# Design Speed, Operating Speed and Posted Speed Relationships

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The use of design speed as a primary factor in selecting a roadway's horizontal and vertical alignments was initiated in the United States in the 1930s. Since that time, highway design criteria were developed to suggest appropriate horizontal curve radii, superelevation rates and vertical curve elements for new roadways, based on the selection of design speed.

The practice of basing posted speed limits on statistical analysis of individual vehicular speeds observed at a spot on the roadway was initiated at about the same time. This procedure has been followed since the 1930s, and the engineering profession has accepted it as an effective and reasonable procedure. An assumption basic to the procedure is that motorists can decide the appropriate speed at which to travel, and the 85th percentile speed is assumed as a reasonable speed for use as the posted speed limit.

Because of differences in design and operations criteria, there are locations where the posted speed limit based on an 85th percentile speed exceeds the roadway's design speed. This situation is a result of the fact that criteria used in highway design incorporate a significant factor of safety. Consequently, it is not surprising that motorists feel comfortable traveling at speeds greater than the roadway's design speed during good weather conditions; however, when posted speed exceeds design speed, exposure to tort liability, whether or not legitimate, is a concern.

The Texas Department of Transportation (TxDOT) sponsored a study[1] to document concerns and difficulties about the relationship between design, operating and posted speeds, and to identify methods being used to address these concerns. Several recent studies examined the relationship between design speed and operating speed on rural, two-lane highways. The collection of data on suburban roadways in this study added to the body of knowledge. The four objectives developed to achieve the study's goals were:

- Identify current state and national concerns, including liability concerns.
- Identify methods being used to address the concerns.
- Recommend guidelines for establishing design and posted speeds.
- Determine the relationship between design and operating speed on suburban highways using data collected at selected sites.

Three data-collection techniques were used during the TxDOT study: mail-out surveys, personal interviews and field studies.

## Mail-Out Surveys

Mail-out surveys were distributed to each TxDOT district and state DOT, and 130 cities and counties across the nation. Separate design- and operations-oriented surveys were sent to the districts and states. Of the 282 surveys distributed, 168 were returned for a final return rate of 58 percent. The high response rate for a survey of this type indicates a high level of interest in the topic.

Although anticipated operating speeds and/or posted speeds are frequently considered when selecting design speed, they are not the most frequently considered factors according to the respondents to the mail-out survey (see Figure 1). Factors including urban vs. rural, functional class and the department's design criteria are considered more often than anticipated operating speed. More than 75 percent of the respondents agreed with the comment that anticipated operating speed should be considered when selecting the design speed of a roadway.

As expected, the most common factor considered in setting speed limits on an existing road is the 85th percentile speed (see Figure 2). Other factors frequently considered included accident experience, roadside development and state-mandated maximum speed limit. Approximately 36 percent of respondents consider design speed. When the facility is new, approximately half of the state respondents indicated that design speed is used as the initial speed. The speed is modified after the facility is in operation, using the 85th percentile operating speed determined from field measurements.

Almost every respondent to the survey indicated that a ball bank indicator is used to set advisory speeds on horizontal curves. Several respondents indicated that they would adjust their procedure to reflect approach conditions to a curve, such as the case of a horizontal curve that follows a long tangent. For example, one state uses larger signs with flashing beacons when a horizontal curve follows a long tangent section. While many respondents expressed concern with the ball bank indicator, no suggestions or recommendations for an improved advisory speed selection process were provided.

Several agencies acknowledged that they have or have had sites on which operating speeds exceed the design speed of the facility. The most frequent action taken was to install advance warning signs. Few respondents stated that they reduce the posted speed limit to match the design speed.

Few respondents had experience with lawsuits involving a posted speed limit that exceeded the design speed of a roadway. Of the six lawsuits identified, three involved advisory speed issues rather than design speed issues. The arguments for one of the three remaining lawsuits focused on consistency of policy for the entire jurisdiction.

Although few lawsuits involving the posted speed/design speed issue have occurred (according to this survey), liability concerns still exist. Several respondents indicated their concern with current definitions and procedures. For example, one city engineer indicated that they are reevaluating how they determine design speed and addressing how to explain this concept to the public and in court, if necessary.

## Follow-Up Interviews

Researchers conducted interviews with two Federal Highway Administration (FHWA) engineers, six members of the American Association of State Highway and Transportation Officials (AASHTO) Task Force on Geometric Design, and 13 traffic engineers from ten states. The initial question regarded the current AASHTO definition for design speed: "the maximum safe speed that can be maintained over a specified section of highway when conditions are so favorable that the design features of the highway govern."[2]

Nearly all of those interviewed agreed that the AASHTO definition of design speed was inaccurate. The term "maximum safe speed" was considered improper because speeds greater than the design speed can be safely negotiated on many sections of highway when "conditions are favorable." In later questions, most of the respondents indicated that speed limits based on 85th percentile speeds are justified even in cases where they exceed design speed, and that such cases do not necessarily create hazardous situations. Most of the engineers recognized that even though no history of legal problems has been associated with the definitions of speed and their relation to each other, these definitions leave room for possible tort litigation in the future.

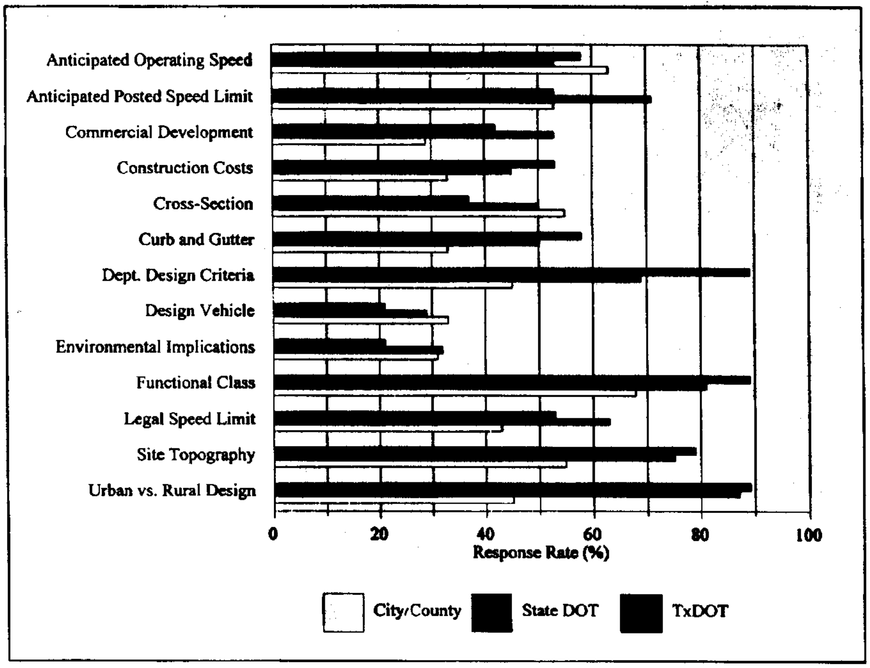


**Figure 1. Factors considered when selecting a design speed**

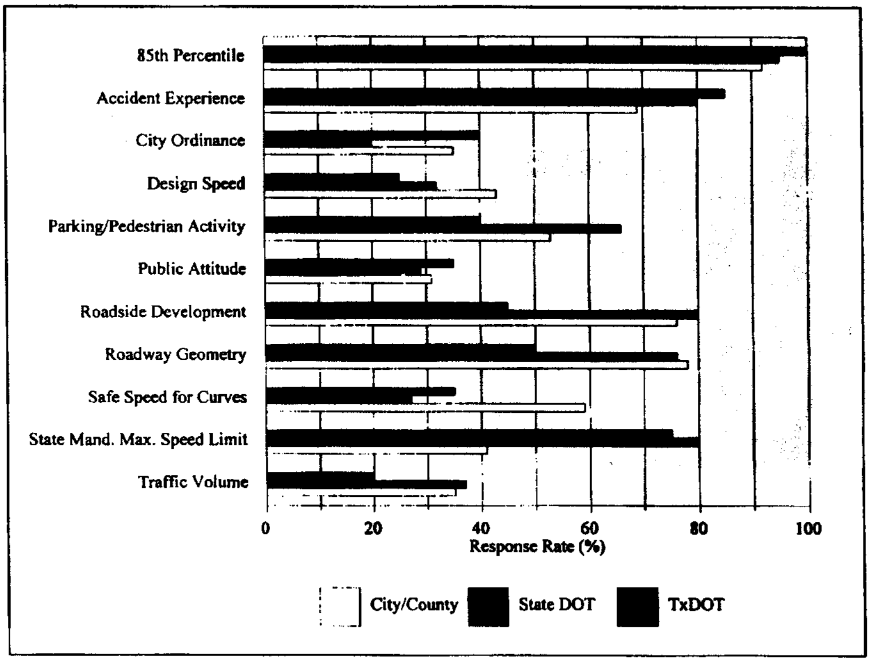


**Figure 2. Factors considered in determining posted speeds for existing facilities**

The engineers stated that roadways are designed with factors of safety that typically allows drivers to exceed the design speed without creating a hazardous condition. They also believe that drivers can be expected to adapt to changing roadway conditions and travel at lower speeds when weather or visibility conditions are less than desirable. While no questions were answered unanimously, most of those interviewed agreed on these basic principles.

## Field Studies

Field studies were conducted on suburban highways with horizontal and vertical curves with low inferred design speed. (Inferred design speed is the design speed calculated using current policy and known variables such as vertical curve length and grades). Free-flow speeds were collected for individual vehicles at both a control and a curve section at 14 horizontal curve sites and nine vertical curve sites. Curve radius for the horizontal curves and inferred design speed (based on available sight distance) for the vertical curves along with approach density were the variables examined to determine their effects on the 85th percentile speed on the control and curve sections. (Approach density is the number of driveways and intersections within the site converted to an approach per kilometer rate.)

The scatter plots of 85th percentile speed vs. approach density indicate that 85th percentile speeds on the tangent approach to horizontal curves are similar for both medium (5 to 7 approaches/km) and high (11 to 12 approaches/km) approach density levels (see Figure 3). Similarly, on the approaches to vertical curve sites, 85th percentile free-flow speeds were not affected by approach density in the range of 5 to 12 approaches/km. Figure 3 shows, however, that 85th percentile speeds were much higher on tangents with fewer than 3 approaches/km.

Regression analyses indicated that curve radius for horizontal curves and inferred design speed (based on available sight distance) for vertical curves are good predictors of the 85th percentile speed on curves. For horizontal curve sites, a curvilinear relationship exists between curve radius and 85th percentile speed (see Figure 4). This result also agrees with previous research on horizontal curves in rural areas. Using approach density in the horizontal curve regression analysis resulted in a slightly better regression model than using curve radius alone.

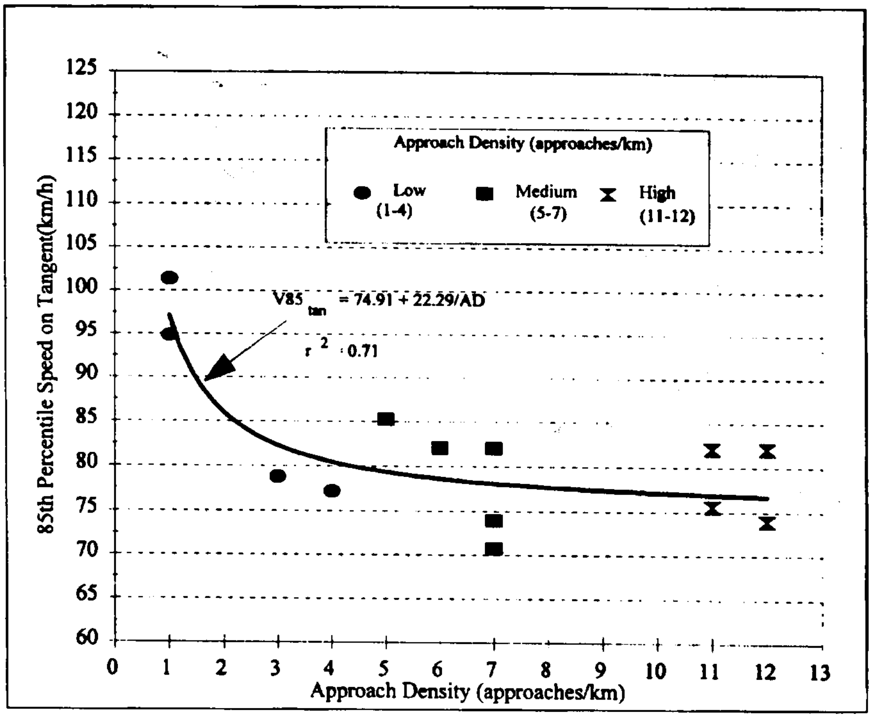


**Figure 3. 85th percentile speed vs. approach density on approaches to horizontal curves**

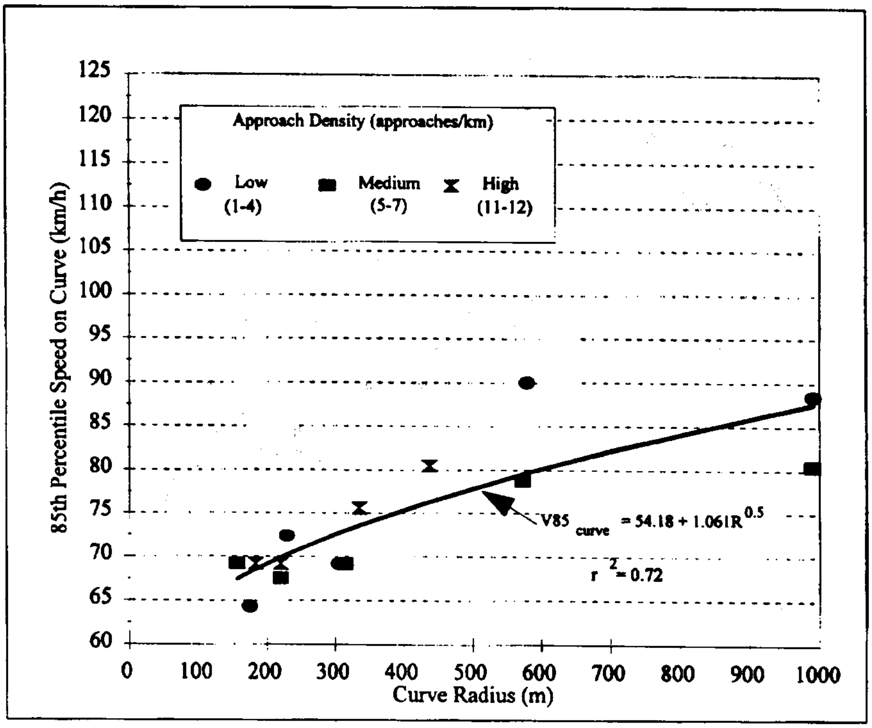


**Figure 4. 85th percentile speed on horizontal curves vs. curve radius**

Figures 5 and 6 illustrate the 85th percentile speed for the 14 horizontal curve sections and the nine crest vertical curve sections vs. their corresponding inferred design speed. The heavy diagonal line represents those points where the 85th percentile speed on the curve would equal the design speed of the curve. The 85th percentile speeds on horizontal curves (see Figure 5) were less than the inferred design speeds for all curves with design speeds greater than 70 km/h and greater than the inferred design speeds for most curves with design speeds less than 70 km/h. The difference between the 85th percentile speed and the inferred design speed on the crest curves was greatest for the lower design speeds and slightly less for the higher design speeds (see Figure 6); however, the difference at the higher design speeds is still rather large (almost 20 km/h).

Previous research documented the point at which the operating speed is approximately equal to the inferred design speed for two-lane roads.[3,4] This study also found that point for the horizontal and vertical curves studied. Suburban horizontal curve drivers operate at speeds above inferred design speed for curves with design speeds of 70 km/h or less, while on rural, two-lane roadways, drivers operate above inferred design speed for curves with design speeds of 100 km/h or less. These points approximate 85th percentile speeds observed on nearby control sections (81 km/h for suburban highways and 100 km/h for rural highways). Similar results were found for the vertical curve sites. The point where 85th percentile speed becomes less than inferred design speed is 105 km/h on rural highways and 90 km/h on suburban highways, whereas the observed 85th percentile speeds on nearby control sections were 98 km/h on rural highways and 78 km/h on suburban highways.

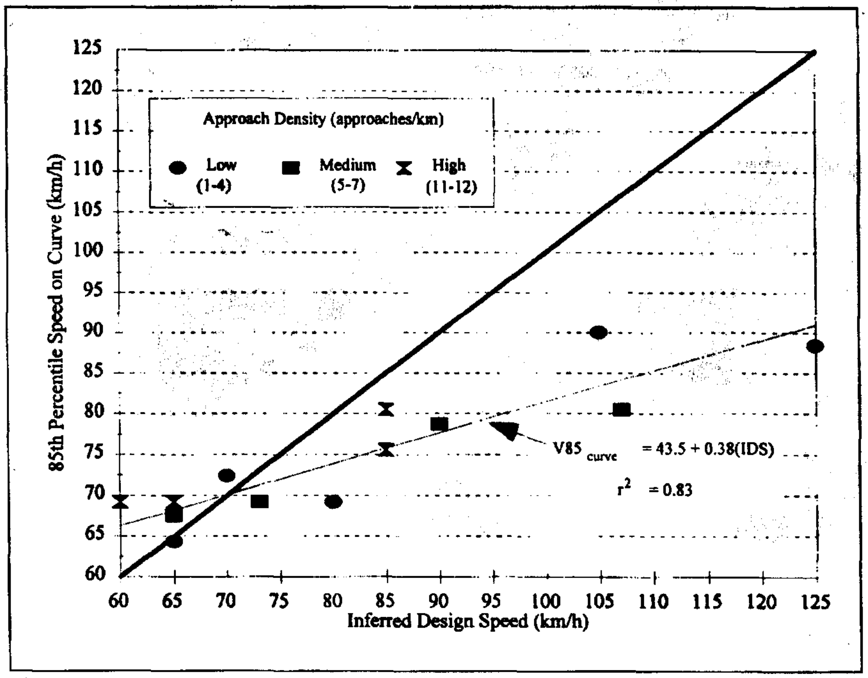


**Figure 5. 85th percentile speeds on horizontal curves vs. inferred design speed**

## Guidelines

The survey and interview results indicated that DOT officials are concerned with posting speed limits greater than the roadway's actual or inferred design speed; however, only a few of the respondents actually experienced a lawsuit relevant to the design speed/posted speed issue. The respondents indicated that the primary concern associated with the posted speed vs. design speed issue rests with the current AASHTO definition of design speed ("the maximum safe speed that can be maintained over a specified section of highway when conditions are so favorable that the design features of the highway govern"). Although it is obvious that the "maximum" safe speed can be exceeded without difficulty on vertical and horizontal curves when good weather conditions are present, it is difficult to convince the general public that a roadway's design speed can be exceeded with safety. If the AASHTO definition for design speed were changed to reflect its actual meaning, liability concerns may be reduced substantially.

Based on the findings from the surveys and interviews and the research team's knowledge and experience, the following guidelines were developed during this study.

1. Speed limits on all roadways should be set by an engineer based on spot speed studies and the 85th percentile operating speed. Legal minimum and maximum speeds should establish the boundaries of the posted speed limits. If an existing roadway's posted speed limit is to be raised, the engineer should examine the roadway's roadside features to determine if modifications are necessary to maintain roadside safety.
2. The 85th percentile speed is considered the appropriate posted speed limit even for those sections of roadway that have an inferred design speed less than the 85th percentile speed. Posting a roadway's speed limit based on its 85th percentile speed is considered good and typical engineering practice. This practice remains valid even where the inferred design speed is less than the resulting posted speed limit. In such situations, the posted speed limit would not be considered excessive or unsafe.
3. Arbitrarily setting lower speed limits at point locations due to a lower inferred design speed is neither effective nor good engineering practice.
4. If a section of roadway has (or is expected to have) a posted speed greater than the roadway's inferred design speed and a safety concern exists at that location, appropriate warning or informational signs should be installed to warn or inform drivers of the condition. Inferred design speeds slightly less than the posted speed limit do not present an unsafe operating condition because of the conservative assumptions made in establishing design stopping sight distances. It is important to remember that any sign is a roadside object and that it should be installed only when its need is clearly demonstrated.
5. New or reconstructed roadways (and roadway sections) should be designed to accommodate operating speeds consistent with the roadway's highest anticipated posted speed limit based on its initial or ultimate function.

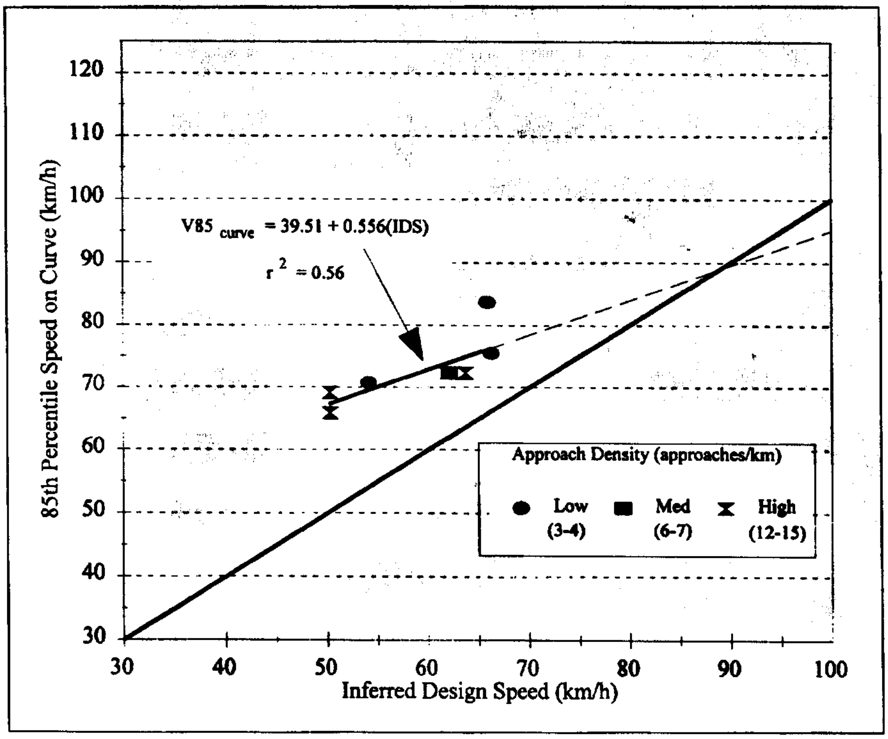


**Figure 6. 85th percentile speeds on vertical curves vs. inferred design speed**

The researchers also developed a document to explain the design, operating and posted speed concepts to individuals who do not have an engineering background.[5] The pamphlet presents the history and purpose of the different speed terms and how they apply to specific circumstances in highway design and traffic operations. It is also designed to be a useful resource for traffic engineers, and public officials involved in legislation involving highway vehicle speeds.

## Summary

Design speed is used in selecting the horizontal and vertical elements for new roadways. Posted speed limits are based on a statistical analysis of individual vehicular speeds observed at a spot on a roadway. Concerns arise at locations where the posted speed limit based on an 85th percentile speed exceeds the roadway's inferred design speed. This inconsistency is a result of the fact that criteria used in highway design incorporate a significant factor of safety—that is, roadways are designed for near worst-case conditions. When posted speed exceeds design speed, liability concerns arise even though drivers can safely exceed the design speed. While there is concern surrounding this issue, the number of tort cases directly involving that particular scenario is small among those interviewed. Even though there is little legal action on this issue, the level of concern indicates that the following actions are needed: 1) changing relevant definitions, and 2) producing and using appropriate methods to communicate to others the procedures used to design and sign roadways. This study addressed both needs.


### Acknowledgments

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