Observations of Pedestrian Behavior and Facilities at Diverging Diamond Interchanges

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Multimodal Benefits of DDIs

• Reduced overall right-of-way footprint, compared to a standard diamond interchange;
• Two-phase traffic signal control with reduced pedestrian wait time;
• Minimized crossing distances;
• Simplification of conflicts to one-directional vehicular traffic; and
• Opportunities for bike lanes and multi-use paths through the interchange.
Challenges for Multimodal Users

• Altered travel paths with travel in the center of the interchange between vehicular lanes;
• Traffic approaching from unexpected directions;
• Unfamiliar signal phases; and
• Uncontrolled crossing of turn lanes.
Pedestrian Center Walkway

MO13 DDI in Springfield, MO

Source: ITRE
Center Walkway

Advantages

• Crossing of the arterial street provided crossing one direction of traffic at a time
• Short crossing distances
• **No exposure to free-flowing left turns to freeway**
• Protected signalized crossing to walkway
• Pedestrian clearance time generally provided in crossover signal phasing
• Pedestrian delay to center minimized by short cycles at two-phase signals
• Side walls provide a positive barrier
• Recessed lighting can provide good illumination of walkway
Center Walkway

Challenges

• Crossing of free-flow right-turn movements to/from freeway
• Pedestrians may not know to look to the right when crossing to center
• Wait at center island dictated by length of signal phase for through traffic
• Location of pedestrian signals can conflict with vehicular signals at crossovers
• **Center walkway placement counter to typical hierarchy of street design**
• Potential discomfort from moving vehicles on both sides of walkway
• Sign and signal control clutter
Pedestrian Outside Walkway

Dorsett Road DDI in Maryland Heights, MO

Source: ITRE
Outside Sidewalk/Path

Advantages

• Crossing one direction of traffic at a time
• Ramp crossing distances are often shorter than through traffic crossing distance
• **Extension of existing pedestrian network (natural placement on outside of travel lanes)**
• Pedestrian typically has view of path ahead (depends on sight lines and obstructions)
• Walkway doesn't conflict with center bridge piers (at underpass)
• Opportunity to use right-of-way outside of bridge piers (at underpass)
Outside Sidewalk/Path

Challenges

• Crossing of free-flow right-turn movements, and conflict with free-flow left turns to freeway
• Crossing of the arterial street sometimes not provided
• Potential sight obstruction of pedestrian crossing left turns behind barrier wall
• Pedestrians may not know which direction to look in, when crossing turn
• Unnatural to look behind to check for vehicles before crossing
• Signalized crossings require more complicated timing
• Need for widened structure for overpass
• Potential for additional right-of-way for underpass
Site Audits: Five key questions to ask

1. Can pedestrian walk safely and comfortably?
2. Do pedestrians understand when and where to cross?
3. Are pedestrian crossings visible for drivers?
4. How fast and how heavy is conflicting vehicular traffic?
5. Are walkways and crossings accessible?
1. CAN PEDESTRIANS WALK SAFELY AND COMFORTABLY?
Without Facilities, Pedestrians are faced with tough choices

Pedestrian walking in road due to lack of pedestrian facilities

Pedestrian walking through ditch outside of concrete barrier.

Source: ITRE
Pedestrian Facilities can become part of the design

Project landscaping at outside pedestrian facilities

Wide center walkway with physical separation that is not too high

Pedestrian walkway with guardrails
Watch for Obstacles, Obstruction, and Uncomfortable Walking Environment

Pole in DDI center walkway

Source: ITRE

Tight DDI center walkway with high barrier walls

Source: ITRE
2. DO PEDESTRIANS UNDERSTAND WHEN AND WHERE TO CROSS?
Pedestrian Channelization and Wayfinding

Source: Google
DDI Walkways

Look Left
Look Right

© 2013 Google
Communicating Direction of Traffic

Pedestrian markings to indicate directionality of traffic (Maryland Heights, MO).
Unusual Geometry brings Unusual Challenges

“Don’t Walk” shown together with vehicle “green” at DDI crossover

Sight-obstructions at DDI crossover

Source: ITRE
3. ARE PEDESTRIANS VISIBLE TO DRIVERS?
Sight Distance and Visibility Matter

• Open sight lines and good visibility can contribute to increased driver awareness and yielding
• Limited sight lines also impact audible information available at the crosswalk
DDI Free-Left Turn Conflict (for Outside Walkway)

Example of pedestrian crossing at free-flow left onto freeway

Source: FHWA
Lighting is Important

Lighting on the pedestrian walkway

Source: ITRE
Lighting in Underpasses

Bicyclist riding in striped shoulder against traffic through DCD crossovers

Source: ITRE
4. HOW FAST AND HOW HEAVY IS CONFLICTING VEHICULAR TRAFFIC?
Speed Matters

- Faster Speeds linked to reduced yielding and increased risk
- Prior research also linking higher speeds to greater injury risk and reduced driver attentiveness to pedestrians
Impact of Speed on Driver Yielding at Two-Lane Roundabouts (6 Sites in 4 states)

All Data - Speed v.s. Percent Yield

- Entry
- Exit

Linear (Entry): $y = -0.0295x + 0.9062$
- Linear (Exit): $y = -0.0261x + 0.4717$

$R^2 = 0.8292$
$R^2 = 0.7965$
Consider Driver Action at DDI

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

- 8 Conflict Points
  - 4 free/flow or accelerating
- 4 stopped or decelerating
Vehicles accelerating to freeway speeds are unlikely to yield (DDI)

Driver failure to yield creates left-turn conflict with pedestrian.

Source: ITRE
Pedestrian-Focused DDI Design

Towards a Pedestrian-Focused DDI Design

• Larger Radii contribute to greater vehicle speeds and more risky crossing environment
Traffic Volume Matters

• Higher traffic volume can contribute to more yielding (vehicles slow and already delayed)

• But higher traffic are also linked to higher likelihood of multiple-threat events (at multi-lane crossings)

• And, higher traffic volume can also increase the ambient noise level
5. ARE WALKWAYS AND CROSSINGS ACCESSIBLE?
Pedestrians with Disabilities –
Basic Principles for Pedestrian Walkways

• Delineate the walkway through landscaping, curbing, or fencing to assist with wayfinding for blind pedestrians.

• Use fencing under the bridge structure where landscaping is more difficult to maintain.

• Provide adequate width and slope for wheelchair users, also considers other non-motorized users.

• Construct an appropriate landing with flat slope and sufficient size at crossing points.
Pedestrians with Disabilities – Basic Principles for Crossing Points

• Provide curb ramps and detectable warning surfaces at the edge of the sidewalk and transition to the street
• Provide accessible pedestrian signals with locator tone at signalized crossings
• Locate push-buttons to be accessible by wheelchairs and adjacent to the crossing at a minimum separation of 10 feet
• Use audible speech messages where spacing is less than 10 feet or where additional narrative for the expected direction of traffic is needed
• Align the crosswalk landing to the intended crossing direction
• Conduct targeted outreach and prepare additional informational material created with these specific users in mind.
Pedestrian Channelization and Wayfinding

Source: Google
Pedestrian Push-Buttons and APS

Undesirable use of single pole with two pedestrian push-buttons, no APS, and insufficient separation of the two detectable warning surfaces
Other Options for Push-Buttons

DDI splitter island with pedestrian signals on same side.

DDI splitter island with diagonal pedestrian signals

LEGEND:
- Pedestrian Push-Button
- Detectable Warning
Consider pedestrians in initial design and throughout design process!

Avoid need to retrofit by better initial placement of pole and/or walkway

Available right-of-way in island would have allowed for “perpendicular” crosswalk and walkway directing peds towards crossing

Source: ITRE
CLOSING THOUGHTS
Five key questions to ask

1. Can pedestrian walk safely and comfortably?
2. Do pedestrians understand when and where to cross?
3. Are pedestrian crossings visible for drivers?
4. How fast and how heavy is conflicting vehicular traffic?
5. Are walkways and crossings accessible?
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
Questions and Discussion
Pedestrian and Bicyclist Accommodations and Crossings on Superstreets

TRB Innovative Intersections for Pedestrians and Bicyclists

August 19th, 2015

Anne M. Holzem, PE, PTOE
Research Objective:

To modify current superstreet design and operations in North Carolina to better serve pedestrians and bicyclists.
Outline

• Superstreet
• Crossing Alternatives
• Field Data – Simulation Calibration
• Simulation
• Results
• Recommendations
• Additional Current Practice
Superstreet
Superstreet (RCUT / J-Turn)

- 2 one-way streets – great signal progression
- 2 signal phases
  - 14 conflict points

www.aarp.org
CROSSING ALTERNATIVES
Crossing Alternatives

Existing Crossing in NC

Source: Google
Crossing Alternatives

Diagonal Cross (Pedestrian)

San Antonio, TX
Source: Gilmer Gaston, Pape-Dawson Engineers
Crossing Alternatives

Median Cross (Pedestrian)
Crossing Alternatives

Two-Stage Barnes Dance Cross (Pedestrian)
Crossing Alternatives

Midblock Cross (Pedestrian)

Source: Patrick Engineering
Crossing Alternatives

Bicycle U-turn Option
Crossing Alternatives

Bicycle Direct Cross
FIELD DATA – SIMULATION CALIBRATION
Analysis Method

Simulation Calibration

<table>
<thead>
<tr>
<th>Speed (fps)</th>
<th>Pedestrians (walk)</th>
<th>Pedestrians (running)</th>
<th>Bicyclists</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>4.8</td>
<td>9.3</td>
<td>15.5</td>
</tr>
<tr>
<td>Ave</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*1,400 pedestrians*  **550 bicyclists**
SIMULATION
Simulation
Simulation

Routes

48 possible routes
Simulation

Variables

• Midblock locations
  o 600’
  o 800’

• Signal Timing (arrival of platoons)
  o Simultaneous
  o Offset

• Cycle Lengths
  o 90 second
  o 180 second

• Splits
  o 75/25
  o 60/40

***16 different scenarios per crossing geometry***
Simulation Outputs (MOEs)

• Average # of Stops per route

• Average Stopped Delay per route (sec)

• Average Travel Time per route (sec)
RESULTS
Results

Pedestrian Crossings

- Factors that contributed to lower travel times for all 4 pedestrian crossings:
  - Offset signal design (vs. simultaneous)
  - 90 second cycle length (vs. 180 second)
  - 60/40 signal split (vs. 75/25)
Results – Pedestrian Crossings

Signal Design

Travel Time (sec)

<table>
<thead>
<tr>
<th>Type</th>
<th>Offset</th>
<th>Simultaneous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barnes Dance Cross</td>
<td>404</td>
<td>440</td>
</tr>
<tr>
<td>Diagonal Cross</td>
<td>449</td>
<td>481</td>
</tr>
<tr>
<td>Median Cross</td>
<td>477</td>
<td>497</td>
</tr>
<tr>
<td>Midblock Cross</td>
<td>472</td>
<td>486</td>
</tr>
</tbody>
</table>
Results – Pedestrian Crossings

Cycle Length

Travel Time (sec)

<table>
<thead>
<tr>
<th>Cross Type</th>
<th>90 second cycle</th>
<th>180 second cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barnes Dance Cross</td>
<td>386</td>
<td>458</td>
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<tr>
<td>Diagonal Cross</td>
<td>415</td>
<td>515</td>
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<tr>
<td>Median Cross</td>
<td>431</td>
<td>543</td>
</tr>
<tr>
<td>Midblock Cross</td>
<td>431</td>
<td>527</td>
</tr>
</tbody>
</table>
Results – Pedestrian Crossings

Signal Splits

<table>
<thead>
<tr>
<th>Cross Type</th>
<th>60/40</th>
<th>75/25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barnes Dance Cross</td>
<td>400</td>
<td>444</td>
</tr>
<tr>
<td>Diagonal Cross</td>
<td>438</td>
<td>492</td>
</tr>
<tr>
<td>Median Cross</td>
<td>447</td>
<td>527</td>
</tr>
<tr>
<td>Midblock Cross</td>
<td>446</td>
<td>512</td>
</tr>
</tbody>
</table>
Results

Bicycle Crossings

- Factors that contributed to lower travel times for all 3 crossings:
  - 90 second cycle length (vs. 180 second)
Results – Bicycle Crossings

Cycle Length

<table>
<thead>
<tr>
<th>Bicycle U-Turn Cross</th>
<th>Bicycle Direct Cross</th>
<th>Bicycle Midblock Cross</th>
<th>Vehicle U-Turn</th>
</tr>
</thead>
<tbody>
<tr>
<td>311</td>
<td>273</td>
<td>325</td>
<td>325</td>
</tr>
<tr>
<td>774</td>
<td>383</td>
<td>532</td>
<td>802</td>
</tr>
</tbody>
</table>

- 90 second cycle
- 180 second cycle
RECOMMENDATIONS
Recommendations

• Pedestrian Crossing:
  o Diagonal Cross with Midblock Cross

• Bicyclist Crossing:
  o Bicycle Direct Cross
  o (Though Bicycle U-turn Cross had potential)
Recommendations

- Short cycle lengths (90 seconds) – peds/bikes
- Offset signal design - pedestrians
- Signal splits near 50/50 (60/40) - pedestrians
ADDITIONAL CURRENT PRACTICE
Additional Current Practice

Source: Google
281 & Evans Rd, San Antonio, TX
Additional Current Practice

Source: Google
281 & Evans Rd, San Antonio, TX
Additional Current Practice

Source: Google
71 & Falwell Ln, Austin, TX
Additional Current Practice

Source: Google
71 & Falwell Ln, Austin, TX
Additional Current Practice

Source: Google
Crain Hwy & Waugh Chapel Rd, Gambrills, MD
Additional Current Practice

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Protected Intersections for Protected Bike Lanes

Nick Falbo
August 19, 2014

Innovative Intersections for Pedestrians and Bicycles
Topics

• Current Practice
• Protected Intersection Design Concept
• History
• Design Elements Today
• Current Developments
Current Practice
Adjacent to Through/Right Turn Lane

Bike Box

“Bend-in”
Adjacent to Right Turn Only Lane

- **Bicycle Signal**
- **Mixing Zone**
- **Drop to regular bike lane**
Current Practice

**Intersection Design Strategies:**

- Increasing Awareness
- Increasing Conspicuity
- Isolating Conflicts
- Clearly Assigning Priority
Current Practice

Intersection Design Strategies:

• Increasing Awareness
• Increasing Conspicuity
• Isolating Conflicts
• Clearly Assigning Priority
• **Maintaining Bikeway Comfort**
“I generally feel safe when bicycling through the intersection.”

Agree or Disagree?
"I generally feel safe when bicycling through the intersections"
"I generally feel safe when bicycling through the intersections"
The Protected Intersection Design Concept
The Concept

ProtectedIntersection.com
History
BIKEWAY PLANNING CRITERIA AND GUIDELINES
April 1972
Design Elements Today
Signalization
Slow Speed Setback Crossing
Slow Speed Setback Crossing

FHWA. Separated Bike Lane Planning and Design Guide. 2015.
Pedestrian Safety Islands
Corner Safety Islands
Current Developments
Austin, TX

Photo: Greg Griffin Via Flickr (CC BY-NC 2.0)
Thank You
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