ASHE National Conference

Diverging Diamond Interchanges

June 13, 2014

Stantec

Agenda

1 Introduction

2 Diverging Diamond Interchange Emergence

3 Diverging Diamond Basics

4 Project Examples

5 Discussion

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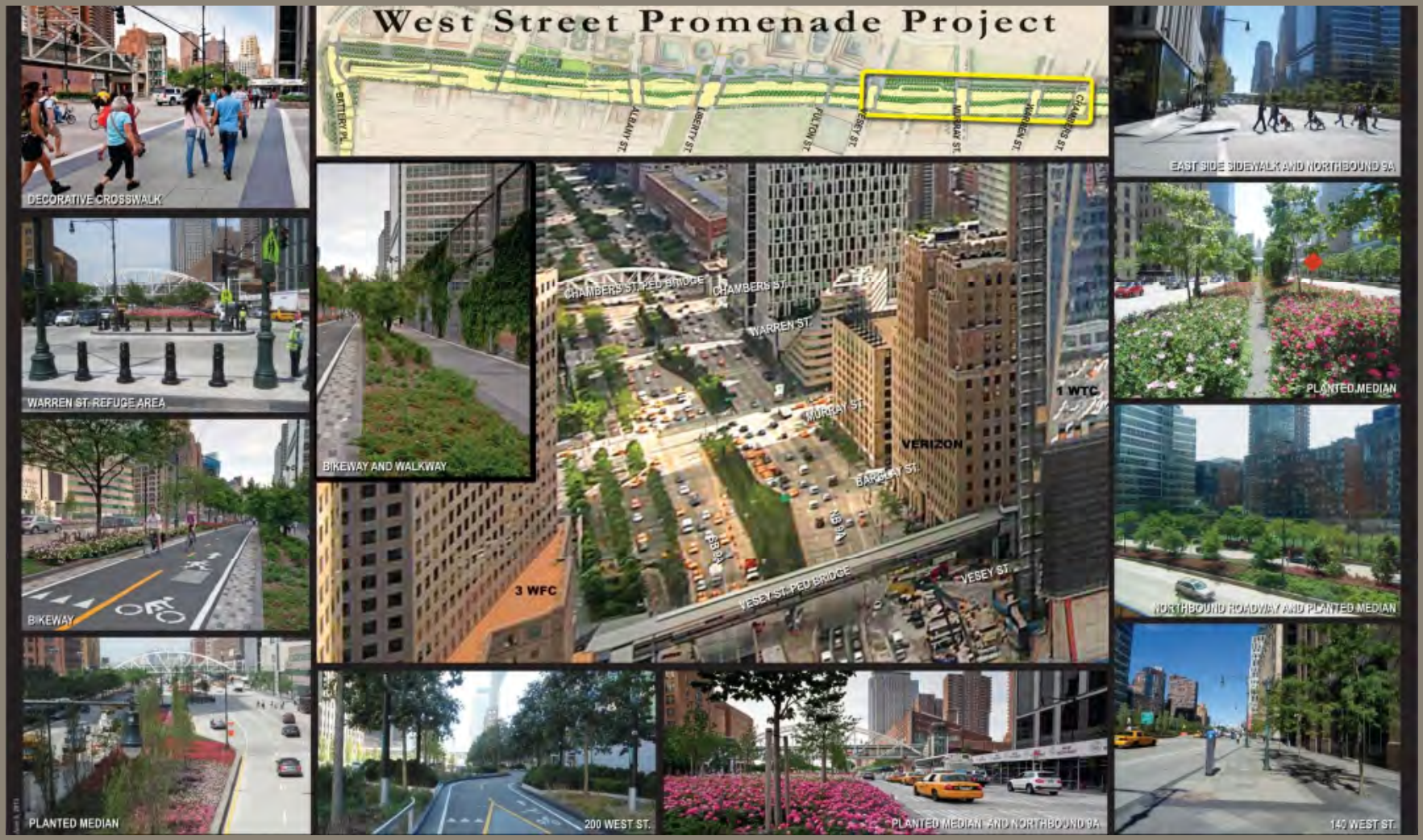

Stantec has 1400 transportation experts company-wide

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Stantec has offices across the US, Canada, and worldwide

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Dale Grove, PE

Project Manager

28+ years designing and constructing transportation projects

- Alaska
- Minnesota Department of Transportation
- Bonestroo/Stantec

Harrodsburg Road and New Circle Road, Lexington, KY,

Tom Fidler, PE

Project Manager/Lead Designer

20 years designing and constructing transportation projects for all agency levels

Bonestroo/Stantec

Jamaica Roundabouts, Cottage Grove

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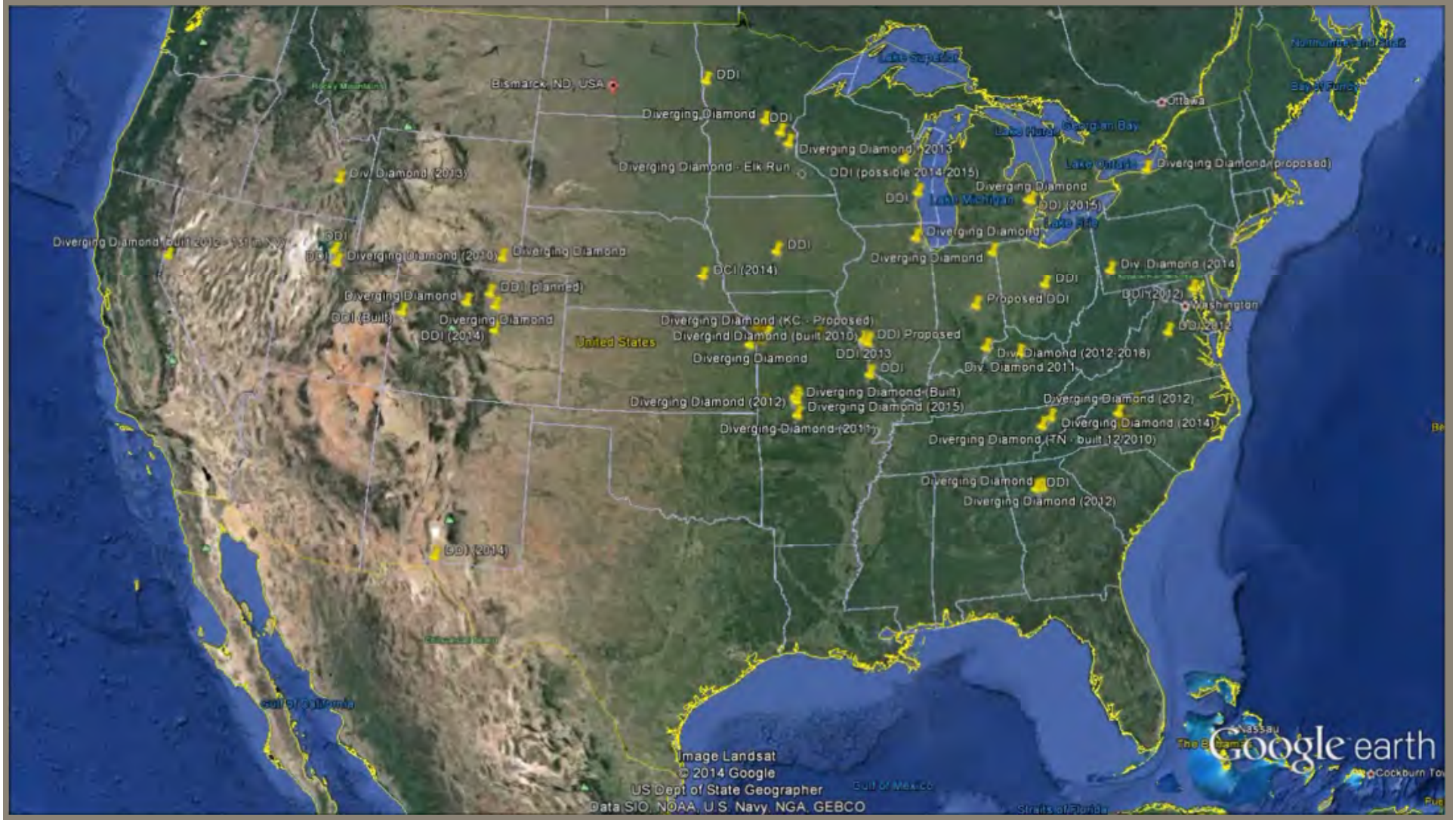
Diverging Diamond

- What is it?
  - A Diverging Diamond (a.k.a. Double Crossover) is an interchange type at which the two directions of the arterial traffic cross to the opposite side before crossing over/under the freeway bridge

Diverging Diamond Emergence

- Five years of use in the US
  - Three similar interchanges in France built in the ‘70s
  - Diverging Diamond/Double Crossover
  - 2009 – First One Built in Springfield, MO
  - 34 built to date – and counting
  - Near Majority of states have or are planning DDIs
  - Some states are in wait-and-see mode

Diverging Diamond Emergence



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Diverging Diamond Basics

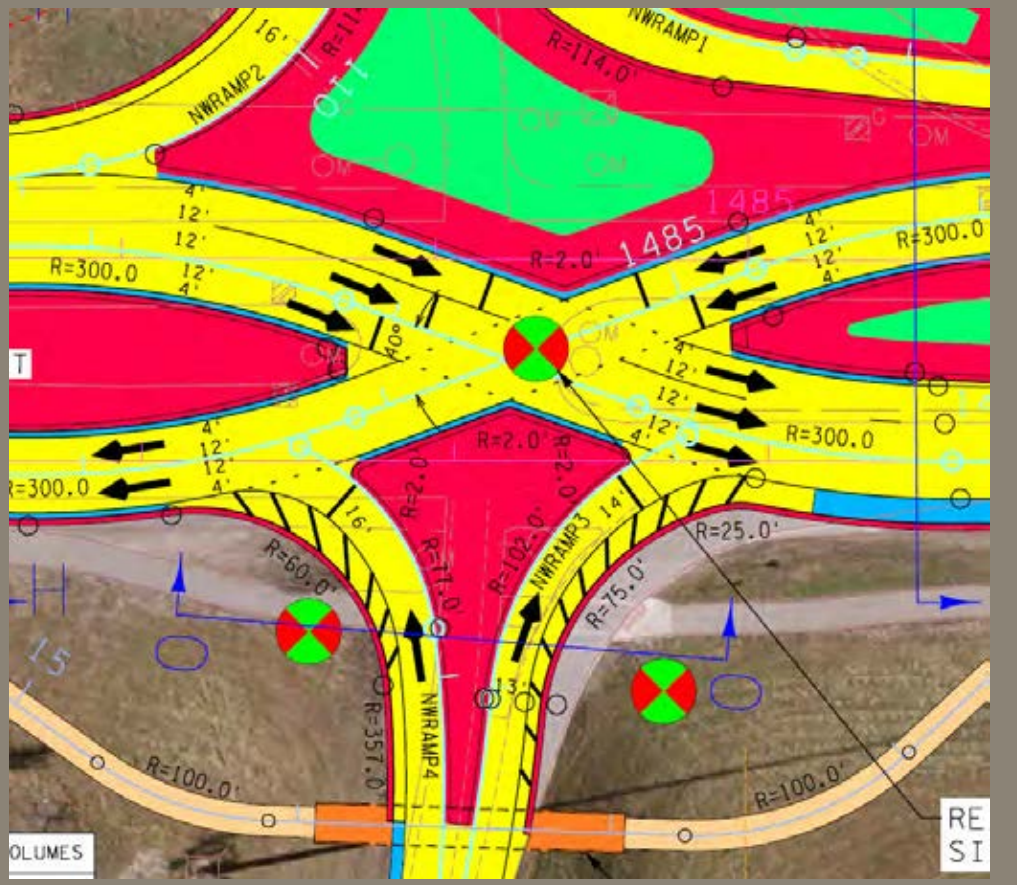
- Advantages
  - Lower Cost
    - Simpler/Narrower Bridge
      - Bridges usually on tangent
      - Left-turning traffic is generally free-flowing
    - Elimination of loops
      - Reduced pavement
      - Reduced right-of-way footprint

Diverging Diamond Basics

- Advantages
  - Higher Capacity ?
    - Site dependent
      - Higher proportion of traffic accessing the freeway sees greater capacity benefit from a DDI
        - Commonly the case for suburban interchanges
      - Arterial through volumes conflict with each other

Diverging Diamond Basics

- Advantages
  - Safety
    - Reduced conflict points
      - 18 vs 30 for a Standard Diamond Interchange
      - 2 vs 10 for critical crossing conflict types
    - Slower Speeds
      - Curves required for the cross-over require 25-30 mph curves



Diverging Diamond Basics

- Advantages
  - Interchange U-turn
    - Replaces Texas turn-around
    - Facilitates emergency or detour u-turns for the freeway

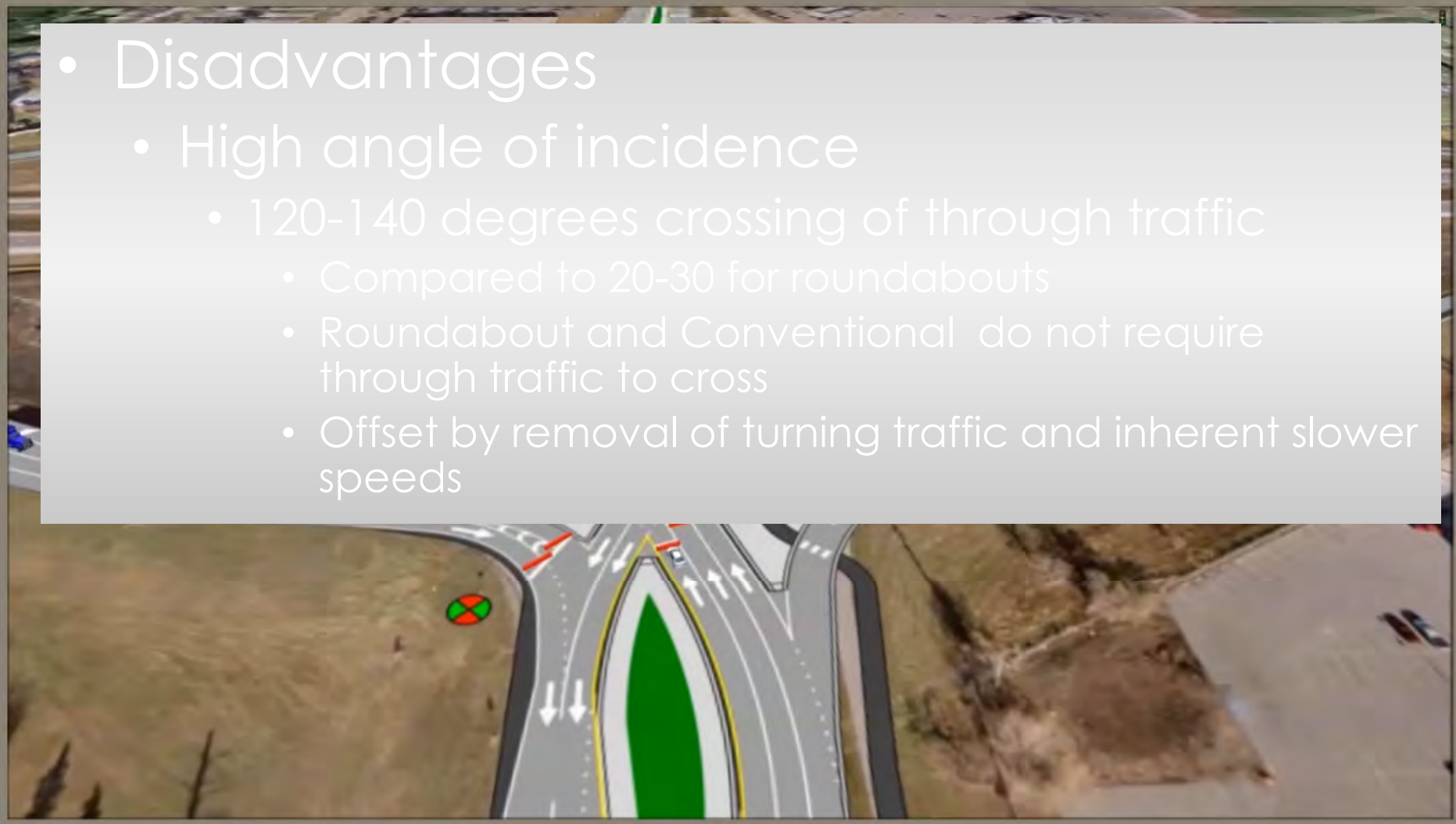
Diverging Diamond Basics

- Disadvantages
  - Closely spaced intersections/Coordination of Traffic
  - Wider off-ramps
  - High angle of incidence
  - No off-ramp re-entry

Diverging Diamond Basics

- Disadvantages
  - Closely spaced intersections/Coordination of Traffic
    - Conflicting through arterial traffic complicates coordination
    - 2-phase signal requires low cycle length
      - Nearby arterial intersections often 6-8 phases with higher cycle lengths

Diverging Diamond Basics

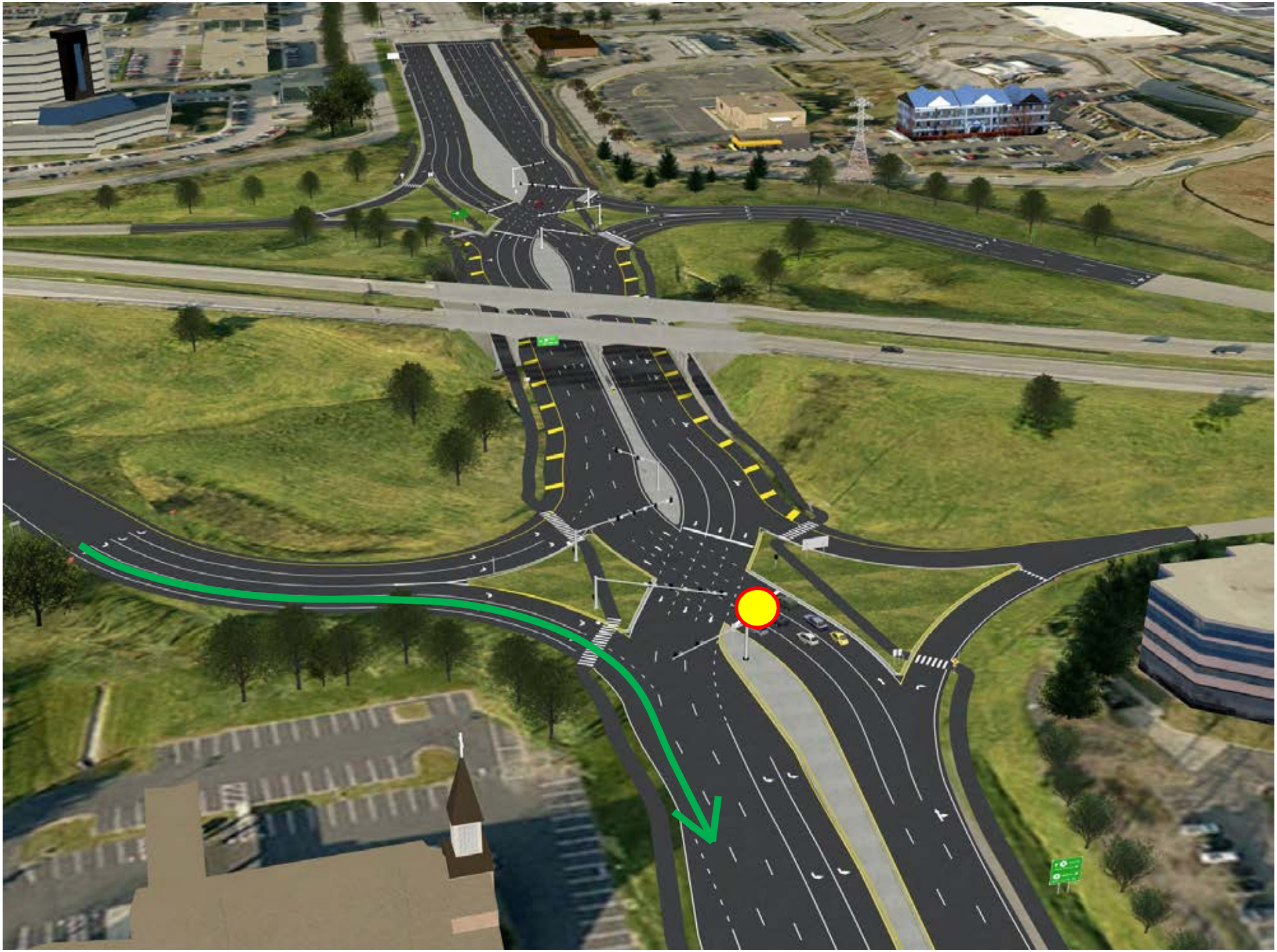


- Disadvantages
  - High angle of incidence
    - 120-140 degrees crossing of through traffic
      - Compared to 20-30 for roundabouts
      - Roundabout and Conventional do not require through traffic to cross
      - Offset by removal of turning traffic and inherent slower speeds

Diverging Diamond Basics

- Disadvantages
  - Wider off-ramps
    - Right and lefts on off-ramp run separately and queue blocking may be more common


EAST
68
WEST
68



Diverging Diamond Basics

- Disadvantages
  - No off-ramp re-entry
    - Temporary/Incorrect exits
    - Oversized loads
    - Detour/incident management traffic

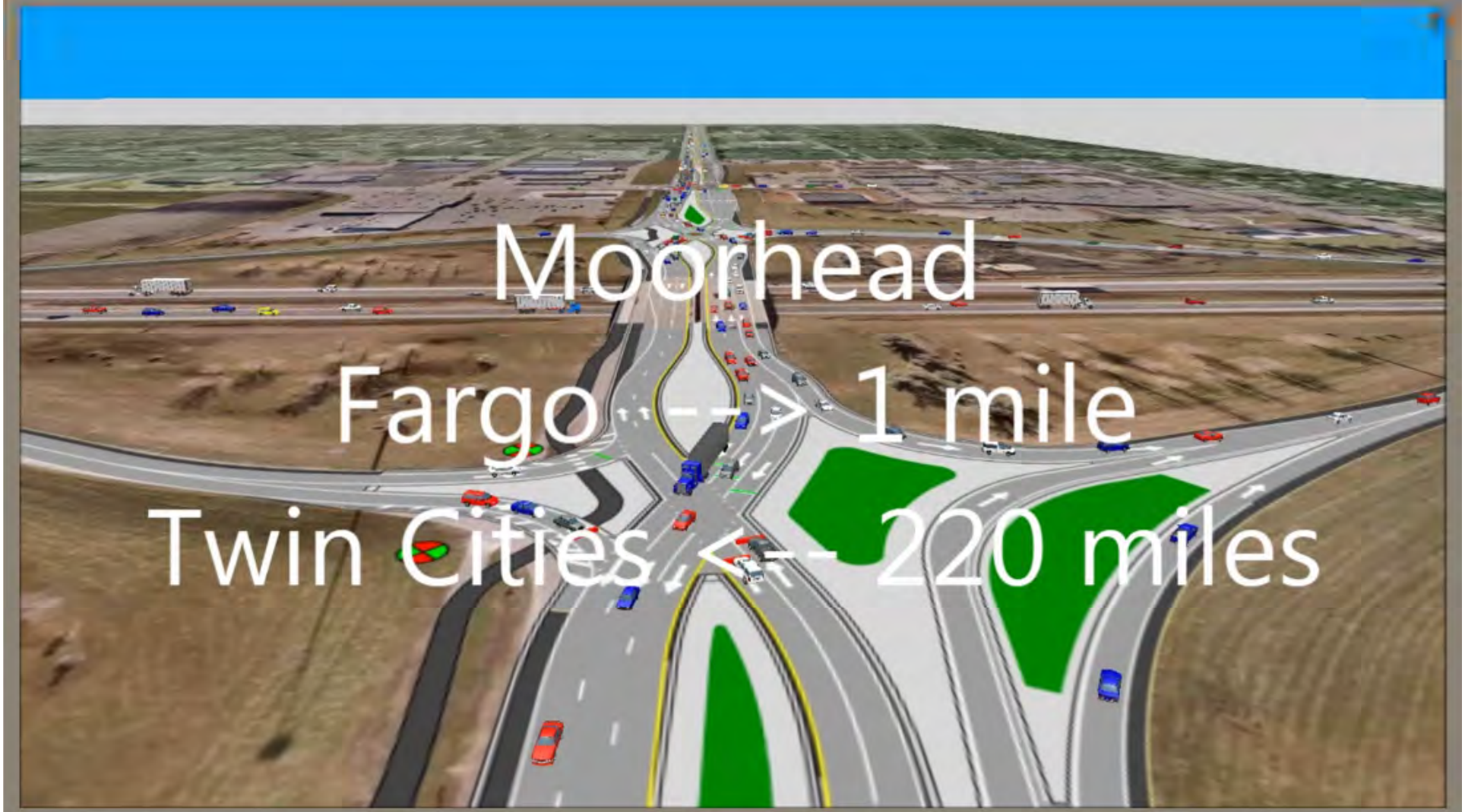
Diverging Diamond Basics

- Design Decisions
  - Traffic Lane Geometry
  - Design Speed
  - Trail/Walk Locations
  - Signalization of off-ramps

Diverging Diamond Basics

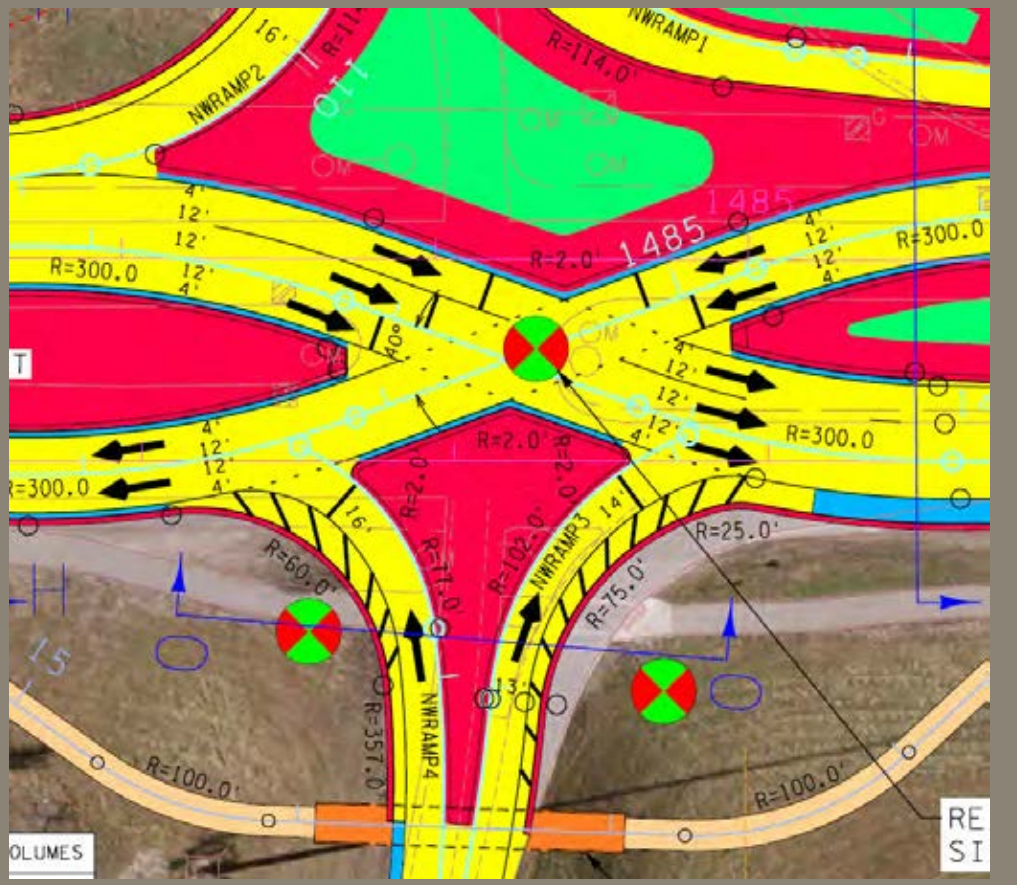
- Design Decisions
  - Traffic Lane Geometry
    - Dependent on Analysis/Simulation

Diverging Diamond Basics



Diverging Diamond Basics

- Design Decisions
  - Design Speed
    - Crossing Angle
    - Curve Radiuses
    - Approach Speeds (within 10-15 mph)
    - Lane Width



Diverging Diamond Basics

- Design Decisions
  - Traffic Lane Geometry
    - Dependent on Analysis/Simulation

Diverging Diamond Basics

- Design Decisions
  - Trail/Walk Locations
    - Depends on external trail system
    - Facility in center may have more legs signalized

Diverging Diamond Basics

I-44 and Highway 13 – Springfield, MO

Diverging Diamond Basics

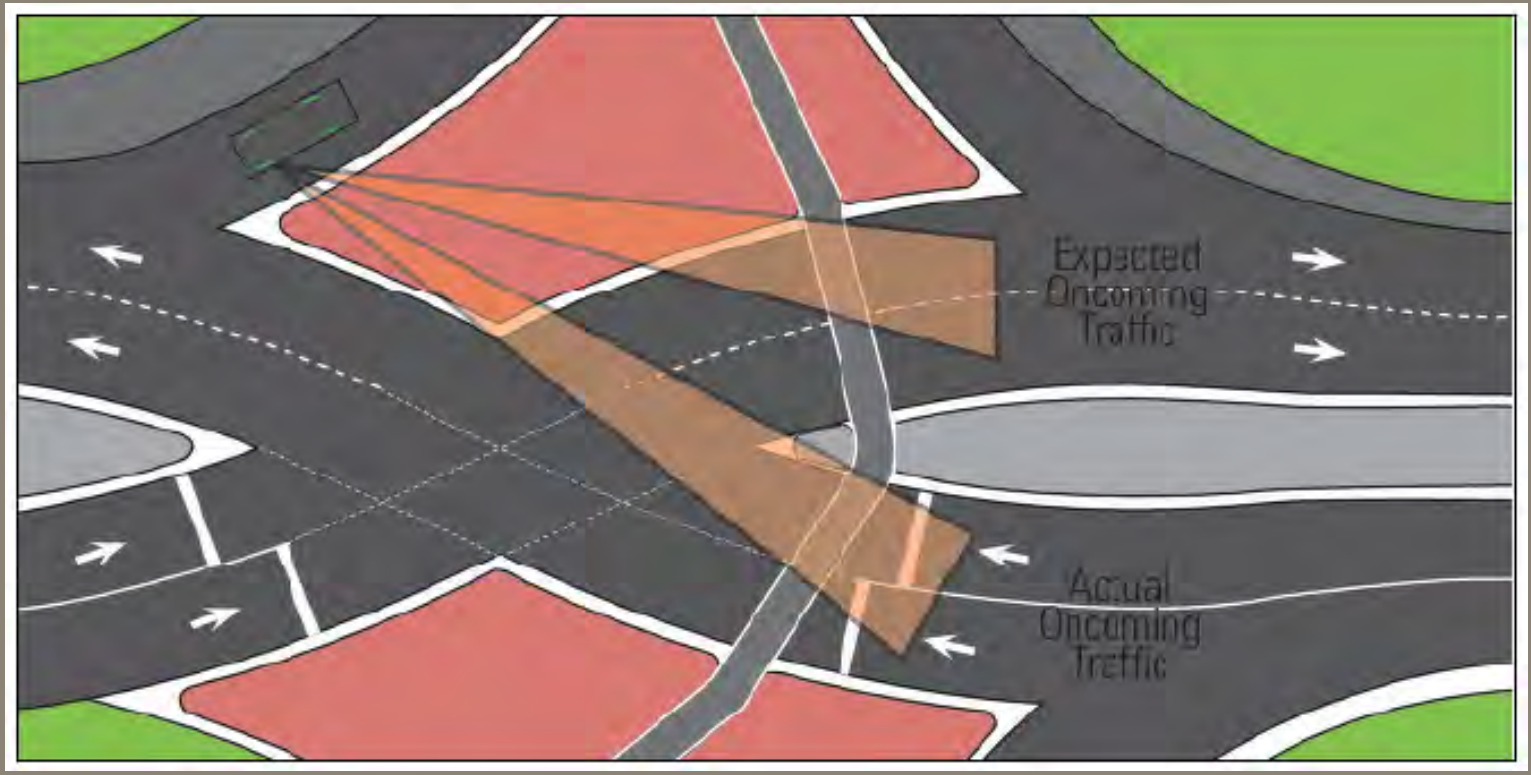
I-44 and Highway 13 – Springfield, MO

Diverging Diamond Basics

- Design Decisions
  - Signalization of off-ramps
    - No turn on red
    - Concern over yielding to wrong lane
    - Signalize of pedestrian crossings

Diverging Diamond Basics

- Design Decisions
  - Signalization of off-ramps (No turns on red)



Source: *Missouri's Experience with a Diverging Diamond Interchange, Lessons Learned*

Diverging Diamond Basics

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Kentucky's First DCD Interchange: *Open to Traffic*

http://transportation.ky.gov/us-68-double-crossover-diamond

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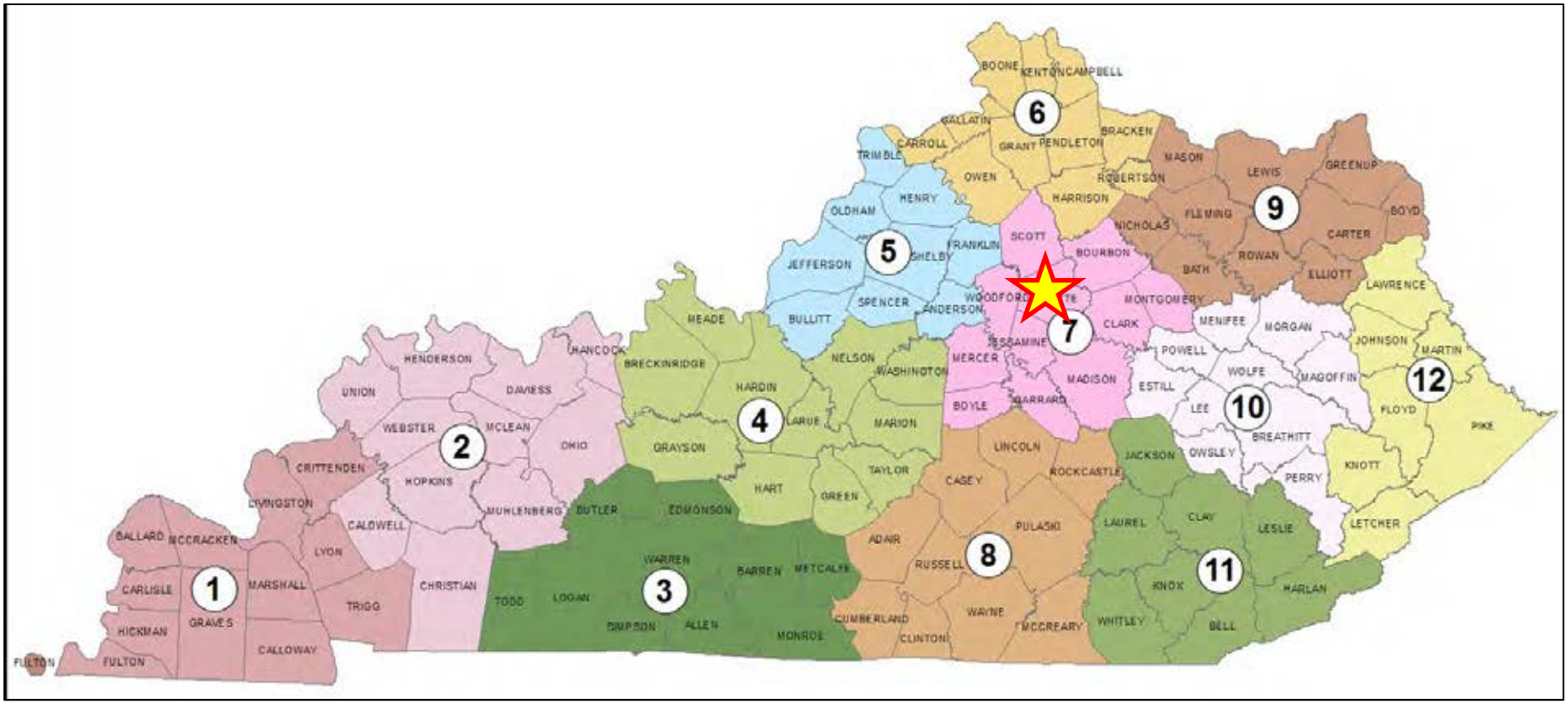
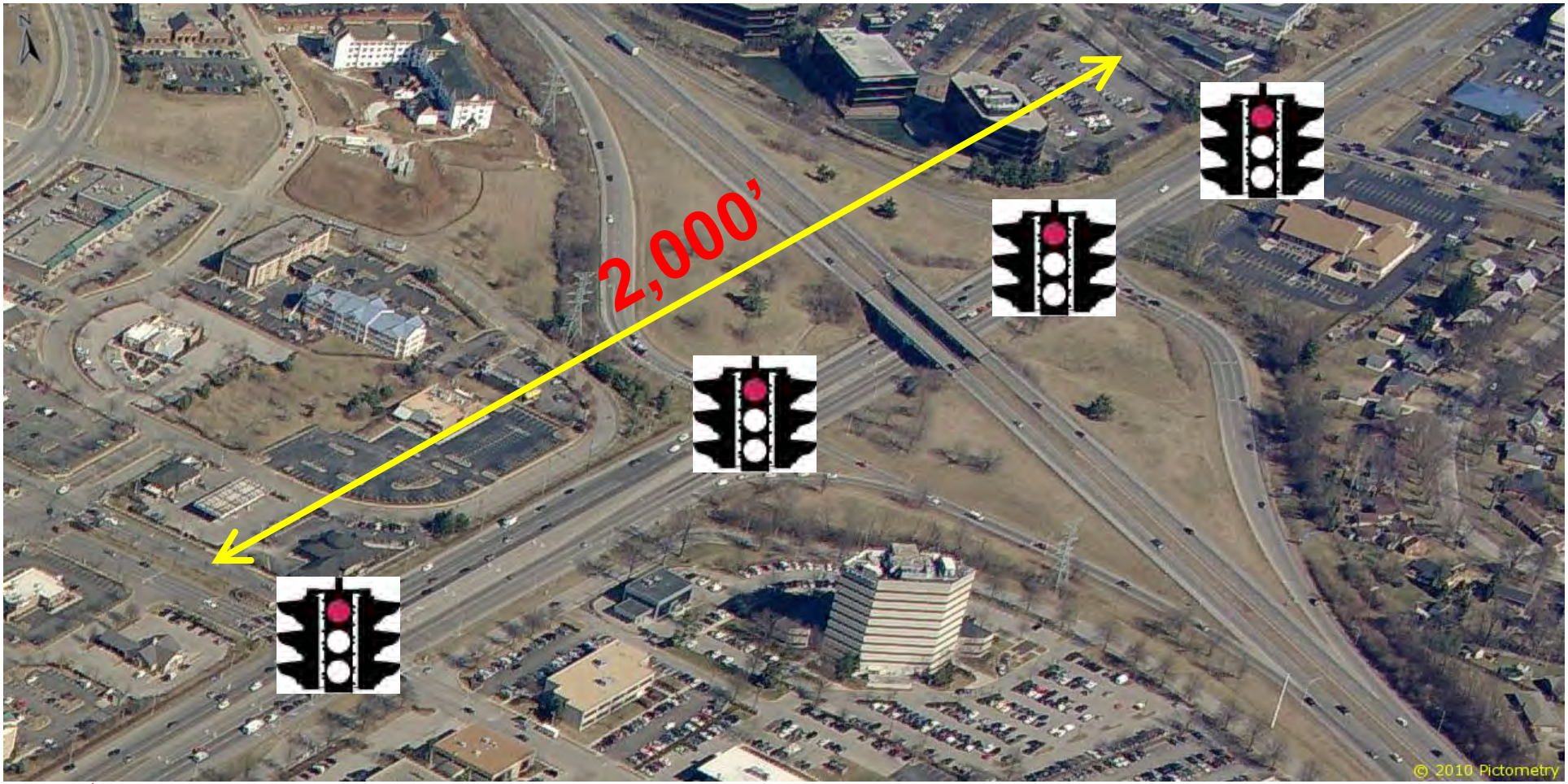
Project Location



Project Location

Project Corridor - Issues

To Downtown



To Man o’ War Blvd.

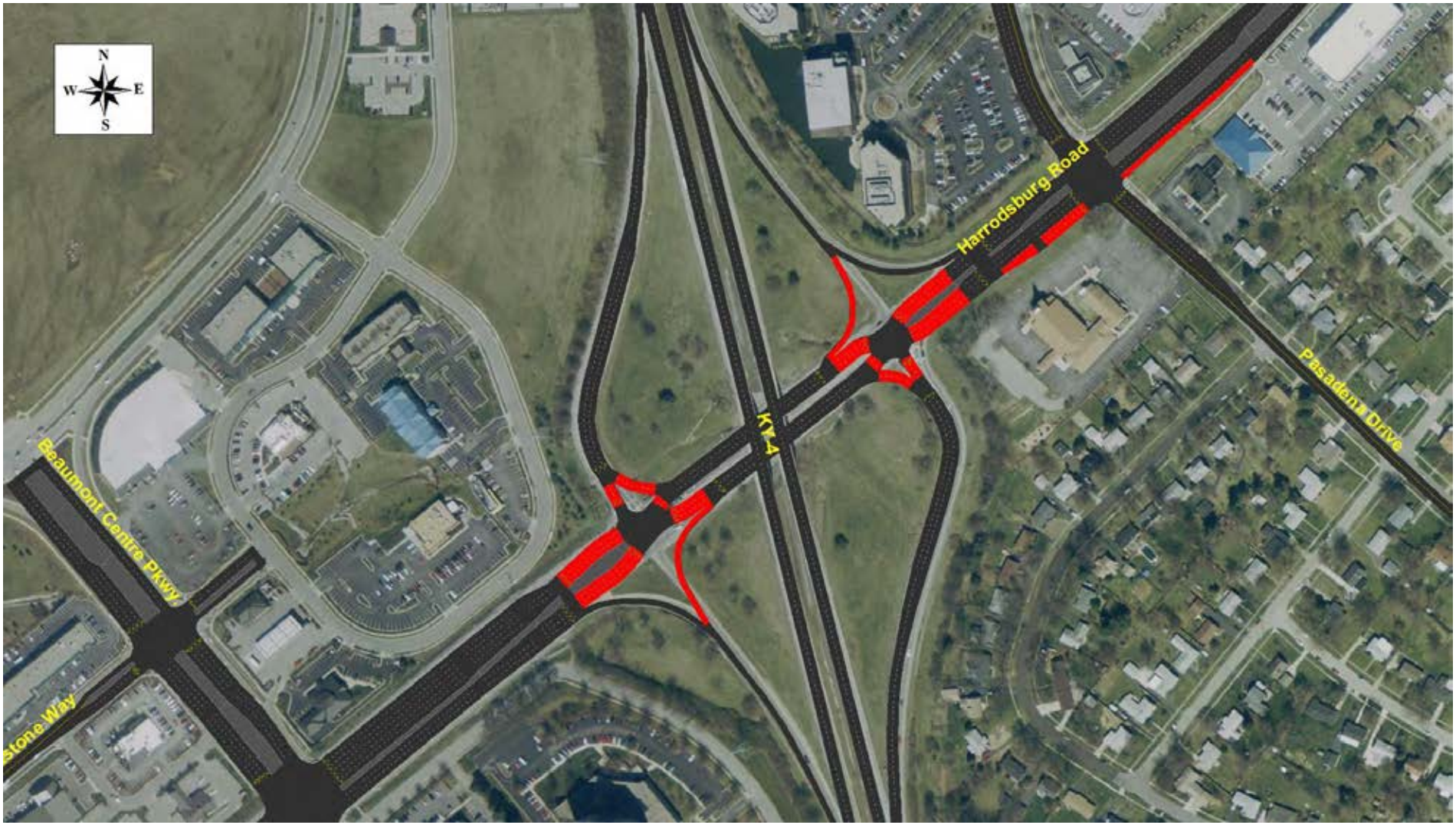
Project Issues

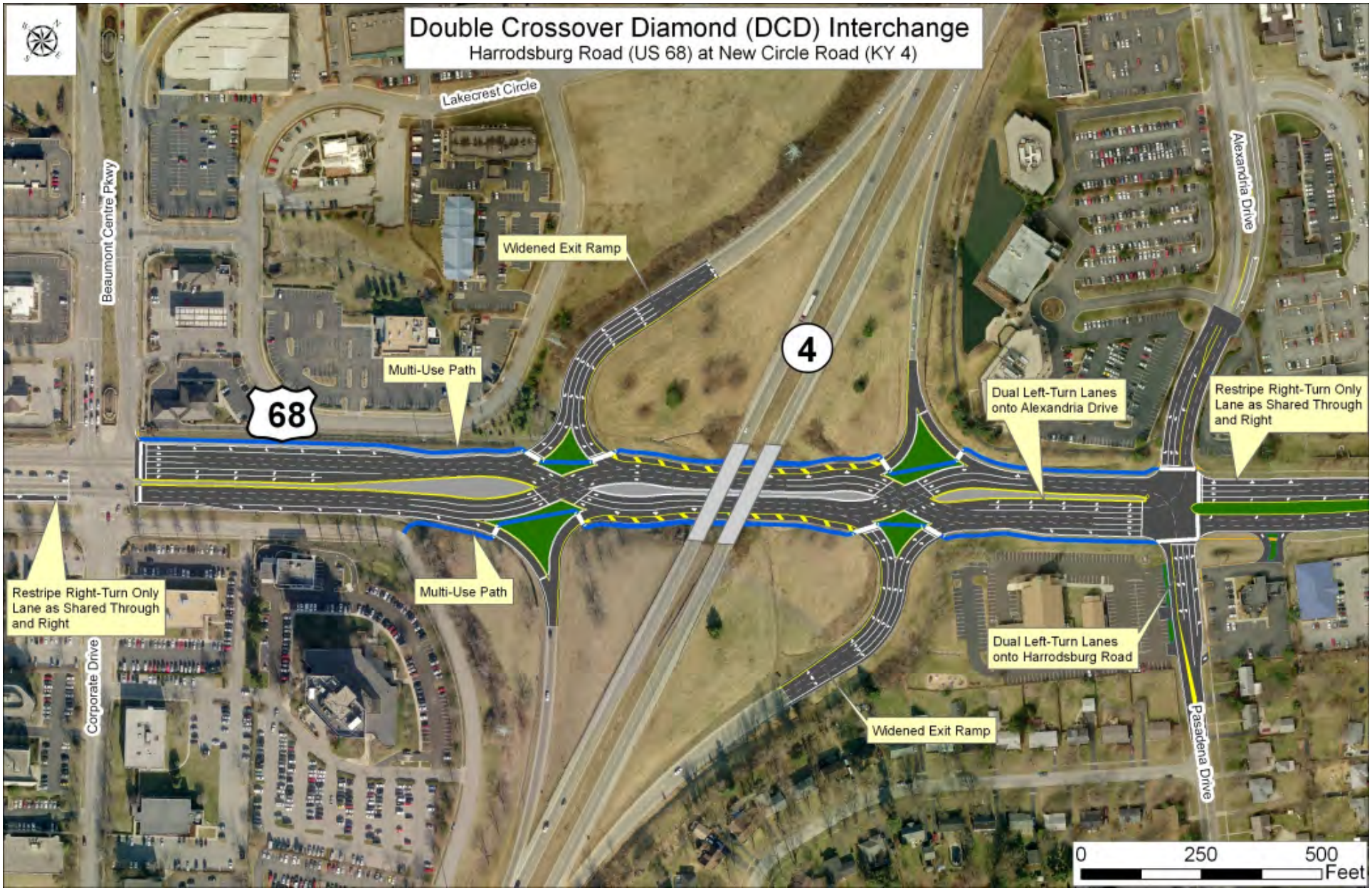
1. High Crash Rate
2. Heavy Through Movement on Harrodsburg Road
3. Heavy Left-Turn Movements onto New Circle

Alternates Considered
Dual Left

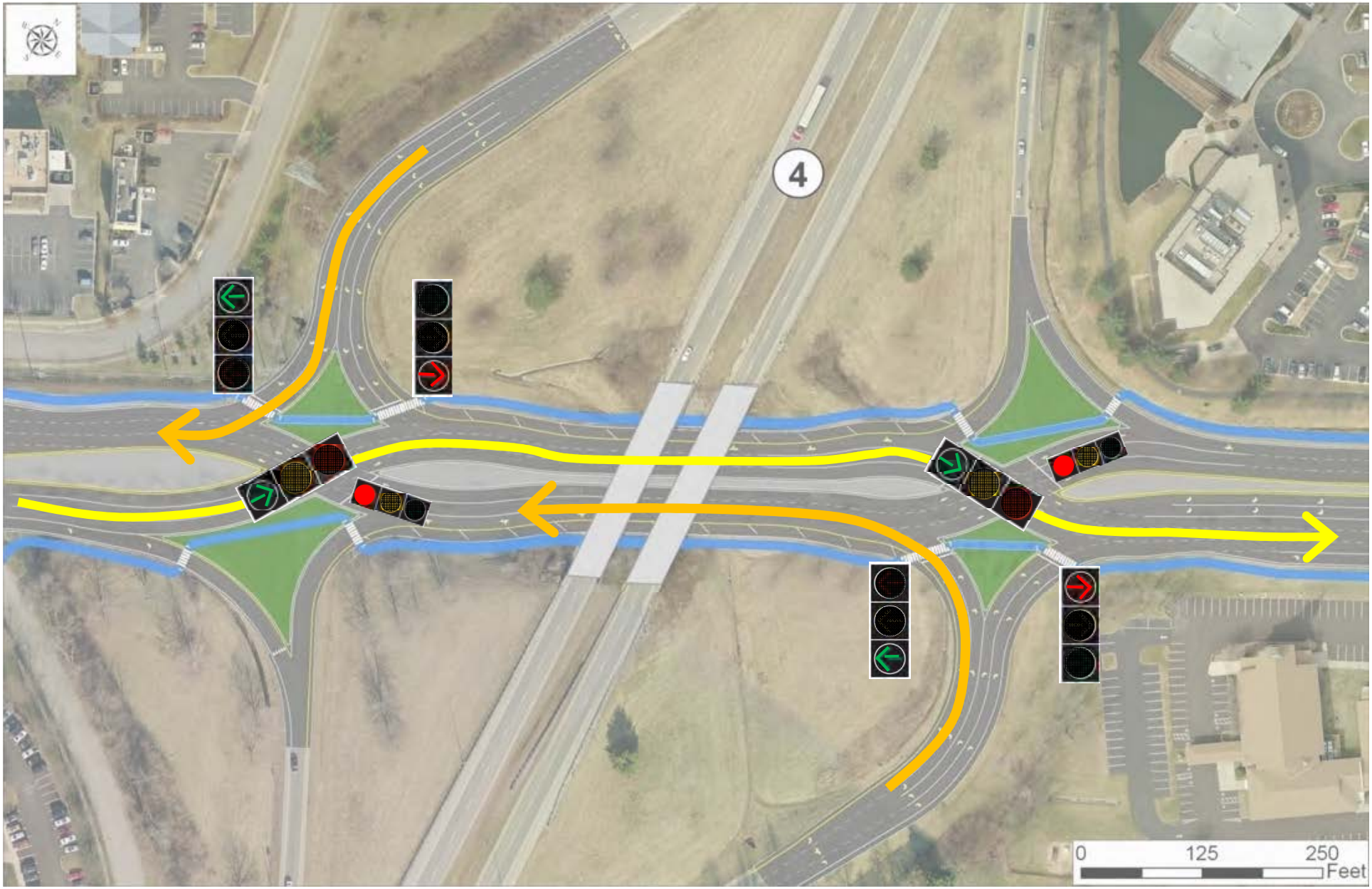
Alternates Considered
Three Through Lanes

Alternates Considered
Diverging Diamond (DDI)

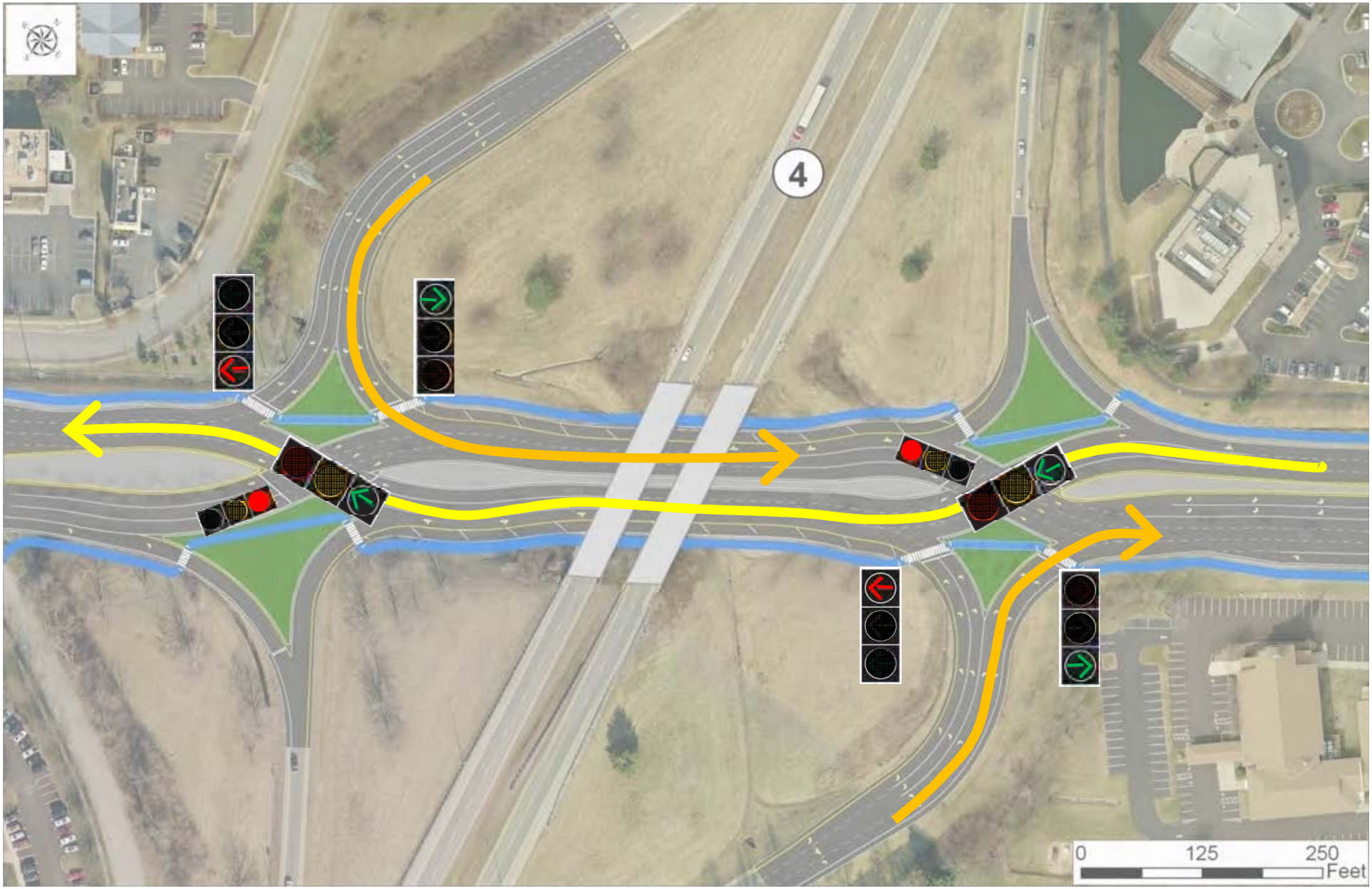



Double Crossover Diamond (DCD) Interchange
Harrodsburg Road (US 68) at New Circle Road (KY 4)
Lakecrest Circle
Beaumont Centre Pkwy
Widened Exit Ramp
Multi-Use Path
68
4
Alexandria Drive
Dual Left-Turn Lanes onto Alexandria Drive
Restripe Right-Turn Only Lane as Shared Through and Right
Restripe Right-Turn Only Lane as Shared Through and Right
Multi-Use Path
Corporate Drive
Dual Left-Turn Lanes onto Harrodsburg Road
Widened Exit Ramp
Pasadena Drive
0
250
500
Feet

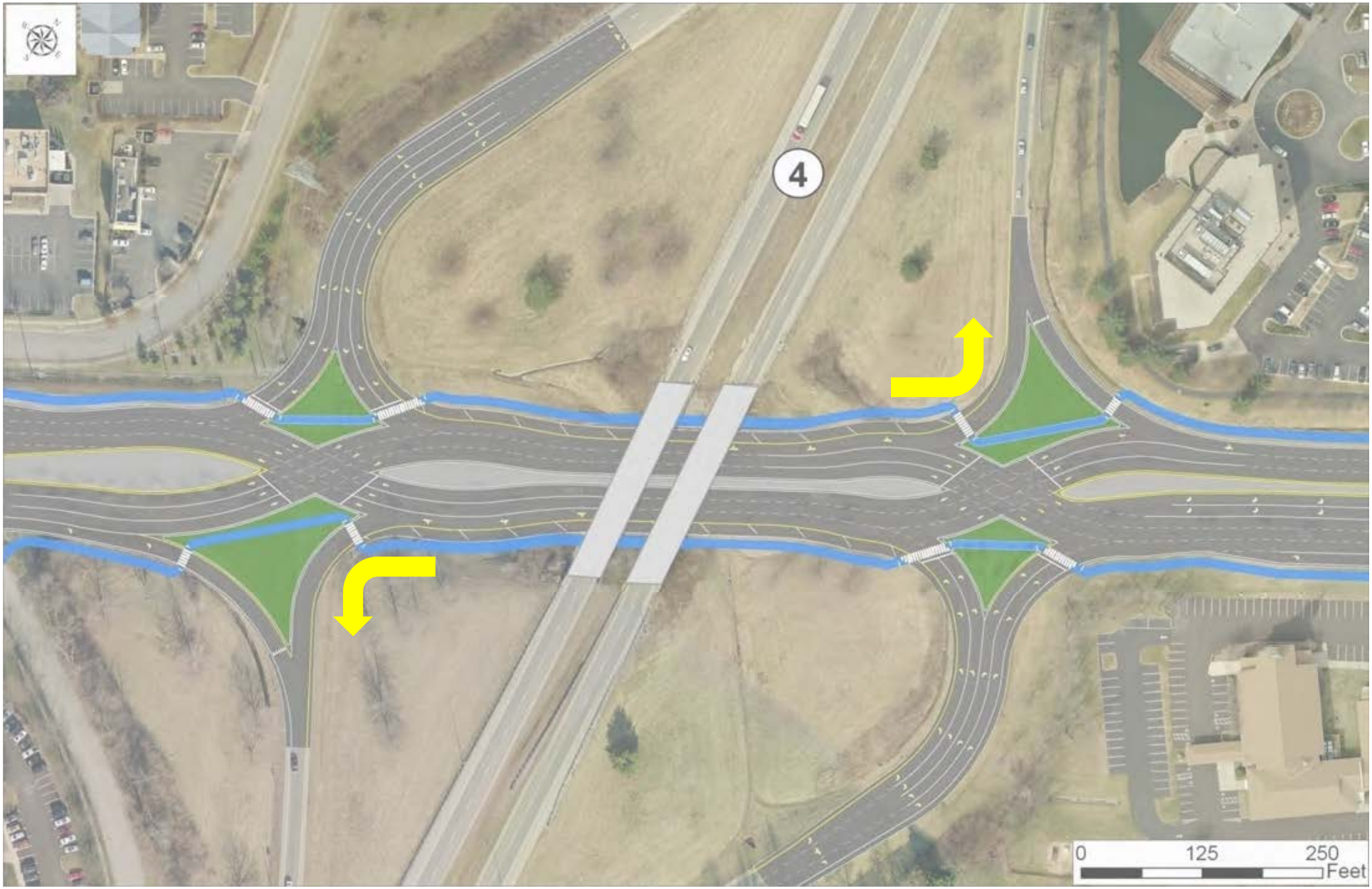
Two-Phase Signal Operation



Two-Phase Signal Operation

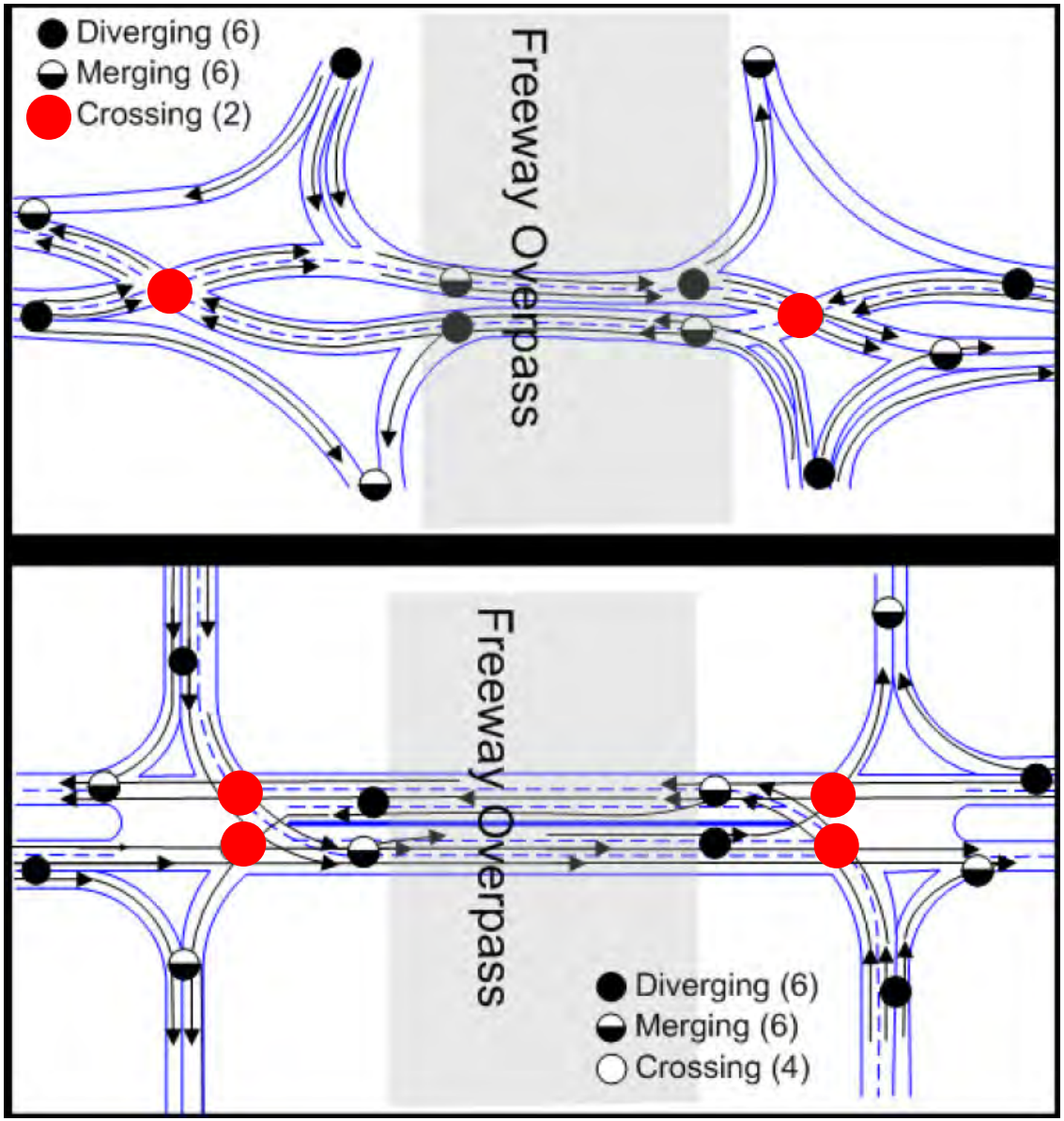


Left turns are free-flow



Conflict Points are Reduced

- DCD
  - 2 crossing conflict points
- Conventional
  - 4 crossing conflict points



Previous Interchange Layout

DCD Interchange Layout


ONLY
ONLY
ONLY
4 North
New Circle Rd

Crash Data*

Harrodsburg Road (US 68) Crash History Before and After Construction of the Double Crossover Diamond (DCD)														
Crashes	**Year**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Average**
Pre-DCD	2008	14	15	7	8	11	12	11	16	12	11	6	6	*10.33*
	2009	13	14	9	9	9	9	13	8	9	17	7	8	
	2010	9	17	4	12	10	6	6	9	7	19	7	17	
	2011	--	--	--	6	7	14	6	10	9	--	--	--	
	Average	*12.0*	*15.3*	*6.7*	*8.8*	*9.3*	*10.3*	*9.0*	*10.8*	*9.3*	*15.7*	*6.7*	*10.3*	

Averaged 10.3 crashes per month from 2008 - 2011

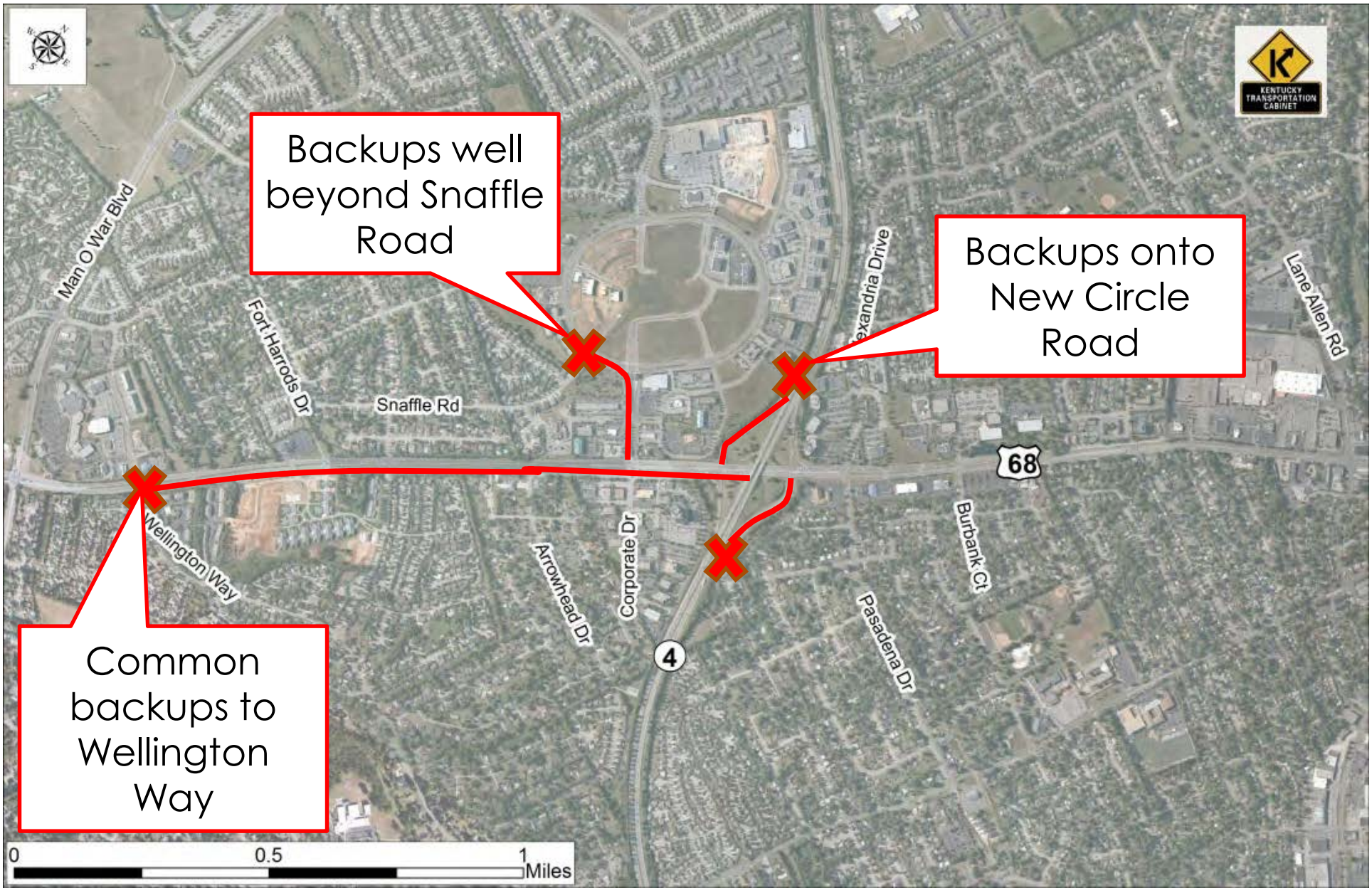
***Includes all reported crashes between Beaumont Centre Parkway and Alexandria Drive.**

Crash Data

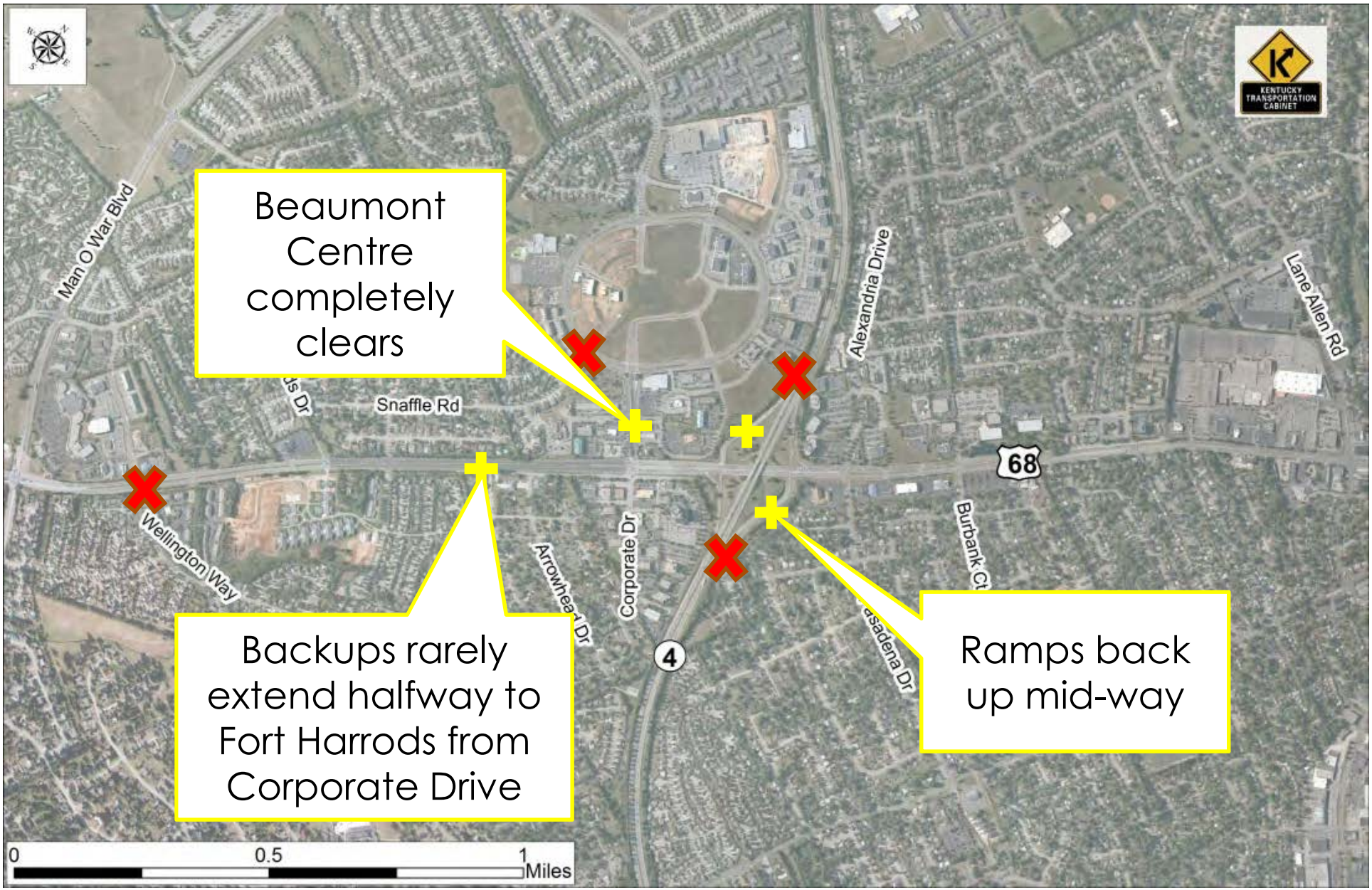
Harrodsburg Road (US 68) Crash History Before and After Construction of the Double Crossover Diamond (DCD)														
Crashes	**Year**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Average**
Pre-DCD	*Average*	*12.0*	*15.3*	*6.7*	*8.8*	*9.3*	*10.3*	*9.0*	*10.8*	*9.3*	*15.7*	*6.7*	*10.3*	*10.33*
	Year	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Average**
Post-DCD	2011	6	6	3	--	--	--	--	--	--	--	--	--	5.67
	2012	--	--	--	8	5	10	6	5	4	6	5	4	
	Percent Reduction	*-50%*	*-61%*	*-55%*	*-9%*	*-46%*	*-2%*	*-33%*	*-53%*	*-57%*	*-62%*	*-25%*	*-61%*	***-45%***

We're averaging 45% fewer crashes with the DCD interchange.

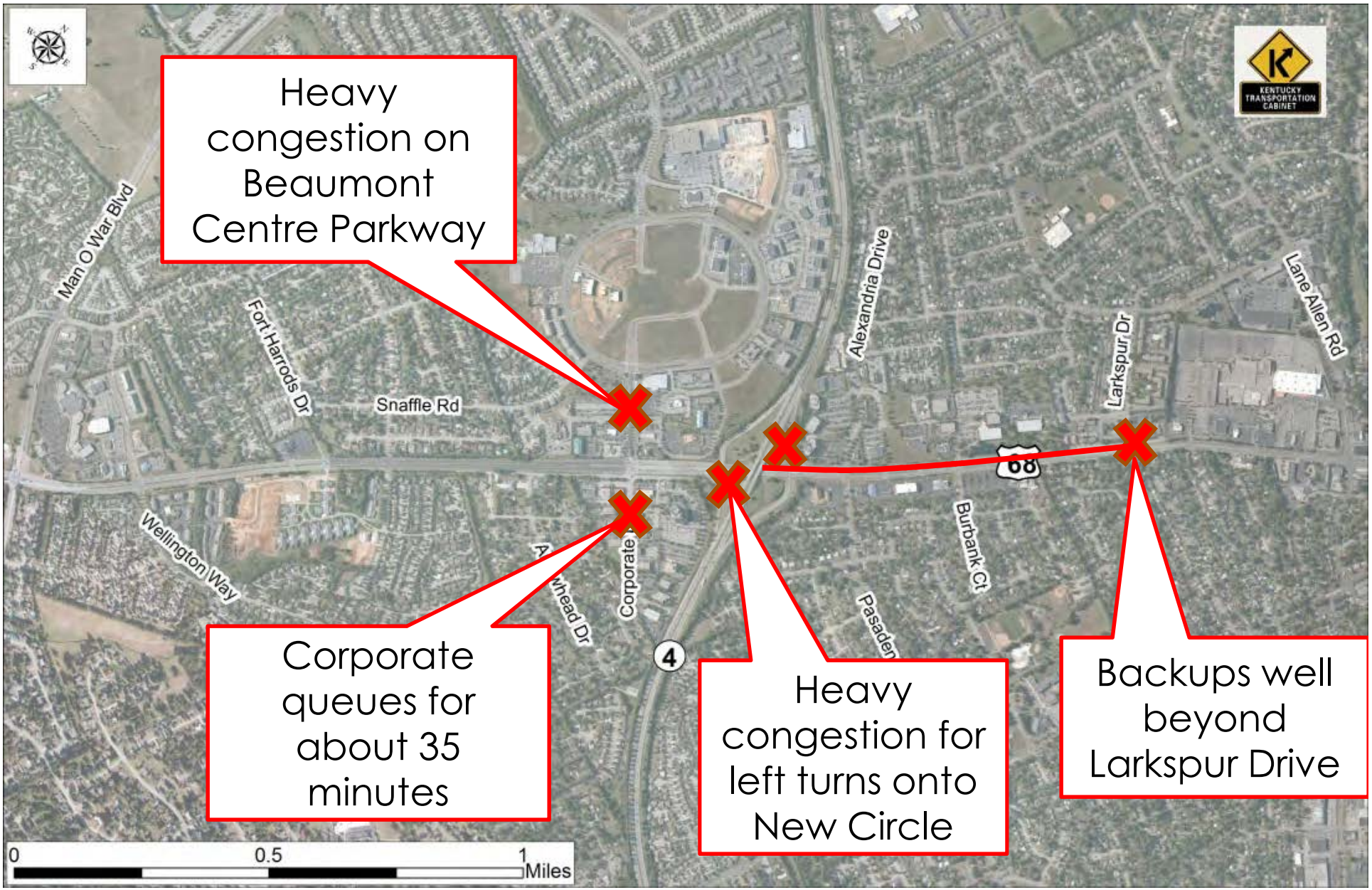
AM Traffic – Pre-DCD



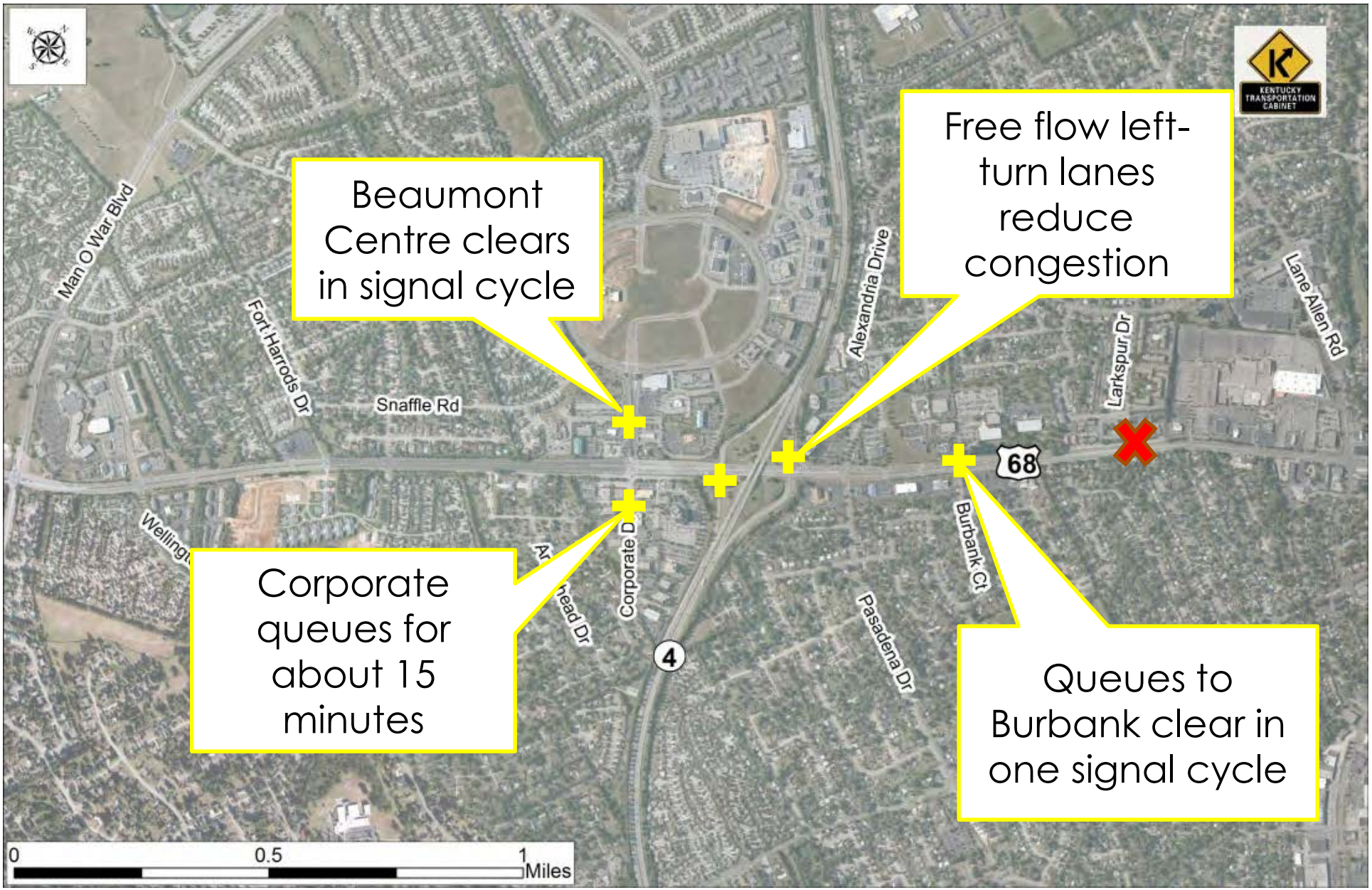
AM Traffic – Post-DCD



PM Traffic – Pre-DCD



PM Traffic – Post-DCD

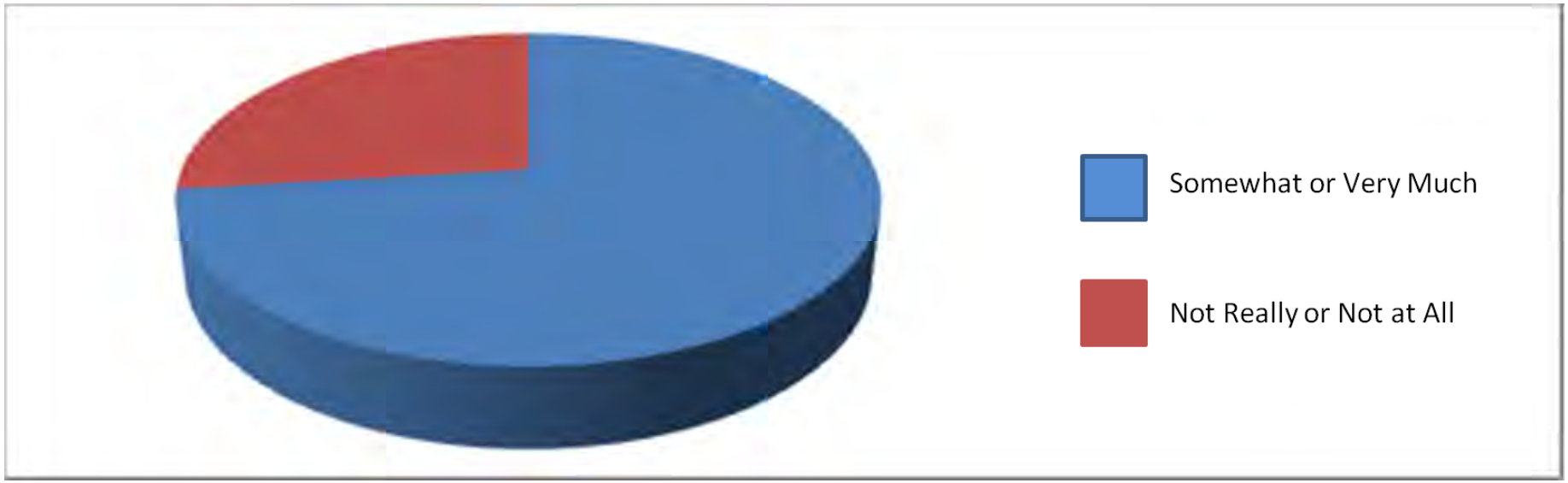


Driver Simulation Video Game

Inner Loop Crossover

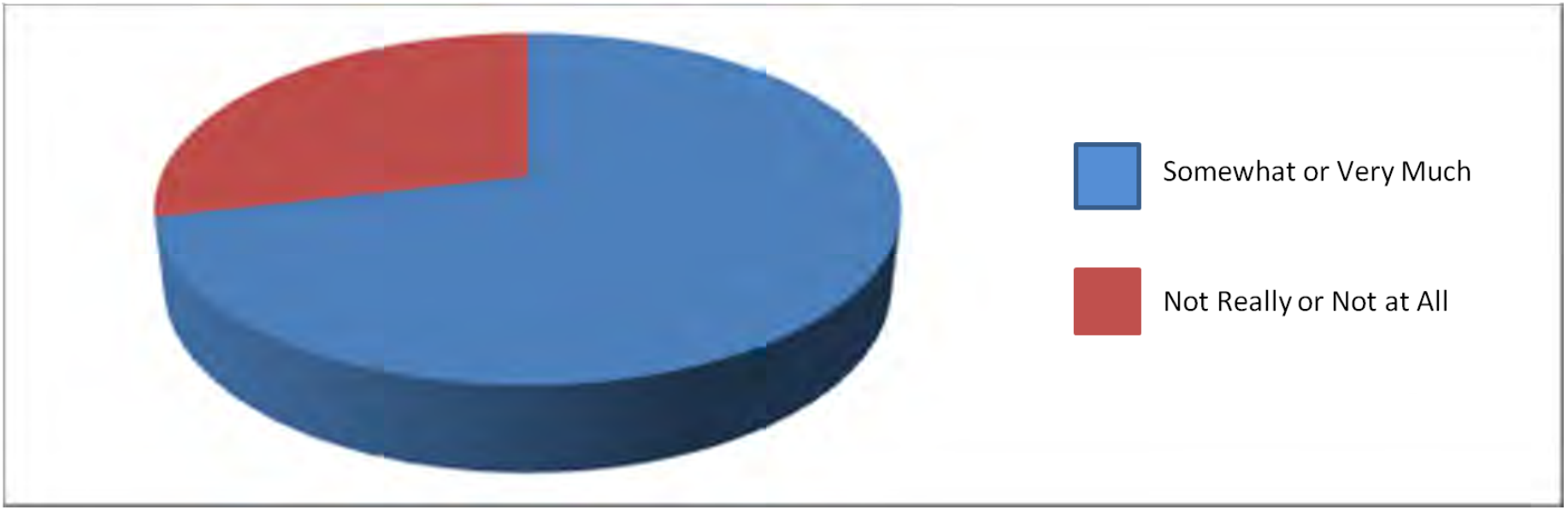
Inner Loop Crossover

Overall, do you think this project was a good transportation solution for this location?



72% said it was a good solution

Do you think a DCD interchange should be considered at other locations in Lexington or elsewhere in Kentucky?



72% said a DCD should be considered elsewhere

Positive Feedback

- *"I am writing to commend Stantec and the KYTC for their work on the DCD interchange on US 68 in Lexington, KY.*

- *… information presented at multiple public meetings, on the project website, and through local media outlets helped me understand how the design works and educated countless citizens about the project.*

- *… The interchange has improved safety, reduced traffic congestion, and made a significant step in connecting Lexington's expanding bicycle and pedestrian network."*

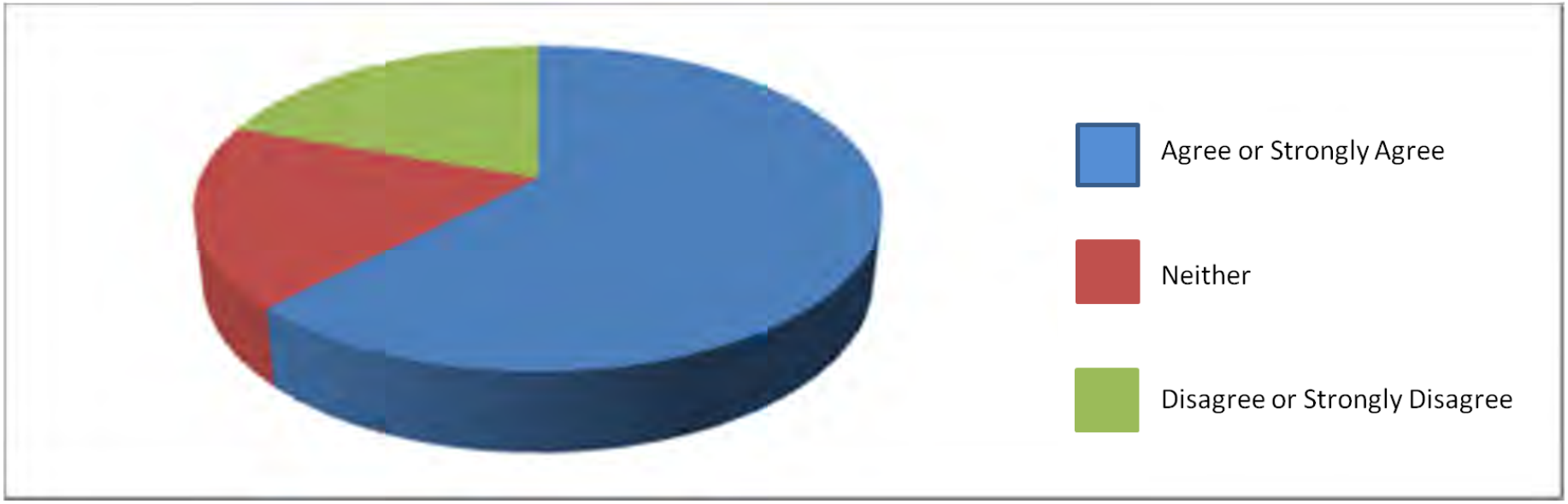
- Lexington-Fayette Urban County Government Councilman Doug Martin

Positive Feedback

"Sadly, I'm hearing the same pessimistic commentary that I did when they were building the Frankfort Pike roundabout. Those naysayer's are nowhere to be found now that it's finished and is ***working like a charm***. No one ever said that the "DCD" would cure all the problems at this particular intersection, but rather that it would reduce a significant amount of the rush hour congestion. From what I've observed during its construction and 3 trips through the intersection (one at morning rush hour), this too is **destined to achieve what was intended by the design**."

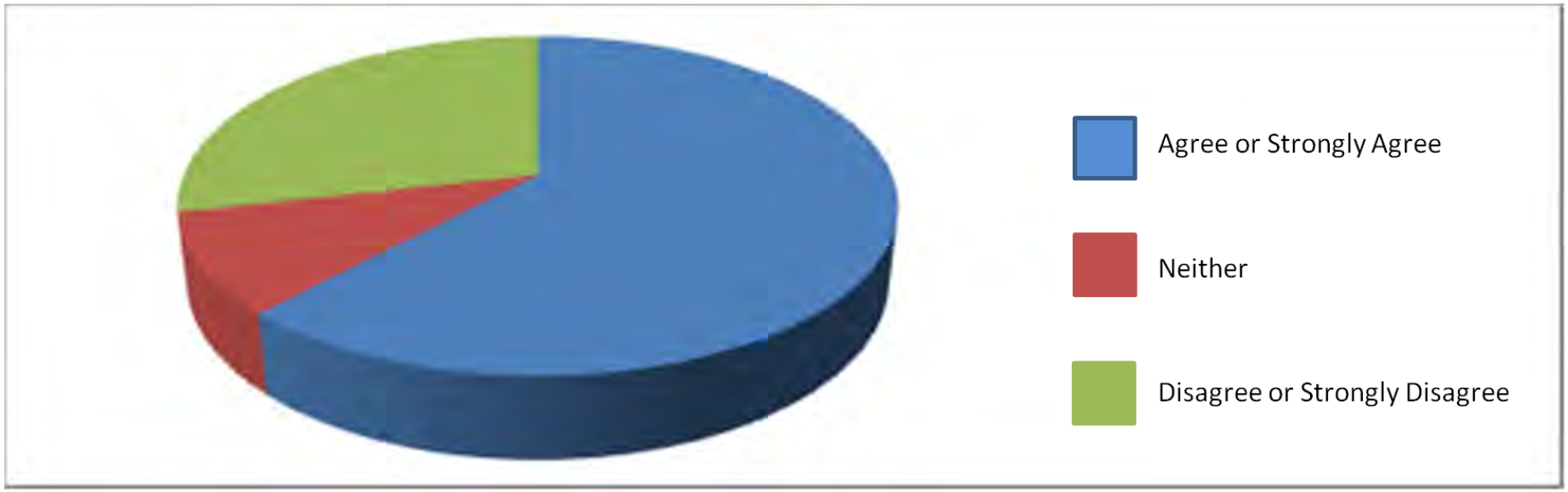
Read more here:
http://www.kentucky.com/2011/08/15/1846182/motorists-navigate-new-harrodsburg.html#storylink=cpy

The roadway is safer than it was prior to the project



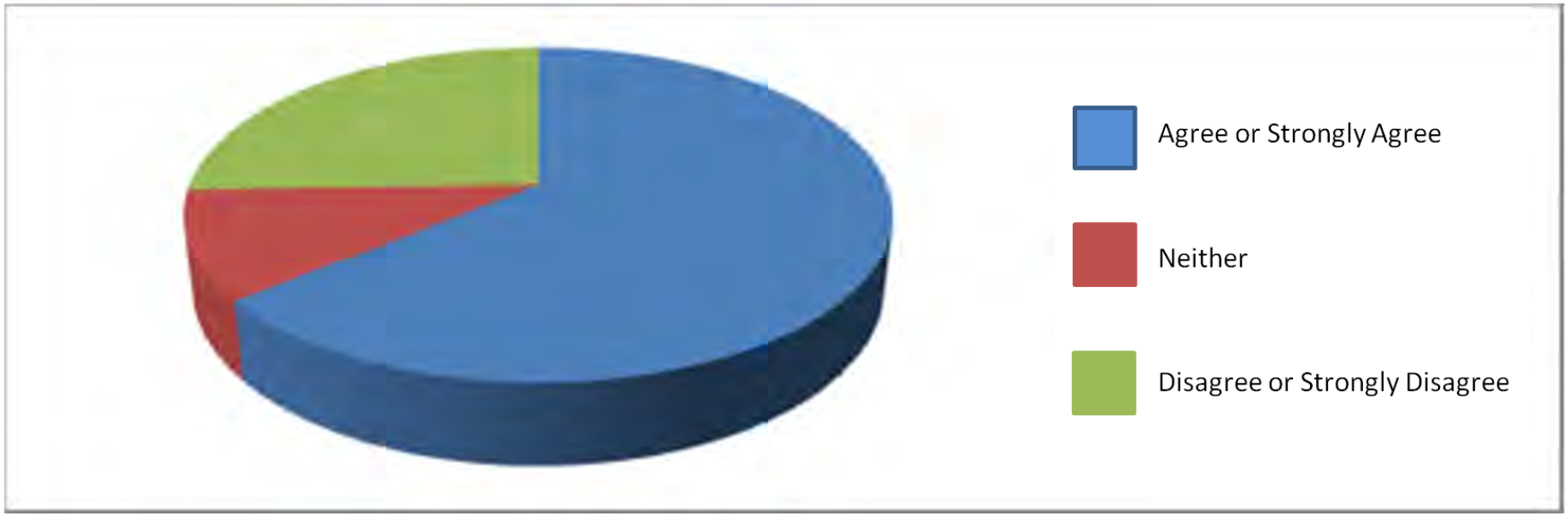
62% said the roadway is safer

The roadway is less congested than it was prior to the project



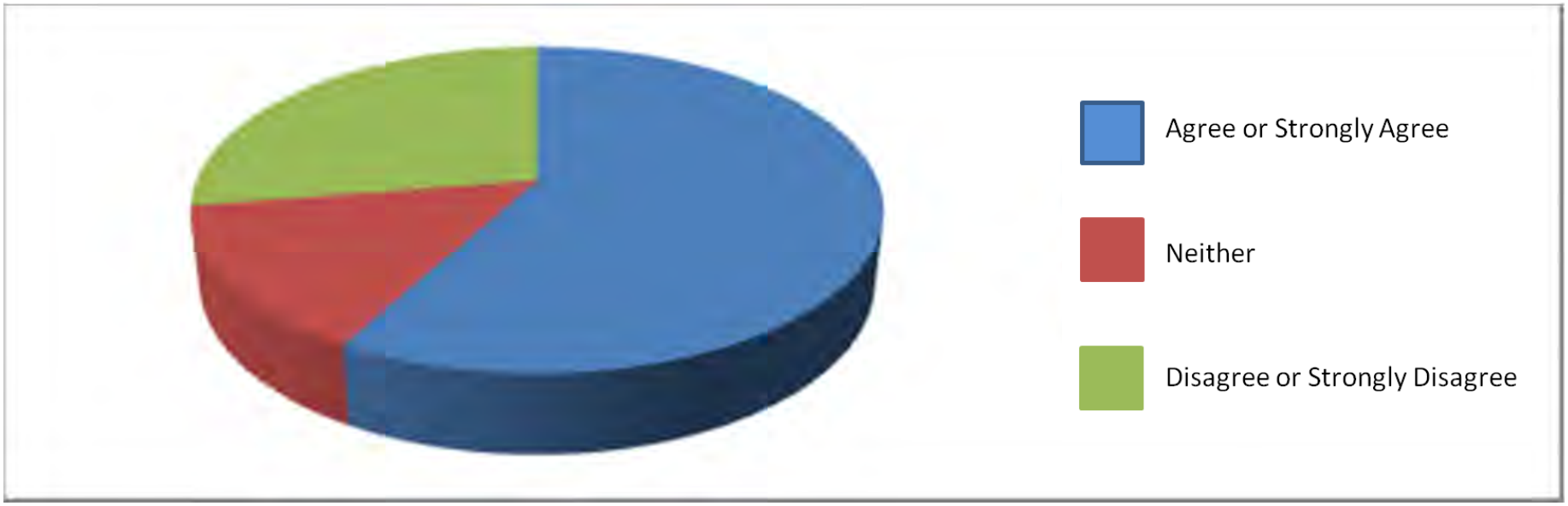
62% said the roadway is less congested

It is more convenient to travel the roadway than it was prior to the project



64% said it is more convenient

The roadway is easier to drive than it was prior to the project

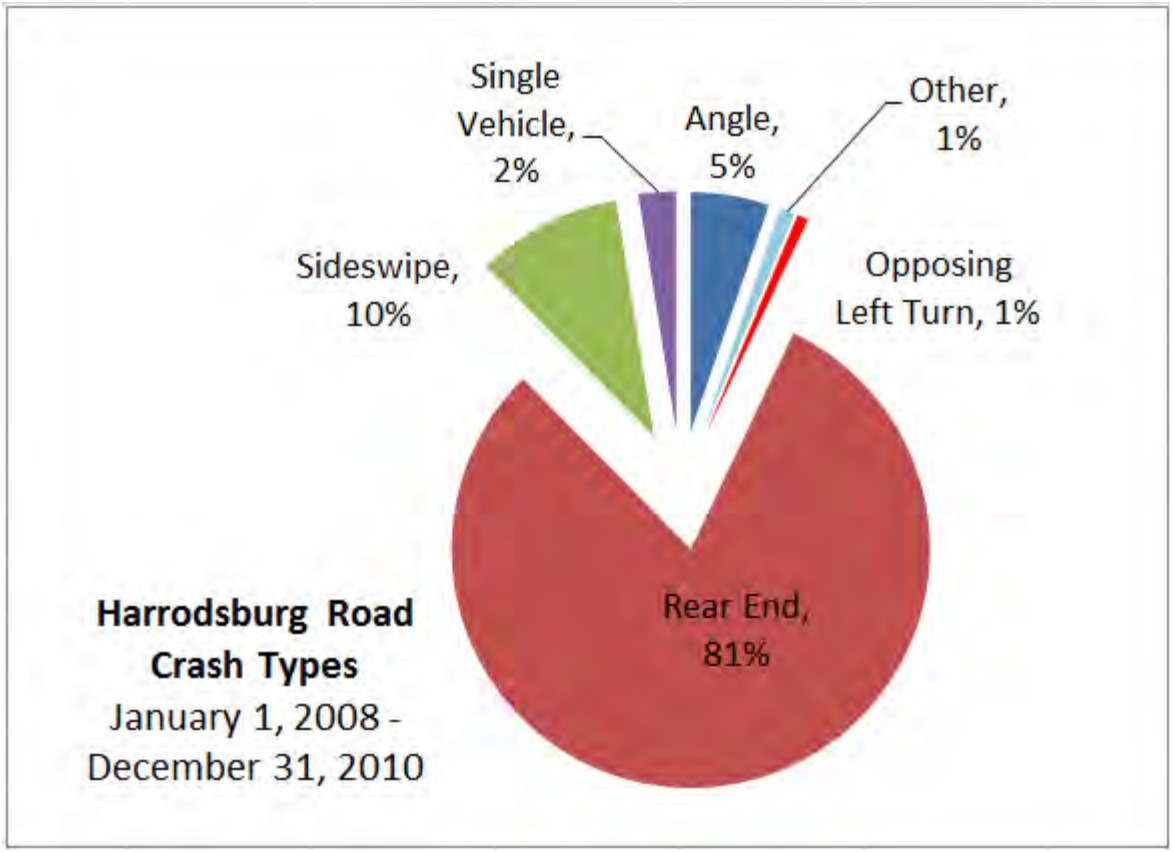


58% said it is easier to drive

(72% still said it is "easy" to drive)

Crash History
January 1, 2008 – December 31, 2010

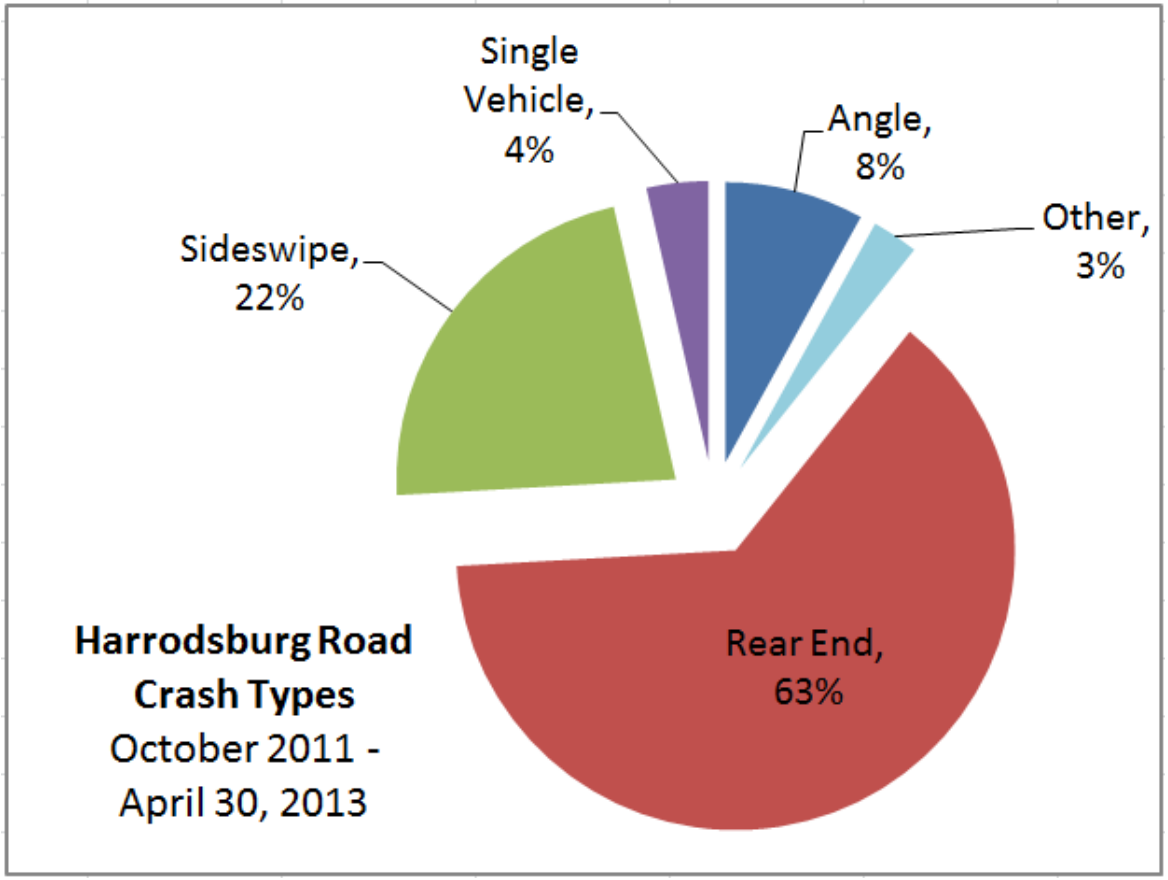
396 Reported crashes
- 319 rear end crashes (81%)
- 39 Sideswipe crashes (10%)
- 77 injury crashes (19.3%)



Post-DCD Crash History
October 1, 2011 – April 30, 2013

112 Reported crashes

- 71 rear end crashes (63%)
- 25 Sideswipe crashes (22%)
- 17 injury crashes (15%)



Awards

- America's Transportation Awards Top 10 Project in the Nation
- Best Use of Innovation Award at the 2012 Mid America Association of State Transportation Officials (MAASTO)
- 2012 ACEC-KY Grand Conceptor Award
- AASHTO Technology Implementation Group (TIG) Additionally Selected Technology
- ASHE (Derby City Section) 2012 Transportation Improvement Award

Stantec

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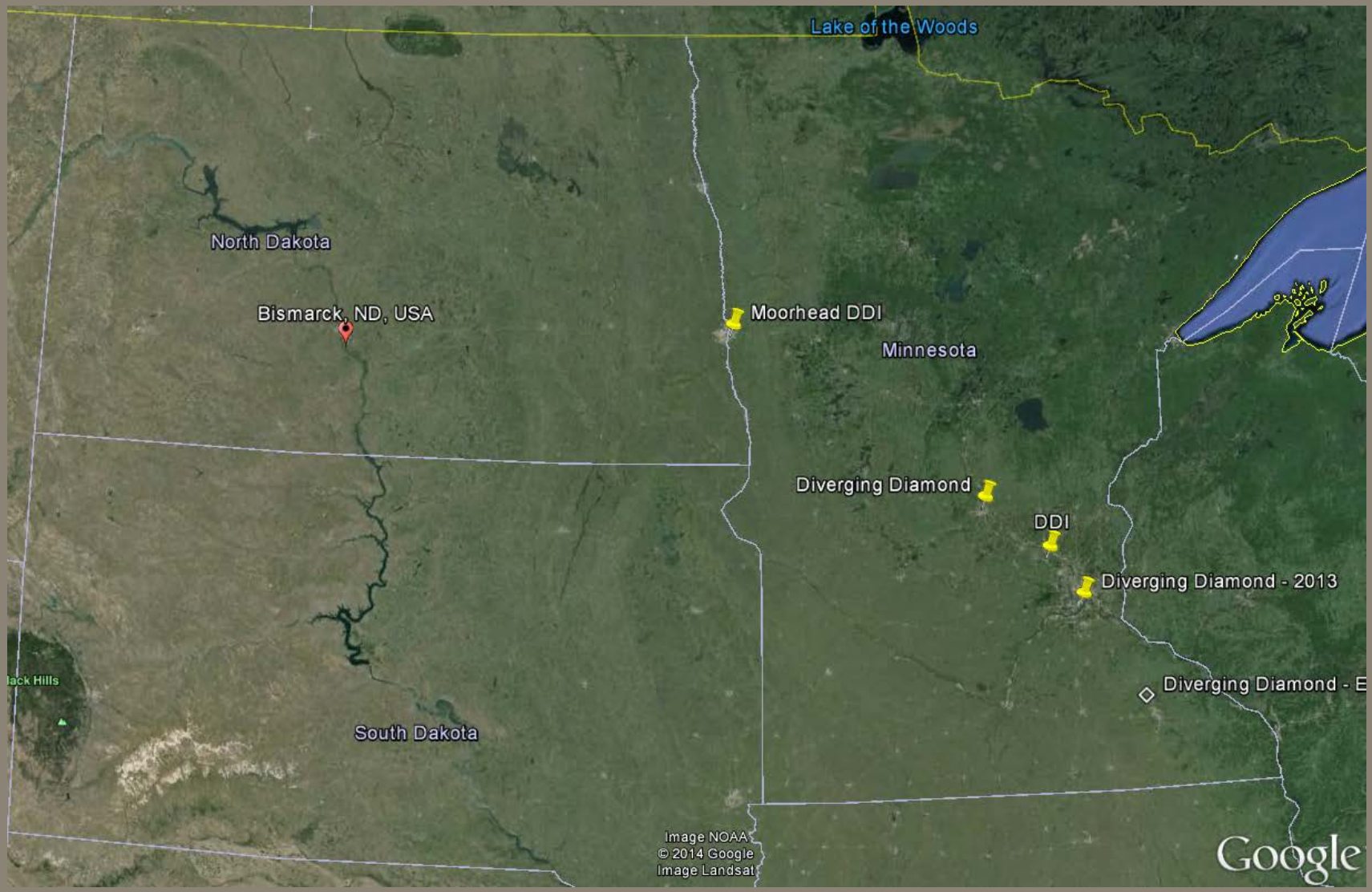
Stantec

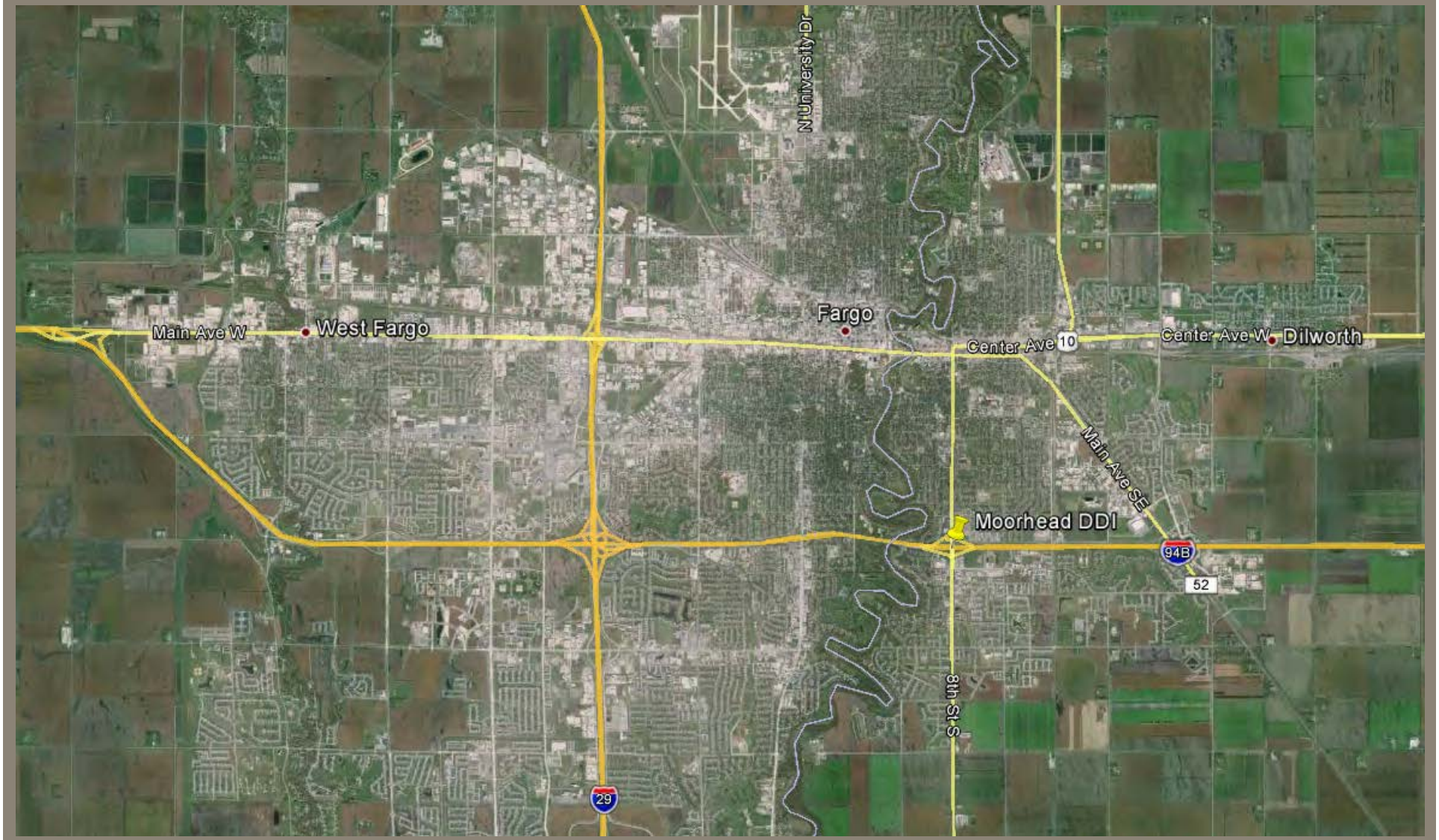
Moorhead, MN

Project Location



Moorhead, MN

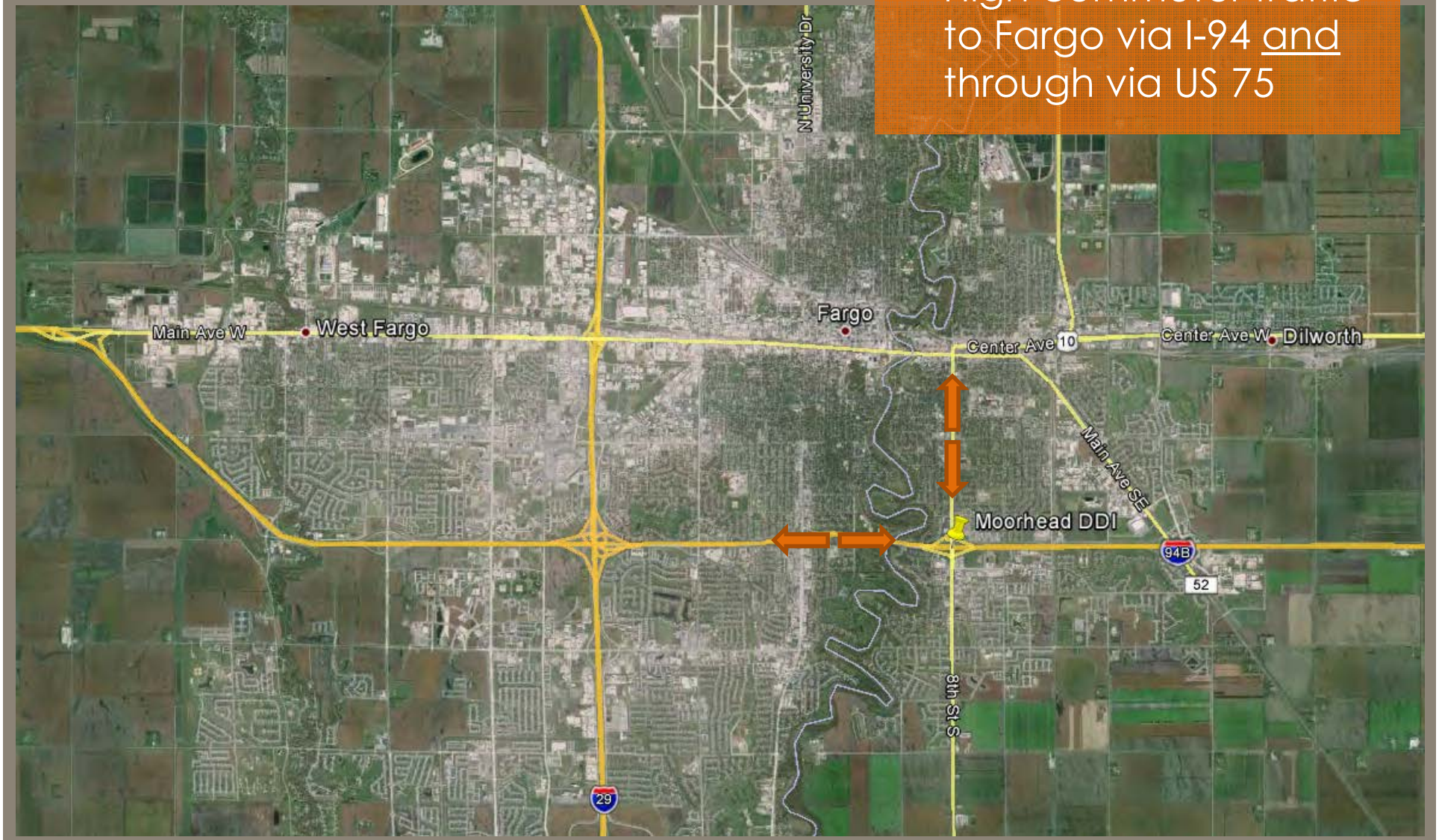
Project Location



Moorhead, MN

Project Issues

- High commuter traffic to Fargo via I-94 and through via US 75



Moorhead, MN

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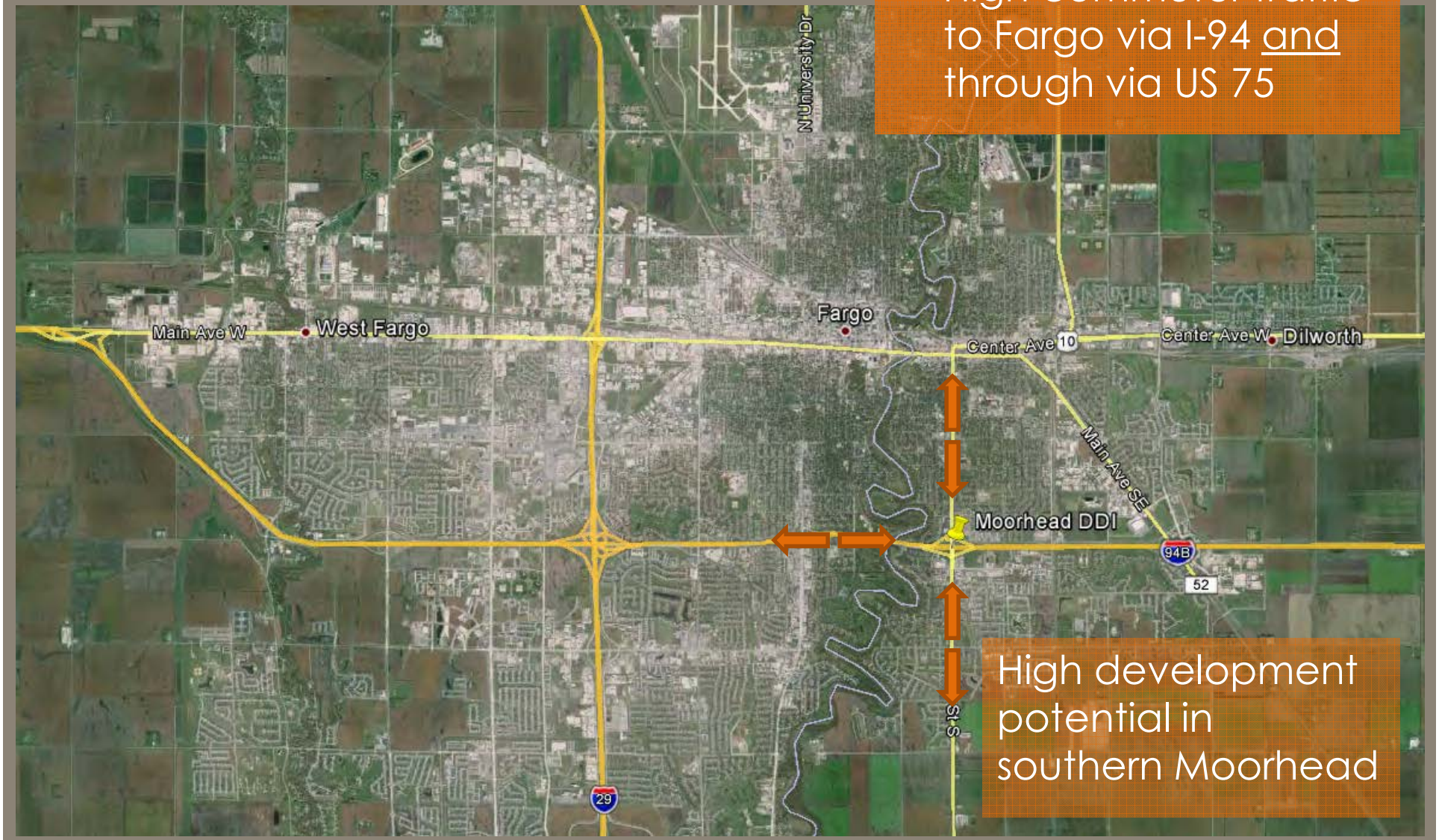
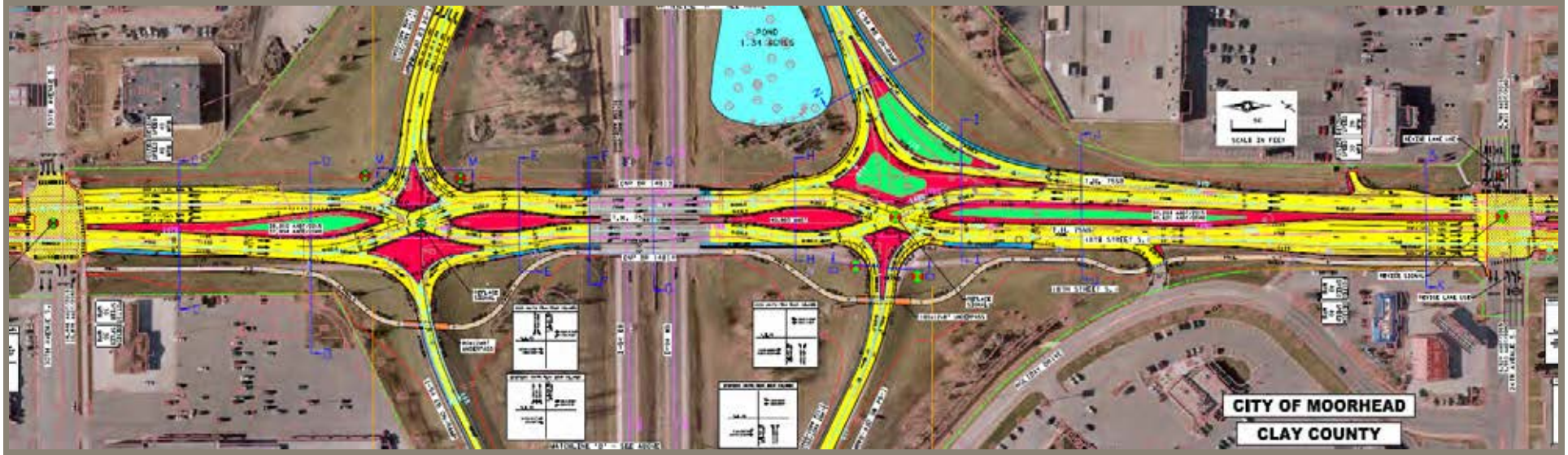


High development potential in southern Moorhead

Moorhead, MN

I-94 and US 75



Moorhead, MN

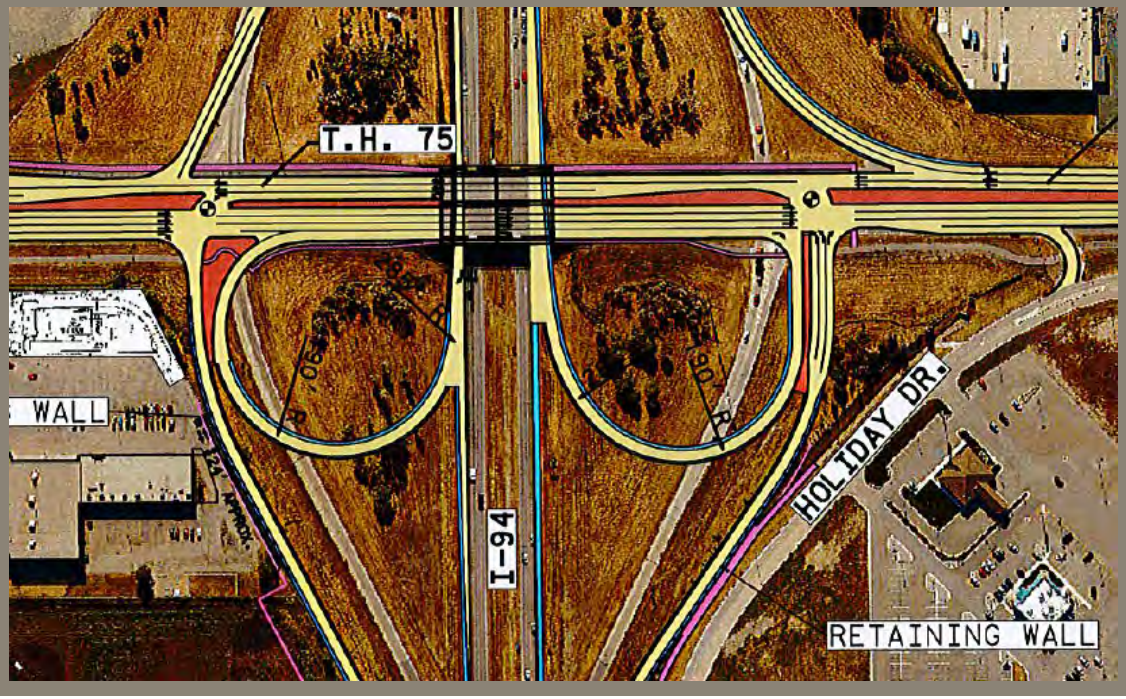
I-94 and US 75 Interchange

- Project Schedule
  - August 2012 – Begin Preliminary Design
  - December 2012 – Value Engineering Study
    - More Extensive Alternatives Evaluation
  - January 2014 – Diverging Diamond 'Preferred'
  - August 2014 – Begin Final Design
  - 2016 Construction

Moorhead, MN

I-94 and US 75 Interchange

- Project Overview
  - Partial Clover leaf was the preferred alternative from a 2008 Corridor Study
  - No Diverging Diamond in the toolbox



Moorhead, MN

I-94 and US 75 Interchange

- Alternatives Summary (from 2008 plus new tools):
  - Half Cloverleaf (NE and SE)
  - Roundabouts
  - Diverging Diamond

Moorhead, MN

I-94 and US 75 Interchange

- Alternatives Summary (VE Study):
  - Added:
    - Single Loop (NE)
    - Parclo (NE and SW)
    - DDI/Parclo
    - Full Cloverleaf

    - Indirect Left at 30th St. Each Alt.

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I-94 and US 75 Interchange

- Projected LOS
  - Several
    Perform Well

Table 3.5 – PM Peak Hour Capacity Analysis
Level of Service Results – Year 2035 Build Conditions

Alternative	Intersections			
	US 75 & 24th Ave S	US 75 & I-94 North Ramp	US 75 & I-94 South Ramps	US 75 & 30th Ave S
Roundabout	E	C	C	C
DDI	D	B	B	C
DDI with Indirect LT at 30th Ave	D	B	C	C
NE Loop	D	A	C	C
NE Loop with Indirect LT at 30th Ave	D	A	C	C
ParClo	D	A	C	C
ParClo with Indirect LT at 30th Ave	D	A	C	B

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I-94 and US 75 Interchange

- Costs
  - Not the sole differentiator
  - MnDOT has more programmed and all keep the existing bridge

Table 5.1 – Preliminary Estimated Construction Costs
US 75 and I-94 Interchange Build Alternatives

Alternative	Estimated Construction Costs
DDI	$4,160,000
DDI with Indirect LT at 30th Ave	$4,660,000
NE Loop	$5,857,000
NE Loop with Indirect LT at 30th Ave	$6,357,000
ParClo	$7,497,000
ParClo with Indirect LT at 30th Ave	$7,997,000

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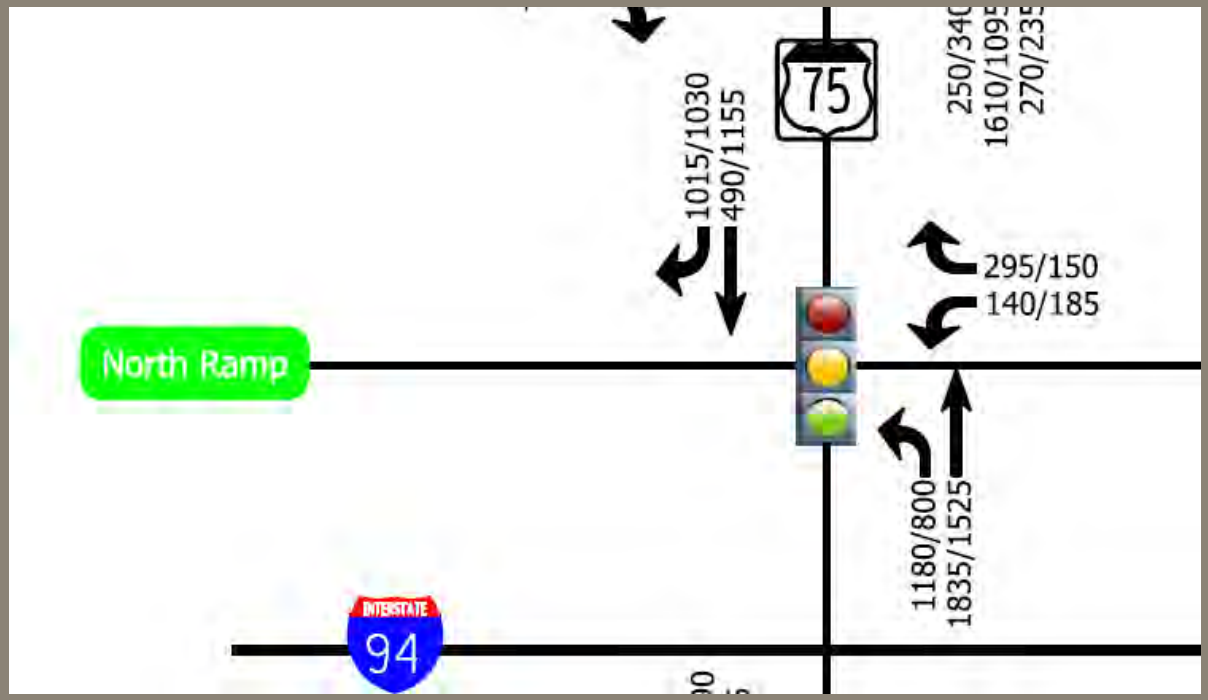
I-94 and US 75 Interchange

- Projected Traffic Volumes
  - Heavy US 75 Traffic heading westbound
    - 1180 NB + 1015 SB = 2195 WB into one lane



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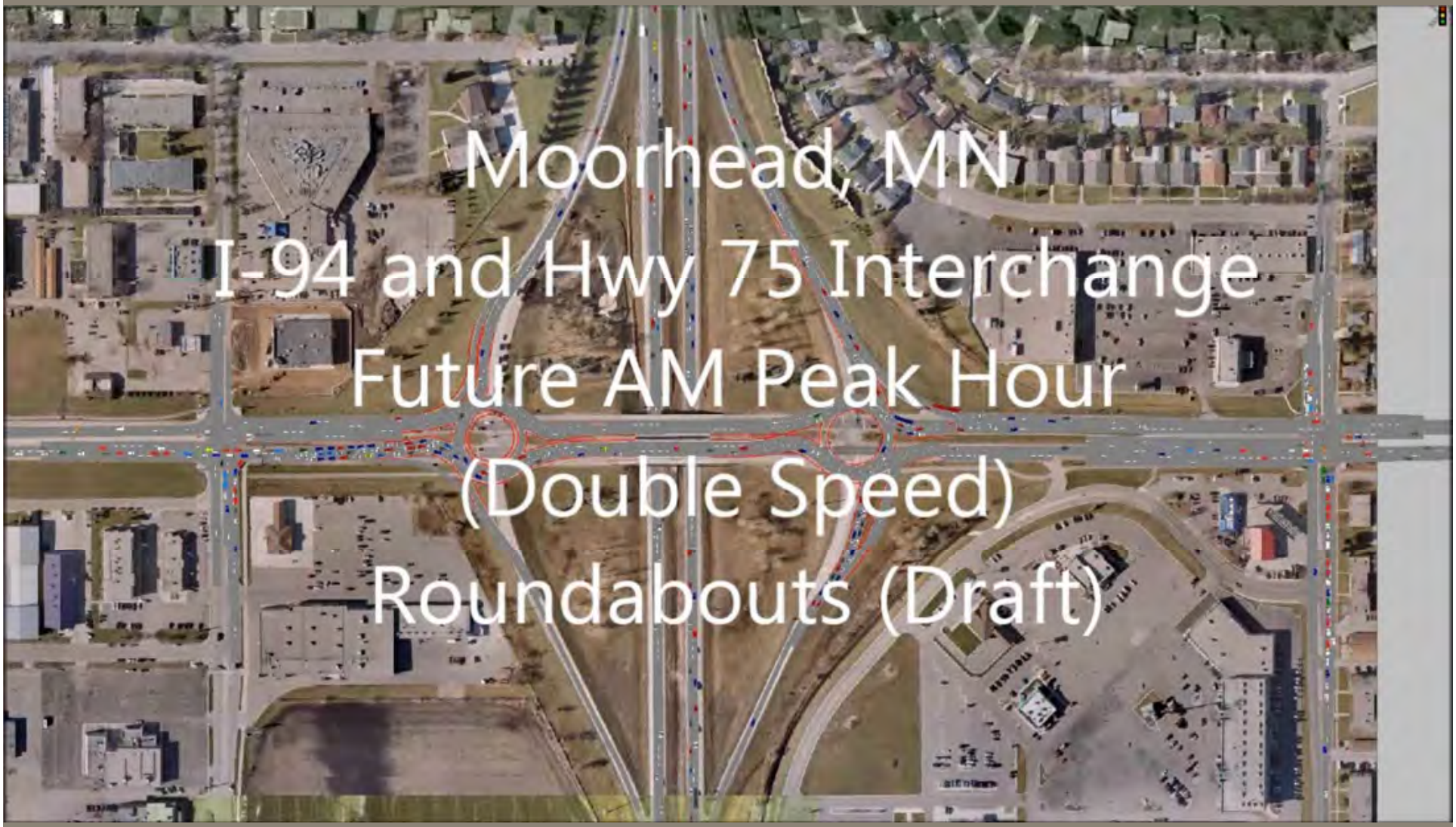
I-94 and US 75 Interchange



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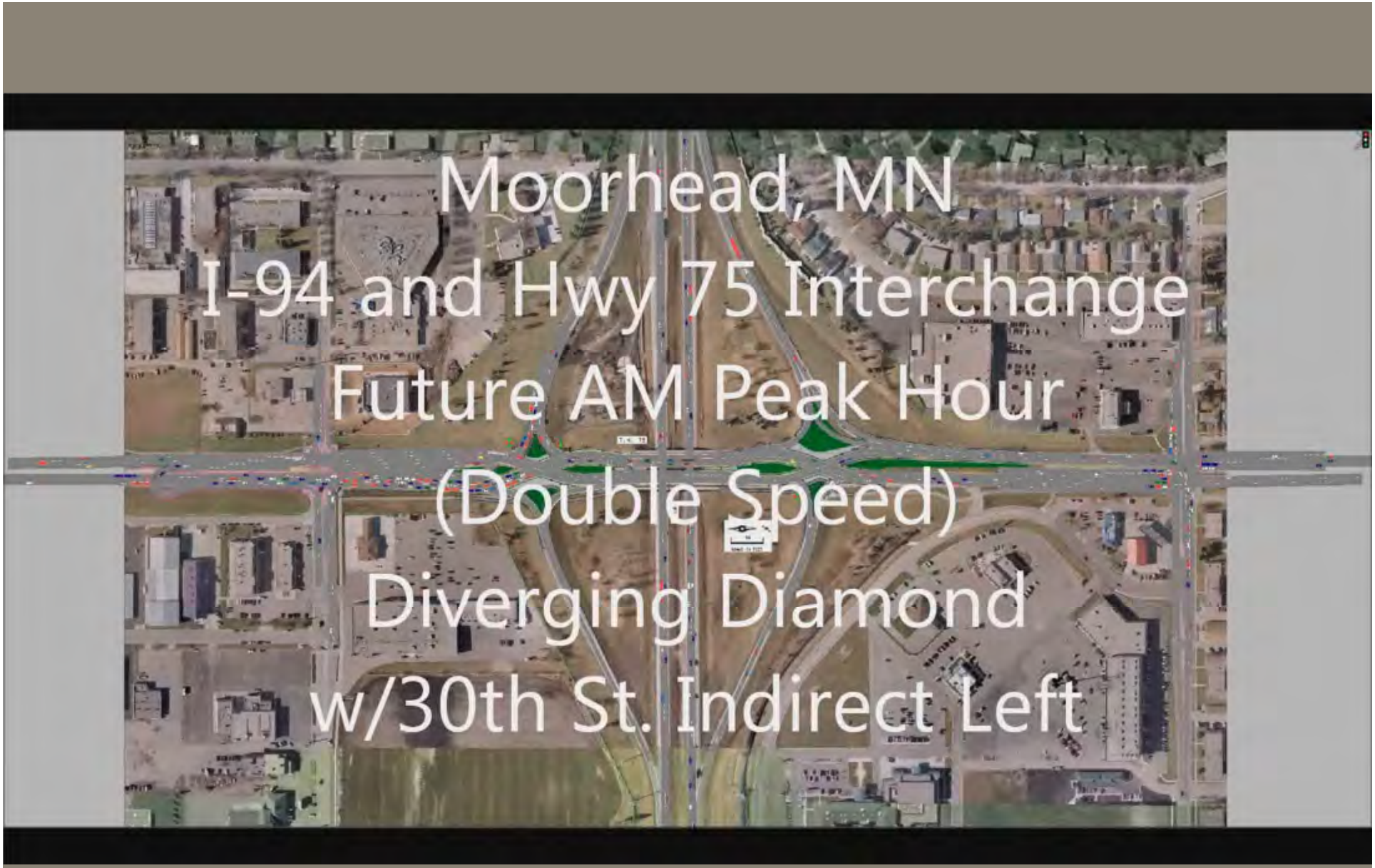
Modeling/Simulations - Roundabouts



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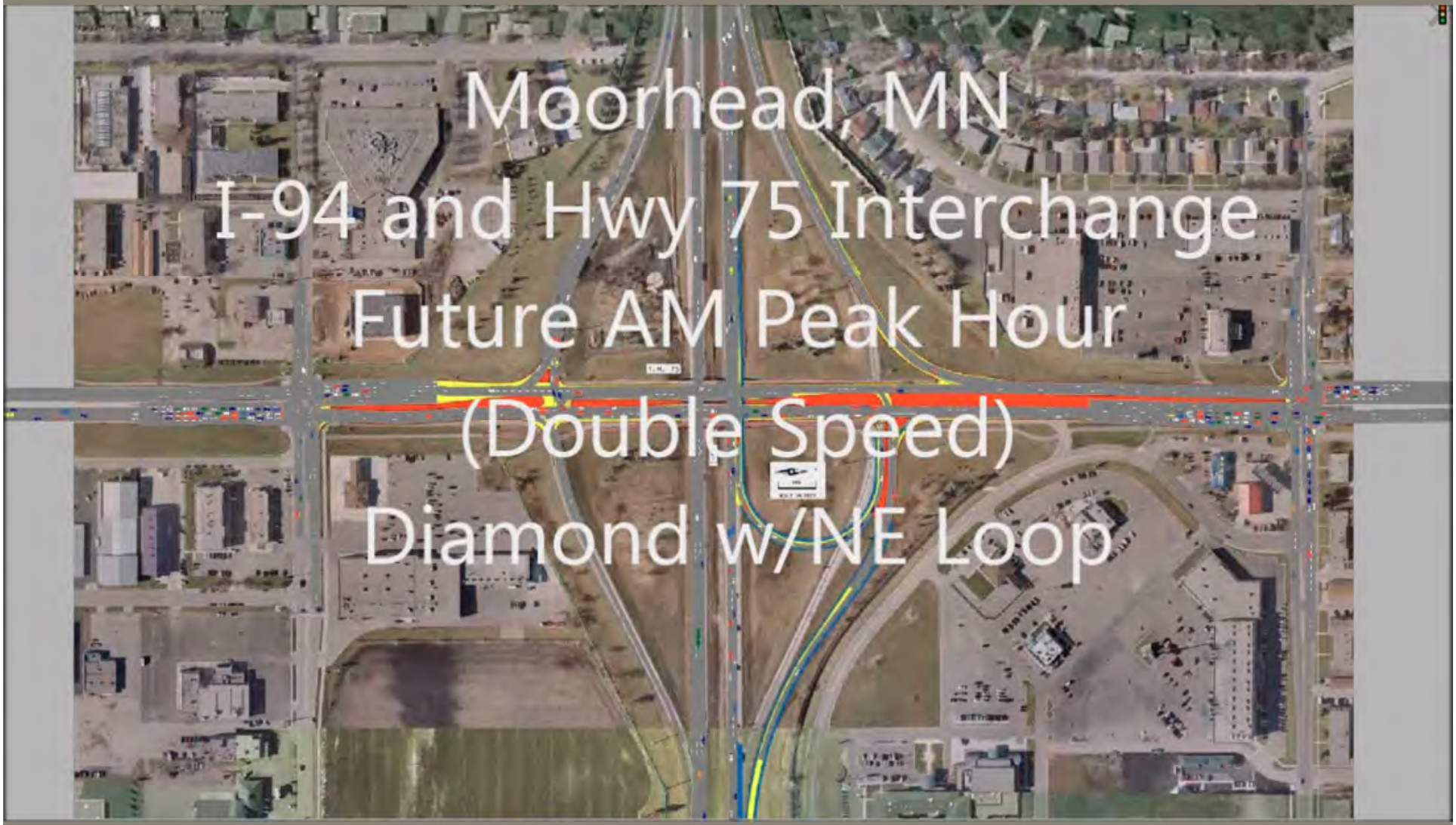
Modeling/Simulations – DDI w/ Indirect Left



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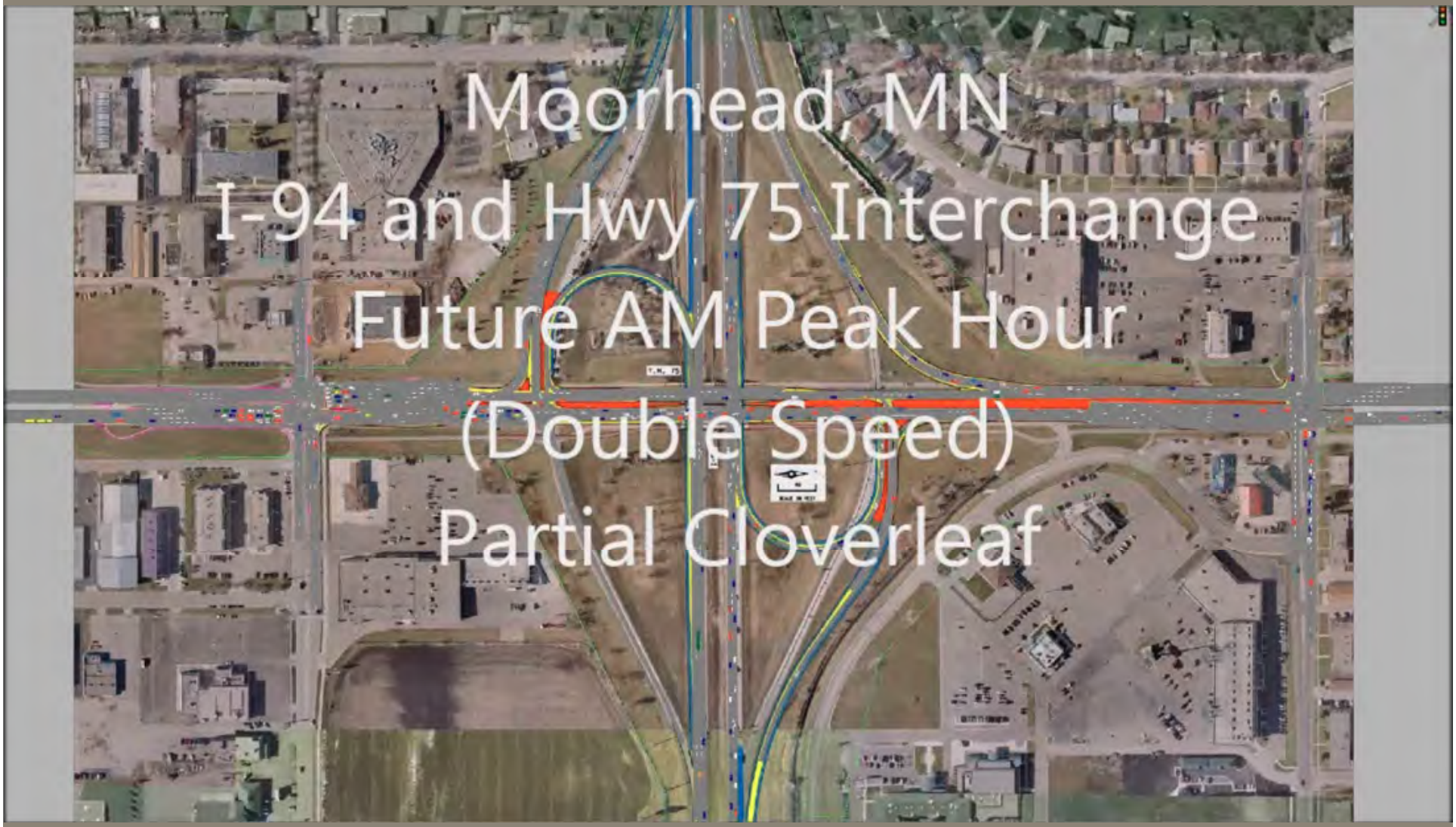
Modeling/Simulations – NE Loop



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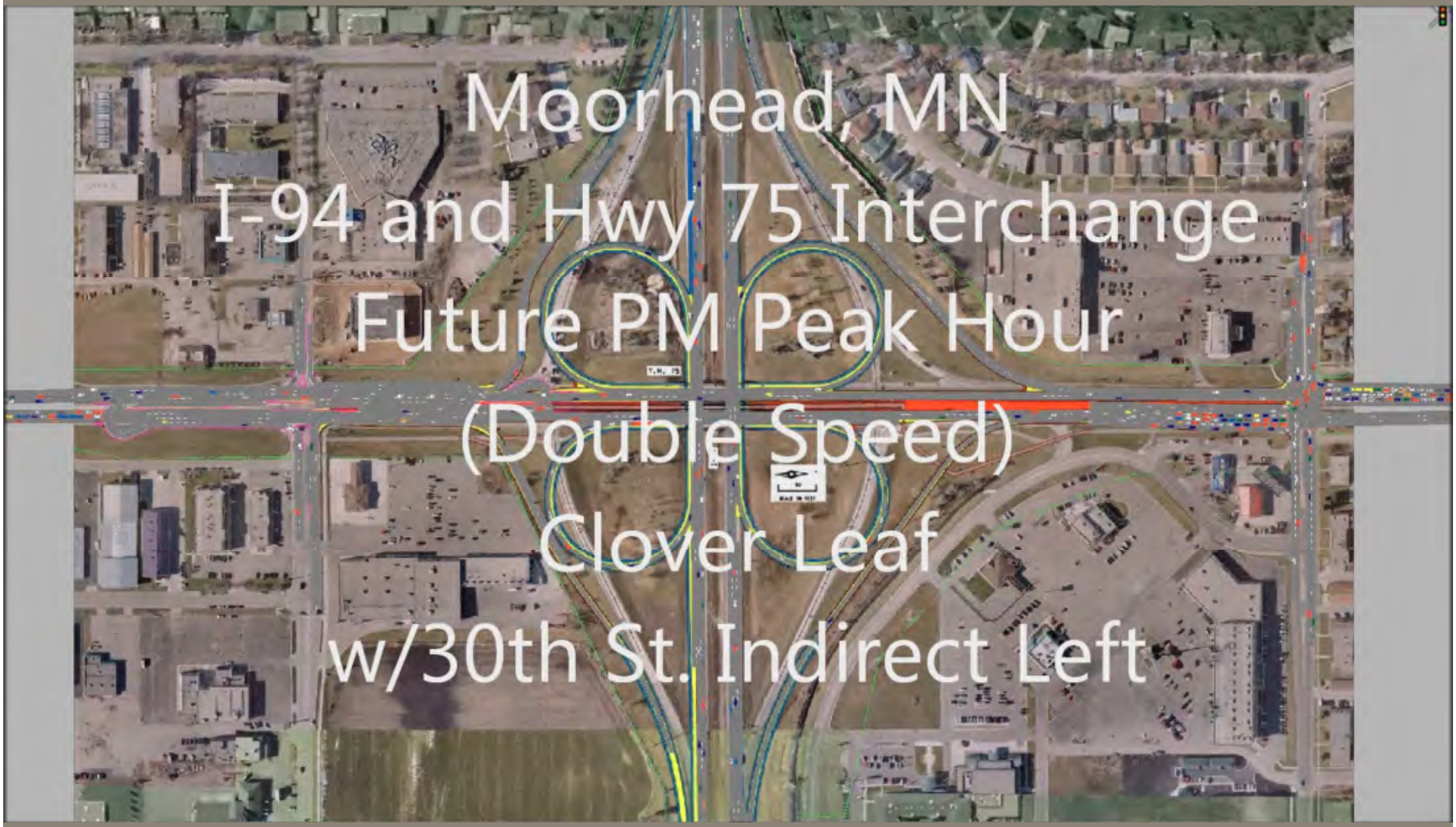
Modeling/Simulations – Partial Cloverleaf



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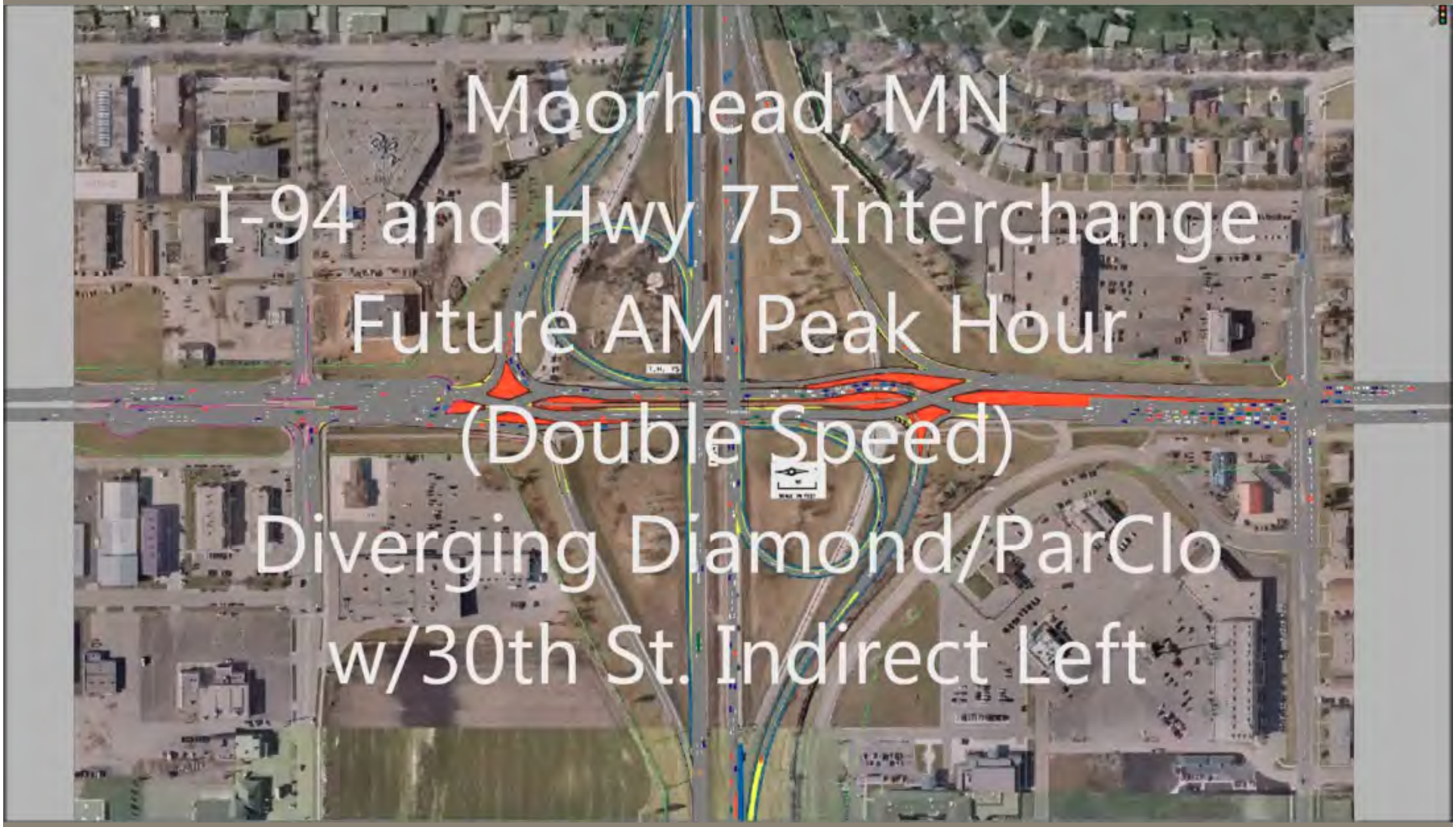
Modeling/Simulations - Cloverleaf



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Modeling/Simulations – DDI/Parclo

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Modeling/Simulations – Diverging Diamond

Questions?

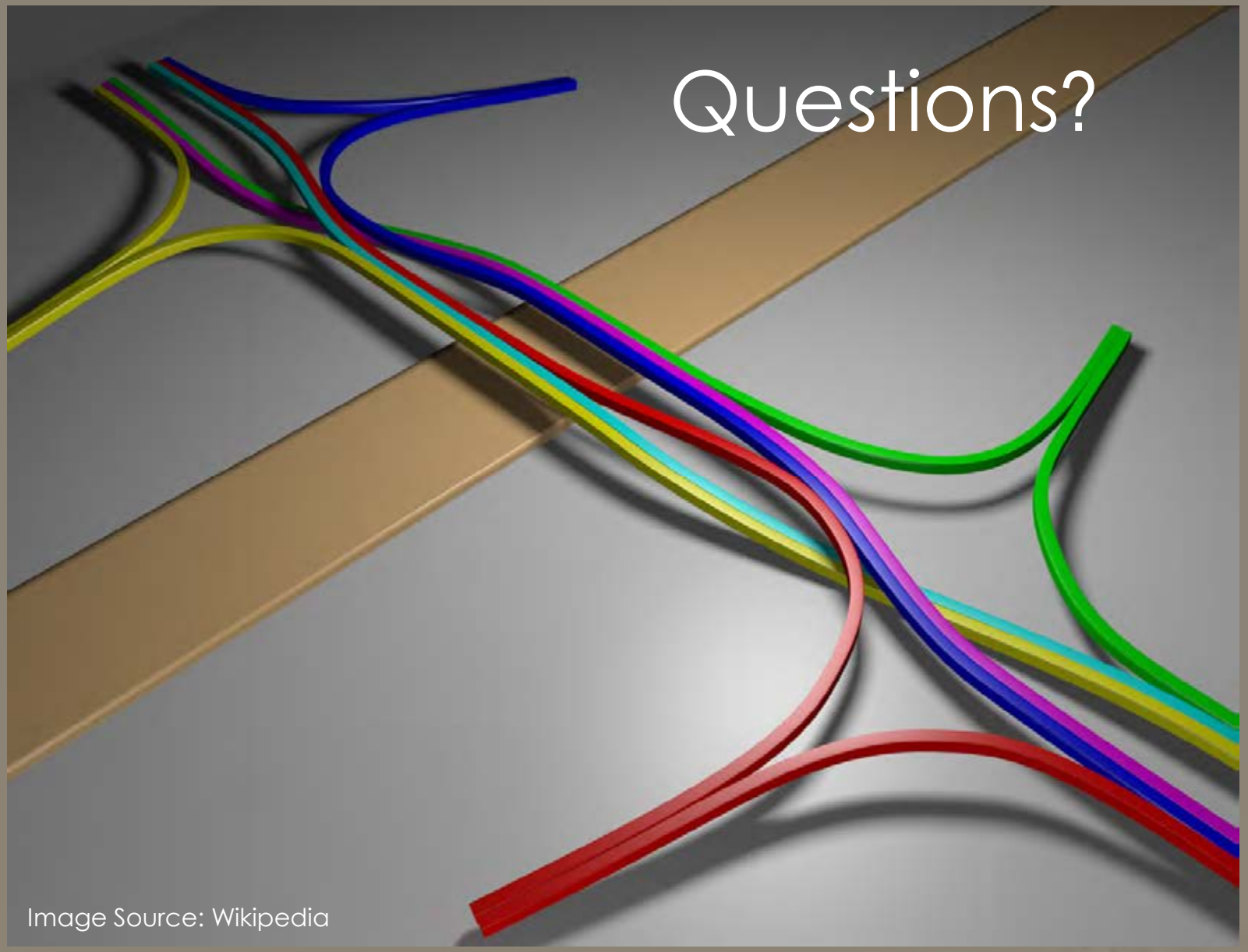

Image Source: Wikipedia

Stantec

Diverging Diamond Emergence