Design for Single-Lane to Dual-Lane Roundabout Expandability

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Abstract
Roundabout planners and designers are often faced with situations where a multi-lane roundabout will be required to handle the design-year traffic volumes, but where a single-lane roundabout would be sufficient for a number of years. Due to issues of safety, complexity, driver familiarity, and sometimes cost, it may be desirable to construct a single-lane roundabout that can be expanded in the future. This paper explores the characteristics of a good expandable roundabout design, including basic procedures that should be followed. The paper does not discuss roundabout design in its entirety. Rather, it focuses on the additional steps that are required to design an expandable roundabout. Two alternatives for the initial single-lane layout are presented, including advantages and disadvantages of each. One alternative involves building the full outside footprint and widening inward, while the other involves building the central island and splitter islands in the ultimate configuration and widening outward. The paper also includes a case study of the Amity Avenue/Happy Valley Road Roundabout in Nampa, Idaho.

BACKGROUND

The City of Nampa contracted with Project Engineering Consultants, Ltd. (PEC) to design and manage the construction of a roundabout at the intersection of Happy Valley Road and Amity Avenue in Nampa, Idaho. Both roadways are two-lane rural arterials that are projected to become multi-lane urban arterials as the surrounding area continues to grow. PEC performed traffic projections and analyses and determined that a single-lane roundabout would be sufficient for the first 10-12 years of the roundabout's operation but that a dual-lane roundabout would ultimately be needed. The need for a future dual-lane roundabout is driven by:

- long-range volume forecasts that exceed single-lane roundabout capacity, and
- the master-planned future expansion of both intersecting roadways to five-lane urban arterials.

PEC and the City recognized that it would be undesirable to construct a dual-lane roundabout initially when a single-lane would adequately handle the traffic for many years. Roundabouts should not be overbuilt for a number of reasons. Those most often cited on this project were concerns with operational simplicity, safety, and cost.

1. Operational simplicity. This roundabout was to be the first arterial roundabout in the Boise-Nampa metropolitan area. Lack of driver familiarity with roundabouts was, therefore, a major concern. The operational simplicity of a single-lane roundabout compared to a dual-lane one was viewed as a key to the success of the project.
2. Safety. Hand-in-hand with the issue of operational simplicity was safety. Even in areas with many arterial roundabouts and a high level of driver familiarity, dual-lane roundabouts do not enjoy as low a crash rate as do those that are single-lane.

3. Cost. The City's budgetary constraints were such that a dual-lane roundabout would have been cost-prohibitive.

The approach to expandable roundabout design developed for the Happy Valley and Amity roundabout project is the subject of this paper. The design steps, including alternatives for the initial single-lane construction and future expansion, will be discussed followed by the details of the Happy Valley and Amity case study. The discussion will conclude with some lessons learned from the case study project.

DESIGN STEPS

The intent of this paper is not to discuss in detail all aspects of performing a roundabout design. Rather, the focus is on the additional steps that are required to design an expandable roundabout. Those steps include:

1. development of the proposed dual-lane roundabout geometry,
2. development of an initial-build, single-lane layout consistent with the proposed dual-lane geometry, and
3. development of the detailed construction drawings for the initial-build layout.

A detailed discussion of each of these three design steps follows.

Development of the Proposed Dual-Lane Geometry

An expandable design should always begin with a good dual-lane layout. Dual-lane operation and design are much more complex than single-lane. While single-lane roundabout operations can be forgiving, to an extent, of shortfalls in the design, the safety and efficiency of dual-lane roundabouts generally suffer significantly from even "small" design problems. Expanding a "good" single-lane design does not necessarily result in a "good" dual-lane design. However, a good single-lane, initial-build layout can often be readily developed as a first phase of the development of a dual-lane roundabout.

The designer must fully check the dual-lane layout to ensure that it will function with the intended safety and efficiency as he or she would do if a dual-lane roundabout were being constructed right from the start. For example, the geometry should be checked for proper entering and circulating speed control (fastest path analysis). It should also be checked for potential entering and exiting lane path overlap issues and proper handling of pedestrians and bicycles.

Figure 1 shows an example dual-lane roundabout.

Development of the Initial-Build Single-Lane Layout

Only after the dual-lane geometry has been developed and thoroughly checked should the initial-build single-lane layout be developed. The two basic alternatives for developing the initial-build, single-lane layout are to:

1. build full outside footprint with future widening inward, or
2. build final interior features with future widening outward.

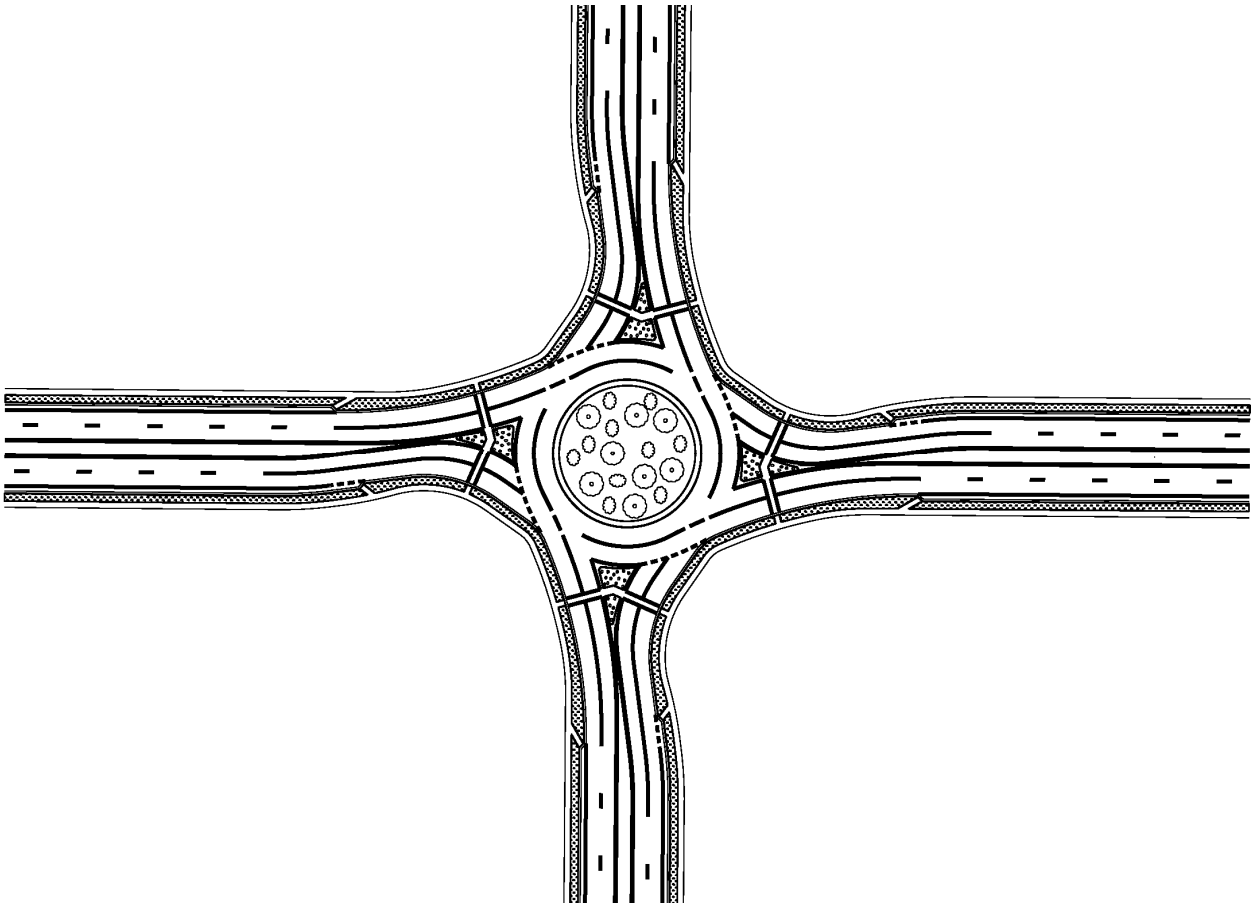

FIGURE 1 Example of dual-lane roundabout layout.

Each of the two options will be discussed in detail in this section of the paper. It should be noted that some may consider there to be a third option: build the full dual-lane roundabout geometry and create the single-lane operation through striping only. The authors are of the opinion that this option should not be pursued because the lack of proper channelization by hard improvements results in drivers ignoring the striping and following the path of least resistance, which results in higher speeds. The desired roundabout operations can only be achieved by constructing sufficient hard improvements to force drivers to follow the desired vehicle paths.

Alternative 1 – Build Full Outside Footprint and Widen Inward

Under this alternative, the roundabout is designed such that the single-lane vehicle path essentially follows the right-hand lanes on the entrances and exits and the outside lane on the circulatory roadway.

The central island is enlarged to force the vehicle paths to the outside lane. This may be accomplished by enlarging the landscaped central island itself or through the use of an expanded truck apron. The future expansion will likely be easier and less costly if only the truck apron needs to be modified to develop the inside lane.

The splitter islands can most likely be constructed in their ultimate configuration. Widening of these islands in the initial-build condition may be desirable in order to force vehicles into the future right-hand lane on the approaches and exits, especially on high-speed approaches. However, in many cases this will be unnecessary because the fastest path will draw motorists away from the splitter islands and toward the outside.

Using the right-hand lanes on the approaches and exits in conjunction with the inside lane on the circulatory roadway is not acceptable because that would provide insufficient vehicle path deflection, resulting in higher-than-desired vehicle speeds.

Figure 2 shows an example of this initial-build alternative.

Advantages This alternative provides some advantages over future outward widening. They are:

- The drainage features and sidewalks are built initially in their ultimate locations. This eliminates the need to develop a temporary drainage solution for the initial build.
- Full right-of-way needs are taken care of up front, eliminating the need to open negotiations with property owners again in the future.

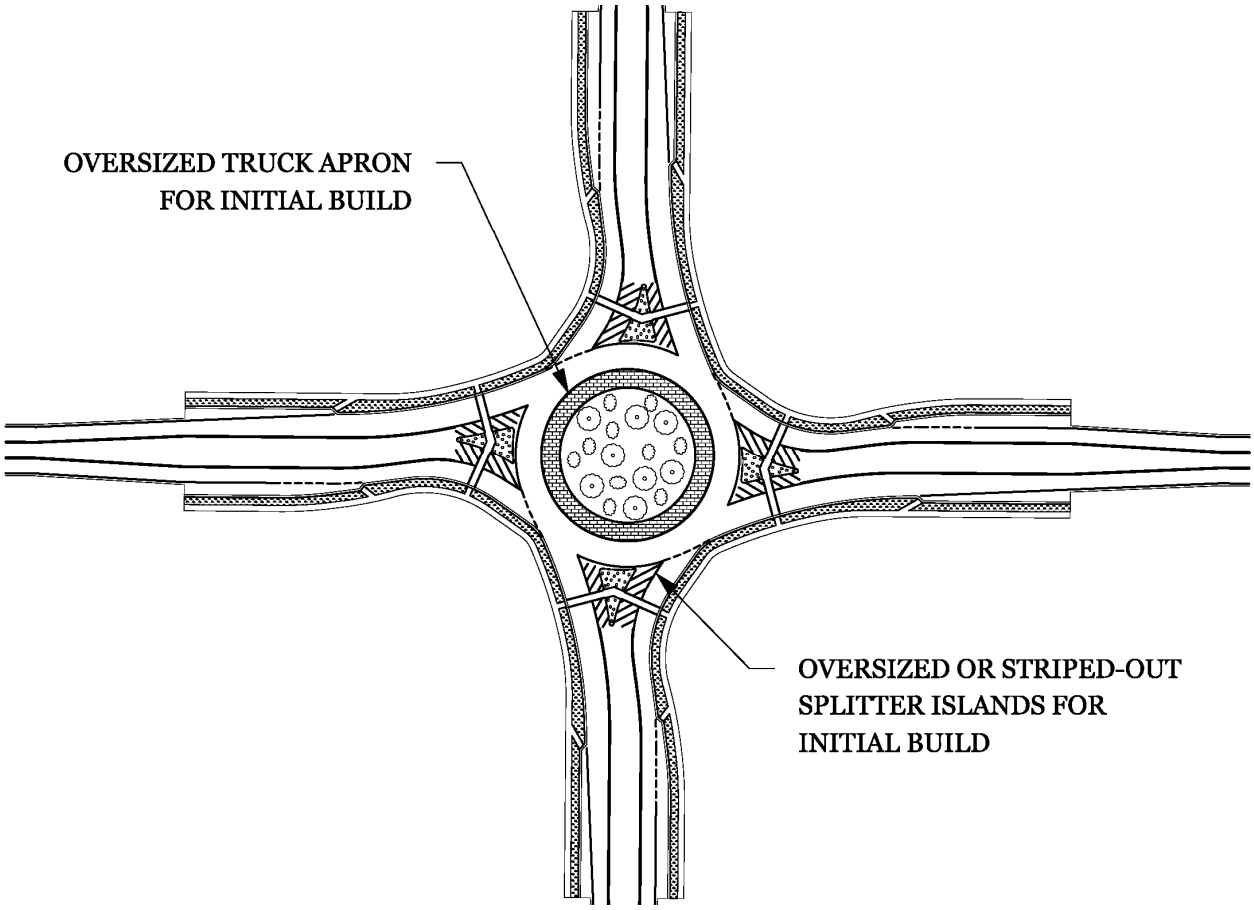

FIGURE 2 Example of initial outside build with future inward widening.

- Future expansion affects the islands only. The adjoining properties will not need to be disturbed with future construction on the outside.

Disadvantages This alternative's disadvantages include:

- More widening of the intersection approaches is required to push the entering and exiting traffic to the outside lanes. In most cases, the initial-build, full-footprint roundabout will need to tie into existing two-lane or three-lane roadways. The transitions from the existing roadway sections to those needed at the roundabout will be much longer than for the other alternative.
- This alternative will generally have a higher initial cost.

Alternative 2 – Build Final Interior Features and Widen Outward

Under this alternative, the roundabout is designed such that the single-lane vehicle path follows the left-hand lane on the approaches and exits and the inside lane on the circulatory roadway.

The central island is constructed for the ultimate dual-lane configuration. The one exception is that the truck apron will likely need to be wider in the initial build than in the ultimate configuration in order to accommodate trucks under single-lane operation. That additional truck apron width is taken out of the landscaped portion of the central island. This will result in a truck apron that is wider than needed once the roundabout is expanded, but this is not expected to impact operations negatively.

The splitter islands are constructed in their ultimate configuration. For the initial-build, single-lane operation, these islands can be lengthened somewhat toward the central island to narrow the circulatory roadway. Because the space that would be occupied by the extension isn't on the fastest vehicle path, however, such extension may not be necessary. In other words, it may be possible to lengthen the islands with striping only, as opposed to hard improvements.

The outside edges of the roadways are not in their ultimate location under this alternative. In a rural setting, it may be possible to construct the edge treatments with just barrow ditches to control the vehicle paths and dispose of stormwater. In urban settings, however, it may be necessary to construct temporary drainage facilities, including curb and gutter.

Figure 3 shows an example of this initial-build alternative.

Advantages This alternative provides some advantages over future inward widening. They are:

- The initial cost may be significantly less. This is particularly true if rural edge treatments are constructed and if right-of-way is only acquired for the initial build.
- Transitioning into the existing two-lane roadways is much easier. The transitions can be shorter and follow more natural vehicle paths.
- The additional right-of-way, drainage features, sidewalks, and planter strip landscaping can potentially be acquired in the future through development exactions. This is only true, of course, where the adjoining parcels are currently undeveloped or where the potential exists for redevelopment.

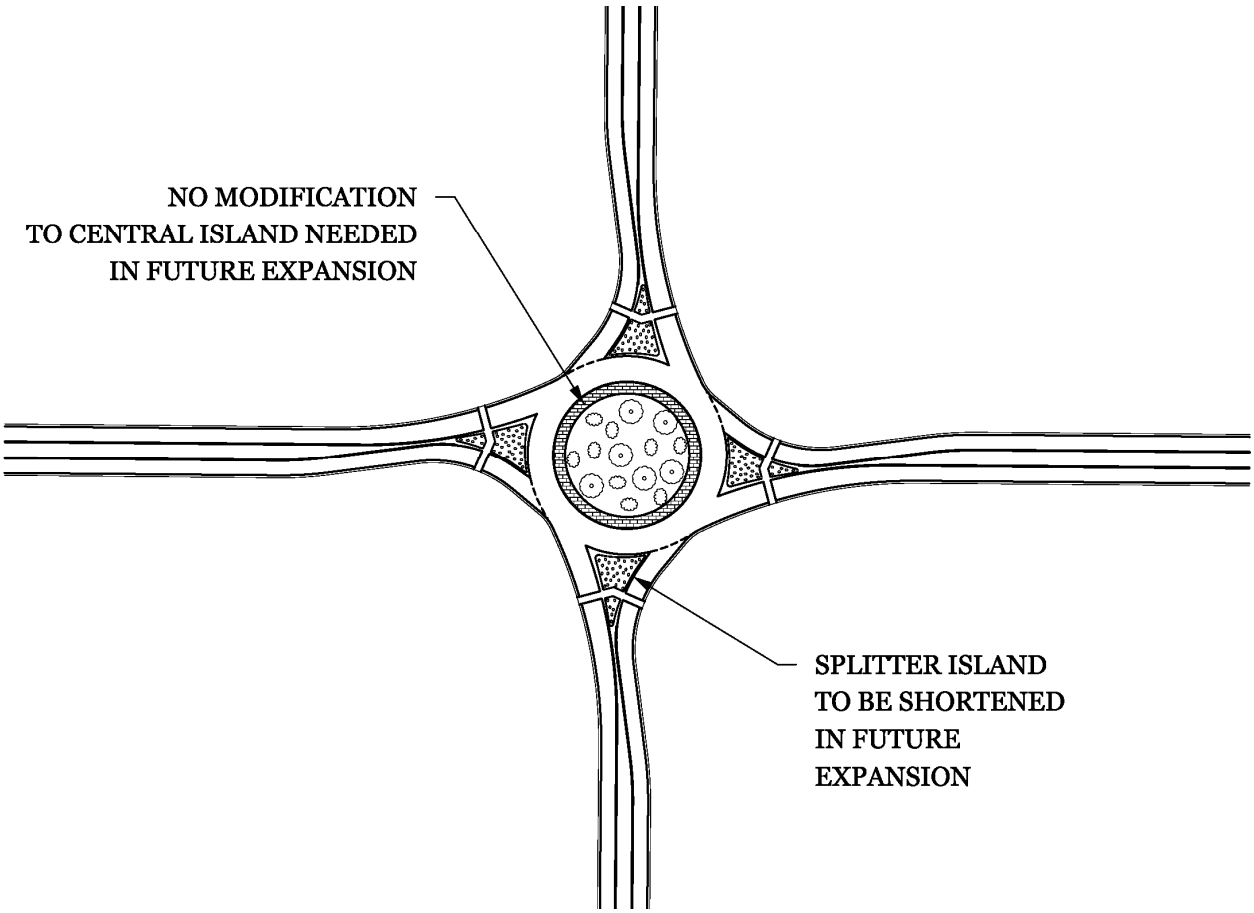

FIGURE 3 Example of initial inside build with future widening outward.

Disadvantages This alternative's disadvantages include:

- The adjoining properties are disturbed twice, at the time of initial construction and at the time of widening.
- Because sidewalks and other pedestrian facilities would normally be constructed with the full-width improvements, there may not be any pedestrian facilities until the roundabout is expanded.
- The long-term cost to the agency may be significantly more if the agency has to acquire more right-of-way and construct the expansion in the future (i.e. all four corners of the intersection are not developed/redeveloped by the time the dual-lane operation is needed).

CASE STUDY – HAPPY VALLEY AND AMITY ROUNDABOUT

As was stated in the beginning of this paper, the Happy Valley and Amity roundabout project in Nampa, Idaho was developed using the process described herein. First, PEC developed a dual-lane layout to meet the intersection's long-term traffic needs. Care was taken to develop a layout that adequately controls vehicle speeds and eliminates entry and exit path overlap problems. The use of "left-offset" design and tangent entry were important in accomplishing those objectives. An artist's rendering of the ultimate-build, dual-lane roundabout is shown as Figure 4.

FIGURE 4 Happy Valley and Amity - artist's rendering of future dual-lane roundabout (looking northeast).

Expandability Options

The project team explored both of the alternatives for staging the initial build outlined in this paper. The alternative of building the full inside improvements with future widening to the outside was selected as preferred. Reasons for that selection in this case were as follows:

- All four corners of the intersection are likely to be developed or redeveloped by the time the full dual-lane roundabout is required. Using an alternative to widen outward in the future makes it possible for the City to acquire the necessary right-of-way, roadway widening, drainage improvements, and sidewalks by development exactions.
- The "inside-out" widening alternative greatly simplified the transitions to the existing two-lane rural arterial roadways. One leg of the intersection has an irrigation crossing, with a large control structure adjacent to the roadway, located only about 260 feet (79 meters) from the center of the intersection. The short transition made it possible to avoid impacts to that control structure with this project.
- The project cost was brought within the City's budget by deferring the cost of the full right-of-way, drainage improvements, and sidewalks to the development/redevelopment process.

Design Features

Some of the key design features/dimensions of this roundabout are as follows:

- Inscribed circle diameter – 180 feet (54.9 meters) for the ultimate build, 160 feet (48.8 meters) for the initial build.
- Design vehicle – AASHTO WB-67 (interstate tractor-trailer rig).
- Circulatory roadway width – 30 feet (9.1 meters) for the ultimate build, 20 feet (6.1 meters) for the initial build.
- Truck apron width – 10 feet (3.0 meters) required for the initial build (will remain unchanged after the widening).

Figure 5 is a photograph of the completed initial-build single-lane roundabout.

Expansion on Northwest Corner

After construction of the initial-build single-lane roundabout was completed in August 2006, the northwest corner of the intersection was developed (left side of photo in Figure 5). The full-width widening, complete with drainage facilities and sidewalks, in that quadrant of the roundabout was constructed by the developer in conformance with the dual-lane layout originally developed.

The expansion created a two-lane entry on the southbound approach and a two-lane exit westbound. The right-hand entry lane was signed and striped as a turn-only lane. In general, the roundabout expansion in the northwest quadrant went smoothly.

FIGURE 5 Happy Valley and Amity - constructed initial-build single-lane roundabout (looking northeast).

Public Outreach

Public and political support to construct this innovative intersection came about through the following efforts:

- behind the scenes work by the City's Mayor and Public Works Director, as well as officials from Nampa Highway District #1 (the City's partner on this project),
- traditional public open house,
- support from the local newspaper,
- involvement of other cities and highway districts, and
- a full-scale roundabout demonstration (mock-up).

The City's Mayor and Public Works Director made an effort to educate themselves on the safety and operational benefits of roundabouts. They then engaged the members of the City Council early in the process to "sell" the project to them and address any concerns they may have had.

Nampa Highway District #1 supported the construction of a roundabout at this location early in the concept study. Their director and engineer attended a roundabout design workshop and educated themselves in other ways, as well, to be able to advise their Board of Commissioners regarding the project and provide valuable input into the design and public outreach.

A traditional public open house was held which focused on the operations and benefits of roundabouts. This helped to dispel a great many incorrect notions that people held as a result of their exposure to other circular intersection types in the past. The open house was especially effective at solidifying support from the elected officials, the local newspaper, and the owners of property adjoining the project.

Largely through the efforts of the City's public information officer, the local newspaper got "on board" with the roundabout project. They published several informative, factual articles that cast roundabouts in a positive light. This proved very beneficial in countering the naysayers who inevitably come out in opposition to the implementation of roundabouts in the area.

Early in the project development process, the project team brought together a group representing not only the City but neighboring cities and highway districts and the state transportation department to discuss the need for a unified approach to educating the public about roundabouts. A number of ideas were discussed. Some of those ideas were implemented as part of this project while others may be implemented later as additional arterial roundabouts come online in the area.

The most significant result of the cooperative effort with neighboring jurisdictions was the full-scale roundabout demonstration. Proposed by Nampa Highway District #1, the mock-up was laid out in a large parking lot at the City's events center. The District took the lead in pulling together supplies and manpower to set out the cones and sand bags, with the City and nearly all the other agencies participating in a meaningful way. The City's public information officer secured coverage from all four of the local television news channels, while others made personal contacts with public safety agencies, truckers, school bus companies, and others to encourage them to bring their vehicles out on the big day and drive them through the roundabout mock-up. Many members of the general public came out in their cars and pickups as well to drive the

roundabout. The result of the demonstration was considerable positive press coverage and the convincing of many that the roundabout would work as advertised.

Figure 6 is a photograph of the full-scale roundabout demonstration.

LESSONS LEARNED – HAPPY VALLEY AND AMITY ROUNDABOUT PROJECT

While the Happy Valley and Amity project was very successful, the project team learned some lessons to apply to future projects. These are:

- At least a preliminary complete vertical design of the ultimate dual-lane roundabout needs to be done before the plans are finalized for the initial-build. The dual-lane design efforts for this project focused almost exclusively on the horizontal geometry. That resulted in some challenges achieving proper drainage when the northwest quadrant of the roundabout was widened and curb, gutter, and sidewalk was installed.
- As can be seen in Figure 5, the splitter islands at Happy Valley and Amity were extended into the area where the outside lane of the circulatory roadway will eventually be. This was done to create the narrowed roadway for single-lane operation. Based on post-construction observations of traffic flow in the roundabout, however, it appears that the extension of the splitter islands could have been done with paint only because the area of extension is not on the

FIGURE 6 Happy Valley and Amity – full-scale roundabout demonstration.

fastest path for any of the vehicular movements. Consideration is being given to using striping for the splitter island extensions in other roundabout projects.

- If the splitter islands or truck apron are to be modified in the future, care must be taken to construct them such that the elevations of the new edges of the islands will match the future pavement. During the construction of Happy Valley and Amity, it was discovered that the future modification to one of the splitter islands would result in an unacceptable cross-slope on the widened circulatory roadway. This necessitated a field modification to the curb elevations on the splitter island to avoid a future problem.
- The engineer needs to be involved in re-striping when all or part of the expansion is completed to ensure that proper signing and pavement markings are installed.