massDOT
Massachusetts Department of Transportation

ROTARY RETROFITS WHITE PAPER

ROTARY RETROFITS

Rotaries can be found throughout the Commonwealth of Massachusetts, ranging in location and function from town centers to freeway interchange ramp terminals. Two such examples are shown in Figure 1.

FIGURE 1: ROUTE 2A, 110, & 111 ROTARY IN AYER (LEFT), INTERCHANGE RAMP TERMINAL ROTARY AT I-93 EXIT 33 (RIGHT)

Courtesy of Google Earth

Rotaries are large-diameter circles conducive to high-speed merging and weaving. Table 1 summarizes the driving behaviors that rotary design elements tend to allow or exacerbate.

TABLE 1: DRIVER BEHAVIOR INFLUENCED BY ROTARY DESIGN ELEMENTS

ROTARY DESIGN ELEMENT	DRIVING BEHAVIOR
Large ICD	Encourages high circulating speeds
Wide, undefined circulatory area	Induces weaving maneuvers that, when combined with large ICD, are more challenging due to higher speeds
Lack of splitter islands	Insufficient channelization to restrict wrong-way maneuvers
Acute angle entry geometry	Poor viewing angle of circulating traffic leads to abrupt braking at the yield line or disregard of the yield sign
Weaving zone	High speed merging maneuver on entry and high speed diverge on exits Promotes reverse priority, where entry traffic does not yield to circulating vehicles
Mixed entry controls	Stop signs on entry can violate driver's expectation of yielding at a rotary

High-speed maneuvers at rotaries lead to poor safety records and increased congestion due to longer decision times required at faster speeds. Applying modern roundabout design principles to rotary retrofits could mitigate some of these behaviors.

1.0 OPPORTUNITIES FOR ROTARY RETROFITS

Rotaries can benefit from the introduction of roundabout design elements by following the principles listed in Section 5 of the Guidelines for the Planning and Design of Roundabouts (GPDR) and by eliminating elements not found at roundabouts. Table 2 summarizes elements never found at roundabouts that could be changed at rotaries and their effect on the rotary operation.

TABLE 2: POTENTIAL CHANGES TO DESIGN ELEMENTS OF ROTARIES AND THEIR EFFECTS

POTENTIAL CHANGES IN DESIGN ELEMENTS	POTENTIAL EFFECTS
Yield on entry (replace stop signs)	Allows for higher capacity and lower delay; promotes consistent behavior at all circular intersections
Pedestrians around, not through (remove crosswalks to the central island)	Access to central island can be hazardous to pedestrians and creates the possibility of gridlock
No parking within the circulatory roadway (remove on-street parking within the intersection)	Parking within a roundabout increases conflicts and reduces circulating capacity
Counterclockwise circulation around the central island	Circulation is around the central island, not in front of or reversed, allowing for predictable driver behavior
Priority to circulating vehicles	Prevents gridlock

ROTARY RETROFIT PROCESS

Each rotary retrofit is a unique case and should follow an iterative design process that balances safety and operations within the physical context of the intersection. The following list of roundabout design principles should be applied in the rotary retrofit design process. It is described in further detail in GPDR Section 5.

LANE CONFIGURATION

Provide the minimum number of lanes and lane assignment needed to achieve target capacity, lane volume balance, and lane continuity.

- Define traffic lanes on entry, exit, and within the rotary based on the traffic demand. Restrict the use of or remove unnecessary pavement.
- Lane changes within the rotary should be discouraged by the use of solid lane lines.

SPEED CONTROL

Set slow entry speeds and consistent speeds between conflicting movements.

- Provide geometric, pavement marking, signing, and/or landscape features on entries and within the intersection center to affect drivers' awareness and reduce speeds. Geometric features are preferred.

NON-MOTORIZED USERS

Integrate the needs of people walking and biking.

- Locate pedestrian, cyclist, and transit facilities in accordance with this guide.
- Ensure that facilities for people walking comply fully with ADA requirements, including meeting the needs of people with mobility and vvisual impairments.

DESIGN VEHICLE

Design for or accommodate vehicles consistent with the intersection context.

- Size geometric improvements to accommodate design vehicles; this may include removing pavement that is not required to complete turn maneuvers.

SIGHT DISTANCE, VISIBILITY, AND VIEW ANGLES

Ensure sight distance and visibility for driver recognition of conflicting users commensurate with approach and circulating speeds.

- Adjust entry angles to provide adequate view of the circulating traffic.

PATH ALIGNMENT

Provide intuitive, self-describing channelization that naturally directs vehicles to intended lanes.

- Align entering and exiting lanes with the intended receiving lanes.
- Discourage weaving maneuvers within the rotary.

Rotary retrofits can be incorporated into a range of improvement projects, from maintenance and roadway resurfacing projects to full intersection reconstruction or rehabilitation. Incremental changes are possible but may not address all roundabout design principles. Adapting an existing rotary to operate with similar safety and capacity characteristics of a roundabout requires a full evaluation of all geometric elements and traffic flows.

1.1 MAINTENANCE PROJECTS

Rotary signing and pavement markings can be updated as part of routine restriping efforts or during resurfacing projects. Signing and pavement markings should complement each other to inform the driver of upcoming decision points and destinations. GPDR Section 5.10 discusses the regulatory, warning, and guide signs that help drivers make decisions at roundabouts. Similarly, GPDR Section 5.11 discusses pavement markings at roundabouts. The addition of lane lines may help define the available movements in advance of the intersections as well as within the circulatory roadway. Excess pavement could be marked off with chevron striping.

Only the number and assignment of lanes needed to achieve intersection capacity and lane continuity should be provided. Marked lanes within the rotary should not promote or require that drivers change lanes within the rotary, as the need to make lane changes is difficult to communicate to drivers. Clearly marked lanes allow drivers to focus on maintaining their path through the rotary and reduce weaving maneuvers.

Pavement and signing improvements have a limited impact on the following characteristics:

- Entry, circulating, and exit speeds
- Entry viewing angles
- Pedestrian accommodations for people with mobility or visual impairments

1.2 SMALL-SCALE IMPROVEMENT PROJECTS

Small-scale geometric updates to rotary elements, in addition to signing and pavement marking, can further improve the intersection. These updates may be part of pedestrian and bicycle improvement projects or compliance with ADA and US Access Board rules and guidelines for improvements. The following list of geometric modifications could be applied at rotaries:

- Adjust the entry channelization to create path deflection and reduce entry speeds. (GPDR Section 5.3.2)
- Adjust the entry nose geometry to increase the viewing angle toward the circulating traffic and promote yielding rather than merging (GPDR Section 5.3.2.3)
- Adjust the entry width to accommodate the minimum number of lanes appropriate for the current or expected level of traffic. (GPDR Section 2.3)
- Move the outside curb line towards the central island. The periphery of the intersection can be repurposed as a sidewalk or shared-use path.
- Build a truck apron around the central island to reduce the circulating width while continuing to accommodate larger vehicles.
- Locate pedestrian and bicycle facilities around the intersection, locate transit facilities at appropriate locations on the entries and/or exits, and accommodate persons of all abilities (GPDR Section 5.4)

Retrofitting exiting rotary geometry may have a limited impact on the following characteristics:

- Entry, circulating, and exit speeds
- Overall speeds, which were unlikely to reduce significantly except in localized areas because the overall diameter of the rotary remains unchanged with this type of improvement
- Entry path alignment for multilane approaches
  - Irregular central island geometry may impact the ability to properly align entering vehicles onto the circulating lanes.
- Pedestrian accommodations for persons with mobility and/or visual impairments
  - Untreated multilane approaches are inaccessible for persons with visual impairments.

1.3 CAPITAL IMPROVEMENT

Retrofitting a rotary to meet roundabout design principles can be difficult while maintaining the original intersection geometry. Converting rotaries to roundabouts may require full reconstruction of the intersection to enable reducing the diameter and/or major realignment of entries and exits. The two case studies in the following section illustrate roundabouts built on the same footprint of a rotary or entirely within the central island of the old rotary.

Signalizing each entry-circulating junction of a rotary may also be an option when total reconstruction is not feasible or when yield-controlled entries are insufficient to serve existing or projected demand. Signalized rotaries could be an appropriate solution at locations with high traffic volumes.

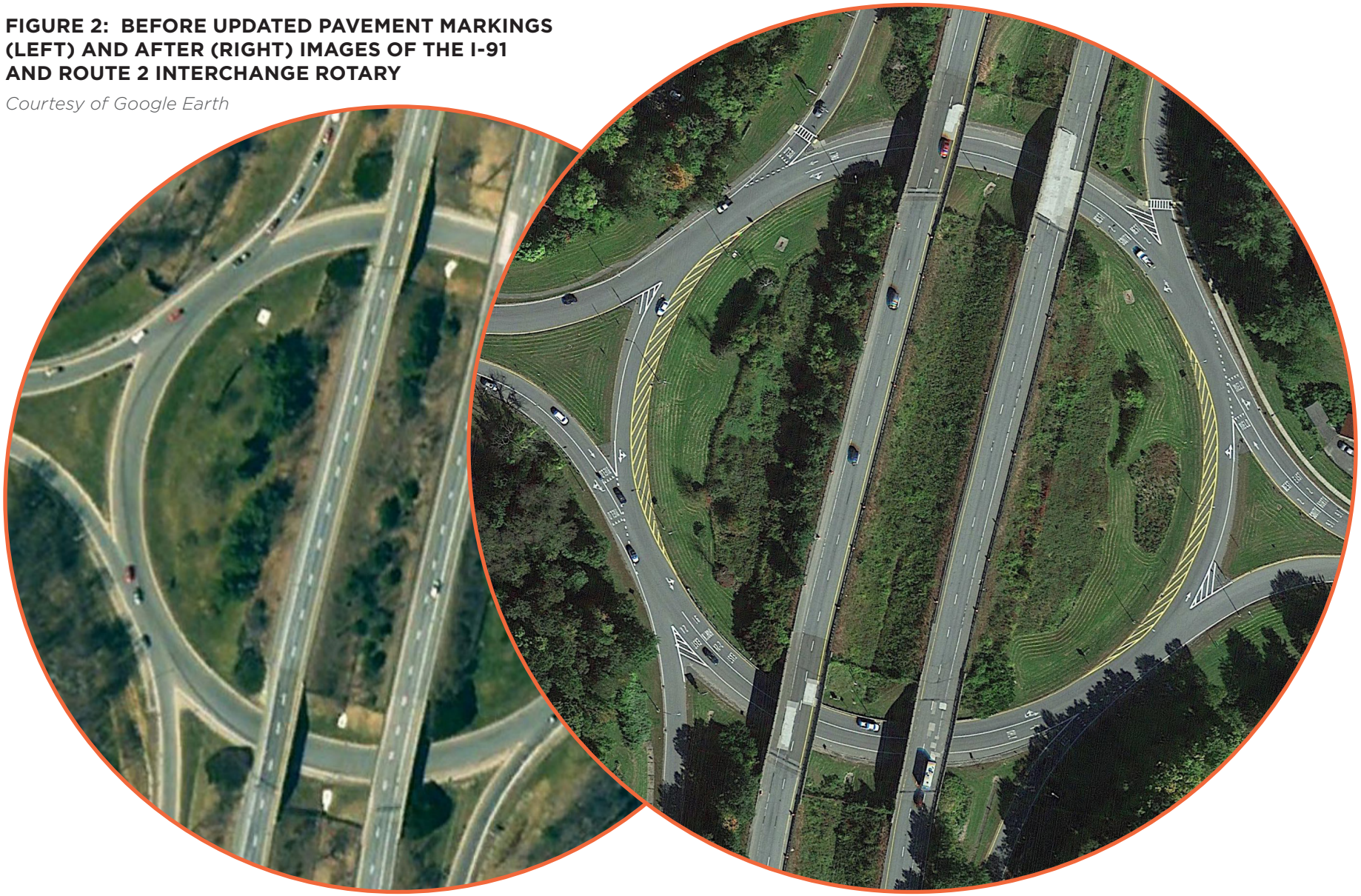
2.0 CASE STUDIES

2.1 PAVEMENT MARKING ADDITIONS

The rotary at I-91 and Route 2 features a combination of two-lane entries on Route 2 (east-west) and single-lane entries on the off-ramps. New pavement markings clearly define the two entry and circulating lanes in the east-west travel directions and narrow the circulatory roadway to one lane in the north-south directions. Figure 2 illustrates the rotary at the ramp terminals between I-91 and Route 2 in Greenfield.

FIGURE 2: BEFORE UPDATED PAVEMENT MARKINGS (LEFT) AND AFTER (RIGHT) IMAGES OF THE I-91 AND ROUTE 2 INTERCHANGE ROTARY

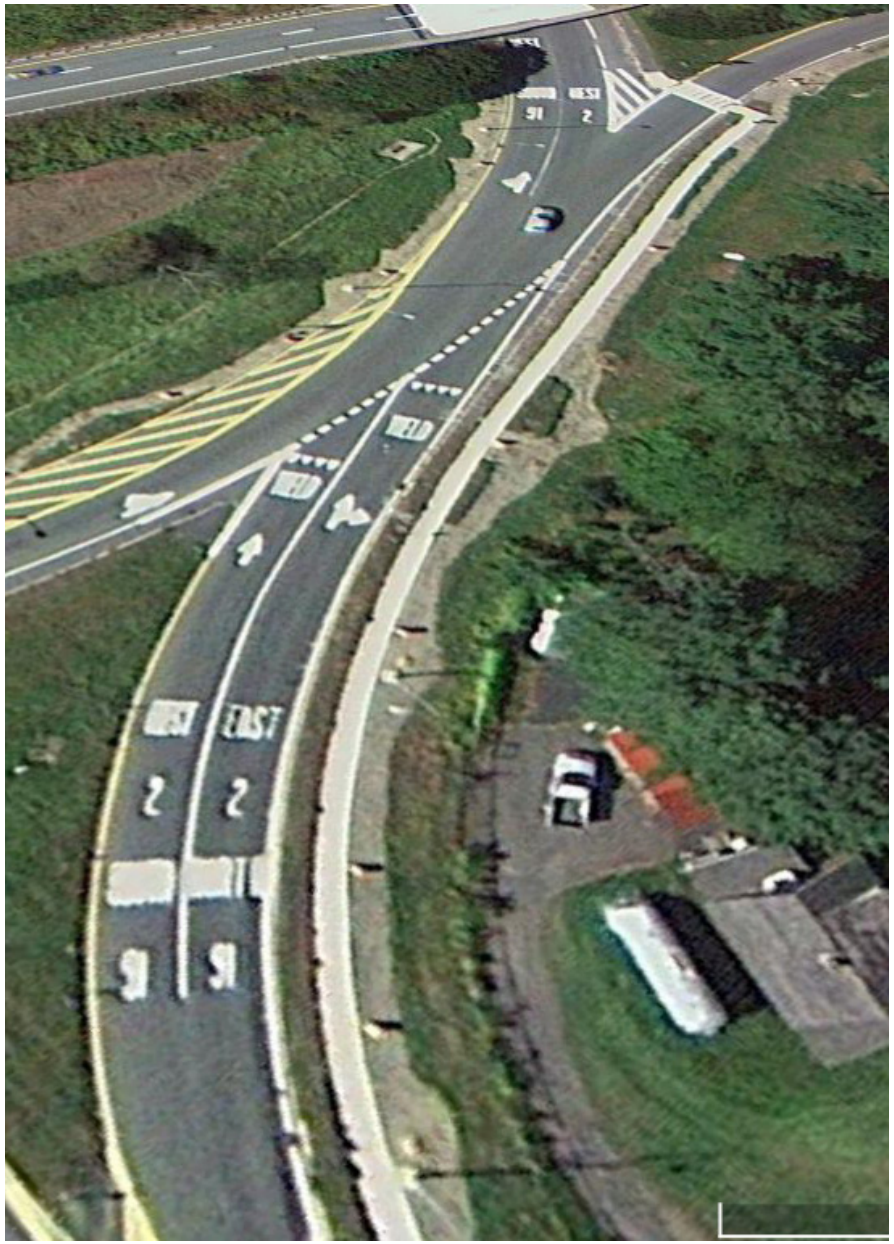
Courtesy of Google Earth



Destinations and directional arrows were marked in each entry and circulating lane. Figure 3 illustrates in greater detail the route markings and directional arrows on the Route 2 westbound approach.

FIGURE 3: ENTRY LANE ROUTE MARKINGS

Courtesy of Google Earth



2.2 CIRCULATORY ROADWAY MODIFICATIONS

Figure 4 illustrates pedestrian improvements made around the US 5 and Route 147 interchange rotary in West Springfield. The circulatory roadway was narrowed in the process of enhancing the pedestrian facilities. The north-south sections of the circulatory roadway were striped out with chevrons to define one circulatory lane.

FIGURE 4: US 5 (TOP) AND ROUTE 147 (BOTTOM) ROTARY IN WEST SPRINGFIELD

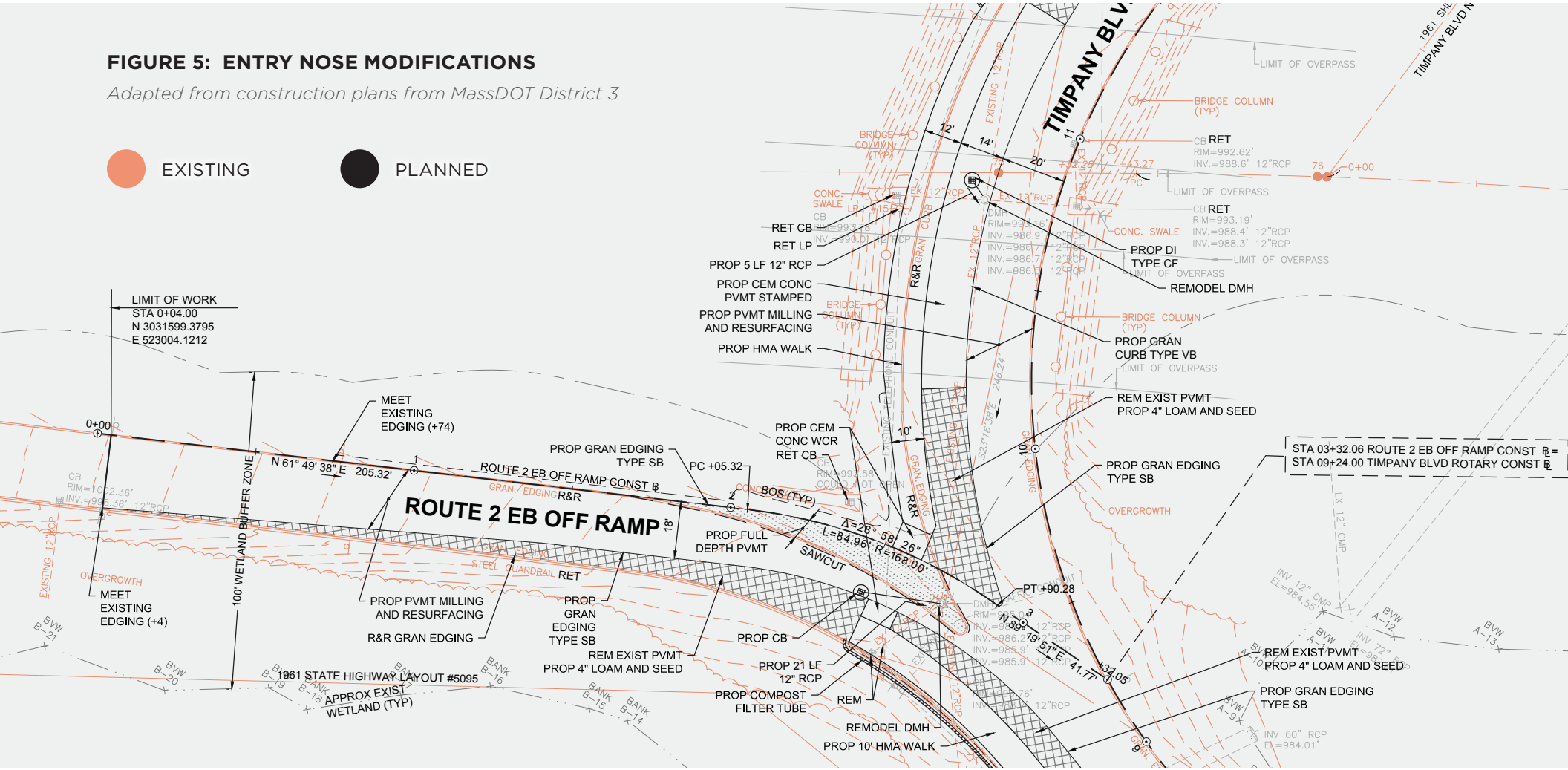
Courtesy of Google Earth

2.3 ENTRY MODIFICATIONS

Figure 5 illustrates a portion of a construction plan for adjusting the entry geometry from the Route 2 eastbound off-ramp into the Route 68 rotary in Gardner. The original entry nose geometry led vehicles nearly parallel with the circulatory lanes. The proposed nose geometry is aligned with the inside curb around the circulatory roadway, leading vehicles into the circulating lane, and deflects their path to promote slower entry speeds.

FIGURE 5: ENTRY NOSE MODIFICATIONS

Adapted from construction plans from MassDOT District 3



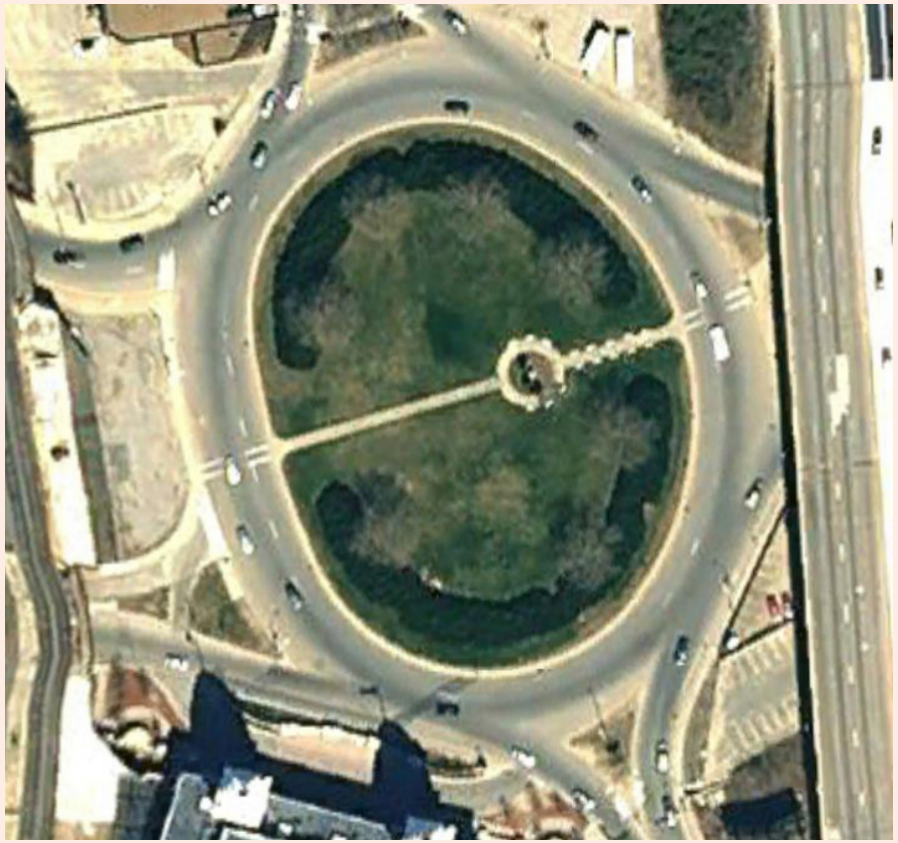
2.4 REPLACEMENT

Modern roundabouts have a smaller footprint than large rotaries and can be built in some cases within the central island of the rotary. Figure 6 illustrates the roundabout built in Washington Square in Worcester completely within the footprint of an old rotary.

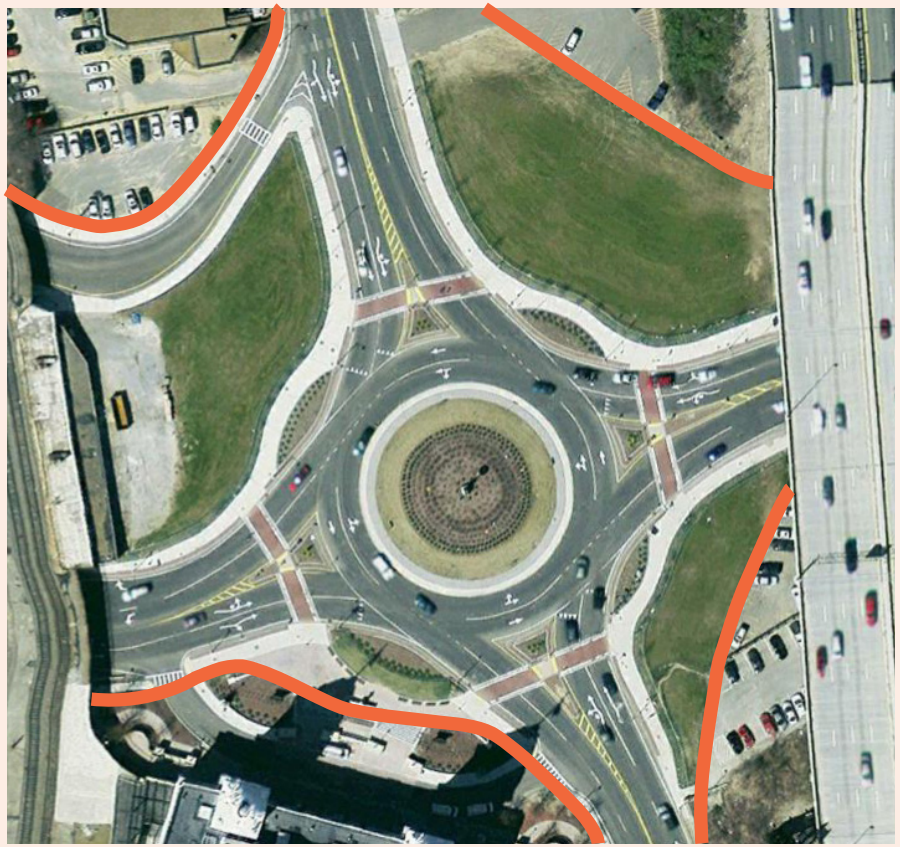
FIGURE 6: WASHINGTON SQUARE, WORCESTER ROUNDABOUT CONSTRUCTION WITHIN THE OLD ROTARY FOOTPRINT

Courtesy of Google Earth

LARGE ROTARY FOOTPRINT



ROUNDABOUT REPLACES ROTARY IN A SMALLER FOOTPRINT



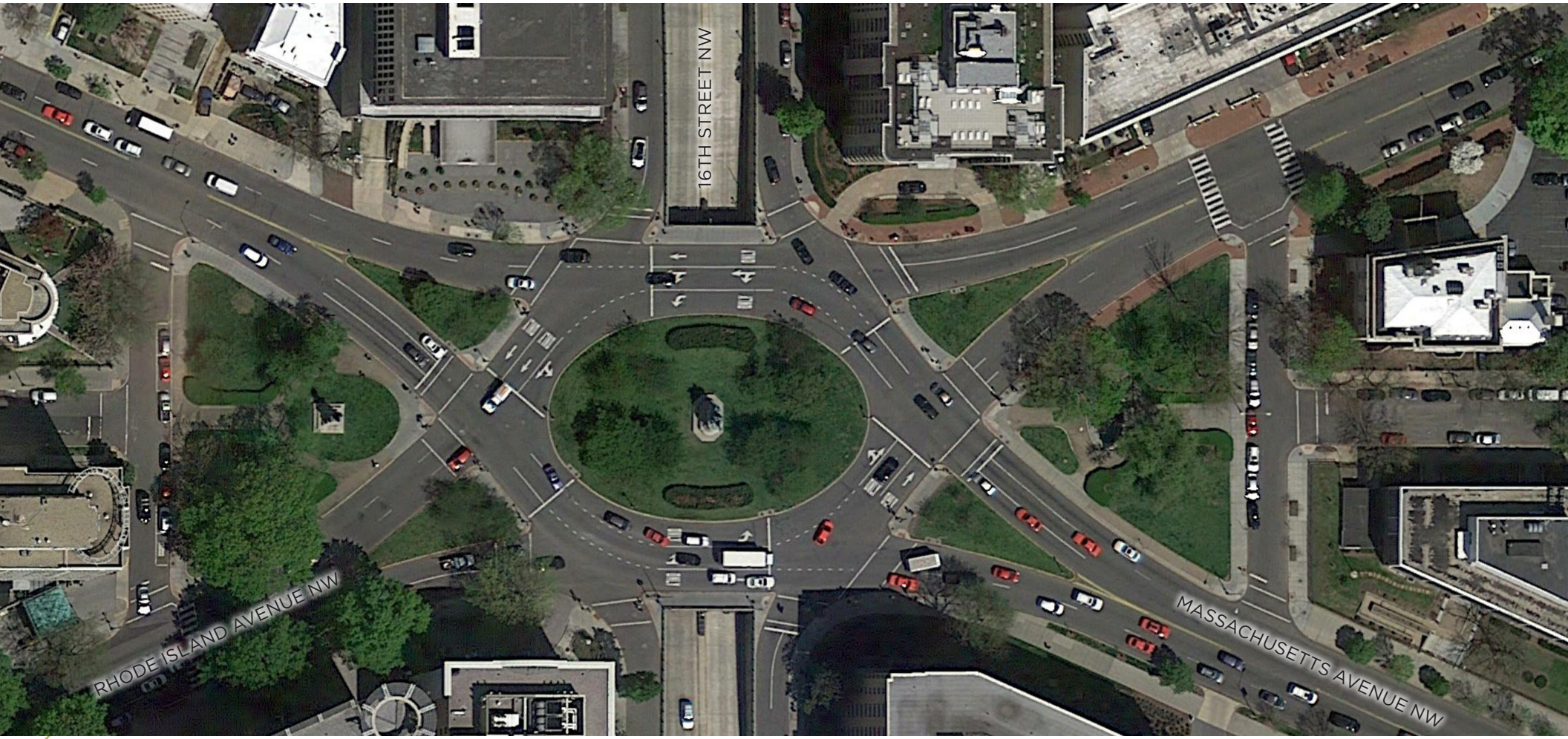
LIMITS OF OLD ROTARY

2.5 SIGNALIZATION

Figure 7 illustrates a signalized rotary in Washington, D.C. at the six-way intersection between Massachusetts Avenue, Rhode Island Avenue, and 16th Street. This rotary functions as a tight-diamond interchange for the 16th Street ramps. The signals can prioritize the ramp traffic and can manage queue lengths and potential spill-backs onto the 16th Street mainline. Traffic signals within rotaries may be beneficial at locations with unbalanced traffic flows by optimizing the progression of vehicles along the dominant travel path.

FIGURE 7: SIGNALIZED ROTARY, SCOTT CIRCLE, WASHINGTON, D.C.

Courtesy of Google Earth



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