

Develop Alternative Intersection Informational Guides

Diverging Diamond Interchange (DDI)

August 27, 2014

Presentation Outline

- **Introduction**
- Project Background, Objectives, and Team
- Overview of Alternative Intersections
- Overview of Diverging Diamond Interchange
- Additional Resources

Introduction

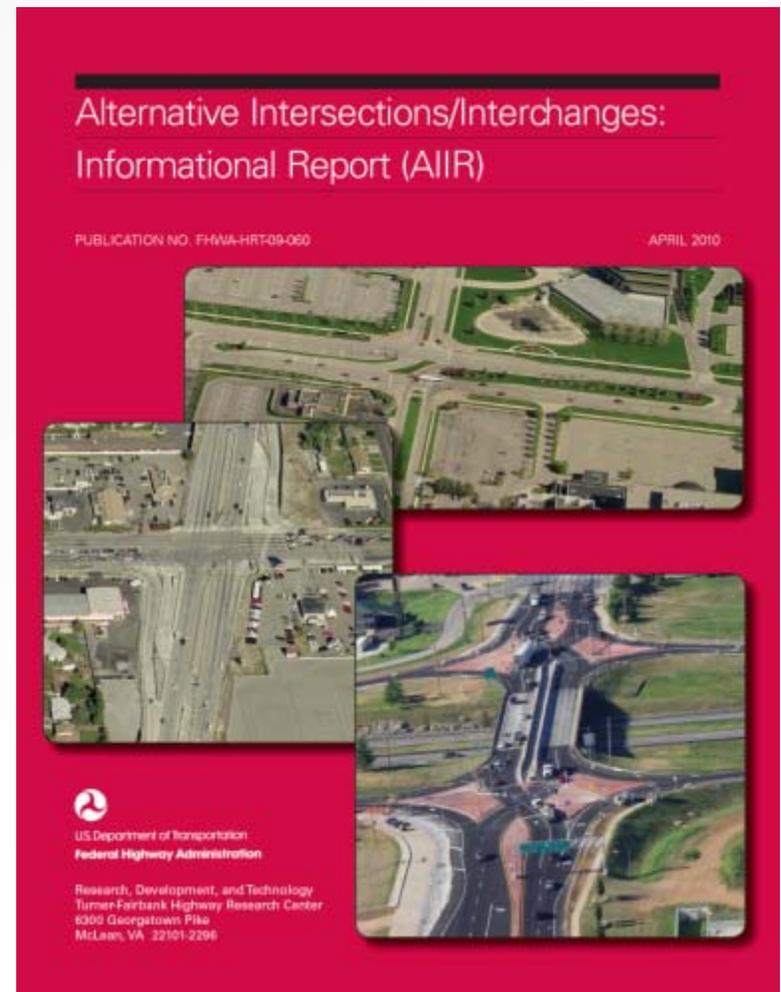
- Today's Presenters
 - Jeff Shaw, FHWA
 - Pete Jenior, Kittelson & Associates, Inc.
 - Dr. Bastian Schroeder (DDI co-author)
 - Chris Cunningham (DDI co-author)
- Webinar Overview

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Project Background

- Past Alternative Intersections/Interchanges: Informational Report (AIIR)
 - Published by FHWA in 2010
 - Provided a summary of the range of intersection forms professionals could consider



Project Background



- Every Day Counts (EDC) Initiative
 - Designed to identify and deploy innovation aimed at reducing the time it takes to deliver highway projects, enhance safety and protect the environment.
- For this project
 - Assisting efforts to bring renewed focus to alternative intersections
 - create easy to use guides and supplementary webinar materials
 - Foster a wider implementation of these EDC intersection and interchange designs by state highway and local road agencies

Project Objectives

- Develop materials that will aid highway planners and designers
- Facilitate the deployment of four (4) Alternative Intersection designs:
 - Diverging Diamond Interchange (DDI)
 - Displaced Left-Turn Intersection (DLT)
 - Restricted Crossing U-Turn Intersections (RCUT)
 - Median U-Turn Intersection (MUT)
- Replace the 2010 AIIR information with current research and findings

Project Objectives

- Guide Outline – consistent for all Guides
 - Chapter 1 – Introduction
 - Chapter 2 – Policy and Planning
 - Chapter 3 – Multimodal Considerations
 - Chapter 4 – Safety
 - Chapter 5 – Operational Characteristics
 - Chapter 6 – Operational Analysis
 - Chapter 7 – Geometric Design
 - Chapter 8 – Signal, Signing, Marking and Lighting
 - Chapter 9 – Construction and Maintenance
 - Appendices

Project Objectives

- Focus of the Guides
 - Policy and planning considerations
 - Multimodal considerations
 - Public outreach materials and resources
 - Current safety research and operational practices
- While still providing
 - Geometric design guidance
 - Signals, signing and pavement marking details
 - Construction considerations

Project Team

- Overall Project Management
 - Federal Highway Administration
 - Virginia Tech Transportation Institute
 - Kittelson & Associates, Inc. (Brian Ray, Principal Investigator)
- Diverging Diamond Interchange
 - Dr. Bastian Schroeder, ITRE at N.C. State University
 - Chris Cunningham, ITRE at N.C. State University
- Displaced Left-Turn Intersection
 - Hermanus Steyn, Kittelson & Associates, Inc.
- Median U-Turn Intersection
 - Jonathan Reid, Parsons Brinckerhoff
- Restricted Crossing U-Turn Intersection
 - Dr. Joe Hummer, Wayne State University

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Overview of Alternative Intersections

- Provide potential to improve safety and reduce delay at a lower cost than traditional solutions
- Often unfamiliar to transportation practitioners due to limited existing applications
- Require specific planning and policy considerations for all users
- Create the need for public involvement and driver education

Planning Considerations

- Alternative intersection evaluations may vary depending on the stage of the project development process
- Planning level design evaluations may not require a detailed level of analysis
- Evaluations should be comprehensive enough to answer key project questions for each unique project context

Pedestrian and Bicycle Accommodation

- Pedestrians may be required to cross multiple lanes with potential multi-stage crossings
- Some maneuvers through intersection are counterintuitive for pedestrians and bicycles
- Bicyclists are accommodated on the road or off-street in shared-use paths
- Evaluate trade-offs to address various user needs



Stakeholder Outreach

- The implementation may require extensive public outreach and educational meetings to familiarize the public with the unusual geometry.
 - Outreach should be directed at all users

See the Diverging Diamond Interchange in Action
youtube.com/MoDOTsouthwest

Contact Us:
888.275.6636
modot.org/southwest
Twitter: @MoDOT_Southwest
Facebook: MoDOT_Southwest
Google+: SouthWest MoDOT District

Diverging Diamond Interchange

How to drive a Diverging Diamond Interchange ddi

Sartell
St. Cloud
120
15

Pedestrians
Access a center pedestrian island in the middle of the bridge. The walkway is protected with concrete barriers.

Motorists
Proceed through the first traffic signal, and simply follow their lane to the opposite side of the roadway. Drivers accessing Highway 15 will turn left at the ramps without stopping or waiting for traffic to pass. Through traffic proceeds to a traffic signal and follows their lane back to the right side of the roadway.

■ Westbound ■ Eastbound ■ Pedestrian

Types of Alternative Intersections

- Displaced Left-Turn Intersection
 - Continuous Flow Intersection (CFI)
 - Crossover Displaced Left-Turn Intersection
- Median U-Turn Intersection
 - Median U-turn Crossover
 - Boulevard Turnaround
 - Michigan Loon
 - ThrU-Turn Intersection
- Restricted Crossing U-Turn Intersection
 - Superstreet Intersection
 - J-turn Intersection
 - Synchronized Street Intersection
- Diverging Diamond Interchange
 - Double Crossover Diamond (DCD)

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- **Overview of Diverging Diamond Interchange**
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Poll

- Are there Diverging Diamond Interchanges in your state?



Diverging Diamond Interchange

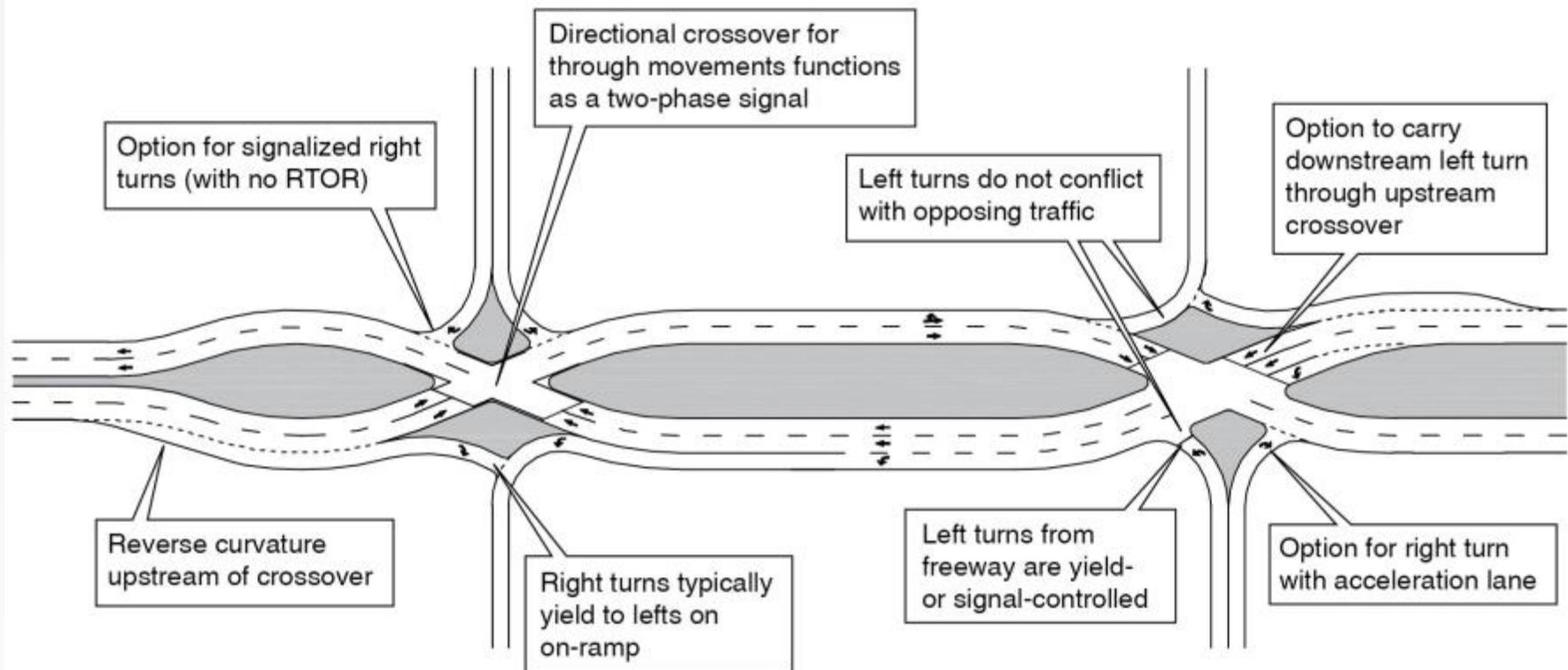
- Overview of Interchange Type
- Multimodal Considerations
- Safety Considerations
- Operations
- Geometric Design
- Signing, Striping and Lighting
- Construction

Diverging Diamond Interchange

- An alternative to the conventional diamond interchange or other alternative interchange forms.
- A DDI is different from a conventional diamond interchange
 - directional crossovers on either side of the interchange
 - eliminates the need for left-turning vehicles to cross the paths of approaching through vehicles.
- Improves the operations of turning movements to and from the freeway facility
- Reduces the number and severity of vehicle-to-vehicle conflict points

Diverging Diamond Interchange Schematic

- Overview of interchange features



Multimodal Considerations

- Generators in the vicinity of the interchange
 - Residential areas, employment centers, parks, downtown areas, shopping, and restaurants
- Desire lines of non-motorized traffic
 - Across the arterial street versus along the arterial street (or both)
- Proximity of transit stops or expected transit lines through the DDI
 - Freeway or cross-street
- Ages of expected users
 - To determine presence/absence of children, elderly, or individuals with disabilities at the interchange

Pedestrian Accommodations

- Center Walkway versus Outside Pedestrian Facilities
- Conflict Points
- Free-Flow Left-turn onto Freeway
- Communicating Direction of Traffic
- Pedestrian Channelization and Wayfinding
- Pedestrians with Disabilities

Pedestrian Center Walkway



**MO13 DDI in
Springfield, MO**



Source: ITRE

Pedestrian Outside Walkway

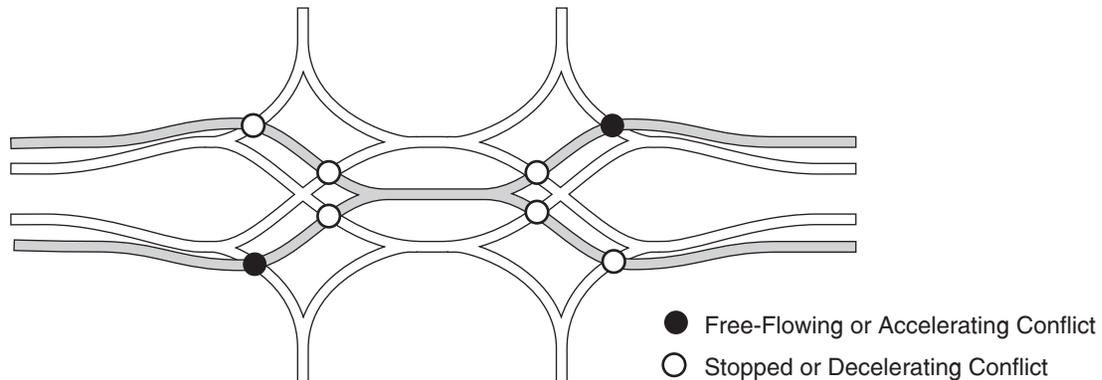


**Dorsett Road DDI in
Maryland Heights, MO**

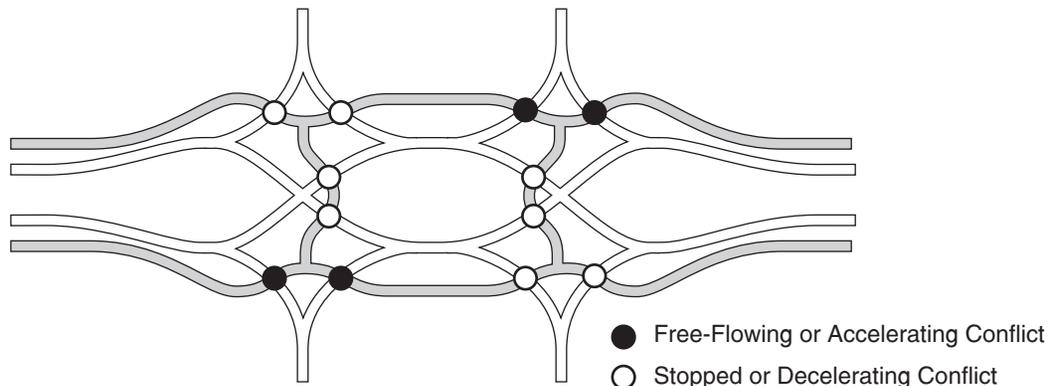


Source: ITRE

Pedestrian-Vehicle Conflict Points

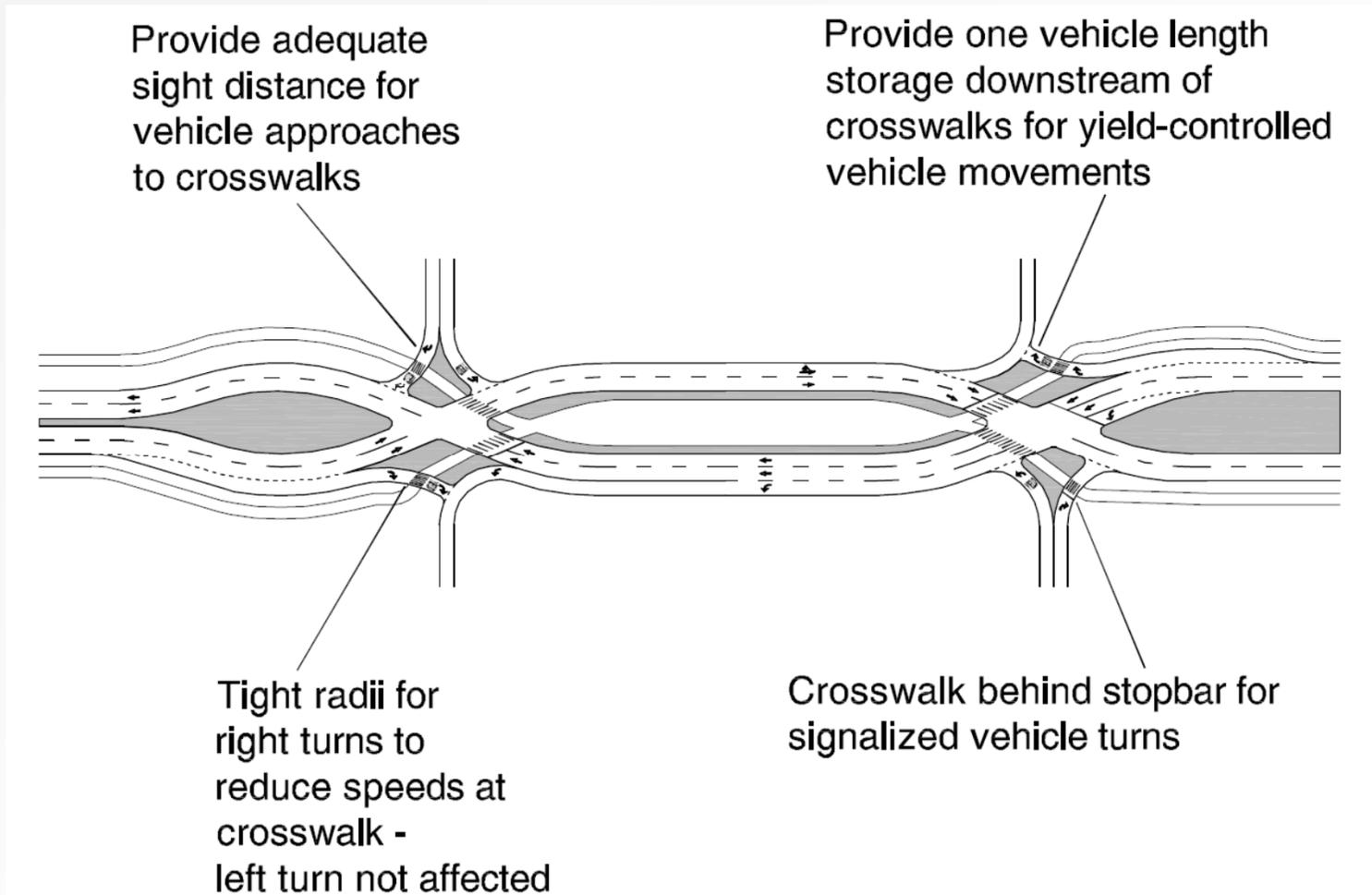


- 8 Conflict Points
 - 2 free/flow or accelerating
 - 6 stopped or decelerating



- 12 Conflict Points
 - 4 free/flow or accelerating
 - 8 stopped or decelerating

Pedestrian-Focused DDI Design



Bicycle Accommodations – Three Options

- A marked bicycle lane throughout the DDI
- A separated bicycle way or multi-use path
- No special bicycle accommodations, which would mean that bicyclists use the vehicular travel lane or pedestrian walkways

Option 1: Marked bicycle lane throughout the DDI



Source: Oregon DOT

Option 2: Bicyclists on Multi-Use Path



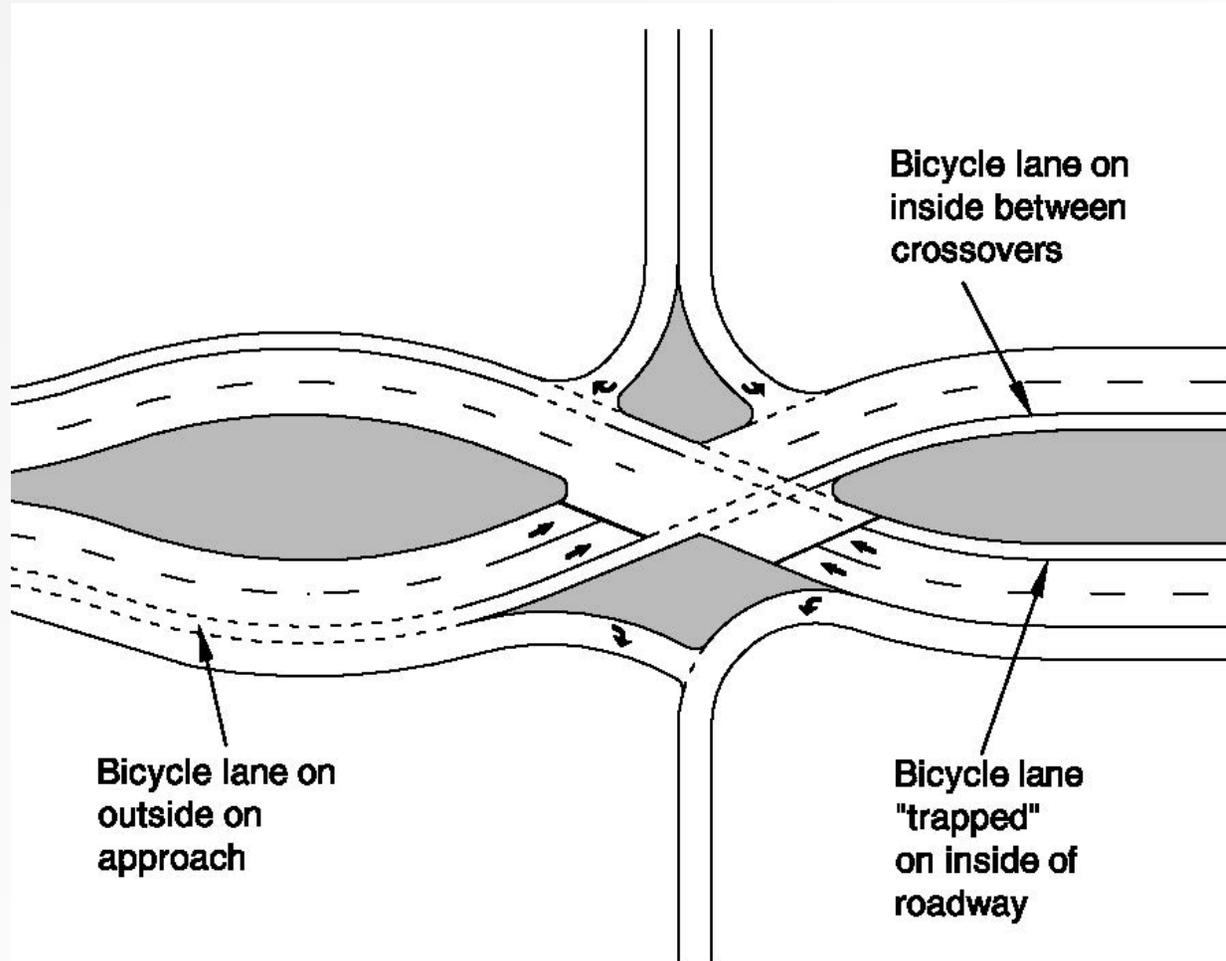
Source: ITRE

Option 3: No special bicycle accommodations



Source: ITRE

Right-Side Bike Lane

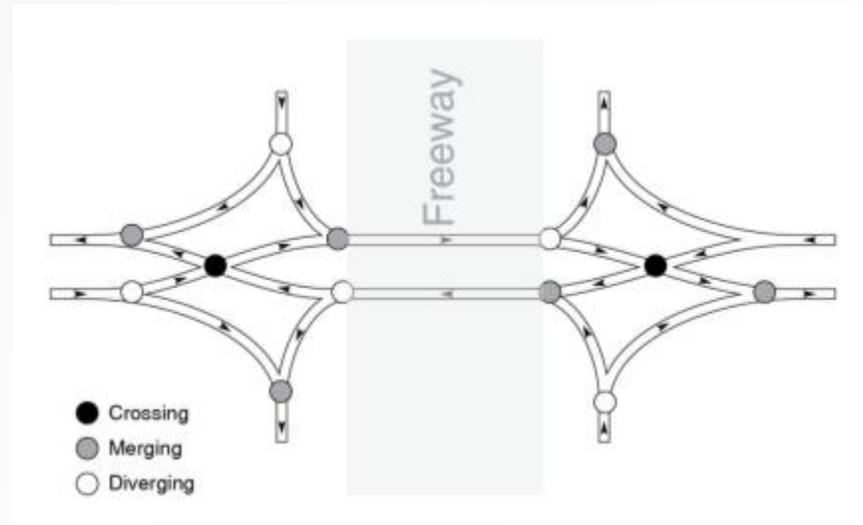
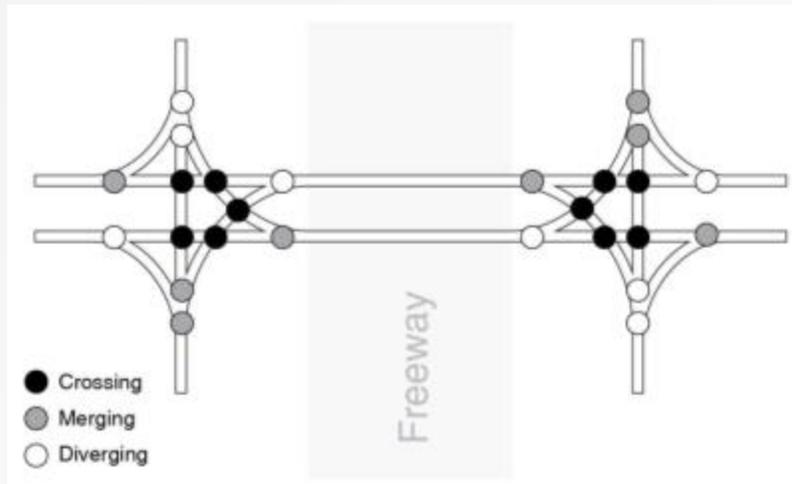


Transit Accommodations

- Transit benefits
 - reduced number of signal phases and reduced delays
- Transit stops within interchange are not recommended
 - unless a wide median is provided
- Requires special consideration for transfer terminals (freeway express to local system)
 - DDI does not allow freeway-to-freeway through movement
- There are opportunities to include light rail through the DDI with preference for inside lanes

Safety Considerations

- Conflict Points



	Crossing	Merging	Diverging	Total
Conventional diamond	10	8	8	26
Diverging diamond	2	6	6	14

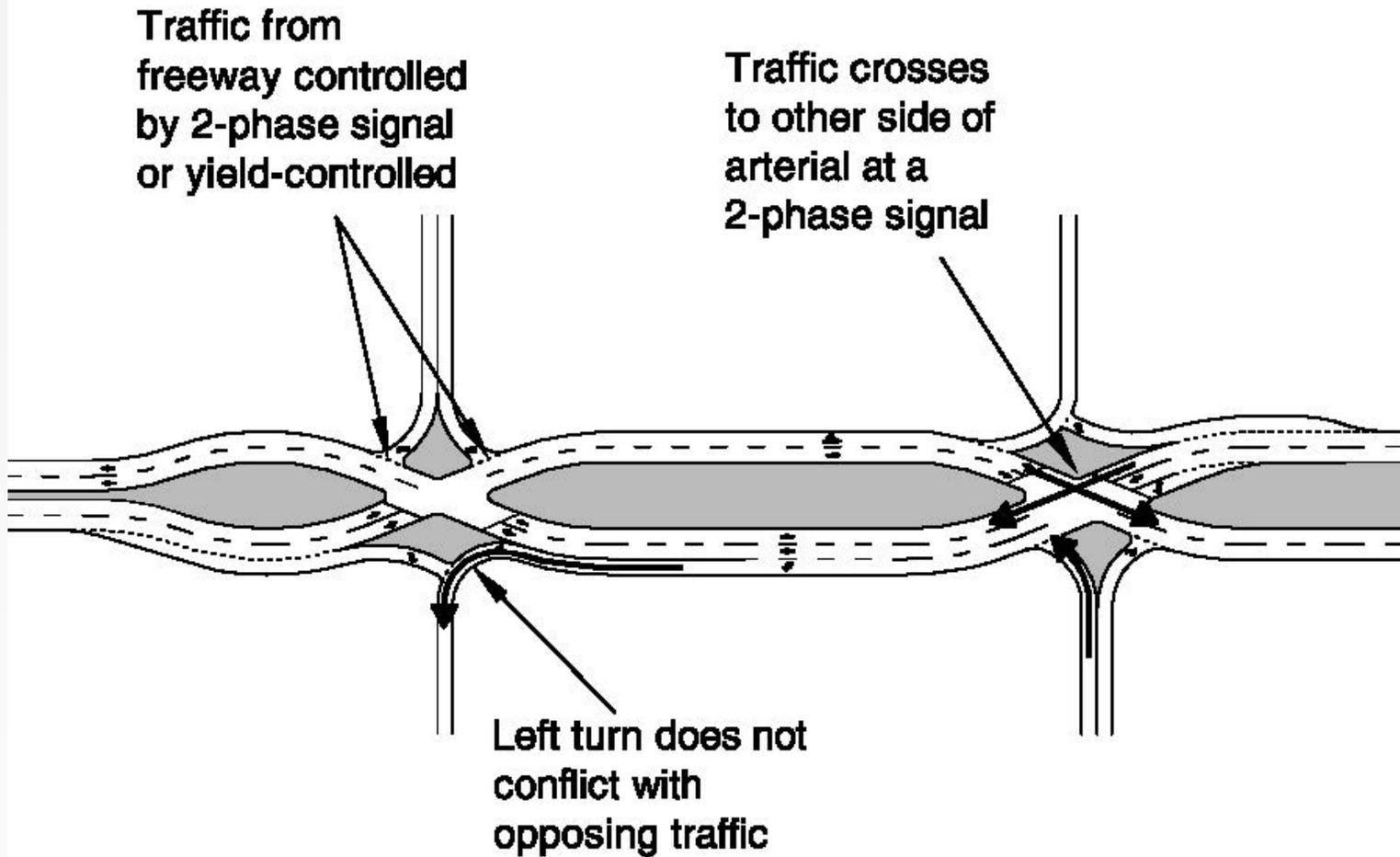
Safety Considerations

- General Safety Concerns
 - Right turn at off-ramp
 - Left turn at off-ramp
 - Heavy Vehicles
 - Wrong-way maneuvers
 - Pedestrian and bicycle safety
- No CMFs exist for DDIs at this time
 - CMFs will be provided in a future edition of the Highway Safety Manual and on FHWA's CMF Clearinghouse.
 - The CMF will likely apply to the entire interchange facility and not individual crossovers.

Operational Considerations

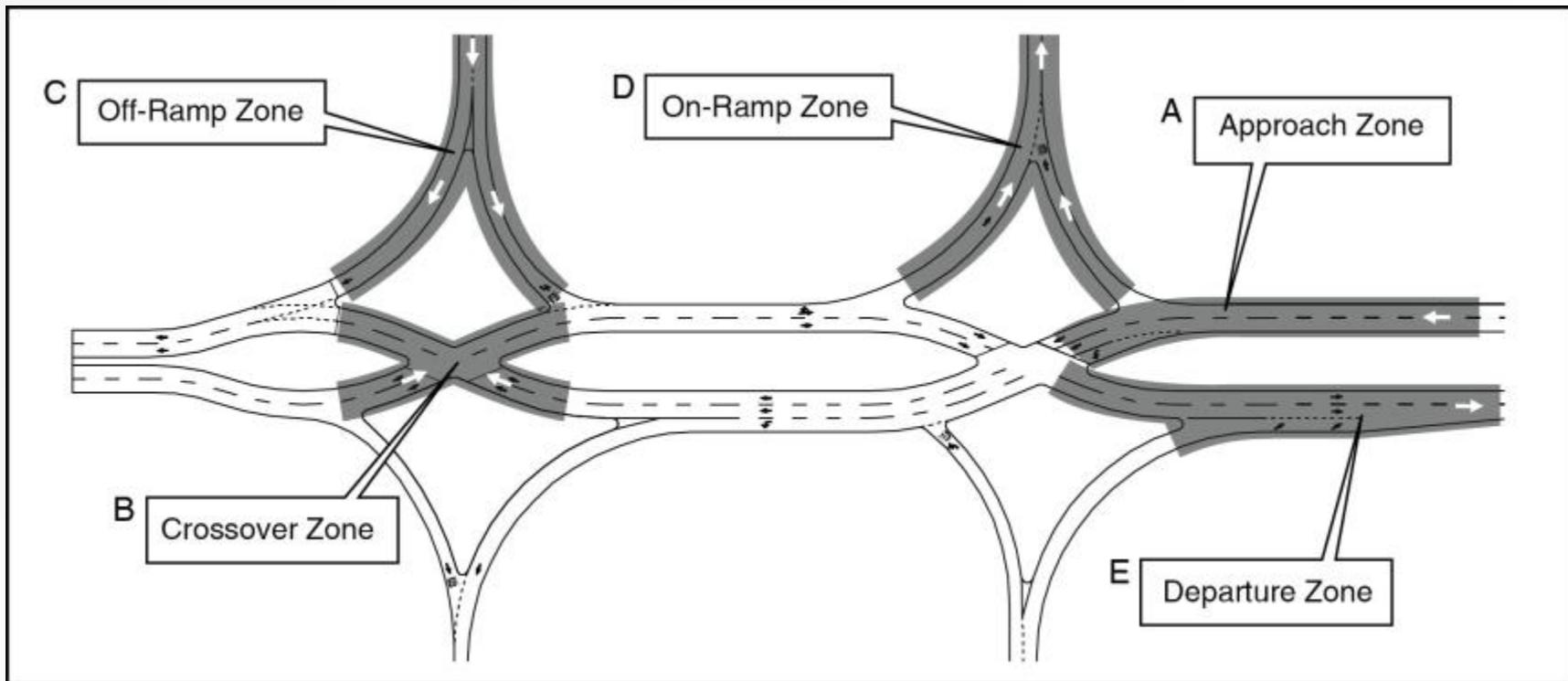
- Queue Spillback
- Demand Starvation
- Signal Progression
- Lane Utilization
- Saturation Flow Rates
- Speed Profiles
- Right-Turn at Off Ramp
- Heavy Vehicles
- Pedestrian Effects on Capacity
- Ramp Area Merge Capacity
- Ramp Metering Impacts
- Weaving Maneuvers
- Emergency Vehicles

Operational Principles



Operational Zones

- DDI's have five unique operational zones, each with key operational considerations



Operational Zone Considerations

- Approach Zone (A)
 - Queue spillback, demand starvation and signal progression.
- Crossover Zone (B)
 - Signal progression between crossovers, lane utilization of approach traffic, saturation flow rate at the crossover, and speed profiles through the crossover.
- Exit ramp Zone (C)
 - Vehicle speed profiles, performance of right-turn movements, and performance of left-turn movements.
- Entrance ramp Zone (D)
 - Speed profiles through the turns, the merge area capacity, and potential ramp metering effects.
- Departure Zone (E)
 - Queue spillback from the downstream signal into the DDI, signal progression, and weaving maneuvers from the freeway exit ramp to a left turn at the next downstream intersection.

Operational Analysis Tool Selection Guidance

- Planning-level analysis
 - results provide estimates of expected performance and are useful in informing the initial DDI feasibility and high-level design features.
- HCM analysis
 - balances operational detail with reasonable data input needs and analysis resource requirements.
 - may provide insight on additional geometric design and signal timing details
- Microsimulation analysis
 - allows for flexible customization and configuration of geometry, signal timing, and other operational parameters.
 - provides visualization of traffic patterns and roadway geometry

Geometric Design Approach

- Designing a DDI requires carefully considering safety, operations, and geometric performance while accommodating the design vehicle and non-motorized users.
- Dependent on project context
 - Urban locations
 - right-of-way footprint, access management in the vicinity of the interchange, and pedestrian and bicycle considerations.
 - Rural locations
 - right-of-way is likely less constrained by adjacent land uses and there may or may not be pedestrian or bicycle facilities.

Design Parameters: Overpass versus Underpass

Center Walkway

Outside Walkway

Overpass

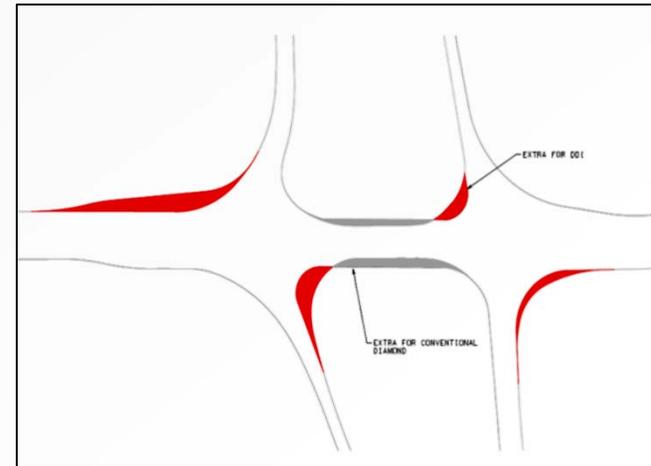


Underpass



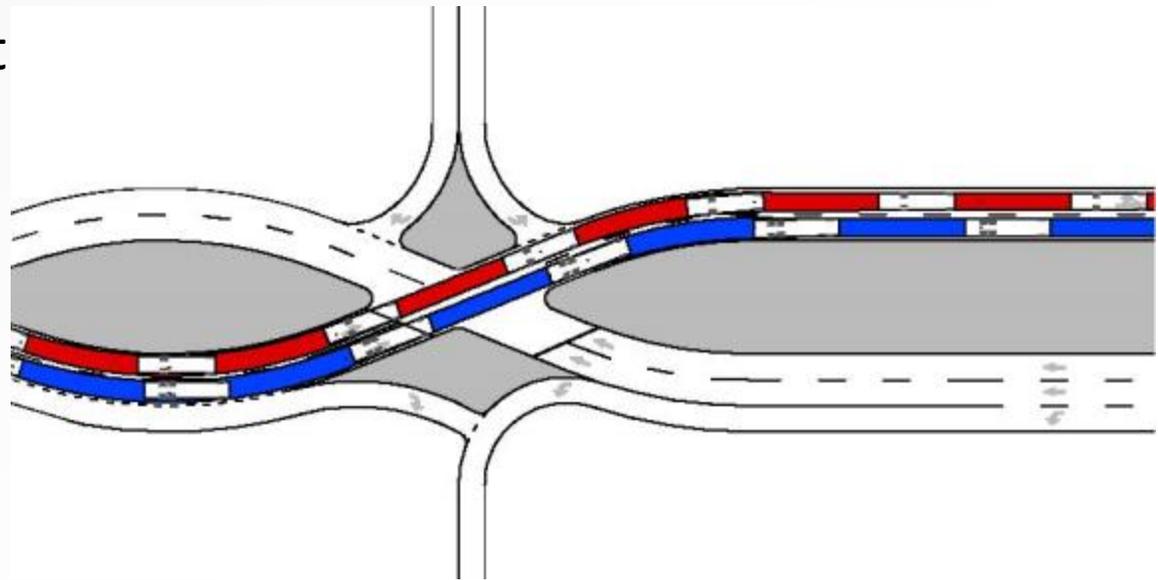
Design Parameters: Right-of-Way

- Usually minimal footprints within the existing ROW
- Three areas that differ from conventional diamond
 - Left-turn storage between intersections
 - Left-turn curve radii onto on-ramp
 - Left-turn curve radii onto cross road
- Two primary exceptions that may require additional ROW
 - Right-turn exit ramp accommodations
 - DDI reconstruction of a TDI or skewed diamond interchange



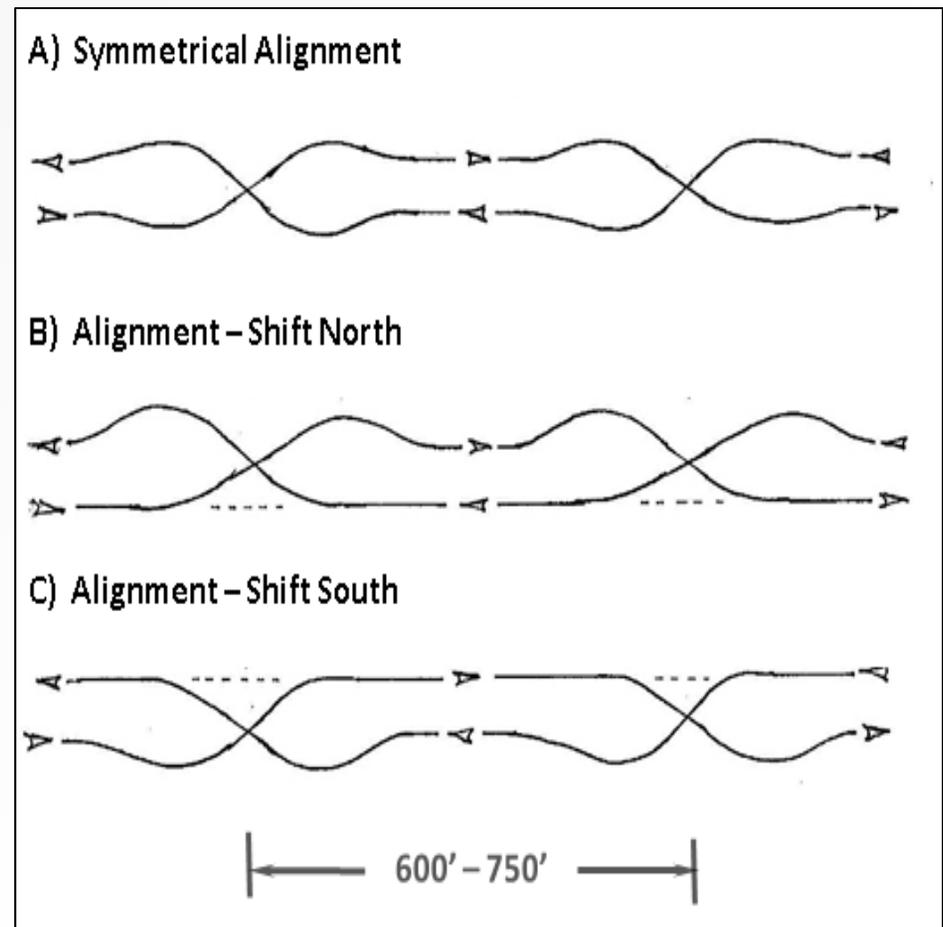
Design Principles

- Principles
 - Design vehicle
 - Design speed
 - Crossover design
 - Path alignment



Alignment Alternatives – Method 1

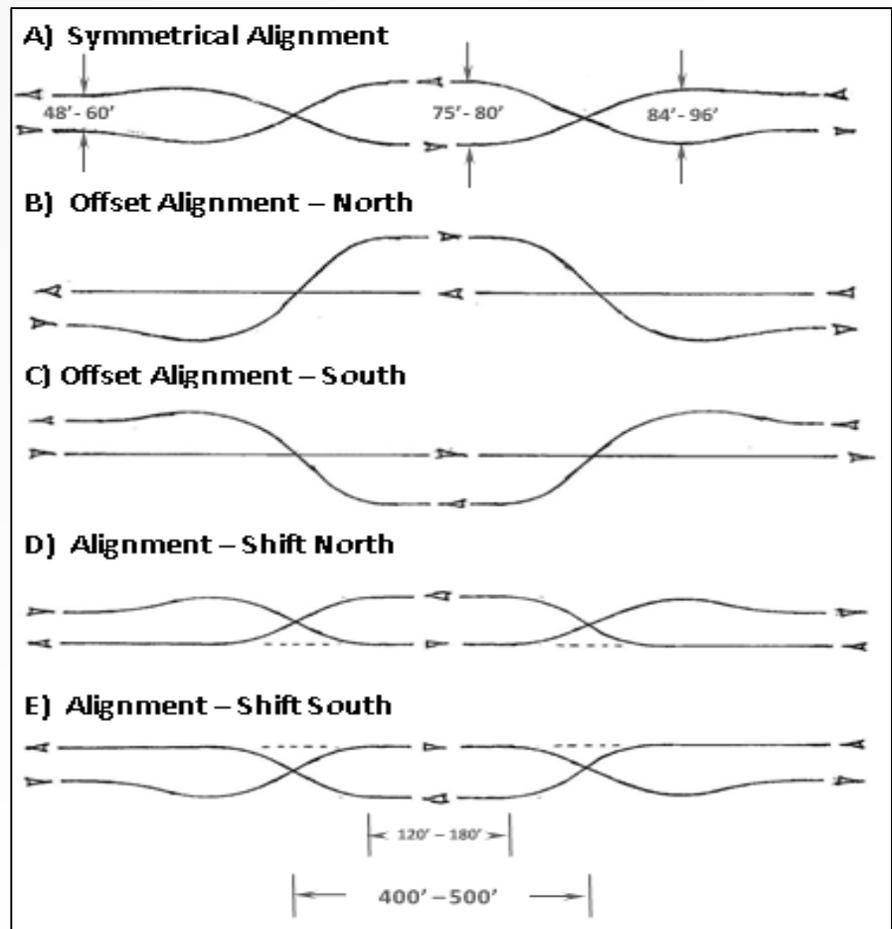
- Minimizing cross sections
 - Symmetrical Alignment (A)
 - Shifted Alignments (B/C)



Source: Field Evaluation of DCD Interchanges

Alignment Alternatives – Method 2

- Minimizing the distance between crossovers
 - Symmetrical Alignment (A)
 - Offset Alignments (B/C)
 - Shifted Alignments (D/E)



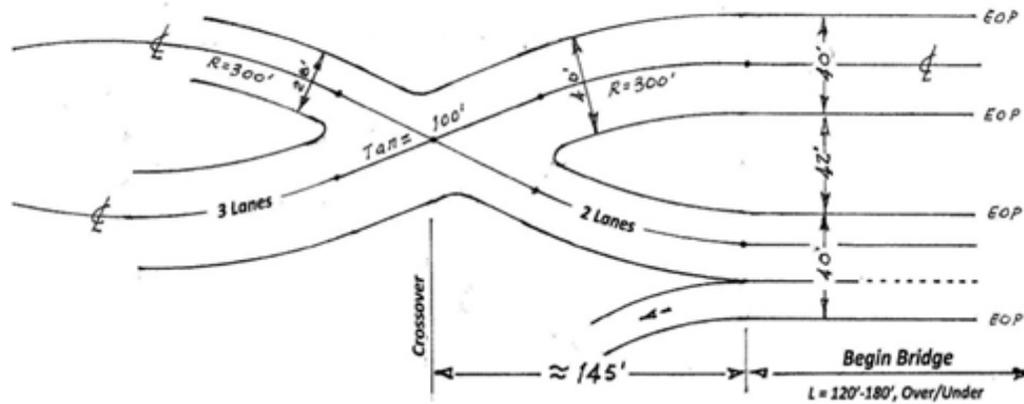
Source: Field Evaluation of DCD Interchanges

Design Guidance: Lane Widths

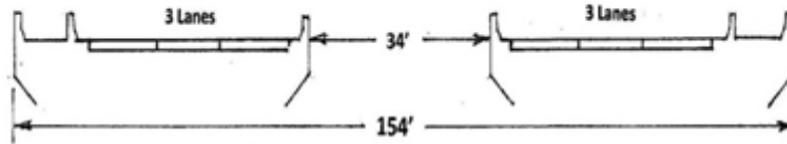
- Crossovers
 - Generally 12' to 15'
 - Dependent on curve radii
 - Design alternative determines the number of reverse curves
- On and off-ramps
 - Right turns similar to conventional diamond
 - Left turn lane widths should be increased where smaller turning radii are used, similar to right turns at conventional diamonds

Horizontal Alignment and Cross Section

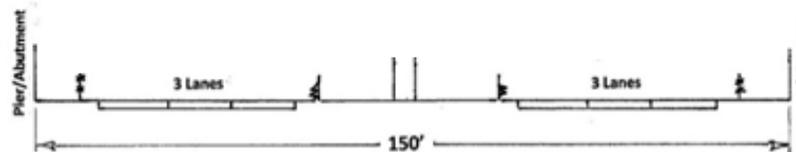
A) Horizontal Alignment



B) Cross Section – Cross Road Over Freeway



C) Cross Section – Cross Road Under Freeway



Source: Field Evaluation of DCD Interchanges

Design Guidance: Sight Distance Considerations

- Stopping sight distance (SSD)
 - SSD should be provided at every point of the DDI and on each approach where yield control is used.
 - Primary locations include exit and entry ramps.
- Intersection sight distance (ISD)
 - ISD considered for minor approaches where gaps are being used to enter the cross road.
 - Primary locations include exit ramp left and right turns
 - Yield control signs, RTOR, flashing operations, power outages

Signals

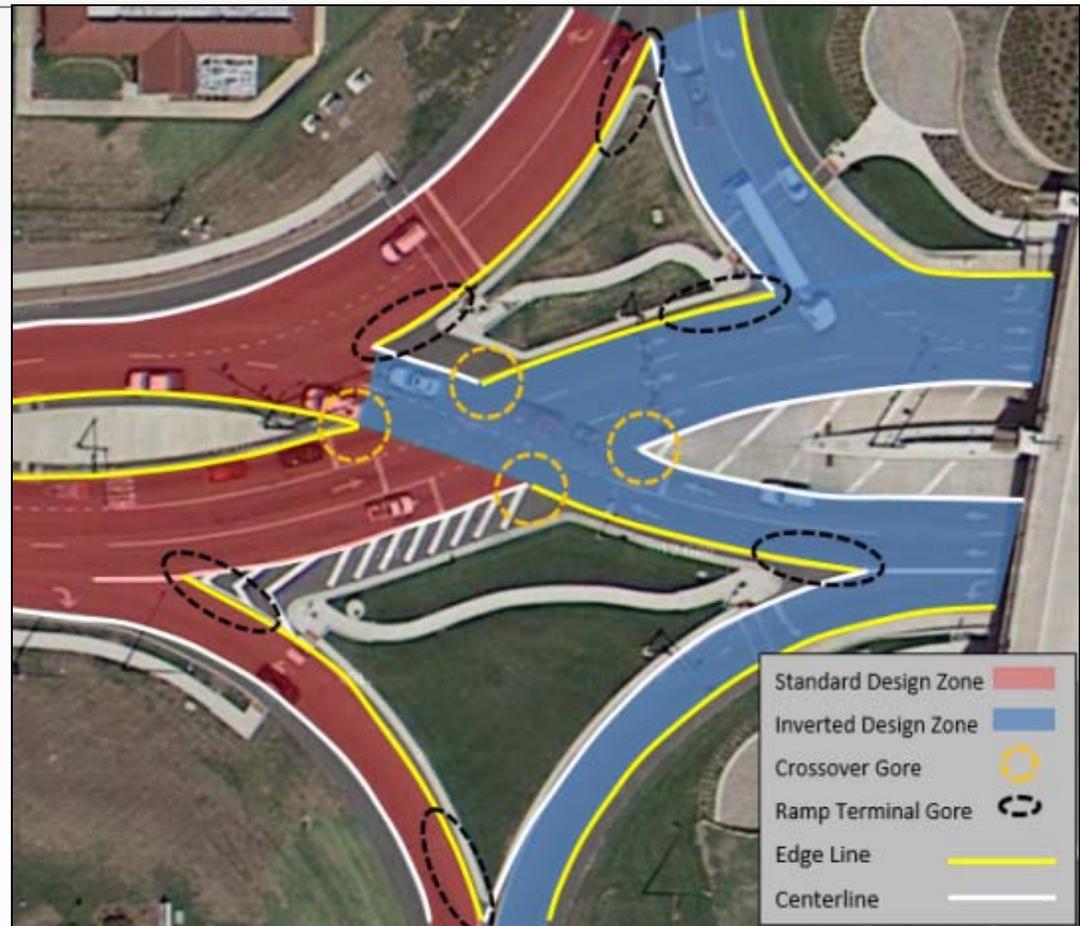
- Two-Phase Control, plus overlapped ramp phases
- Overlap Phasing to Minimize Lost Time
- Single vs. Multiple Controllers
- Signal Progression
 - Favoring Arterial Through
 - Favoring Left Turns from Freeways
- Pre-Timed vs. Actuated Control

Signals: One vs. Two Controllers

Single Signal Controller		Two Signal Controllers	
+	Reduced hardware cost	+	Ability to better control offsets
+	Used at most existing DDIs	+	More flexibility if all turns are signalized
+	Avoids need to set up communication between controllers	+	More transparency in signal design and cabinet set up
+	Improved flow during “free running” signal operation (late night)	-	Need for controllers to communicate
-	Increased need for wiring across DDI	-	Additional hardware and installation cost
-	More complicated signal design and cabinet set-up	-	May result in undesirable gap out situations during low volume periods

Pavement Markings

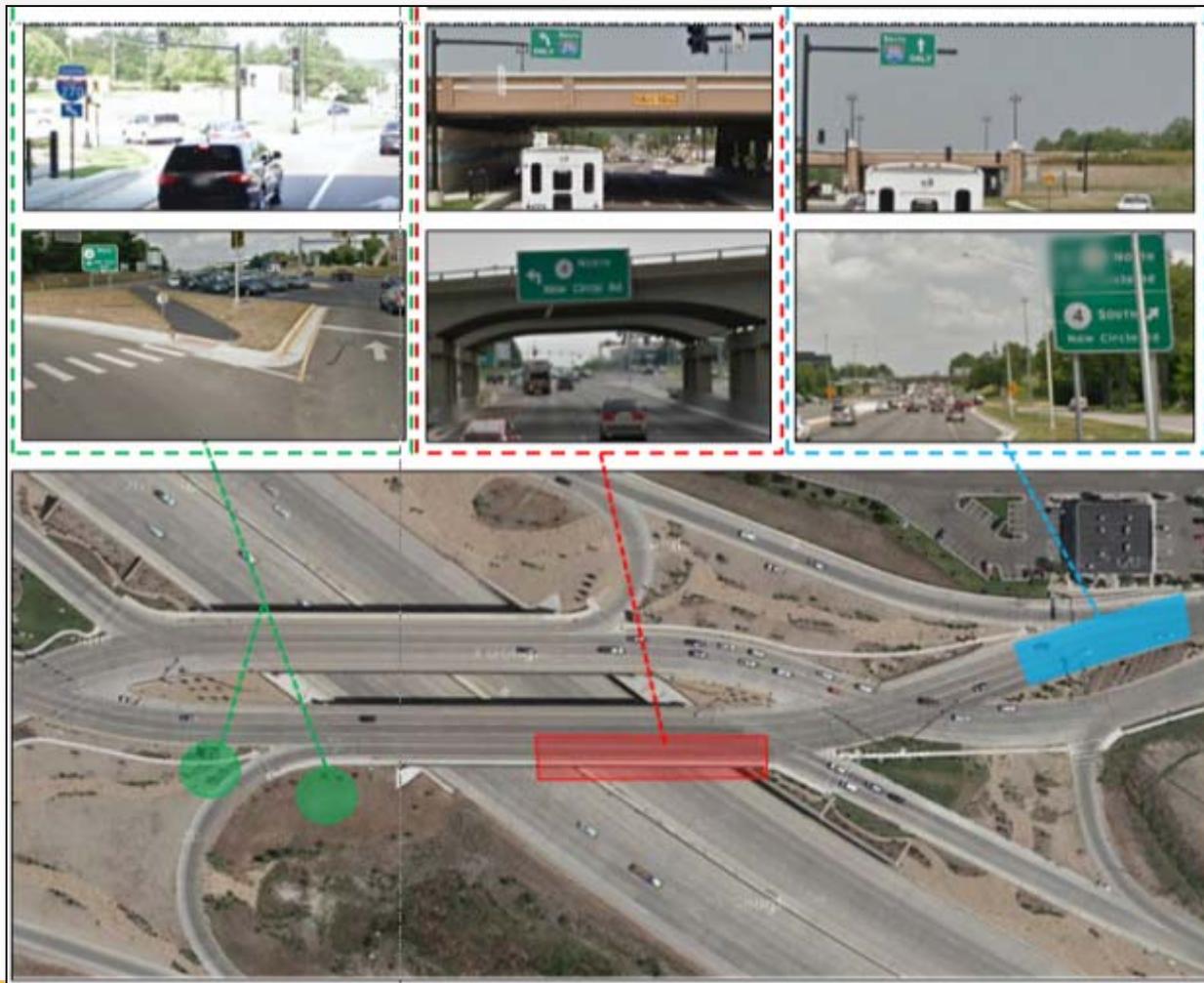
- Includes many types of markings
 - Centerlines and Edge Lines
 - Lane Lines
 - Lane Use Arrows
 - Stop Bars and Yield Lines
 - Pedestrian Crosswalk Markings
 - Special Markings



Signing

- Sign type usage highly variable
- States favor some sign types over others in many situations (i.e. “One Way” vs. “No Left/Right Turn”)
- Documents Regulatory, Warning, and Guide Signs from 5 DDI’s

Signing: Example Guide Signs



Source: Google

Lighting

- Special lighting considerations may be required where...
 - there is increased potential for wrong-way movements is expected
 - significant path alignment, lane assignment, or path following adjustments exist
 - Twilight or nighttime pedestrian volumes are high
- Recommend practice includes:
 - Complete Interchange Lighting (CIL) where feasible
 - Partial Interchange Lighting (PIL)

Lighting: Continuous Interchange Lighting(CIL)

- Urban Setting



Source: Google

Construction Staging

- DDIs often require shorter construction time than some other alternatives
- Staging options are similar to traditional designs.
- Considerations:
 - Can the interchange be closed?
 - Is the existing pavement going to be used or replaced?
 - Is additional cross-section necessary to accommodate future traffic?
 - When are the best times to switch traffic between various stages of the project?

Construction Staging: Dual Bridge Design (1 retrofit, 1 new construction)



Source: UDOT

Cost Estimates

- Highly dependent on whether the DDI uses an existing structure or is new construction

Interchange	Location	Cost	Retrofit
Bessemer St. and US 129	Alcoa, TN	\$2.9M	Yes
MO 13 and I-44	Springfield, MO	\$3.2M	Yes
Winton Rd. and I-590	Rochester, NY	\$4.5M	Yes
National Ave. and US-60	Springfield, MO	\$8.2M	Yes
Timpanogos Hwy. and I-15	Lehi, UT	\$8.5M	Yes
Mid Rivers and I-70	St. Peters, MO	\$14M	No
CR 120 and Hwy 15	St. Cloud, MN	\$17.5M	No
Pioneer Crossing and I-15	American Fork, UT	\$22M	No

DDI Summary of Advantages and Disadvantages

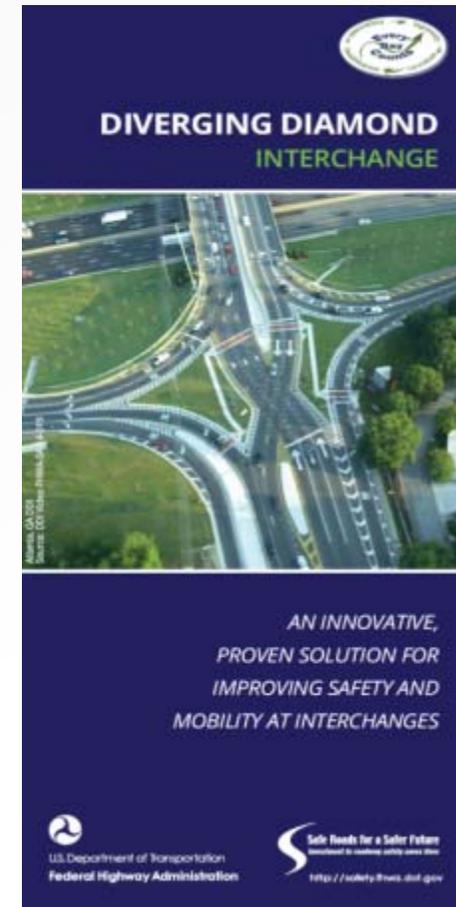
- Advantages
 - Reduces conflicts between vehicles and pedestrians for most crossing movements
 - Provides two-stage crossing opportunities
 - Reduction from 10 to 2 vehicle crossing conflicts compared to standard diamond
 - Two-phase signals reduce lost time at interchange and increase capacity
 - Challenging to coordinate through traffic in both directions
- Disadvantages
 - Pedestrians may have to cross unsignalized, channelized right and left turns onto freeway
 - May have potential for wrong-way maneuvers at crossovers
 - Challenging to coordinate through traffic in both directions
 - May require access control beyond interchange to prevent weaving maneuvers

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Additional Information on Alternative Intersections

- FHWA created informational videos
 - FHWA YouTube channel
<https://www.youtube.com/user/USDOTFHWA>
- FHWA has developed alternative intersection brochures
 - FHWA website
<http://safety.fhwa.dot.gov>



Questions

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