NCHRP 03-106: Traffic Control Device Guidelines for Curves

Paul J. Carlson, Ph.D., P.E.
Texas A&M Transportation Institute

AASHTO SCOTE Mtg
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Objective

• Identify potential improvements to the MUTCD guidelines for the application of traffic control devices on curves, including
  – conditions to consider in deciding whether a particular TCD should be installed (safety, speed, volume, etc)
  – descriptions of appropriate engineering studies
### Background

#### Table 2C-5. Horizontal Alignment Sign Selection

<table>
<thead>
<tr>
<th>Type of Horizontal Alignment Sign</th>
<th>Difference Between Speed Limit and Advisory Speed</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>5 mph</td>
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<tr>
<td>Turn (W1-1), Curve (W1-2), Reverse Turn (W1-3), Reverse Curve (W1-4), Winding Road (W1-5), and Combination Horizontal Alignment/Intersection (W10-1) (see Section 2C.07 to determine which sign to use)</td>
<td>Recommended</td>
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<tr>
<td>Advisory Speed Plaque (W13-1P)</td>
<td>Recommended</td>
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<td>Chevrons (W1-8) and/or One Direction Large Arrow (W1-6)</td>
<td>Optional</td>
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<tr>
<td>Exit Speed (W13-2) and Ramp Speed (W13-3) on exit ramp</td>
<td>Optional</td>
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</tbody>
</table>

Note: Required means that the sign and/or plaque shall be used, recommended means that the sign and/or plaque should be used, and optional means that the sign and/or plaque may be used.

See Section 2C.06 for roadways with less than 1,000 ADT.

**Compliance date: Dec 31, 2019**
Overview

• Research performed by TTI and VHB
  – TTI: human factors testing
  – VHB: crash modeling
• Project started: July 2012
• Project update meeting: May 2013
• 6 Tasks in Phase 1 (completed)
• 7 Tasks in Phase 2 (just underway)
Phase 1 Tasks

1. Literature Review
2. State / International Practice Survey
4. Driver Behavior Pilot Test
5. Safety Study Feasibility
6. Interim Report/Panel Meeting
Summary of Previous TCD Research

• Curve-related TCDs have been widely researched.
  – Usually “positive” conclusions, though sometimes contrary effects were found

• Rarely were devices analyzed as a system

• In many cases, the studies were observational
  – Familiar drivers in before/after conditions
## State Practices: Level of MUTCD Adoption

<table>
<thead>
<tr>
<th>States (Ref.)</th>
<th>AL (2)</th>
<th>AZ (3)</th>
<th>CA (4)</th>
<th>CO (5)</th>
<th>DE (6)</th>
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<td>Upward Sloping Arrow Sign</td>
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- ☐: Accepts 2009 MUTCD in entirety
- ☐: Minor revision
- ☐: Major revision
International Practices: Notable Methods

• Hierarchical Approaches

Order of severity:
- Delineator
- Warning Sign
- Chevrons
- Adv. Speed

Order of severity:
- Curve Sign
- Turn Sign
- Larger Signs

Australia

Denmark
Review of State Driver Manuals

• 51 manuals reviewed for content regarding curve TCDs and safe curve navigation
• 38 manuals contain at least one example of a curve-related TCD
• 13 manuals have no TCD examples:
  – Arkansas
  – Hawaii
  – Idaho
  – Kentucky
  – Nevada
  – New Hampshire
  – New Mexico
  – New York
  – North Carolina
  – South Dakota
  – Utah
  – Vermont
  – Wyoming
Pilot Study: Site Description

- Study Site: FM 3090, Navasota, TX
  - 35+ notable changes in alignment across 15 miles
  - Various TCDs currently in use
    - Curve, turn, reverse curve, reverse turn, and winding road signs
    - Advisory speed plaques
    - Chevrons
    - RPMs
  - Many different geometric conditions
Pilot Study: Data Collection

Data Acquisition System

- Infrared Eye Tracking
- GPS positioning
- Outboard camera
Daytime Gaze Analysis

Beginning of tangent section
Centroid: (-0.30, 3.8)
Disp$_{75}$: 163.6
Disp$_{25}$: 19.4

Middle of tangent section
Centroid: (-0.16, 4.5)
Disp$_{75}$: 199.8
Disp$_{25}$: 17.9

Left curve approach with sign
Centroid: (-0.58, 4.1)
Disp$_{75}$: 164.3
Disp$_{25}$: 20.1
Nighttime Gaze Analysis

Beginning of tangent section
Centroid: (-0.97, -1.0)
Disp$_{75}$: 47.8
Disp$_{25}$: 5.5

Middle of tangent section
Centroid: (-1.0, -0.41)
Disp$_{75}$: 43.7
Disp$_{25}$: 4.7

Left curve approach with sign
Centroid: (-0.83, -1.3)
Disp$_{75}$: 61.9
Disp$_{25}$: 7.1
Analysis Techniques

Chevrons

No Chevrons

Day

Night
Inputs Initiating Driver Response

• See advance warning devices (signs)
  – What is a driver’s response to viewing an advance warning sign?
  – How does the distance of the sign from the curve affect the response?

• See devices in curves (chevrons, delineators, RPMs)
  – How do drivers respond to devices in a curve before they enter it?

• Feel lateral acceleration
  – How does a driver respond to the lateral forces felt while negotiating a curve, considering the devices used?
Safety Study Design

• Primary study question
  – What is effect of curve-related TCDs on crash frequency and severity?

• Target facility type
  – 2-lane roads
  – Rural/Urban
  – Isolated curves
  – Series of curves
Safety Study Design

- Target crash types for analysis
  - Total crashes
  - Injury crashes
  - Lane departure crashes
  - Nighttime crashes
  - Lane departure crashes at night
Safety Study Design

• Do effects vary by:
  – Type and number of signs?
    • Approaching curve
    • Within curve
  – Traffic volumes?
  – Curve radius?
  – Roadside hazard rating?
  – Posted speed limit?
  – Advisory speed?
Safety Study Design

- Crash Modification Factor (CMF)
  - Constant, discrete value
  - Example: CMF for enhanced signing on curves

<table>
<thead>
<tr>
<th>Crash Type</th>
<th>Radius</th>
<th>CMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane Departure</td>
<td>&lt; 150 m</td>
<td>0.75</td>
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<tr>
<td></td>
<td>&gt; 150 m</td>
<td>0.91</td>
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</table>
Safety Study Design

- Separate models for each facility type
- Explore options for substructures
  - Model by crash type with indicators for TCD combo
  - Model by specific TCD combination and crash type

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**Facility Type**

- Isolated

**Target Crashes**

- Total
- Injury

**TCD Combinations**

- TCD 1
- TCD 2
- TCD 1
- TCD 2
Safety Study Design

- Options for defining combinations of TCDs
  - Option 1: based on number and type of TCDs
    - Level I: curves with basic striping (no signs)
    - Level II: Level I plus *advance* curve warning sign
    - Level III: Level II plus advisory speed
    - Level IV: Level II plus warning signs *within* the curve
    - Level V: Level IV plus advisory speed
Phase 2 Objectives & Tasks

7. Driver behavior studies
   – Evaluate curve TCDs as an integrated system that affects driver behavior

8. Safety analysis
   – Develop robust safety performance functions that include factors for curve-related TCDs

9. Assess findings from Tasks 7 and 8
   – Find commonalities for the effects of TCDs on safety and operations

10. Determine approximate costs for treatments

11. Develop methodology for selecting TCD treatments

12. Final report containing MUTCD-appropriate guidelines
## Proposed Schedule of Work

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<thead>
<tr>
<th>Task</th>
<th>Month and Year</th>
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<tr>
<td></td>
<td>2013</td>
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<tr>
<td>Task 7. Driver Behavior Studies</td>
<td>5 6 7 8 9 10 11 12</td>
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<td>Task 8. Safety Analyses</td>
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<tr>
<td>Task 9. Assess Findings from Tasks 7 &amp; 8</td>
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<td>Task 10. Treatment Cost Evaluation</td>
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<td>Task 11. TCD Selection Methodology</td>
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<td>Task 12. Guidelines / Project Deliverables</td>
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<td>Task 13. Review and Revise Deliverables</td>
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