

# MEMORANDUM

---

DATE: June 14, 2013

TO: Sharlene Shadowen, CDOT, Matt Wessel, Atkins,

FROM: David Woolfall, P.E., TSH

SUBJECT: Mulberry/I-25 and Prospect/I-25 Bike Lanes, Double Right Turn Lanes, and Mulberry Frontage Road access

---

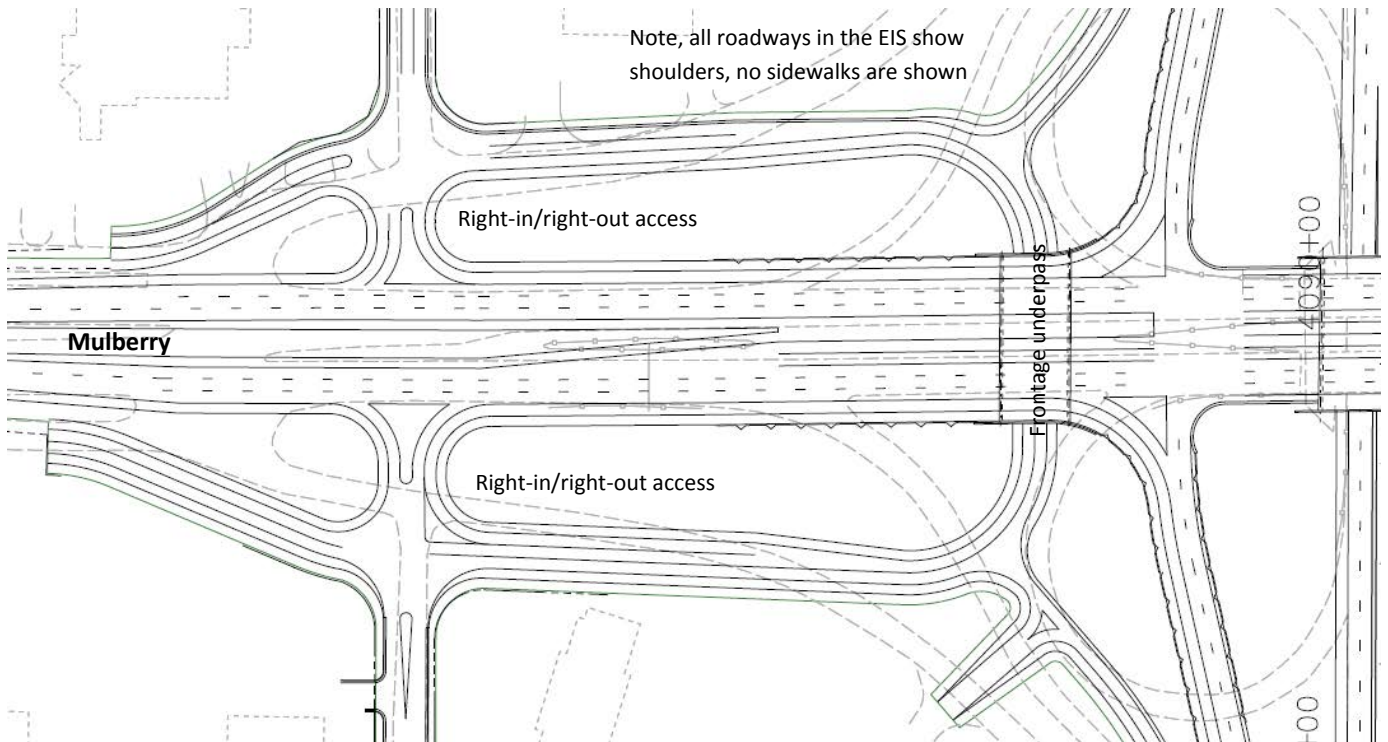
This memorandum summarizes continuing work on the Mulberry/I-25 interchange and the Prospect/I-25 interchange to address the high proportion of right turns at I-25 at both interchanges and how to incorporate on-street bicycle lanes. The Mulberry interchange also has the challenge of incorporating the west-side frontage road intersection which further complicates the bike lane design.

There are several locations in the Denver metro area with similar high proportions of right turns from the arterial to a freeway on-ramp. Most of these locations have been retro-fitted to obtain the additional capacity of a second right turn lane. However the retrofit designs usually do not address the needs of pedestrians and bicycles, except for some locations where grade separations for pedestrians/bicycles have been constructed. In developing the FIR design for the Mulberry and Prospect interchanges, the project team has the opportunity to develop the optimal design for both double-right turns and for good at-grade accommodation of pedestrians and bicycles.

## Challenges with the EIS Design

The design concept shown in the EIS for Mulberry is shown on the following page. The EIS design concept was not intended to solve all challenges as is being done with the current design effort, and it had several functional and operational challenges that needed to be addressed, which are discussed below:

- At both the Mulberry and Prospect interchanges in the eastbound direction, over 50% and up to 65% of EB traffic wants to turn right at I-25. Ideally for a 3-lane eastbound cross section, the EB right lane (#3 lane) will drop at I-25, and ideally the #2 lane will allow shared through-rights to allow sufficient capacity and good lane balance for this right turn movement. This traffic volume and lane balance relationship is detailed later.
- At Mulberry, if all of the right turning traffic were in lane #3 approaching I-25, it would likely queue or leave very few gaps for traffic entering Mulberry from the frontage road access.
- At Mulberry there would be a short weave distance between the west-side right-in/right-out (RIRO) access points and the I-25 interchange ramps. This lack of spacing in the EB direction is critical due to the high EB traffic turning south (or right) on the I-25 ramps requiring two lanes.

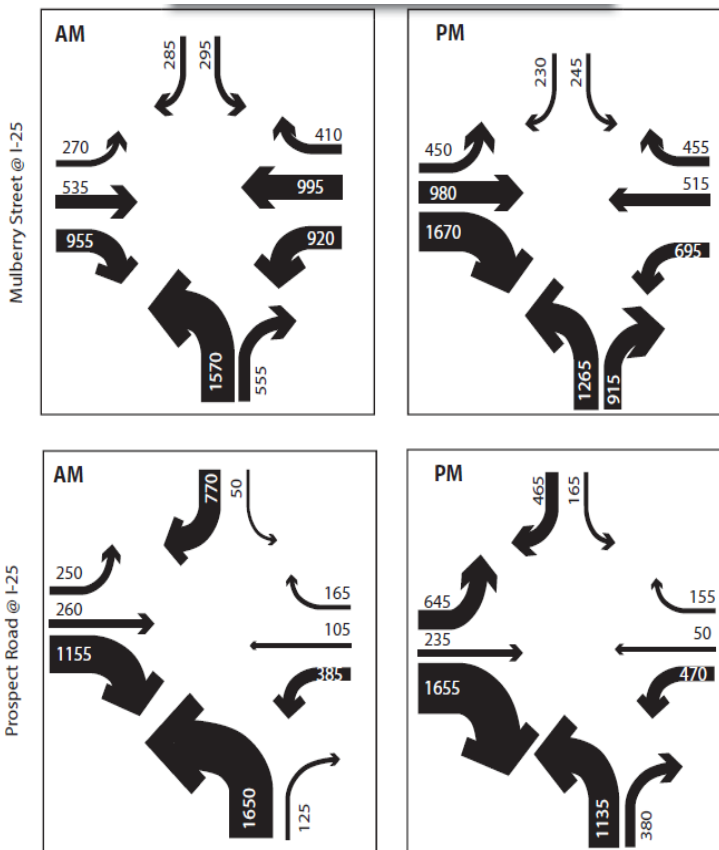


- At Mulberry, the frontage road access intersections serve relatively high traffic volume and numerous large trucks, and the intersections need to be directly adjacent to mainline Mulberry. This combination limits the possible design solutions to address intersection spacing, intersection capacity, intersection sight distance, etc.
- A continuous bike lane on both Mulberry and Prospect are challenging to incorporate safely, particularly in the eastbound direction due to the right turning volume at I-25. The EB right lane (#3 lane) will drop at I-25, and ideally the #2 lane will allow shared through-rights, complicating both the bike lane transition and the traffic weaving from the adjacent frontage road RIRO.

### Traffic Volumes

The forecasted 2035 traffic volumes (from FEIS forecasts done in 2011) have been detailed in other project memorandums and are summarized in a figure on the next page. The PM turning volumes at the Mulberry frontage road intersections are also included in the following page.

Traffic forecasting updates being done during 2013/2014 are likely to result in slightly lower 2035-2040 forecasts since the 2009/2010 recession will be incorporated. However, the general emphasis of heavy right turning traffic at the interchanges is unlikely to change.



North Frontage - PM



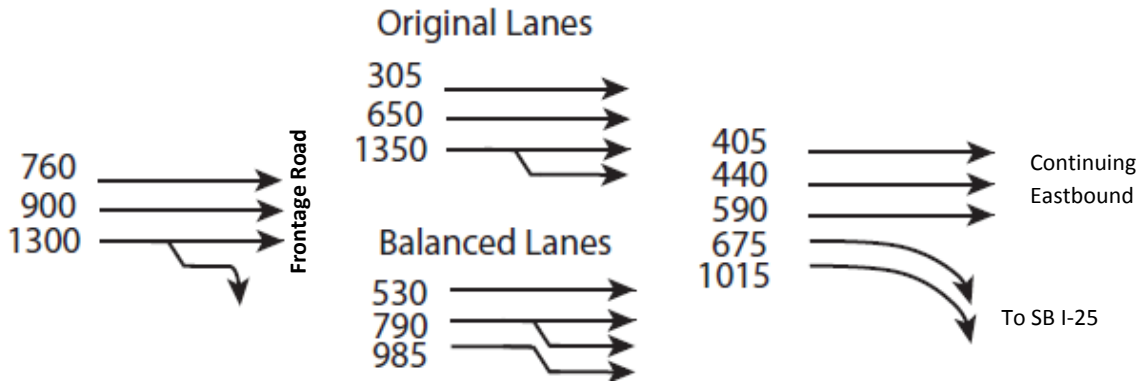
South Frontage-PM



The heavy right turning traffic toward I-25 at both interchanges and the analysis of operations at the ramp intersections led the project team to conclude that double right turns from EB to SB would be necessary at both Mulberry and Prospect. Double-right turns are used at several locations in the Denver/Boulder area, many of those have been retrofit designs. The opportunity exists to properly design the Mulberry and Prospect interchanges to better accommodate the traffic volumes and also incorporate pedestrian and bicycle lanes.

First, the transition of EB arterial lanes to the expanded number of lanes at each interchange was evaluated. In order to optimize the balance of traffic in lanes approaching the interchange, right turn traffic should be split into two EB lanes as soon as possible. If the #1 lane is the inside/median thru lane, the EB right lane (#3 lane) will drop at I-25, and ideally the #2 lane will allow shared through-rights. The approaching volume lane balance for the heavy PM peak traffic is shown on the following page

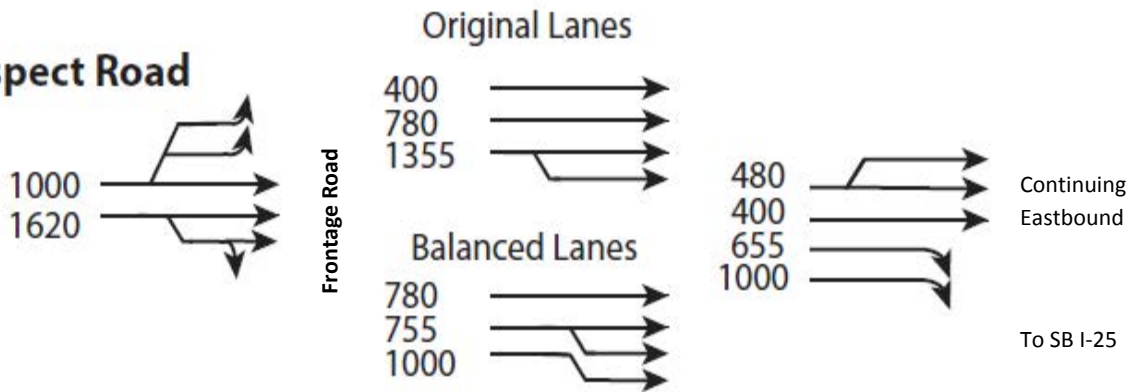
# Mulberry Street



Approach volumes per Lane, west of frontage Road

Volume per lane with typical added 4<sup>th</sup> lane ("Original") and with lane split ("balanced") between Frontage and I-25

# Prospect Road



Approach volumes per Lane, west of frontage Road

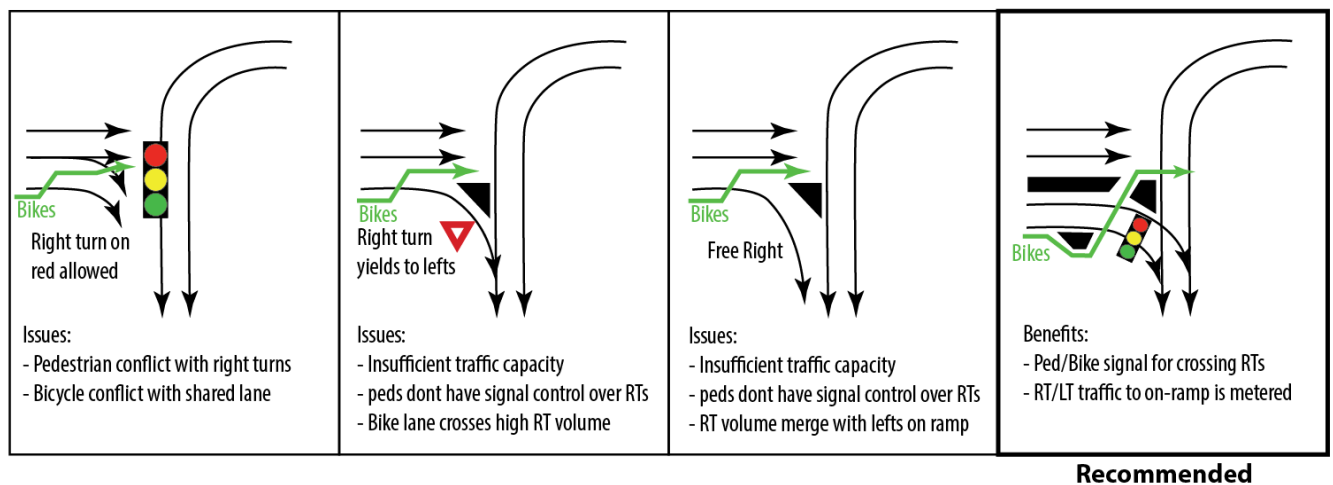
Volume per lane with typical added 4<sup>th</sup> lane ("Original") and with lane split ("balanced") between Frontage and I-25

## Ramp Lanes

The signalized double-rights offer an opportunity to keep the number of ramp lanes for the SB on-ramp at both Mulberry and Prospect at two lanes. The signalized double-rights solve the traffic capacity, bike conflict, pedestrian accommodation, and also meter the on-ramp traffic so that additional ramp lanes would not be necessary.

Many diamond interchange on-ramps are designed for right turns to be added as a 3<sup>rd</sup> lane to the on-ramp. Typically the 3<sup>rd</sup> lane merges, and sometimes the two lanes merge to one prior to the gore point. The design options with the preferred on-ramp designs for both the Mulberry and Prospect interchanges is shown below:

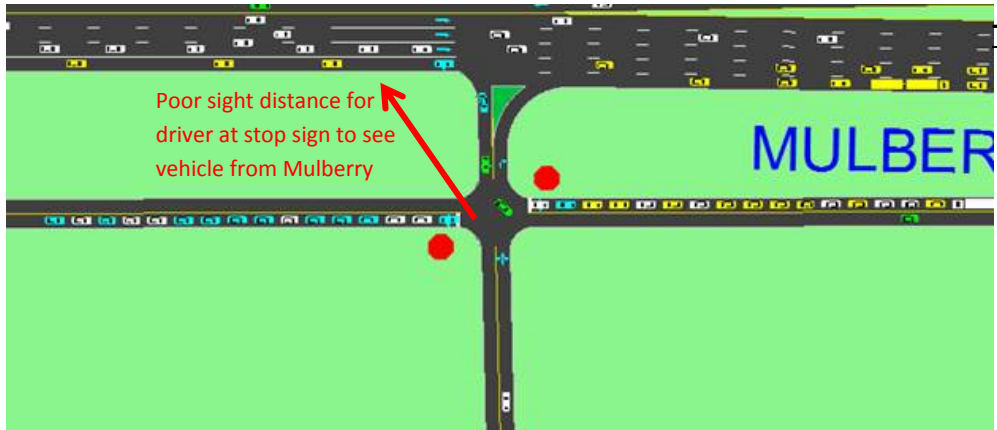
### Options for left+right turn lanes to freeway on-ramp



## Frontage Road Intersection Design and Traffic Control

The perpendicular intersections shown in the EIS concept have several operational flaws which make the perpendicular intersection type undesirable for this location. The RIRO accesses (plus local underpass connection) takes the place of a signalized access that serves interstate-oriented businesses, so traffic levels normally served by double-left turn lanes at a signal are condensed onto single right turn lanes, and intersecting at an unsignalized intersection.

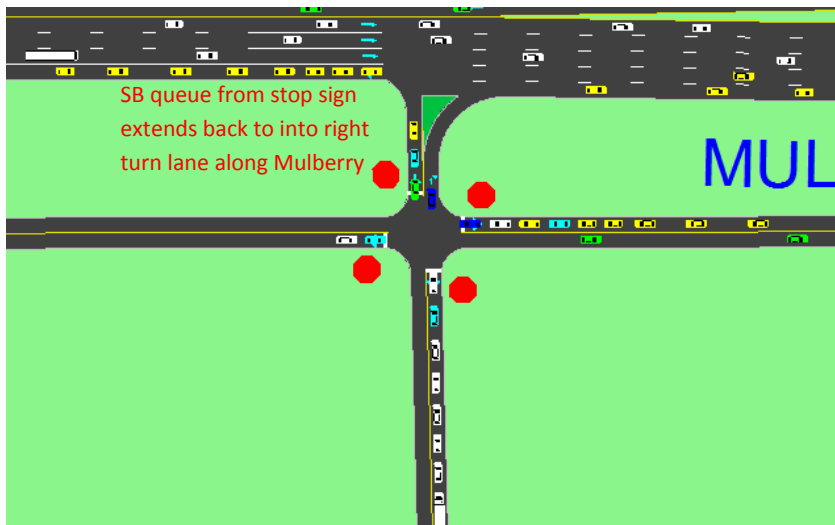
- A two-way stop, as implied by the EIS concept, results in substantial side-street delay, although queuing is reduced back onto mainline Mulberry.
- An all-way stop intersection also does not have sufficient capacity and causes queuing back onto mainline Mulberry.
- Only a roundabout addresses the intersection capacity and queuing issues. This is shown in comparable SimTraffic screen shots below:



**Two-Way stop as shown in EIS**

LOS F for EB and WB approaches to stop signs

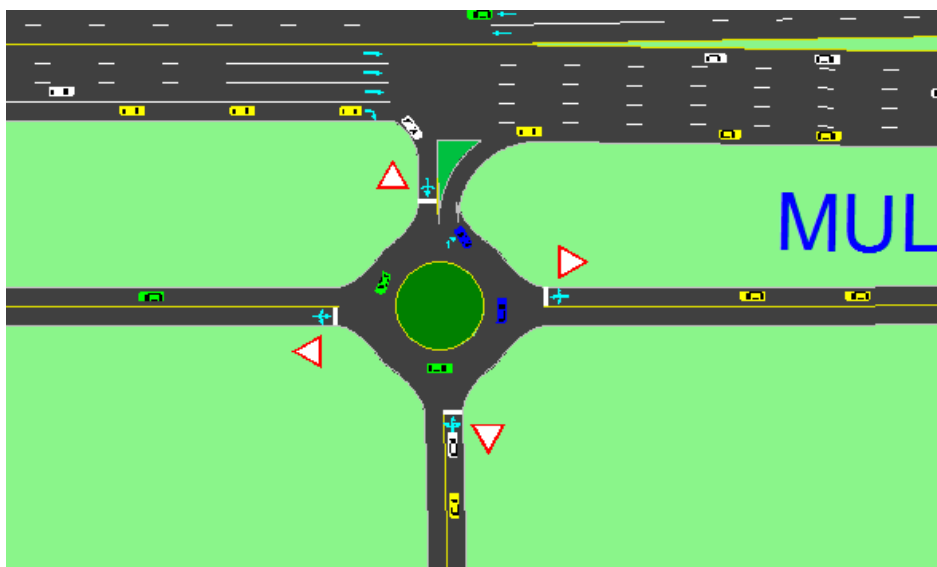
Screen shot of simulation for two-way stop control, south intersection. Queuing on the two stop-controlled approaches, minimal queuing back to Mulberry



**Option: All-Way Stop**

LOS F for 3 of the 4 approaches, v/c 1.2 to 1.6

Screen shot of simulation for all-way stop control, south intersection. Inadequate capacity for all-way stop control, and queuing back onto Mulberry



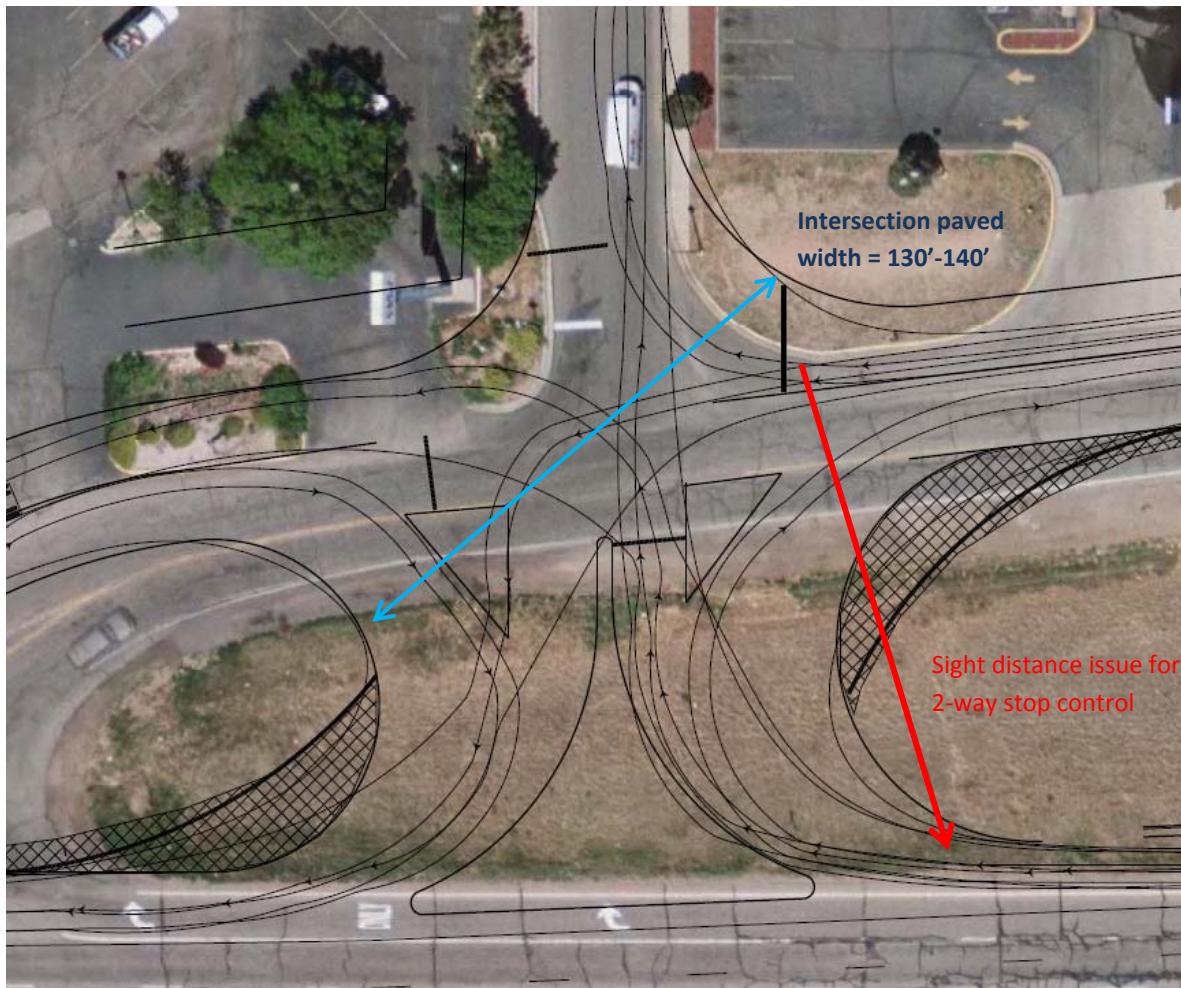
**Option: Roundabout**

LOS D reported for HCM 2010, v/c of 0.62. Simtraffic simulation did not show any capacity issues

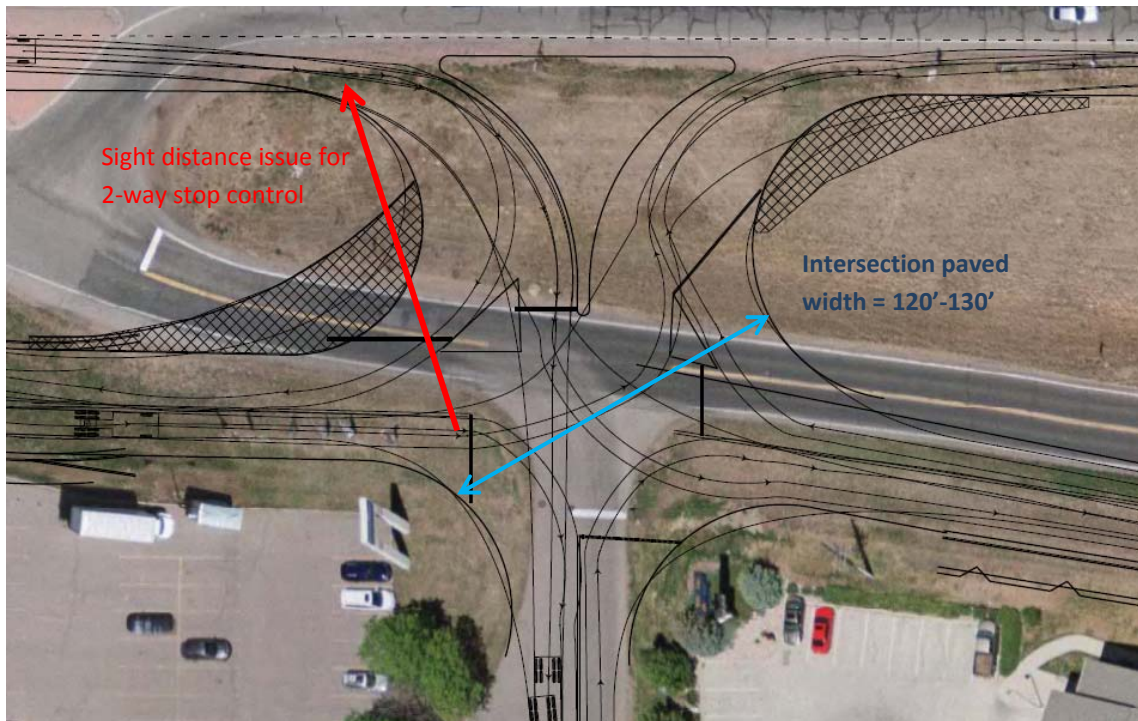
Screen shot of simulation for roundabout control, south intersection Roundabout provides traffic capacity and does not cause queue back to Mulberry

Besides traffic capacity there are several design issues with the frontage road intersections adjacent to mainline Mulberry:

- Sight distance, particularly for the two-way stop scenario shown in the EIS. Traffic on the EB frontage road approach would need to see traffic coming almost from behind (EB Mulberry traffic turning right to Frontage Road) in order to decide if they were clear to enter the intersection. See Figure below.
- Geometry for large trucks. The need to provide truck turning widths for all turning movements results in an intersection that is overly wide for its intended function. A layout of the north and south side frontage road intersections is shown below with the WB 67 truck movements overlaid. Several truck turns cross over the double-yellow line or raised islands for several left or right turn movements using this intersection configuration. The biggest challenge is the close spacing of the frontage road intersections to the Mulberry mainline, creating 180 degree turns for some large vehicles resulting in the expanding of the intersection footprint.



North-side Frontage Road, standard 4-way intersection layout with truck templates. Hatched areas could be raised truck aprons to discourage standard vehicle use.



South-side Frontage Road, standard 4-way intersection layout with truck templates  
Hatched areas could be raised truck aprons to discourage standard vehicle use.

### Proposed Design Alternative – both interchanges

The above challenges with the EIS concept and the additional need to incorporate bike lanes through the interchange led the project team to test several concepts to meet the unique needs of the west-side access on Mulberry. The following are the primary proposed solutions:

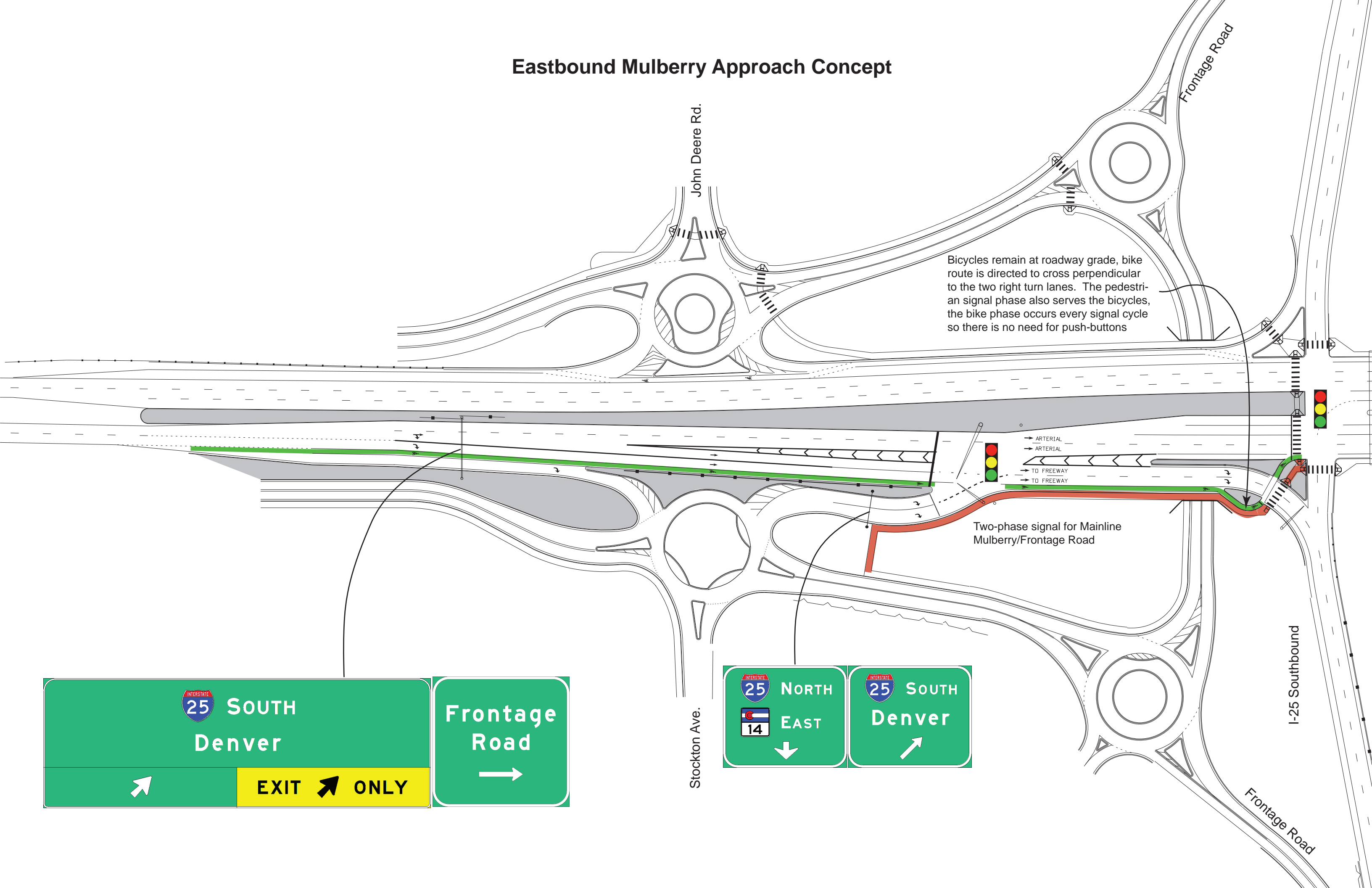
- For both Mulberry and Prospect, incorporate a separated double-right turn lane that develops out of a shared arterial lane. This approach offers better traffic distribution balance on the arterial lanes approaching I-25 and reduces the number of lane changes necessary by drivers.
- At Mulberry the use of roundabouts as intersection control for the frontage road intersections. Roundabouts meet the intersection capacity needs and can be modified to accommodate large trucks without compromising the other intended functions of roundabout traffic control.
- Add a signalized access to eastbound Mulberry from the south-side frontage road. This signal eliminates the weave conflict as well as providing one option for a signal-protected on-street bike lane to continue east on Mulberry.

The concepts for each interchange are shown in the 11x17 figures attached. Comparable designs from other locations are shown in the appendix.



# Appendix

# Eastbound Mulberry Approach Concept






Bicycles remain at roadway grade, bike route is directed to cross perpendicular to the two right turn lanes. The pedestrian signal phase also serves the bicycles, the bike phase occurs every signal cycle so there is no need for push-buttons

- ARTERIAL
- ARTERIAL
- TO FREEWAY
- TO FREEWAY

Two-phase signal for Mainline Mulberry/Frontage Road

 <b>25 SOUTH</b> <b>Denver</b>	<b>Frontage Road</b> →

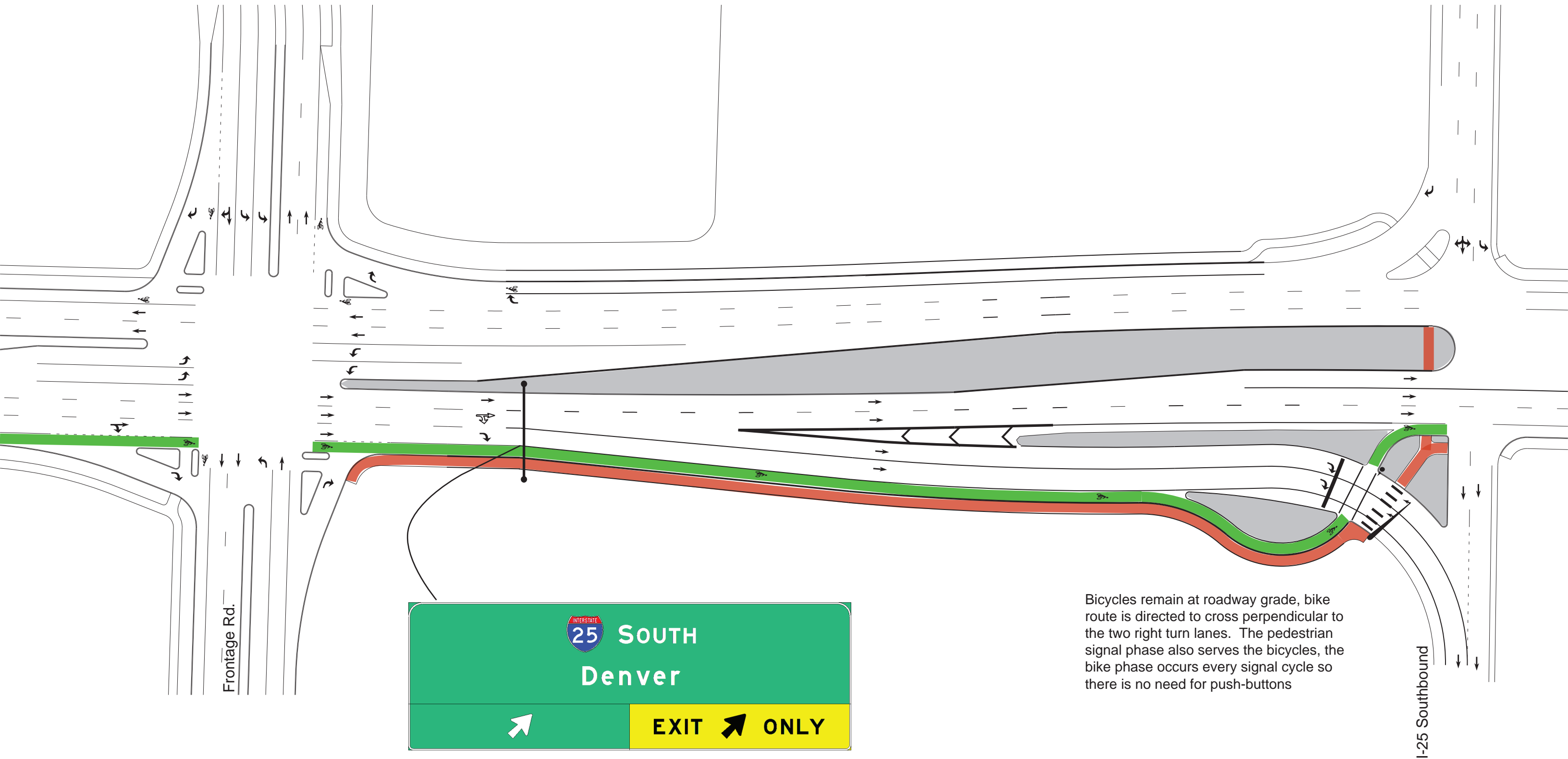
 <b>25 NORTH</b>	 <b>25 SOUTH</b>
 <b>14 EAST</b> ↓	<b>Denver</b> ↗

Stockton Ave.

I-25 Southbound

Frontage Road

# Eastbound Prospect Approach Concept



## Comparable Designs

While the idea of double-right turns at an interchange may seem unusual, there are numerous implementations of similar designs throughout the Denver area. While the traffic volumes are not available for all of these locations, it is likely they are in the same neighborhood as the 1,800 vph forecasted for Mulberry in 2035. It is notable that none of these locations has an on-street bike lane, most of the locations have either an off-street shared-use path or a simple attached sidewalk.

Parker Road (SH 83) and Hampden, Aurora, CO.  
#2 lane split similar to Mulberry & Prospect concepts  
Ped/bike underpass below double-rights



Arapahoe Road and I-25, Centennial, CO  
No bicycle lane, peds cross two-lane ramp with no protection



## Baseline and US 36, Boulder

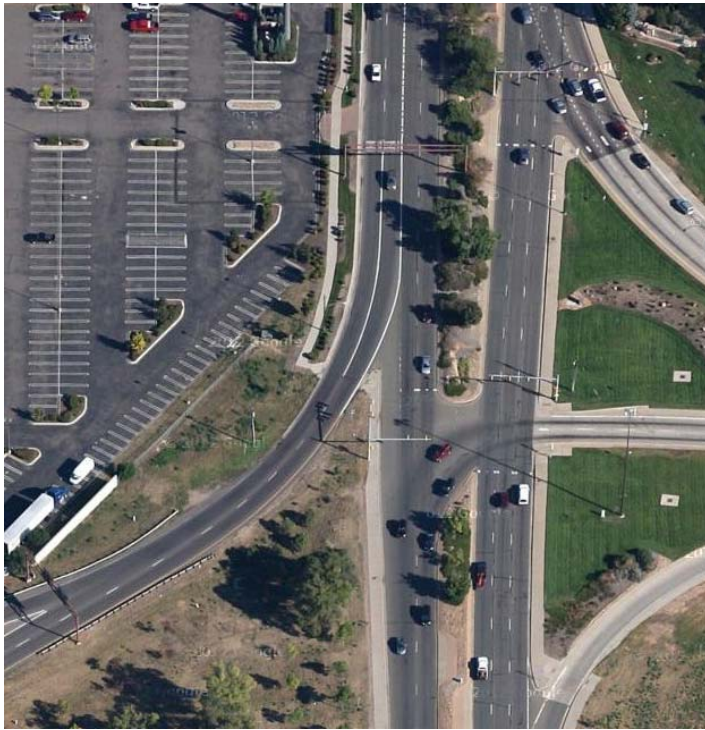
Peds/bikes have grade separated crossing on a detached path

Note also the double-rights signalized at the adjacent intersection, similar to the Mulberry concept.



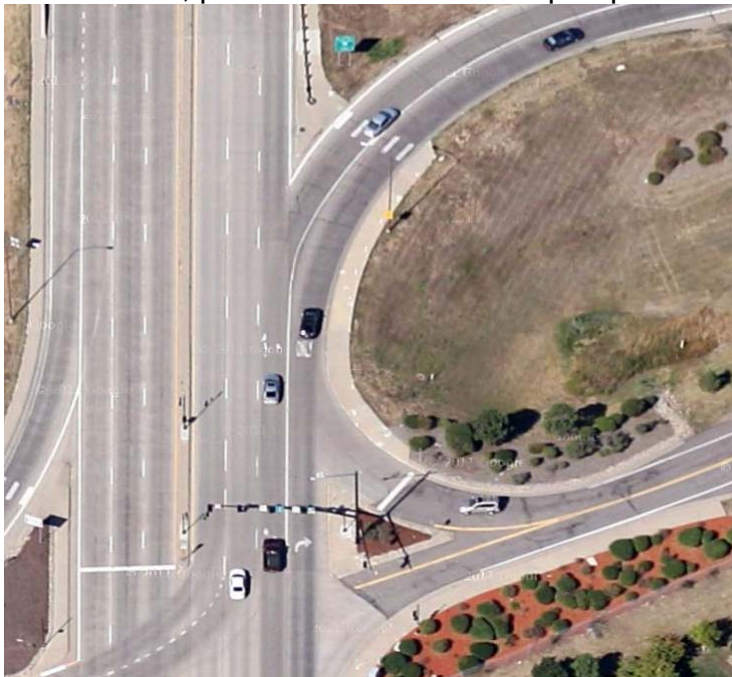
Wadsworth and I-70/I-76, Arvada, CO

#3 and #4 lanes drop to the ramp. No bike lane, peds cross 2-lane ramp unprotected



Lincoln Blvd. and I-25, Lone Tree, CO

#4 Lane drops at I-25, #3 lane is shared thru-right  
No bike lane, peds cross two-lane ramp unprotected



Park Avenue and I-25, Denver, CO

Double-rights yield, originally designed for signalization of double rights but the signals were never installed, perhaps due to low conflicting volume from lefts onto the ramp. Pedestrians cross two lanes with no protection.



Colorado Blvd. and I-25, Denver, CO – pedestrians cross both lanes with no signal protection

