2022 Road Design Conference

Work Zone Safety: Improving Safety in Work Zone Transition Areas

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SOUTHBOUND

NORTHBOUND
Earlier...
i.e., some background first

General Considerations for MOT Design

Keep Human Factors in Mind:
• Perception-Reaction Time
• Motorists Age
• Familiarity (area, work zone)
• Typical Motorist Behavior
• other factors...
General Considerations for MOT Design

TTC should provide clear, positive guidance to
1. Alert motorists
2. Inform motorists
3. Instruct motorists

• 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!
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

Parts of a Work Zone (a brief review)
Parts of a Work Zone

Source: MUTCD

Parts of a Work Zone: Advance Warning Area

Source: MUTCD
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

Parts of a Work Zone: Transition Area

Source: MUTCD
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)

Parts of a Work Zone: Activity Area

Source: MUTCD
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

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Delineation at Temporary Traffic Barrier Flares
- IMUTCD, TA-34 (MERGE) and TA-36 (SHIFT)
Parts of a Work Zone: Termination Area

Source: MUTCD

Improving Safety in Transition Areas
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.

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.
Widen Lanes through Shifts by Staggering the Start

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

\[ W_2 < W_1 \]

Widen Lanes through Shifts by Staggering the Start

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

\[ W_3 > W_1 \]
Widen Lanes through Shifts by Staggering the Start

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.
The staggered blue transition lines can be "slid" upstream or downstream.

Staggered Lane Width Reduction

Perspective View

12 ft Lane Widths

Staggered Lane Width Reduction

12 ft Lane Widths
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.

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.
### Stagger Distance Computation

**STAGGER DISTANCE COMPUTATION**

- \( L \): Speed (mph)
- \( a \): Camber (ft)
- \( L_s \): Lane Shift Taper Length (ft)
- \( K \): Transition lane width (%)
- \( W_i \): Up- or Downstream Lane Width (ft)
- \( x \): Offset (ft)
- \( F \): Stagger Distance (ft)

\[
F = \frac{W_i - W}{a}
\]

### Coming Soon!

#### Transition Along Curve – Why Avoid?

![Image of a highway curve transition](image-url)
Transition Along Curve

If the intent is to shift outside lane over 1 lane to left

The blue bars represent the left and right edges at the start and end of the transition.
Straight Line Transition Along Curve

37

Straight Line Transition Along Curve

38
Straight Line Transition Along Curve

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

Linear Transition Along Curve (Spiral) - Theoretical
**Linear Transition Along Curve (Spiral) - Reality**

- Tight “radius” “curve”
- Straight line transitions at the ends

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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.
Transition Areas Case Study
A well-coordinated multi-agency incident response reduces clearance time and improves safety for motorists and first responders. This presentation will cover several after-action reviews and discuss how the UAS imagery can be used for training.
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

Linear Transition Along Curve (Spiral) - Reality

Tight “radius” “curve”

Straight line transitions at the ends
Braking Mid-curve

Difficulty Staying in Lanes; Braking
Packed Tight with Trucks

Upstream Approach and Descent into Work Zone
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.
Notice the difference in the deflection angle at both ends of the structures, where widths are tightest.

**SB direction, at Structure:**

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

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

- Provide 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.

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

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.
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.

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.
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.

SB direction, Additional Delineation

• 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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