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16. Abstract

Curve warning signs are intended to improve curve safety by alerting the driver to a change in geometry that may not be apparent or expected. However, several research projects conducted in the last 20 years have consistently shown that drivers are not responding to curve warning signs or complying with advisory speed plaques.

A new engineering study method was developed to improve consistency in curve signing and driver compliance with advisory speeds. This report documents two activities that were conducted to promote implementation of the new method. One activity is the development of a software program to measure curve geometry while driving through the curve. The geometric data are then used to determine an appropriate curve advisory speed and to select effective, curve-related traffic control devices.

The second activity for this project was a series of workshops that described use of the new method. The workshop provided a mixture of classroom discussion and hands-on training activities for the participants. The workshop participants generally indicated that they believed the new method would benefit their districts and looked forward to implementing it. Recommendations for future research in this area were identified.

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WORKSHOPS ON USING THE GPS METHOD
TO DETERMINE CURVE ADVISORY SPEEDS

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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.

ACKNOWLEDGMENTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Curve warning signs are intended to improve curve safety by alerting the driver to a change in geometry that may not be apparent or expected. However, several research projects conducted in the last 20 years have consistently shown that drivers are not responding to curve warning signs or complying with advisory speed plaques.

A new engineering study method was developed to improve consistency in curve signing and driver compliance with advisory speeds (*1*). This report documents two activities that were conducted to promote implementation of the new method. One activity was the development and field evaluation of the new method. This method entails the use of a software program to measure curve geometry while driving through the curve. The software uses data from a global positioning system (GPS) receiver and an electronic ball-bank indicator to calculate curve radius, deflection angle, and superelevation rate. This new method is referred to herein as the "GPS Method" because of its use of GPS data to measure curve geometry.

The second activity for this project was a series of workshops that described the use of the GPS Method to establish curve advisory speed and determine the need for other curve-related traffic control devices. The workshop provided a mixture of classroom discussion and hands-on training activities for the participants. During the hands-on training, each participant used the GPS Method while traveling through a test curve.

This report consists of four parts. The first part documents the development of the GPS Method for determining curve advisory speeds. The second part provides an evaluation of the GPS Method. The third part describes the workshops that were conducted to facilitate implementation of the GPS Method in Texas. The last part recommends some additional research intended to further evaluate and refine the GPS Method.

GPS METHOD DEVELOPMENT

This part of the report describes the development of the GPS Method for determining curve advisory speeds. It identifies the equipment used with the method and describes the software used to monitor this equipment. A procedure for using the equipment and software is documented in Appendix A of *Procedures for Setting Curve Advisory Speed* (*2*).

The GPS Method involves the measurement of curve geometry and the use of this information to determine the curve advisory speed. The method is used while driving the test vehicle at a reasonable and safe speed through the subject curve. It relies on a laptop computer to continuously monitor the output from the GPS receiver and electronic ball-bank indicator. In this manner, the "critical" portion of the curve (i.e., the portion with the smallest radius) is precisely identified and used to determine the appropriate advisory speed.

Equipment

The equipment used to implement the GPS Method includes a GPS receiver, an electronic ball-bank indicator, and a laptop computer. The GPS receiver serves as the curve radius and deflection angle survey instrument. The electronic ball-bank indicator is used to estimate superelevation rate. A typical equipment setup is shown in Figure 1. The GPS receiver and ball-bank indicator are shown in Figure 1b. The rectangular object mounted on the dash in the center of the figure is the ball-bank indicator. The GPS receiver is the small black object mounted on top of the ball-bank indicator.

| a. Equipment Setup. | b. Measurement Devices. |

Figure 1. Equipment Setup in Test Vehicle.

GPS Receiver

The GPS receiver measures speed and heading repeatedly at short time intervals as the test vehicle travels along the curve. The GPS receiver outputs data sentences that follow National Marine Electronics Association (NMEA) 0183 interface standard. The data used in the GPS Method are from the RMC sentence. This sentence is one of eight sentences output by NMEA-compliant receivers. It contains time, date, position, and speed data. The GPS receiver used for the GPS Method provides output sentences at a rate of 5-Hz (i.e., every 200 ms). It is connected to the laptop computer via the universal serial bus (USB) port (version USB 2.0).

Electronic Ball-Bank Indicator

The electronic ball-bank indicator is used to measure lateral acceleration. The electronic ball-bank indicator must have a digital output data stream matching that of the Rieker RDS7-BB-C Digital Ball-Banking Indicator (or Inclinometer). The electronic ball-bank indicator reports the ball-bank angle at a rate of 4-Hz (i.e., every 250 ms). The Rieker product supports RS-232 serial communications with the laptop computer. If the laptop computer does not have an RS-232 serial port, then a serial-to-USB converter is required to allow the Rieker product to be connected to one of the laptop's USB ports.

The use of the electronic ball-bank indicator is optional. However, if the ball-bank indicator is not used, then the GPS Method will provide only an estimate of radius and deflection angle. The analyst will need to estimate superelevation rate using other means (e.g., reviewing as-built plans, measurement with a digital level).

Software

The Texas Roadway Analysis and Measurement Software (TRAMS) monitors the GPS receiver and the electronic ball-bank indicator and records their output. It is designed to operate on a computer with Windows® XP operating system (Service Pack 2) or newer. TRAMS is used to record the data from the equipment while the test vehicle is driven along the curve. After the curve is traversed, TRAMS calculates curve radius and superelevation rate from the data streams. These data can then be exported to a second software tool—the Texas Curve Advisory Speed (TCAS) software. TCAS uses the data to calculate the recommended advisory speed and identifies other curve-related traffic control devices that may be needed. TCAS operates within an Excel® spreadsheet.

TRAMS and TCAS are described in the following two subsections. Procedures for using these programs to implement the GPS Method are described in the *Procedures for Setting Curve Advisory Speed* (*2*).

Texas Roadway Analysis and Measurement Software (TRAMS)

The TRAMS program continuously collects data from the GPS receiver and ball-bank indicator while the test vehicle is driven through a curve. After the test run is completed, TRAMS processes the data and calculates radius, superelevation rate, and deflection angle for the curve. In general terms, the processing entails dividing the curve into a series of segments. The length of each curve segment is calculated as the product of the average test vehicle speed and the travel time along the segment. Segment deflection angle is calculated as the vehicle's heading change between the start of the segment and its end. Each segment's length is divided by its deflection angle to estimate the average radius of the segment. Additional details about these calculations are provided in the following paragraphs.

The heading data received from the GPS receiver are relatively noisy and require some initial filtering before they can be used to estimate radius. One technique for removing this noise involves the use of a Kalman filter. This filter is used with the raw heading data to remove some of the random variation in the individual heading estimates. A second technique involves the use of a regression model with the filtered heading data, as described in the next paragraph.

Using the filtered heading and speed data, the curve is divided into 25-ft segments and the segment deflection angle is computed. An equation is then derived that predicts deflection angle as a function of travel time along the curve. A sixth-order polynomial was found to be well-suited for this purpose given the typical variation in deflection angle along a curve. This polynomial is then used to estimate the expected deflection angle for every 25-ft segment.

If the average deflection angle in the 25-ft segments is less than 5 degrees, then consecutive segments are combined to yield longer segments such that the combined segments each have a deflection angle of 5 to 8 degrees. This amount of deflection, when combined with the variance in heading estimates, corresponds to a segment radius error of 5 percent.

If an electronic ball-bank indicator is used, superelevation rate for each segment is calculated using the average of the ball-bank readings recorded while traveling along each combined segment. Depending on the speed of the test vehicle, between 2 and 15 readings are typically obtained for each segment. The average ball-bank reading is combined with the vehicle speed estimate from the GPS receiver and the computed segment radius to estimate the superelevation rate for the segment. Details of the method used to calculate superelevation rate from ball-bank readings are provided in Appendix A of Report 0-5439-1 (*1*).

After the geometric data for each curve segment are calculated, TRAMS identifies the segment with the smallest radius. TRAMS then reports this radius and the corresponding superelevation rate and deflection angle for determination of advisory speed.

Texas Curve Advisory Speed (TCAS) Software

TCAS is a spreadsheet program that was developed by Bonneson et al. (*2*). The program calculates curve advisory speed based on curve geometry and tangent speed. It also provides guidance on traffic control device selection for the curve. It requires the following input data:

- 85th percentile tangent speed,
- total deflection angle,
- segment deflection angle,
- segment superelevation rate, and
- segment radius.

The 85th percentile tangent speed is needed to estimate the curve advisory speed. This speed can be obtained from a speed zone study conducted along the road where the subject curve is located, it can be estimated based on knowledge of traffic conditions in the vicinity of the curve, or it can be estimated with TCAS using the regulatory speed limit and the curve radius.

GPS METHOD EVALUATION

Activities undertaken to evaluate the GPS Method are documented in this part of the report. The purpose of these activities was to assess the ability of the GPS Method to accurately measure curve geometry for a range of geometric characteristics and test vehicle speeds.

Data Collection

To evaluate the GPS Method, ground truth data were collected on four test curves that collectively represented a range of geometric characteristics. The test curves were then evaluated using the GPS Method for a range of test vehicle speeds. The following two subsections describe the data collection methods.

4

Ground Truth Curve Data

The traffic control and geometric characteristics of the four test curves are provided in Table 1. The radius and superelevation rates shown represent average values for the length of the curve. The presence of spiral transitions on each curve could not be verified. Therefore, the data in Table 1 reflect the average of measurements taken in the central portion of each curve, where it is most likely to be circular.

Table 1. Test Curve Characteristics.

Curve No.	Posted Speeds, mph		Radius, ft [1]	Superelevation Rate, % [1]	Deflection Angle, deg.	GPS Method Test Speeds, mph
	Regulatory	Advisory				
1	70	No sign	1480	6.2	40	40, 60, 70
2	70	55	1110	6.5	40	25, 45, 55
3	70	No sign	1750	5.5	50	40, 60, 70
4	30	No sign	380	2.0	80	10, 20, 30

Note:
1 – Radius and superelevation rate values represent averages along the circular portion of each curve.

Radius and superelevation rate were measured for a series of consecutive 50-ft segments along the test curves. The long chord of each segment was located with a measuring tape along the marked edgeline of the curve. Then, the offset between the chord and the marked edgeline was measured at the center of the chord. Segment radius was calculated using the chord length and the offset distance. Superelevation rate was measured at the endpoints of each segment using a digital level. These data were computed for each segment and then interpolated to obtain ground truth values for radius and superelevation rate for each 1-ft interval along the curve.

TRAMS Curve Data

The GPS Method was implemented on the test curves to obtain radius and superelevation data from TRAMS. These data were collected at three different test speeds on each curve to quantify the effect of test speed on the TRAMS calculation accuracy.

Results

To evaluate the accuracy and precision of the GPS Method measurements of radius and superelevation rate, the measurements were compared to the ground truth data. This comparison was conducted only for curve segments that were located entirely on the test curves; segments that were located on or near the approach and departure tangents were excluded. Thirty-eight segments were obtained in this manner.

The ground truth data representing each 1-ft interval in a segment were averaged to obtain a ground truth estimate of radius and superelevation rate for the segment. These values were then compared with the radius and superelevation rate values obtained using the GPS Method. The results of these comparisons are presented in the following subsections.

Radius

Figure 2 shows a comparison of the true radii extracted from the ground truth data with the radii computed by TRAMS. Each point represents one of the 38 segments, and the thin line represents the "$y = x$" line. Points falling on this line indicate cases where the radius measured using the GPS Method agreed with the ground truth radius.
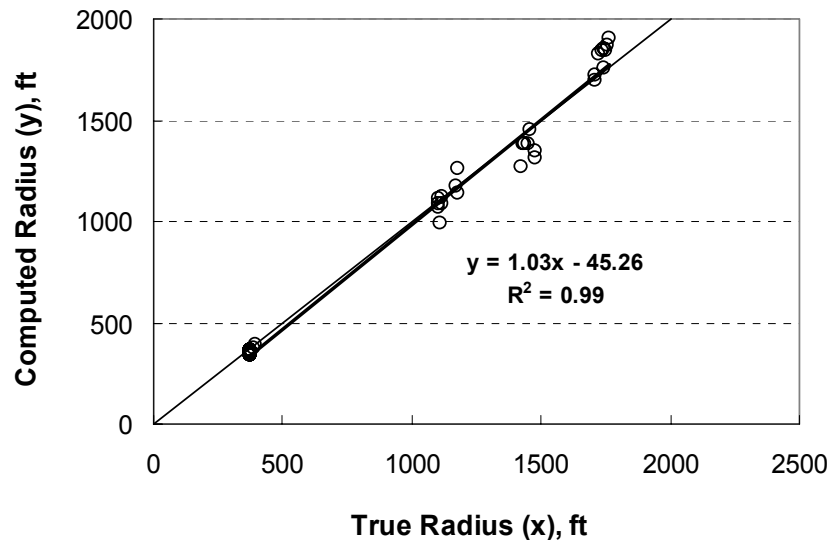

Figure 2. Comparison of True and Computed Radius Data.

A linear regression trend line is also shown in Figure 2, along with its equation. Tests of significance on each of the equation coefficients indicate that the line is not significantly different from the "$y = x$" line. Thus, the TRAMS algorithm provides accurate and precise measurements of curve radius.

To examine variability in the computed radius data, the standard error was computed for each test run using paired computed and ground-truth data for each of several segments on a common curve. The standard error is the standard deviation of the radius estimate divided by the average ground-truth radius and converted to percentage.

As noted in a previous section, the TRAMS algorithm was developed to yield a radius estimate with an error of 5 percent or less relative to the true radius. Examination of the standard errors of the radius estimates revealed that the target 5 percent error was achieved by the algorithm. It also indicated that this error may be reduced slightly when the test run speed is 10 mph or more below the advisory speed (or speed limit if an advisory speed is not posted).

Superelevation Rate

An examination of the ground truth superelevation rate data revealed a large amount of variability in superelevation rate while moving along the curve. This finding is contrary to the

6

objective of curve design where a constant rate of cross slope is desired along the curve. It is likely due to pavement settlement that has occurred since the roadway was constructed.

The superelevation rate measurements from TRAMS were compared to the average ground truth superelevation rate values that were given in Table 1. This comparison is shown in Figure 3. The linear regression trend line in Figure 3 is not significantly different from the "$y = x$" line. This finding indicates that the TRAMS algorithm provides an accurate measurement of curve superelevation rate.
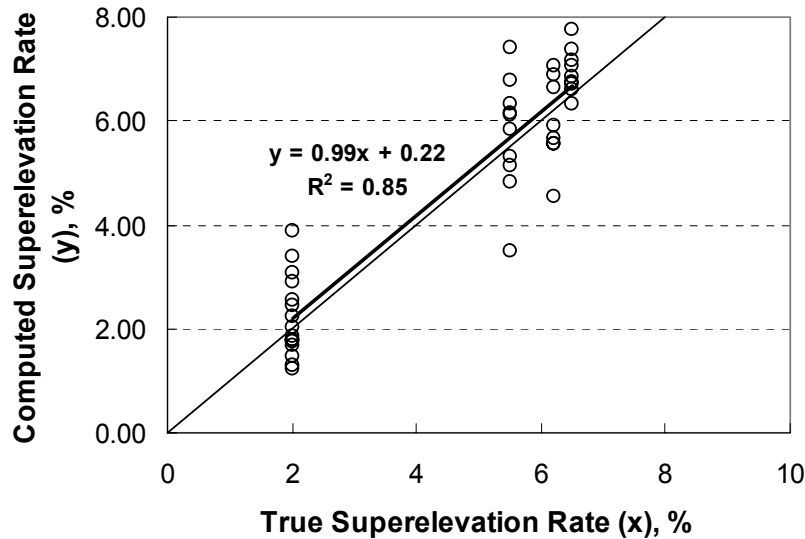

Figure 3. Comparison of True and Computed Superelevation Rate Data.

Inspection of Figure 3 indicates that the superelevation rate obtained from TRAMS tends to be highly variable. This variability is partly due to the uneven pavement surfaces in the forward direction of travel, as noted during the field survey of ground truth data. It is also likely due to rutting associated with vehicle tire tracks. The aforementioned variability in radius measurement can also induce variability in the superelevation rate estimate, as the computed radius for each segment is used to compute the superelevation rate for the segment.

To assess the superelevation rate error range obtained using TRAMS, the superelevation rate data were used to calculate a standard deviation for each test run. These standard deviations were calculated using paired computed and ground-truth data for each of several segments on a common curve. The standard deviations generally increased with increasing test speed. This trend is logical and reflects the increased instability of the vehicle (and resulting ball-bank readings) with increasing speed (*1*).

The TCAS program requires a superelevation rate with a standard deviation of 0.9 percent or less. Examination of the standard deviations indicated that this threshold is reached at a maximum speed of about 45 mph. Hence, 45 mph is considered an upper limit on the test speed when superelevation rate is being measured, with a slower speed desired because it will yield a more accurate estimate.

Findings

The analysis of radius and superelevation rate variability indicates that slower test speeds tend to yield more stable estimates of radius and superelevation rate. Based on these findings, the following recommendations are made regarding the test run speed:

- The test run speed should be at least 10 mph below the existing curve advisory speed (or speed limit if an advisory speed is not posted), provided the resulting test run speed is not less than 15 mph and is not too low to make it difficult to detect the curve.
- If superelevation rate is being measured, test runs should be conducted at 45 mph or less, with slower speeds considered desirable in terms of yielding more accurate estimates of superelevation.

The analysis indicated that superelevation rate variability increases with speed. To inform TRAMS users of the relationship between speed and variability, the curve report file indicates the 95th percentile superelevation rate error range. This range should be checked after each test run. If it exceeds 3 percent, then the test run should be repeated. As long as the 95th percentile superelevation rate error range is less than or equal to 3 percent, the superelevation rate data obtained from the GPS Method should be sufficiently precise to determine appropriate curve advisory speeds.

WORKSHOP SUMMARY

This section provides a summary of the workshop content and a review of the workshop presentations at six venues in Texas. The first subsection to follow provides an overview of the workshop. It is followed by a review of the workshop learning objectives. Then, the workshop format and venues are outlined. The final subsection summarizes the participant evaluations.

Workshop Overview

The workshop objectives were to: (1) document the challenges associated with communicating changes in horizontal alignment, (2) inform engineers and technicians about the availability of a new method for efficiently determining curve advisory speed, and (3) demonstrate the use of the method and related software tools. The workshop was developed for engineers and technicians.

These two activities were undertaken to develop and present the workshops:

- Develop workshop training materials (i.e., visual aids, handouts, participant exercises, hands-on training sessions, software, etc.) that impart to workshop participants the information needed to effectively evaluate curves, determine advisory speeds, and select curve traffic control devices.
- Conduct a one-day workshop in each of six Texas cities.

Workshop Learning Objectives

The workshop 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 applications. The visual aids were supplemented with a course workbook that contained a print copy of the visual aids and the *Procedures for Setting Curve Advisory Speed* (*2*). The computations associated with the evaluation of several example curves were automated using the TCAS program.

The workshop training objectives were achieved through hands-on training sessions. These sessions were conducted before and after the PowerPoint slide presentation. During each session, participants were taken in a test vehicle to a nearby curve to use the equipment and apply the software as part of the engineering study method. They were challenged to make a determination of the appropriate curve advisory speed and identify the need for supplemental curve-related traffic control devices.

The following key points were emphasized throughout the workshop:

- The objective of curve signing is a consistent display of traffic control 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.
- The 85th percentile speed on tangent roadway sections usually exceeds the posted speed limit.
- Selection of devices should be based on an engineering study that considers 85th percentile speed, sight distance, presence of intersections or driveways, and presence of adjacent curves.

All of these key points were repeated throughout the workshop to emphasize their importance and ensure their retention by participants.

To further facilitate implementation, one participant from each TxDOT district was given a GPS receiver for the district's use. The participants were also provided with copies of the TRAMS and TCAS programs.

Workshop Format

The workshops consisted of approximately six hours of instruction, which included a presentation, a demonstration of the TRAMS and TCAS programs, four interactive participant exercises, and hands-on training sessions. The visual aids used in each workshop consist primarily of 140 PowerPoint slides.

The workshop agenda is provided in Table 2. It consists of six sessions. These sessions comprehensively describe the issues associated with, and methods for, communicating changes in horizontal alignment. Sessions 2 through 5 contain self-paced exercises that incorporate the

information presented and challenge the participant to gauge their understanding of the concepts and procedures. These exercises involve the use of TCAS with example curve site data.

Table 2. Workshop Agenda.

Session	Description
1. Communicating Changes in Horizontal Alignment	Statement of curve signing objectives. Discussion of issues with the current practice. Introduction to the GPS Method. Explanations of the Direct Method and the Design Method as described in the *Procedures for Setting Curve Advisory Speed*.
2. Texas Curve Advisory Speed (TCAS) Software	Training in the use of the TCAS software.
Participant Exercise 1	Opportunity for workshop participants to use the TCAS software to determine the advisory speed and choose the traffic control devices for an example curve.
3. GPS Method for Setting Advisory Speed	Description of the GPS Method. Introduction to the TRAMS program.
Participant Exercise 2	Opportunity for workshop participants to use the TCAS software to determine the advisory speed and choose the traffic control devices for an example curve.
4. Advisory Speed Setting Procedure	Discussion of methods and considerations in setting advisory speed for curves. Explanations of site-specific concerns that need to be considered that are not directly observed during the implementation of the GPS Method.
Participant Exercise 3	Opportunity for workshop participants to use the TCAS software to determine the advisory speed and choose the traffic control devices for an example curve. Includes discussion of site-specific concerns.
5. Curve Signing Guidelines	Explanation of the concept of curve severity. Demonstration of assessing curve severity to determine the need for curve traffic control devices. Comparison with existing guidelines in the *Texas Manual on Uniform Traffic Control Devices* (*TMUTCD*).
Participant Exercise 4	Opportunity for workshop participants to assess the robustness of the advisory speed and curve severity category provided by TCAS for an example curve.
6. Engineering Principles	Discussion of key trends regarding curve safety, curve speed, and driver safety that underlie the guidance presented in the workshop.

Workshop Venues

Six workshops were conducted. Table 3 summarizes the locations, dates, and attendance numbers for each workshop. All workshops were held at TxDOT district training facilities. Practitioners from 24 of the 25 districts were able to attend. Most of the participants were the districts' speed zone contacts or their assistants.

Table 3. Workshop Venues and Attendance.

Venue:	Austin (pilot)	Houston	Lubbock	Tyler	Fort Worth	Corpus Christi
Date:	11/12/2008	2/18/2009	3/24/2009	4/9/2009	5/14/2009	6/9/2009
Attendance:	13	9	12	7	12	10

Workshop Evaluation

Participants were given evaluation forms near the end of each workshop and asked to comment on the course content and format. The evaluation form contained four questions about the course content and four questions about 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. The responses to the first four questions are summarized in Table 4.

Table 4. Participant Evaluation of Workshop Content.

Question	Average Participant Response by Workshop Venue [1]						
	Austin (pilot)	Houston	Lubbock	Tyler	Fort Worth	Corpus Christi	Average
1	1.3	1.7	1.1	1.0	1.3	1.2	**1.3**
2	1.4	1.4	1.2	1.0	1.5	1.1	**1.3**
3	1.9	1.3	1.3	1.0	1.4	1.3	**1.4**
4	1.2	1.4	1.2	1.0	1.3	1.0	**1.2**
Average:	**1.5**	**1.5**	**1.2**	**1.0**	**1.4**	**1.2**	**1.3**

Notes:
1 – Scores of 1 to 5 were possible. A "1" indicates "Yes" in response to the question. A "5" indicates "No" and values of 2, 3, and 4 indicate somewhere between "Yes" and "No" (e.g., "Maybe").

The second set of four questions inquired about the participant's general observations of course strengths and weaknesses. Unlike the first four questions, each of the questions in the second set was open-ended.

The questions that inquired about course strengths and weaknesses were the following:

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 workshop?
8. Do you have any other comments?

Of the 63 workshop participants, 59 provided responses to questions 5-8. When asked what portion of the workshop the participant liked best, the most common responses were the hands-on training exercises (21 participants), the participant exercises with TCAS (10 participants), and the provision of GPS receivers for the districts (4 participants).

A total of 26 participants gave positive comments about the organization and presentation of the workshop, referring to the material as "informative," "concise," "to the point," or "straightforward." These comments increased in frequency after the pilot workshop, when initial concerns about the workshop coverage were addressed and the presentation materials were refined.

In response to some early concerns about the new guidance for selecting traffic control devices discussed in session 5, the workshop slides for this session were enhanced. In particular, a comparison of the new guidance and the existing guidance in the *Texas Manual on Uniform Traffic Control Devices* was added that showed the two sets of guidance produced similar results for most curves. After this clarification was included, participants understood the new guidance, and one participant stated that the new guidance was his favorite part of the TCAS spreadsheet.

Three participants stated that they wanted to see similar guidance and procedures for curves on freeway interchange connector ramps. These participants were from primarily urban districts (two from Houston and one from San Antonio). It was noted in the workshop that the Texas Transportation Institute did recently complete research on freeway interchange connector ramp advisory speeds (*3*), although the guidance and procedures did not employ the GPS Method.

Participants commonly expressed a desire to have increased automation built into the TRAMS program. Two ideas consistently surfaced. One idea was to modify TRAMS such that it could be activated once at the beginning of a series of curves (i.e., curves that are treated together with the Reverse Curve, Reverse Turn, or Winding Road signs) and then have the capability to identify all of the curves and determine their appropriate treatments. Another idea was to enhance the links between TRAMS and TCAS such that data for multiple curves could be exported to TCAS simultaneously. However, participants generally agreed that it would be wise to test the current versions of TRAMS and TCAS more extensively before any changes are made.

Participants asked about the necessity of using an electronic ball-bank indicator to implement the GPS Method. Only about one-half of the districts have electronic ball-bank indicators. Of these districts, only about one-half have the newer model (Rieker RDS7-BB-C) that was used in the development of TRAMS. To address the concerns of these districts, the

TxDOT Traffic Operations Division has acquired the necessary equipment for one complete setup and will assist any district that does not have the Rieker RDS7-BB-C ball-bank indicator. Communications between Rieker and TxDOT have also been initiated to negotiate a favorable price in the event that the districts choose to buy the ball-bank indicator.

SUMMARY AND RECOMMENDATIONS

The positive responses to the workshop material and the GPS Method suggest that the workshop content is effective and its format is well-organized. The participants generally indicated that they believed the GPS Method would benefit their districts and looked forward to implementing it.

The suggestions about adding further automation to the TRAMS program could become the focus of future development efforts. This automation could enable multiple curves to be evaluated during a test run. To maximize efficiency in development activities, further automation should be considered after the TxDOT districts have had a few years to test the GPS Method in its current form. At that time, it will be easier to identify refinements that would benefit all users.

After the GPS Method is used to change advisory speeds or traffic control device treatments on curves, before-after studies should be conducted to quantify the effects of the change on driver behavior and curve safety. Specifically, it should be determined whether changing posted advisory speeds results in changes in vehicle speed, crash frequency, or both.

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