Is a Median Reversible At-Grade Toll Lane a Good Fit for Your Highway Corridor?

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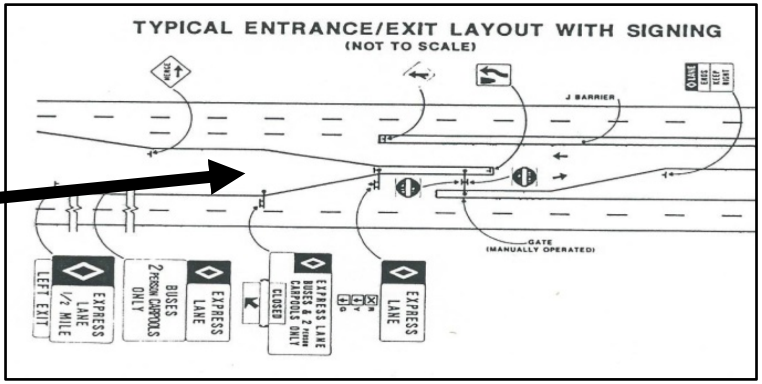
Presentation created by Denny Eyler for 2019 ITE Annual Meeting and Exhibit

Introduction

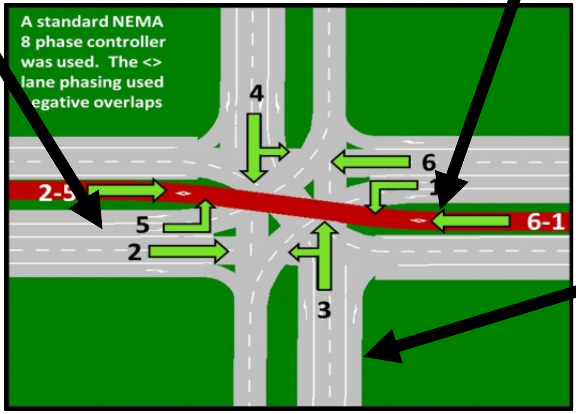
- High Occupancy Vehicle (HOV) lanes, High Occupancy Toll (HOT) lanes, and dynamically managed lanes on freeways have proven successful where used in the US.
- Can a similar lane be added to a surface-divided roadway and be a toll lane? It can be described as a Median Reversible At-Grade Toll Lane (MRATL).
- A MRATL prototype operated successfully for seven years in Minneapolis, MN. It was a reversible HOV lane built in the median of an at-grade roadway (US 12) and added capacity during the conversion of US 12 to I-394. The design has been unique to date.
- This presentation outlines the process for considering a MRATL and the initial steps in developing and evaluating a corridor concept.



Reversible Lane Entrance

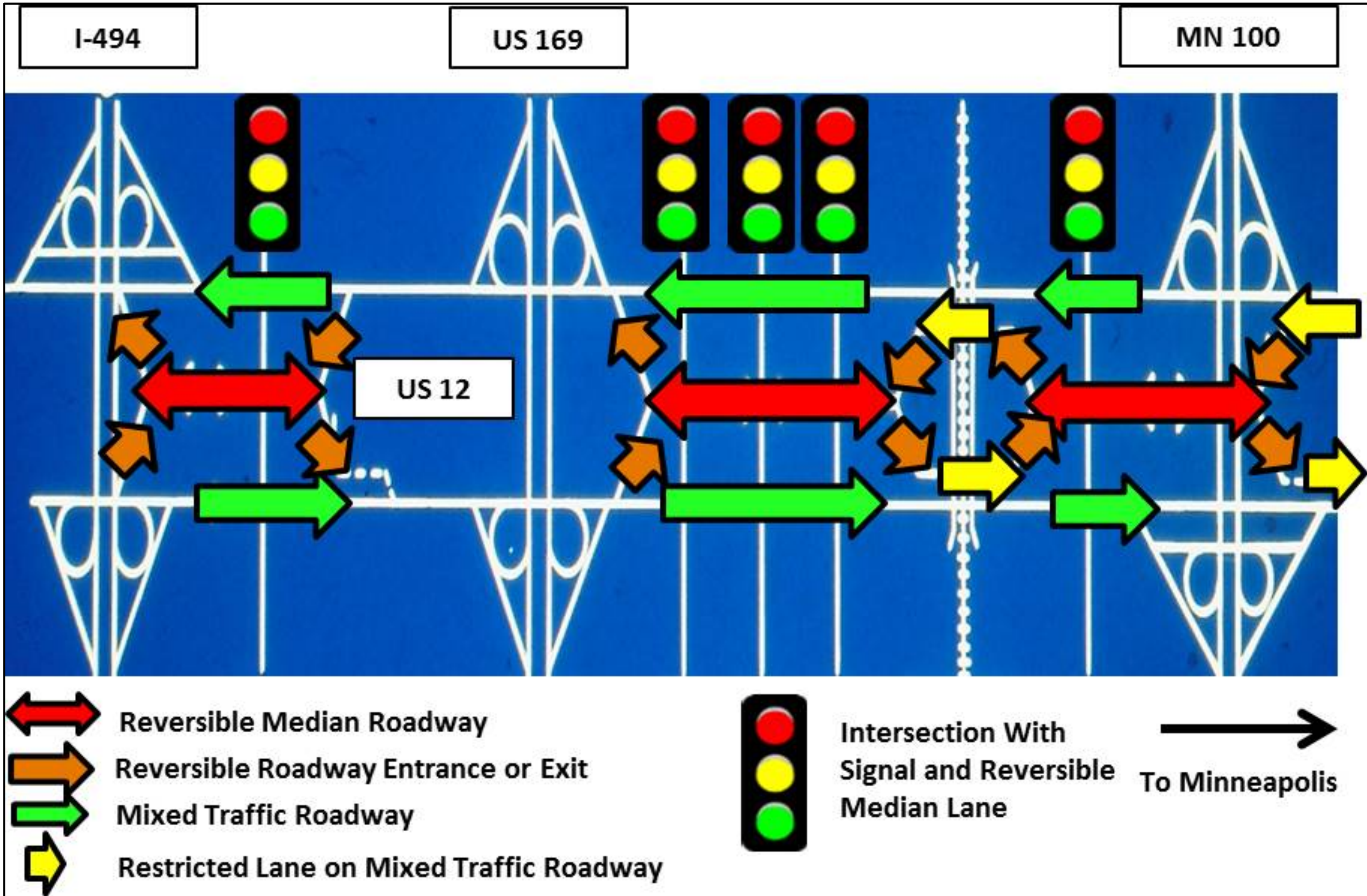
In the Reversible Lane

Signal and Oncoming Reversible Lane



Side Street Approach

US 12 Reversible Lane Schematic



What is a MRATL?

- Located in the median of a surface-divided highway
- Open during the peak period in the peak direction of travel
- Runs through traffic signal controlled intersections
- Where access is usually not permitted at intersections
- Where entry and exit points are typically located away from intersections
- Can be a toll and/or an HOV facility and serve as a busway
- May use grade separations at key locations

What can it do?

A reversible lane can:

- Add capacity when the need is of short duration
- Add capacity when the need is directional
- Add capacity when funding is limited
- Improve bus service
- Add capacity when physical and social constraints rule out a freeway
- Generate revenue
- Serve as an interim improvement until the roadway can be converted to a freeway

Criteria for Selecting Candidate Corridors: Traffic Conditions

- Demand equal to or greater than capacity – critical lane volumes above 1,400
- High travel times and delays
- Directional imbalance of 3:2 or greater
- Peak period greater than two hours
- ADT greater than 40,000
- Are there parallel routes that can supply additional demand?
- Express bus or BRT route
- Supply of carpools: 2 or 3+
- Corridor can also serve recreational peaks
- Agency has existing toll collection system or willing to establish one
- Ability to use demand-based dynamic pricing

Criteria for Selecting Candidate Corridors: Physical Conditions

Geometrics

- Logical termini to collect and disperse added traffic
- Divided Roadway with median width of 24+ feet
- If medians are narrow, consider alternative intersection designs
- Locations for entrance and exits with adequate weaving distances
- Ideally, no turns permitted to or from MRATL at intersections

Signals

- Protected only lefts across MRATL
- Coordination favors MRATL
- Alternative intersection signals will have alternative phasing
- Ideally, green time in MRATL lane is nearly equal to open lanes

Evaluating Candidate Corridors

- Develop peak hour traffic forecasts assuming added toll lane capacity.
- Check for directional imbalance.
- Check intersection geometry and median widths. A basic median width of 24 feet or larger is needed between intersections. At intersections, the required width would be dependent on the number of required left turn lanes on the major roadway.
- Perform planning-level capacity intersection calculations (critical lane). Then, determine toll lane capacity (it should be 700 vph or greater).
- Check segment termini for capacity issues. There should be available capacity to handle the added traffic reaching the end of the toll segment. If the MRATL terminus is at an interchange, consider adding connections to entrance ramps. If capacity is not sufficient, a signal may be used with priority for the MRATL.
- At entrance and exit locations, consider weaving issues. Remember you will have a platooned flow environment. Signal control may be required to manage a merge. Try to avoid short left lane drops.

Evaluating Candidate Corridors - continued

- Inventory all median openings without existing traffic signal control.
  - Determine which median openings can be closed. Consider a MRATL project as an opportunity to do access management.
  - If median openings cannot be closed, can they have restricted geometry with full or part time signal control?
  - Determine which median openings must remain open and assume signals will be added.
- Consider alternative intersection designs or grade separations when median space is limited or to reduce travel times in the toll lane to meet travel time improvement goals.
- Simulation is recommended to uncover any operational issues. To be considered a candidate for tolling, a travel time savings of one minute per mile in the MRATL should be obtainable.

Survey of MRATL Potential by State

The following table summarizes whether there could be candidate MRATL corridors in a state.

Each state was rated as:

- Likely
- Maybe
- Unlikely

Primary criteria were:

- Population
- Presence of high volume, at-grade divided highways
- Use of innovative intersection designs
- Toll collection infrastructure

States Where MRATL Corridors Could Be Considered

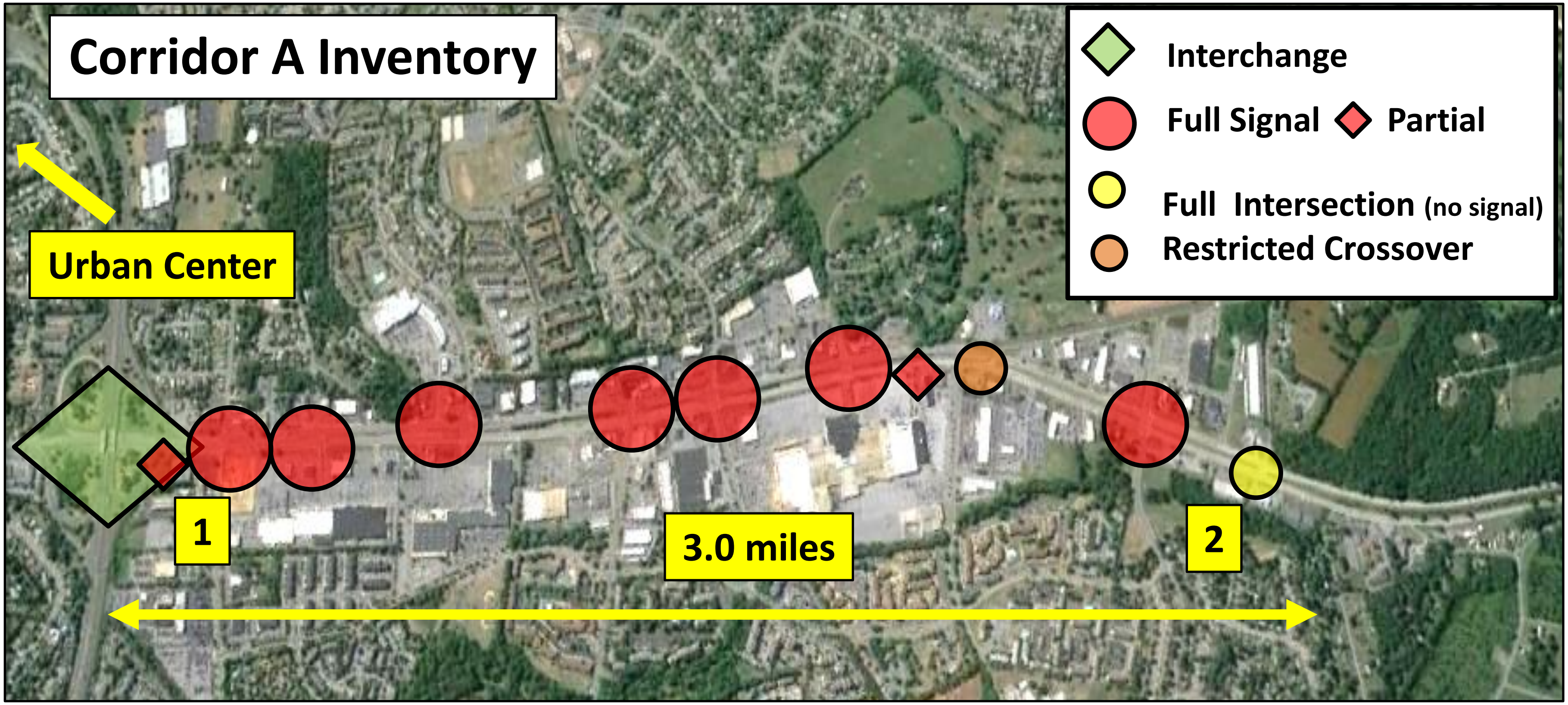
State	Candidate Corridors	State	Candidate Corridors	State	Candidate Corridors	State	Candidate Corridors
Alabama	Maybe	**Indiana**	Likely	**Nevada**	Maybe	**South Carolina**	Unlikely
Alaska	Unlikely	**Iowa**	Maybe	**Nebraska**	Maybe	**South Dakota**	Unlikely
Arizona	Maybe	**Kansas**	Unlikely	**New Hampshire**	Unlikely	**Tennessee**	Maybe
Arkansas	Unlikely	**Kentucky**	Maybe	**New Jersey**	Likely	**Texas**	Likely
California	Likely	**Louisiana**	Unlikely	**New Mexico**	Unlikely	**Utah**	Maybe
Colorado	Likely	**Maine**	Unlikely	**New York**	Likely	**Vermont**	Unlikely
Connecticut	Maybe	**Maryland**	Likely	**North Carolina**	Likely	**Virginia**	Likely
Delaware	Unlikely	**Massachusetts**	Maybe	**North Dakota**	Unlikely	**Washington**	Maybe
Florida	Likely	**Michigan**	Likely	**Ohio**	Likely	**Washington D.C.**	Unlikely
Georgia	Likely	**Minnesota**	Likely	**Oklahoma**	Unlikely	**West Virginia**	Unlikely
Hawaii	Unlikely	**Mississippi**	Maybe	**Oregon**	Unlikely	**Wisconsin**	Maybe
Idaho	Unlikely	**Missouri**	Maybe	**Pennsylvania**	Maybe	**Wyoming**	Unlikely
Illinois	Maybe	**Montana**	Unlikely	**Rhode Island**	Unlikely		

Sample Corridors

- The following four corridors are shown to demonstrate the initial inventory process and suggest possible techniques to handle MRATL termini.
- Corridors hypothetical and not related to any actual projects or corridor studies that are currently underway.
- After initial corridor inventories were completed, a candidate corridor was selected to be tested in simulation to determine:
  - Travel time changes from adding a MRATL
  - Effects of use of alternative intersection designs
  - Effects of managing toll lane volumes through pricing

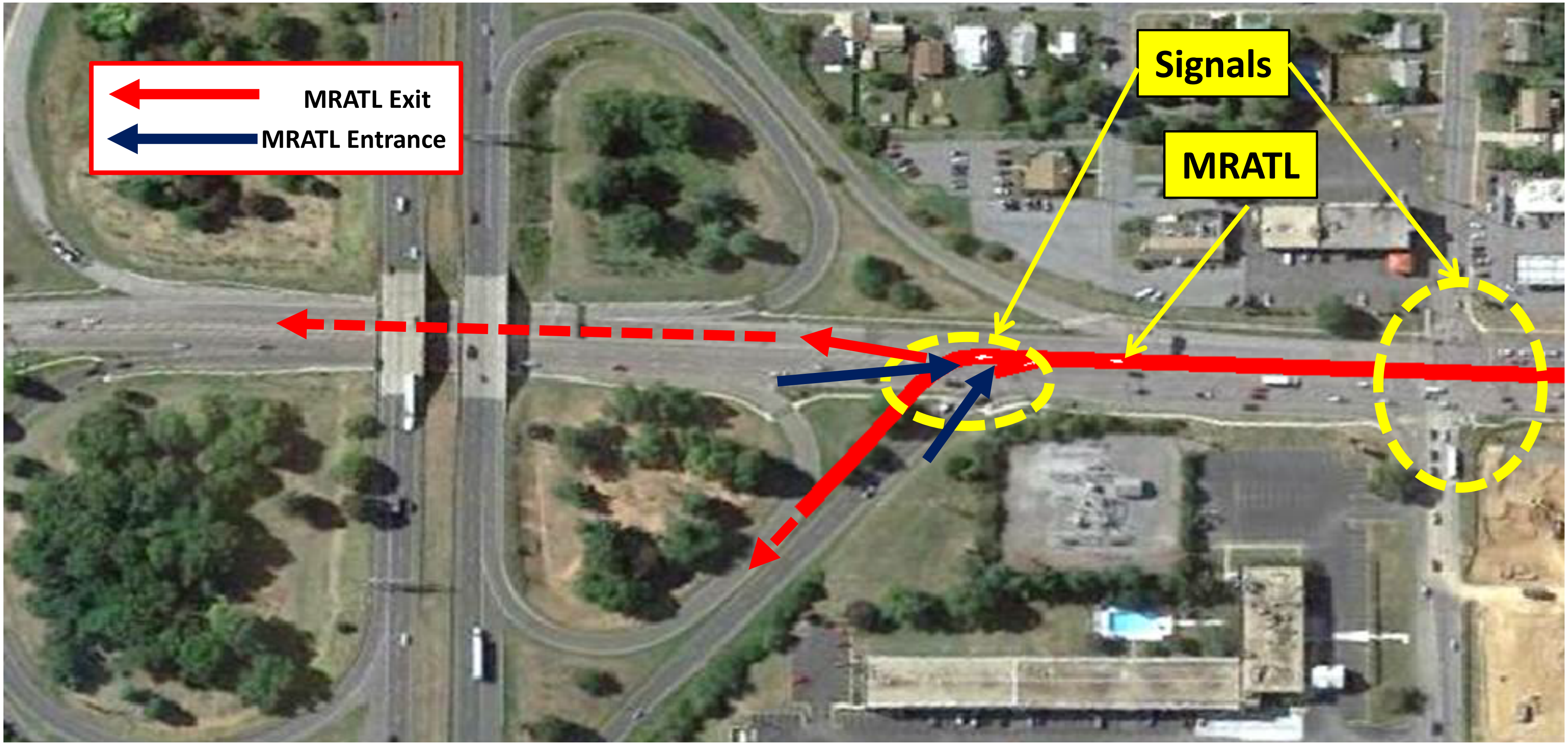
Design Options

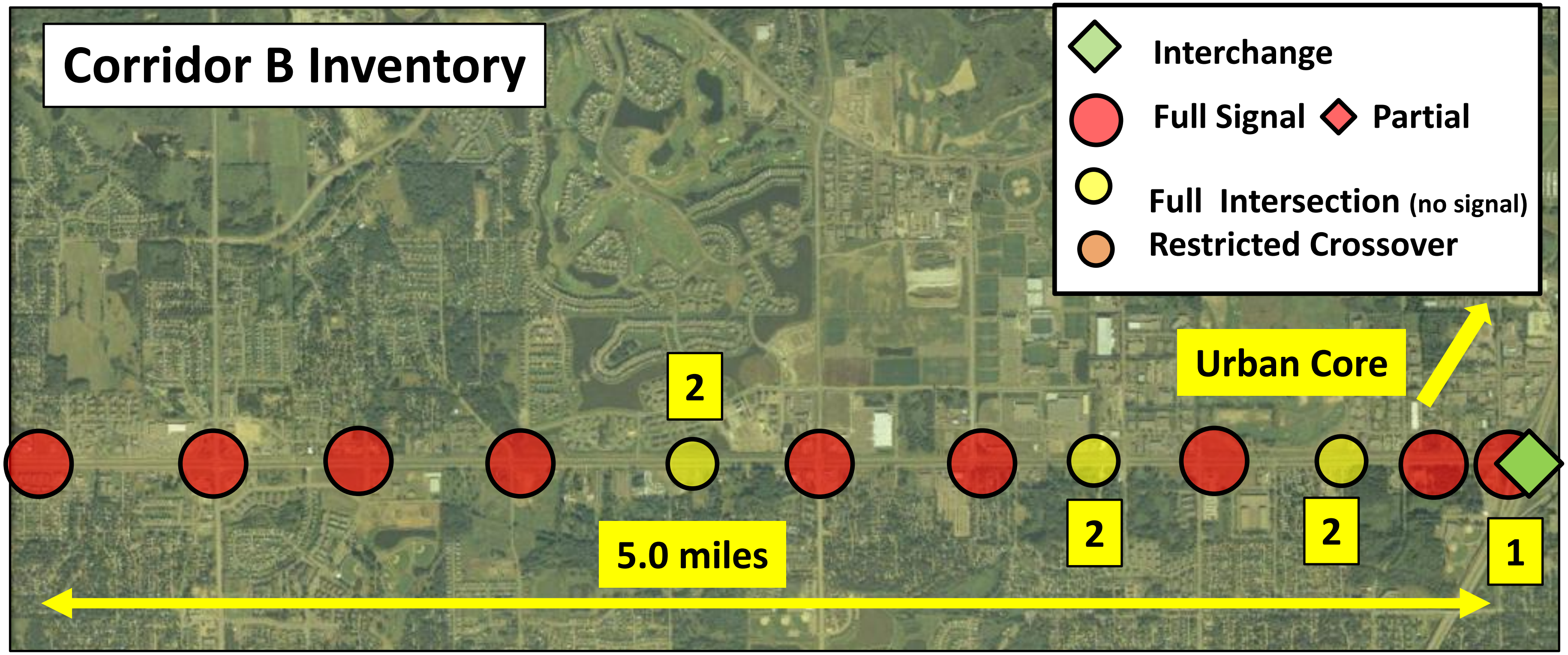
- Basic MRATL concept assumes entry and exit to the lane would occur away from signal controlled intersections.
- If the need arises, access could be provided at signals, particularly if certain innovative designs are used, including RCUT, mainline median u-turn, and through-about intersections.
- If MRATL corridor ends at an interchange, there are options to add connecting roadways to avoid creating weaving problems.
- If grade separations are to be used at any signal controlled intersection, consider underpasses rather than overpasses.
  - The underpass could be constructed as a cut and cover tunnel.
  - Vertical curves can be shorter and aesthetics would be better for underpass.
  - May be possible to locate major roadway left-turn lanes on top of underpass.
  - Overpass may be easier to construct without diverting traffic while it is being built.



1. Close spacing of signal controlled intersection to cloverleaf interchange will require unique treatment for entrance/exit. Option: provide signal controlled left turn to entrance loop at exit ramp with partial signal control.
2. The full intersection with no signal on right end of corridor will require median closure or adding some form of signal control. The restricted crossover intersection will require signals.
3. With seven full signal controlled intersections in less than three miles, travel time savings should justify the toll charge.

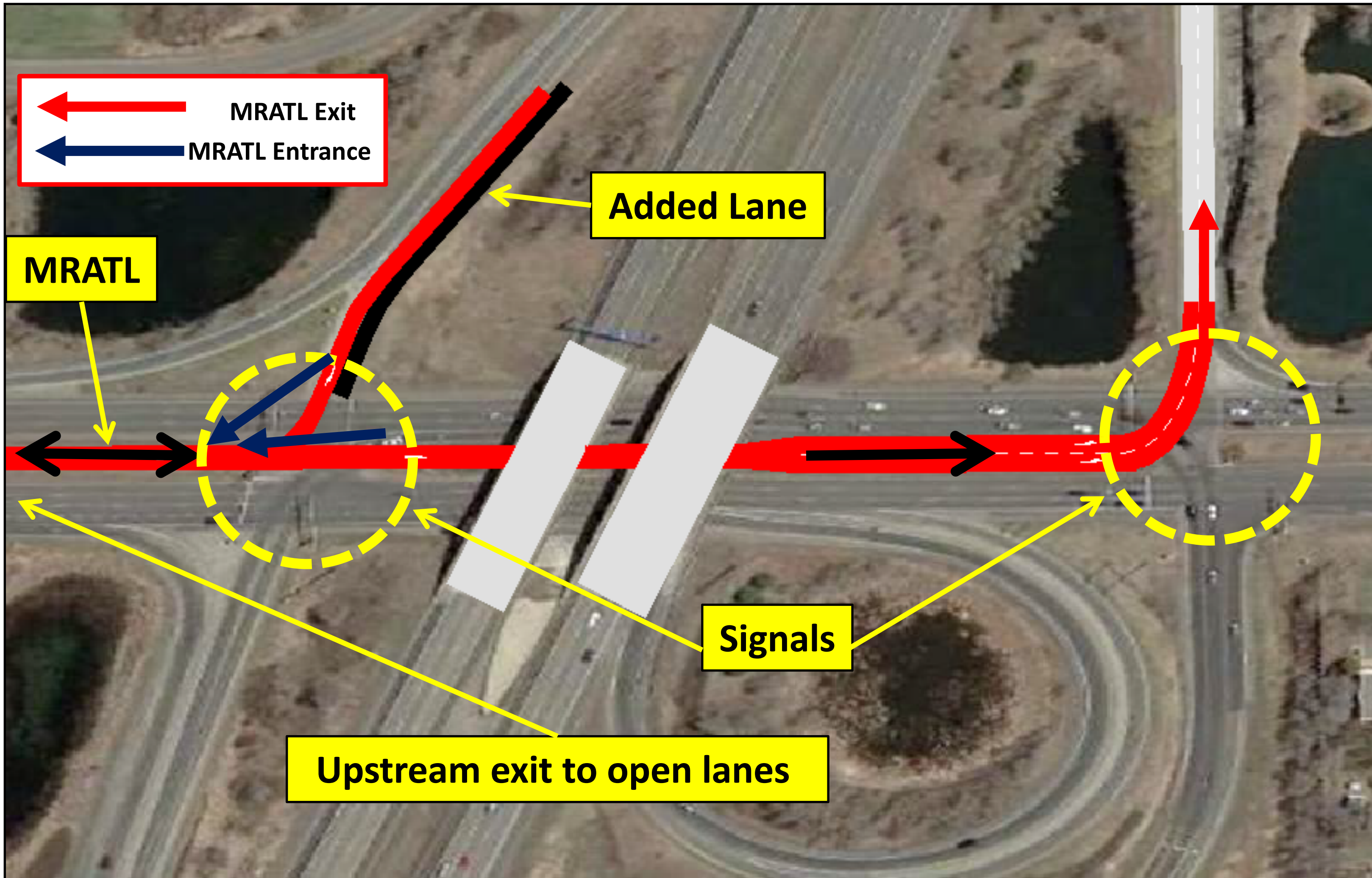
Corridor A Terminal - Interchange Connection

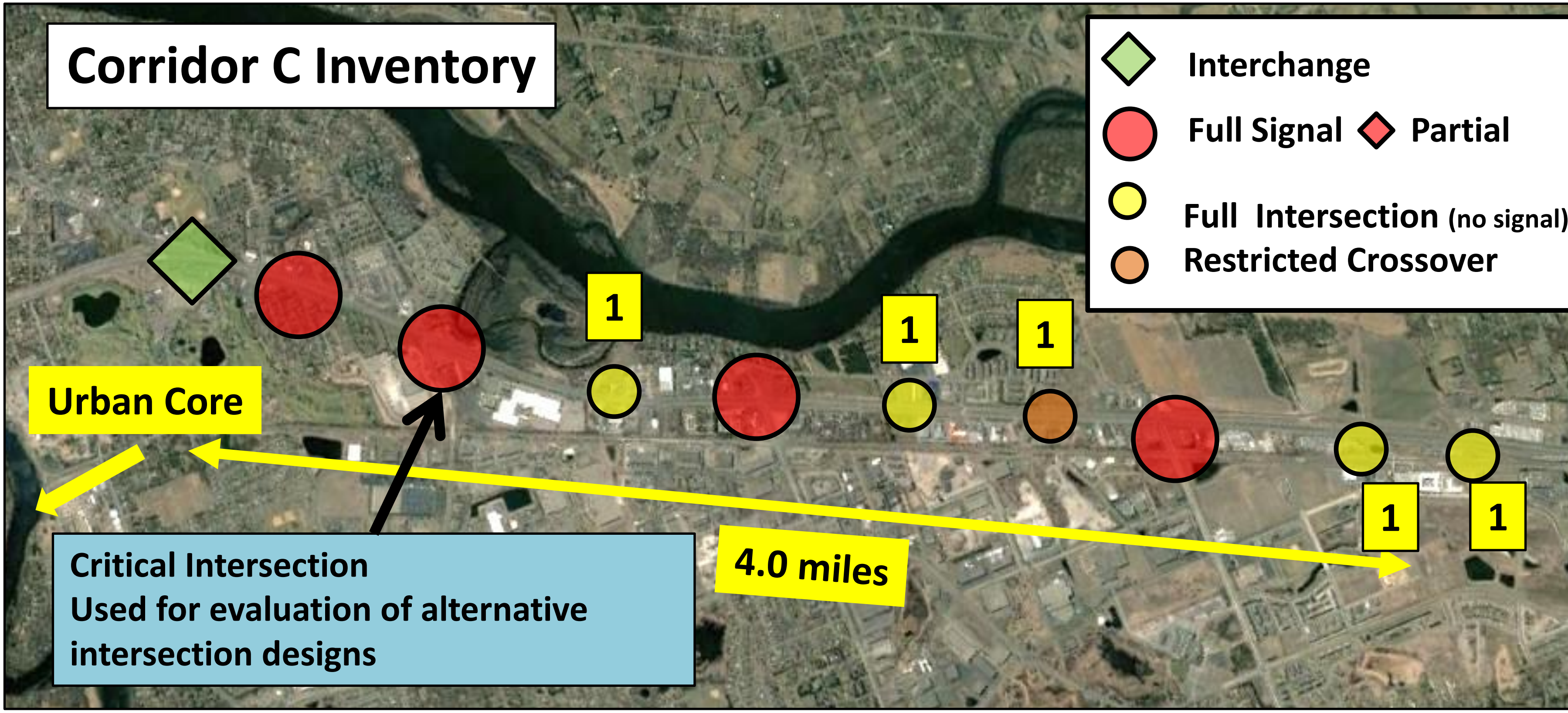




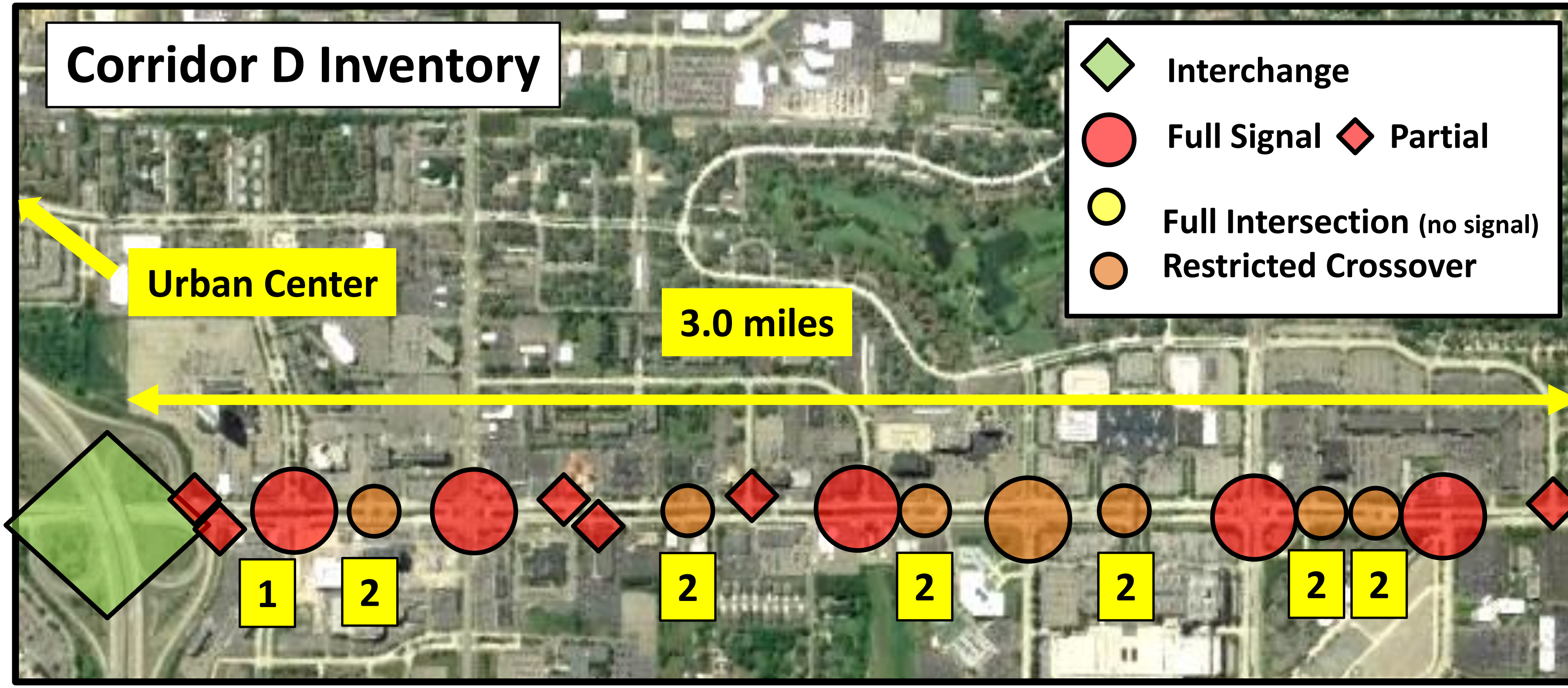
1. The close spacing of the signal controlled intersection to interchange at right end of corridor will require unique treatment for entrance/exit. Option: provide signal controlled left turn to entrance ramp mixed lanes have access to freeway via entrance loop.
2. The full intersections with no signal will require median closure or adding some form of signal control.
3. With nine to 12 full signal controlled intersections in less than five miles, travel time savings should justify the toll charge.

Corridor B Terminal - Interchange Connection





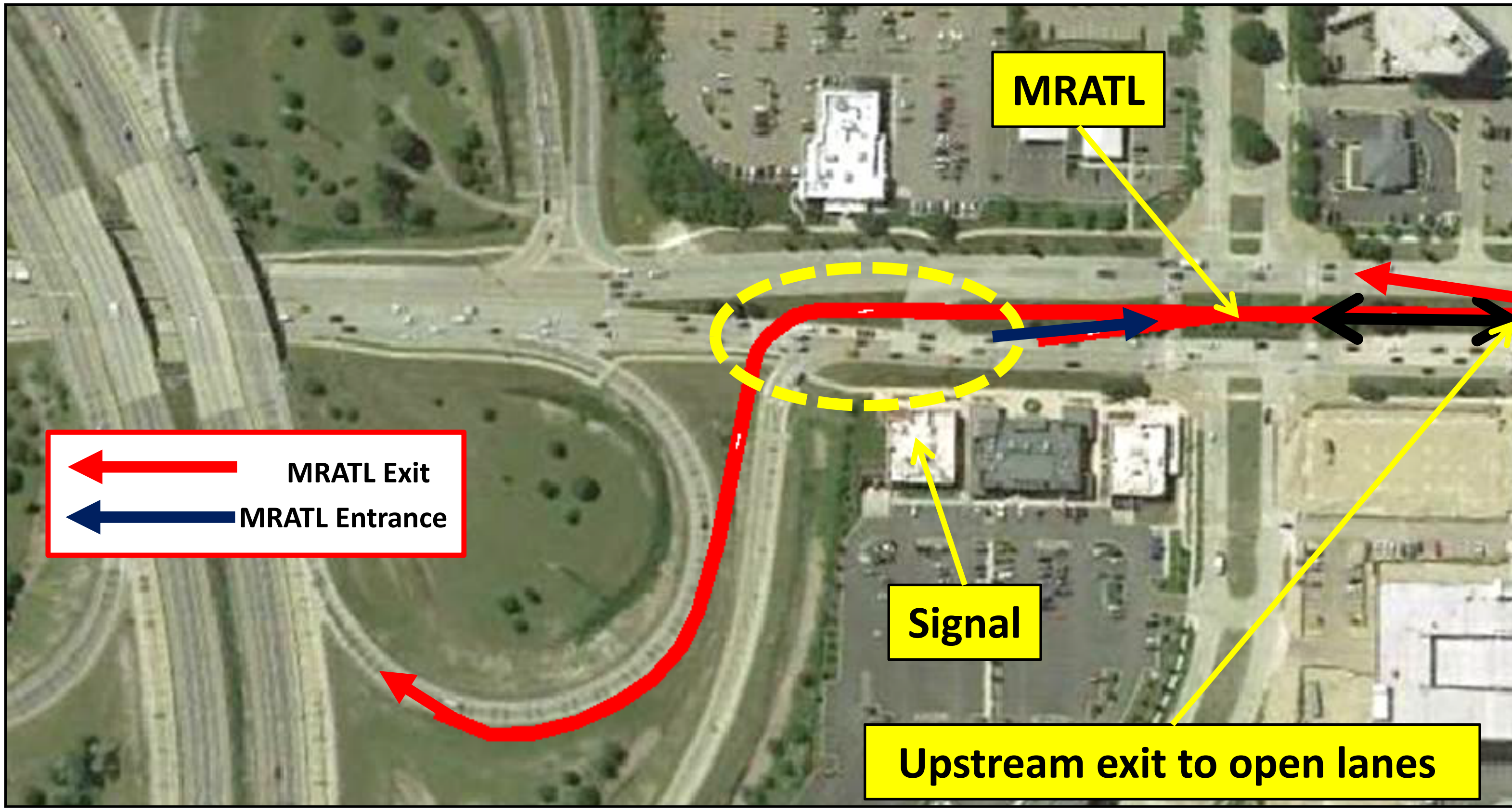
1. Full intersections and restricted crossovers with no signals will require median closure or adding some form of signal control.
2. With four full signal controlled intersections in three miles, travel time savings would not initially seem to justify a toll charge. However, the critical intersection has a forecast demand well beyond its capacity.
3. This critical intersection also provides a good place to test the possible corridor benefits of using an alternative intersection design or grade-separated toll lane.
4. The corridor transitions to a freeway segment on the left and a rural divided highway without signals on the right. Therefore, the termini are not an issue.



Noted items:

1. Close spacing signal controlled intersection to cloverleaf interchange will require unique treatment for entrance/exit. Option: provide signal controlled left turn to entrance loop at exit ramp with partial signal control.
2. The restricted crossover intersections without signal control will require median closure or addition of some form of signal control.
3. With 5 full signal controlled intersections and 2 or more partial signal controlled intersections in less than 3 miles, travel time savings should justify toll charge.

Corridor D Terminal - Interchange Connection

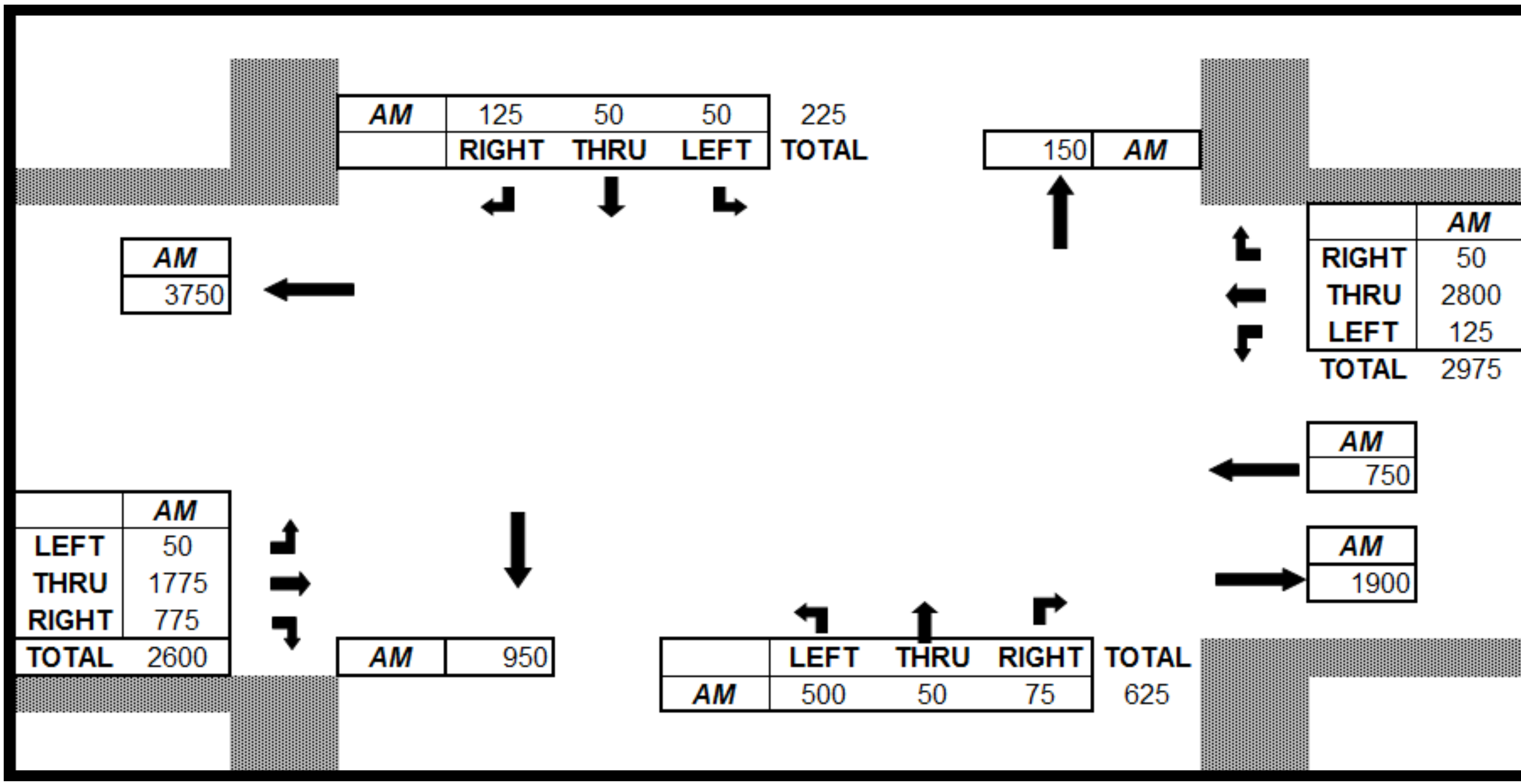


Selected Corridor: Corridor C

- Peak hour traffic forecasts assumed an ultimate conversion to a freeway. ADT is 70,000.
- Those numbers were tested at the key intersection denoted on the Corridor C map with and without a MRATL.
- This intersection was selected because it would control the capacity of the corridor.
- The AM peak hour forecasts were run in simulation for three different volumes in the toll lane: 500, 750, and 1,000. Ten runs were made for each alternative and total travel times for each of the 12 movements and MRATL were captured between ¼ mile upstream to ¼ mile downstream of intersection.
- AM peak hour numbers were also tested with various intersection types including innovative designs.
- Simulations were not performed to determine a “best” intersection design, only to understand the issues and benefits of each design. Right-of-way constraints may determine the selection of an alternative design or whether certain movements get added lanes.

Intersection Simulation Results	Toll Lane Volume	Average Travel Time Toll Lane	Average Travel Time ML Thru	Average Travel Time All Vehicles	Unserved Demand
Standard Intersection with toll lane	500 750 1,000	57 59 68	104 97 70	91 88 79	550 347 34
Restricted crossover / U-turn with toll lane	500 750 1,000	56 59 64	84 78 74	91 92 93	639 414 198
Mainline median U-turn with toll lane	500 750 1,000	52 55 60	82 77 68	85 83 80	577 389 108
Side street median U-turn with toll lane	500 750 1,000	44 45 48	94 84 68	83 78 71	159 22 9
Through-about direct lefts onto mainline with toll lane	500 750 1,000	48 50 54	123 114 109	107 103 94	736 531 302
Mainline Jug handle Lefts with toll lane	500 750 1,000	46 47 50	86 78 63	75 72 65	199 0 0
Side street jug handle lefts with toll lane	500 750 1,000	43 44 47	83 70 62	74 67 63	59 41 31
Grade separated with toll lane	500 750 1,000	35 35 35	103 97 67	89 86 72	534 347 36
Standard intersection - no toll lane	0	N/A	135	115	836

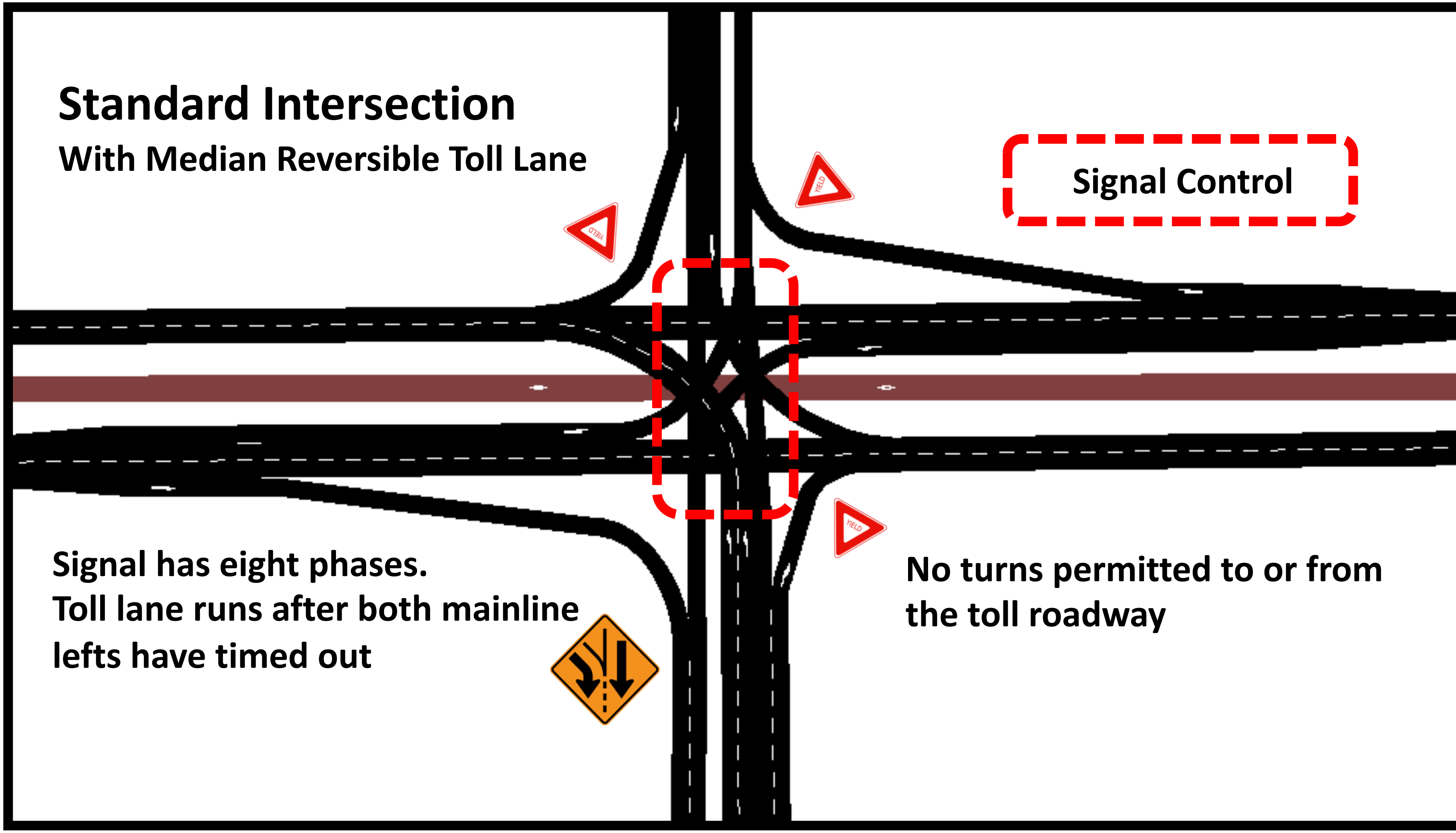
Corridor C Critical Intersection
AM Peak Hour Forecast Traffic Volumes



Corridor C Critical Intersection Inventory

- **As an additional measure of comparison, planning level, critical lane volume, capacity analyses were done for each alternative intersection concept with an assumed toll lane volume of 750 vehicles per hour.**
- **Desired median widths and right-of-way widths for each alternative intersection design were tabulated.**
- **Number of signal controlled intersections and number of conflicting phases for MRATL are tabulated for each alternative intersection design.**
- **Following the table, concept drawings of each alternative intersection design are shown.**

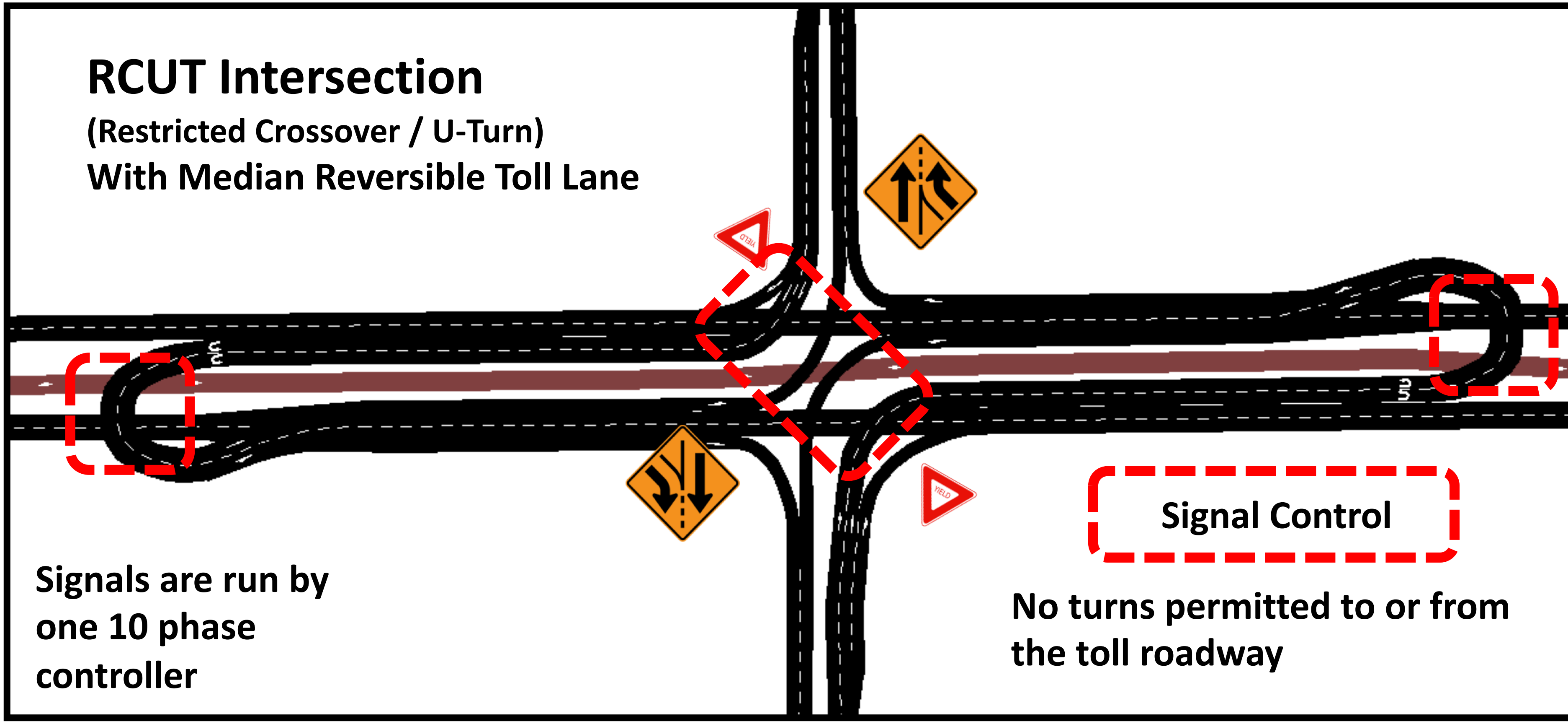
Intersection With Toll Lane	Median Width Required (feet)	Signal Controlled Intersections on MRATL	Critical Signal Phases Conflicting w/ MRATL	Minimum R/W Width (feet)	Critical Lane Volumes Intersection/ MRATL with 750 vph	Notes
Standard Intersection	38 50	1	3	150	1750 / 1175	Single left turn lanes Dual left turn lanes
Restricted Crossover U-Turn	38 50	3	1 at each intersection	150	1750 / 1025	Single left turn lanes Dual left turn lanes
Mainline Median U-Turn	38 50	3	1 at each intersection	150	1775 / 1025	Single left turn lanes Dual left turn lanes
Side Street Median U-Turn	24	1	1	140	1675 / 1025	
Through-About	24	2	1 at each intersection	140+100 Each side at intersection	1750/1000 1650/1000	Direct lefts onto mainline Indirect lefts to mainline
Mainline Jug Handle Lefts	24	1	1	140 + 200 for loop quadrants	1650/1000	
Side Street Jug Handle Lefts	24	1	1	140 + 200 for loop quadrants	1650/1000	
Grade Separated	30 44 56	0	0	150	1750/750	If left turn lanes are spanned Single left turn lanes Dual left turn lanes
Standard No Toll Lane	N.A.	N.A.	N.A.	150	2075/0	


Standard Intersection
With Median Reversible Toll Lane
Signal Control
Signal has eight phases.
Toll lane runs after both mainline lefts have timed out
No turns permitted to or from the toll roadway

RCUT Intersection

(Restricted Crossover / U-Turn)

With Median Reversible Toll Lane

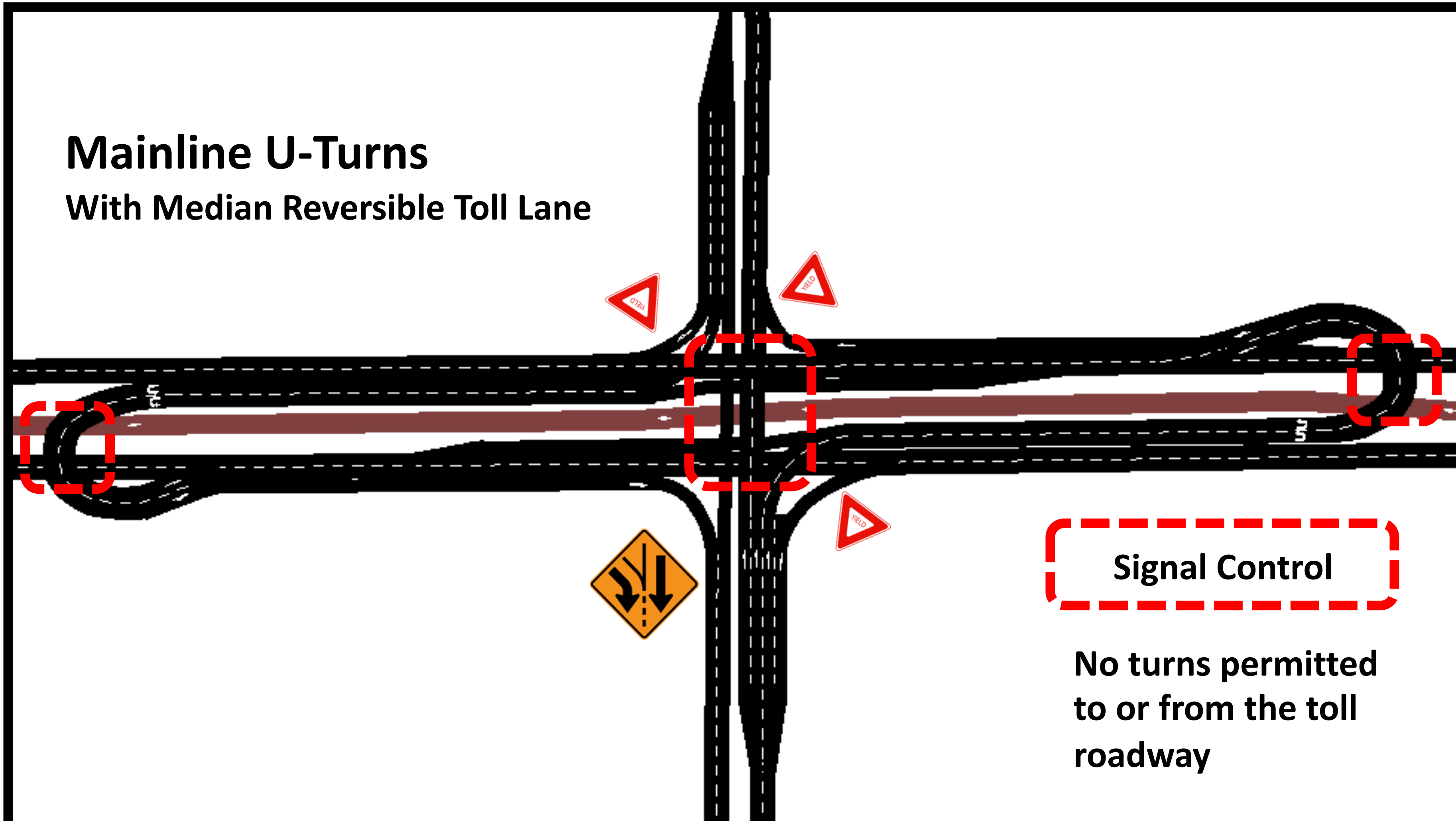


Signals are run by one 10 phase controller

No turns permitted to or from the toll roadway

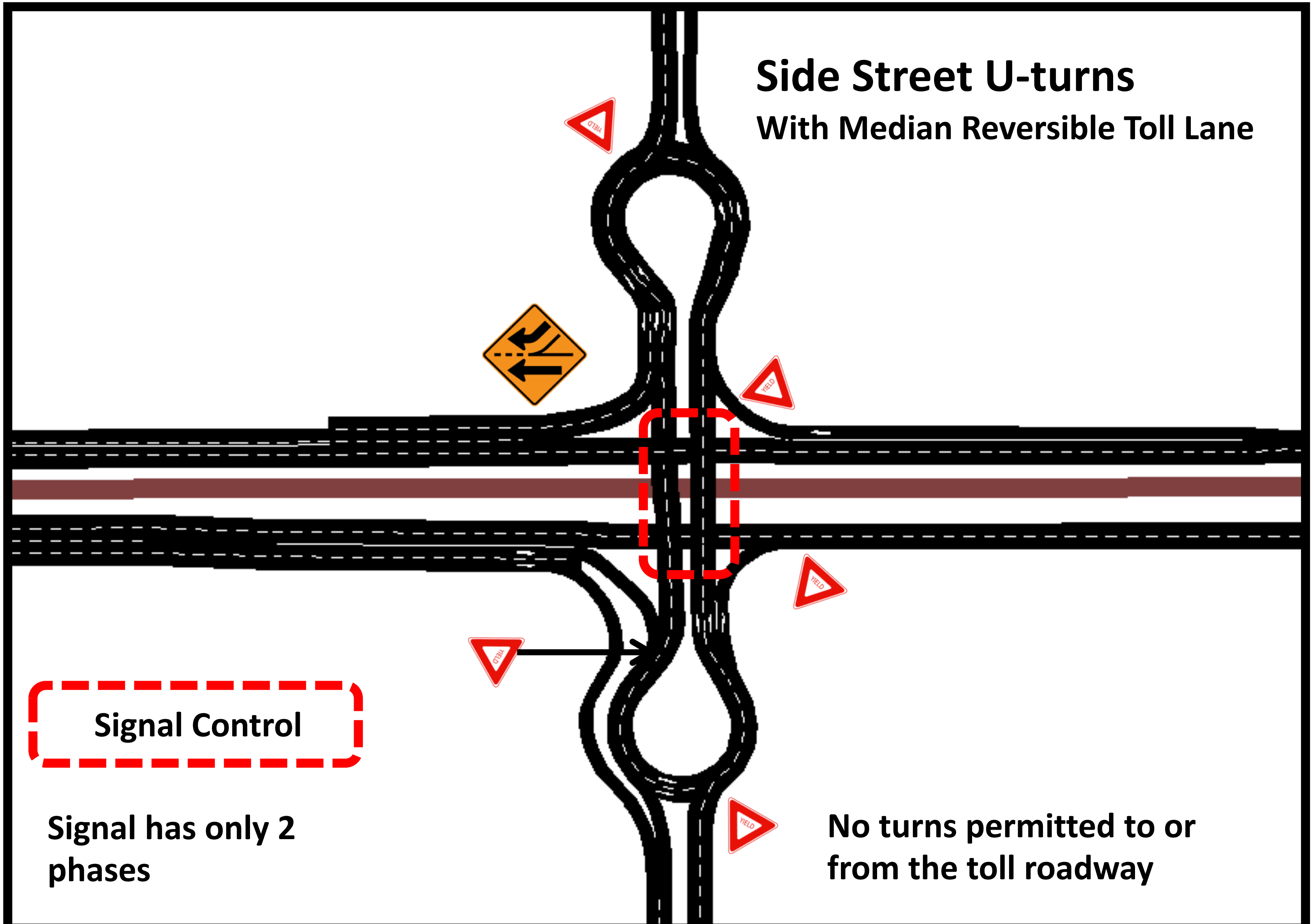
Mainline U-Turns

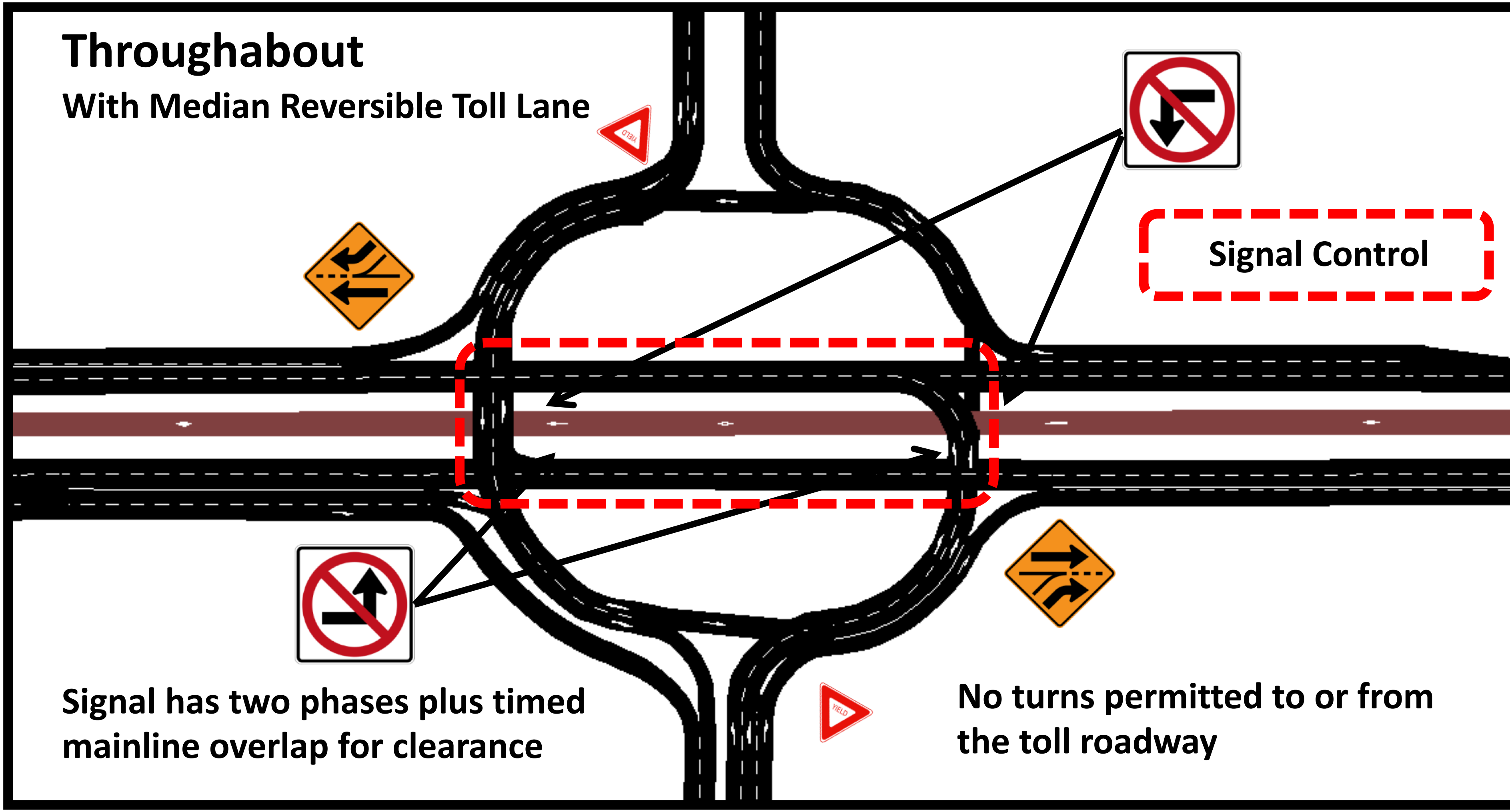
With Median Reversible Toll Lane

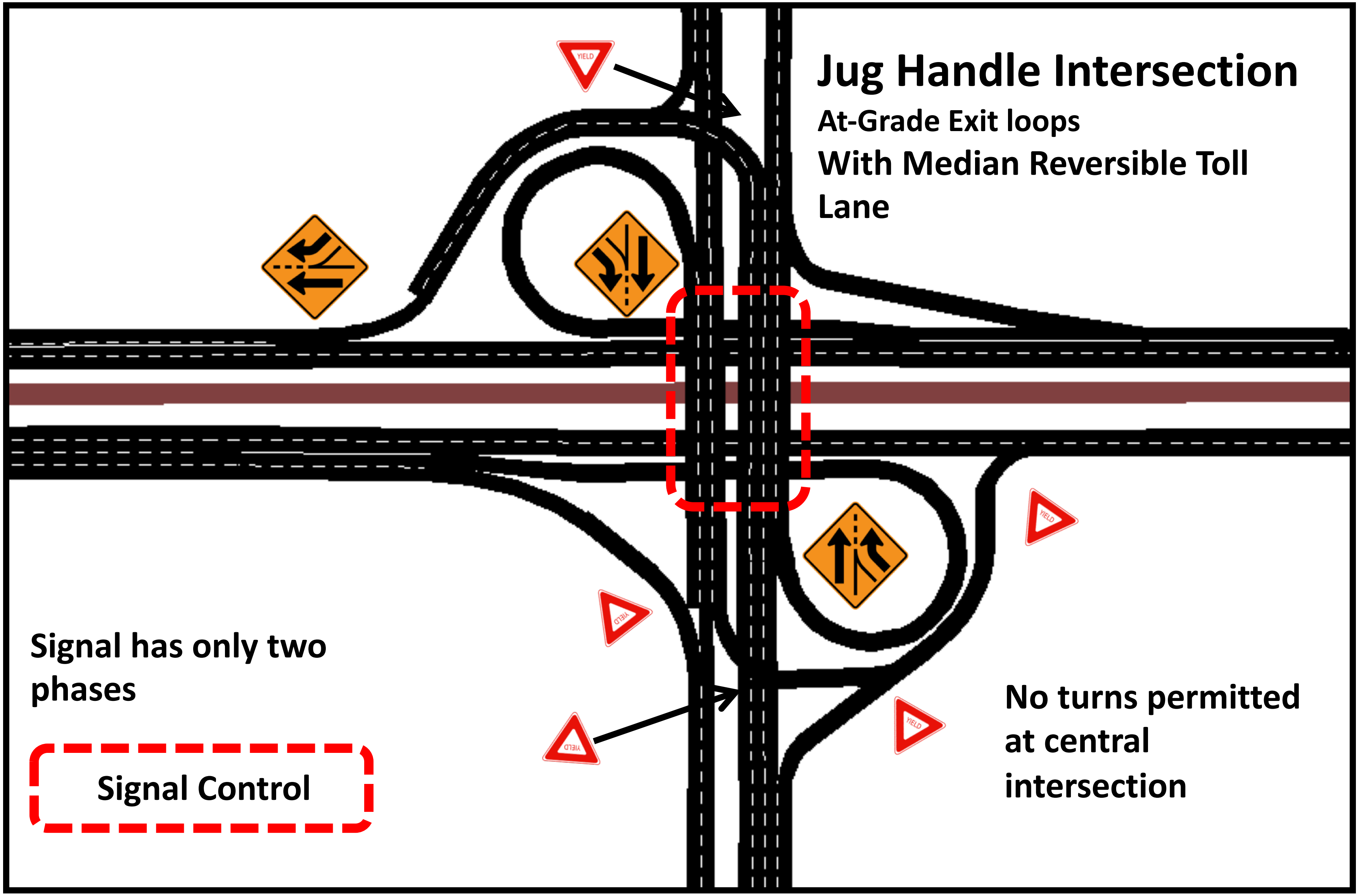


Signal Control

No turns permitted to or from the toll roadway


Side Street U-turns
With Median Reversible Toll Lane
Signal Control
Signal has only 2 phases
No turns permitted to or from the toll roadway

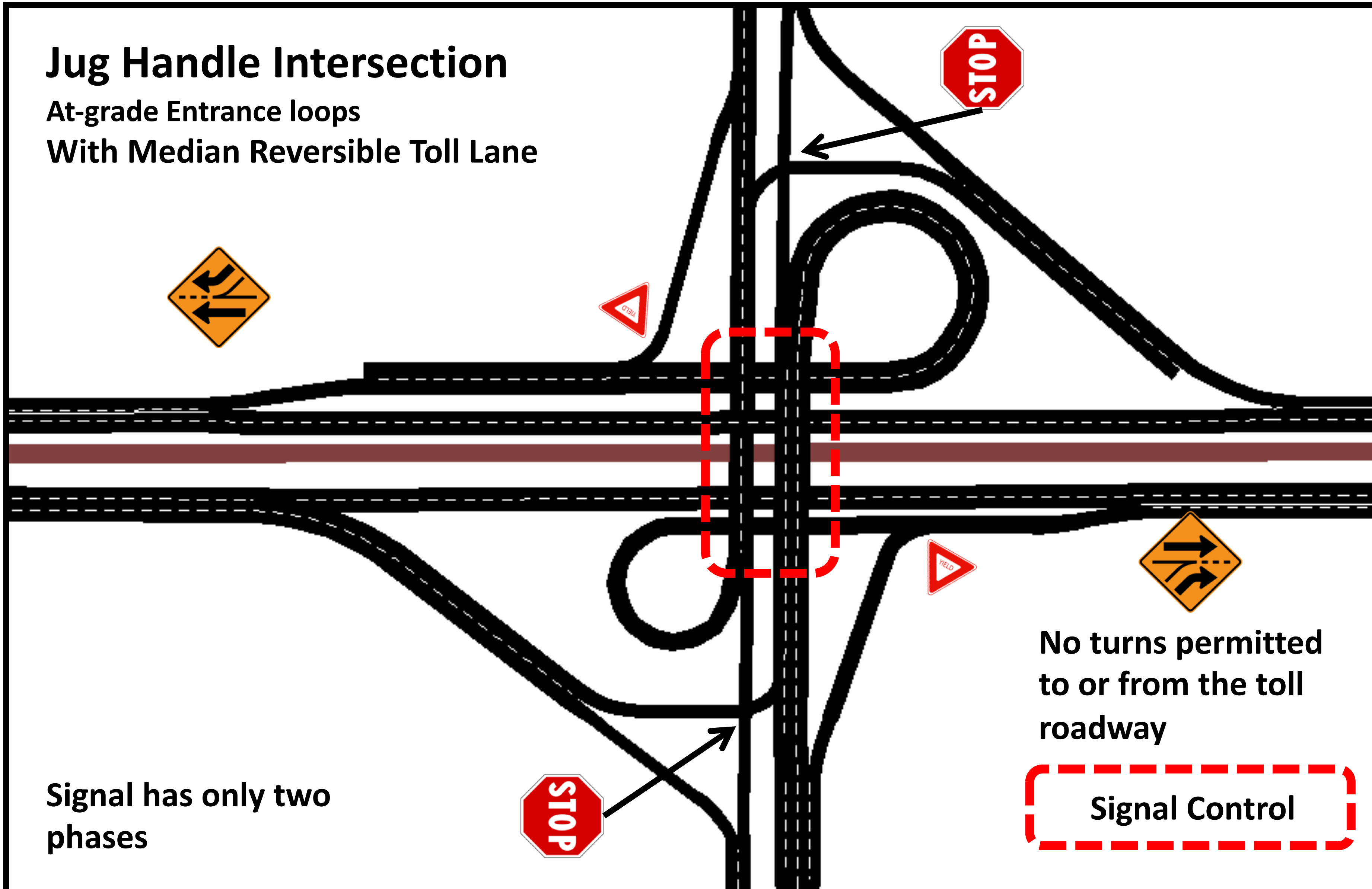

Throughabout
With Median Reversible Toll Lane
Signal Control
Signal has two phases plus timed mainline overlap for clearance
No turns permitted to or from the toll roadway


Jug Handle Intersection
At-Grade Exit loops
With Median Reversible Toll
Lane
Signal has only two
phases
Signal Control
No turns permitted
at central
intersection

Jug Handle Intersection

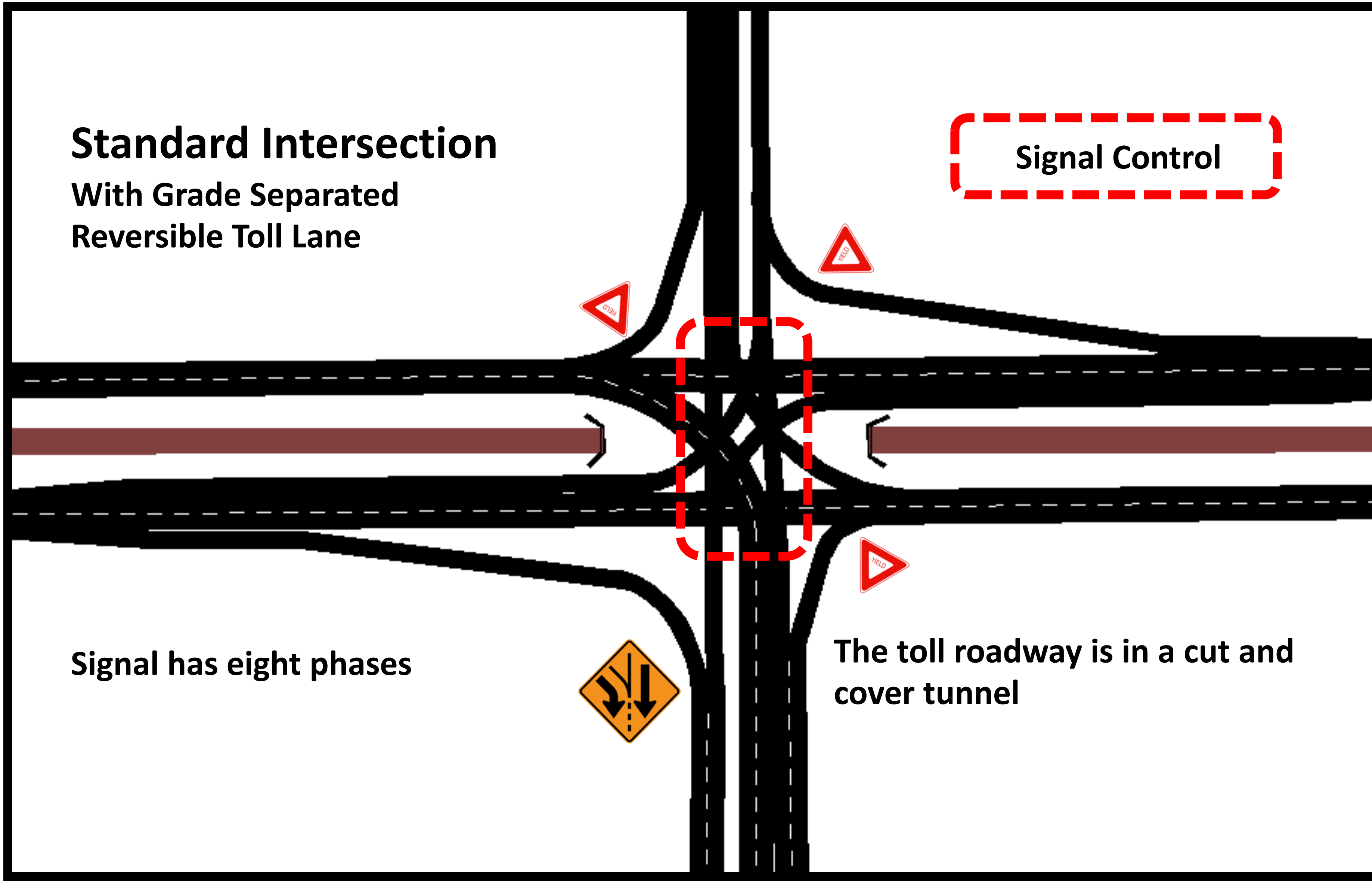
At-grade Entrance loops

With Median Reversible Toll Lane



No turns permitted to or from the toll roadway

Signal has only two phases


Standard Intersection
With Grade Separated
Reversible Toll Lane
Signal Control
Signal has eight phases
The toll roadway is in a cut and
cover tunnel

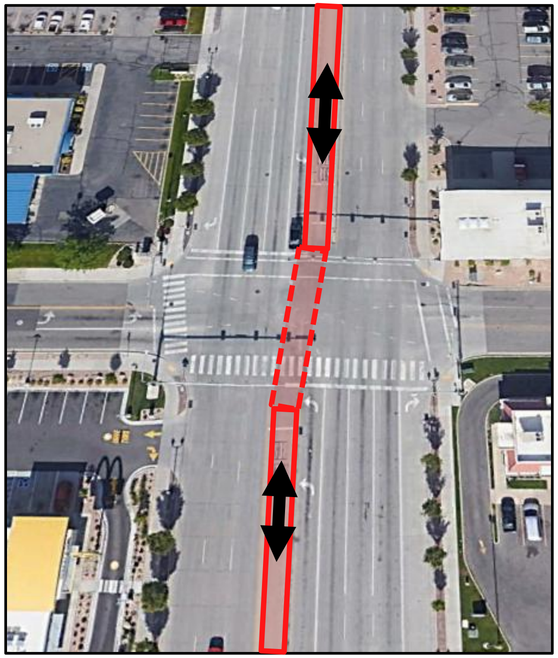
Similar Transportation Facilities

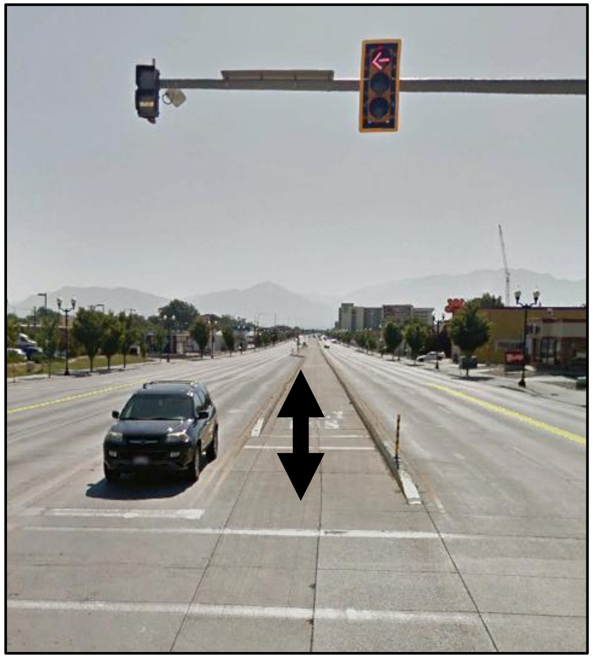
- There are many median running, specialized transportation facilities in North America.
- Most of those located in medians are light rail transit (LRT) facilities.
- There are several bus-only facilities on surface roadways in the U.S. and Canada; some are median running. A few are also open to taxis and HOVs. Only a limited number feature reversible, single-lane operation. None are toll facilities.
- An example of a bus-only median reversible lane is the West Valley Busway near Salt Lake City, Utah.
- There are a few side running busways and several side running LRT lines in the U.S. When considering a candidate corridor for a MRATL, a side running facility may be suggested as an alternative.
- There is a side running busway near Miami ,Florida. It has experienced traffic operation problems.

West Valley Busway in Utah

In the southwest suburbs on Salt Lake City, Utah

- On 3500 South, Utah State Route 171
- It is a bus only facility, and uses transit style signals to control buses.
- It has two-lane, two-way segments and a one-lane reversible segment.
- It is less than two miles long and runs through five intersections controlled by signals.





West Valley Busway in Utah

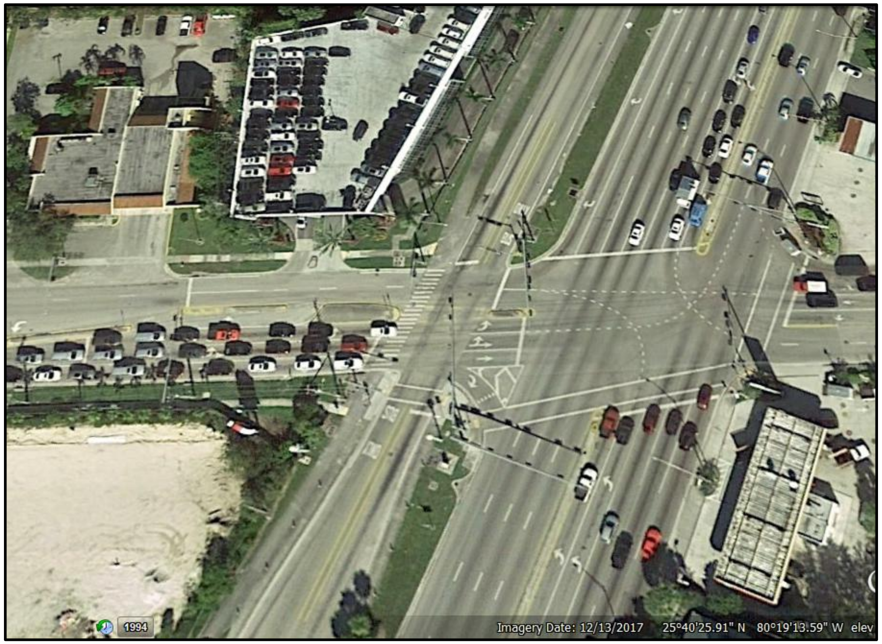
Benefits

- Improved bus operation
- No additional right-of-way needed
- Median running produces only minimal impacts to other traffic
- Fairly simple signal operations at intersections

Issues

- Signal lane section controlled with transit signals limiting operational flexibility
- Minimal available space in median limits what can be done with transit stations
- No snow storage: winter maintenance will be a concern
- Minimal widths of medians may increase crash potential with oncoming traffic

South Dade Busway in Miami



South Dade Busway: A Side Running Facility

Benefits

- If space is available, construction is easier and may be less costly
- Could have easier connections to park-and-ride lots
- More room for transit stations
- Access to the tollway could be allowed at intersections

Issues

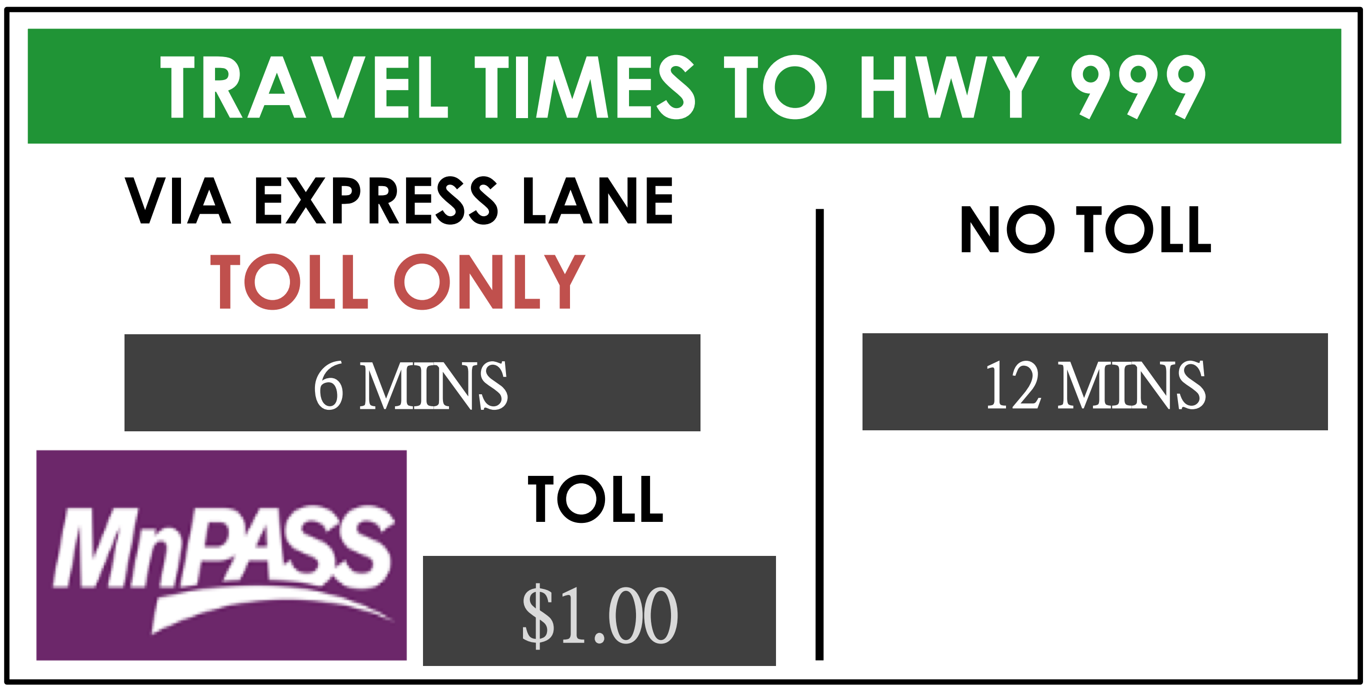
- Side running creates additional conflict points.
- Drivers desiring to make right turns on red from the side street need to be controlled or prohibited.
- Drivers making right turns from major roadway across the transit way need to be controlled

Issues

- Side running toll lanes would have far less green time than open lanes.
- With a reversible roadway, cross street drivers will have added confusion
- Miami has a side running, two-way busway with high crash rates. It is being considered for conversion to a tollway, but with grade separations
- LRT does not have driver recognition problems as a surface roadway - tracks provide greater contrast than pavement. Wrong turns onto roadway are more likely than with rail.

Signing for MRATLs

- Various traffic control signs for use at signal controlled intersections and entrances and exits for the MRATL were developed for the US 12/I-394 project.
- Toll-related signing will be needed along with travel time information to aid the driver in their decision to use the toll lane.



Operations and Pricing

- MRATL would typically run inbound during AM hours (6:00 to 11:00) and outbound from 1:00 to 10:00 PM. Time should be available between direction changes to clear disabled vehicles.
- Hours could be adjusted to serve traffic for other peaks, including weekend recreational peaks or sports events.
- Toll collection would be done “in motion” using transponders. Toll collection using license plate readers is an option.
- A dynamic toll algorithm will be needed to ensure demand is managed to maintain good levels of service through the signals in MRATL. Toll pricing will need to be flexible to match local driver’s value of time. Experience has shown that AM peak traffic often needs and accepts higher tolls. For the simulations performed for this presentation, a value for time of $15/hour was used.
- A performance goal for the toll lane is 30 seconds of time saved per signal passed through or alternatively one minute per mile on the corridor.
- Allowing HOVs (or “green” vehicles) to use the lane toll free or at reduced cost will be a local decision and affect cost versus benefit considerations and reduce flexibility to manage demand in the lane.
- Toll revenue is unlikely to cover the entire construction and operating costs of the MRATL. However, the benefits to traffic in the general purpose lanes should be considered in the evaluation and justifying the concept to elected officials.
- If the roadway system has only some reserve capacity at the termini of the MRATL, then the pricing of the MRATL can be adjusted to control demand to match that capacity.

Technology

The following devices could assist operation of a MRATL:

- Automated gate operation with manual override
- Coordinated signal operation with a traffic responsive master control and traffic actuated intersection controllers
- Full color dynamic message signs
- Video detection for actuated operation, counting, wrong way or prohibited movements
- Video surveillance of critical areas such as narrow segments , control gate locations, transit stops and breakdown bays
- Capability to link toll transponders in the same vehicle for splitting the billing or giving discounts to car pools
- Emergency vehicle pre-emption with or without access to the toll lane by emergency vehicles
- Traffic signal to vehicle communication to improve safety and to help minimize stops in the toll lane. End of green warning flashers could also be used.
- With specific enhancements, toll lane could be used by two way, bus only, traffic during off peak hours by having regularly spaced wide meeting areas, a GPS location system for buses and a transit signaling system to ensure the buses arrive and wait at the passing zones. This would allow the corridor to have a higher form of BRT.
- Dynamic intersection geometry and signal phasing to reduce conflicting signal phases for the toll lane. Example: change a restricted crossover, U-turn (RCUT) intersection to a U-turn only configuration

Conclusions

- A MRATL may be a viable option for your corridor
- Essential elements of geometry and signal control have been developed and demonstrated to perform safely and provide additional peak period capacity as well as being a mobility option
- Any corridor to be considered will have unique design challenges and they should be fully understood
- Pricing algorithm needs to be adaptive to local driver behavior
- Signal coordination should favor the MRATL, but be aware of the possible negative impacts on other traffic
- MRATL can offer the benefit of improved bus transit in the corridor

Recommendations

- Have a long-range view of the need for the project and your options
- Understand existing and forecast traffic
  - Understand the variables in the forecasts
    - Possible changes to the roadway network
- Future development – how tenuous?
- How does the preferred alternative meet the project goals
  - Is the project “interim”?
    - A phase on the way to the “ultimate”
    - A temporary fix with its own life-cycle
  - Or will it be the answer for 20 or 30 years?

Recommendations

- Develop a corridor inventory
- Do a planning-level intersection capacity analysis
- For intersections, consider the use of alternative designs – traffic simulation will likely be needed
- Consider maintenance and enforcement issues
  - Snow plowing and snow removal
  - Toll transponders can assist enforcement
- Consider signing requirements
  - Don’t build it if you can’t sign it