NCHRP 03-113a

Guidance for **Traffic Signals** at Diverging Diamond Interchanges and Adjacent Intersections

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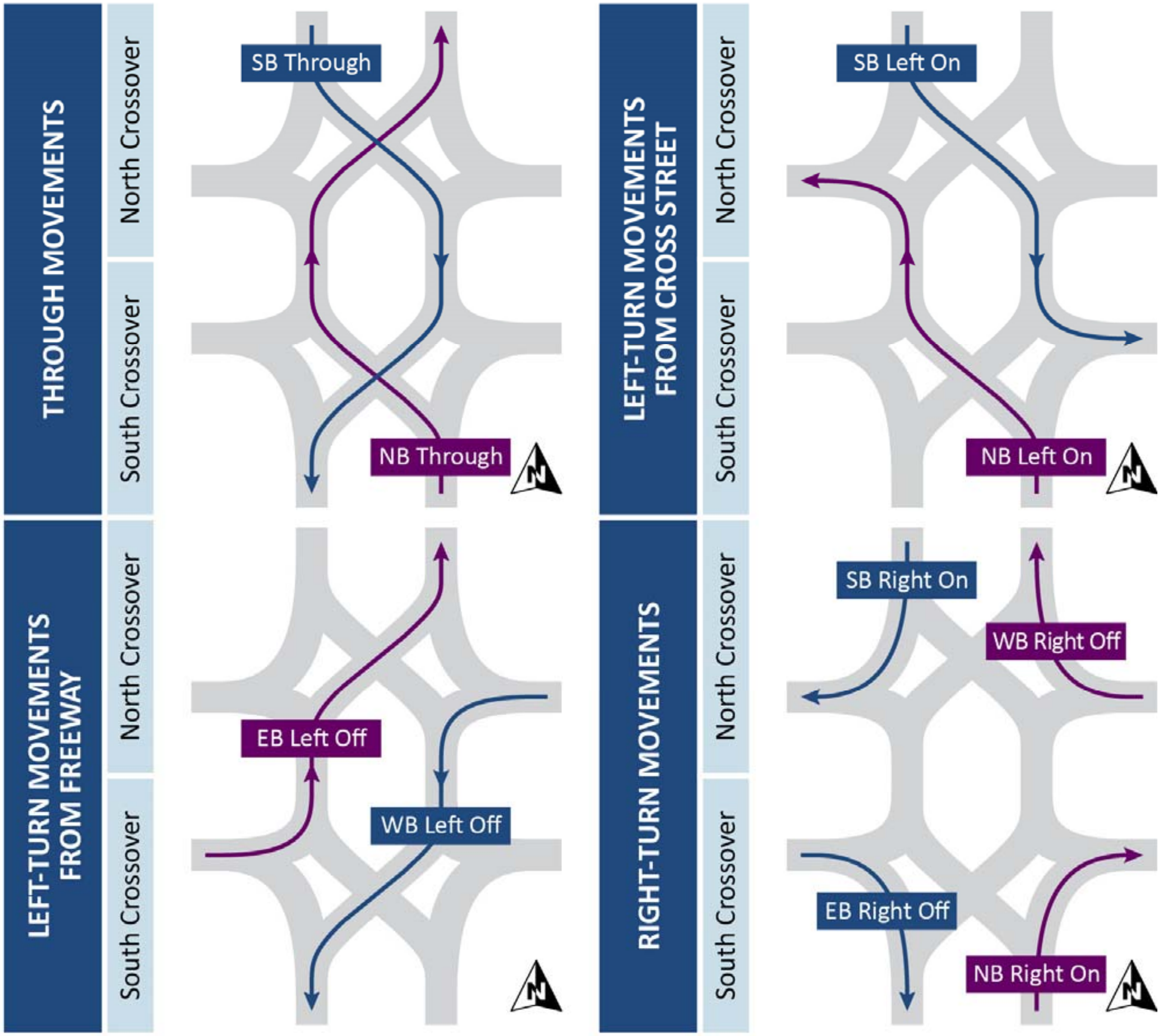
NCHRP 3-113a Objective

1. Provide states with guidance on performance of DDIs within a corridor context that apply to a wide range of users,
2. Evaluate corridor operations through modeling and simulation of a wide range of scenarios,
3. Test select strategies under real-world conditions

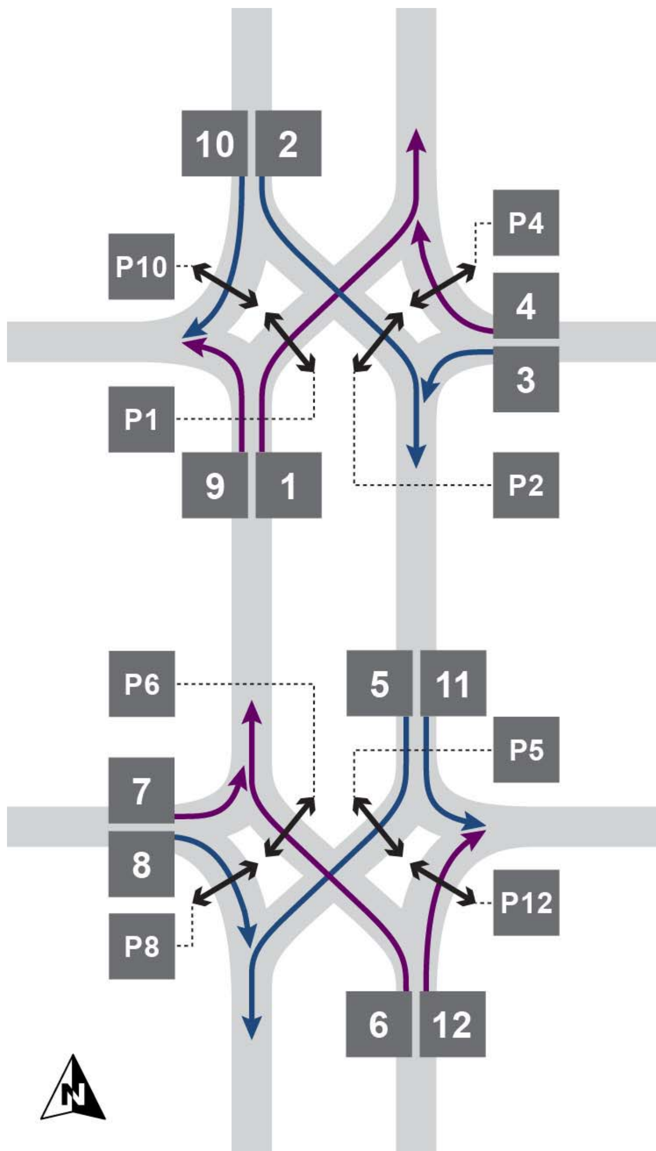
Chapter 5 Conceptual Operations

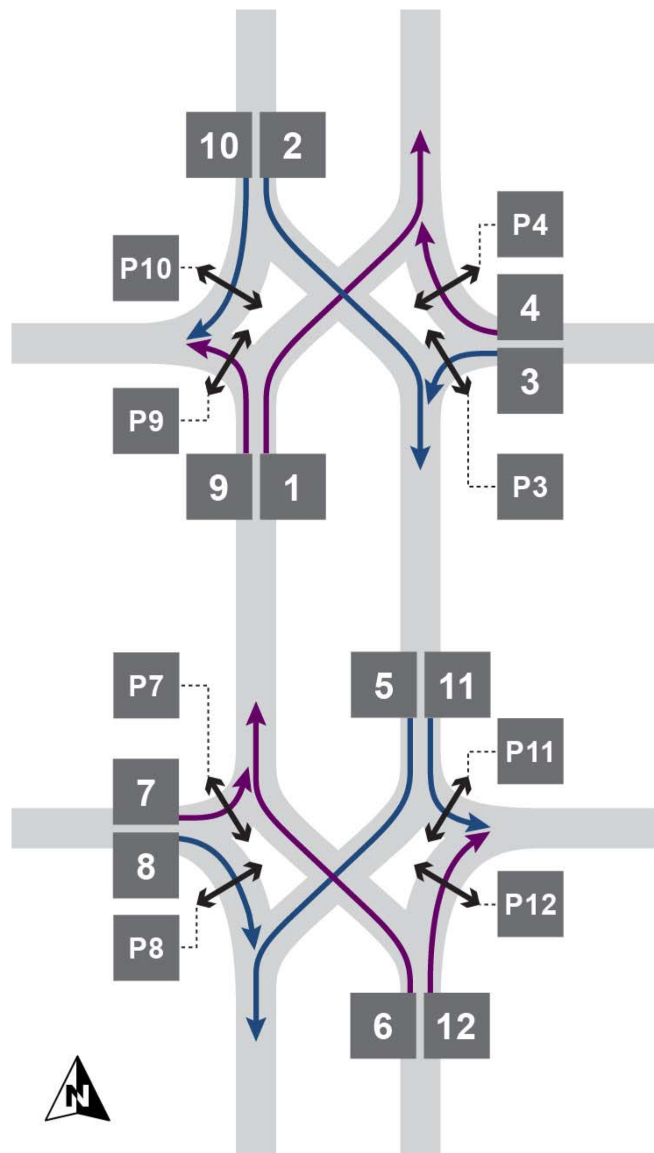
- 5.1 Preliminary Operations Considerations
- 5.2 Signal Timing Conventions
- 5.3 Phasing Schemes
- 5.4 System Needs
- 5.5 Operational Analysis

Naming Conventions

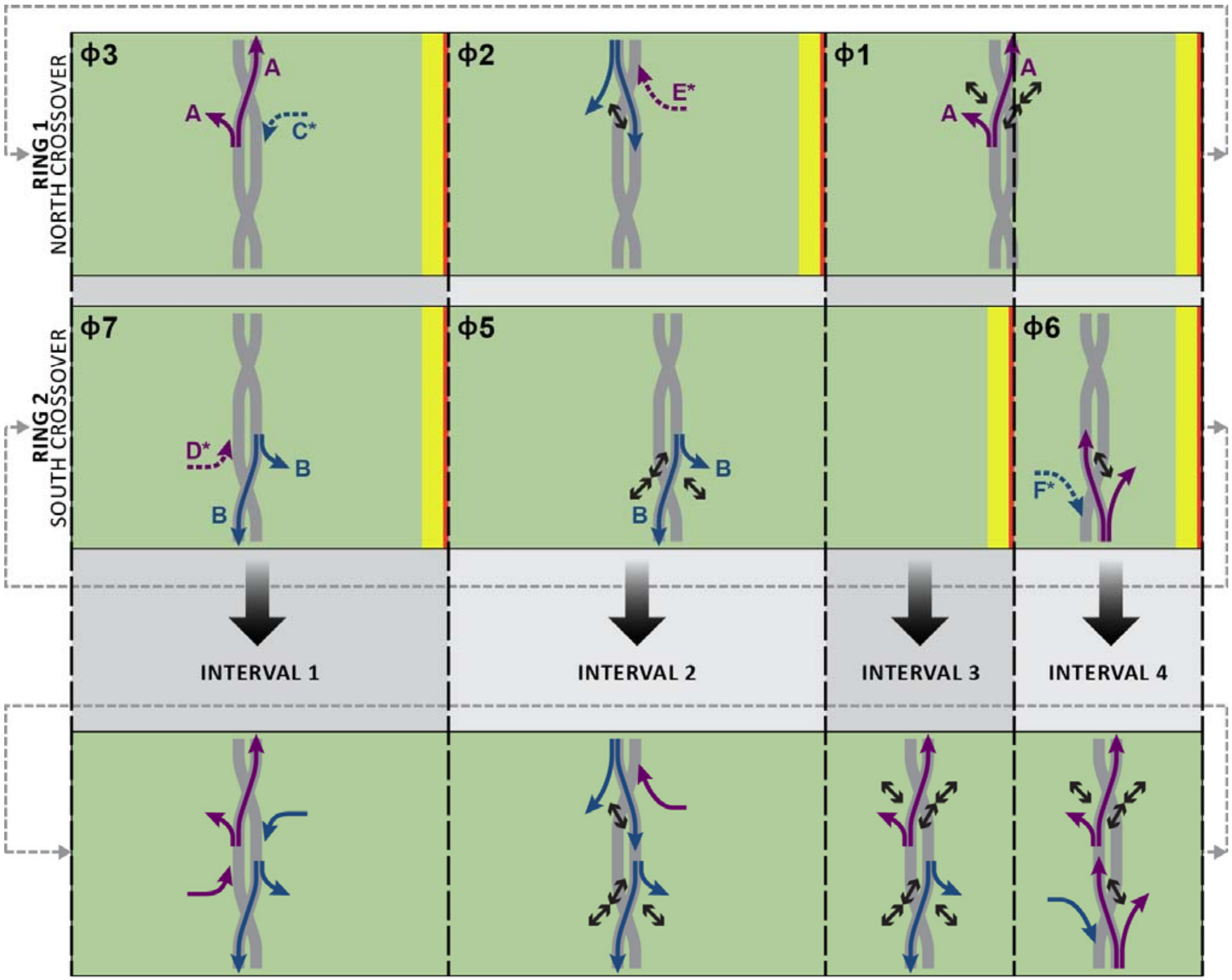


Movement Numbering





Phases versus Intervals



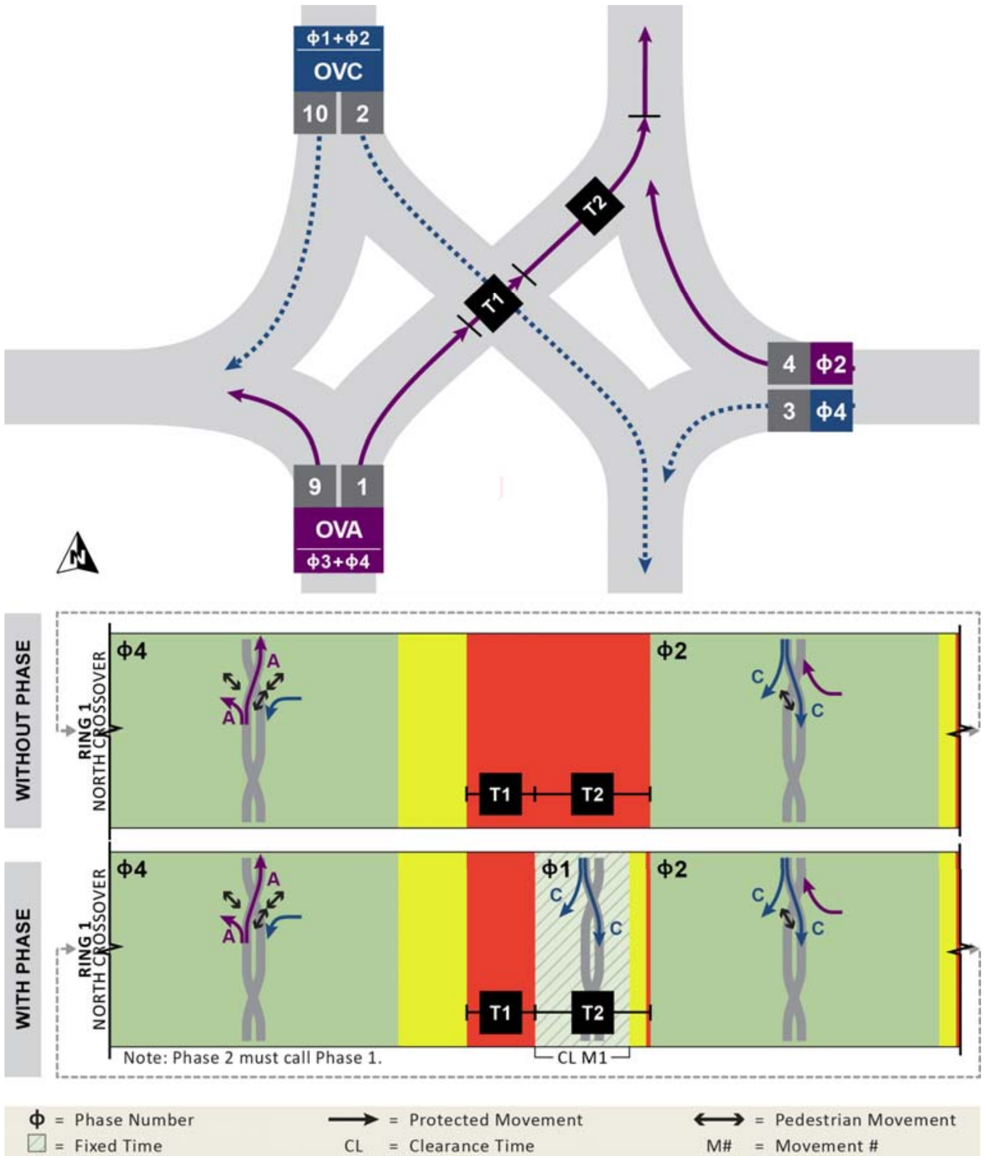
* OVC requires delay or extended clearance on ϕ2. OVD requires delay or extended clearance on ϕ6.
OVE requires delay or extended clearance on OVA. OVF requires delay or extended clearance on OVB.

ϕ = Phase Number → = Protected Movement ----→ = See Note ⟷ = Pedestrian Movement

Signal Timing Considerations

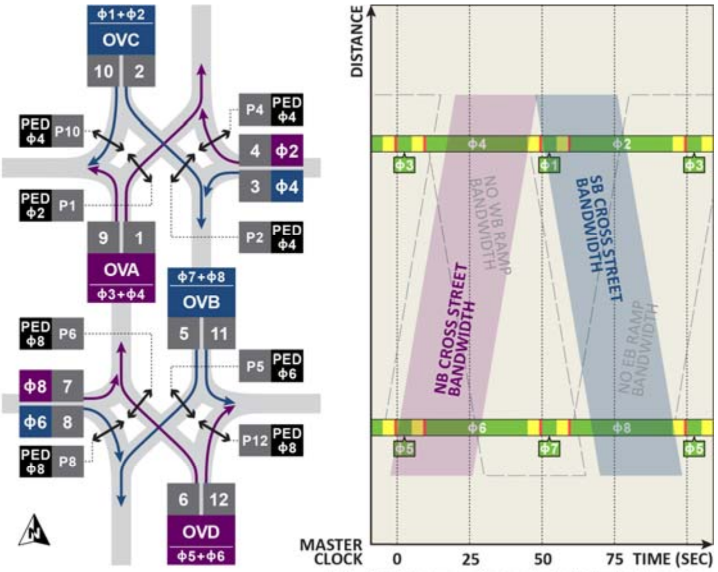
- Clearance Time
- Travel Time
- Cycle Length

Clearance Time

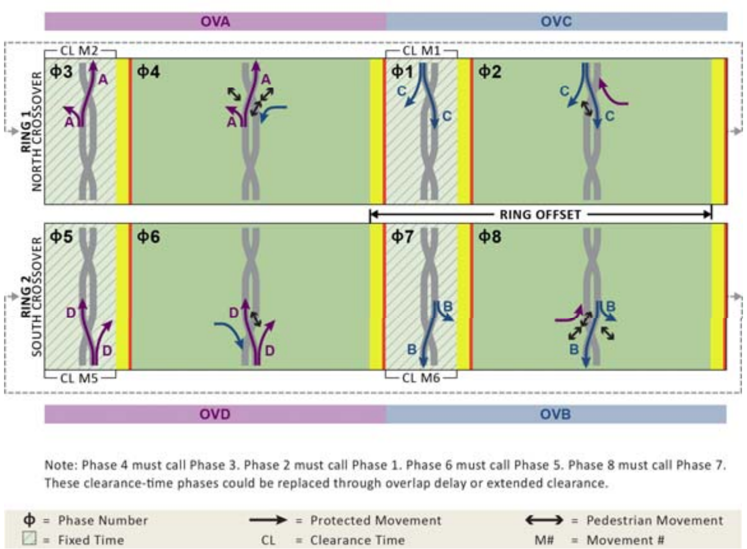


- Short, fixed-time phases following the through movements
- Off-ramp overlaps in combination with overlap delay
- Extended clearance intervals (i.e. longer red clearance) on the through-movement phases

Two-Critical-Movement Phasing Scheme (Cross-Street Progression)

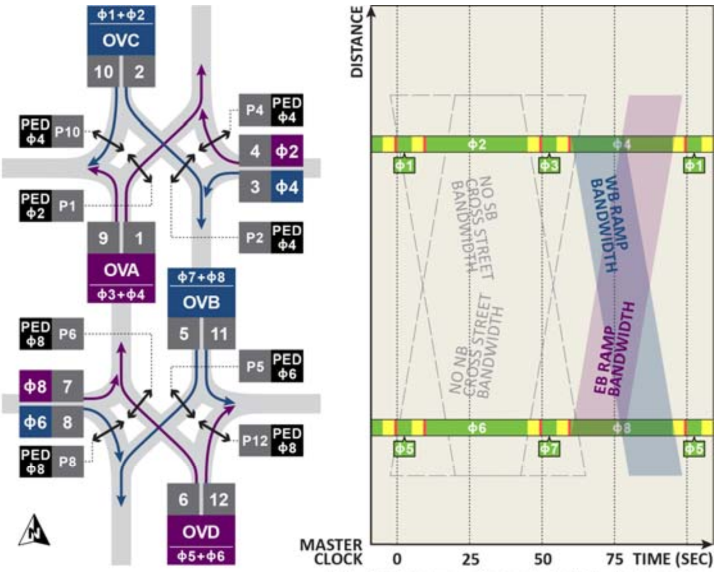


Note: Exhibit assumes single controller for both intersections.

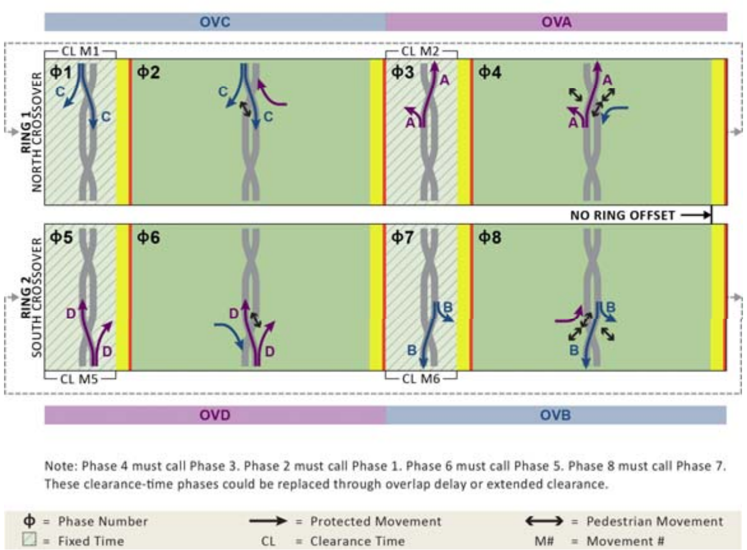


	Benefits		Challenges
+	Ability to coordinate through movement on the cross street or dominant left-turn movement from the ramps	–	Limited ability to progress multiple movements (e.g., both cross street and movements from the ramps)
+	Generally easy to understand/implement and troubleshoot in the field due to low complexity of phase assignments	–	May result in more stops internal to the DDI than other strategies
+	Minimizes lost time because of the low number of phases		
+	Highest potential capacity of the three phasing schemes		
+	Adaptable to any crossover spacing		

Two-Critical-Movement Phasing Scheme (Ramp Progression)

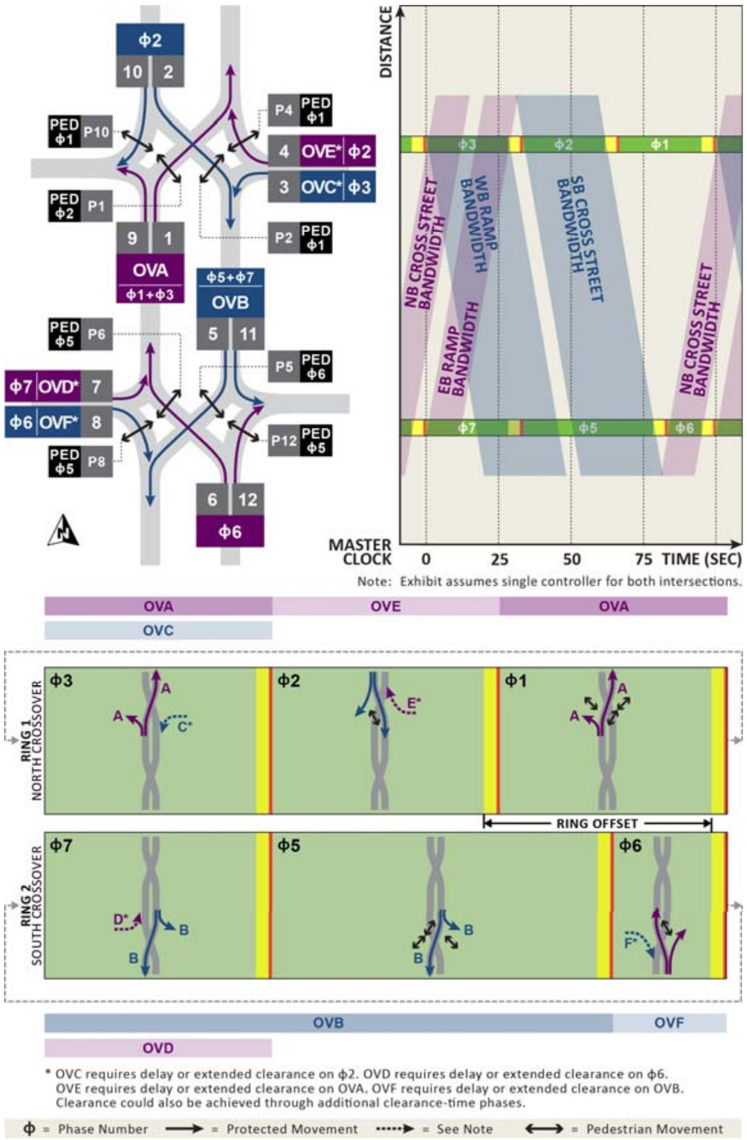


Note: Exhibit assumes single controller for both intersections.



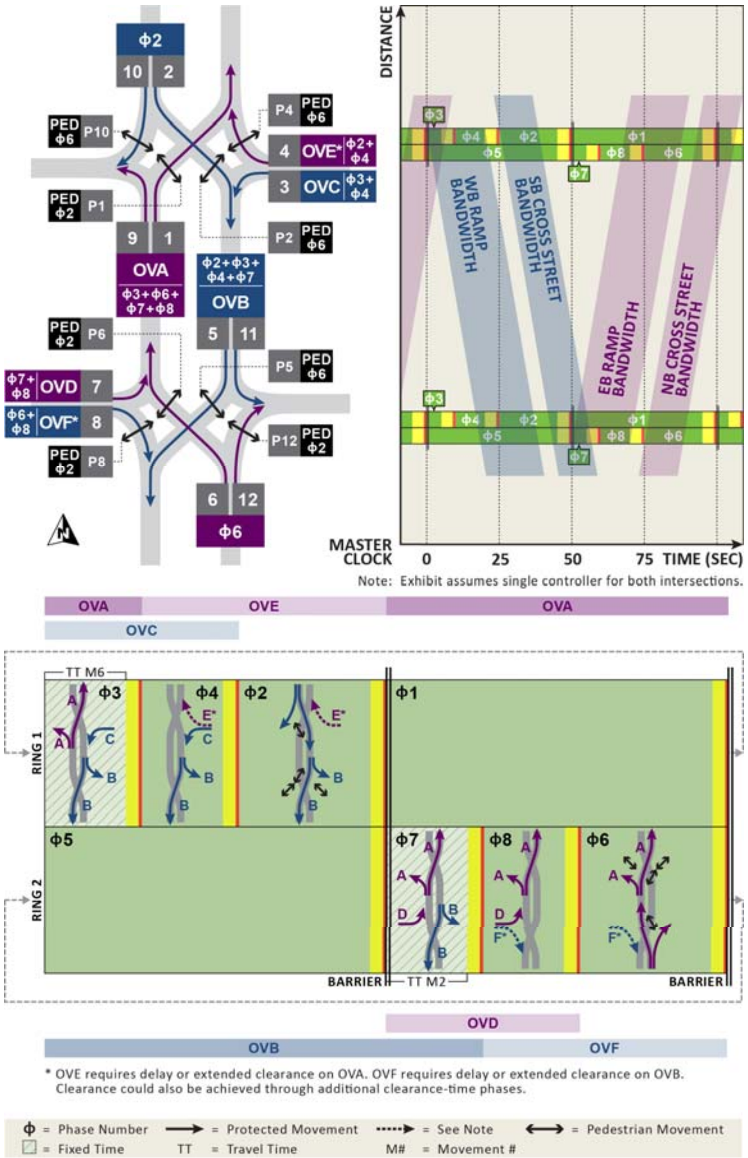
	Benefits		Challenges
+	Ability to coordinate through movement on the cross street or dominant left-turn movement from the ramps	–	Limited ability to progress multiple movements (e.g., both cross street and movements from the ramps)
+	Generally easy to understand/implement and troubleshoot in the field due to low complexity of phase assignments	–	May result in more stops internal to the DDI than other strategies
+	Minimizes lost time because of the low number of phases		
+	Highest potential capacity of the three phasing schemes		
+	Adaptable to any crossover spacing		

Three-Critical-Movement Phasing Scheme



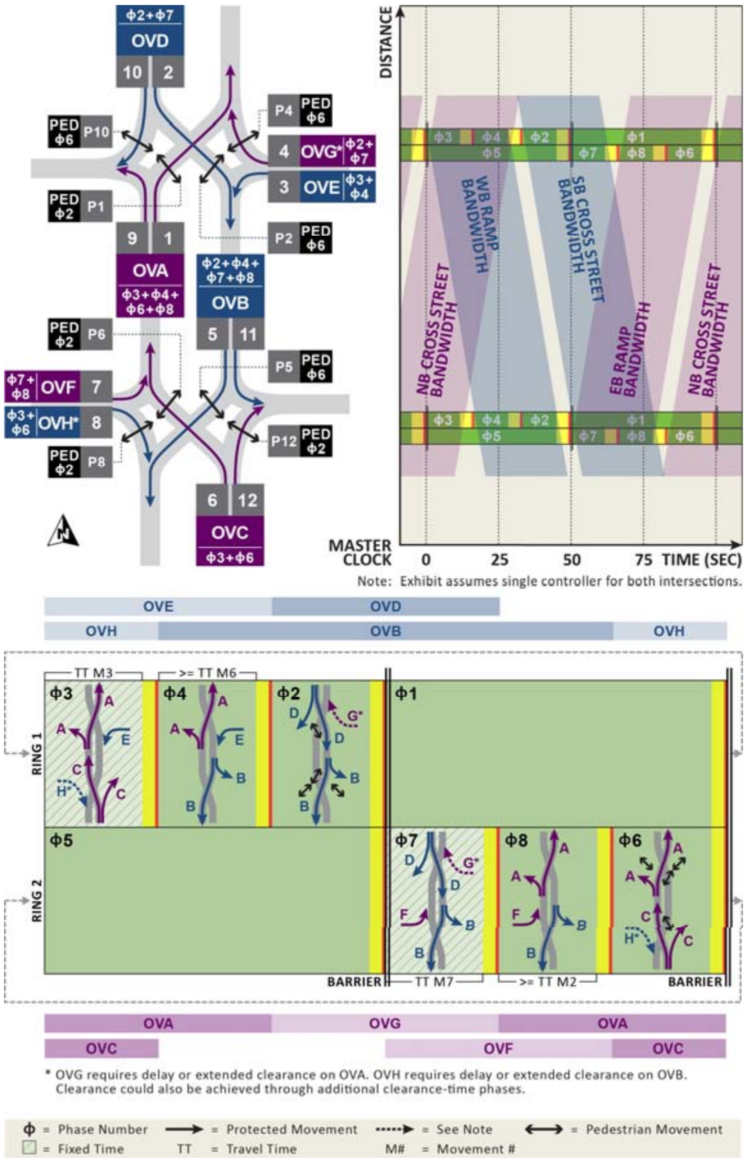
	Benefits		Challenges
+	Ability to coordinate through movements on the cross street and left-turn movements from the ramps	–	More complex than two-critical-movement phasing scheme
+	Possible to troubleshoot in the field due to the low complexity of phase assignments	–	Less efficient than two-critical-movement phasing scheme
+	Moderate lost time with only three critical phases	–	May result in stops internal to DDI for non-dominant movements
+	High-capacity phasing scheme for multiple dominant movements		
+	Adaptable to any crossover spacing		

Four-Critical-Movement Option A



	Benefits		Challenges
+	Ability to progress all movements through the DDI	–	Works best with balanced volumes and may be challenging with one or more dominant movements
+	Minimizes stops internal to the DDI (resulting in a better user experience)	–	More difficult to understand/implement and troubleshoot in the field due to complexity of phase assignments
+	Most flexible and adaptable phasing scheme	–	Highest lost time among the three phasing schemes because of the number of phases
		–	Less capacity than other phasing schemes
		–	Inefficient for wide crossover spacings

Four-Critical-Movement Option B

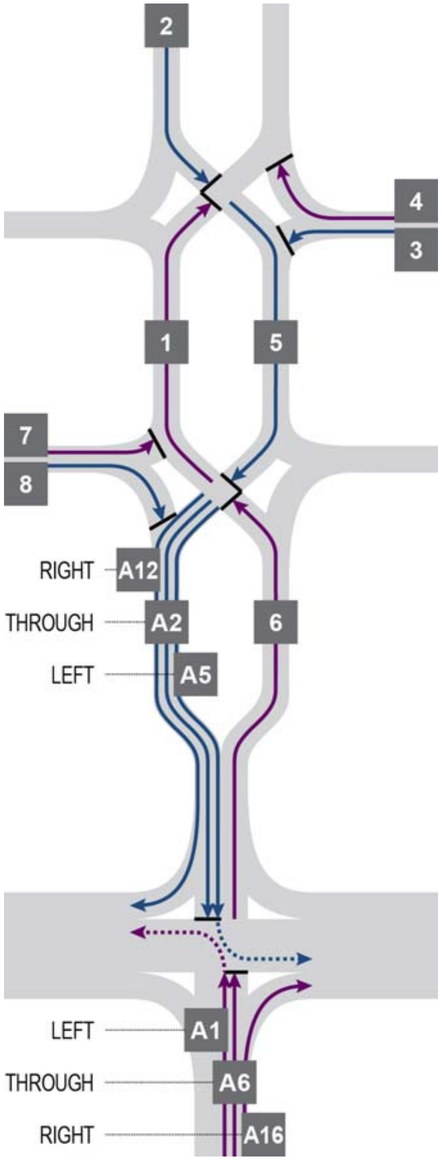


	Benefits		Challenges
+	Ability to progress all movements through the DDI	–	Works best with balanced volumes and may be challenging with one or more dominant movements
+	Minimizes stops internal to the DDI (resulting in a better user experience)	–	More difficult to understand/implement and troubleshoot in the field due to complexity of phase assignments
+	Most flexible and adaptable phasing scheme	–	Highest lost time among the three phasing schemes because of the number of phases
		–	Less capacity than other phasing schemes
		–	Inefficient for wide crossover spacings

Specialized Signal Timing Applications

- Pre-Timed Control
- Half Cycle
- Vehicle Preemption (“Ramp Flush”)
- Dynamic Overlap Phasing
- Meter Traffic at Upstream Adjacent Signalized Intersection
- Exclusive Pedestrian Phase
- Transit Preferential Treatment

Anticipated Delay and Queuing for Different Crossover Spacings



Heavy Demand Path(s)	Two-Critical Movements		Three-Critical Movements		Four-Critical Movements	
	Anticip. Level of Delay	Movements that May Experience Significant Queueing	Anticip. Level of Delay	Movements that May Experience Significant Queueing	Anticip. Level of Delay	Movements that May Experience Significant Queueing
Through	Low	-	Low	-	Medium	6, A6
Left Off	Medium	1, 5, 6, 7, 8, A6	Medium	4, 7, 8	Medium	3, 4, 6, 7, 8, A6
Right Off	Low	4	Low	3, 4, 7, 8	High	3, 4, 6, 7, 8, A6
Left On	Medium	3, 4, 5	Medium	3, 4, 5	Medium	3, 4, 5, 7
Through + Left Off	Low	1, 7, 8	Low	7, 8	Medium	3, 4, 6, 7, 8, A6
Through + Right Off	Low	4	Low	3, 4, 7, 8	Medium	3, 4, 6, 7, 8, A6
Through + Left Off + Right Off	Low	1, 4, 7	Low	3, 4, 7, 8	Medium	3, 4, 6, 7, 8, A6
Balanced	Low	-	Low	-	Low	-

Note: Example table is for 300-foot crossover spacing.
Note: Table assumes dominant movements are at or near capacity.

Strategies to Improve Corridor Operations

Strategy	Low Volume		Heavy Through		Heavy Left Off		Heavy Right Off		Heavy Left On		Heavy Through + Right	
	Heavy Movement	All Movements	Heavy Movement	All Movements	Heavy Movement	All Movements	Heavy Movement	All Movements	Heavy Movement	All Movements	Heavy Movement	All Movements
Half Cycle	++	-	++	++	o	--	--	++	++	o	-	o
Signalized On-Ramp Left Turn			o	o					o	o	o	o
Dedicated Phase for Concurrent Off-Ramp Left and Right Turns					o	o	o	++			++	o
Right-Turn-on-Red (RTOR) Allowed at Off-Ramp			o	-	o	o	--	--			-	o
Left-Turn-on-Red (LTOR) Allowed at Off-Ramp			-	--	o	o	--	--			o	-
LTOR & RTOR Allowed at Off-Ramp			-	--	o	+	o	--			o	--
Dynamic Overlap Phasing					o	o	-	o			o	o
Alternate Side-Street Phases at Downstream Signal			o	o	++	+	-	o			+	o
Lead/Lag Phasing for Outbound Lefts at Downstream Signal			o	o	--	o	+	o			--	-
Eliminate Phases at Adjacent Intersection					++	+	--	--	o	++	--	-
Free / Uncoordinated	++	+	++	++	++	o	++	++			++	+

++	High Delay Increase	+	Low Delay Increase	o	Minimal Delay Change	-	Low Delay Decrease	--	High Delay Decrease

Selecting the Appropriate Level of Analysis

Analysis Tool	Level of Analysis	Required Inputs	Available Outputs	Level of Effort	Limitations
Cap-X	Pre-screening the DDI as an interchange alternative	▪ # of lanes ▪ Hourly TMCs[1]	▪ v/c[2] ratios ▪ Comparison to other designs	Low	▪ No delay and LOS ▪ No queues ▪ No signal timing ▪ No corridor effects ▪ No multimodal
Critical movement analysis	Determining initial lane configuration and signal parameters	▪ # of lanes ▪ Hourly TMCs	▪ v/c ratios ▪ Cycle lengths ▪ Queue check	Low	▪ No delay and LOS ▪ No corridor effects ▪ No multimodal
HCM DDI method	Estimating interchange delay and LOS	▪ # of lanes ▪ Hourly TMCs ▪ Signal timing	▪ v/c ratios ▪ Delay and LOS ▪ Queues	Moderate	▪ No corridor effects ▪ No multimodal ▪ No signal timing optimization guidance[3]
Micro-simulation	Evaluating DDI corridor and multimodal performance	▪ # of lanes ▪ Corridor O/D[4] volumes ▪ Signal timing ▪ Corridor data ▪ Ped/bike data	▪ Delays and LOS ▪ Queues ▪ Corridor performanc e ▪ Multimodal	High	▪ No signal timing optimization guidance[5]

1 TMC = turning movement count

2 v/c = volume-to-capacity ratio

3 While the HCM does not contain any optimization routines, commercial implementations of the methods may provide optimization capabilities.

4 O/D = origin-destination

5 Some microsimulation tools offer built-in optimization, while others work in exchange with macro-level tools to provide optimization capabilities.

Chapter 7 Final Design

- *7.1 Vertical Alignment (Part of NCHRP 03-113b)*
- *7.2 Signing and Marking (Part of NCHRP 03-113b)*
- 7.3 Signal Equipment
- 7.4 Signal Timing Parameters
- 7.5 Document Local Practices

Signal Equipment

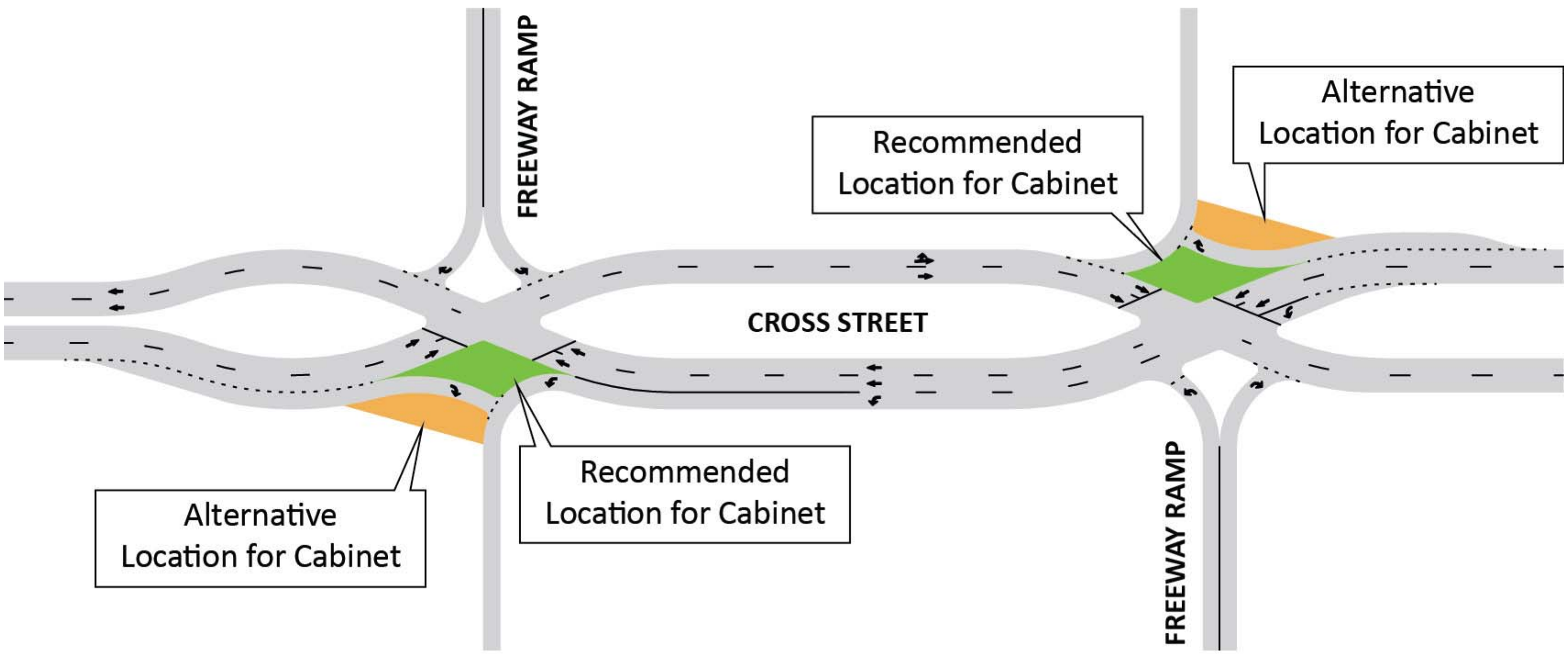
- Signal Cabinet
  - Number of Controllers
  - Other Cabinet Equipment
  - Locating the Cabinet(s)
- Signal Poles and Displays
  - Vehicle Signal Heads
  - Pedestrian Signals
  - Bicycle Signals
- Detection
- Communications
- Preliminary Cost Estimate

Number of Controllers

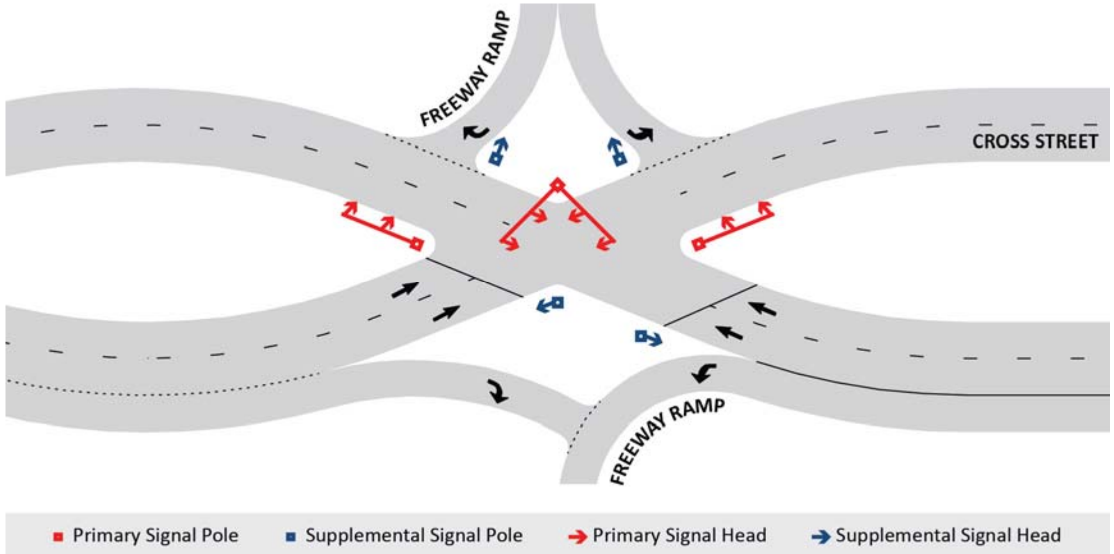
	One Signal Controller		Two Signal Controllers
+	Reduced hardware and installation costs	+	More transparency in signal design and cabinet set-up for designers and technicians
+	Potentially avoids the need for communication infrastructure between crossovers (if no adjacent intersections)	+	Ability to control offsets directly rather than through overlap phases or other programming
+	Improved flow during “free” signal operations (e.g., late night)	+	Easier for technicians to see operations from the cabinet
–	More complicated signal design and cabinet set-up for designers and technicians	+	More room in each cabinet to allow for complicated scenarios (e.g., light rail)
–	More difficult maintenance and troubleshooting for technicians	–	Additional hardware and installation costs
–	Additional wiring required from signal equipment to controller	–	Need for controllers to communicate and potential for time drift that may impact progression
–	More difficult for technicians to see operations at both crossovers from the cabinet	–	May result in undesirable gap-out situations during low-volume periods

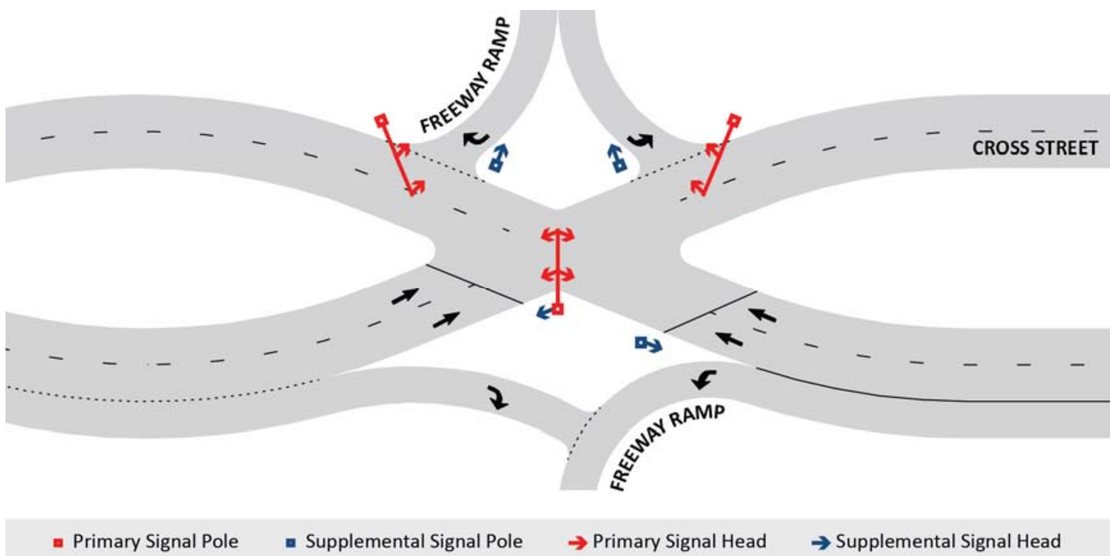
Note: Benefits are shown with a (+) and challenges with a (-).

Locating the Cabinet(s)

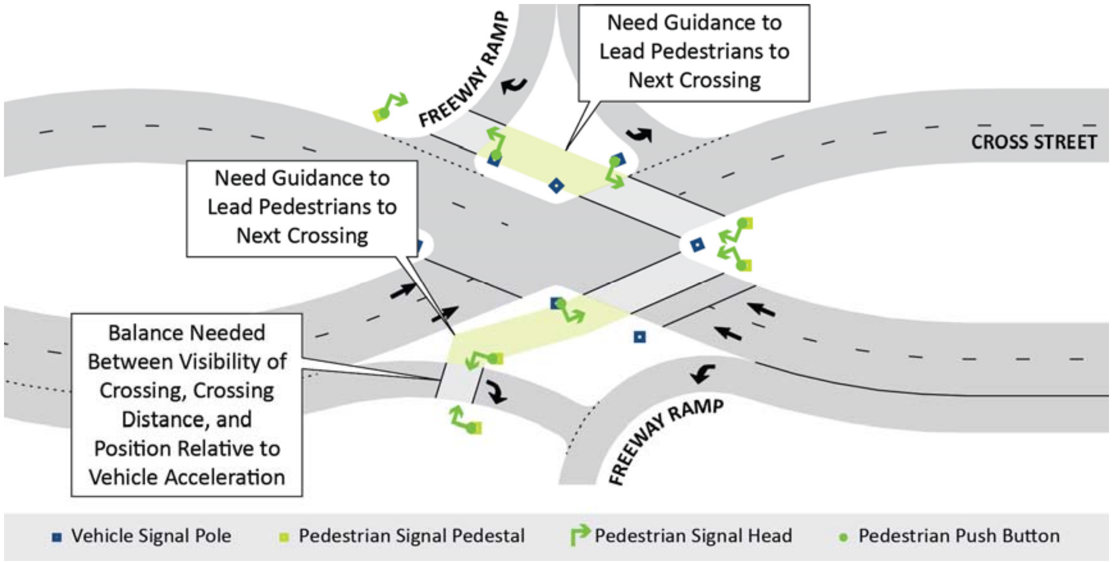


Signal Poles and Displays





Pedestrian Signals



NCHRP 03-113b

An Assessment of **Safety** and **Geometric Design** Criteria for Diverging Diamond Interchanges

June 2016 – June 2018

5th Urban Streets Symposium
May 22, 2017

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NCHRP 3-113b Objective

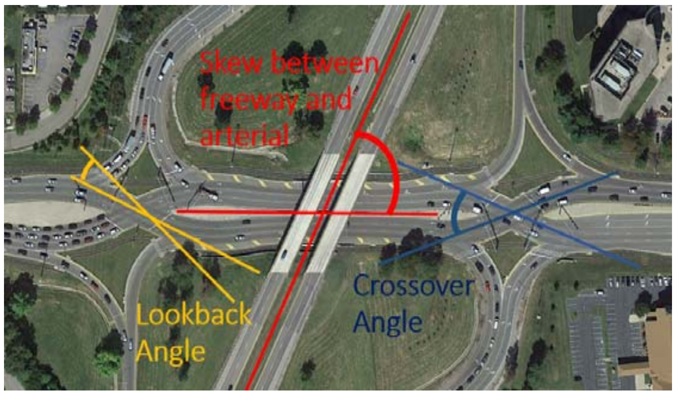
Identify, review, and evaluate the geometric design features and the associated safety and operational performance of in-service DDIs across the U.S.

Schedule and Tasks

			Month	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
	TASK	Start	End	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18
3-113b (Geometrics and Safety)	Phase I of Project	Jun-15	Jan-16																									
	Phase II of Project	Feb-16	Jun-18																									
	1. Inventory of In-Service DDI's	Jun-15	Jul-15							Panel Review and Comment																Panel Review and Comment		
	2. Meet with Stakeholders	Jul-15	Sep-15																									
	3. DDI Design Process Assessment	Aug-15	Sep-15																									
	4. Experiment Design	Sep-15	Oct-15																									
	5. Interim Report and Panel Meeting	Nov-15	Jan-16																									
	6. Data Collection and Analysis	Feb-16	Jan-17																									
	7. Guidelines	Sep-16	Jan-17																									
	8. Guidebook Production	Jan-17	Jun-18																									
REPORTS & MEETINGS																												
Panel Meeting (IP - In person, CC - Conf. Call)											IP																	CC
Quarterly Reports (Q)				Q			Q			Q			Q			Q			Q			Q			Q			Q
Interim Reports (DIR and IR)									DIR		IR																	
Draft/Final Report or Guide (D, F)				F																						D		F

Crossover Intersection

Skews and Angles



Curb Type

Abutment

Curb

Pavement Markings

Pavement markings

Median Widths

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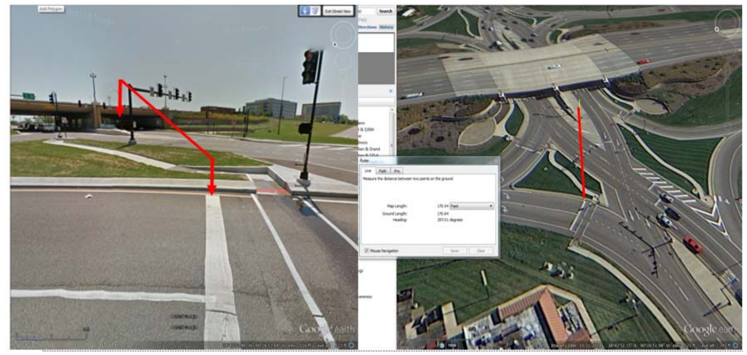
Right Turn Off Freeway

Barrier Height

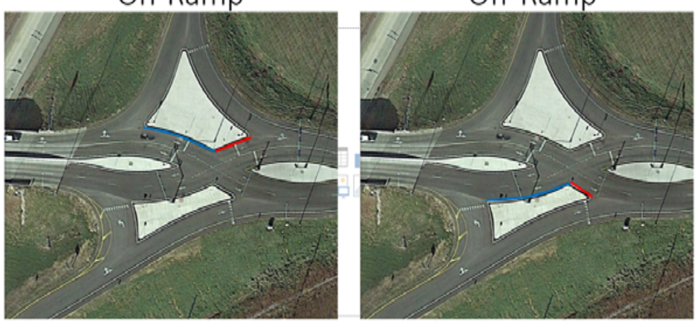
Sight Distance



Setback Distance

On-Ramp

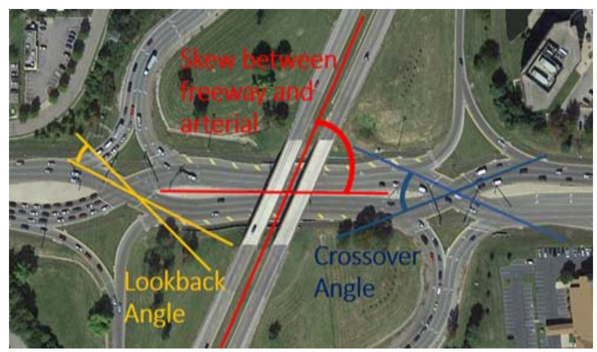
Off-Ramp



Inbound and Outbound

Inbound and Outbound

Lookback Angle



Column Presence

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Left Turn onto Freeway

Curve Radius

Signalization at Pedestrian Crossing

Lane Assignment

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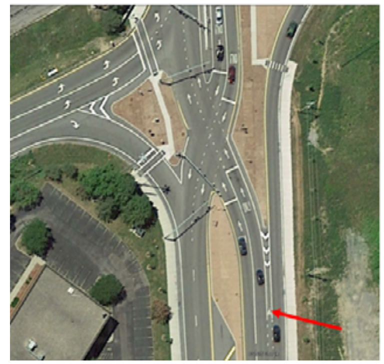
Upstream Left Turn

Upstream Developed Lanes

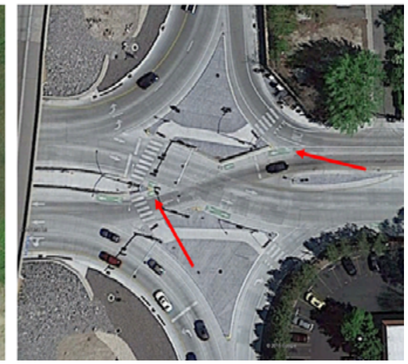
Peds and Bikes

Bike Lanes

Dropped



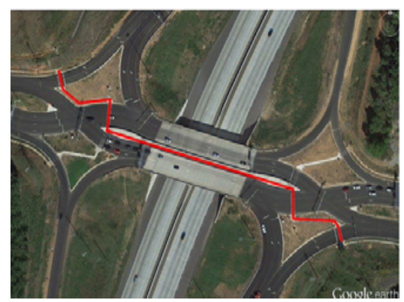
Continuous



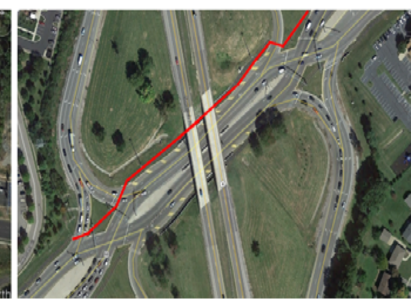
Non-Motorist Access

Pedestrian Services

Inside



Outside



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Design Process

- Provide guidance based on principles and performance checks similar to the Roundabout Design Guide

Design Principle

Crossover – Inbound Path Alignment

Performance Check

“Eye-Brow Test”	Stop Bar Alignment	Design Speed

Design Features

Crossover Angle	Lead-in Tangent Length	Barrier	Markings	Island Gore	Reverse Curve Inbound	Median Width

Contact Information

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