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Texas A&M Transportation Institute

Curve Advisory Speed and Curve Safety Assessment Practices: Training Development and Support

Technical Report 5-6960-01-R1

Cooperative Research Program

TEXAS A&M TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS

in cooperation with the
Federal Highway Administration and the
Texas Department of Transportation
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16. Abstract

The Texas Department of Transportation's (TxDOT's) engineering study methods for setting curve advisory speeds were recently updated to extend the guidance to more types of rural highways (e.g., four-lane highways and freeways). Additionally, the software suite used to implement the Global Positioning System (GPS)-based engineering study method for setting advisory speeds was updated to accommodate four-lane rural highways and add technical capabilities, such as the ability to process multiple curves with a single data collection run and to add the capability to measure vertical grade. These resources facilitate the goal to check and update Texas's curve advisory speeds.

The researchers developed training workshop and webinar materials to assist TxDOT practitioners in their application of these new resources. The researchers presented these workshops and the webinar to TxDOT practitioners who are responsible for traffic operations and for signing and marking rural highways. The researchers also provided technical support and guidance for the software suite, which consists of the executable Texas Roadway Analysis and Measurement Software (TRAMS) program and the spreadsheet-based Texas Curve Evaluation Suite (TCES) program.

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CURVE ADVISORY SPEED AND CURVE SAFETY ASSESSMENT PRACTICES: TRAINING DEVELOPMENT AND SUPPORT

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DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data published herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration (FHWA) and/or the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation. It is not intended for construction, bidding, or permitting purposes. The engineer in charge of the project was Michael P. Pratt, P.E. #102332.

NOTICE

The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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The researchers would like to acknowledge the support and guidance provided by the Project Monitoring Committee:

- Mr. Wade Odell, Project Manager (TxDOT, Research and Technology Implementation Office).
- Ms. Christina Gutierrez, Project Advisor (TxDOT, Traffic Safety Division).
- Mr. Darren McDaniel, Project Advisor (TxDOT, Traffic Safety Division).
- Mr. Alexander Choy, Project Advisor (TxDOT, Traffic Safety Division).
- Ms. Rebecca Wells, Project Advisor (TxDOT, Atlanta District).
- Mr. Jeffrey Miles, Project Advisor (TxDOT, Bryan District).
- Mr. Jacob Chau, Project Advisor (TxDOT, Waco District).
- Mr. Bahman Afsheen, Project Advisor (TxDOT, Dallas District).
- Mr. Donald Maddux, Project Advisor (TxDOT, Lufkin District).
- Mr. Daniel Bolden, Contract Specialist (TxDOT, Research and Technology Implementation Office).

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INTRODUCTION

Horizontal curves are an essential element of the state highway system, but they represent significant safety and operational concerns. Various safety treatments exist for horizontal curves, including warning motorists of the presence and sharpness of the curve through signs and markings, increasing the side friction supply by installing pavement friction treatments, or making geometric improvements such as straightening the curve or increasing the superelevation rate.

Over the past two decades, the Texas Department of Transportation (TxDOT) has sponsored several research projects to assist practitioners in evaluating and treating curves. These projects include the following:

- Research Project 0-5439 (*1*): developing guidelines for setting curve advisory speeds on two-lane rural highways with a regulatory speed limit of 70 mph or less.
- Implementation Project 5-5439 (*2*): creating software tools and the Global Positioning System (GPS) Method to collect the required input data and apply the guidelines from Research Project 0-5439.
- Research Projects 0-6714 (*3*) and 0-6932 (*4*): developing guidance for evaluating the adequacy of curve pavement friction and identifying treatments to improve friction.
- Research Project 0-6960 (*5*):
    - Extending the advisory speed guidelines to four-lane rural highways and freeways.
    - Extending the advisory speed guidelines to two-lane rural highways with a speed limit of 75 mph.
    - Updating software tools to incorporate the extended guidelines and capability to measure roadway grade.

The researchers developed a workshop to demonstrate how to apply the guidelines through classroom discussion and hands-on training. The hands-on training sessions involved driving through curves on roadways near the workshop venue to allow the participants to use the computer system that runs the programs that collect and analyze the curve data. These programs are the executable Texas Roadway Analysis and Measurement Software (TRAMS) program and the Texas Curve Evaluation Suite (TCES) spreadsheet. The researchers also provided technical support to practitioners who used these resources. Contact information for technical support is provided in the Help menu in the TRAMS program.

This report consists of three main parts following this Introduction section. The first part describes the workshop and webinar that were developed and conducted. The second part describes the technical support activities. The third part summarizes the project activities and provides suggestions for future activities. The Student’s Guide for the workshop participants is included as an Appendix to this report.

WORKSHOP AND WEBINAR DESCRIPTION

This section provides a description of the workshop and webinar content and a review of the course presentations online and at 10 venues in Texas. The first subsection provides an overview of the workshop course, which is followed by a review of the learning objectives. Then, the course format and venues are outlined, and the participant evaluations are summarized. The final subsection documents the webinar.

Workshop Overview

The workshop objectives were to (a) inform participants about challenges associated with horizontal curve signing (particularly setting advisory speeds) on rural highways, (b) inform participants about guidelines and software tools for signing curves, and (c) demonstrate the use of these tools. The procedures and guidance are documented in the *Horizontal Curve Evaluation Handbook* (*Handbook*) (*6*). The workshop and the *Handbook* were developed for engineers and technicians.

The following two activities were undertaken in relation to the workshop:

- Develop training materials (i.e., visual aids, handouts, hands-on training sessions, software, etc.) that impart the information needed to analyze horizontal curves.
- Conduct one 1-day training course at each of 10 TxDOT district offices.

Workshop Learning Objectives

The course content was tailored to facilitate participant learning. The visual aids were primarily in the form of a PowerPoint® presentation. This presentation included numerous photographs, illustrations, and example situations for discussion. The visual aids were supplemented with printed materials that included a *Student's Guide* that contained a print copy of the visual aids. The *Student's Guide* is included as an Appendix to this report.

The following key points were emphasized throughout the workshop:

- The objective of curve signing is a consistent display of traffic control devices, particularly advisory speeds when needed.
- Traffic control devices should be uniform among curves of similar geometry, character, and road condition.
- Advisory speeds should be conservative but consistent with driver expectation.
- Curve traffic control devices should be selected based on an engineering study that accounts for key site characteristics, particularly vehicle speeds, sight distance, presence of access points such as intersections and driveways, and proximity to adjacent curves.

Each of these key points was repeated throughout the workshop to emphasize its importance and ensure information retention by participants.

Workshop Format

The workshop presentations consisted of approximately six hours of instruction, which included a presentation, demonstration of the TRAMS program in the field, and review of the TRAMS-collected field data using the TCES program. The visual aids used in the course consisted primarily of 81 PowerPoint® slides.

The course agenda is provided in Table 1. It consisted of four lessons. These lessons comprehensively described the issues associated with, and methods for, evaluating rural horizontal curves and selecting signs for the curves. The agenda also included two hands-on training sessions, one before lunch and the other after the conclusion of the workshop presentation.

Table 1. Workshop Agenda.

Start Time	Lesson	Objectives
9:00	Introduction	
9:15	Lesson 1: Background	Discuss the curve signing objectives. Summarize the signing and marking guidelines and engineering study procedures for setting curve advisory speeds.
9:30	Lesson 2: Horizontal Curve Evaluation Tools	Provide an overview of the procedures for using the TRAMS and TCES programs for collecting and analyzing horizontal curves, setting advisory speeds, and selecting curve traffic control devices.
10:00	Hands-On Training Session 1	Conduct a field demonstration of the TRAMS program on several highway curves near the workshop venue.
11:30	Lunch Break	
1:00	Field Data Review	Demonstrate methods to post-process and analyze the TRAMS-collected field data using the TCES spreadsheet program.
1:45	Lesson 3: Curve Evaluation Study Methods	Present a detailed discussion of engineering study methods for evaluating curves, including the GPS, Direct, and Design Methods.
2:15	Lesson 4: Curve Signing Guidelines	Present a detailed discussion of curve signing guidelines, including setting advisory speeds and selecting traffic control devices such as Chevrons.
3:00	Adjourn/Hands-On Training Session 2	Conduct a field demonstration of the TRAMS program on several highway curves near the workshop venue.

The hands-on training sessions involved taking workshop participants in groups of three into the field to demonstrate a curve evaluation run. Participants were familiarized with the TRAMS program and the required data collection equipment, including the GPS receiver, the electronic ball-bank indicator, and the various cables and mounting devices. Test runs were repeated several times so each participant would have an opportunity to operate the laptop computer while the instructor drove the test vehicle. At most workshops, 12 participants were accommodated during the first hands-on training session. This effort required two instructors (or an instructor and a practitioner who had been trained in the use of the TRAMS program), two test vehicles, and two sets of the required equipment. Each complete run took about 45 minutes, so the first group of participants began at 10:00 AM and the second group began at 10:45 AM.

After the lunch break, the instructor conducted a field data review, which involved using the TCES spreadsheet program to analyze the data files collected during the morning hands-on training sessions. The instructor conducted the following activities:

- Showed the participants where the field data files were stored on the laptop computer and then gave the participants suggestions for organizing files from multiple test runs.
- Opened the TCES program.
- Imported and processed the data files to show how TCES identifies individual curves.
- Showed the participants which key geometric variables are calculated, particularly curve radius, superelevation rate, and deflection angle.
- Used online maps to show the participants how to locate the curves using their coordinates in the TCES program, and then compared the computed curve radius values with values measured from online aerial photography sources.
- Used the TCES program to compute advisory speeds for the curves.
- Showed the participants how to use the computed advisory speeds and the *Texas Manual on Uniform Traffic Control Devices* (*7*) to select traffic control devices, particularly Chevrons, for each curve.

The instructor used the second hands-on training session if additional demonstrations were needed after the workshop presentation was concluded.

Workshop Venues

Ten workshop presentations were conducted. Table 2 summarizes the locations, dates, and attendance numbers for each course presentation. All course presentations were held at TxDOT facilities. Practitioners from 21 of the 25 TxDOT districts, as well as from two TxDOT divisions and several consultant firms hired to implement the GPS Method for TxDOT districts, were able to attend.

Table 2. Course Venues and Attendance.

Venue	Date	Participant Count	Districts, Divisions, and Agencies Represented
Austin (pilot)	8/15/2019	5	Traffic Safety Division
Atlanta	8/20/2019	13	Atlanta, Lufkin, Paris, and Tyler Districts
Dallas	8/21/2019	28	Dallas District
Corpus Christi	8/28/2019	16	Corpus Christi, Laredo, and Pharr Districts; Research and Technology Implementation Division; consultants
San Antonio	10/2/2019	7	San Antonio and Yoakum Districts; Traffic Safety Division
Houston	10/4/2019	14	Houston District; Research and Technology Implementation Division; consultant
Fort Worth	10/8/2019	3	Fort Worth District
Lubbock	10/10/2019	9	Amarillo, Childress, Lubbock, and Odessa Districts
El Paso	10/17/2019	9	El Paso Districts
Bryan	10/23/2019	9	Amarillo, Bryan, Brownwood, Waco, and Wichita Falls Districts
	Total:	113	—

Workshop Evaluation

Participants were given evaluation forms near the end of each workshop presentation and asked to comment on the course content and format. The evaluation form contained four questions on the course content and four questions on the participant's general observations about the strengths and weaknesses of the course format.

The four questions that inquired about course content were the following:

1. Did the course meet your expectations?
2. Was the material presented at the correct level of difficulty?
3. Was the topic of the course covered adequately (nothing left out, no one topic overemphasized)?
4. Was the software easy to use?

Participants were instructed to respond to each question using a scale of 1 to 5, with 1 indicating *yes* and 5 indicating *no*. Each question was posed such that a *yes* response indicated a high degree of satisfaction. Table 3 summarizes the responses to the first four questions.

Table 3. Participant Evaluations of Workshop Content.

Course Venue	Number of Responses	Average Participant Response by Question *				Average
		1	2	3	4	
Austin (pilot)	5	1.2	1.0	1.4	1.4	1.3
Atlanta	11	1.5	1.4	1.5	1.7	1.5
Dallas	11	2.1	2.3	1.6	1.9	2.0
Corpus Christi	13	1.5	1.6	1.4	1.3	1.4
San Antonio	5	1.0	1.0	1.0	1.2	1.1
Houston	4	1.0	1.0	1.0	1.0	1.0
Fort Worth	3	1.0	1.0	1.0	2.0	1.3
Lubbock	7	1.4	1.4	1.4	1.6	1.5
El Paso	6	1.7	1.7	1.7	1.8	1.7
Bryan	9	2.0	2.0	1.8	1.8	1.9
Average or total:	74	1.5	1.6	1.4	1.6	1.5

* Scores of 1 to 5 were possible: 1 = yes; 5 = no; and values of 2, 3, and 4 = somewhere between yes and no (e.g., maybe).

The second set of four questions inquired about each participant's general observations of course strengths and weaknesses. Unlike the first four questions, the questions in the second set were open-ended. The specific questions posed to the participants included:

5. What did you like most about the course?
6. What did you like least about the course?
7. What can we do to improve this course?
8. Do you have any other comments?

Of the 113 course participants, 63 provided responses to Questions 5–8. When asked what portion of the training course the participant liked best, the most common responses were the hands-on training sessions with TRAMS (26 participants), the presentation organization and style (21 participants), the updates to the software made in the past two years (four participants), and the data review session (four participants). Regarding the presentation, participants liked the instruction style, inclusion of examples, interactivity, and opportunity for question-and-answer sessions and discussions of issues that the practitioners encounter in their work.

The four participants who liked the software updates were familiar with the earlier version of the TRAMS program and Texas Curve Advisory Speed (TCAS) spreadsheet that were developed in TxDOT Implementation Project 5-5439 (*2*), and some were still using these programs. Those participants were interested in the TCD worksheet in the TCES spreadsheet, which was modeled after the Analysis worksheet from TCAS.

Three early workshop participants expressed concern about not having the latest version of TRAMS available for use. The TRAMS program had to be updated to address stability issues that emerged with the rollout of Windows® 10. This update was completed near the end of the workshop efforts (mid-October 2019) and installed on TxDOT computers in February 2020. Five participants stated that the material was too in depth, presented too quickly, or not entirely relevant to their work. Two participants wished to have a longer hands-on training session or a session with different types of curves from those used in the training session. During the scheduling and preparation for the workshops, the instructors corresponded with practitioners in the hosting TxDOT district to choose curves for the training sessions, but some workshops were hosted by district offices that were located in large urban areas where rural highway curves were not available within a reasonable distance. At these venues, curves on nearby city arterials were used, which still allowed the data collection procedures to be demonstrated, but on roadway types that are not typically the focus of curve advisory speed engineering studies.

Several comments provided by early workshop participants led to key improvements to the workshop format and guidance material in the *Handbook*. For example, the original schedule for the pilot workshop called for the first hands-on training session to occur before the classroom instruction began, but the participants suggested moving the hands-on training after Lesson 2. Several pilot workshop participants also suggested a checklist for the procedures and equipment needs for using TRAMS. In response to this feedback and additional comments in later workshops, a compilation of quick-reference checklists was added into the *Handbook*.

Webinar Presentation and Evaluation

After the workshop series was completed, the research team received a request to present a streamlined online version of the workshop. The research team prepared and presented one webinar for practitioners in the Austin District on August 6, 2020. A total of 10 practitioners from the Austin District attended, in addition to one each from the Research and Technology Implementation Division and the Traffic Safety Division. Table 4 provides the agenda for the webinar. The agenda focused on the highlights from the workshops but omitted the hands-on training sessions. The field data review lesson used field data collected from previous workshops to demonstrate use of the TCES program.

The research team assembled an online survey form with the same questions as the hardcopy form used in the workshops and sent a link to the online survey to the webinar attendees to give them an opportunity to evaluate the webinar. The research team received two responses to the survey, which are summarized in Table 5. The respondents stated that they liked the webinar content, but one respondent would have liked to receive hands-on training for the software programs.

Table 4. Webinar Agenda.

Start Time	Lesson	Objectives
10:00	Introduction	
10:15	Lesson 1: Background	Discuss the curve signing objectives. Summarize the signing and marking guidelines and engineering study procedures for setting curve advisory speeds.
10:30	Lesson 2: Horizontal Curve Evaluation Tools	Provide an overview of the procedures for using the TRAMS and TCES programs for collecting and analyzing horizontal curves, setting advisory speeds, and selecting curve traffic control devices.
11:00	Lesson 3: Curve Evaluation Study Methods	Present a detailed discussion of engineering study methods for evaluating curves, focusing on the GPS Method and summarizing the Direct and Design Methods.
11:15	Field Data Review	Demonstrate methods to post-process and analyze TRAMS-collected field data using the TCES spreadsheet program.
11:45	Lesson 4: Curve Signing Guidelines	Present a detailed discussion of curve signing guidelines, including setting advisory speeds and selecting traffic control devices such as Chevrons.
12:00	Adjourn	

Table 5. Webinar Evaluation.

Question Summary	Participant Responses by Question*				
	1 (yes)	**2**	**3**	**4**	**5 (no)**
1. Met your expectations?	2	0	0	0	0
2. Correct level of difficulty?	2	0	0	0	0
3. Topics covered adequately?	2	0	0	0	0
4. Software easy to use?	1	0	1	0	0
5. What did you like the most?	• Liked the pace and answers to questions. • Liked the visual aids and data demonstration.				
6. What did you like the least?	• Disliked not being able to have the hands-on training.				
7. How can we improve the course?	No responses received.				
8. Other comments	No responses received.				

* For Questions 1–4, scores of 1 to 5 were possible: 1 = yes; 5 = no; and values of 2, 3, and 4 = somewhere between yes and no (e.g., maybe). For Questions 5–8, the participants could provide free-form responses.

TECHNICAL SUPPORT

As an additional measure to facilitate implementation of the GPS Method, the researchers provided technical support to users of the TRAMS and TCES programs. The Help menu in the TRAMS program provides the program's version number and contact information for users who need technical support (see Figure 1). The researchers responded to technical support requests within two business days of receipt and provided guidance as needed.

Between the months of July 2019 and August 2020, the researchers received 41 requests for technical support. Thirty of these requests came from TxDOT practitioners, and most of the remaining 11 requests came from consultants who had been hired to implement the GPS Method for TxDOT districts. Most of the requests were for guidance on using the TRAMS and TCES programs or setting up the required equipment for the GPS Method. These issues have since been addressed in the *Handbook*, which was formally published in May 2020. Several requests also related to the stability issues that TRAMS experienced following the rollout of Windows® 10; these issues were addressed in the TRAMS Version 7.2 update. Some users also requested information about GPS receivers that the researchers had successfully used with TRAMS. The researchers explained that any GPS receiver would suffice, provided it meets the specifications listed in the *Handbook*.

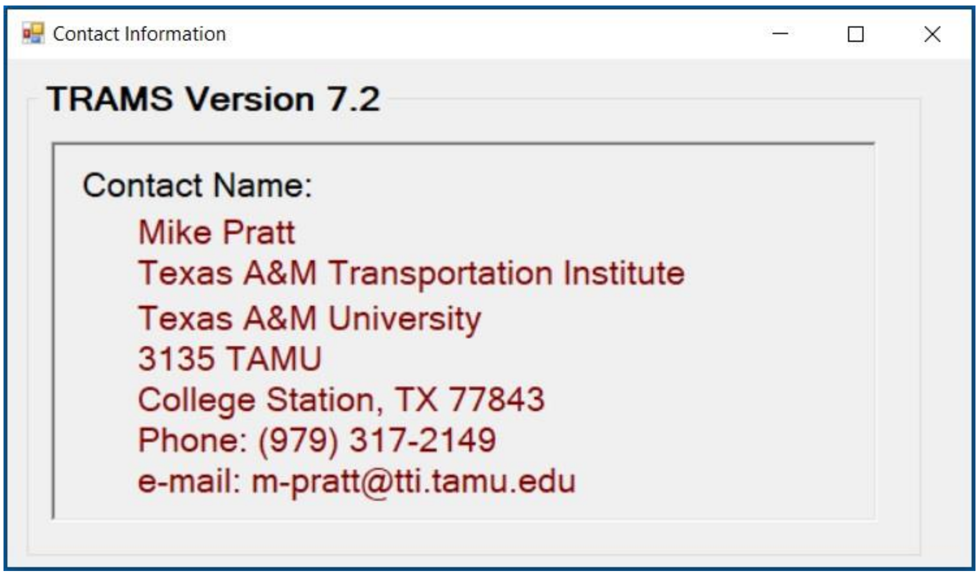

Figure 1. Technical Support Contact Information.

The most significant technical support issue that arose was the stability of TRAMS in the Windows® 10 operating system. TRAMS Version 7.1 ran smoothly in Windows® 7 but would occasionally freeze and stop responding in Windows® 10. Tests revealed that TRAMS Version 7.1 would run smoothly for a limited (and unpredictable) amount of time, but then would suddenly begin to account for large portions of the computer's power usage, at which point the program would stop updating the screen and begin writing all input data to the computer's physical memory instead of the hard disk. This issue required a detailed examination of the TRAMS code to identify and eliminate operations that taxed the computer's resources, as well as the addition of a control to deactivate the continuous refreshing of status update messages on the main TRAMS screen. These messages are deactivated by default in TRAMS Version 7.2.

SUMMARY AND RECOMMENDATIONS

The researchers presented 10 workshops at TxDOT district or division facilities around the state, reaching a total of 113 participants representing 21 districts and several consultant firms. The workshop participants gave positive feedback about the material, especially the hands-on training sessions and the data review session in each workshop. To facilitate implementation of the GPS Method, it is necessary to conduct hands-on training in the field followed by a guided review and analysis of the collected field data. With the assistance of practitioners at the hosting district, the researchers were able to demonstrate the GPS Method and explain procedures to analyze the data to obtain an advisory speed for each curve.

The researchers supplemented the workshops with one webinar presentation to provide training to an additional 10 participants at one TxDOT district. The webinar provided an abbreviated version of the material presented at the workshops, including the field data review lesson but not the hands-on training sessions in the field using the TRAMS program. The webinar participants gave positive feedback about the material and the discussion but expressed that they would benefit further from hands-on training.

The TRAMS and TCES programs were the primary focus of the workshops since these resources are essential to the goal of checking and updating curve advisory speeds. The TCES program is designed to batch-process a large number of curves, compute an advisory speed for each curve, and assist the analyst in identifying needed signs, particularly Chevrons. These capabilities are beneficial for engineers and technicians who are responsible for traffic operations and signs and pavement markings.

The TCES program is also a useful tool for conducting a margin-of-safety analysis for curves if additional data are provided to describe the pavement friction characteristics. However, this application of TCES was not addressed in detail in the workshops because the workshop focus was on the more immediate need to evaluate curve advisory speeds. An additional series of workshops or webinars could be offered in the future to assist TxDOT practitioners in identifying curves that would benefit from the installation of pavement friction treatments. This training would be most beneficial for engineers and technicians responsible for pavement maintenance.

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APPENDIX

Curve Advisory Speed and Curve Signing Workshop

Training Course

Student's Guide

October 2019

CURVE ADVISORY SPEED AND CURVE SIGNING WORKSHOP

Date: October 23, 2019
Location: TxDOT Bryan District
Contact: Mike Pratt, (979) 317-2149, m-pratt@tti.tamu.edu

Agenda

9:00	Introduction
9:15	Lesson 1: Background
9:30	Lesson 2: Horizontal Curve Evaluation Tools
10:00	Hands-On Training Session 1
11:30	Lunch Break
1:00	Field Data Review
1:45	Lesson 3: Curve Evaluation Study Methods
2:15	Lesson 4: Curve Signing Guidelines
3:00	Adjourn / Hands-On Training Session 2

Course Materials: Student's Guide

CURVE ADVISORY SPEED AND CURVE SIGNING WORKSHOP

<u>Notes</u>

Curve Advisory Speed and Curve Signing Workshop

Enhancing Curve Advisory Speed and Curve Safety Assessment Practices (5-6960)

Welcome

- **Introductions**
- **Introductory session**
  - *Objectives*
  - *Scope*
  - *Main points*
  - *Background*
  - *Agenda*

Introductions

- **Course Instructors**
  - *Mike Pratt*
  - *Raul Avelar*
  - *Srinivas Geedipally*
  - *Minh Le*
- **Participants**
  - *Now it's your turn. . .*

Objectives

- Objectives
  - *To inform participants about. . .*
    - Challenges associated with curve signing
    - Availability of tools to determine appropriate signs
  - *To demonstrate how to apply these tools*

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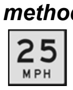
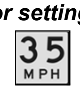
Objectives

- Course Elements
  - *Guidelines for curve signing*

  - *Criteria and methods for setting advisory speed*





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Scope

- Intended Audience
  - *Engineers and technicians who want information about curve signing issues, procedures, and practices*
- Roadway Types
  - *Horizontal curves*
  - *Rural highways*
    - Two-lane undivided (2U)
    - Four-lane undivided (4U), divided (4D), or freeway (4F)

Texas Department of Transportation

Main Points

- **Points to Remember**
  - ***Objective of curve signing is a consistent display of devices and advisory speed***
  - ***Devices should be uniform among curves of similar geometry, character, and road condition***
  - ***Advisory speed should be consistent with driver expectation***
  - ***Selection of devices should be based on an engineering study that considers...***
    - **Vehicle speeds**
    - **Sight distance**
    - **Intersections**
    - **Adjacent curves**

Background

- **Project 0-6960**
  - ***"Enhancing Curve Advisory Speed and Curve Safety Assessment Practices"***
    - **Project Director: Darrin Jensen**
    - **Implementation Director: Wade Odell**
  - ***Product:***
    - ***Horizontal Curve Evaluation Handbook* (0-6960-P1)**
    - **Updated Texas Roadway Analysis and Measurement Software program (TRAMS)**
    - **Texas Curve Evaluation Suite (TCES) spreadsheet**

Agenda

- **Lesson 1: Background**
- **Lesson 2: Evaluation Tools**
  - ***Handbook***
  - ***Texas Roadway Analysis and Measurement Software***
  - ***Texas Curve Evaluation Suite***
- **Hands-on Training**
- **Lunch Break**

Agenda

- Lesson 3: Curve Evaluation Methods
  - *GPS Method*
  - *Other methods*
- Lesson 4: Curve Signing
  - *Setting the advisory speed*
  - *Selecting traffic control devices*
- Wrap-up / Hands-on Training

Policy on Questions

- Questions are encouraged
- Please ask them as they occur to you

1. Background

- Curve Signing Objectives
- Signing and Marking Guidelines
- Study Procedures

Curve Signing Objectives

- **Warning Signs**
  - ***Display devices consistently***
    - **Similar message displayed in similar situations**
    - **Consistent display of traffic control devices on curves of similar geometry, character, and condition**
  - ***Benefit of consistency***
    - **Uniformity simplifies the task of the road user**
    - **"Uniformity of the meaning of traffic control devices is vital to their effectiveness" (*TMUTCD* 1A.02)**

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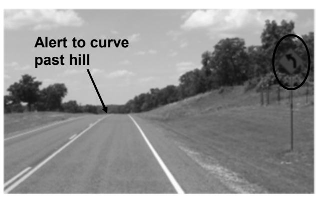
Curve Signing Objectives

- **Warning Signs**
  - ***Call attention to unexpected conditions*** ***(TMUTCD, Chapter 2)***



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Curve Signing Objectives

- **Warning Signs**
  - ***Alert drivers of the need to reduce speed or perform some action in the interests of traffic safety and efficiency*** ***(TMUTCD, Chapter 2)***

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Guidelines

- **Warning Signs** 

- **Advisory Speed Plaque** 

- **Chevrons & Large Arrow** 

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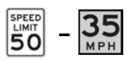
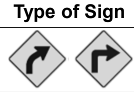
Guidelines

TMUTCD Table 2C-5	Difference: 				
Type of Sign	**5**	**10**	**15**	**20**	**≥ 25**
	Rec.	Req.	Req.	Req.	Req.
	Rec.	Req.	Req.	Req.	Req.
	Opt.	Rec.	Req.	Req.	Req.

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Procedures

- **Goals**
  - *Promote uniform use of curve signs*
  - *Avoid overuse of devices*
- **Components**
  - *Advisory speed criteria*
  - *Engineering study method*
  - *Curve signing guidelines*

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Procedures

- **Advisory Speed Criteria**
  - *Considerations*
    - Car vs. truck speed
    - Average vs. 85th percentile vs. BBI reading
    - Curves are inherently unsafe, so advisory speed should be conservatively low
    - Drivers should feel advisory speed is reasonable
    - On sharp curves, 85th percentile driver tends to adopt a speed that may be borderline unsafe

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Procedures

- **Advisory Speed Criteria**
  - *Recommend using average truck speed*
    - Roughly equivalent to 40th percentile car
    - Truck speed is generally 95-97% of car speed
    - Round to 5-mph increment

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Procedures

- **Engineering Study Methods**
  - *GPS method*

  - *Direct method*

  - *Design method*

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GPS Method

- Field Measurements
  - *Drive through curve with instruments*
    - GPS receiver
    - Electronic ball-bank indicator
    - Laptop computer with TRAMS program
- Determine Advisory Speed
  - *Based on sharpest part of curve*
- Confirm Speed for Conditions

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GPS Method

- Curve geometry
  - *Sharpest curve arc*
    - Radius
    - Superelevation rate
    - Deflection angle
  - *Entire curve*
    - Deflection angle

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GPS Method

- Advisory Speed Calculation
  - *Texas Curve Evaluation Suite (TCES), List worksheet*
    - Excel® spreadsheet
  - *Available from Traffic Safety Division*
  - *Steps*
    - Enter geometry data
    - Enter tangent speed
    - Read advisory speed

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Questions?

2. Evaluation Tools

- Texas Roadway Analysis and Measurement Software (TRAMS)
- Texas Curve Evaluation Suite (TCES)

TRAMS Program

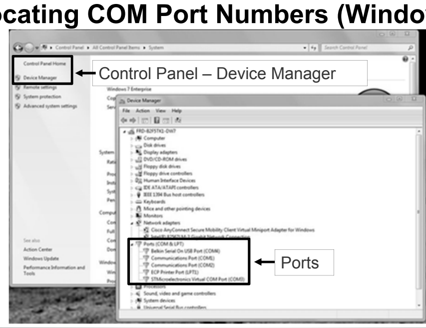
- Overview
  - *First program used to apply GPS Method*
  - *Monitors data streams from GPS, electronic ball-bank indicator, and barometer in real time*
  - *Records continuously when activated*
  - *Two application methods*
    - Activate for individual curves
    - Activate once for continuous run

TRAMS Program

- **Equipment Requirements**
  - *GPS receiver*
    - 10 Hz recommended
    - RMC and GGA sentences enabled
  - *Electronic ball-bank indicator*
  - *Cables*
    - USB cable for GPS receiver
    - Ball-bank indicator cable + serial/USB adapter
    - Computer power cord (DC recommended)
    - Y-adapter for cigar lighter
  - *Device drivers*

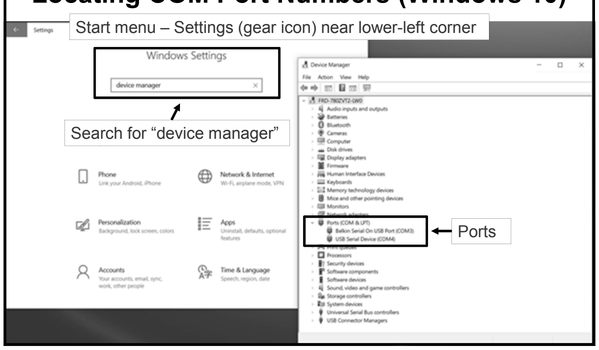
TRAMS Program

- **Locating COM Port Numbers (Windows 7)**



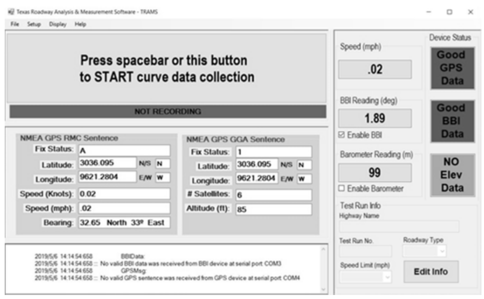
TRAMS Program

- **Locating COM Port Numbers (Windows 10)**



TRAMS Program

- **Welcome**



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TRAMS Program

- **Device Status**

- ***GPS receiver – required***
- ***Electronic ball-bank indicator – required to measure superelevation***
- ***Barometer – optional, used for more precise grade measurement***

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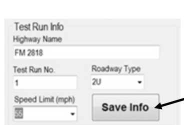
TRAMS Program

- **Test Run Information**

- ***Click "Edit Info" to enter test run information***
  - **Highway name**
  - **Test run number**
  - **Roadway type**
  - **Speed limit**



- ***Click "Save Info" to save test run information***

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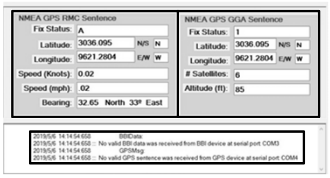
TRAMS Program

- Device Status
  - *GPS RMC sentence – horizontal position*
  - *GPS GGA sentence – elevation*
  - *GPS receiver and ball-bank indicator*



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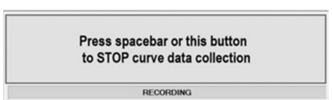
TRAMS Program

- Space Bar Button



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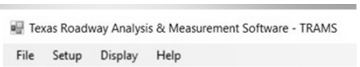
TRAMS Program

- Menus
  - *File*
    - Save settings
    - Show data folder location
  - *Setup*
    - Device communication settings
    - BBI calibration factor
  - *Display – GPS sentences*
  - *Help – About*



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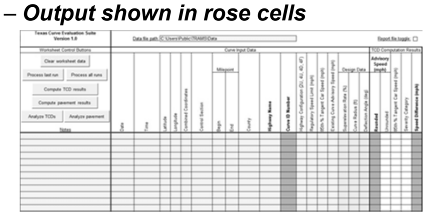
Questions – Comments?

TCES Software

- Overview
  - *Second program used to apply GPS Method*
  - *Processes data files from TRAMS and provides output*
    - Advisory speed
    - Speed difference (for TMUTCD Table 2C-5)
    - Detailed TCD and Pavement analysis (optional)
  - *Identifies curves in data stream*
    - Ignores curve if Dc < 2 (R > 2865 ft)
    - Ignores data if speed < 8 mph

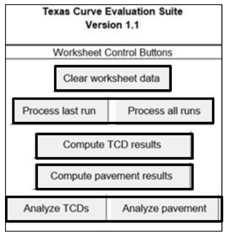
TCES Software

- List – Layout
  - *One row per curve, any number of curves*
  - *Enter data into blue and green cells*
  - *Output shown in rose cells*



TCES Software

- List – Controls
  - *Clear data*
  - *Process run(s)*
  - *Compute TCD results*
  - *Compute pavement results*
  - *Transfer data to detailed analysis worksheets*



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TCES Software

- TCD
  - *Same as TCAS Analysis worksheet*

CURVE ADVISORY SPEED WORKSHEET

General Information						
County: Brazos	Curve Data Source:		Date:	February 28, 2019		
Highway: FM 1234	Known curve geometry		Analyst:			
Input Data						
Data Description	**Curve ID Number**					
	1	2	3	4	5	6
Curve deflection, left or right	Right	Left	Left	Left	Left	Left
Roadway configuration (2U, 4U, 4D, 4F)	2U	2U	2U	2U	2U	2U
Compass heading 1, degrees	251.7	124	254	239	330	189
BBI reading of superelevation, degrees	4.8	5.1	7.4	1.0	1.0	8.3
Deflection of ball for superelevation reading, left or right	Right	Left	Left	Right	Right	Left
Speed when recording the BBI reading of superelevation, mph	0	0	0	0	0	0
Curve length, ft Caution, curve length outside equation range.	216	237	118	57 See note.	57 See note.	110
Compass heading 2, degrees	261	94	244	207	300	158
Survey method (partial or full)	Partial	Partial	Partial	Partial	Partial	Partial
Regulatory speed limit, mph	60	60	65	60	55	60
Estimate of 85th% tangent speed, mph	66	64	69	60	55	60
Alternate Input Data *(if data are entered here, they will be used instead of estimates from the data above)*						
85th% tangent speed, mph						
Total curve deflection angle, degrees	28	90	30	96	90	93
Curve deflection angle, degrees	9.3	30.0	10.0	32.0	30.0	31.0
Superelevation rate, percent	7.4	8.0	11.6	-1.6	-1.6	13.0
Curve radius, ft	1331	453	676	102	90	203

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TCES Software

- Pavement
  - *Same as TCMS Analysis worksheet*

Texas Curve Margin of Safety Worksheet

General Information					
District	Brazos	Control section	3456-78	Date	February 26, 2019
Highway	FM 1234	Beginning milepoint	1.5	Analyst	
Curve ID number		Ending milepoint	1.7	Curve deflection	Right

Clear data | Return data to List

Site Characteristics Input Data		
Average daily traffic volume (ADT, veh/d)		18000
Truck percentage		10
ADT growth rate (%)		
Roadway configuration		
Curve radius (ft)		
Deflection angle (degrees)		
85th % tangent speed (mph)		
Regulatory speed limit (mph)		70
Advisory speed (mph)		45
Average lane width (ft)		11
Average shoulder width (ft)		2
Grade (%)	PC	2
(Deflection to Right)	MC	0
	PT	-2
Annual precipitation rate (inches)		35

Enter 2U for two-lane undivided, 4U for four-lane undivided, or 4D for four-lane divided.

Crash Prediction Model Calculations		
Predicted Crash Counts in Analysis Period		
	Before	After
	6.974	6.406
	0.438	0.294
R)	7.085	6.414
Wet-weather ROR	0.401	0.267
Predicted Change in Crash Count		
All		-9.9%
Wet-weather		-35.6%
Run-off-road (ROR)		-10.9%
Wet-weather ROR		-35.6%
Overall Crash Modification Factors (CMFs)		
Curve radius	6.179	
Annual precip.	1.632	

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Questions?

Training / Lunch Break

Data Review

3. Curve Evaluation Methods

- GPS Method
- Direct Method
- Design Method

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GPS Method

- Equipment Setup

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GPS Method

- Equipment Setup

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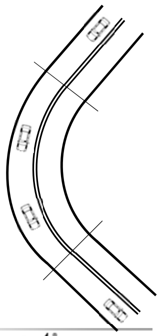
GPS Method

- **Measurement Procedure**
  - ***At beginning of data run***
    - **Press space bar to start recording**

  - ***Drive along the highway***
  - ***At end of data run***
    - **Press space bar to stop recording**



GPS Method

- **Measurement Procedure**
  - ***Track the pavement markings carefully***
  - ***Choose slow but reasonable speed***
    - **Rule of thumb: 10 mph below existing advisory speed**
    - **No less than 15 mph**
    - **No greater than 45 mph if superelevation is being measured**

GPS Method

- **Tangent Speed**
  - ***A speed that is representative of the 85th percentile speed on the tangent sections of the highway where the subject curve is located***
    - **General descriptor of highway**
    - **Precise measurement not needed at every curve**
    - **Can estimate using regulatory limit and curve radius**

GPS Method

- Other Considerations
  - *Length of data run*
    - TRAMS can continuously record data
    - TCES ignores low speeds or gradual curves
  - *Program limitations*
    - TRAMS: computer disk space
    - TCES: rows in Excel® (65,536); cell formatting ends at row 300, but calculations continue to end

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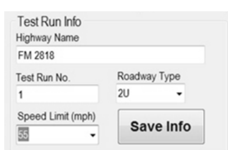
GPS Method

- Other Considerations
  - *Consider starting new run if:*
    - Turned onto different highway
    - Roadway type changed
    - Speed limit changed



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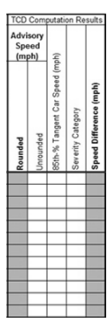
GPS Method

- Determine Advisory Speed and Curve Sign Selection
  - *Review calculations in TCES*
    - Rounded advisory speed
    - Speed difference
  - *Check advisory messages*
    - “TCD (re-)analysis calculations completed.”
    - Prefer a superelevation range width of 3% or less
- Confirm Speed for Conditions



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Questions?

Direct Method

- Field Measurements
  - *Measure speed of 125 free-flow <u>cars</u>*
    - Stop after 2 hours (radar)
    - Stop after 4 hours (classifier)
  - *Compute average and 85th percentile*

- Determine Advisory Speed
  - *Compute average truck speed*
  - *Add one and drop down*
    - 34, 35, 36, 37, 38 → 35 mph
- Confirm Speed for Conditions

Direct Method

- Example
  - *Roadway data*
    - 2-lane undivided highway
    - Speed limit = 65 mph
  - *Curve speed data*
    - Average (125 cars) = 46.1 mph
  - *Compute advisory speed*
    - Average truck speed = 0.97 x 46.1 mph = 44.7 mph
    - Advisory speed = 45 mph

Design Method

- Obtain Curve Geometry
  - *Get curve data from plans*
    - Good for newly-constructed or reconstructed curves
- Determine Advisory Speed
  - *Estimate curve and tangent speed*
- Confirm Speed for Conditions

Design Method

- List worksheet
  - *Use the light green data input cells*
  - *Note: Can also use the light green column for superelevation rate if implementing the GPS Method without the electronic ball-bank indicator*

Highway Name	Curve ID Number	Highway Configuration (2U, 4U, 4D, 4F)	Regulatory Speed Limit (mph)	85th-% Tangent Car Speed (mph)	Existing Curve Advisory Speed (mph)	Design Data		
						Superelevation Rate (%)	Curve Radius (ft)	Deflection Angle (deg)

Questions – Comments?

4. Curve Signing

- Determine Advisory Speed
- Confirm Speed for Conditions
- Select Horizontal Alignment Signs

Determine Advisory Speed

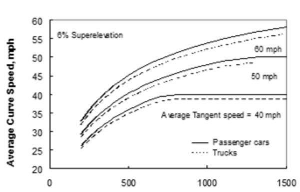
- Criterion
  - *Average truck speed*
  - *Add 1.0 mph to average and drop down to nearest 5 mph increment*

- Note on Rounding
  - *Break points at _4.0 and _9.0*
  - *If unrounded speed is 54.0 → 55 mph*
  - *If unrounded speed is 53.9 → 50 mph*

45					50					55				
44	45	46	47	48	49	50	51	52	53	54	55	56	57	58

Determine Advisory Speed

- Model Variables
  - *Configuration: number of lanes, median type*
  - *Geometry: radius, superelevation rate, deflection angle*
  - *Traffic control: <u>approach tangent speed</u>*



Determine Advisory Speed

- Note on Calculations
  - *Changing any variable may cause a change to the advisory speed!*
    - Configuration or geometry: re-collect the data
    - Traffic control: update the TCES List worksheet and re-run the calculations

Highway Name	Curve ID Number	Highway Configuration (2U, 4U, 4D, 4F)	Regulatory Speed Limit (mph)	85th-% Tangent Car Speed (mph)	Existing Curve Advisory Speed (mph)

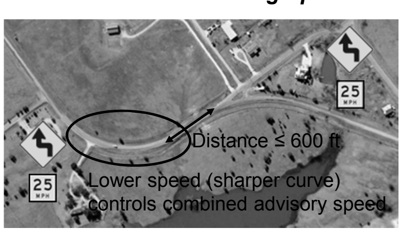
Determine Advisory Speed

- TCES Software
  - *In the office*
  - *In the field*
- Results
  - *Rounded advisory speed*
  - *Speed difference*
  - *Other calculations*

TCD Computation Results				
Advisory Speed (mph)		85th-% Tangent Car Speed (mph)	Severity Category	Speed Difference (mph)
Rounded	Unrounded			
50	53.0	69.1	B	15
55	58.7	69.1	A	10
55	58.1	69.1	A	10
50	52.1	69.0	C	15
50	53.6	69.0	B	15
55	58.1	69.1	A	10
60	59.6	69.1	A	5
60	59.0	69.1	-	5

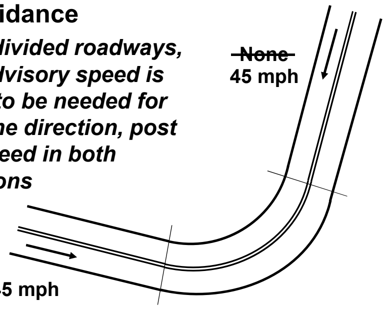
Determine Advisory Speed

- TxDOT Guidance
  - *Procedures for Establishing Speed Zones*



Determine Advisory Speed

- **Sign Guidance**
  - ***On undivided roadways, if an advisory speed is found to be needed for only one direction, post this speed in both directions***



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Confirm Speed for Conditions

- **Engineering Study**
  - ***Site-specific examination***
  - ***Issues <u>not</u> considered by TCES include:***
    - **Approach sight distance**
    - **Visibility around curve**
    - **Intersections in curve**
    - **Proximity to other curves**
    - **Crash history**
  - ***Test run at the advisory speed***
    - **Does the advisory speed "feel" right?**
  - ***Adjust guidance from TCES if appropriate***

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Confirm Speed for Conditions

- **Approach Sight Distance**

Texas Department of Transportation

Confirm Speed for Conditions

- **Visibility Around Curve**

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Confirm Speed for Conditions

- **Intersections or Driveways in Curve**

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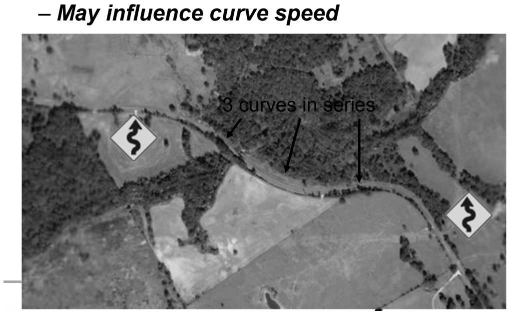
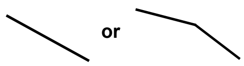
Confirm Speed for Conditions

- **Proximity to Other Curves**
  - ***May influence curve speed***



Confirm Speed for Conditions

- Check Data Consistency
  - *Consistent between opposing directions?*
    - Superelevation
      - Differ by 0 - 4%



    - Radius
      - Within 10% in opposing directions
    - Deflection angle
      - Within 2 degrees in opposing directions
    - Smooth curve tracking is important
  - *Consistent with judgment?*

Confirm Speed for Conditions

- Example
  - *Radius and deflection angle are consistent*
  - *Superelevation differs by 7%*
  - *Consider re-driving the curve*

Direction	Left	Right
Radius (ft)	1105	1040
Deflection angle (deg)	38	38
Superelevation (%)	2	9

Questions – Comments?

Select Signs

Table 2C-5. Horizontal Alignment Sign Selection

Type of Horizontal Alignment Sign	Difference Between Speed Limit and Advisory Speed				
	5 mph	10 mph	15 mph	20 mph	25 mph or more
Turn (W1-1), Curve (W1-2), Reverse Turn (W1-3), Reverse Curve (W1-4), Winding Road (W1-5), and Combination Horizontal Alignment/Intersection (W1-10 series) (see Section 2C.07 to determine which sign to use)	Recommended	Required	Required	Required	Required
Advisory Speed Plaque (W13-1P)	Recommended	Required	Required	Required	Required
Chevrons (W1-8) and/or One Direction Large Arrow (W1-6)	Optional	Recommended	Required	Required	Required
Exit Speed (W13-2) and Ramp Speed (W13-3) on exit ramp	Optional	Optional	Recommended	Required	Required

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.

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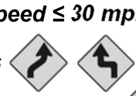
Select Signs

- **Curve Warning Signs**
  - *Default* 
  - *Advisory speed ≤ 30 mph* 
  - *Two curves* 
  - *Three or more curves* 
  - *Deflection angle ≥ 135°* 

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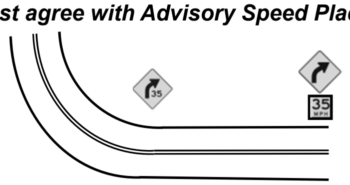
Select Signs

- **Combination Signs (W1-1a, W1-2a)**
  - *Optional supplement to warning sign & advisory speed plaque*
  - *Post at curve PC*
  - *Must agree with Advisory Speed Plaque*



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Select Signs

- **Chevrons**
  - *Spacing guidance in Table 2C-6*
  - *May supplement delineators*
- **One-Direction Large Arrow**
  - *Supplement or replacement for Chevrons*
  - *Supplement for Turn or Reverse Turn*
- **Delineators**
  - *Spacing guidance in Table 3F-1*
  - *For guidance, not warning*

Questions – Comments?

Training / Wrap-Up

- **A Last Request**
  - *Please fill out the evaluation form*
- **Thank you for your time!**

CURVE ADVISORY SPEED AND CURVE SIGNING WORKSHOP

Date: October 23, 2019
Location: TxDOT Bryan District

Your Agency:____

Your Position:____

Course Content (circle one)

	Yes				No
1. Did the course meet your expectations? Comments:	1	2	3	4	5
2. Was the material presented at the correct level of difficulty? Comments:	1	2	3	4	5
3. Was the topic of the course covered adequately (nothing left out, no one topic overemphasized)? Comments:	1	2	3	4	5
4. Was the software easy to use? Comments:	1	2	3	4	5

General Observations

5. What did you like most about the course?

6. What did you like the least about the course?

7. What can we do to improve this course?

8. Other Comments:

Thank you for taking the time to complete this course evaluation form. Please make sure the course instructor receives it before you leave.