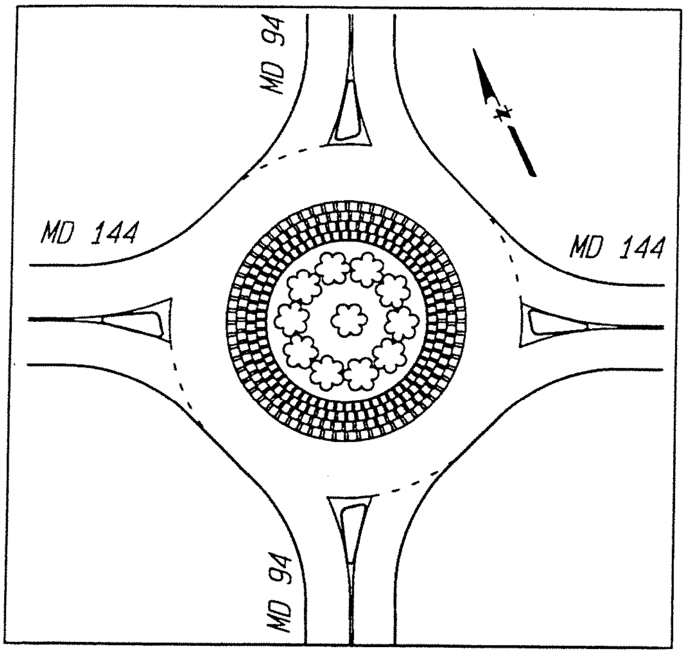

Figure 16

Lisbon Roundabout, Lisbon, MD. ICD=100'. 2010 DHV=1425 vph. To be constructed this spring, this will be the first roundabout on the Maryland state highway system. Designers, Ourston and Myers.

diamond interchange regulated by traffic signals would require widening the existing four-lane undercrossing to six lanes. The modern roundabout interchange will save $10 million while causing roughly one-tenth the delay and one-half the accidents of the traffic signal alternative.

2 and 3. The California Department of Transportation has commissioned a study of the feasibility of using modern roundabouts to increase capacity without overcrossing widening at two Highway 101 interchanges in Ventura County, at Lost Hills Road and at Reyes Adobe Road.

4. A modern raindrop interchange is proposed for Rice Avenue over U.S. Highway 101 in Oxnard, California (Figure 19). This interchange would save the high cost of right of way required by a conventional partial cloverleaf interchange now under study.

5. Osprey Investment Company has funded the study of a roundabout-based interchange which will increase capacity without overcrossing widening

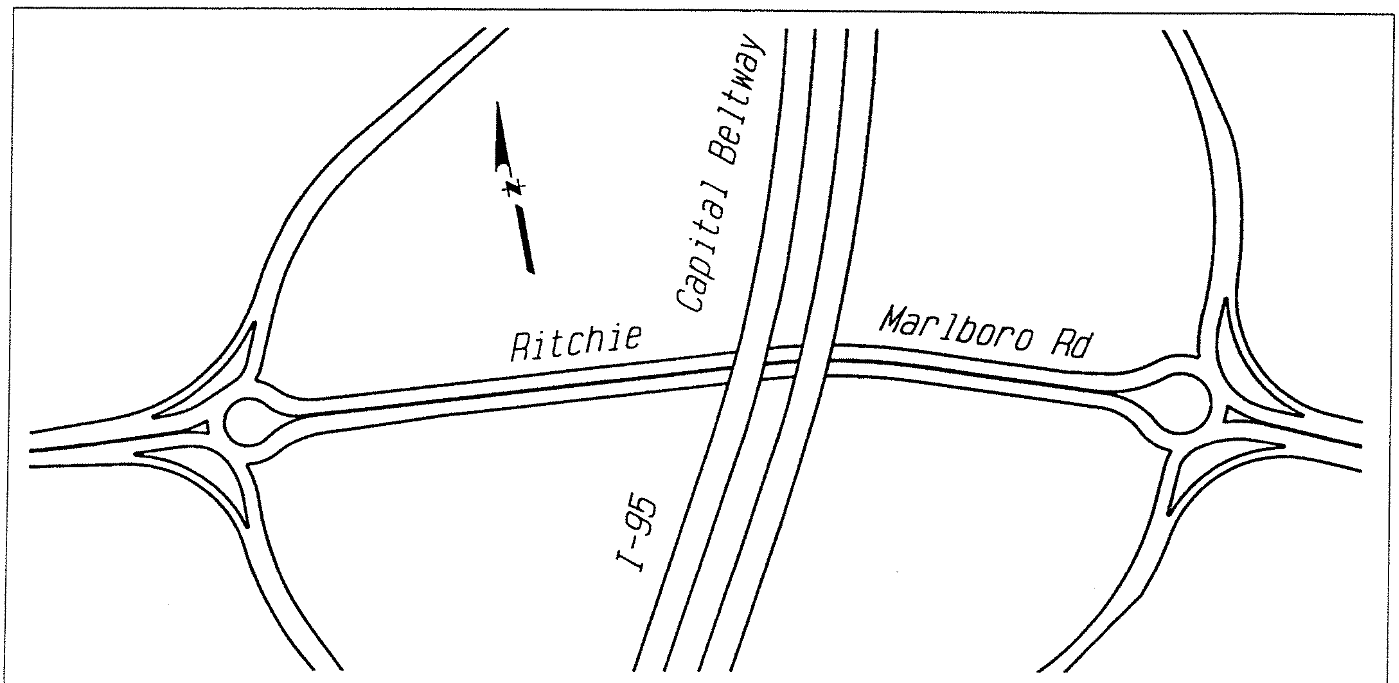

Figure 17

I-95/Ritchie Marlboro Road. ICD=160', west roundabout; 160' and 170', east roundabout. 2010 DHV=5000 vph entering each roundabout. The interchange will use modern raindrop-style roundabouts, which prevent wrong way left turns onto the off ramp, facilitate signalization of the off ramp entry if necessary, and eliminate yield lines for traffic leaving the undercrossing. Since traffic entering the roundabouts from the undercrossing is always moving, the number of lanes under the structure is less than would be required if these lanes were sometimes stopped for red lights as at a signalized diamond interchange. Designers, Ourston and Myers.

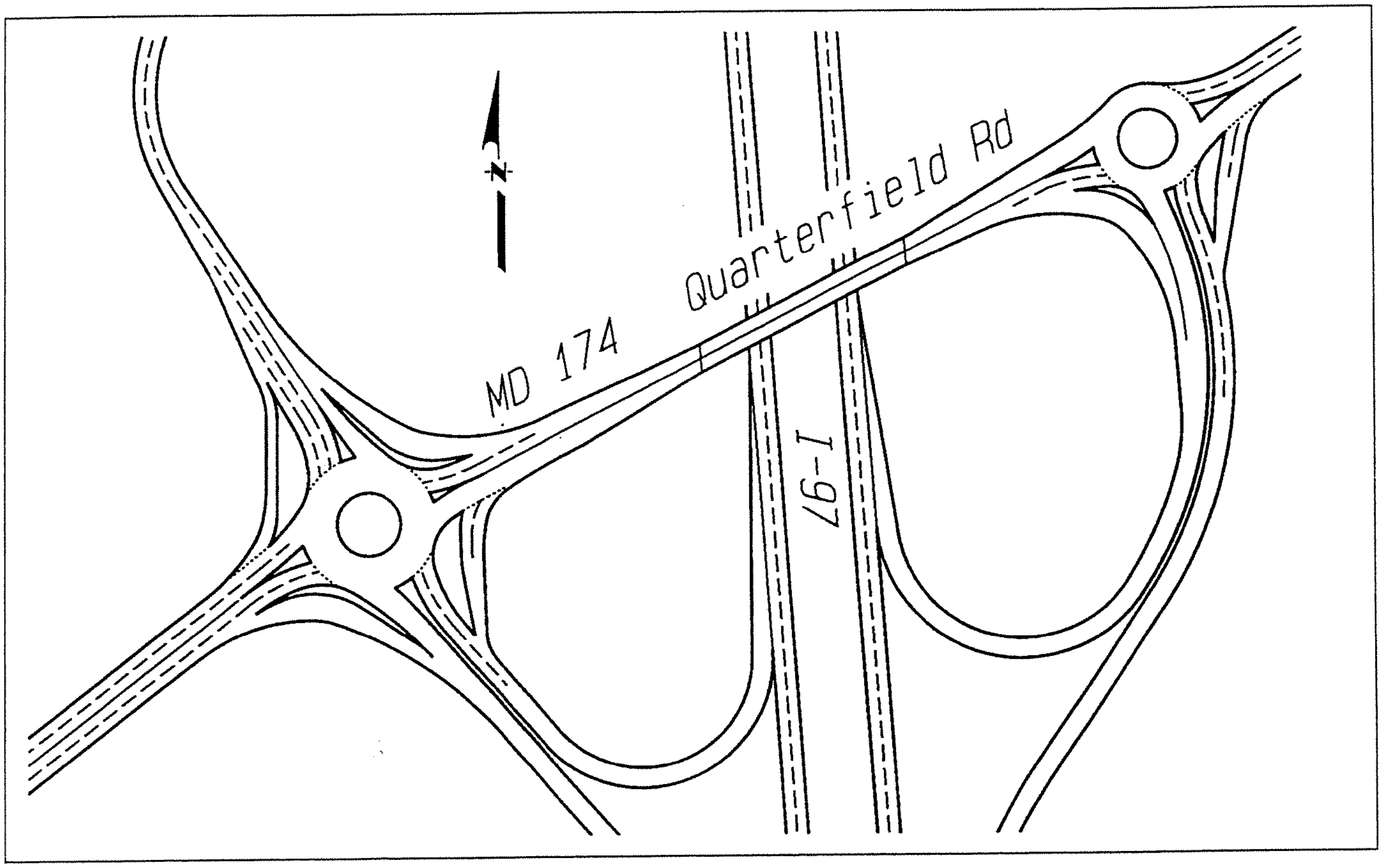

Figure 18

Quarterfield Road/I-97. ICD=150', west roundabout; 120', east roundabout. 2010 DHV=4140 vph entering the west roundabout and 3425 vph entering the east roundabout. The cost of adding roundabouts to the ramp intersections is roughly estimated at $500,000, compared to $20 million for signals and structure widening. Designer, Ourston.

at Quarterfield Road/Interstate 97 in Maryland (Figure 18). This project, if approved, will save nearly $20 million over previously planned interchange modifications, which would have involved widening the grade separation, loop ramps, and traffic signals.

6 and 7. In Santa Barbara, California, modern roundabouts are proposed to improve two U.S. Highway 101 interchanges. At La Cumbre Road (Figure 9) modern roundabouts would save the cost of structure widening and right of way that would be required by a conventional traffic signal alternative. At the north end of the Milpas Street undercrossing a modern roundabout built within existing right of way would eliminate congestion caused by the traffic signal which presently regulates a five-leg intersection (Figure 20).

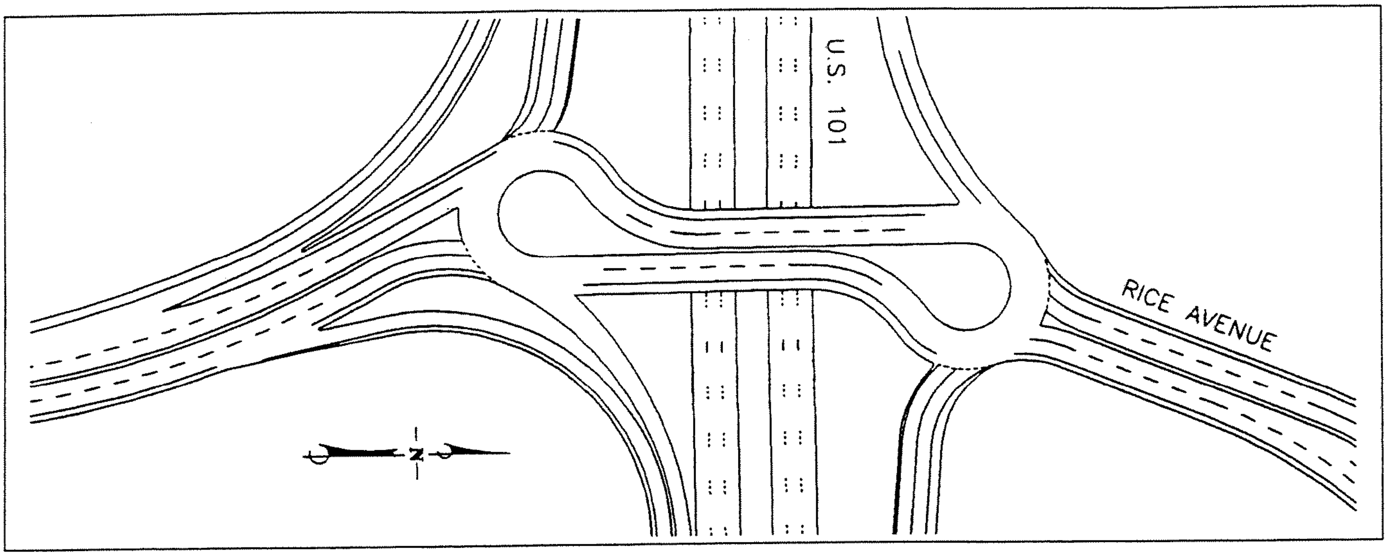

Figure 19

Rice Avenue/U.S. Highway 101, Oxnard, CA. ICD=140'. DHV=4200. Proposed to the City of Oxnard, this raindrop interchange would save expensive land required by a partial cloverleaf interchange now under study. Designer, Doctors.

CONCLUSION

The modern roundabout revolution, which has only recently spread from overseas to America, opens the opportunity for cities, counties, states, and developers to save money between roundabouts by building narrower road links. Of greatest importance are the modern roundabout interchange projects now planned, proposed, and under study, because it is at freeway-to-street interchanges that the most money can be saved, through use of a narrower structure. Nearly all freeway-to-street interchanges in the United Kingdom are based on the modern roundabout, but the United States continues to widen overcrossings and undercrossings at great expense while signalizing ramp and frontage road intersections.

Road systems based on wide nodes and narrow roads are not only more cost effective; they also perform better. Modern roundabouts, the wide nodes, save accidents, time, fuel, and air pollution while improving capacity and providing landscaping opportunities. Narrow link roads are safer and easier for pedestrians and vehicles to cross, and they reduce the amount of land that is sacrificed to pavement.

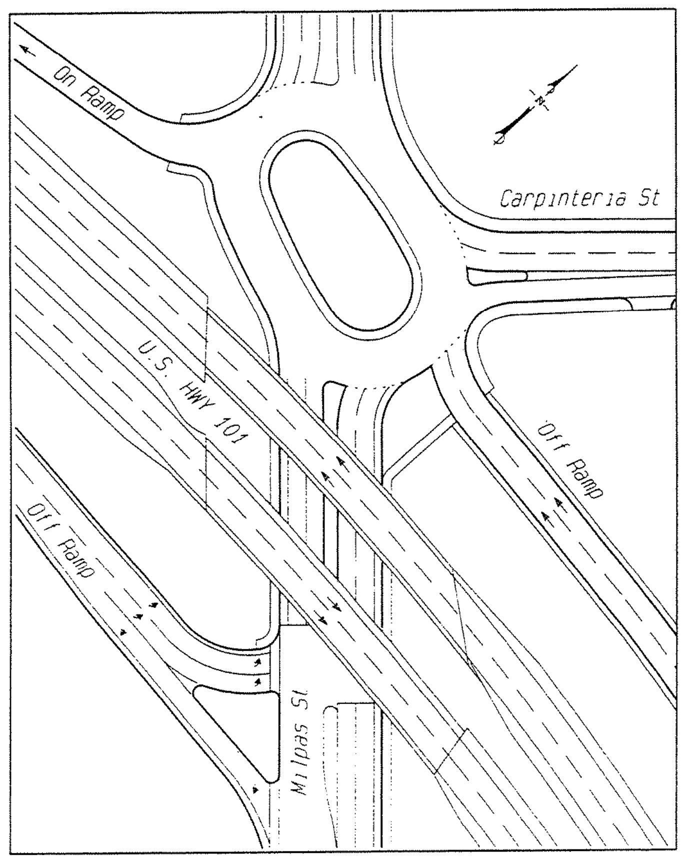

Figure 20

U.S. 101/Milpas St. interchange, Santa Barbara, CA. ICD=120' and 130', each end. PHV=3400 vph. Proposed to the City of Santa Barbara as the lowest cost congestion relief for this five-points ramp intersection. Designer, Doctors.