EFFECT OF 55-MPH SPEED LIMIT ON AVERAGE SPEEDS OF FREE-FLOWING AUTOMOBILES ON AN INTERSTATE BRIDGE IN WEST VIRGINIA

Bernard F. Byrne, Department of Civil Engineering, West Virginia University; and
Robert R. Roberts, Traffic and Transportation Center, University of South Carolina

Data on average speeds of free-flowing automobiles were collected from a study of vehicle speed and placement on an Interstate bridge in West Virginia. Because the study included data collected in the summers of 1973 and 1974, it was possible to compare mean speeds for each summer to determine whether the nationwide speed limit of 55 mph (89 km/h) had any effect. It was found that mean speed declined from 61.0 mph (98.2 km/h) in 1973 to 54.5 mph (87.7 km/h) in 1974. The standard deviation of the distribution also declined from 9.2 mph (14.8 km/h) to 6.0 mph (10.0 km/h), thus providing another possible explanation for the reduction in automobile accidents.

•IN RESPONSE to the shortage of gasoline, the U.S. Congress enacted legislation requiring all states to impose a general speed limit of 55 mph (89 km/h) on Interstate highways as a fuel conservation measure. How effective this speed limit has been in reducing average traffic speed has been questioned. We will attempt to answer that question as it pertains to a local situation. Hopefully, a number of local answers may help to formulate a general answer.

The situation examined in this paper concerns an Interstate bridge on I-79 east of Fairmont, West Virginia. The West Virginia Department of Highways is sponsoring a research project to examine the effect on speed and lateral placement of vehicles of narrowing a bridge by means of various combinations of curbing and guardrails. This research has been in progress for a number of years; specific studies on speed and lateral placement were performed in the summers of 1973 and 1974. However disastrous the imposition of the 55-mph (89-km/h) speed limit may have been to the comparability of the data between 1973 and 1974, an opportunity is presented to study average speeds before and after imposition of the speed limits.

DATA COLLECTION

The effect of various combinations of curbing and guardrail on vehicle speed and placement was examined by investigating the study site, data collection methods, data analysis, and consequent data limitations. Data collection procedures require sight distances of 1,500 ft (457.2 m) upstream and 750 ft (228.6 m) downstream of the bridge and tangent roadway. The roadway throughout the test section is a 4-lane highway divided by a grass median. Each lane is 12 ft (3.7 m) wide. During the summer of 1972, the West Virginia Department of Highways repaired this section with an overlay of bituminous concrete. The study site is located in the southbound lane and has a 5 percent downgrade. Its average daily traffic was 6,400 in 1972. The speed limit for this section in 1973 was 70 mph (112.7 km/h).

To meet the objectives of the study, we made measurements of vehicle speed and placement by using a tape-switch system 1,000 ft (304.8 m) and 500 ft (152.4 m) upstream of the bridge, at the upstream end, middle, and downstream end of the bridge, and 500 ft (152.4 m) downstream of the bridge. The tape switches, shown in Figure 1, were numbered from 1 to 6 beginning at the upstream end of the study section.

The recording instruments were set up in the median at the downstream end of the bridge so that traffic could be observed throughout the test section and the operator could be hidden. When a free-flowing vehicle was observed approaching the first set of tape switches, the operator activated the recording system. A free-flowing vehicle was defined as a vehicle whose performance was not affected by any nearby vehicle. The maximum distance between any 2 traps was 500 ft (152.4 m), so vehicles selected for the sample were always 500 ft (152.4 m) behind any preceding vehicle because the preceding vehicle would activate the trap. Vehicles traveling behind the study vehicle could not be recorded until the system was reset. A vehicle ahead of the study vehicle could come into the system only if the study vehicle were to approach the lead vehicle within 500 ft (152.4 m). The data thus collected excluded trucks, motorcycles, and automobiles less than 500 ft (152.4 m) apart.

A series of tape-switch vehicle detectors together with the appropriate electronics and recording equipment can be used to determine the time-position signature of a vehicle over some distance, from which data speed and lateral placement values then can be computed. The tape switch is a vinyl-clad electrical strip switch that is flat, flexible, and pressure-sensitive. It is $^3/_4$ in. (19.1 mm) wide and $^3/_8$ in. (9.5 mm) thick and can be cut to any length and fitted with a connecting electrical lead. The system in this study consisted of 4 major parts

1. Tape-switch detectors and their connectors and cables,
2. Electronics package built by FHWA in their laboratory,
3. A printing Hewlett-Packard 5050B digital recorder, and
4. Power supply (12-Vdc battery and 12-Vdc to 110-Vac power inverter).

The tape-switch detectors were connected to the electronics package by special, shielded cables. The electronics package consisted of gating circuits, a 100-μs clock, and storage registers. The gating circuits accepted inputs from the tape-switch detectors in sequential order to prevent signal overlap. Activation of the second tape-switch detector produced no response in the system unless the first tape-switch detector had been activated; the same principle applied to the third tape-switch detector. Activation of a tape-switch detector caused the input channel of that particular tape-switch detector to close. This process continued until the last detector had been activated or until the system was reset. In this manner, the tape-switch system tracked only 1 vehicle at a time through the system.

In its initial state, the clock was set at zero. When the first tape-switch detector was activated the clock was started. Each time a detector was activated current clock time was stored in a buffer register, from which place it was transmitted to the printer. The printer printed the tape-switch sequence number and the current clock time to the nearest 100 μs each time a switch was activated. The system had controls for resetting and starting the tape-switch system and for indicating good and bad data. It also had a series of switches for turning on or off each individual input channel.

Each trap consisted of 3 tape-switch detectors: 2 were installed perpendicular to the direction of travel 18 ft (5.49 m) apart, and 1 was installed in the middle of the road at a 45-deg angle to the direction of travel. The detectors extended 6 ft (1.83 m) into the roadway so that traffic in the right lane only was recorded.

Figure 2 shows the layout of the tape-switch trap. The formula for speed is

$$V = L/t_L$$

where

V = speed,
L = distance from tape switch 1 to tape switch 3,
$t_L = t_3 - t_1$,

t_1 = time vehicle passed over tape switch 1, and
t_3 = time vehicle passed over tape switch 3.

The formula for lateral placement is

$$P = (Lt_D/t_L - R) \tan \theta$$

where

P = lateral placement,
$t_D = t_2 - t_1$, and
t_2 = time vehicle passed over tape switch 2.

An error analysis of the tape-switch system was undertaken, and it was found to be accurate to within ±0.1 mph (0.16 km/h).

RESULTS

Before recording speeds and placements for the curb and guardrail conditions on the bridge, we established the base condition to provide a basis for comparison. Because curb condition tests were run in 1973 and guardrail condition tests were run in 1974, running a base condition test in 1974 to determine whether the 55-mph (88.6-km/h) speed limit had any effect on speed was thought necessary. The base condition data for 1973 were collected on June 8, 11, 12, and 14. The base condition data for 1974 were obtained on June 13. Because these 2 periods were at the same time of year, speed variation due to time of year was eliminated. A related study (1) showed that days of the week could be combined for statistical analysis. In each case data were taken on days with good weather (no rain). For data collection with curb and guardrail in place, a warning sign stating TEST BRIDGE AHEAD was placed 1,500 ft (457.2 m) upstream of the site. For data collection during the base conditions discussed in this paper, no such sign was on the site.

The speed profiles for the 2 different base conditions for the first trap were calculated and are shown in Figure 3. Trap 1 was used in all comparisons because it was least affected by the grade through the site and proximity to the bridge.

In 1973, the sample size was 851; in 1974, it was 245. For 1974 the mean speed was 54.5 mph (87.7 km/h), and for 1973 it was 61.0 mph (98.2 km/h). Two statistical tests were run: one to determine the equality of variances, the other to determine the equality of means. In both cases a 5 percent level of confidence was used. To determine the equality of variances an F-test was used. The F-ratio was formed. In this case $F = 2.22$. If this is less than the critical F-value, then the hypothesis of equal variances is accepted. In this instance, for a 5 percent level of confidence and $n - 1$ degrees of freedom (df), the critical F-value is 1.23. Therefore, the hypothesis is rejected and the variances are not equal.

To test the hypothesis of equal means when the variances may not be equal, the Smith-Satterthwaite t' statistic is used (2). This approximates Student's t-distribution with n df. The values of t' and n are

$$t' = (\bar{x}_1 - \bar{x}_2)/(S_1^2/n_1 + S_2^2/n_2)^{1/2}$$

$$n = (S_1^2/n_1 + S_2^2/n_2)^2/[(S_1^2/n_1)^2/(n_1 - 1) + (S_2^2/n_2)^2/(n_2 - 1)]$$

Figure 1. Positions of tape switches.

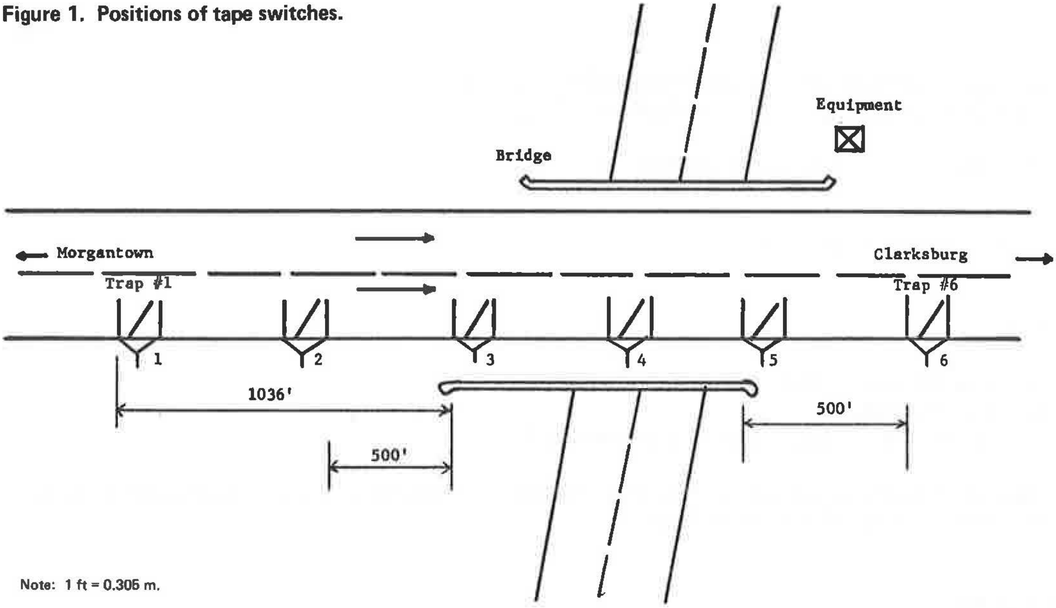


Figure 2. Typical tape-switch trap.

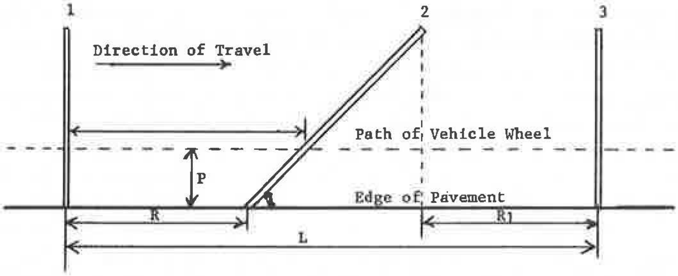
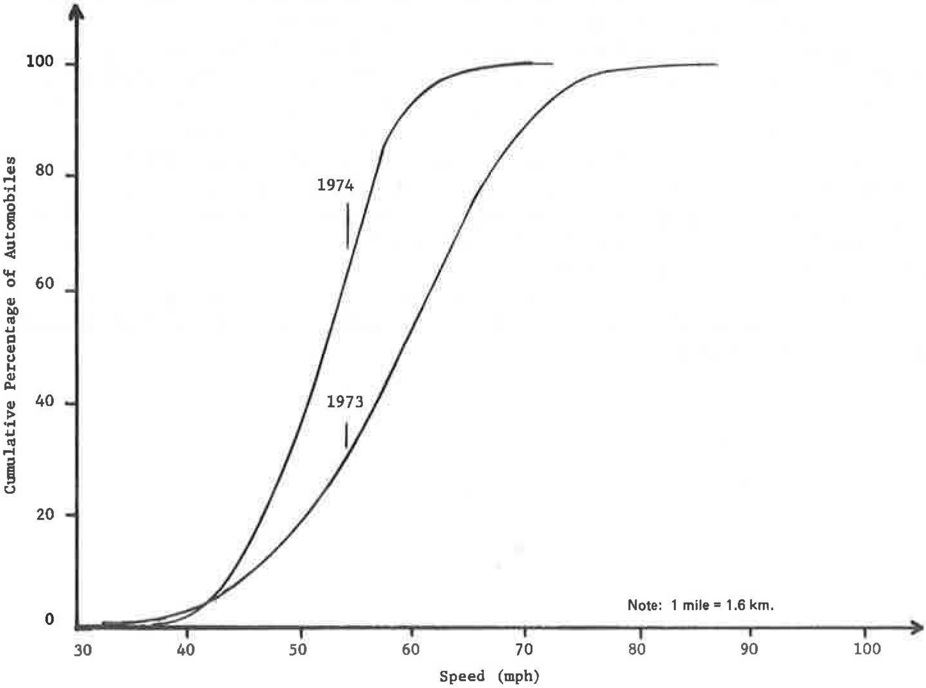


Figure 3. Speed profile for trap 1, 1973 and 1974.



where

X_1 = sample mean,
S_1^2 = sample variance, and
n_1 = sample size.

In this case $t' = 12.89$ with 587 df. Using a 2-sided t-test at a 5 percent level of confidence, we can reject the hypothesis of equal means if $t' < t_{0.025}$. The critical value of t is 1.90, so the hypothesis of equal means is rejected.

The standard deviation was 6.2 mph (10 km/h) for 1974 and 9.2 mph (14.8 km/h) for 1973. One may establish ranges for the 2 years by using the usual figures for a normal distribution in which 95 percent of the sample lies within 2 standard deviations of the mean and 99 percent of the sample lies within 3 standard deviations of the mean. These and other distributions are given below (where 1 mph = 1.6 km/h).

Item	1973 Speed (mph)	1974 Speed (mph)
95 percent of sample	42.6 to 79.4	42.1 to 66.9
99 percent of sample	33.4 to 88.6	35.9 to 73.1
15th percentile	47	49
85th percentile	68	58

With regard to the established speed limits 50 percent of the drivers exceeded 55 mph (88.6 km/h) and 8 percent exceeded 60 mph (96.6 km/h) in 1974 and 10 percent exceeded 70 mph (112.7 km/h) and 3 percent exceeded 75 mph (120.8 km/h) in 1973.

CONCLUSIONS

From the examination of the results, one may conclude that not only has the mean speed been reduced but also the distribution of speeds has been compressed so that differences in speeds of automobiles on the highway have been reduced. An additional explanation for the reduction in accidents and fatalities may be that not only have speeds been reduced, which lowers the severity of accidents, but also speed differences have been reduced, which provides fewer conflicts.

Although the reduction in the variance of speeds also may affect level of service, no effect on highway capacity is envisioned because capacity flow occurs at speeds that are somewhat less than those discussed here. However, significant effects on service volumes for various levels of service may be anticipated. A lower variance in the speed distribution would imply that fewer passing maneuvers need be performed. Because the levels of service are defined qualitatively (ease of passing is one of the measures), the need for fewer passing measures would imply that service volumes could be raised within each level of service without adversely affecting the quality of flow, at least for those levels of service that are less than capacity.

The limitations of these data also should be kept in mind when one draws conclusions. These data were taken at 1 place on an Interstate highway in West Virginia and apply only to free-flowing automobiles. Despite these limitations we feel that the results herein are significant and offer a possible explanation for the recent reduction in accidents.

ACKNOWLEDGMENTS

This paper is part of a report prepared for the West Virginia Department of Highways in cooperation with the Federal Highway Administration. The contents of this paper reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the state or the Federal Highway Administration.

We wish to acknowledge the help of Fern Wood, Karen Ruckle, Majid Kabariti, J. S. Duggal, Mike Romansky, Kulanand Jha, and Charles Kona.

REFERENCES

1. R. R. Roberts. The Effect of Bridge Shoulder Width on Traffic Operational Characteristics. West Virginia University, PhD dissertation, 1974.
2. I. Miller and J. E. Freund. Probability and Statistics for Engineers. Prentice-Hall, Inc., Englewood Cliffs, N.J., 1960.