2022 Road Design Conference

Work Zone Safety: Improving Safety in Work Zone Transition Areas

Mischa Kachler
Work Zone Safety Section

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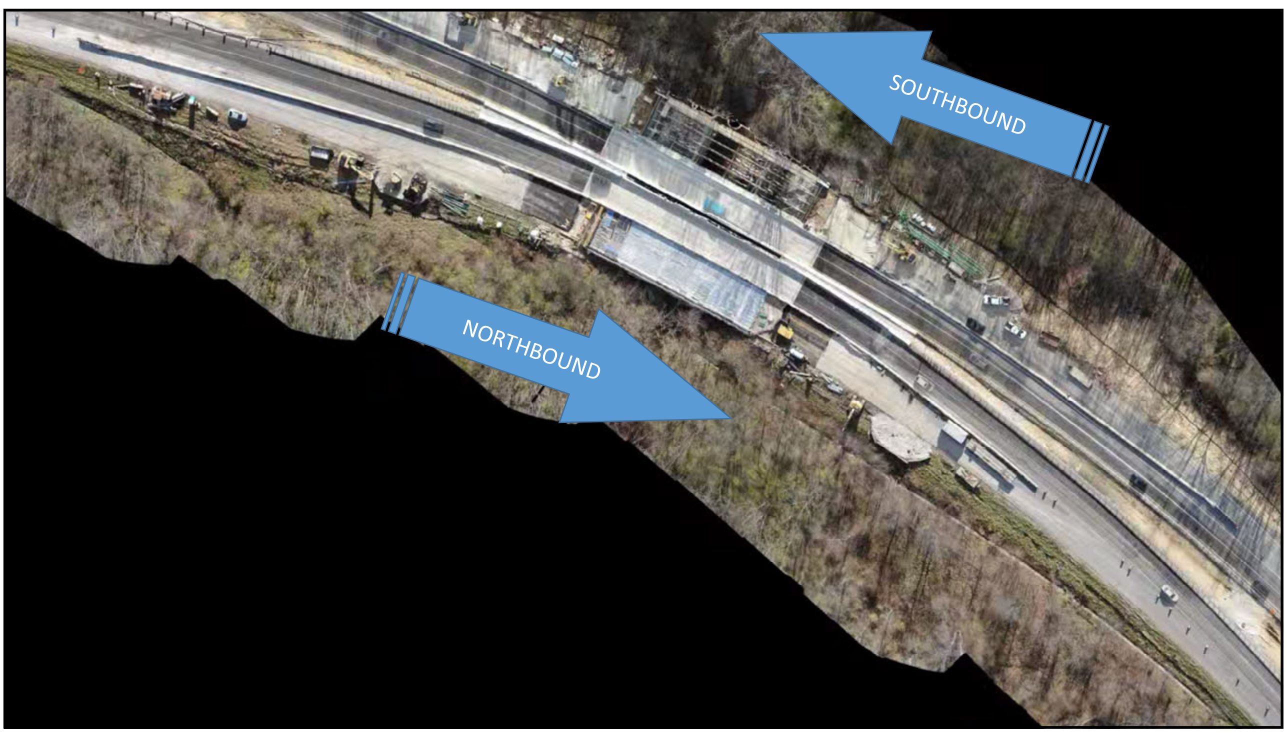

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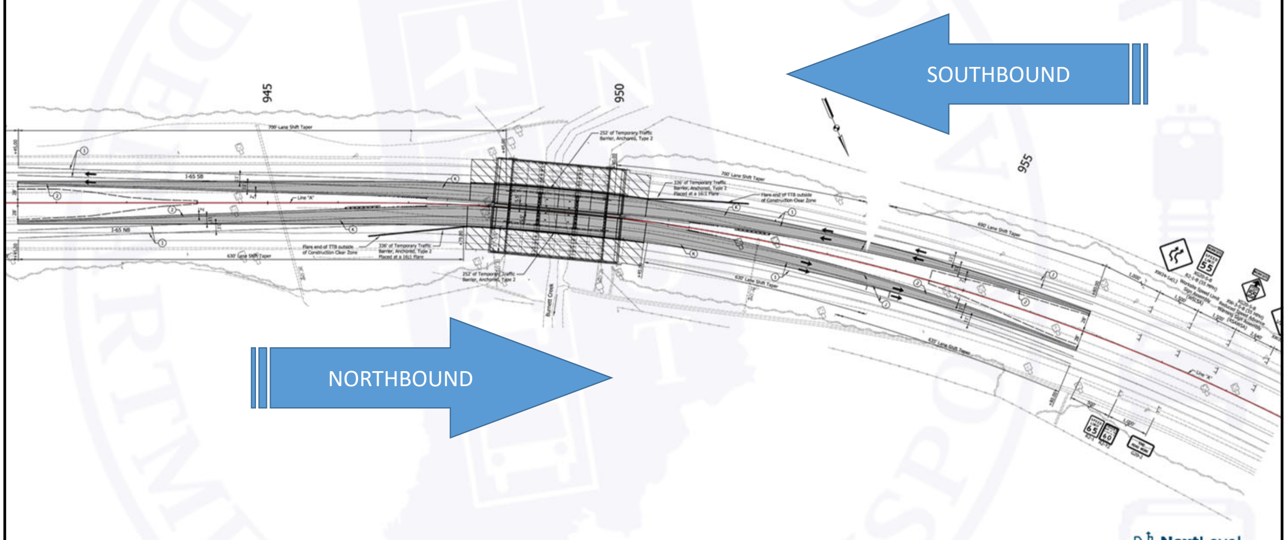
MOT Plan



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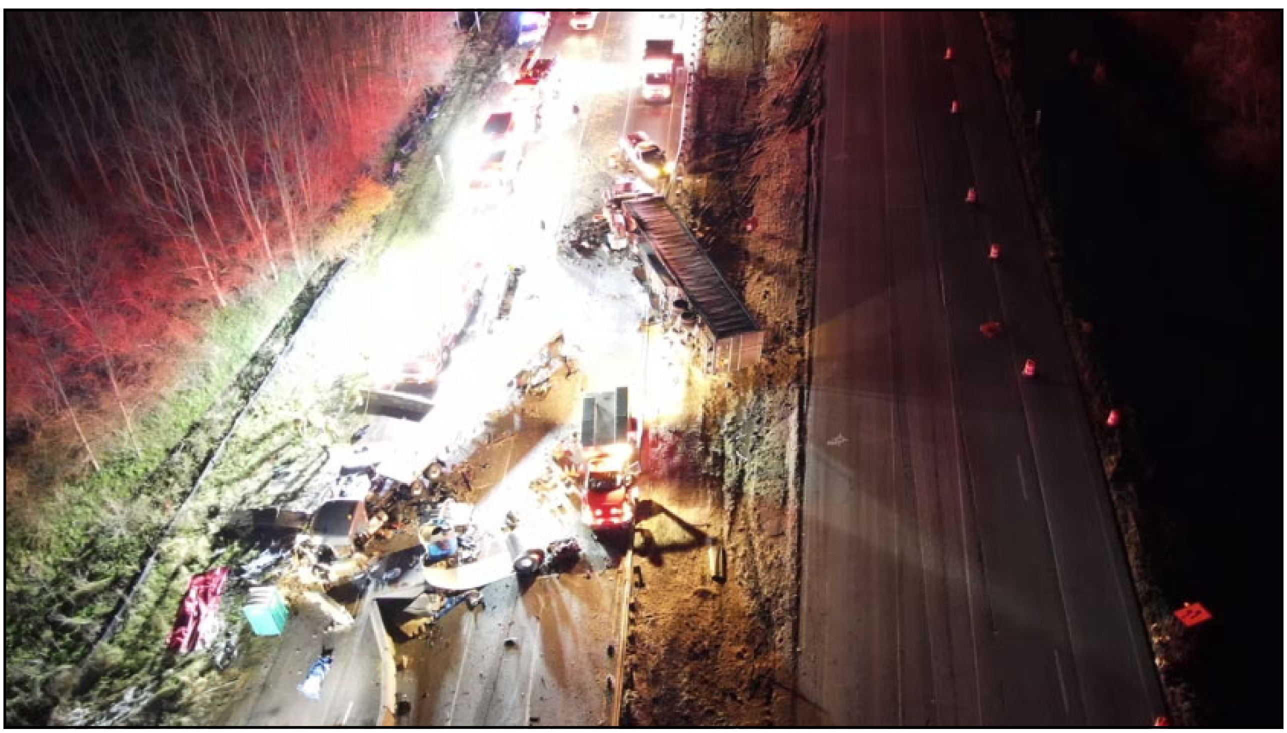

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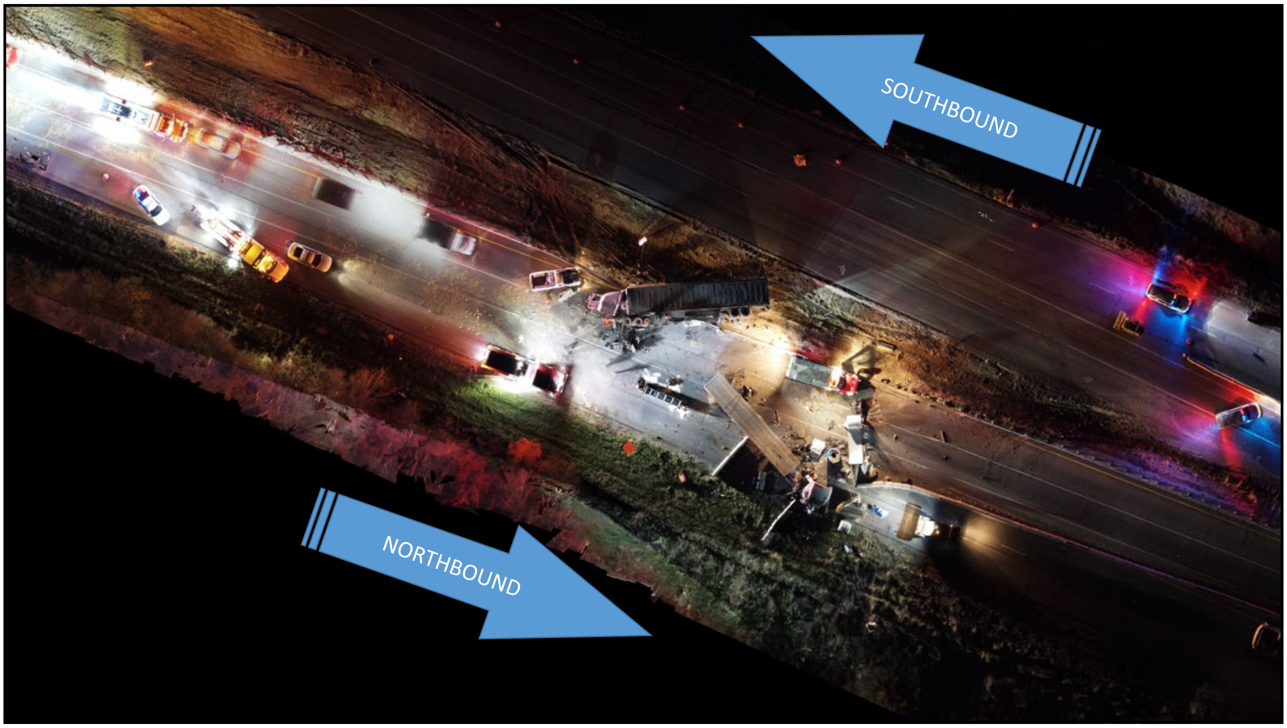

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Earlier…

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i.e., some background first

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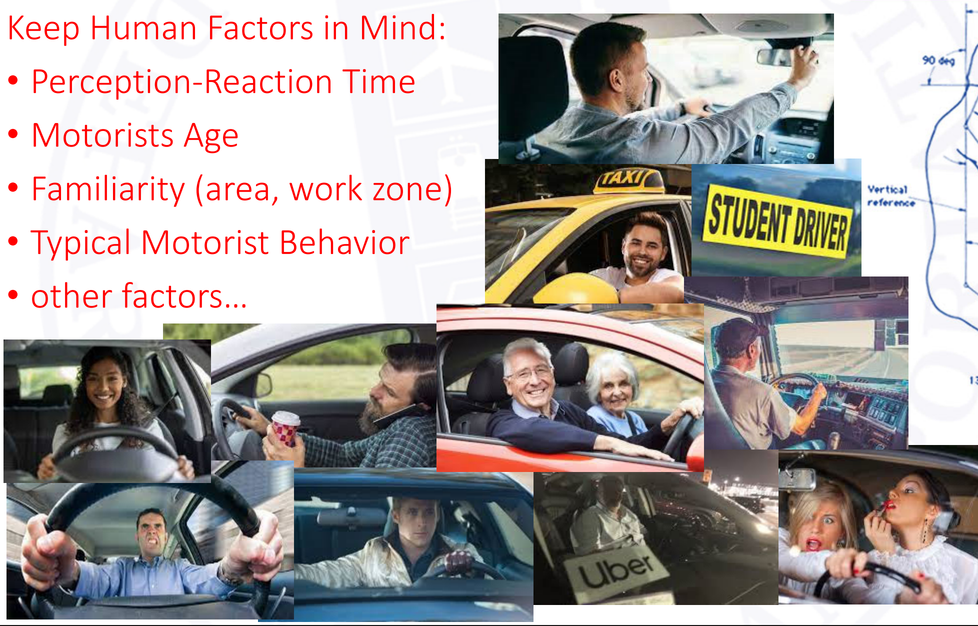
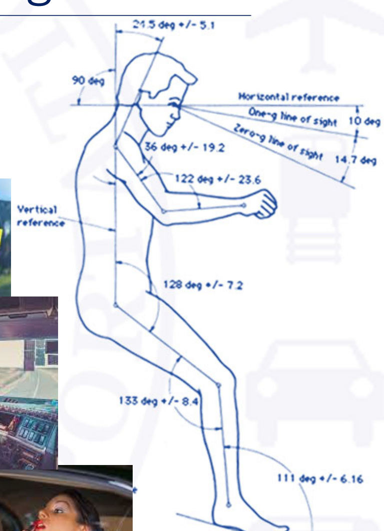
General Considerations for MOT Design

Keep Human Factors in Mind:

- Perception-Reaction Time
- Motorists Age
- Familiarity (area, work zone)
- Typical Motorist Behavior
- other factors…





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General Considerations for MOT Design

TTC should provide clear, positive guidance to

1. Alert motorists
2. Inform motorists
3. Instruct motorists

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General Considerations for MOT Design

- Human Factors
  - Perception-Reaction Time
  - Motorists Age
  - Familiarity (area, work zone)
  - Typical Motorist Behavior
- Provide clear positive guidance
  1. Alert motorists
  2. Inform motorists
  3. Instruct motorists

- Basically:
  - Don't overload motorists
  - Provide smooth transitions
  - NO SURPRISES!

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General Considerations for MOT Design

- Consider Work Zone Strategy (Type) as early as possible.
  → If applicable, involve TMP stakeholders
- For interstates, perform queue analysis as early as possible to guide decision making.
- For interstates, consider the Interstate Highways Congestion Policy as early as possible → queue mitigation strategies.
- Construction Zone Design Speed: desirably same as Design Speed; not arbitrarily reduced; if reduced, desirably, not by more than 10 MPH.
- Consider lane and shoulder widths IDM 503-3.04(02):
  - Off a structure, the "Available Cross Section" extends from ROW to ROW
  - If clear travel width < 12 ft 4 in, Restricted Widths requirements apply
- Consider pavement and shoulder strength and condition.
  → Consider the effect of corrugations

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Parts of a Work Zone (a brief review)

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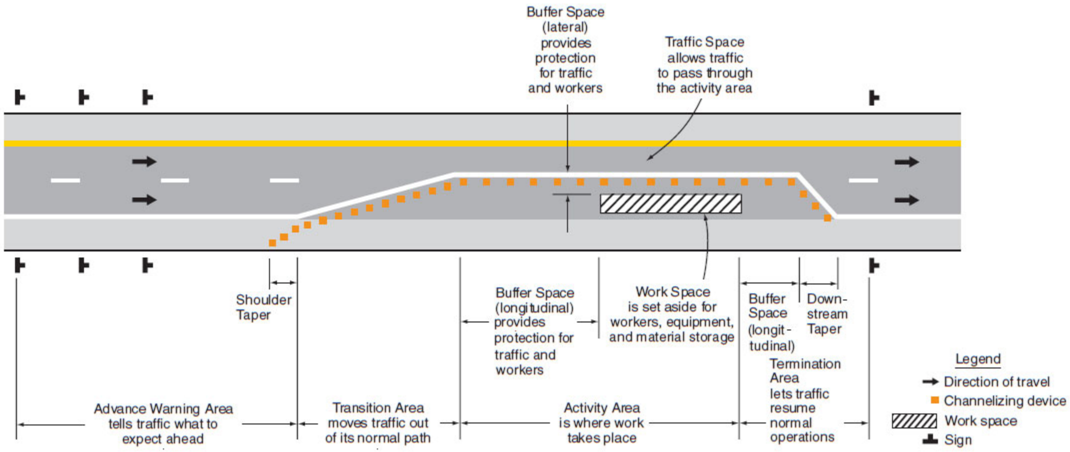
Parts of a Work Zone



Source: MUTCD

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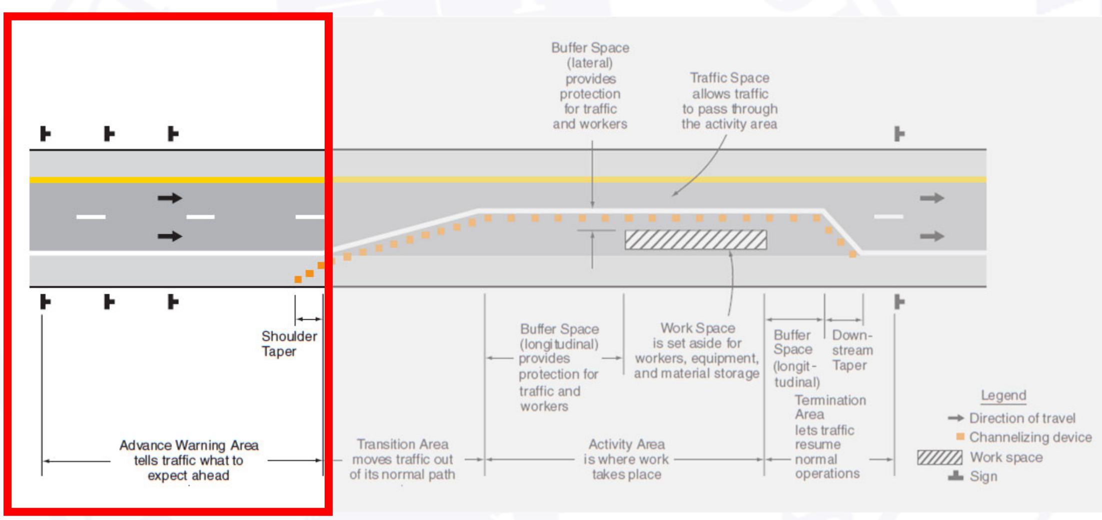
Parts of a Work Zone: Advance Warning Area



Source: MUTCD

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Advance Warning Area

- First opportunity to provide clear positive guidance
  1. Alert motorists
  2. Inform motorists
  3. Instruct motorists

- Advance Signing with Warning Lights
  → Provide the minimum required separation distance between signs
- Speed Limit Reduction (Worksite Speed Limit)
- PCMS (Stand alone or part of Queue Detection and Warning System)
- Buzz Strips
  → Always immediately follow with guidance for the motorist
- Consider Presence Lighting to provide additional conspicuity at night

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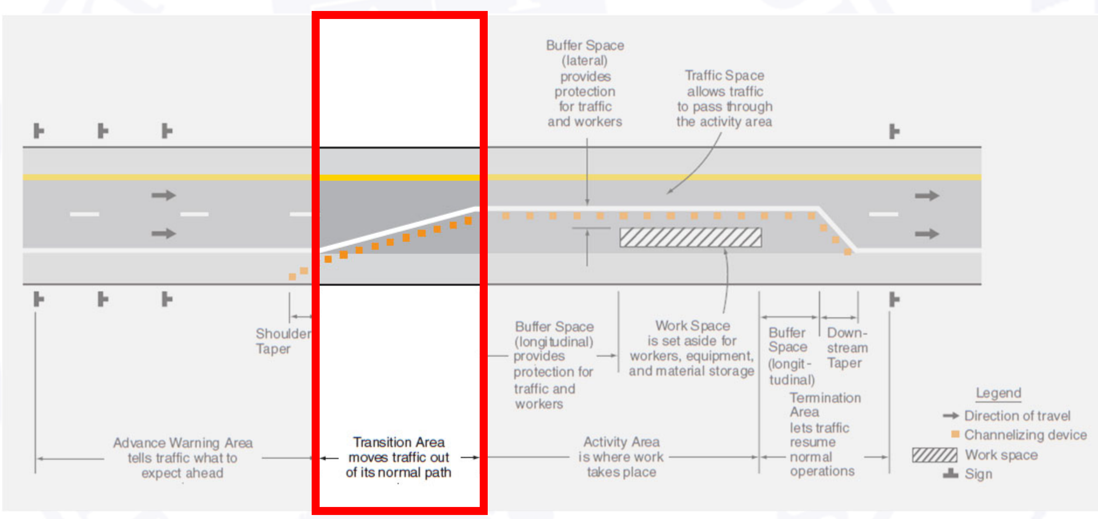
Parts of a Work Zone: Transition Area



Source: MUTCD

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Transition Area

- Areas of the work zone where road users are directed out of their normal path:
  - Lane Merges and Lane Shifts
  - Lane Width Reductions
  - Cross Overs and Diverging/Converging Lanes
- First transition area into work zone will have greatest speed differential
  → Elongate transition tapers using upstream non-work zone speed limit
- Consider how large vehicles (trucks) will be affected by transition area
  → Provide additional space through transition areas
- Remember: multi-lane lane shifts require temporary lane markings, regardless how short the duration
- Provide a tangent length between successive tapers:
  → 2L tangent for a merge taper followed by a merge taper. (IMUTCD TA-37)
  → ½L tangent for a merge taper followed by a lane shift. (IMUTCD TA-32)

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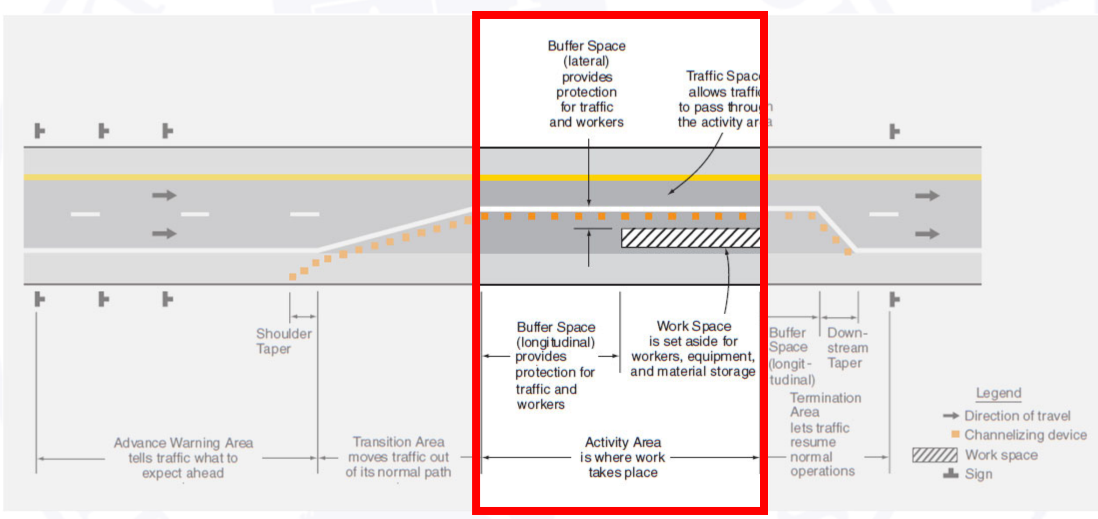
Parts of a Work Zone: Activity Area



Source: MUTCD

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Always Provide an SSD-Based Long. Buffer Space*

* Unless there is a justifiable reason for not doing so

- Often not provided in MOT plans or of insufficient length
- IMUTCD 6C.06 and Table 6C-2

Table 6C-2 Stopping Sight Distance as a Function of Speed

Speed (mph)	Distance (ft)
20	115
25	155
30	200
35	250
40	305
45	360
50	425
55	495
60	570
65	645
70	730
75	820

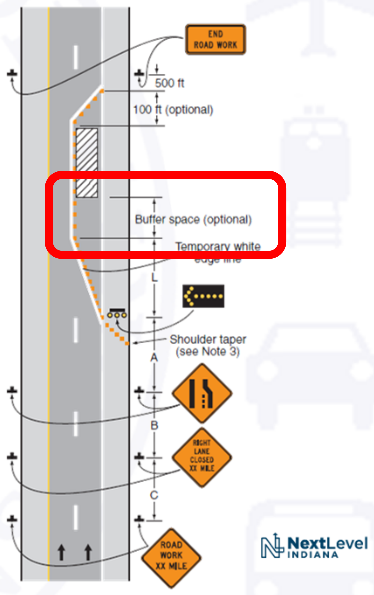

Figure 6H-33. (TA-33)

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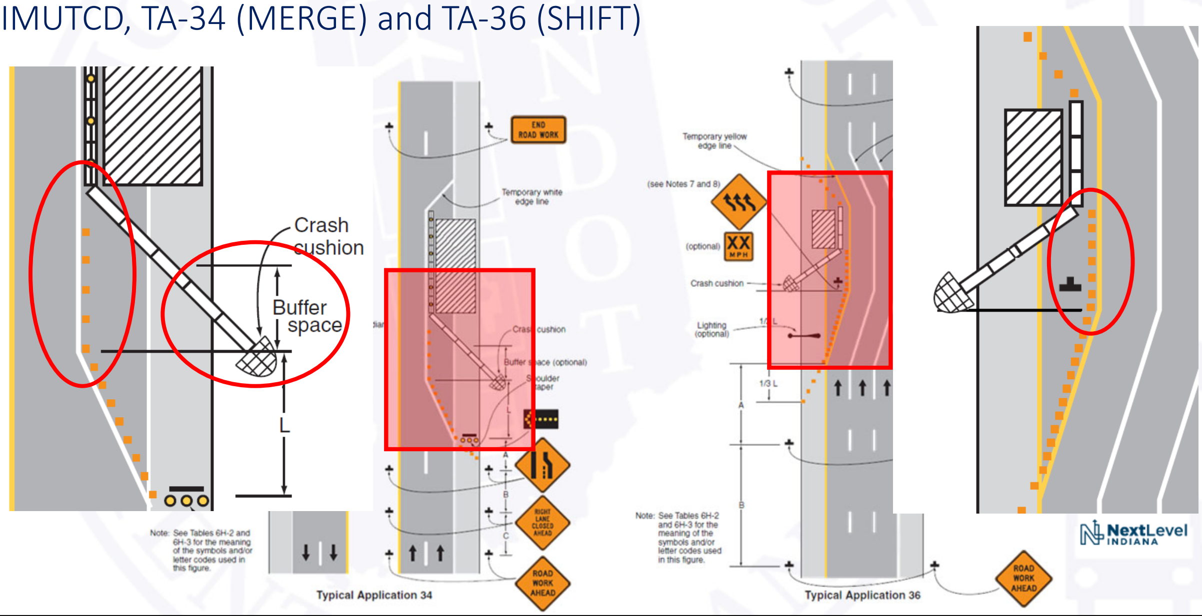
Delineation at Temporary Traffic Barrier Flares

- IMUTCD, TA-34 (MERGE) and TA-36 (SHIFT)



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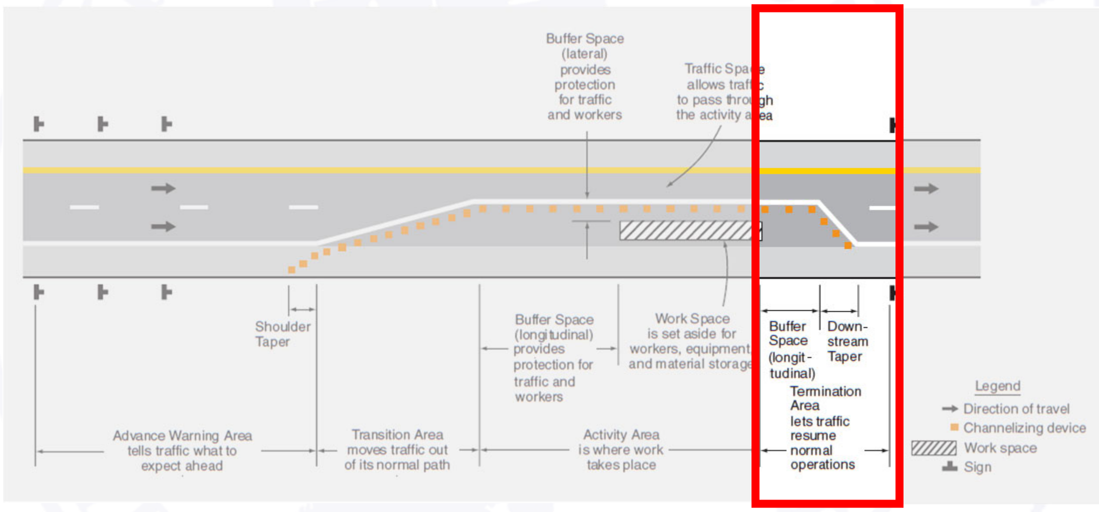
Parts of a Work Zone: Termination Area



Source: MUTCD

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Improving Safety in Transition Areas

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Separate Transitions

- Do not combine transition areas:
  - 😩 A merge and lane shift taper.
  - 🤢 Even worse: merge + shift + lane width reduction
  - 🤮 Even worse: merge + shift + lane width reduction ending at end of TTB flare
- Avoid transitions near or within:
  - Horizontal and vertical curves
  - System Interchanges/Entrance ramps
  - Points of ingress/egress to construction area
  - Other factors
- If possible, provide a tangent length between successive transition areas.

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Improve Transitions Into and Within the Work Zone

- Use longer tapers into the work zone by using the upstream existing Speed Limit.
- Provide additional lane width (NOT LESS!) through transitions
  - lane width reduction → use staggered lane lines
  - multi-lane shifts → use staggered lane lines
  - cross-overs → staggering works for curves, too
- Provide sufficient shoulder width (lateral buffer space) – optimally, 2 ft minimum
- Delineate merge and shift tapers with construction drums and pavement markings – NOT TEMPORARY TRAFFIC BARRIER (TTB)!
- Provide longitudinal Buffer Space based on SSD to allow errant vehicles space to recover → Especially after merge tapers and BEFORE TTB!
- Consider nighttime presence lighting of transition areas.

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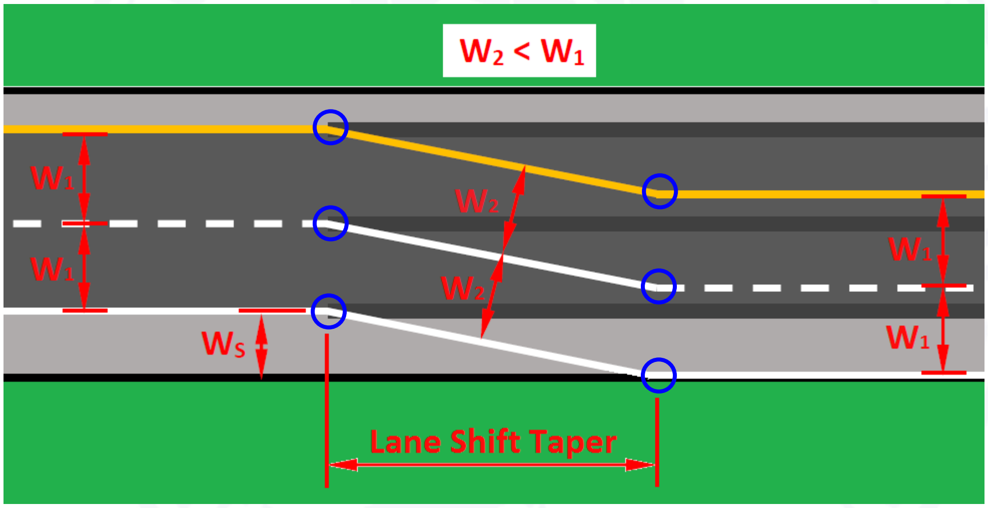
Widen Lanes through Shifts by Staggering the Start

- If all lanes start at same station, lane width decreases through shift!



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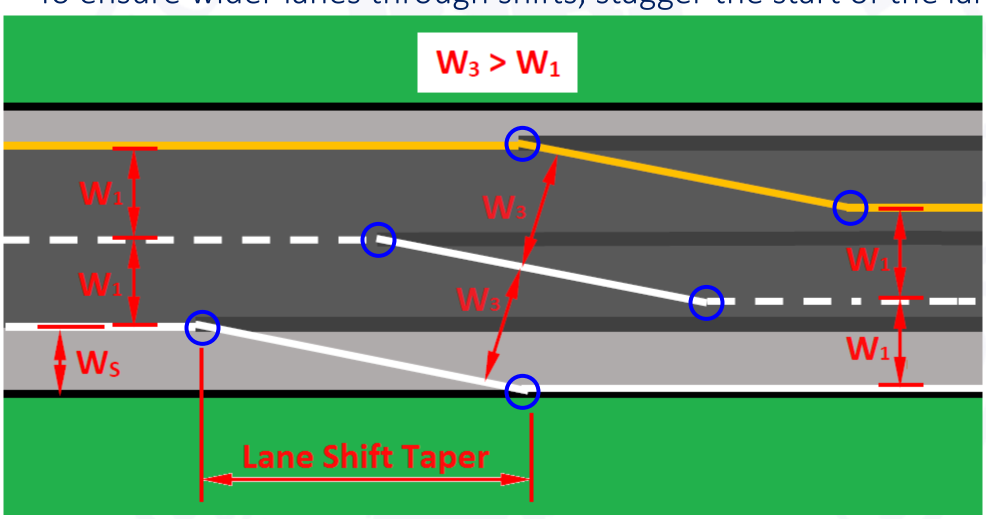
Widen Lanes through Shifts by Staggering the Start

- To ensure wider lanes through shifts, stagger the start of the lane shift lines.



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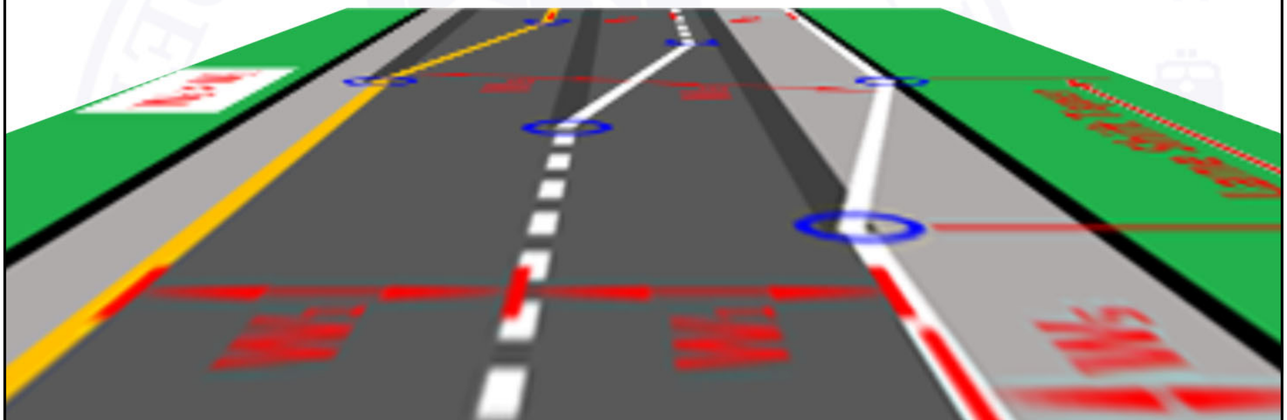
Widen Lanes through Shifts by Staggering the Start



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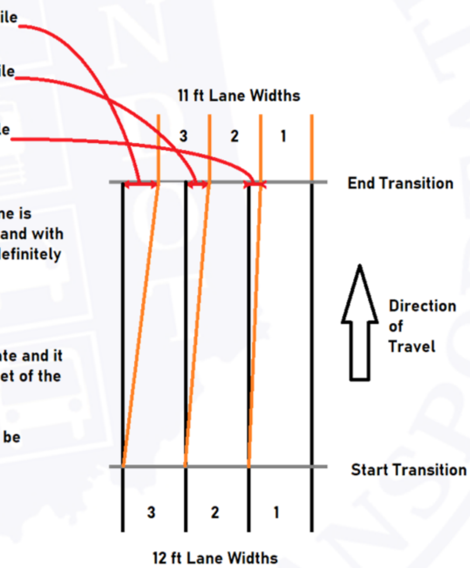
Lane Width Reduction

For a 1 ft lane reduction on all lanes...

Lane 3 experiences a 3 ft lane shift while undergoing the 1 ft restriction.

Lane 2 experiences a 2 ft lane shift while undergoing the 1 ft restriction.

Lane 1 experiences a 1 ft lane shift while undergoing the 1 ft restriction.



When lane widths are reduced, each lane is being shifted, but by different amounts and with different taper rates. These are most definitely lane shifts.

By applying the stagger:

(1) all lanes will have the same taper rate and it will be the appropriate rate for the offset of the shift.

(2) through the transition the lanes will be wider and a consistent width.

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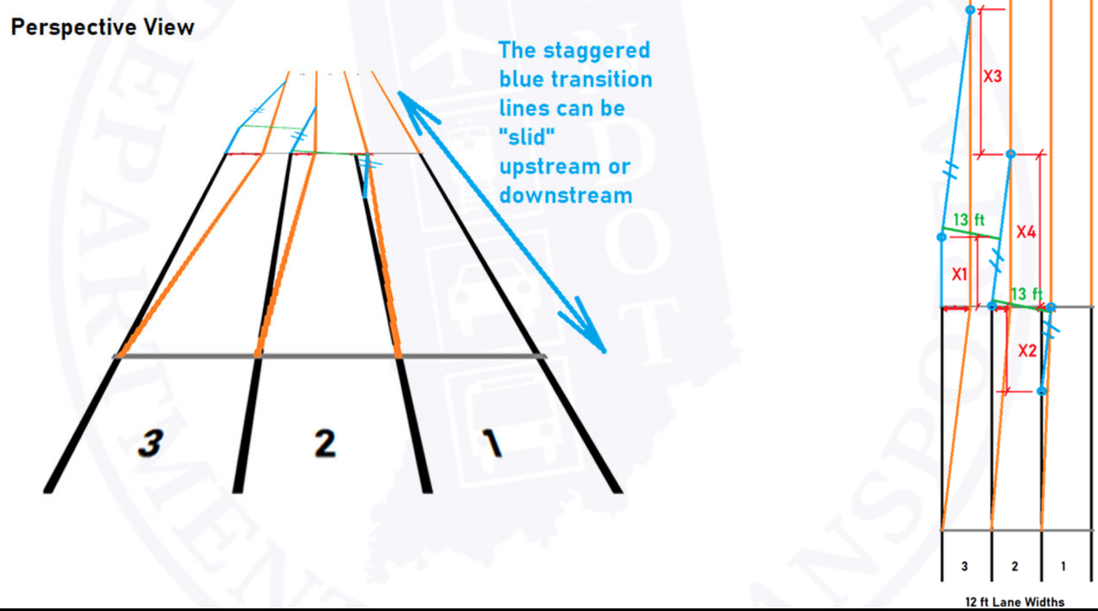
Staggered Lane Width Reduction



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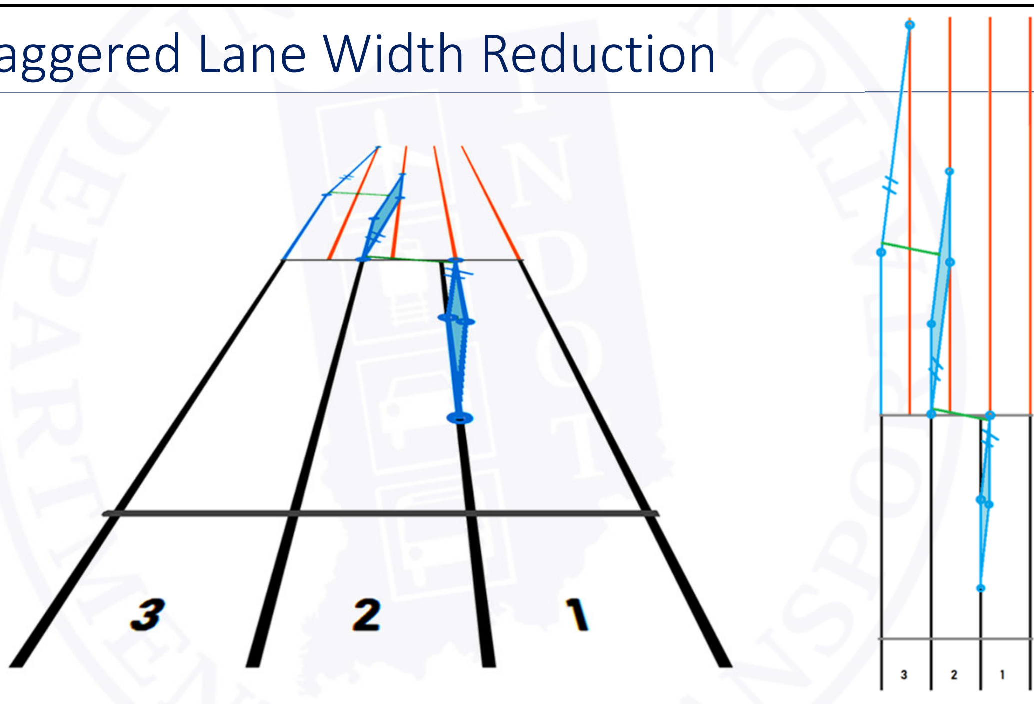
Staggered Lane Width Reduction



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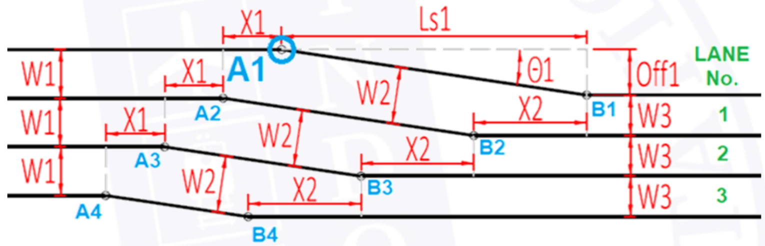
Stagger Distances to Provide 13 ft wide Transition



- If upstream and downstream lane widths are the same, then use 40 ft staggers. (for W1=W3; X1 = X2 = 40 ft)
- If upstream and downstream lane widths differ by up to 1 ft, then use a combination of 40 ft and 80 ft staggers. (for W1=W3+1 ft; X1 = 40 ft; X2 = 80 ft)
- Otherwise, determine stagger via CAD or computation.

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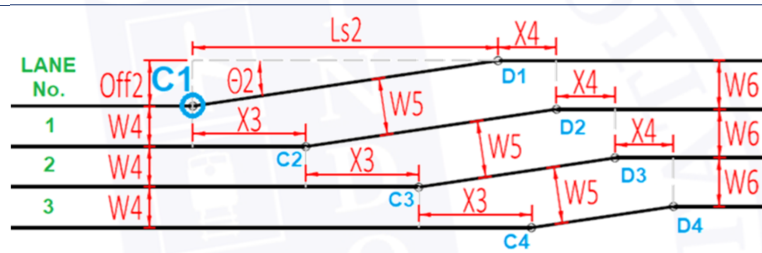
Stagger Distances to Provide 13 ft wide Transition



- If upstream and downstream lane widths are the same, then use 40 ft staggers. (for W4=W6; X1 = X2 = 40 ft)
- If upstream and downstream lane widths differ by up to 1 ft, then use a combination of 80 ft and 40 ft staggers. (for W6=W4+1 ft; X3 = 80 ft; X4 = 40 ft)
- Otherwise, determine stagger via CAD or computation.

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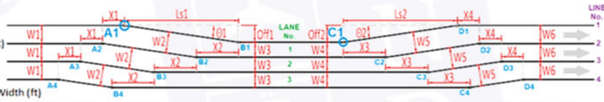
Stagger Distance Computation

STAGGER DISTANCE COMPUTATION

- S = Speed (MPH)
- Off = Offset (ft)
- Ls = Lane Shift Taper Length (ft) = ½ × S × Off
- W_T = Transition Lane Width (ft)
- W_L = Up- or Downstream Lane Width (ft)
- $\Theta = \tan^{-1}\left(\frac{Off}{L_s}\right)$
- X = Stagger Distance (ft) $= \left(\frac{W_T}{\sin(\Theta)}\right) - \left(\frac{W_L}{\tan(\Theta)}\right)$



- W1 = Upstream Lane Width (ft)
- W2 = Lane Width thru upstream transition (ft)
- W3 = Lane Width after upstream transition (ft)
- X1 = Stagger Distance entering upstream transition (ft)
- X2 = Stagger Distance exiting upstream transition (ft)
- W4 = Lane Width before downstream transition (ft)
- W5 = Lane Width thru downstream transition (ft)
- W6 = Downstream Lane Width (ft)
- X3 = Stagger Distance entering downstream transition (ft)
- X4 = Stagger Distance exiting downstream transition (ft)

Yellow fields are for User Input: Example

TRANSITION TO RIGHT (UPSTREAM TRANSITION IN DIAGRAM)

S	(MPH)	
Off1	(ft)	

Ls1	(ft)	0
Θ1	(Rad)	

Pt	(Sta)	(Offset)
A1		

Lane (#)	W1 (ft)	W2 (ft)	W3 (ft)	X1 (ft)	X2 (ft)
1					
2					
3					

Ls (ft)	Off (ft)
0	0.0

Line (#)	A	(Sta)	(Offset)	B	(Sta)	(Offset)
1	A1	0+000.00	0.00	B1	0+000.00	0.00
2	A2		0.00	B2		0.00
	A3			B3		
	A4			B4		

TRANSITION TO LEFT (DOWNSTREAM TRANSITION IN DIAGRAM)

S	(MPH)	
Off1	(ft)	

Ls1	(ft)	0
Θ2	(Rad)	

Pt	(Sta)	(Offset)
C1		

Lane (#)	W4 (ft)	W5 (ft)	W6 (ft)	X3 (ft)	X4 (ft)
1					

Ls (ft)	Off (ft)
0	0.0

Line (#)	C	(Sta)	(Offset)	D	(Sta)	(Offset)
1	C1	0+000.00	0.00	D1	0+000.00	0.00
2	C2		0.00	D2		0.00

Coming Soon!

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Transition Along Curve – Why Avoid?

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Transition Along Curve

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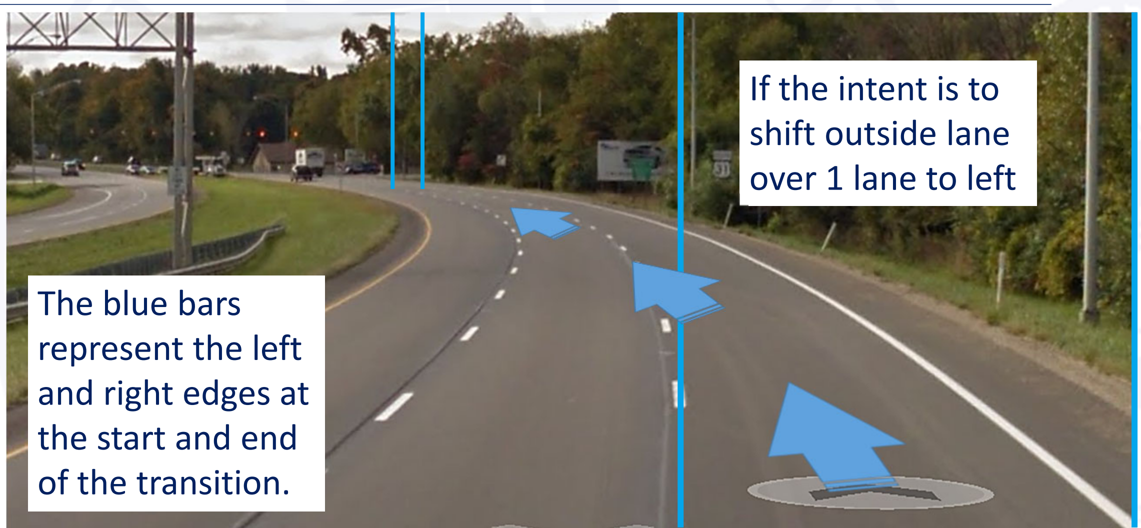
Transition Along Curve



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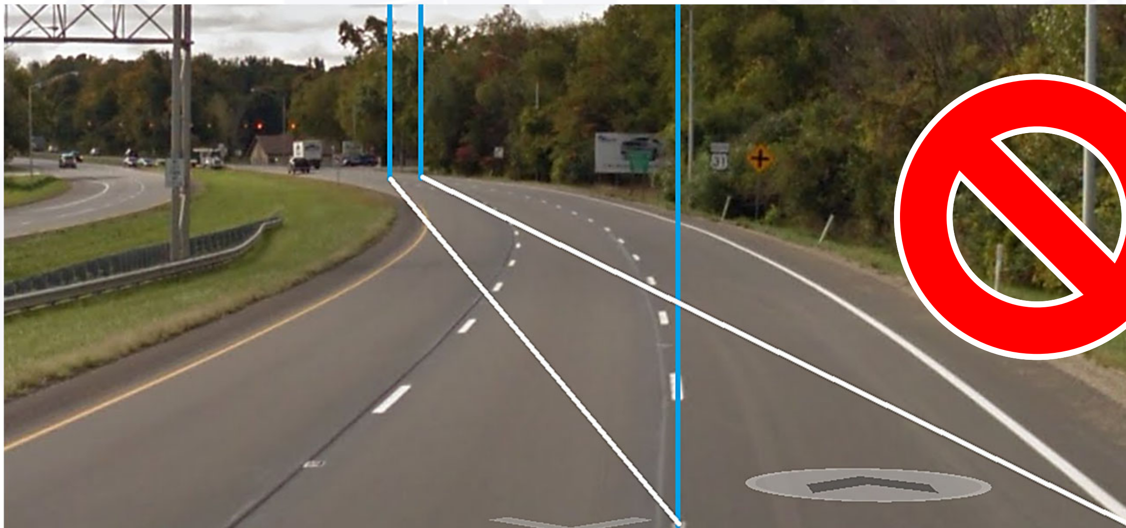
Straight Line Transition Along Curve



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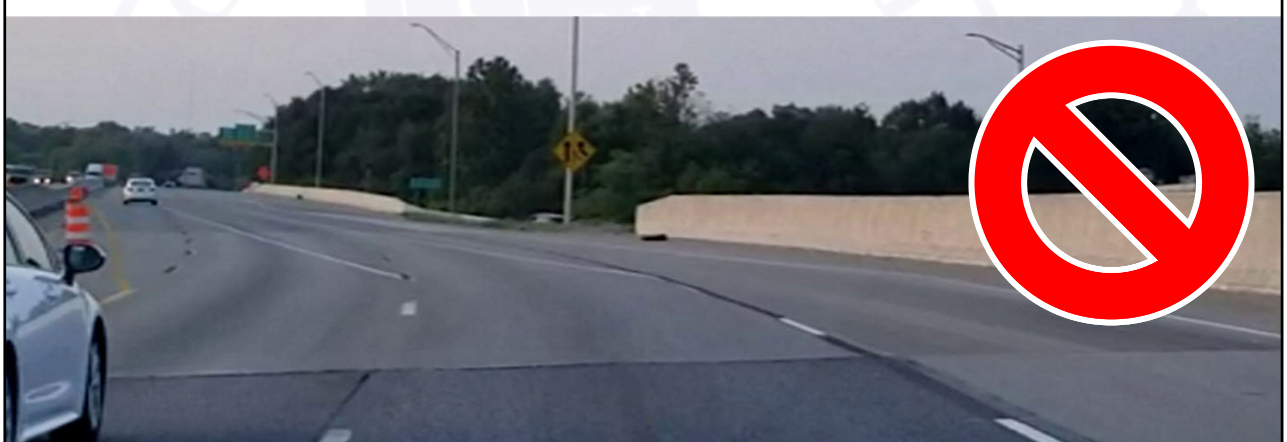
Straight Line Transition Along Curve



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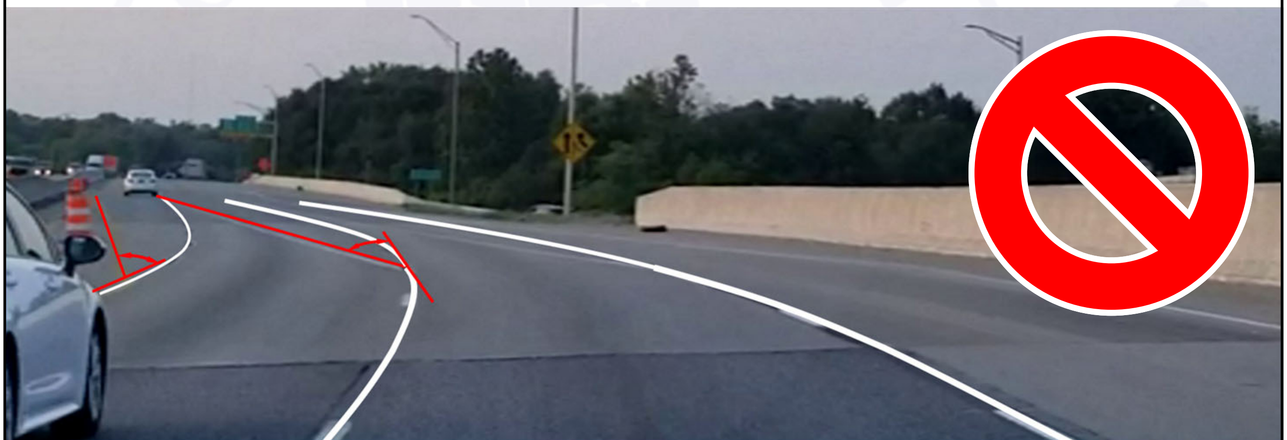
Straight Line Transition Along Curve



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Linear Transition Along Curve (Spiral) - Theoretical

If possible, it is still preferable to relocate shift off the curve to a tangent section.

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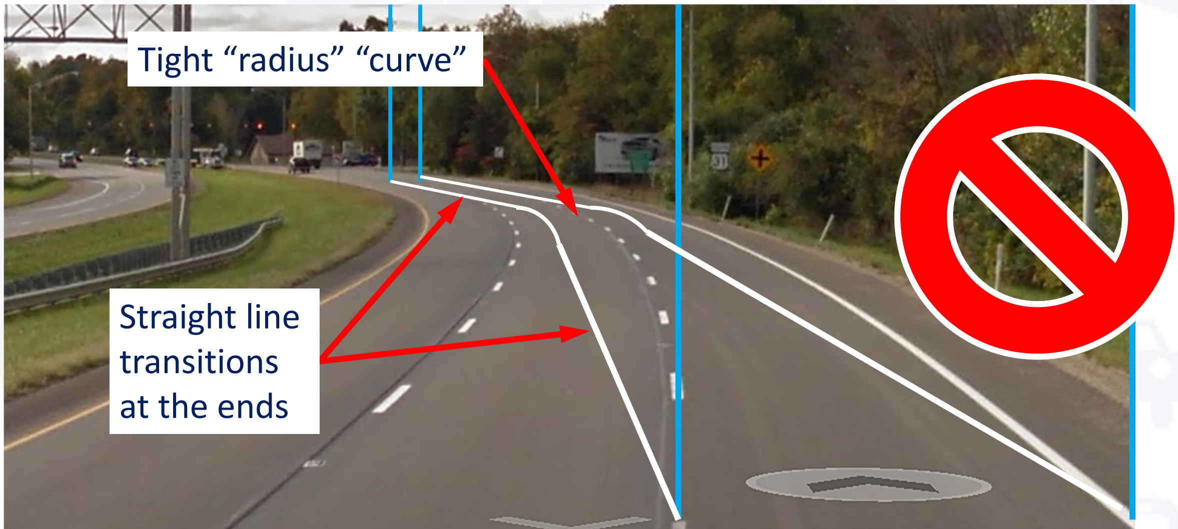
Linear Transition Along Curve (Spiral) - Reality



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Single Radius Curve Transition (Compound Curve)

- Tangent at both ends of the transition curve: very smooth

If possible, it is still preferable to relocate shift off the curve to a tangent section.

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Transition Areas Case Study

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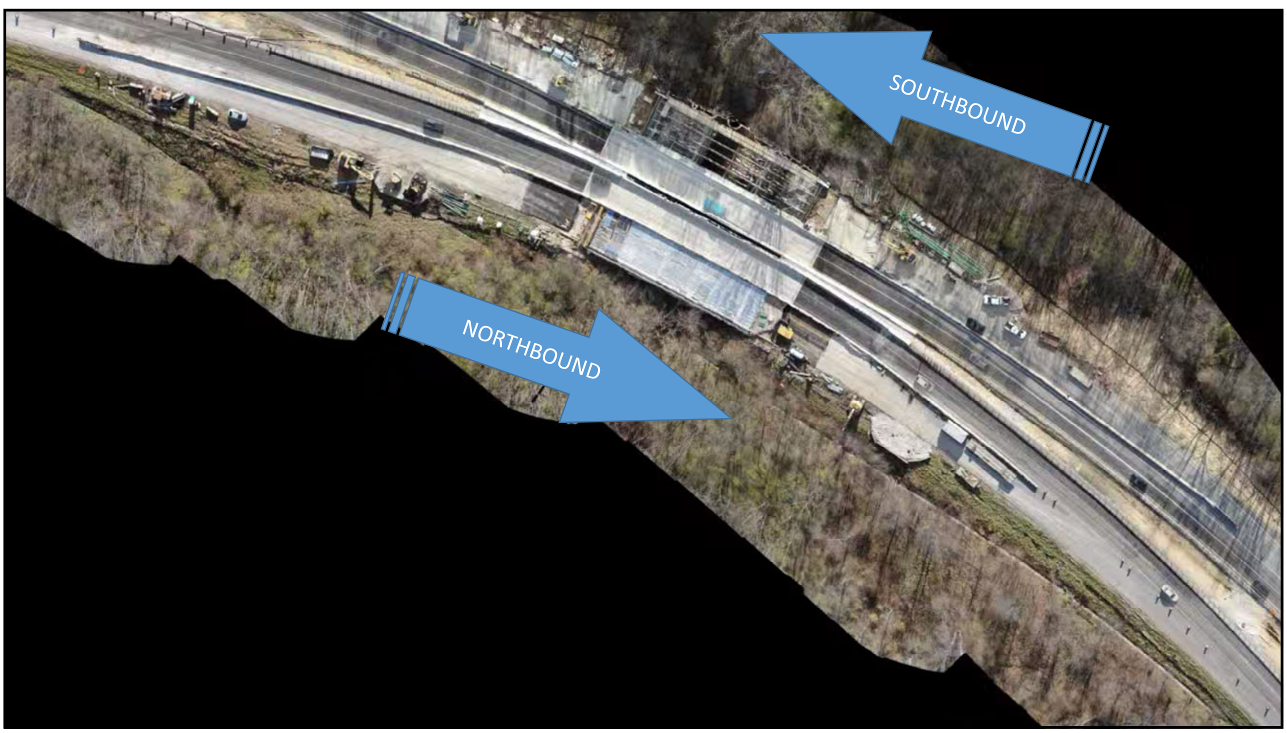

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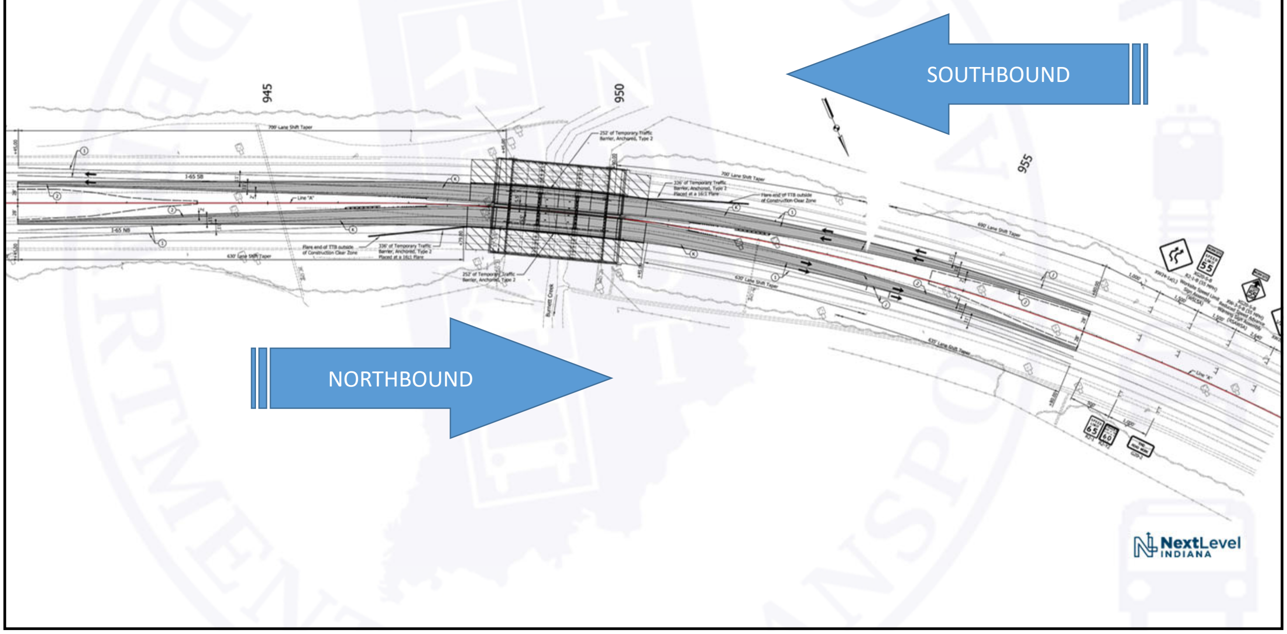
MOT Plan



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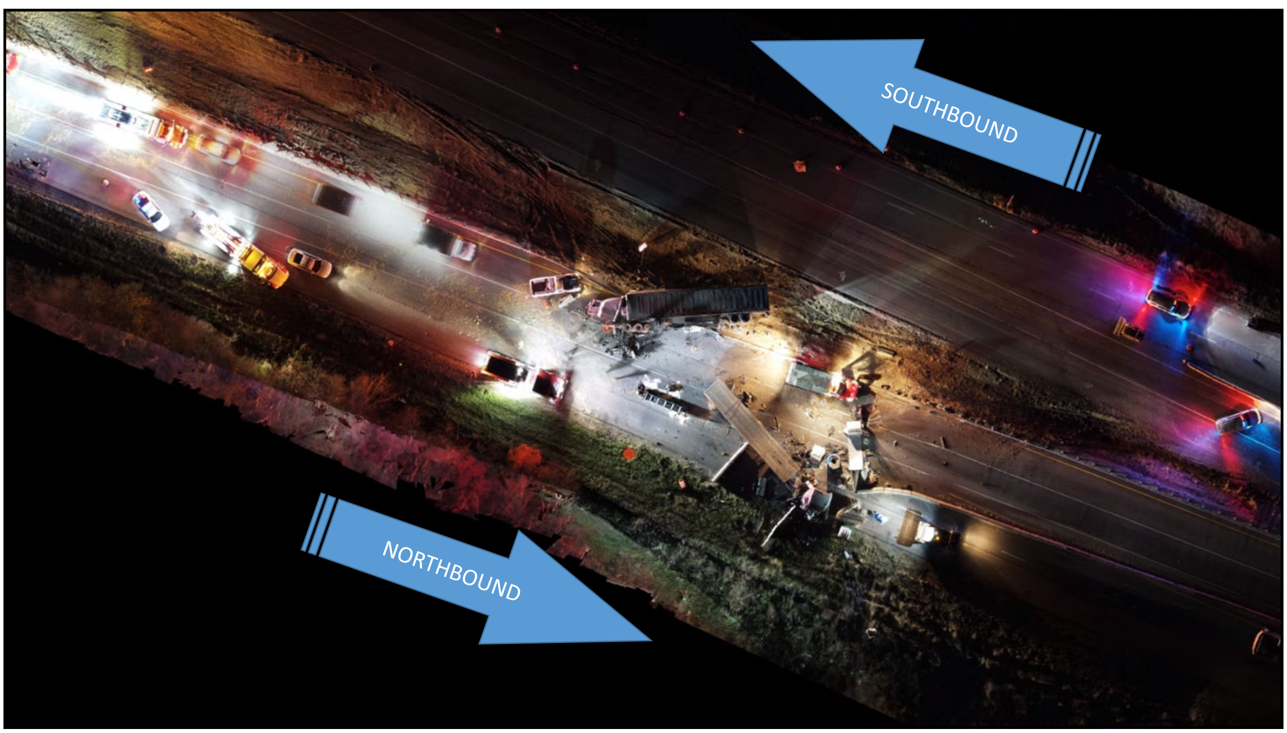

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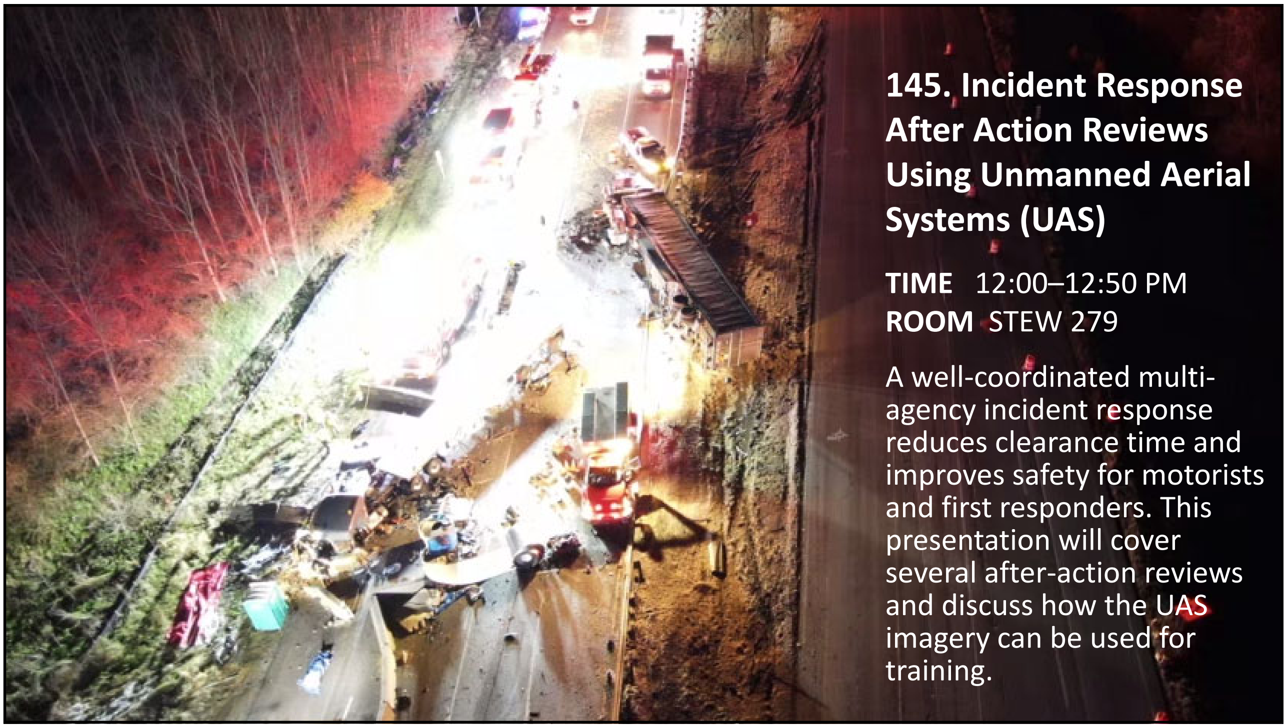

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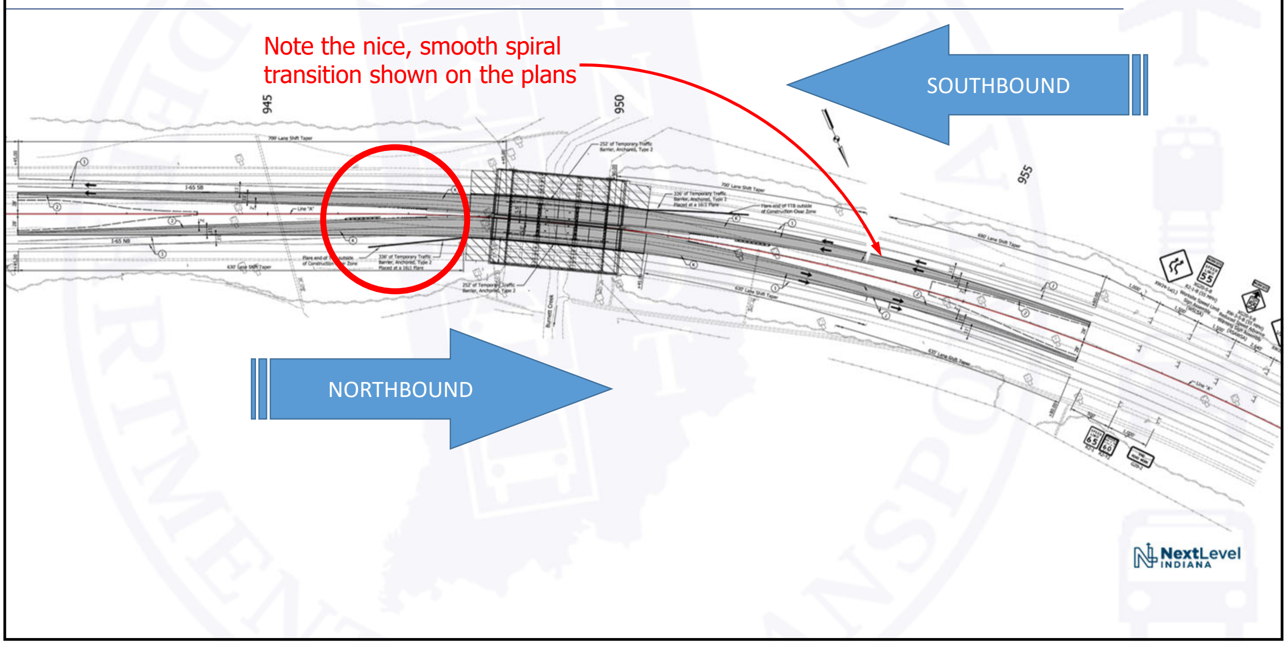
MOT Plan – Crash Location



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Work Zone Conditions

- Narrow Lane Width Across Structure
- Narrow Shoulder/Buffer Width Across Structure
- Lane Width Transition in combination with Lane Shift Taper
- TTB Along Transitions
- Along Horizontal Curve
- Along Vertical Curve
- Long, straight, flat stretch of roadway preceded work site
- Traffic Speeds above posted limit
- Rural Area, Dark at Night

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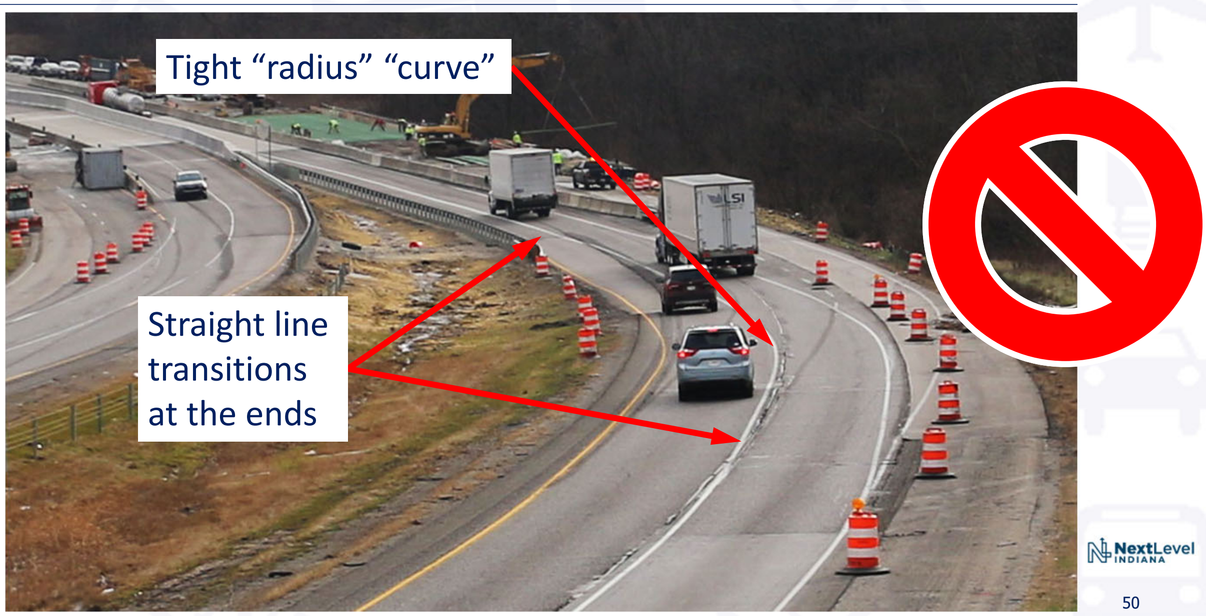
Linear Transition Along Curve (Spiral) - Reality



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Braking Mid-curve

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Difficulty Staying in Lanes; Braking

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Packed Tight with Trucks

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Upstream Approach and Descent into Work Zone

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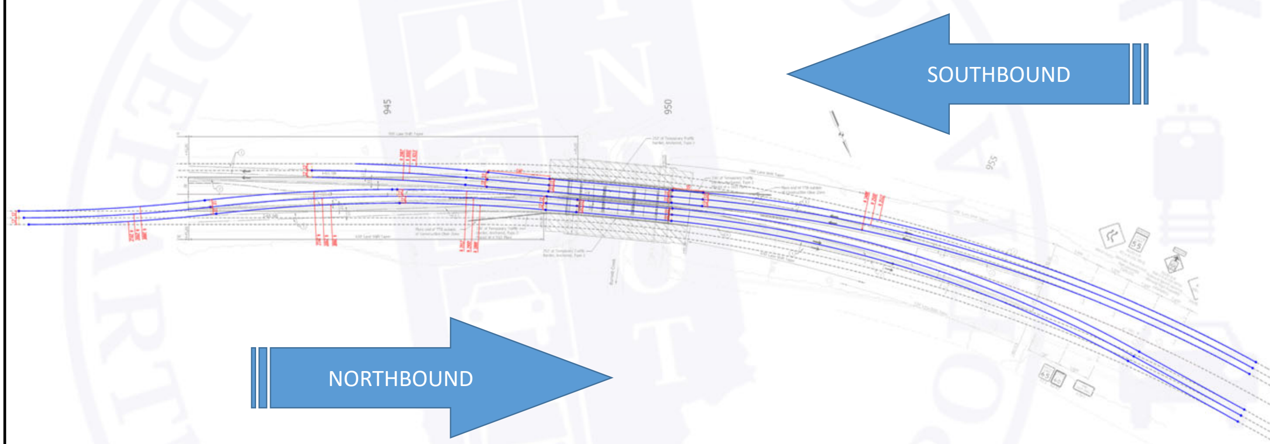
What else could be done? For consideration:



- Southbound recommendations were feasible during construction.
- Northbound geometry was not feasible given the current configuration of construction but may have been possible with planning.

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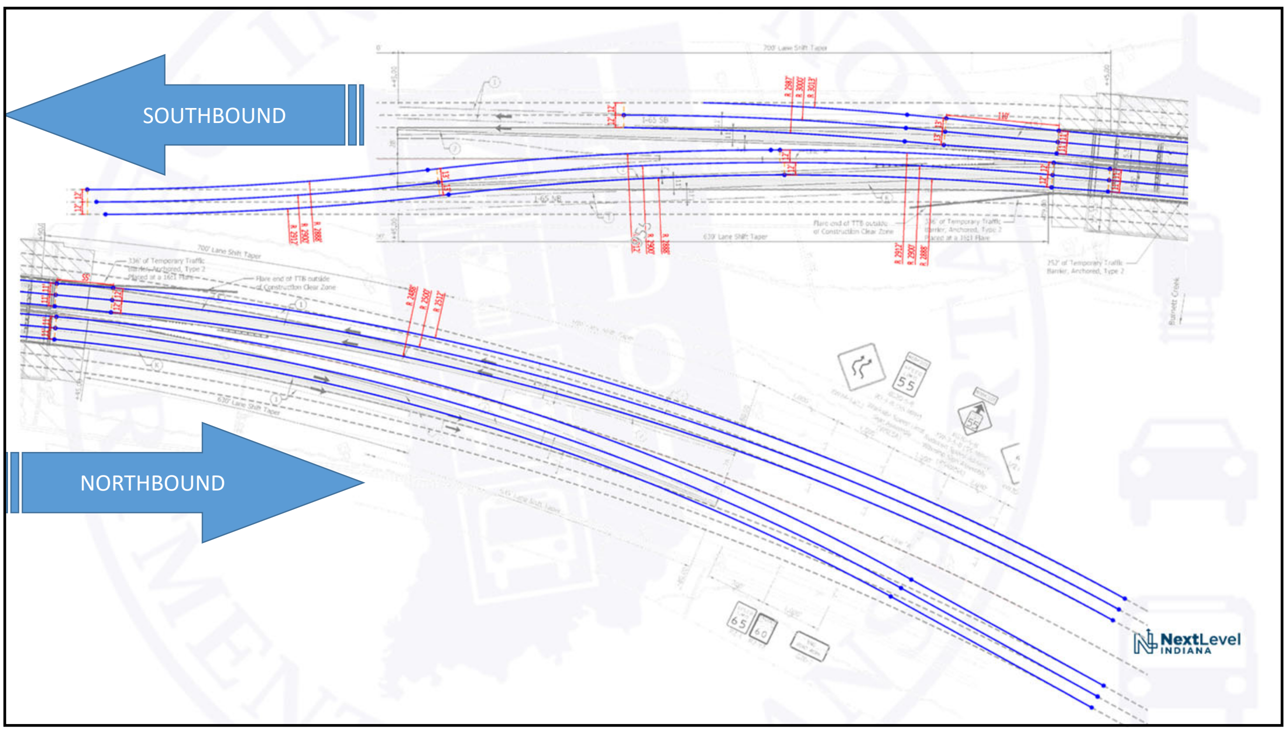

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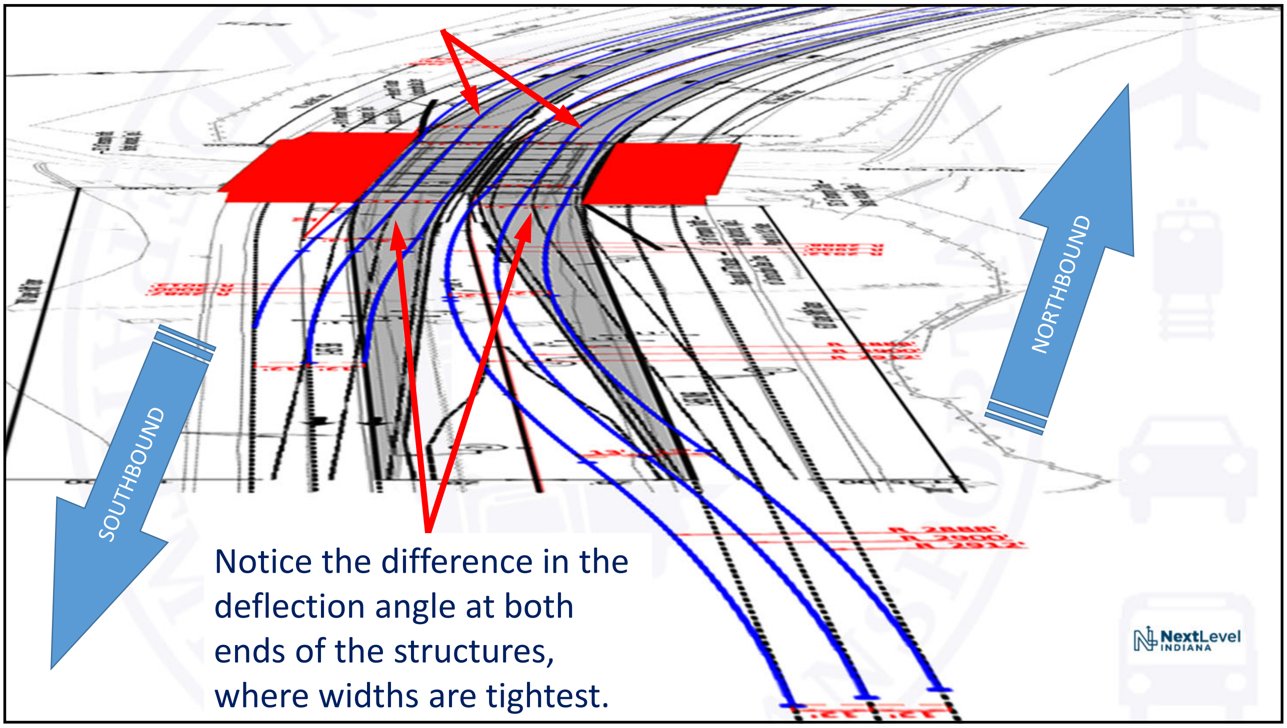

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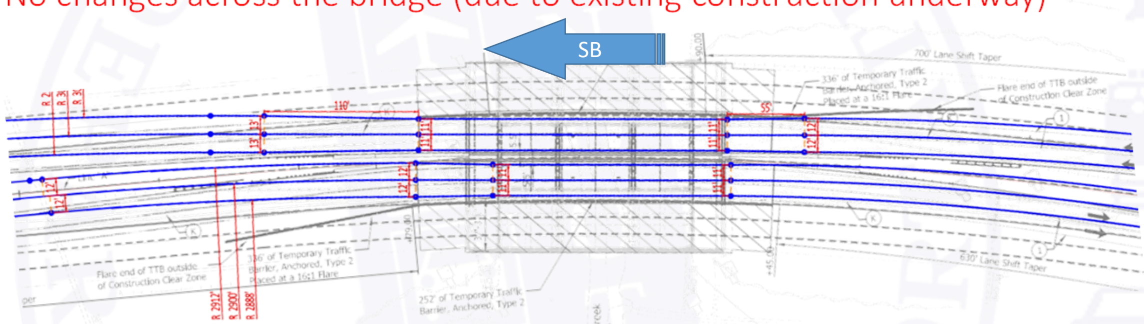
SB direction, at Structure:

- No changes across the bridge (due to existing construction underway)



- <u>Extend the tangent section</u> that currently exists across the structure at least 100 ft upstream and downstream of the structure.
  → Goal: have <u>trucks aligned in lane</u> prior to bridge and have trajectory across the bridge be a straight line for the driver.

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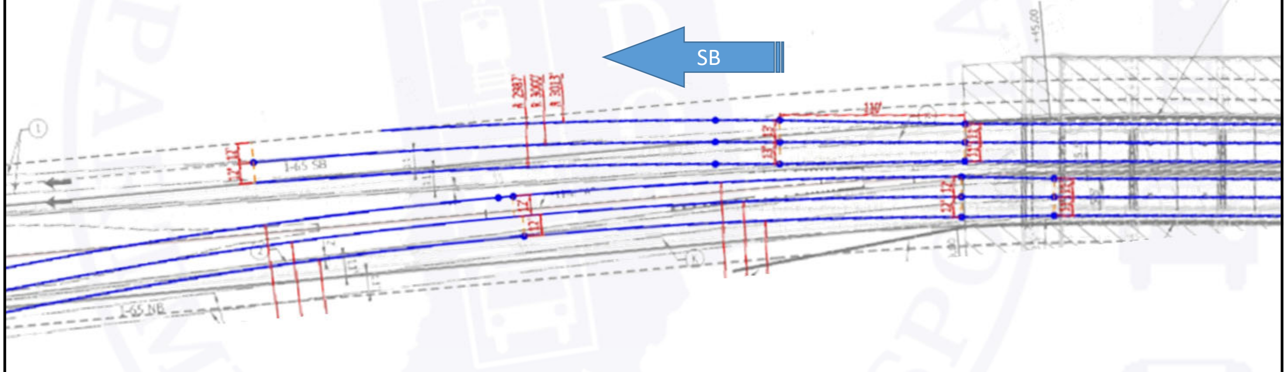
SB direction, Downstream Transition

- Provide <u>single radius transitions</u> from the existing lanes to extended tangent section.
  → Goal: provide an <u>easier curve</u> for the motorist to navigate than a spiral curve.



- The downstream curve can be as large and comfortable as the pre-construction curve.

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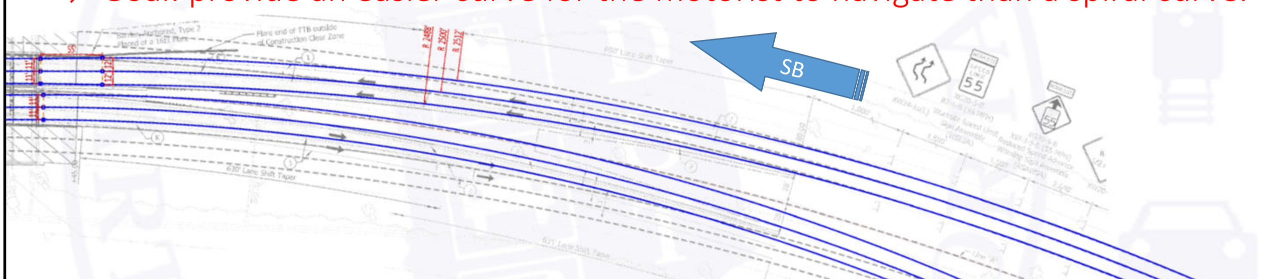
SB direction, Upstream Transition (similar)

- Provides single radius transitions from the existing lanes to extended tangent section.
  → Goal: provide an easier curve for the motorist to navigate than a spiral curve.



- Upstream curve: the radius is necessarily smaller than existing radius.
  → Goal: align traffic on a straight trajectory across the bridge prior to it and to get truck trailers (closer to being) in line with the tractor.

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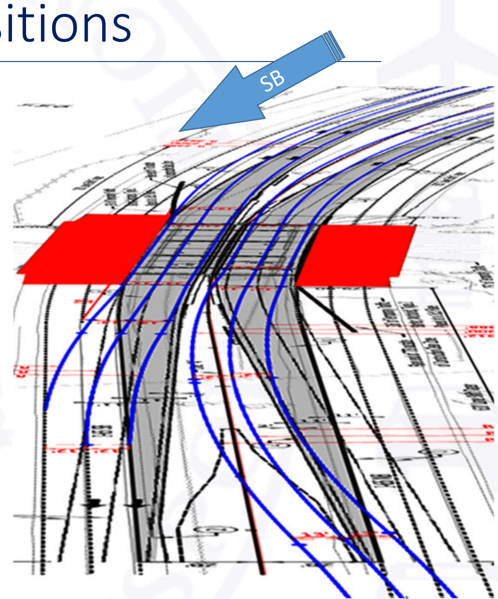
SB direction, Lane Width Transitions

- Provides 12 ft lane width along the entire length of curve.
  → Goal: make it easier for trucks and other vehicles to stay in their lanes.
- Places lane width reduction and widening transitions along the tangent between the curves and off the bridge.
  → Goal: reduce driver anxiety by separating tasks and also making the narrowing down of the lanes easier.



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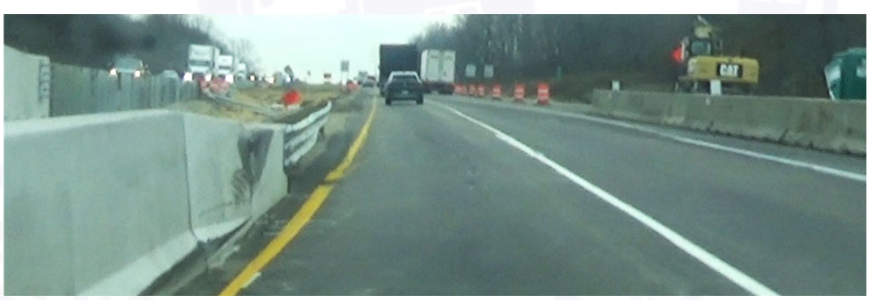
SB direction, TCB placement

- Relocate/realign the TCB beyond the bridge to follow the lane width transitions and to provide 2 ft of clearance where the 12 ft lane end and begin, upstream and downstream of the bridge, respectively.
  → Goal: provide room for the realignment and greater lane width through the curves.
- The TCB upstream will need to be shortened and the attenuator relocated.
  → This is due to the realignment of the TCB and to maintain construction access.



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SB direction, Additional Notes

Notes about curve radii used

- Cross over standards (E 801-TCCO-01 → -03) are for speeds up to 55 MPH
- Cross over standards require an outside edge line radius of 1,345 ft.
- This recommendation provided outside edge line radii:
  - 2,012 ft upstream
  - 3,000 ft downstream.

Mitigate radius change (reduction) by:

- Addressing the speeding through additional upstream signage and enforcement
- Informing the motorist of the curve through signage and delineation
- Delineating the curve well, especially the point of compound curvature where the radius of the pre-construction curve becomes the tighter temporary curve.

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SB direction, Additional Delineation

W1-8L
Chevron (Left)

- Delineate the outside edge of the curve on the approach to the bridge beginning at the point of compound curvature. This can be accomplished with construction drums and chevrons (W1-8L).
  → Goal: (chevrons) highlight the change of the radius of the compound curve is tightening and (construction drums) to delineate the right edge line along the transition and then the TCB.

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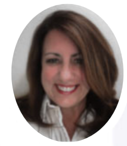

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