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Design Factors That Affect Driver Speed on Suburban Streets

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Many roadway factors have an effect on driver behavior. Geometric, roadside, and traffic control device variables that may affect driver behavior on four-lane suburban arterials were investigated. Traffic signals and traffic volume were considered within the study site selection and data collection criteria and, therefore, were not included in the analysis. Regression techniques were used to determine how selected variables affect operating speed on horizontal curves and straight sections. When all variables were considered, posted speed limit was the most significant variable for both curves and straight sections. Other significant variables for curve sections were deflection angle and access density class. In another series of analyses performed without using posted speed limit, only lane width was a significant variable for straight sections, but median presence and roadside development were significant for curve sections. The analysis that included posted speed limit, however, produced stronger relationships between speed and significant variables than did the analysis that excluded posted speed limit.

Driver behavior is affected by many roadway factors. Particularly in suburban networks, drivers are besieged by sensations that likely influence behavior. This project investigated geometric, roadside, and traffic control device variables that may have an effect on driver behavior on major suburban four-lane arterials. Other elements that may affect driver speed are traffic signals and the presence of other vehicles. These elements were not included in the analyses because they were considered within the study site selection (sites were selected beyond the range of influence of a signal) and data collection criteria (only free-flow vehicles were measured). The goal was to identify cause-and-effect relationships so that the knowledge could be used to develop designs that result in desired driver behavior. When the operating speed matches the designer's intended speed, the facility design should be more consistent with driver expectancy. The convergence of design speed, operating speed, and posted speed limit should improve safety and operations for these facilities.

STUDY OBJECTIVES

The objectives of a recent Texas Department of Transportation (TxDOT) project were to identify those factors that affect speed on suburban arterials and to determine the range of the influence (*1*). The findings can provide planners and designers with knowledge on how selected elements affect operating speed. The research project was designed to help answer the following questions:

- Do roadway variables affect speed on suburban arterials?
- Which alignment, cross section, roadside, or traffic control device variables affect operating speed?
- For a variable that affects speed, what is the range that is influential?

DATA COLLECTION

Site Selection

Data were collected at both horizontal curves and straight sections (defined as being the straight portion of a suburban arterial between horizontal curves or traffic control devices). The general control (criteria) used to select study sites included

- Area type (urban or suburban),
- Grade (+4 percent to –4 percent),
- Surface condition (fair to good),
- Sight distance (adequate),
- Number of lanes (four lanes),
- Terrain (level to rolling),
- Edge control (curb and gutter only),
- Posted speed limit [48 to 88 km/h (30 to 55 mph)],
- Distance from adjacent horizontal curve [200 m (656 ft)], and
- Distance from adjacent signal or stop sign [300 m (984 ft)].

These criteria were carefully selected to provide a degree of uniformity and to minimize the effects of elements not under consideration in this study. Variables selected for study included median type [two-way left-turn lane (TWLTL), raised, and none] and access density [less than 10 access points (pts)/km (16.1 pts/mi)] and greater than or equal to 10 pts/km [16.1 pts/mi]. In addition, for horizontal curve sites, horizontal curvature was varied [less than 200 m (656 ft)] and greater than or equal to 200 m (656 ft). For straight section sites posted speed limit was varied [48 to 56 km/h (30 to 35 mph), 64 to 72 km/h (40 to 45 mph), and 80 to 88 km/h (50 to 55 mph)]. Roadside environment was measured and evaluated during the study, along with other variables such as lane width and pedestrian activity.

Researchers collected data at a total of 24 horizontal curve sites and 36 straight section sites located in several areas of Texas, including College Station/Bryan, Houston, Dallas/Ft. Worth, San Antonio, Waco, and Corpus Christi. Although data were collected at more sites than initially planned, difficulties with equipment, the need to have speeds measured in a specific location, or both resulted in the use of 19 horizontal curve sites and 36 straight section sites in the analysis.

Data Collection Methodology

Laser guns were used to collect the speed of free-flowing vehicles as they approached, traversed, and departed the study site. A vehicle

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was considered free flowing if it had greater than a 5-s headway or a 3-s tailway (as estimated in the field). A speed profile for a straight section or a horizontal curve and its approaches was recorded. The laser guns were connected to laptop computers that recorded speed data about three times per second while the gun was activated. The speed profile was combined with the measurements made of the roadway and roadside elements. Data collectors were hidden in cars or behind bushes to minimize their effects on driver speed. If a vehicle's speed pattern, as reviewed during data reduction, indicated that the driver may have been reacting to the data collector, the data were eliminated. The data collectors had a goal of obtaining data from 100 free-flow vehicles or collecting data for a maximum of 3 h. Data were collected during nonpeak, daylight conditions.

Selection of Location for Evaluation

The first step in the analysis process was to decide where the speeds were most influenced within the curve or along the straight section. Set increments of distance [50 and 100 m (164 and 328 ft)] were selected before and after a curve, while set quartiles of the curve (25, 50, or 75 percent) or equal intervals of the straight section length (e.g., 10 or 20 percent) were used within those elements. For curves, minimum speed was used as the criterion, while the highest speed was used for straight sections. In theory, the lowest speed within the curve would be the speed most influenced by the characteristics of the curve. The highest speed on a straight section is assumed to be the speed drivers would prefer to drive and, therefore, to be the best reflection of the characteristics of the roadway. Because the accuracy of the laser guns was 1.6 km/h (1 mph), speed profiles for each site were searched for the absolute minimum or maximum speed, and any speed within 1.6 km/h (1 mph) of that speed was identified.

A visual inspection was used to reveal where speeds were most influenced. For horizontal curves, the minimum values occurred between the midpoint and three-quarter point of the curve. For straight sections, the area of maximum speed was not as evident. The straight sections were subdivided into 10 increments. Most of the highest speeds occurred between the third and seventh increments, although a few of the highest speeds extended to the end of the defined straight section. The speeds at the middle of the straight sections were selected for the analysis.

VARIABLE IDENTIFICATION AND TESTING

Tables 1 and 2 list the variables by category included in the initial evaluations for the horizontal curve and straight section analyses.

TABLE 1 Variables Used in Horizontal Curve Analyses

CATEGORY	Variables, range
ALIGNMENT	Curve radius,177 to 513 m (580.3 to 1,682.0 ft)
	Curve length, 59 to 301 m (193.4 to 986.9 ft)
	Deflection angle, 21°–72°
	Upstream control type and distance to upstream control:
	Traffic Signal, 256 to 1170 m (839.3 to 3,836.1 ft)
	Stop Sign, none
	Horizontal Curve, 170 to 751 m (557.4 to 2,462.3 ft)
	Downstream control type and distance to downstream control:
	Traffic Signal, 245 to 1479 m (803.3 to 4849.2 ft)
	Stop Sign, 367 to 808 m (1203.3 to 2649.2 ft)
	Horizontal Curve, 187 to 1051 m (613.1 to 3,445.9 ft)
CROSS SECTION	Lane width - outside, 3.20 to 4.27m (10.5 to 14.0 ft)
	Lane width - inside, 3.05 to 3.96 m (10.0 to13.0 ft)
	Superelevation - outside, –3.65 to 3.91
	Superelevation - inside, –3.9 to 5.73
	Median type and width:
	Raised (9 sites), 3.05 to 10.37 m (10.0 to 34.0 ft)
	Two-Way Left Turn Lane (4 sites), 4.88 to 5.18 m (16.0 to 17.0 ft)
	None (6 sites)
	On-Street Parking (all sites had no on-street parking)
	Bike Lane (only one site had a bike lane, 1.52 m [5.0 ft])
ROADSIDE	Roadside development: residential (11), commercial (6), park (1), or school (1)
	Access density (all access points on both sides of road), 5 to 28 pts/km (8.1 to 45.1 pts/mi)
	Roadside environment (sum of two values: scale of 1 (low) to 5 (high) to reflect frequency of rigid objects and scale of 1 (far) to 5 (close) to reflect distance between objects and road), 5 sites had a value between 2 and 5, and 14 sites had a value between 6 and 10
	Pedestrian activity (1 to 5 scale to reflect presence of pedestrians), 17 sites had scale of 1 (low pedestrian activity) or 2 (medium pedestrian activity with buffer), and 5 sites had a scale of 5 (high pedestrian activity with no buffer)
TRAFFIC CONTROL DEVICE	Signal spacing, 0.33 to 1.5 sig/km (0.5 to 2.4 sig/mi)
	Posted speed limit, 48 to 72 km/h (30 to 45 mph)
	Presence of curve or turn signs: yes (9) and no (10)
	Presence of advisory speed sign: yes (4) and no (15)

TABLE 2 Variables Used in Straight Section Analyses

CATEGORY **Variables, range**
ALIGNMENT
Straight section length, 149 to 1398 m (488.5 to 4583.6 ft)
Upstream control type and distance to upstream control:
Traffic Signal (26 sites), 393 to 998 m (1288.5 to 3272.1 ft)
Stop Sign (6 sites), 375 to 700 m (1229.5 to 2295.1 ft)
Other (Curve, T, Bridge) (4 sites), 568 to 700 m (1862.3 to 2295.1 ft)
Downstream control type and distance to downstream control:
Traffic Signal, 393 to 804 m (1288.5 to 2636.1 ft)
Stop Sign, 375 to 998 m (1229.5 to 3272.1 ft)
Other (Curve, T, Bridge), 568 to 700 m (1862.3 to 2295.1 ft)
CROSS SECTION
Lane width - outside, 2.95 to 4.57 m (9.7 to 15.0 ft)
Lane width - inside, 3.05 to 4.17 m (10.0 to 13.7 ft)
Median type and width:
Raised (15 sites), 2.44 to 4.38 m (8.0 to 14.4 ft)
Two-Way Left Turn Lane (12 sites), 3.05 to 4.57 m (10.0 to 15.0 ft)
None (9 sites)
On-Street Parking, all sites had no on-street parking
Bike Lane, only two sites had bike lanes, 2.13 m (7.0 ft)
ROADSIDE
Roadside development: residential (26), commercial (8), mixed (2)
Access density (all access points on both sides of road), 0 to 29 pts/km (0 to 46.7 pts/mi)
Roadside environment (sum of two values: scale of 1 (low) to 5 (high) to reflect frequency of rigid objects and scale of 1 (far) to 5 (close) to reflect distance between objects and road), 17 sites had a value between 2 and 6, and 19 sites had a value between 7 and 10
Pedestrian activity (1 to 5 scale to reflect presence of pedestrians), 18 sites had scale of 1 (low pedestrian activity) or 2 (medium pedestrian activity with buffer), and 18 sites had a scale of 4 (high pedestrian activity with buffer) or 5 (high pedestrian activity with no buffer)
TRAFFIC CONTROL DEVICE
Signal spacing, 0.0 to 2.5 sig/km (0.0 to 4.0 sig/mi)
Posted speed limit, 48 to 88 km/h (30 to 55 mph)

Multicollinearity

By focusing exclusively on suburban arterials with curb and gutter, some variables have a limited range of values. Because of this limited range, some variables may be correlated with others. In certain circumstances, this correlation can be explained and is expected. However, in other circumstances, the limited range in certain variables creates apparent relationships that may not be valid. These types of relationships can significantly affect the results of the regression analyses. They need to be identified and addressed in order to develop valid statistical results. Using Statistical Analysis System (SAS) and the proc CORR command, those variable pairs with multicollinearity problems were identified. The value of 0.05 for alpha was used.

To minimize the effects of multicollinearity, inside and outside lane widths were averaged to create one lane-width variable. Similarly, inside and outside superelevation rates were averaged to create one average superelevation for each curve. Because curve length was related to many other factors, including curve radius (a variable that was judged likely to be significant), it was omitted from further analyses. While these modifications did not completely eliminate the multicollinearity problems, they greatly reduced the effect multicollinearity could have had on the results of the regression analyses. Final models were checked for collinearity problems after the significant variables were identified.

Variable Transformations

Transformations on certain variables can improve their statistical power for identifying possible relationships. Typically, curve radius and grade are the variables that are the focus of these transformations. During the site selection effort, an attempt was made to keep all grades within a range between +4 and −4 percent. Grades were essentially flat and constant among all sites and were not considered to be a factor. Consequently, the only variable considered for transformation in this study was the curve radius. Two commonly used transformations were attempted: square root of radius and inverse of radius.

Variable Types

During the data analyses, several modifications of various variables were attempted. For instance, access density was originally a continuous variable ranging from 5 to 28 pts/km (8 to 45 pts/mi). Analyses showed that access density in the continuous form was not significant for the curve sites. However, previous research and preliminary plots led to further investigation. A breakpoint of 12 pts/km (19.3 pts/mi) was identified as reasonable, and the continuous variable access density was changed to a class variable. The values assigned to the class variable of access density were classified as "low" for values less than or equal to 12 pts/km (19.3 pts/mi) and "high" for values greater than 12 pts/km (19.3 pts/mi). Another modification included changing median type from three classes to two classes on the basis of the presence or absence of a median. Various other modifications were also examined.

HORIZONTAL CURVE ANALYSIS

The process for identifying variables that influence speed began with an overview of how different categories of the data can be associated with speed. Multiple regression techniques from SAS (proc REG and proc GLM) were used to determine how the variables within each category of data affect speed. Table 3 summarizes these findings. Most of the categories only explain about 25 percent of the variation in the speed data. The traffic category explained as much as 49 percent of the variation. When combined, as much as 70 percent of the speed variation is explained.

Of the alignment variables examined, curve radius and deflection angle were the only significant variables. Curve radius has been found in other studies to affect driver speed on low-speed residential streets and on two-lane rural highways (*2–4*). The presence of a median (rather than the type of median) was found to be significant among the variables in the cross section category. This finding agrees with other research that has found that greater delays are associated with undivided roadways (*5*). Access density and roadside development were the roadside variables found to be significant. Access density is a class variable; the value is 0 when access density is less than or equal to 12 pts/km (19.3 pts/mi) and 1 when the access density is greater than 12 pts/km (19.3 pts/km). Roadside development is also a class variable consisting of four classes: park, school, residential, and commercial. Posted speed was the variable from the traffic control device category that was significant, explaining a large portion of the variation of the data (49 percent). The findings shown in Table 3 indicate that driver speed behavior on suburban arterials is influenced by more than one category.

After the analyses associated with each category were complete, all significant variables were combined, and a final series of analyses was conducted to determine the variables that, when all variables were considered, affected speeds on horizontal curves in this study. The findings are shown in Table 3 in the "All" category. When all the variables were considered, cross section variables did not significantly affect operating speeds on horizontal curves on suburban arterials with curb and gutter. The significant variables included posted speed limit, deflection angle, and access density. The variables found to best explain the variation associated with 85th percentile speed are examined in Table 4. The variation inflation factors shown in the rightmost column are indications of multicollinearity concerns. Values near or above 10 indicate problems. The values indicate that multicollinearity among the variables was not of concern.

A regression model also is used to check each variable to determine whether the sign and value of the parameter estimate are reasonable. Stated another way, does the sign of the parameter estimate agree with expected behavior at horizontal curves? For the model shown in Table 4, higher posted speed limits were associated with higher speeds, while higher deflection angles were associated with lower speeds. Both of these results would be expected along a suburban arterial: higher speed limits would be associated with higher operating speeds (or vice versa), and larger deflection angles would be associated with slower speeds. The influence of access density is nominal until it reaches a critical value. Above that critical value, speeds are lower. For the data in this study, that value was 12 pts/km (19.3 pts/mi), above which the predicted speed is 4.4 km/h (2.7 mph) slower.

Other Attempts to Explain Variation in Speeds

Posted Speed Limit

One potential area of concern with the findings from this analysis is that the variable "posted speed limit" was included as a significant variable. In fact, Table 3 shows that posted speed limit was the variable most related to 85th percentile operating speed. However, one school of thought says that because posted speed limits are based on 85th percentile speeds, the two variables should be significantly correlated and, therefore, not considered for inclusion in such an analysis. While this may be the case with the data herein, a previous study has included posted speed limit in the list of potential variables, and it has been shown to be insignificant (*2*). In addition, a recent ITE survey on speed zoning found that more than half of the speed zoning recommendations from studies provided to the committee were for speeds that were not supported by the 85th percentile speed (*6*). In summary, past research findings have been inconclusive in determining whether posted speed and operating speed are indeed causally related.

To provide findings for both situations, another series of analyses was performed without using posted speed limit. Statistics of the best model are summarized in Table 5. These results show the significance of speed limit. With speed limit in the model, the adjusted R^2-value and model F-statistic both indicate stronger relationships. Without speed limit, the effect of median presence becomes significant along with roadside development. The confounding (as measured by the variation inflation factor) among these variables is low, and the signs of the coefficients are as expected.

Radius

Almost every previous study of speeds on horizontal curves, regardless of the functional classification of the roadway, has identified horizontal curve radius as a key variable for explaining the variation of

TABLE 3 Summary of Regression Analyses for Horizontal Curve Sites

Category	Adjusted R^2 (%)	p-value	Significant Variables
Alignment	21	0.0480	1. Curve radius 2. Deflection angle
Cross Section	24	0.0320	1. Median presence
Roadside	40	0.0228	1. Access density (low ≤ 12 pts/km [19.3 pts/mi], high > 12 pts/km [19.3 pts/mi]) 2. Roadside development
Traffic Control Device	49	0.0005	1. Posted speed limit
All	71	0.0001	1. Posted speed limit 2. Deflection angle 3. Access density (low ≤ 12 pts/km [19.3 pts/mi], high > 12 pts/km [19.3 pts/mi])

TABLE 4 Final Analysis with Speed Limit for Horizontal Curve Sites

Variables	Parameter Estimate	p-value	Variation Inflation Factor
Intercept	43	0.0001	0.000
Speed Limit (km/h)	0.52	0.0001	1.021
Deflection Angle (deg)	−0.15	0.0183	1.025
Access Density (if below 12 pts/km [19.3 pts/mi] then 1, otherwise 0)	4.4	0.0262	1.007
$R^2 = 75\%$ Adjusted $R^2 = 71\%$	F-statistic = 15.341 p-value = 0.0001		

speeds on curves (*2–4, 7–10*). Preliminary observations of speed versus radius and speed versus inverse radius indicated that a similar trend may be present in the data for suburban arterials. The statistical evaluation, however, demonstrated that deflection angle was the horizontal curve variable that most contributed to explaining the variation in speeds on a horizontal curve when speed limit was included in the model.

Additional evaluations were conducted with various forms of radius while excluding deflection angle to illustrate the influence of radius if deflection angle was not included. Lower adjusted R^2-value resulted, and in some cases the results even indicated that both access density and radius should not be included because their p-values exceeded the 0.05 limit.

In summary, for the data collected in this project, other variables were better at explaining the variation in operating speeds on horizontal curves than the radius of the curve. A previous study on suburban arterials, however, did find a strong relationship between radius and speed (*7*). Data collected at additional sites, especially beyond the range present in this study [i.e., sites with a radius of less than 177 m (580.3 ft) or more than 513 m (1682.0 ft)], could provide additional insight into the relationship between radius and speed.

A reason that deflection angle may be stronger than radius is that drivers on suburban arterials may be more sensitive to how the curve looks (as represented by deflection angle) than driver comfort (as represented by radius). Curves on multilane roadways with large deflection angles may appear to be more severe, causing drivers to slow more. A study that asked people to estimate speeds by looking at roadway scenes found that they were much more influenced by the curve angle than by the radius in estimating the appropriate speed (*11, 12*).

Range of Influence of Variables

Previous studies have demonstrated that certain variables can be very influential on speeds but only within certain ranges or at the extremes. In other words, beyond a given value, the variable no longer influences speed, or only at the relative extremes of certain variables will speed be affected. An objective of this research project was to identify the ranges of variables that significantly influence speed. The best model for the data collected in this study found the following three variables to influence speed: speed limit, deflection angle, and access density [above 12 pts/km (19.3 pts/mi)]. When speed limit was omitted from the analysis, median type and roadside development also influenced speed.

For speed limits typically used on suburban arterials [e.g., 48 to 72 km/h (30 to 45 mph)], all speed limit values influence operating speed. Similar to posted speed, the entire range of deflection angles studied in this project (21 to 72 degrees) also influenced speed. As always, caution must be used in extrapolating findings beyond the limits of the study data.

The findings for access density and median type provided the clearest examples of variables that influence speeds only in a certain range. When access density was a continuous variable, it did not significantly contribute to explaining the variation in speed. When converted to a class variable, access density influenced speed when more than 12 pts/km (19.3 pts/mi) were present. Fewer driveways and intersections within the 2-km (1.2-mi) section around the midpoint of the horizontal curve did not have an influence on the speed within the curve. When a median was present, higher speed resulted than when a median was not present. The analysis demonstrated that the type of median present (e.g., raised versus TWLTL) was not

TABLE 5 Final Analysis Without Speed Limit for Horizontal Curve Sites

Variables	Parameter Estimate	p-value	Variation Inflation Factor
Intercept	45	0.0001	0.000
Median Presence (if Raised or TWLTL then 1, otherwise 0)	9.2	0.0023	1.115
Roadside: if School then 1, otherwise 0	13	0.0733	1.894
Roadside: if Residential then 1, otherwise 0	18	0.0032	5.146
Roadside: if Commercial then 1, otherwise 0	19	0.0025	5.068
$R^2 = 62\%$ Adjusted $R^2 = 52\%$	F-statistic = 15.265 p-value = 0.0001		

significant for the data available, but the presence of a separation between lanes did result in higher speeds. Note that other studies have demonstrated that the type of median does have an effect on operations and safety; therefore, it is important not to assume that a raised median will perform in a manner similar to a TWLTL in all situations. The selection of the type of median best suited for a given roadway is a complex decision that is beyond the scope of this study. However, this study does demonstrate that the designer should expect higher speeds when a median is used than when a median is not present.

STRAIGHT SECTION ANALYSIS

The process for identifying those variables that influence speed on straight sections began with an overview of how different categories of the data can be associated with speed. Multiple regression techniques from SAS (proc REG and proc GLM) were used to determine how the variables within each category of data affect speed. Table 6 summarizes these findings. Similar to the findings for the curve sites, the alignment and cross section categories explained less than 25 percent of the variation in the speed data. The traffic category explained as much as 53 percent of the variation.

Of the alignment variables examined, the distance to the downstream control was the significant variable. Lane width was found to be significant among the variables in the cross section category. None of the roadside variables was found to be significant. Again, posted speed was the variable from the traffic control device category that was significant, and it explained a large portion of the variation of the data (53 percent). After the analyses associated with each category were complete, all significant variables were combined, and a final series of analyses was conducted to determine the variables that, when all variables were considered, affected speeds at the midpoint of the straight section. The findings are listed in Table 6 in the "All" category. Once all the variables were considered, the only significant variable was posted speed limit. The variable that was found to best explain the variation associated with 85th percentile speed at the midpoint of a straight section is examined in Table 7. Similar to the curve analysis, higher posted speed limit values are associated with higher 85th percentile speeds.

Because 85th percentile speed is frequently used to set the posted speed limit, it should be expected that one value would be able to predict the other, as is shown in this analysis. As discussed in the curve analysis section, a previous study has included posted speed limit in the list of potential variables, and it has been shown to be insignificant (*2*). Another series of analyses was performed without using posted speed limit so as to provide information on predicting operating speed when not considering posted speed limit. Statistics of the final model are summarized in Table 7. These results show the significance of speed limit. With speed limit in the model, the adjusted R^2-value and model F-statistic both indicated stronger relationships. Without speed limit, only lane width was a significant variable, explaining about 25 percent of the variability of the speeds. The sign of the coefficient was as expected—as the width of the lane increased, the speed on the roadway increased. Figure 1 shows the plot of the model and data points for lane width versus 85th percentile speed. When lane widths are 1 m (3.3 ft) greater, speeds are predicted to be 15 km/h (9.4 mph) faster.

SUMMARY AND CONCLUSIONS

Driver behavior is affected by many roadway factors. This project investigated geometric, roadside, and traffic control device variables that may affect driver behavior on four-lane suburban arterials. The analyses used 85th percentile speeds and ordinary least-squares multiple regression. This decision permitted easier comparison of the results between the curve and straight sections and with previous work. In addition, 85th percentile speed is widely accepted as a quantifiable definition of operating speed. The correlation coefficients of significance for the curve and straight section variables were determined. This effort identified pairs of variables that were correlated and, therefore, that should be eliminated or used cautiously. During the data analyses, several transformations of variables were attempted. For example, access density was originally recorded as a continuous variable. In the analyses, it was examined as a two-class variable with the breakpoint at 12 pts/km (19.3 pts/mi) for the curve sites and at 10 to 12 pts/km (16.1 to 19.3 pts/mi) for the straight section sites. Other transformations included changing median type from a three-class scheme to a two-class variable defining the presence of a median and reclassifying the pedestrian variable into a three-class scheme (low, medium, and high).

The process of identifying those variables that influence speed began with an overview of how different categories of the data can be associated with speed. Multiple regression techniques using SAS were performed to determine how the variables within each category affect speed. The alignment and cross section categories explain about 25 percent of the variation in the speed data for both the curve sections and the straight sections. The variables included in the roadside category were not significant for straight sections and explained about 40 percent of the variation in speed for the curve sections. The traffic control device category explained as much as 53 percent of the speed variation.

TABLE 6 Summary of Regression Analyses for Straight Section Sites

Category	Adjusted R^2	p-value	Significant Variables
Alignment	17	0.0068	Downstream distance to control
Cross Section	25	0.0012	Lane width (average)
Roadside	n/a	n/a	No variables found significant
Traffic Control Device	53	0.0001	Posted speed limit
All	53	0.0001	Posted speed limit

TABLE 7 Final Analysis for Straight Section Sites

Variables	Parameter Estimate	p-value
With Speed Limit		
Intercept	29	0.0002
Speed Limit (km/h)	0.70	0.0001
$R^2 = 54\%$ Adjusted $R^2 = 53\%$	F-statistic = 40.503 p-value = 0.0001	
Without Speed Limit		
Intercept	19	0.2345
Average Lane Width (m)	15	0.0012
$R^2 = 27\%$ Adjusted $R^2 = 25\%$	F-statistic = 12.594 p-value = 0.0012	

After the analyses associated with each category were complete, all significant variables were combined, and a final series of analyses was performed to determine the variables that affected speeds at the midpoint of the horizontal curve and the midpoint of the straight section. Once all the variables were considered, the only significant variable for straight sections was posted speed limit. In addition to posted speed, deflection angle and access density classes influenced speed on curve sections.

Because 85th percentile speed is frequently used to set the posted speed limit, one value should be expected to predict the other, as shown in this analysis. Other studies have included posted speed limit in their list of potential variables; however, this variable has been shown to be insignificant, and other studies have questioned the assumed strong relationship between 85th percentile speed and posted speed limit. Therefore, another series of analyses was performed without using posted speed limit. These results showed the significance of speed limit. With speed limit in the model, the adjusted R^2-value and model F-statistic both indicated stronger relationships. Without speed limit, only lane width was a significant variable for straight sections, explaining about 25 percent of the variability of the speeds. For curve sites, the effect of median presence, together with roadside development, became significant.

RECOMMENDATIONS

Urban street design involves balancing safety, operations, community standards, and other requirements. Even with careful consideration of these issues, operating speeds on roadways can greatly exceed the desired speed for the facility. Having a methodology that can be used to accurately predict operating speeds on different types of facilities assists the designer in developing roadways that operate as expected. This project illustrates that certain variables, such as the presence of medians, can affect operating speeds. This project also demonstrates that more investigation of speed choice is needed to better understand what influences drivers on suburban arterials. The influence could be the complex interaction of combinations of variables; the overall environment, including off-road conditions; or primarily a function of drivers' characteristics. Additional research into these issues is needed to provide better guidance for developing roadway designs.

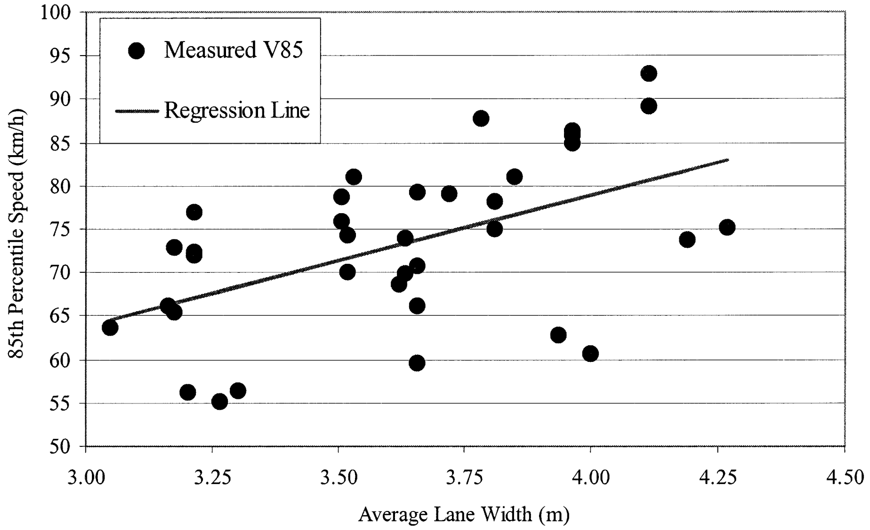

FIGURE 1 Average lane width versus 85th percentile speed.

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