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
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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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

- Option for signalized right turns (with no RTOR)
- Reverse curvature upstream of crossover
- Directional crossover for through movements functions as a two-phase signal
- Left turns do not conflict with opposing traffic
- Left turns from freeway are yield- or signal-controlled
- Option to carry downstream left turn through upstream crossover
- Option for right turn with acceleration lane
- Right turns typically yield to lefts on on-ramp
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

- Provide adequate sight distance for vehicle approaches to crosswalks.
- Provide one vehicle length storage downstream of crosswalks for yield-controlled vehicle movements.
- Tight radii for right turns to reduce speeds at crosswalk - left turn not affected.
- Crosswalk behind stopbar for signalized vehicle turns.
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

- Bicycle lane on inside between crossovers
- Bicycle lane on outside on approach
- Bicycle lane "trapped" on inside of roadway
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

<table>
<thead>
<tr>
<th></th>
<th>Crossing</th>
<th>Merging</th>
<th>Diverging</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional diamond</td>
<td>10</td>
<td>8</td>
<td>8</td>
<td>26</td>
</tr>
<tr>
<td>Diverging diamond</td>
<td>2</td>
<td>6</td>
<td>6</td>
<td>14</td>
</tr>
</tbody>
</table>
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

- Traffic from freeway controlled by 2-phase signal or yield-controlled

- Traffic crosses to other side of arterial at a 2-phase signal

- Left turn does not conflict with opposing traffic
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

- **Overpass**
  - Center Walkway
  - Outside Walkway

- **Underpass**
  - Inside View
  - Outside View
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

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

<table>
<thead>
<tr>
<th>Interchange</th>
<th>Location</th>
<th>Cost</th>
<th>Retrofit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bessemer St. and US 129</td>
<td>Alcoa, TN</td>
<td>$2.9M</td>
<td>Yes</td>
</tr>
<tr>
<td>MO 13 and I-44</td>
<td>Springfield, MO</td>
<td>$3.2M</td>
<td>Yes</td>
</tr>
<tr>
<td>Winton Rd. and I-590</td>
<td>Rochester, NY</td>
<td>$4.5M</td>
<td>Yes</td>
</tr>
<tr>
<td>National Ave. and US-60</td>
<td>Springfield, MO</td>
<td>$8.2M</td>
<td>Yes</td>
</tr>
<tr>
<td>Timpanogos Hwy. and I-15</td>
<td>Lehi, UT</td>
<td>$8.5M</td>
<td>Yes</td>
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<tr>
<td>Mid Rivers and I-70</td>
<td>St. Peters, MO</td>
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<td>CR 120 and Hwy 15</td>
<td>St. Cloud, MN</td>
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<td>Pioneer Crossing and I-15</td>
<td>American Fork, UT</td>
<td>$22M</td>
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</table>
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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