Important Considerations for When and How to Design a Diverging Diamond Interchange

Presented by:
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OTEC 2015
DDI Locations
Diverging Diamond 101
Case Studies
  - I-49 & Route 291
  - I-29 & Tiffany Springs Parkway
  - I-70 & Woods Chapel Road
  - I-96 & Cascade Road
  - I-95 & Viera Road
Diverging Diamond Interchanges

- First DDI opened in Springfield, Missouri in June, 2009
- Now more than 20 open, 100+ in development in US
Diverging Diamond Traffic 101

- Two-Phase traffic signal – no left-turn signal required
- Traffic Crosses over at intersections
- Heavy traffic movements can operate simultaneously
- Use existing bridge, room to add sidewalk
Why a DDI?

- Improved Safety
  - Fewer conflict points
  - Accident history at Springfield DDI has been very good

Source: FHWA
Diverging Diamond Geometry 101

**DDI Analysis**
- DDI selected based on cost, efficiency & footprint
- If through traffic higher than traffic to/from ramps:
  - Queue lengths become an important consideration
- Operational considerations
  - Cycle lengths
  - Clearance times through crossovers / signal phasing
  - Lane utilization
Diverging Diamond Geometry 101

Crossover Design

Key design component of DDI

Provide tangent section through crossover

Crossover Angle

Design Guidelines

- At least 20 feet of tangent on each side of crossover to provide directional guidance
- 40 degree angle recommended by guides
- We have found that 30+ degree crossovers work effectively
Truck Accommodation

- 15’ lanes through crossovers and across bridge are typical
- Alternative approaches to accommodate existing bridge width:
  - Flare median
  - Flatten curves
Right-Turns from Ramps

- Right-turning drivers tend to look to nearside lanes (traffic flowing away)
- Median barrier can also be an obstacle
Right-Turns from Ramps

- Pedestrian crossing with yield or free-flow movement
- Separate pedestrian crossing and yield movements
  - Pedestrian Crossing
    - Good visibility of crossing as vehicles travel up ramp
  - Yield Movement
    - Driver can now concentrate on gaps
- Or, signalize right turn movement
  - May require no RTOR, reduces efficiency
Sight Lines Critical

- Bridge piers can create “picket fence” effect
Diverging Diamond Geometry 101

Right-Turns from Ramps
- Suggested approach: Free-Flow
  - Highest capacity
  - Downstream acceleration lane
  - Pedestrian crossing
    - Signalize crossing with independent signal phase
Diverging Diamond Geometry 101

Ramp Merges

- Yield – most common
- Signal – protected pedestrian movement
- Free-flow – most efficient
  - Signalize pedestrian crossing with independent phase
Pedestrian Accommodations

- Pedestrians Typically Cross to Median
- Can be Accommodated on One side only
- Dependent on Ramp Signalization
- Avoid Crossing Free Flowing Ramps
Traffic Signal Phasing

2 Phase operation
Overlap to provide extra clearance for ramps
Right turns – RTOR or free-flow
Traffic Signal Timing

- Cycle Lengths – Consider queue management between crossovers
- Queues and 2 phase operation favor shorter cycle lengths
- Consider adjacent signals – Often 8 phase requiring longer cycle lengths
71/291 Partners in Progress

The 71/291 Partners in Progress Transportation Development District (TDD) represents a collection of existing property owners who have formed a politically entity whose sole purpose is the construction of infrastructure improvements in the area. Participating businesses have imposed an additional 1-cent sales tax to pay for the improvements.

The TDD is managed by a Board of Directors, elected by the property owners, along with representation from the City of Harrisonville and MoDOT.
I-49 & Route 291 – Existing Interchange
I-49 & Route 291 – Project Conditions

Utilities
There are many utility facilities within the limits of the project. The owners of these facilities include: Embarq, Missouri Gas Energy, Atmos Energy, Charter Communications, LightCore, KCPL, Osage Valley Electric, and the City of Harrisonville.

Bridge
- The existing bridge over U.S. 71 is 45 years old and is in satisfactory condition.
- It is a voided slab type structure which is difficult to widen.
- Clearance above U.S. 71 was measured to be 16'-3" which is less than the desirable 16'-6" used for new bridges.

The Environment
An initial environmental scan has revealed that the project area includes:
- Several areas of potential wetlands.
- FEMA 100 yr floodplains.

This Curve on Cantrell Rd. is tighter than desirable.

The departure angle of Ramp 3 does not provide the definite break with U.S. 71 that is desirable.
I-49 & Route 291 – Alternatives Considered

- **Diamond Interchange With Roundabouts**
  - Example: Rte 152 & Congress

- **Single Point Urban Interchange (SPUI)**
  - Example: I-35 & 87th

- **Collector-Distributor Road System**
  - Discarded due to high cost and impracticality.

- **Partial Cloverleaf Interchange**
  - Creates an undesirable weaving condition on S.B. U.S. 71 between the two loop ramps.

Roundabout interchanges are cost effective and becoming more common throughout the region. However, the roundabouts at Commercial St and the southbound U.S. 71 ramps were found to not be able to handle projected traffic volumes.

SPUIs have a high price tag and do not address the traffic patterns at this location as well as other concepts.
I-49 & Route 291 – Alternatives Considered

Option A – Standard Interchange

Option B – Roundabout Loop Interchange

Option C – Diverging Diamond Interchange
# Measures of Comparison

<table>
<thead>
<tr>
<th>Measure</th>
<th>Symbol</th>
<th>Description</th>
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<tbody>
<tr>
<td>Operating</td>
<td><img src="image" alt="Symbol" /></td>
<td>All intersections are operating at LOS C or better during a typical weekday peak period and LOS D on a Summer Friday Peak. No intersections exceed capacity (v/c &lt; 1.0).</td>
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<td></td>
<td><img src="image" alt="Symbol" /></td>
<td>All intersections are operating at LOS D or better during a typical weekday peak period, with some operating at LOS E. No intersections exceed capacity (v/c &lt; 1.0).</td>
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<tr>
<td></td>
<td><img src="image" alt="Symbol" /></td>
<td>Some intersections operate at LOS F or intersections exceed capacity (v/c &gt; 1.0).</td>
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<tr>
<td>Cost</td>
<td>$</td>
<td>Construction Cost in Millions.</td>
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<tr>
<td>Familiarity</td>
<td><img src="image" alt="Symbol" /></td>
<td>Configuration is typical and readily recognized by all drivers.</td>
</tr>
<tr>
<td></td>
<td><img src="image" alt="Symbol" /></td>
<td>Configuration is less common, but many drivers have experienced before.</td>
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<tr>
<td></td>
<td><img src="image" alt="Symbol" /></td>
<td>Configuration is relatively new.</td>
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<tr>
<td>Safety</td>
<td><img src="image" alt="Symbol" /></td>
<td>Intersection configurations are designed to reduce the potential for serious (right-angle) collisions.</td>
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<tr>
<td></td>
<td><img src="image" alt="Symbol" /></td>
<td>Intersection configurations are controlled, but some risk of right-angle collisions exist.</td>
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<tr>
<td></td>
<td><img src="image" alt="Symbol" /></td>
<td>Intersection configurations provide uncontrolled movements where the risk of right-angle collisions exist.</td>
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## Summary of Options

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<thead>
<tr>
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<th>Cost</th>
<th>Familiarity</th>
<th>Safety</th>
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<tr>
<td><strong>Option A</strong></td>
<td><img src="image" alt="Symbol" /></td>
<td>$10.4 - $12.5</td>
<td><img src="image" alt="Symbol" /></td>
<td><img src="image" alt="Symbol" /></td>
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<tr>
<td>Standard Diamond</td>
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<td><strong>Option B</strong></td>
<td><img src="image" alt="Symbol" /></td>
<td>$11.5 - $13.8</td>
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<td><img src="image" alt="Symbol" /></td>
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<td>Roundabout with Loop</td>
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<tr>
<td><strong>Option C</strong></td>
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<td>$9.0 - $10.8</td>
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<tr>
<td>Diverging Diamond</td>
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I-49 & Route 291 – Selected Concept - DDI
I-49 & Route 291

- Phase 1 – Interchange & Route 291/Commercial Intersection
- Letting – Spring 2014
- Completion – 2016
- Construction Cost: $13m
- Crossing Angle = 40°
- Approach Radii = 200-ft
- Approach Tangent = 10-ft
Considered a range of concepts:
- Standard Diamond
- Diamond w/offset ramp
- Diamond w/NB on Loop
- SPUI
- Roundabouts

Began preliminary design on standard diamond

1st DDI opened in Springfield
I-29 & Tiffany Springs Pkwy – Completed Project
I-29 & Tiffany Springs Pkwy – Completed Project
I-29 & Tiffany Springs Pkwy – Design Challenges

- Ramp split – driver guidance
- West Outer Road – move out
- Drainage
- Sidewalk location
- Geometry –
  - Crossing Angle = 35°
  - Approach Radii = 200-ft
  - Approach Tangent = 15-ft
- Right-turns signalized
I-29 & Tiffany Springs Pkwy – Completed

- Completion – Fall 2014
- Construction cost $10.5m (includes outer road and ramp relocations, I-29 auxiliary lane extensions to Route 152)
I-70 & Woods Chapel Rd. – New Development Potential

- Chapel Oaks
- Canyon Creek
- 39th Street
- Others

[Bar chart showing daily traffic volumes with values for North of I-70, South of I-70, South of Outer Road, and South of Valley View.]

[Map showing development areas in yellow and red, with a red area marked for potential expansion.]
I-70 & Woods Chapel Rd. – Project Challenges
I-70 & Woods Chapel Rd. – Reuse of Bridge

Reused existing bridge
Added sidewalk
I-70 & Woods Chapel Rd. – Facts

- Opened to traffic September 25, 2013
- Construction cost $13.1m (includes ~1 mile of arterial improvements, outer road relocations, landscaping)
I-70 & Woods Chapel Rd. – Completed
I-70 & Woods Chapel Rd. – Crossover Design

Crossing Angle = 48°
Approach Tangent = 0-ft
Approach Radii = 180-ft
Sidewalks
Right-turn Signal control
Pavement Markings

Crossing Angle = 55°
Approach Tangent = 0-ft
Approach Radii = 180-ft
I-96 & Cascade
I-95 & Viera Road
I-95 & Viera Road
DDIabout?

- MoDOT
  DDI/Roundabout Concept
- US 50 & Route 291
- Addresses closely spaced outer road
Diverging Diamond Summary

- Evaluate all options
- DDI’s Don’t work everywhere – check performance
- Can be very cost-effective (structure reuse)
- Be aware of the cross over angle
- Control speeds with the approach radii
- Provide adequate lane widths – Passenger Cars and Trucks
- Provide adequate queue storage between signals
- Verify sight distance is adequate
- Understand pedestrian usage
Questions?

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