Diverging Diamond Interchange in Minnesota

When driving on the left side makes sense...

By
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MnDOT State Geometrics Engineer

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Outline

• Overview
• Advantages / Disadvantages
• Design Considerations
  • Safety
  • Traffic Operations
  • Cost
Problem Scenario

• The current transportation infrastructure system in Minnesota is at a point where increasing demand on the system is outpacing its current capacity.

• Transportation demand continues to escalate while State DOT’s budgets begin to dwindle.
Problem Scenario

The sizes of bridges today are an average six times the size of its predecessor…
Federal Bridge Inventory Report

In 2010, Twin Cities was ranked 10th most congested city in the nation...
2011 Urban Mobility Report
Overview

Age Profile and Investment Strategy of State Highway Bridges

![Bar Chart]

4,581 Structures

- Replace (2008 - 2028)
- Improve (2008 - 2028)

Decade
- < 1908: 3
- 1908-1917: 2
- 1918-1927: 31
- 1928-1937: 262
- 1938-1947: 203
- 1948-1957: 395
- 1958-1967: 634
- 1968-1977: 815
- 1978-1987: 831
- 1988-1997: 735

Preventive Maint (2008 - 2028)
Types of Interchanges

- Diamond
- Cloverleaf
- SPUI
- Folded Diamond
- Roundabout Interchange
- Directional
A diverging diamond interchange (DDI), sometimes referred to as a double crossover diamond (DCD), is a diamond interchange that more efficiently facilitates heavy left-turn movements.
DDI Background / History

  • DDI in Versailles, France

• 2005 – FHWA conducted study

  Candidate projects
  • I-75 & US 224 in Findlay, Ohio
  • I-435 / Front St in Kansas, Missouri

• 2009 – first DDI in the U.S.
  • I-44 & SR 13 in Springfield, Missouri

A13 & Rd 182
Versailles, France
Advantages

- Reduced conflict points
- Higher capacity
- Traffic calming effect
- Signal operation improvement
- Reduced project cost
- Easy U-turn capability
Disadvantages

- Constrained through movement
- Potentially confusing
- Off-ramp traffic cannot cross
- Ramps may require signalization
- Nearby signals complication
- Public acceptance / new idea
DDI Simulation

Simulation courtesy of Missouri DOT
Design Elements

- Design Speed
- Horizontal Cross Over Geometrics
- Intersection sight distance
- 2-Phase Signal / Signal spacing
- Signing / Striping
- Bike / Pedestrian Accommodation
- R-O-W / Access control
Design Elements

- Pedestrian Walkway
- Striping/Signing
- Crossing Angle
- Horizontal Curve
- Shoulder
- Lane Width
- 2-Phase Signal
Design Considerations

- Safety
- Operations
- Cost

DDI Performance Evaluation
Points of Conflict

Diamond

SPUI

DDI
Points of Conflict Comparison

<table>
<thead>
<tr>
<th>Type</th>
<th>Diamond</th>
<th>SPUi</th>
<th>DDI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diverging</td>
<td>10</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Merging</td>
<td>10</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Crossing</td>
<td>10</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>24</td>
<td>18</td>
</tr>
</tbody>
</table>

In general, reducing conflict points eliminates potential for crashes therefore safer.
Human Factor Driver’s Evaluation

Greatest concern: wrong-way movement
Human Factor Driver’s Evaluation

- FHWA Human Centered Systems team
- Driver simulation of DDI at I-435 & Front St
- Three interchange types: DDI, DDI (mod), and Diamond
- 74 licensed drivers (balanced gender and age representation)
Measures of Effectiveness

• Wrong-way violations
  ➢ NO wrong-way violations (1,041 opportunities)

• Navigation errors
  ➢ Incorrect path - very low at only 2.3% of total opportunities

• Red-light violations
  ➢ Compliance rate about the same

• Speed at crossover
  ➢ DDI - ave. speed at 24 mph
  ➢ Diamond - ave. speed at 34 mph
Operational Comparison

Interchange Volume Scenarios

A – Heavy eastbound to northbound
B – Heavy westbound to southbound
C – Heavy through movements on crossroad
D – Heavy exchange movements

(Siromaskul, MnDOT presentation)
Operational Comparison

Signal Phasing

Improved operational benefit of 2-phase signal operation due to elimination of left turn phase
## Operational Comparison

### Delay Comparison of Tight Interchange Concepts

<table>
<thead>
<tr>
<th>Scenario</th>
<th>DDI (sec/veh)</th>
<th>SPUI (sec/veh)</th>
<th>Dia. (sec/veh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>25.2</td>
<td>23.3</td>
<td>27.5</td>
</tr>
<tr>
<td>B</td>
<td>24.8</td>
<td>53.0</td>
<td>26.2</td>
</tr>
<tr>
<td>C</td>
<td>25.6</td>
<td>49.6</td>
<td>16.7</td>
</tr>
<tr>
<td>D</td>
<td>21.5</td>
<td>47.2</td>
<td>29.1</td>
</tr>
</tbody>
</table>

*(Siromaskul, MnDOT presentation)*
Operational Comparison

Lanes Required on Bridge
For Tight Interchange Concepts

<table>
<thead>
<tr>
<th>Scenario</th>
<th>DDI</th>
<th>SPUI</th>
<th>Dia.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>B</td>
<td>5</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>C</td>
<td>5</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>D</td>
<td>5</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

(Siromaskul, MnDOT presentation)
Operational Comparison

In general, DDI

- Increases overall capacity by 15% to 25%
- Increases throughput by 10% to 15%
- Reduces intersection delay by 15% to 60%

(Bared, Edara, & Jagannathan, 2005)
## Cost Comparison

<table>
<thead>
<tr>
<th>Interchange</th>
<th>Location</th>
<th>DDI Cost (real or estimated)</th>
<th>Alternative Design Cost</th>
<th>Cost Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-44 / Route 13</td>
<td>Springfield, Missouri</td>
<td>$3.2 Million</td>
<td>Over $10 Million</td>
<td>About 70%</td>
</tr>
<tr>
<td>I-435 / Front St</td>
<td>Kansas City, Missouri</td>
<td>$6.7 Million</td>
<td>Diamond $11.4 Million, SPUI $25 Million</td>
<td>About 75%</td>
</tr>
<tr>
<td>SR-265 / SR-62</td>
<td>Utica, Indiana</td>
<td>$52 Million</td>
<td>$118 Million</td>
<td>$66 Million</td>
</tr>
<tr>
<td>I-590 / Winton Rd</td>
<td>Brighton, New York</td>
<td>$3-4 Million</td>
<td>SPUI $10 Million</td>
<td>About $75%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Triple Left Diamond $13.6 Million</td>
<td></td>
</tr>
</tbody>
</table>
In general, a DDI is 40% less than a standard diamond and 70% less than a SPUI.
But DDI is not the solution for every situation...
Public Involvement

- Traffic modeling and simulation
- Drive-through simulation, video, project testimonies
- Project website
  - One-pager brochure
  - Pictures / driving guide
- Other social media
  - Facebook
  - Twitter
DDI Drive-through simulation

This video animation/simulation is a graphic representation and is intended to be used for informational and entertainment purposes only and does not necessarily follow Missouri Department of Transportation Specifications or Standards. This video animation/simulation is not intended to be a comprehensive standard or guideline for use or placement of traffic control devices.

Simulation courtesy of Missouri DOT
Questions

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Proposed Diverging Diamonds in Minnesota

- TH15 & CSAH 120 in Sartell near St. Cloud
- TH52 Elk Run Development in Pine Island
TH15 & CSAH 120 in Sartell near St. Cloud

PROJECT BACKGROUND

Safety
- 64 crashes in the past 5 years

Traffic
- ADT on Hwy 15 is 32,000; projected to 50,000 by 2033

Partnerships
- MnDOT, Stearns County, and the cities of Sartell and St. Cloud

Cost
- $17.5 million
TH15 & CSAH 120 in Sartell near St. Cloud

FINDINGS

- High volume of left turns required an 8 lane bridge in a standard diamond interchange and would have been past capacity in 20 years.

- SPUI had a better LOS than the standard diamond but was cost prohibitive and it couldn’t have been expanded in the future.

- The DDI handled the left turners with a four-lane bridge and the LOS showed excess capacity in 20 years.
### TH15 & CSAH 120 in Sartell near St. Cloud

#### Table 1: Northbound Exit Ramp Operational Comparison

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Forecast Demand Scenario (PM Peak Hour)</th>
<th>Intersection Delay</th>
<th>Intersection LOS</th>
<th>Movement NB to WB Delay</th>
<th>Movement NB to WB LOS</th>
<th>Movement NB to EB Delay</th>
<th>Movement NB to EB LOS</th>
<th>Maximum Ramp Queue (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tight Diamond Interchange (Signalized)</td>
<td>2033</td>
<td>33.2</td>
<td>C</td>
<td>40.9</td>
<td>D</td>
<td>12.3</td>
<td>B</td>
<td>469</td>
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<tr>
<td></td>
<td>2033 plus 5%</td>
<td>60.8</td>
<td>E</td>
<td>38.6</td>
<td>D</td>
<td>10.6</td>
<td>B</td>
<td>455</td>
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<tr>
<td></td>
<td>2033 plus 10%</td>
<td>67.9</td>
<td>E</td>
<td>43.7</td>
<td>D</td>
<td>13.5</td>
<td>B</td>
<td>607</td>
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<tr>
<td></td>
<td>2033 plus 15%</td>
<td>122.6</td>
<td>F</td>
<td>45.0</td>
<td>D</td>
<td>15.9</td>
<td>B</td>
<td>803</td>
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<td></td>
<td>2033 plus 20%</td>
<td>136.0</td>
<td>F</td>
<td>48.3</td>
<td>D</td>
<td>18.4</td>
<td>B</td>
<td>796</td>
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<tr>
<td>SPUI Interchange</td>
<td>2033</td>
<td>24.4</td>
<td>C</td>
<td>35.4</td>
<td>D</td>
<td>3.2</td>
<td>A</td>
<td>430</td>
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<td></td>
<td>2033 plus 5%</td>
<td>28.8</td>
<td>C</td>
<td>39.5</td>
<td>D</td>
<td>4.5</td>
<td>A</td>
<td>550</td>
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<td>2033 plus 10%</td>
<td>31.1</td>
<td>C</td>
<td>44.0</td>
<td>D</td>
<td>4.1</td>
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<td>605</td>
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<td>2033 plus 15%</td>
<td>36.7</td>
<td>D</td>
<td>62.0</td>
<td>E</td>
<td>6.6</td>
<td>A</td>
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<td>2033 plus 20%</td>
<td>38.9</td>
<td>D</td>
<td>66.8</td>
<td>E</td>
<td>7.8</td>
<td>A</td>
<td>1400</td>
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<tr>
<td>Loop Interchange</td>
<td>2033</td>
<td>27.7</td>
<td>C</td>
<td>20.3</td>
<td>C</td>
<td>46.5</td>
<td>D</td>
<td>490</td>
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<td></td>
<td>2033 plus 5%</td>
<td>29.2</td>
<td>C</td>
<td>25.5</td>
<td>C</td>
<td>46.9</td>
<td>D</td>
<td>824</td>
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<td>2033 plus 10%</td>
<td>57.7</td>
<td>E</td>
<td>91.3</td>
<td>F</td>
<td>107.4</td>
<td>F</td>
<td>1007</td>
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<td>2033 plus 15%</td>
<td>68.1</td>
<td>E</td>
<td>121.7</td>
<td>F</td>
<td>141.2</td>
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<td>2033 plus 20%</td>
<td>137.1</td>
<td>F</td>
<td>312.1</td>
<td>F</td>
<td>328.6</td>
<td>F</td>
<td>1001</td>
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<tr>
<td>Loop Interchange with Added WB Lane</td>
<td>2033</td>
<td>24.0</td>
<td>C</td>
<td>8.3</td>
<td>A</td>
<td>37.6</td>
<td>D</td>
<td>371</td>
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<tr>
<td></td>
<td>2033 plus 5%</td>
<td>27.7</td>
<td>C</td>
<td>11.3</td>
<td>B</td>
<td>42.4</td>
<td>D</td>
<td>502</td>
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<td>2033 plus 10%</td>
<td>31.5</td>
<td>C</td>
<td>21.3</td>
<td>C</td>
<td>51.9</td>
<td>D</td>
<td>628</td>
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<td>2033 plus 20%</td>
<td>37.2</td>
<td>D</td>
<td>25.7</td>
<td>C</td>
<td>66.4</td>
<td>E</td>
<td>808</td>
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<tr>
<td>Diverging Diamond Interchange</td>
<td>2033</td>
<td>11.1</td>
<td>B</td>
<td>18.6</td>
<td>B</td>
<td>6.4</td>
<td>A</td>
<td>284</td>
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<td></td>
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<td>10.9</td>
<td>B</td>
<td>17.0</td>
<td>B</td>
<td>5.5</td>
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<td>B</td>
<td>18.0</td>
<td>B</td>
<td>6.8</td>
<td>A</td>
<td>317</td>
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<td>2033 plus 15%</td>
<td>13.4</td>
<td>B</td>
<td>20.7</td>
<td>C</td>
<td>9.8</td>
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<td>463</td>
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<td></td>
<td>2033 plus 20%</td>
<td>15.2</td>
<td>B</td>
<td>24.8</td>
<td>C</td>
<td>12.8</td>
<td>B</td>
<td>456</td>
</tr>
</tbody>
</table>
TH52 Elk Run Development

Pre-Development
TH52 Elk Run Development

PROJECT BACKGROUND

Development
- 2,325-acre master planned development
- 200-acre Biobusiness Park
- Job creation

Schedule
- Anticipated completion Fall 2012

Cost
- $34.3 million
TH52 Elk Run Development

FINDINGS

- Mn/DOT proposed diamond interchange layout reaches maximum capacity at 40% build-out.
- Proposed DDI layout reaches maximum capacity at 79% of build-out.
- DDI Concept was ultimately selected by Mn/DOT.
## TH52 Elk Run Development

<table>
<thead>
<tr>
<th>Traffic Control Type</th>
<th>Intersection</th>
<th>Worst Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LOS</td>
<td>Delay (sec.)</td>
</tr>
<tr>
<td><strong>Standard Diamond</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Side-Street Stop Control</td>
<td>F</td>
<td>406.6</td>
</tr>
<tr>
<td>TH 52 West Ramp</td>
<td>F</td>
<td>1018.5</td>
</tr>
<tr>
<td>TH 52 East Ramp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All-Way Stop Control</td>
<td>E</td>
<td>49.2</td>
</tr>
<tr>
<td>TH 52 West Ramp</td>
<td></td>
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</tr>
<tr>
<td>TH 52 East Ramp</td>
<td>C</td>
<td>481.1</td>
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<td>Traffic Signal Control</td>
<td>C</td>
<td>20.8</td>
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<tr>
<td>TH 52 West Ramp</td>
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<td>29.5</td>
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<tr>
<td>TH 52 East Ramp</td>
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<td></td>
</tr>
<tr>
<td>Roundabout Control</td>
<td>A</td>
<td>7.9</td>
</tr>
<tr>
<td>TH 52 West Ramp</td>
<td>C</td>
<td>17.2</td>
</tr>
<tr>
<td>TH 52 East Ramp</td>
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<tr>
<td><strong>Diamond with Loops</strong></td>
<td></td>
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</tr>
<tr>
<td>Traffic Signal Control</td>
<td>B</td>
<td>11.9</td>
</tr>
<tr>
<td>TH 52 West Ramp</td>
<td>B</td>
<td>15.4</td>
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<tr>
<td>TH 52 East Ramp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roundabout Control</td>
<td>A</td>
<td>5.5</td>
</tr>
<tr>
<td>TH 52 West Ramp</td>
<td>B</td>
<td>10.4</td>
</tr>
<tr>
<td>TH 52 East Ramp</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SPUI</strong></td>
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<td></td>
</tr>
<tr>
<td>Traffic Signal Control</td>
<td>C</td>
<td>24.7</td>
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<tr>
<td>TH 52 Ramps</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DDI</strong></td>
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<tr>
<td>Traffic Signal Control</td>
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<td>TH 52 West Ramp</td>
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<td>15.1</td>
</tr>
<tr>
<td>TH 52 East Ramp</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Results from RODEL analysis.*
Let’s Test Drive

DDI Actual Driver’s Perspective