

Continuous Speed Measurement of Individual Drivers on Suburban Arterials

MARK D. WOOLDRIDGE

*Texas Transportation Institute
College Station, TX 77843
mwooldridge@tamu.edu*

KAY FITZPATRICK

*Texas Transportation Institute
College Station, TX 77843
kfitzpatrick@tamu.edu*

ABSTRACT

Driver speed choice is influenced in part by the geometric characteristics of the roadway. Developing a better understanding of this influence on drivers would aid designers in matching their roadway designs to the eventual operating conditions. A limited study was conducted to determine the feasibility of using individual drivers in an instrumented test vehicle to study the influence of geometric elements on speed. It was concluded that although the technique was limited because of sample size requirements and the time required to collect data for each individual, strong statistical comparisons could be made using this type of data.

INTRODUCTION

Driver behavior is affected by many driving environment factors. Particularly in suburban or urban networks, drivers are besieged by sensations which likely influence behavior. The degree to which geometric elements and other driving environmental factors affect driver behavior on rural and low-speed urban roadways has been researched recently. The influence of these factors on major suburban arterial drivers, however, is essentially unknown. If factors providing major driver behavioral influences can be identified, and if cause and effect relationships can be developed, this knowledge can yield designs to affect driver behavior that will likely result in a facility that is safer and more efficient. The measure most frequently used to describe driver behavior on a roadway is operating speed. Operating speed is easy to record and is the most common measure used to evaluate the quality of service present on the roadway.

While operating speed is used in evaluating an existing roadway, the anticipated operating speed is not explicitly used when designing a roadway. The selection of design speed and the values for the different geometric elements is made with little empirical data on their influences on drivers' speed choice. Research is needed to provide a fundamental step in understanding the relationship between drivers' choice of speed and geometric design decisions for major suburban arterials.

With a better understanding of how geometric design elements affect operating speeds, designers will be able to make more effective design decisions for major arterials.

Better design decisions should lead to actual operating speed more closely approximating the intended operating speed of these facilities. When operating speed matches the designer's intended speed, the facility design should also be more consistent with driver expectancy. The convergence of design speed, operating speed, and posted speed limit will effect an inherent improvement on safety and operations for these facilities.

OBJECTIVE

The objective of the work reported here was to determine whether a study could be efficiently conducted using individual drivers in an instrumented vehicle. The study would need to identify those factors that affect speed on suburban arterials and to determine the nature of that influence. The findings from the pilot study could then be used to guide further research efforts.

DATA COLLECTION

Data collection for the individual driver pilot study centered around the use of a test vehicle that researchers had equipped with recording devices to monitor speed. Subjects drove a Ford Taurus station wagon on open roadways selected to provide a variety of designs and environments.

Drivers

Six subject drivers were drawn from among this agency's employees. Both research and administrative staff were part of the pool of available volunteers. All drivers were required to have a valid U.S. driver's license at the time of the testing. Because of the large number of potential drivers, it was possible to select from among the volunteers such that a relatively diverse group of drivers actually performed the testing. Researchers recruited drivers that represented a relatively wide age range, with equal representation of males and females (see Table 1).

It was also considered desirable to provide as diverse an education level as possible considering the available subject pool. The drivers used in the study included a wide range of education levels, as shown in Table 1. Additional information obtained from the drivers was the approximate number of miles driven annually and where they drove most.

Testing Equipment

A 1991 Ford Taurus station wagon was used for the study (Figure 1). The use of a station wagon provided ample room for instrumentation and a comfortable vehicle for the test drivers. During the testing, the speed in km/h and the location of the vehicle relative to control locations on each roadway were recorded using a laptop computer and data acquisition unit in the rear passenger area of the vehicle (Figure 2). Speeds were recorded every 0.3 seconds as the subjects drove through the test roadways. The control program permitted the recording interval to be set by the experimenter (between 0.001 and 2 seconds). The computer created a data file that recorded speed, the time and location associated with each measured speed, the test roadway, and the driver identification number.

TABLE 1 Demographic Characteristics of Drivers

Age (years)	18 - 24	2
	25-54	3
	55+	1
Gender	Male	3
	Female	3
Education Level	GED or High School Diploma	-
	Some College	3
	Associate Degree	-
	Bachelors Degree	-
	Masters Degree	2
	Doctoral Degree	1
Annual Miles Driven	0 - 5,000	1
	5,001 - 10,000	2
	10,001 - 15,000	1
	15,001 - 20,000	2
	over 20,000	-
Location of Most Driving	Urban Areas	1
	Suburban Areas	2
	Rural Areas	1
	Mix of All Areas	2

Distance and velocity were sensed by means of a Datron electronic (no contact) fifth wheel suspended from the back of the vehicle. Times when the driver was impeded by the presence of other vehicles within an estimated 5-second headway or tailway were denoted by an input to the data file (in the "event" column). The view from a forward-looking video camera from behind the rear-view mirror was recorded on a video cassette recorder. The videotape, used for confirmation of the data, included an imprint of the driver number, run, test roadway, and the running distance and time. The test drivers



FIGURE 1 1991 Ford Taurus station wagon used for testing.



FIGURE 2 In-vehicle instrumentation.

were aware of the recording being made and were shown the location and orientation of the camera; the drivers did not appear in the videotapes.

Additional data that was recorded during each test run included whether a vehicle was present in driveways or intersections passed on the right side, whether the driver made a right or left lane change, and whether a slow or stopped vehicle was passed.

Study Sites

Four separate roadways were selected for testing. Pictures of the selected roadways are shown in Figure 3. They represent a variety of driving environments. A constraint that weighed in the selection process was that the roadways had to be reasonably close together. Testing of the drivers had to be accomplished within a relatively short time period (one to one-and-a-half hours) to prevent fatigue effects from biasing the data. Other considerations included having a variety of median types, lateral clearances, and access density. Figure 4 illustrates the location of the study sites in the cities. Table 2 lists the characteristics at each site.

Although clearly the factors shown in Table 2 are not all-encompassing descriptions of the test sites, one additional non-geometry-based factor is also listed: speed limit. Speed limit is an interesting characteristic to study. Because speed limits are frequently based on measurements of actual speeds at sites (specifically, the 85th percentile speed), speed limits as an influence on speed represent a circular reasoning problem. Are speeds low because of a low speed limit, or are they low because site characteristics dictate that drivers maintain low speeds (and thus, coincidentally, result in a low speed limit)?

A key to the research effort is to be able to associate a speed with a geometric feature. Researchers mapped the roadway features of interest (driveways, streets, median openings, median type changes, and rigid and yielding objects) using coded keyboard inputs to the laptop computer during mapping runs in the test vehicle. This allowed graphical representations to be prepared for comparison to measured speeds obtained during driver testing.

Procedure

After the drivers were shown a map of the course to be followed, they were provided verbal instructions about the experimental task and what they could expect to occur. They



South College Avenue



Finfeather Road



University Drive



Jon Kimbrough

FIGURE 3 Test roadways.

were told that during the test they would be accompanied by the researcher and that they would be asked to:

- Drive “normally”—i.e., the way they would drive on a typical trip,
- Generally drive in the right lane, although if a stalled/slower/stopped vehicle were in the lane they could pass it,
- Expect directions in advance of intersections where the driver would be expected to turn, and
- Expect that some parts of the route would be driven several times.

After inviting and responding to any questions, researchers asked the drivers to sign an informed consent document allowing them to participate in the research program.

The drivers then proceeded to drive to the various test roadways. Because of their proximity to each other, South College Avenue and Finfeather Road (referring to Figures 3 and 4) were paired, as were Jon Kimbrough and University Drive. The drivers drove through a roadway pair four times before proceeding to the next pair, thus completing four repetitions of driving each roadway. To eliminate practice and/or fatigue effects

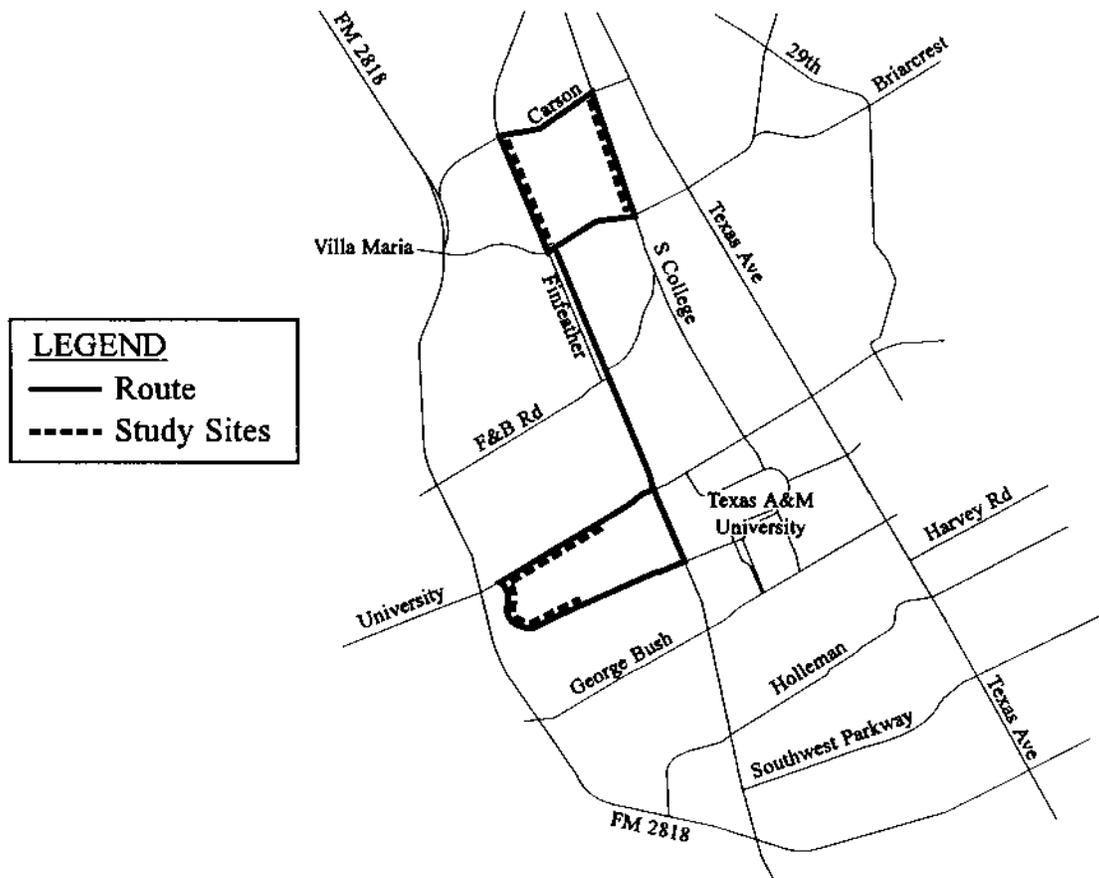


FIGURE 4 Study site locations.

from influencing the results of the study, initial roadway starting points were assigned at random to the six drivers (counterbalancing).

DATA REDUCTION

The data reduction effort for the individual driver pilot study was relatively modest. The various data files for each of the four test roadways were combined to form a complete set

TABLE 2 Site Characteristics for Individual Driver Study

Site	Median Type	Access Density	Lateral Clearance	Speed Limit km/h (mph)
South College Ave.	None	High	Restricted	64 (40)
Finfeather Road	None	Low	Unrestricted	72 (45)
University Drive	Divided (TWLTL)	Low	Unrestricted	64 (40)
Jon Kimbrough	Divided (Raised)	Moderate	Restricted	48 (30)

of data. Because each line of data contained a single data record and included information regarding the subject, test run, test roadway, the distance associated with the data point, the measured speed, whether the driver was impeded at that point, and any special codes entered by the experimenter during the test, the records could be assembled readily into a larger database without losing accountability regarding the individual data points. Computer files were next prepared that contained both the site mapping data and the speed data. This facilitated the preparation of speed plots and representations of the physical characteristics of the test sites.

FINDINGS

Average measured speeds varied between 50 and 75 km/h on the four test sites. Figures 5, 6, 7, and 8 provide graphic representations of speed measurements and geometric variations observed at the four sites. The plots contain the individual speed measurements in relation to the geometric feature present at the location. Features shown include intersections (heavy vertical lines), driveways (light vertical lines), roadside objects that would yield if struck (plus symbols), and rigid objects on the roadside (triangles). The rigid and yielding objects were classified as adjacent to the roadway (less than 2 m from the curb face) or near the roadway (2 m to 5 m from the curb face).

Per Site Findings

The University Drive test section (Figure 5) is a relatively wide-open roadway with a two way left turn lane (TWLTL), and few access points or roadside obstacles. Speeds were relatively constant through the test section after steady speeds were reached.

The Jon Kimbrough test section (Figure 6) is a more constrained roadway with a raised median, few access points, and higher numbers of roadside obstacles. Speed decreases were observed at some of the horizontal curves encountered.

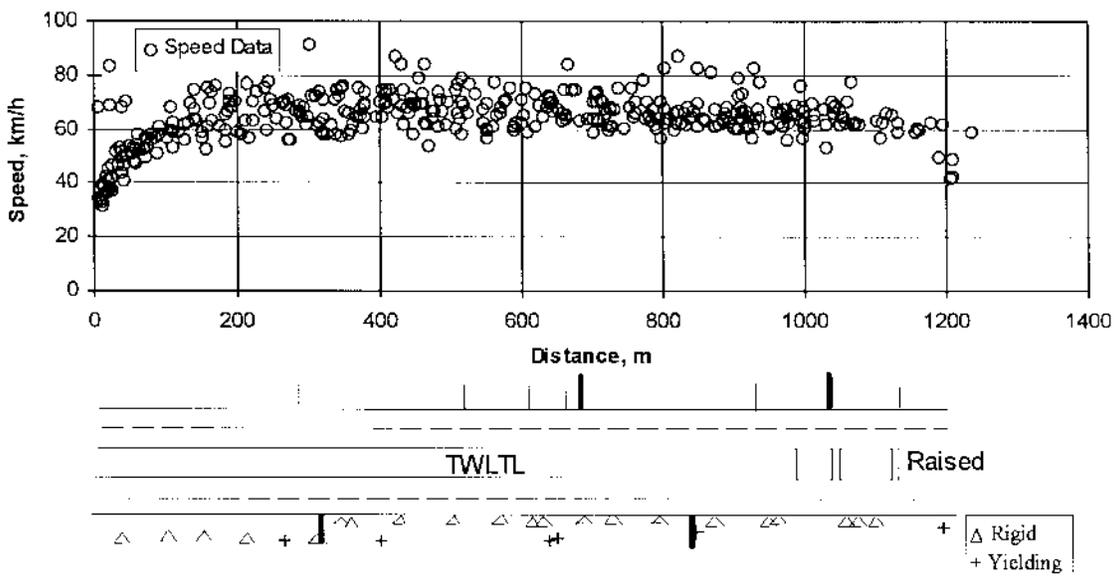


FIGURE 5 University—speed measurements and geometric variations.

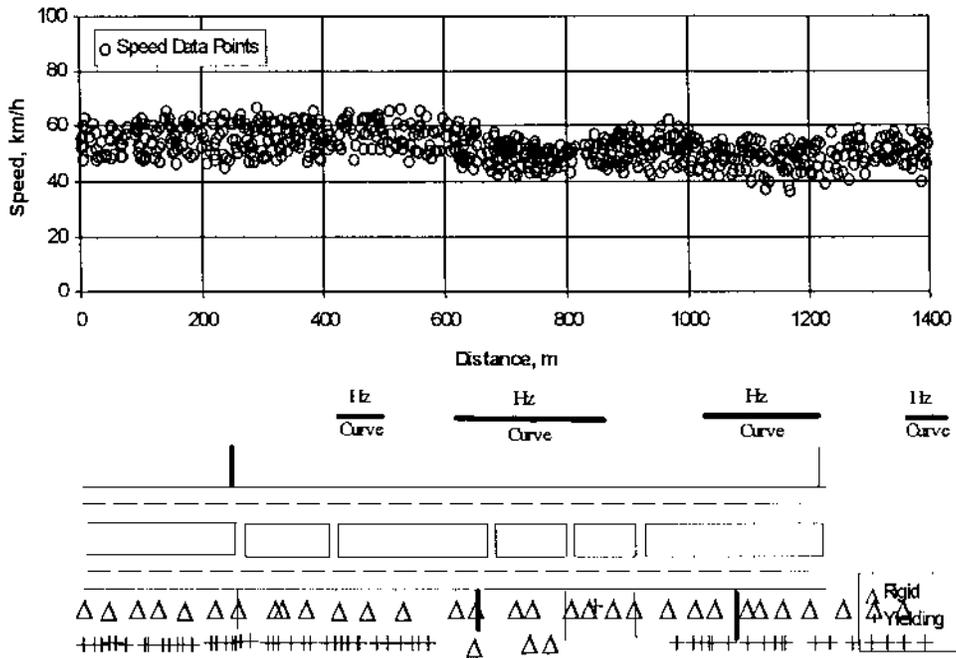


FIGURE 6 Jon Kimbrough—speed measurements and geometric variations.

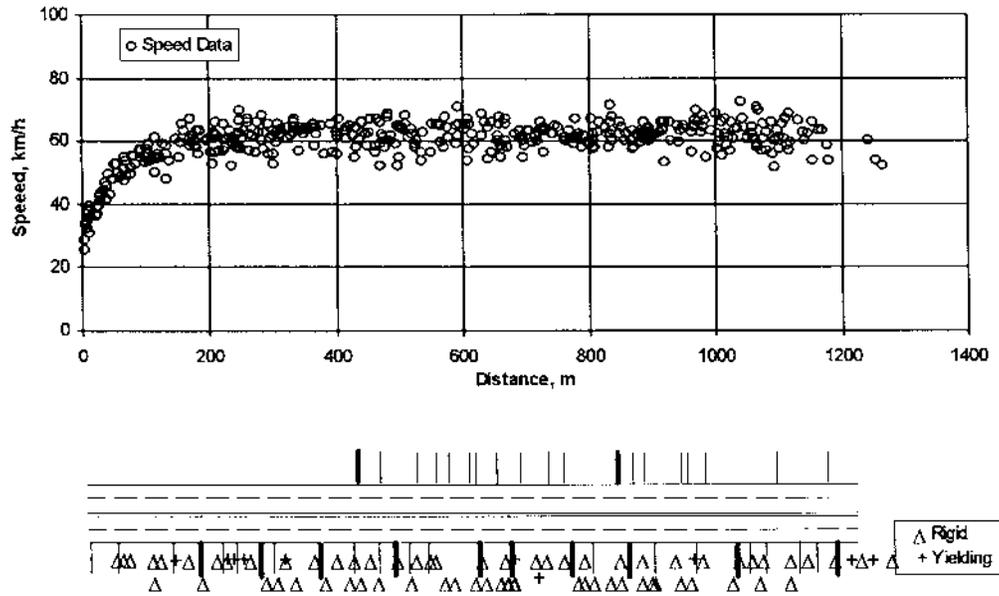


FIGURE 7 South College—speed measurements and geometric variations.

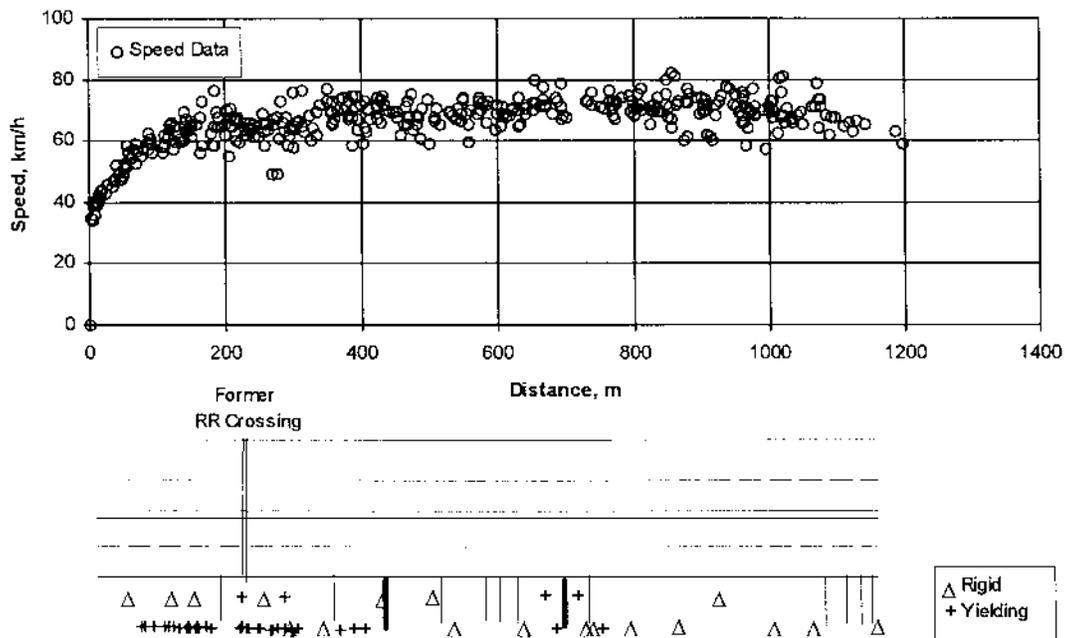


FIGURE 8 Finfeather—speed measurements and geometric variations.

The South College test section (Figure 7) is an undivided roadway with high numbers of access points and higher numbers of roadside obstacles. Similarly to University Drive, the test drivers drove at a relatively constant speed after initial acceleration.

The Finfeather test section (Figure 8) was undivided and had few access points or roadside obstacles. A noticeable decrease in speed was observed at this site near the former railroad crossing, which remains elevated when compared to the remainder of the roadway.

Comparison of Site Findings

A number of plots were made comparing average speeds on 400-m tangents in the four test sections. The plot comparing access level and its potential influence on average speed (Figure 9) does not indicate a clear effect. A similar plot comparing median type and average speed (Figure 10) also does not indicate a clear effect. A plot comparing the number of obstacles and average speed does, however, appear to indicate a relationship between the two variables (Figure 11). When a low number of obstacles are present, speeds are higher.

Next, a plot was prepared that compared speed limit and average speed (Figure 12). In this plot, a 45 degree line was placed to provide a visual reference point—if the average speed equaled the speed limit the data point would lie on the line. As shown in the figure, a positive relationship appears to be indicated between speed limit and average speed. Further examining Figure 12, those sites with divided medians had average speeds that were higher than the speed limit, while sites without medians had average speeds lower than the speed limit.

CONCLUSIONS

Confounding geometric variables and the low number of test sites and drivers restrict both the certainty and range of any conclusions regarding these speed measurements. That is, were

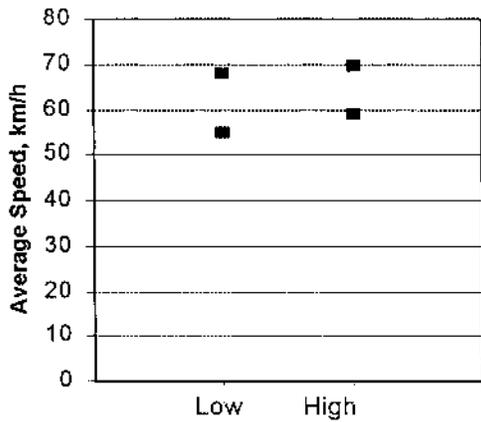


FIGURE 9 Access density.

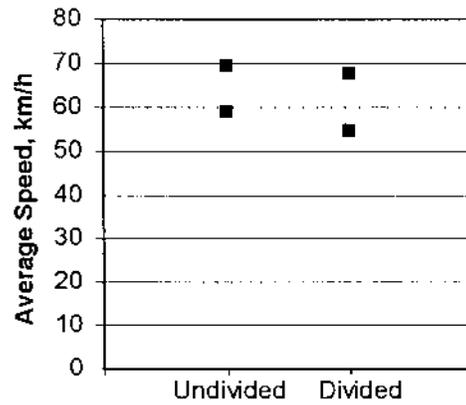


FIGURE 10 Median type.

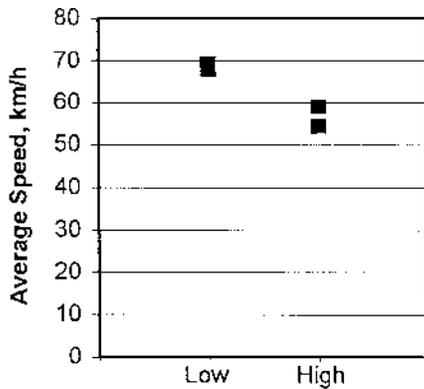


FIGURE 11 Obstacles.

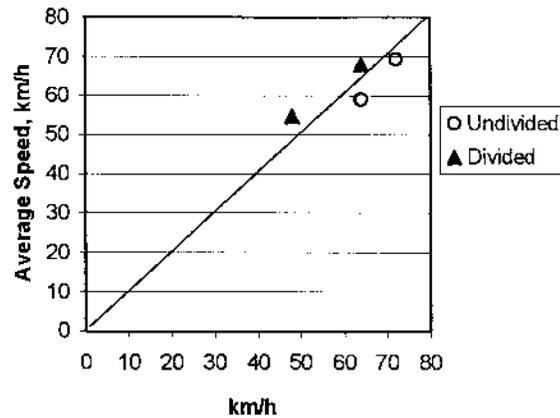


FIGURE 12 Speed limit and median type.

the speeds low at South College Avenue and Jon Kimbrough because they had relatively restricted lateral clearance, high access density, or low speed limits? Did Jon Kimbrough have the lowest speeds because of the high number of obstacles? It is not possible to answer these questions with the limited amount of data available at this time because sufficient information is not available to distinguish the different possible influences present.

Although absolute answers regarding variables influencing speed cannot be provided at this time, it does seem apparent that the variables studied appear to be associated with speeds that differ markedly. That is, we cannot answer precisely which variable or combination of variables is influencing the observed speeds, although differences that could be associated with the various site characteristics were apparent.

Median type, access density, and lateral clearance appear to be promising variables for further study. Based on observations made by the research team during the selection of test sites, it appears likely that considerable confounding is present between access density and lateral clearance. That is, when access density is high, lateral clearance tends to be restricted; when access density is low, lateral clearance tends to be unrestricted. Confounding

between median type and access density also appears to be likely because TWLTLs are frequently utilized in areas of high access density to provide the means of access for left-turning motorists. If these combinations of characteristics are found to be representative of test sites in general it will be difficult to distinguish the actual cause of observed speed variations. On the other hand, it may not be necessary to absolutely distinguish the cause if a set of characteristics can be defined rather than one individual factor.

One of the restrictions on a study using test drivers is that of maintaining a reasonable assurance that fatigue effects do not influence the results. This concern generally dictates that study sessions take no longer than one to one-and-one-half hours. Because driving time between test sites in the pilot stage is expected to be representative of that encountered in any future tests, this factor becomes problematic.

The strength of a repeated-measures study using test drivers is based on analyses that look at variations within the individual drivers. By accounting for variation between drivers and primarily examining differences in speeds at the different test sites or within the test sites, very strong statistical comparisons can be made. This strength, however, is negated when adequate numbers of test sites cannot be used in the study. As shown in Figure 13, individual drivers' speeds can be monitored as they traverse features on the test sites. In this figure, drivers' speeds are monitored as they approached, traversed, and departed a horizontal curve. Acceleration rates, speed changes, and speed profiles can be developed to provide detailed information that cannot generally be determined using conventional speed collection techniques. Given sufficient time and resources, the use of individual drivers in instrumented vehicles could be a very effective approach to study effects on speed.

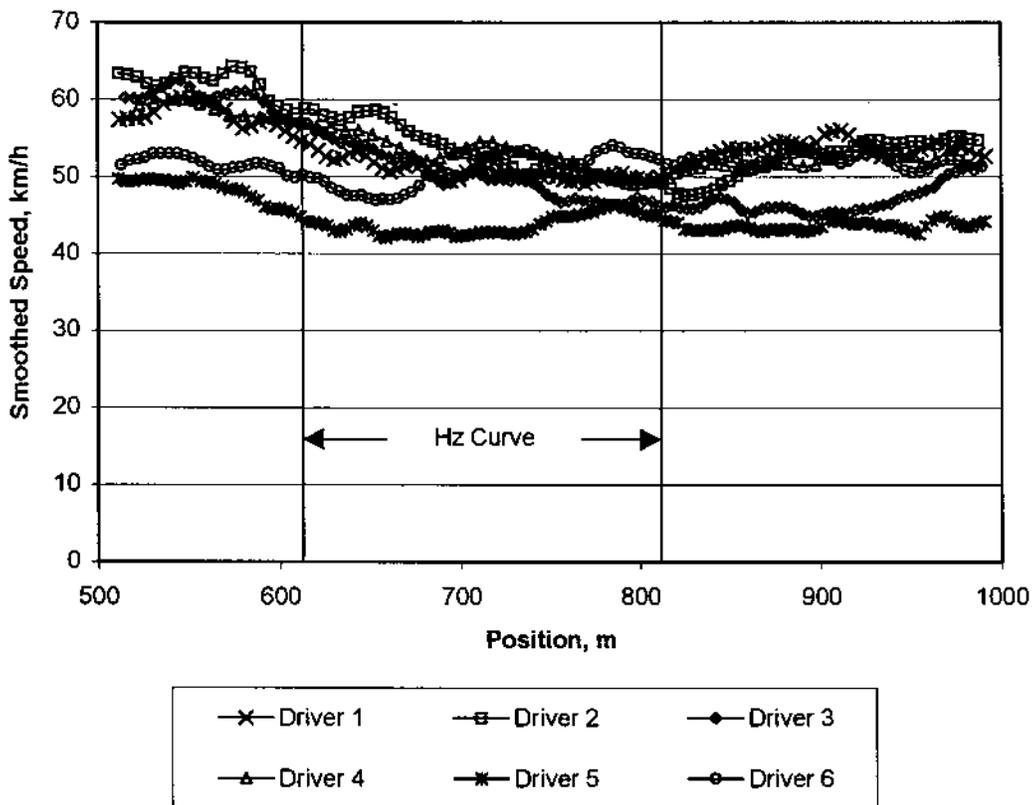


FIGURE 13 Speeds of individual drivers for a single run.