Diverging Diamond Interchanges
Key Operational Considerations

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What is a Diverging Diamond Interchange (DDI)?

A diamond interchange form that allows the two directions of traffic on the crossroad to temporarily divide and cross to the opposite side to gain access to and from the freeway more easily.
How does a DDI operate?

- Two-phase signals move a lot of traffic!!
  - Typically allows more traffic to flow through the interchange area
  - Fewer conflict points improve safety
  - Can be made “pedestrian friendly”

DDIs are particularly advantageous in conditions with heavy through and left-turn volumes on the crossroad.
Portions of the downstream green are unused while demand is stuck at the upstream intersection.

Source: TRB Highway Capacity Manual 2010 Exhibit 22-9
What Are the Benefits of a DDI?

- **Operations**
  - Improves capacity with two-phase signals
    - Eliminates left turn phases to get traffic to/from the freeway

- **Safety**
  - Fewer conflict points

- **Lower cost**
  - Small footprint
  - Short construction timeframe
  - May salvage bridge

DDIs are particularly advantageous if the existing structure can remain in-place.
FIRST IN THE NATION

DIVERGING DIAMOND INTERCHANGE

MoDOT

CITY of SPRINGFIELD
“Before” – Traditional Diamond
Before Condition
Traditional Diamond
Where Do They Exist in the USA?

- Operational
- In Construction
- Advanced Design
- Under Study

[Map of the USA with states colored to indicate operational, in construction, advanced design, or under study status.]
Early Concerns

Will it ______ ?

◦ Cause driver confusion
◦ Cause pedestrian confusion
◦ Have many wrong-way movements
◦ Not accommodate trucks or emergency vehicles
◦ Work when the power goes out
◦ Work when it snows
◦ Work when all the polar ice melts
Signals at a DDI

- Two signalized “crossover” intersections to establish the right-of-way for each direction of through traffic
  - Two Phases at Each
  - No Left-Turn Phases

- Accommodates one “parallel” direction on the cross road – then the other (unlike a typical intersection phasing, but similar to a “split” phase operation)
  - Can also signalize the left or right turns onto the surface street, but the timings mimic the crossover signals
Simplified Signal Phasing of a DDI

Note that the transition from $\Phi_4$ to $\Phi_2$ does not need to happen at the same time as the transition from $\Phi_8$ to $\Phi_6$. 
Signal Phasing: Favoring Cross-Street
Signal Phasing: Favoring Off-Ramps

Phase 1

Phase 2
“Dummy” and “Overlap” Phases
Should the Ramp Turning Movements be Signalized?

MO:I-44/MO-13
Right Turn from Freeway: Signalize or Yield?

Source: MoDOT
More Signals Can be an Improvement!

- Especially where conflicts may cause problems:
  - Right turn from off-ramp
  - Left turn to on-ramp
  - All turns regarding pedestrians
  - All ramp movements with downstream weaving and merging

MO: I-270/Dorsett Rd.
Strongly recommend forming all lanes before first crossover for better signing purposes.
Design Speed and Reverse Curvature

- Design speed at a DDI affects the reverse curve radii through the two intersection crossovers
  - Typically ranging from 25 to 35 mph
  - Typical crossover angles of 40-50 degrees
  - The crossover angle is dictated by right-of-way constraints and available cross-section over or under the bridge
The greater the crossing angle, the less “different” the intersection will seem

- Recommended crossover angles of 40-50 degrees
  - Existing DDIs have angles as low as 28 degrees
- Low crossover angles may increase the likelihood for wrong-way maneuvers into opposing lanes
- Low angles increase crossing distances and increase signal clearance time
Tangent Before and After Crossover

- RECOMMENDED TANGENT LENGTH AFTER CROSSOVER: 10’ — 15’
- RECOMMENDED TANGENT LENGTH BEFORE CROSSOVER: 15’ — 20’
Tangent Through the Crossover

Source: Brian Toombs, P.E. – Burgess & Niple
“To ∞ and beyond ...”
Applicability of the DDI

- When might the DDI not be an appropriate alternative?
  - Close adjacent signalized intersections that are saturated and unable to be improved
    - Overall surface road corridor operations not significantly improved
  - Where existing driveways and a lack of ability to improve access control would reduce operational effectiveness
  - When there is substantial need to accommodate over-height vehicles with a exit ramp to entrance ramp “through”
Adjacent Intersection Spacing

- Key to ensuring quality of traffic flow along corridor
- Close spacing creates issues
  - Weaving conflicts
  - Merging conflicts with weaving traffic
  - Queue spillback/blocking of intersection
  - Crashes
  - Public disappointment
- Likely that the DDI will be more efficient than nearby signals
  - Therefore, nearby signals likely to control the capacity and progression of the corridor
Queue spillback

Since DDIs generally have fewer signal phases than adjacent intersections, they provide greater throughput and queue spillback may occur into the DDI departure zone if the downstream intersection cannot handle the traffic processed by the more efficient upstream DDI.
Nearby Signals

- DDI is often more efficient than nearby signals
  - Nearby signals control capacity and progression along corridor
  - Examine risk of spillback
- Consider weaves to adjacent intersection left turn bays
Grade Separate

Grade separate to eliminate the signalized intersection

Springfield, MO – Route 60 & National Ave
Opened August 2010
Grade Separate

The left turn (into a hospital) was modified to take a right, followed by another immediate right turn that loops under the cross road.
Relocate the intersection farther away.
This treatment was used at Dorsett Road in Maryland Heights, MO
Relocate Intersection Farther Away

Dorsett Road in Maryland Heights, MO.
Reduce Signal Phases at Adjacent Intersection

Utilize innovative intersection designs to reduce the number of signal phases at adjacent intersections along the corridor.
Reduce Signal Phases at Adjacent Intersection

Utah ThrU Turn

Distinguishing Features

- Direct left-turns are eliminated from main intersection
- Bump-out or “loon” beyond the outside lane (or coinciding with a sidestreet tee intersection or driveway)
Reduce Signal Phases at Adjacent Intersection

Utilize innovative intersection designs to reduce the number of signal phases at adjacent intersections along the corridor.
**DDI Advantages for Pedestrians**

- The two-phase DDI signal better serves pedestrian movements compared to three-phases
  - Typically allows more crossing time per phase to serve pedestrians
- With the separation and channelization of the two directions of vehicular traffic, pedestrians only have to cross one direction of traffic at a time
Cut-through walkways can guide the pedestrian directly to the intended crossing point
Key issue for outside path: Signalized or Free Left
Bicycle Provisions

Four Basic Options:
1. Marked bicycle lane throughout the DDI
2. Marked bicycle lane on the approach to the DDI terminating upstream of the first crossover
3. Separated bicycle way or multi-use path
4. Bicyclists use the vehicular travel lane or pedestrian walkways (i.e. no specific bicycle provisions)
Questions ???