Develop Alternative Intersection Guides

Displaced Left Turn (DLT)
Median U-Turn (MUT)
Restricted Crossing U-Turn (RCUT)

August 2014
Presentation Outline

• **Introduction**
• Project Background, Objectives, and Team
• Overview of Alternative Intersections
• Overview of Displaced Left-Turn
• Overview of Median U-Turn and Restricted Crossing U-Turn
• Additional Resources
Introduction

• Today’s Presenters
  • Jeff Shaw, FHWA
  • Pete Jenior, Kittelson & Associates, Inc.
  • Hermanus Steyn, Kittelson & Associates, Inc. (DLT author)
  • Dr. Joe Hummer, Wayne State University (RCUT author)
  • Jonathan Reid, Parsons Brinkerhoff (MUT 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
  – Chris Cunningham

• 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**
• Overview of Displaced Left-Turn Intersection
• Overview of Median U-Turn and Restricted Crossing U-Turn Intersections
• Additional Resources
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

Source: Utah Department of Transportation
Source: North Carolina Department of Transportation

UDOT is building a new type of intersection at 3500 South and Bangert Highway. The Continuous Flow Intersection (CFI) will

THE THRU-TURN INTERSECTION (TTI) will reduce delay and improve safety by redirecting left turns from the main intersection to nearby U-turn locations.

SCAN THIS QR CODE WITH YOUR SMART PHONE TO SEE AN ANIMATION OF HOW THE TTI WILL WORK.

udot.utah.gov/5400south

Superstreet Intersection Design
Progressive design to:
• Help improve safety
• Reduce travel time
• Reduce construction costs
• Reduce impacts on the environment

No left turns or crossing traffic from side streets
U-turns provide left turn and through movements for vehicles from side streets
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)
Presentation Outline

- Introduction
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  - Overview of Displaced Left-Turn Intersection
  - Overview of Median U-Turn and Restricted Crossing U-Turn Intersections
- Additional Resources
Poll

- Are there Displaced Left Turn intersections in your state?
Displaced Left-Turn Intersection

- Overview of Intersection Type
- Multimodal Considerations
- Safety Considerations
- Operations
- Geometric Design
- Signing, Striping and Lighting
- Construction
Overview: Displaced Left-Turn Intersection

- Any intersection form relocating one or more left-turn movements on an approach to the other side of the opposing traffic flow.
  - Allows left-turn movements to proceed simultaneously with the through movements
    - Eliminates the left-turn phase for this approach
  - Reduces the number of traffic signal phases and conflict points (locations where user paths cross)
    - Can result in improvements in traffic operations and safety performance
  - Green time can be reallocated to facilitate pedestrian crossings
Overview: Displaced Left-Turn Intersection

- Four-legged DLT with displaced lefts on a major street
Overview: Displaced Left-Turn Intersection

• Range of Configurations
  – Four-legged DLT intersection with four displaced lefts
    • With channelized right turns
    • Without channelized right turns
  – Four-legged DLT intersection with major street displaced lefts and channelized right turns
    • With channelized right turns
    • Without channelized right turns
  – Three-legged DLT intersection with major street displaced left
  – Three-legged DLT intersection with minor street displaced left
With/Without Channelized Right Turns

Displaced left-turn

Non-channelized right-turn
Multimodal Considerations/Complete Streets

• Design elements
  – Width of roadway
    • Crossing distance for pedestrians
    • Exposure of bicyclists in conflict zones
  – Bus stop locations relative to natural walking paths
  – Unique movements
  – Large vehicles
Pedestrians

• Design and operational challenges
Bicycles: On-Street Bicyclists

- Consider bicycle crossing of the left turn and right turn movement
- Bicycle exposure to right turning vehicles
- Lane shared with motorized vehicles
Bicycles: Off-Street Bicyclists

- Bicycle ramp to get cyclists back to bicycle lane
- Bicycle ramp to place cyclists on separated path
Bicycles: Bicycle Left-Turn

On-Street Left: Bicycle Box

Off-Street Left: Share with Pedestrians
Transit: Bus Pull-out

- Potential Queue Jump for Left/Through Buses
Transit: In Travel Lanes Bus Stops

- Queuing behind stopped buses
Safety Principles

- There is limited documentation about the safety performance of DLT intersections.
- Conflicts are correlated with collisions and are often used as a surrogate measure.
- DLT Intersection Conflict analysis is shown below.

**Partial DLT:** 30 conflict points
14 crossing, 16 merging/diverging

**Conventional:** 32 conflict points
16 crossing, 16 merging/diverging
Safety Concerns

• Driver unfamiliarity
  – Counterintuitive design features
  – Use appropriate design and signing to prevent wrong-way movement

Desirable

Undesirable
Operational Principles

- DLTs usually implemented to maximize throughput
- Operational Benefit
  - allowing left turns to move concurrently with through traffic
Signal Phasing

- DLT can have up to 5 signalized intersections
  - 1 is the main intersection
  - 2 through 5 are the crossover intersections

- DLT intersections typically have shorter cycle lengths than similarly sized traditional intersections
  - Due to the reduced number of phases
  - and the need to reduce queue lengths between the closely-spaced intersections
System-wide Considerations

- Can be implemented as a corridor-wide treatment
- Fewer signal phases allow for longer green bands, improving signal coordination
- Bangerter Highway with 8 DLT intersections and one DDI
Operational Analysis and Tools

• Planning-level Tools
  – Critical lane analysis
    • Cap-X
  – HCM Analysis Methods
    • HCS, Synchro, Vistro
    – Limitations
      • Closely spaced intersections
      • Modeling unusual geometry; e.g., displaced left-turns
  • Microsimulation
Geometric Design

- Left turns cross opposing traffic prior to main intersection at crossover
- Unopposed left turns at main intersection
- Left turns cross opposing traffic prior to main intersection at crossover
Geometric Design Parameter and Principles

• Main Intersection
  – Unique displaced left-turns configuration
    • Accommodating pedestrians (refuge islands)
    • Appropriate turning paths
Geometric Design Parameters and Principles

• Crossover Intersection Geometry
• Crossover Intersection
  – There are two ways to accommodate the geometry where the right-turn bypass lane joins the cross road through lanes:

  - Signalized right-turn
  - Add lane with a downstream lane merge
Operational Effects of Geometric Design

• Crossover Intersection
  – Traffic operations establishes initial clearance time for traffic signal
  – Entrance to left turn pockets is farther in advance than at conventional intersections
  – TRB paper presents deterministic model that minimizes DLT delay based on geometric spacing
  – NCHRP Synthesis 225: Left-Turn Treatments at Intersections—A Synthesis of Highway Practice describes several design features for DLT Intersections
Design Guidance

• Right-of-way Requirements
  – Tangent alignment vs. undesirable deflections
Design Guidance

- S-curves through crossovers
  - Lane widths typically wider
  - Dual turns should accommodate the design vehicle

Side-by-side crossover maneuver

Semi-truck maneuver at crossover
Design Guidance

• Dual left-turns at Main Intersection
  – Dual turns should accommodate the design vehicle

Side-by-side left-turn maneuver

Semi-truck maneuver at crossover
Design Guidance

- Intersection spacing

![Diagram of intersection with spacing标注为300'-500']
Signals - Possible Signal Design Pole Layout
Signing

- Wayfinding
  - Advance signage critical component
Pavement Markings

- Prevent stop bar overrun
  - Placement of symbols
  - “STOP HERE ON RED” signs and/or nearside signals
Lighting

• Lighting standards and specifications
  – AASHTO’s Roadway Lighting Design Guide
  – FHWA’s Lighting Handbook
  – Illuminating Engineering Society of North America
    • American National Standard Practice for Roadway Lighting

• Lighting approach
  – Road functional and pedestrian conflict area classifications
  – Intersections lighting
    • 1.5 times roadway lighting or adding approaching roadways
Construction

• Common options
  – Close entire intersection
  – Close one cross road at a time
  – Accommodate all movements during construction
• Operational analyses can help inform and guide decision making regarding staging sequence
• Coordination with stakeholders and explaining trade-offs between construction options
Cost Estimates

- Review of previous projects

Baton Rouge, LA
$4.4 million
(bid price, incl. $1.0 million for frontage roads)

West Valley City, UT
$7.5 million
(total project cost)

Fenton, MO
$4.5 million
(construction cost)
Summary Advantages and Disadvantages

• **Advantages**
  – Reduces number and severity of conflicts
  – Increases lane capacity by 30 to 70 percent
  – Reduced number of signal phases improves progression
  – Significant cost benefit over grade separation solution

• **Disadvantages**
  – Potential for wrong-way movements
  – Larger footprint than conventional intersection
  – Corner business access challenges
  – Longer pedestrian crossing distances and time
  – Additional sign and signal maintenance cost
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• Overview of Alternative Intersections
• Overview of Displaced Left-Turn
• Overview of Median U-Turn/Restricted Crossing U-Turn
• Additional Resources
Poll

• Are there Median U-Turn or Restricted Crossing U-Turn intersections in your state?
Median U-Turn / Restricted Crossing U-Turn Intersections

• Overview of Intersection Type
• Multimodal Considerations
• Safety Considerations
• Operations
• Geometric Design
• Signing, Striping and Lighting
• Construction
Median U-Turn / Restricted Crossing U-Turn Intersections

- Median U-Turn Intersection (MUT)
  - Replaces direct left turns at an intersection with indirect left turns using a U-turn movement in a wide median.
    - Eliminates left turns on both intersecting streets
- Restricted Crossing U-Turn Intersection (RCUT)
  - Replaces direct left turns and through movements at the cross street approaches with indirect left turns using a U-turn movement in a wide median.
    - Eliminates left-turns and through movements from cross streets
- Both types of intersections
  - Reduce the number of traffic signal phases and conflict points
  - May result in improved intersection operations and safety
Median U-Turn Intersection

- MUT with signals at the main intersection and two crossover locations
- MUT may also have signals at the main intersection but unsignalized crossovers

Indirect left turns are made by first turning right and then making a U-turn in the wide median

No direct left turns at main intersection
Median U-Turn

- **Design variations**
  - Placing a stop-controlled directional crossover immediately prior to the primary intersection
  - Placing directional crossovers on the minor street to minimize major street median width and right-of-way requirements
  - Placing directional crossovers on both the major and minor street
Restricted Crossing U-Turn Intersection

• Three types of RCUT intersections
  – Signalized (shown below)
  – Stop-controlled
  – Merge- or yield-controlled
Multimodal Design

• Wide median on one or both roadway
  – Consider the challenge this may present to pedestrians and bicyclists
  – Provides unique transit opportunities

• Reduction in signal phases
  – Provides greater time for pedestrian and bike movements
  – Reduces delay for vehicle through movements

• Accommodations of Heavy Vehicles
  – Design U-turn crossovers for design vehicle
  – Consider weaving requirements
  – Consider location of bus stops
Pedestrian-Vehicle Conflict Points

Conventional intersection: 24 conflict points

MUT intersection: 16 conflict points

RCUT intersection: 8 conflict points
MUT Pedestrian Movements

Pedestrian Crossing Options

Two-stage crossing

Single-stage crossing

Signalized mid-block crossing

Regular traffic signal or PHB
MUT Bicycle Left Turn Options

- Preferred option
- Potential option
- Legal but undesirable option
RCUT Pedestrian Movements

Four-approach intersection

Three-approach intersection
RCUT Minor Street Bicycle Through Options
Bicycles at MUT and RCUT Intersections

- Bicycles: On-street through movements
Safety Principles: Conflict Points

- Reduces number of conflicts
- Type of conflicts are correlated with severity
  - Crossing more severe than merge/diverge
- Greater speed control and simplified driver decisions

Conventional intersection: 32 conflict points
MUT intersection: 16 conflict points
RCUT intersection: 14 conflict points
Safety Concerns: Violating Left Turn Prohibitions

- There is no physical barrier to prohibit illegal left turns at MUTs
- Proper signing, marking, and geometric design are important factors in discouraging illegal left turn at the main intersection
Safety Concerns

• Truck Navigation of Dual Lane Crossovers
  – Signage should direct large trucks to use outside U-turn lanes
  – Crossover design must anticipate heavy vehicle tracking through the crossover to eliminate path overlap with vehicles in the inner lane
Operational Considerations

• Traffic operational benefits
  – Signal phases are reduced, thus shortening overall signal cycle lengths

• RCUT Intersections
  – Signals on one side can be independent of signals on the other side
  – Makes “perfect progression” possible
    • Both directions of main street can have progression band equal to smallest green time
    • At any speed—allowing speed control
    • With any signal spacing—providing flexibility in signal location

• MUT Intersections
  – Signals at main intersection only switch between 2 phases:
    • Main street through and right movements
    • Minor street through and right movements
  – Main and U-turn intersections coordinated to provide flow through both intersections
  – All left turns are made indirectly
RCUT Corridor Signal Coordination

- Each direction independent
- Equivalent to one-way couplet
Operational Analysis

• Operational Analysis and Tools
  – Planning level analysis
  – Highway Capacity Manual (HCM) analysis
  – Microsimulation analysis

• Most important input data are the turning movement counts, which must be translated from conventional movements to the alternative movements of an RCUT or MUT intersection

• Factors in operations
  – U-turn Crossover Flow Rates
  – Signal Timings/Operations
  – Weaving
  – Queue Storage
Geometric Design

• Design approach
  – Relationships/interaction between safety, operations, design
  – Understanding trade-offs of the physical, environmental and right-of-way constraints
  – Meet driver expectations
  – Numbers of lanes in crossovers
  – Distances from main intersection to crossovers
  – Median width or provision of loons

• Design Principles
  – Number of approaches
  – Number of through lanes
  – Intersection angle
  – Design vehicle - critical for U-turn crossover
  – Design speed - typical 15 mph for U-turn crossover
  – Sight distance - critical for U-turn crossover
Design Guidance: U-turn Intersection Spacing

- Trade-off between queue storage and left turn travel distance
  - Short distance risks spillbacks into through lanes
  - Long distance risks motorist acceptance of design

<table>
<thead>
<tr>
<th>MUT</th>
<th>RCUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Michigan DOT: optimal distance of 660 feet ± 100 feet</td>
<td>- 400 to 800 feet for signal- or stop-controlled RCUT</td>
</tr>
<tr>
<td>- AASHTO Green Book recommends range of 400 to 600 feet</td>
<td>- Up to 2600 feet for merge-controlled RCUT</td>
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</tbody>
</table>
Design Guidance—U-Turn Crossovers

- Loons can minimize median width
- Other treatments can also help u-turning vehicles, such as mountable curbs, strengthened shoulders, right turn lanes and bus stops.
Design Guidance—Median Width

<table>
<thead>
<tr>
<th>Type of Maneuver</th>
<th>Length of Design Vehicle (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>19</td>
</tr>
<tr>
<td>Inner Lane to Inner Lane</td>
<td>30</td>
</tr>
<tr>
<td>Inner Lane to Outer Lane</td>
<td>18</td>
</tr>
<tr>
<td>Inner Lane to Shoulder</td>
<td>8</td>
</tr>
</tbody>
</table>

U.S. Customary

M—Minimum Width of Median (m) for Design Vehicle

- Median width is major factor in right-of-way width
- Designing turn bays back-to-back can reduce width
Signals

- Placement of signal poles and heads follow the same guidance as conventional intersection (provided in MUTCD)
  - Exception: no direct left-turn lanes are provided
  - Mast arms typically located opposite the U-turn crossover on the outside of the opposing major roadway lanes
  - Two signal heads must be used for thru traffic in U-turn crossover
Signing

• Special considerations:
  – Provide guide signing for the minor street left turn and through movements
  – Include devices to guide motorists to the optimum lane in a multilane minor street approach or in a multilane crossover
  – Provide signing for RTOR or LTOR prohibitions
Pavement Markings

- Pavement markings at RCUT and MUT intersection generally follow same principles as conventional intersections
- MUTCD does not provide pavement markings guidance for U-turn crossovers
  - MDOT has developed pavement marking standards for U-turn crossovers in Michigan

\[\text{Diagram showing pavement markings for U-turn crossovers.}\]
Lighting

• Lighting standards and specifications
  – AASHTO’s Roadway Lighting Design Guide
  – FHWA’s Lighting Handbook
  – Illuminating Engineering Society of North America
    • American National Standard Practice for Roadway Lighting

• Lighting approach
  – Road functional and pedestrian conflict area classifications
  – Intersections lighting
Construction

- MUTCD principles and applications apply in constructing a RCUT or MUT intersection
- May require additional lanes to be added:
  - In center of major road for exclusive U-turn movements
  - To the right of the U-turn movements for thru movements
  - On the far right for right turning movements
- Widen symmetrically on both sides or perform all widening exclusively on one side, depending upon:
  - Geometric design
  - Project cost
  - Maintenance of traffic
  - Overall impact to adjacent land owners and the community if additional right-of-way must be purchased
Cost Estimates for Recent MUT Projects

Legacy Drive at Preston Parkway, Plano TX
Opened: July 27, 2010
Cost: $1.7M

Minuteman at 12300 South, Draper, UT
Opened: Nov 2011
Cost: $5.1M

Haggerty Connector, Novi MI (2-mile, 8-lane boulevard on new alignment including two MUT intersections)
Opened: Nov 1, 2002
Cost: $21M
Summary Advantages and Disadvantages

• Advantages
  – Reduces number and severity of conflicts
  – Reduced signal phases and shorter cycle length
    • results in decreased intersection delay, congestion, and queuing
  – Increases intersection capacity
  – Allows for installation of additional midblock crossing pedestrian signals
  – Significant cost benefit over grade separation solution

• Disadvantages
  – Without special facilities, crossing bicyclists may have challenges
  – Increases travel time and distance for movements that are redirected
  – May require additional right-of-way for loons or wider medians
  – Higher construction cost than conventional intersection due to additional pavement, signs, and signals
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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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