

Speed-Reduction Patterns of Vehicles in a Highway Construction Zone

RAHIM F. BENEKOHAL, LI WANG, ROBIN ORLOSKI, AND LYNN M. KASTEL

Drivers may change their speeds at different locations within a work zone in response to roadway geometry and traffic control devices. Speeds of vehicles at different locations within a work zone were determined in this study in order to plot their speed-reduction profiles. Vehicles were followed from the time they entered a 1.5-mi-long study section until they exited from it. Automobiles and trucks showed similar speed-reduction patterns. Four categories of drivers were identified on the basis of these patterns. About 63 percent of drivers reduced their speeds considerably after passing the first work zone speed-limit signs (Category 1). Nearly 11 percent of drivers reduced their speeds when they neared the location of construction activities (Category 2). About 11 percent of all drivers did not reduce their high speeds (Category 3). The remaining drivers did not indicate a distinct pattern (Category 4). Three distinct speed-reduction patterns were observed for the drivers in Category 1. The first group decreased their speeds near the first speed-limit signs and had further speed reductions at the work space. The second group drove similarly to the first group, but increased their speed between the two points. The third group reduced their speed near the first speed-limit signs and kept that speed until they passed the work space. The average speed decreased as the vehicles approached the work space, but rapidly increased after passing it. Even at the work space, about $\frac{2}{3}$ of automobile drivers and more than half of truck drivers exceeded the speed limit.

Excessive speed of motorists in construction zones has been a safety concern for highway officials. Some states (e.g., Pennsylvania) have doubled their fines for speeding in work zones to discourage drivers from doing so. Most drivers slow down when they perceive a potential danger on the road, such as the presence of a crew or large equipment near the traveled lane (1). However, there are some questions that remain to be answered. Where do drivers begin to slow down or speed up in a work zone? Do drivers travel at the reduced speed throughout the work zone? Does the speed limit sign work well as a method for obtaining the speed reduction in a work zone? In order to respond to these questions, speed profiles of vehicles in the work zone are needed.

From speed profile data, velocity of a vehicle at different locations along the work zone can be obtained and the speed-reduction effects of various roadway features and traffic control devices may be determined. The speed profile study provides information that is not available from previous studies (2-7), which had measured speeds at only one or two points within work zones. The information from the speed profile

study would provide insight into drivers' behavior in work zones that could be used to select more efficient and effective methods of traffic control.

In this study, speeds of vehicles at different locations within a work zone were determined and their speed profiles plotted. The field experiment consisted of obtaining video images of vehicles as they traveled through the construction zone. Discussed in this paper are data collection and reduction, speed profile patterns, driver categories, and speed characteristics of vehicles. Statistical tests on the speed profile data are not included because of space limitations. The terminology suggested by Lewis (8) is used, whenever possible, to identify different locations within a work zone.

DATA COLLECTION

Study Site

The study site was in a construction zone on Interstate 57, near Mattoon, Illinois. The highway has two lanes per direction, but one lane on each direction was closed. The work zone was about 4 mi long. The construction work mainly consisted of bridge deck repairs: a bridge over State Route 16 and another over a railroad about 2.5 mi to the south of Route 16. Other construction activities included overlay and shoulder reconstruction on the ramps for Route 16 and I-57. There is a full cloverleaf interchange at Route 16, but the inner loops from Route 16 (on ramps) to the highway were closed. During the data-collection period, several men were working on the Route 16 bridge, and a crane, one or two pick up trucks, and other small pieces of equipment were present on the bridge.

The speed limit inside the construction zone was 45 mph for all vehicles. Two small yellow flashing lights mounted on top of the regulatory 45 mph speed-limit signs were on during data collection. Outside the work zone the speed limit was 65 mph for automobiles and 55 mph for heavy trucks. One of the Illinois Department of Transportation's (DOT's) standard traffic control plans (TCP) was used in this work zone. In general, the TCP follows the procedures given in the *Manual on Uniform Traffic Control Devices* (9). The signs used for traffic control in this work zone are shown in Figure 1.

Plan and Profile of Site

The plan, profile, location of the influence points (IPs), and speed stations in the study section are shown in Figure 2.

R. F. Benekohal and L. Wang, University of Illinois At Urbana-Champaign, 205 N. Mathews Ave., No. 1201, Urbana, Ill. 61801. R. Orloski, DeLeuw, Cather & Company, 525 W. Monroe St., Chicago, Ill. 60606. L. M. Kastel, Bucher Willis Ratliff Consulting Engineers, 7920 Ward Parkway, Kansas City, Mo. 62114.

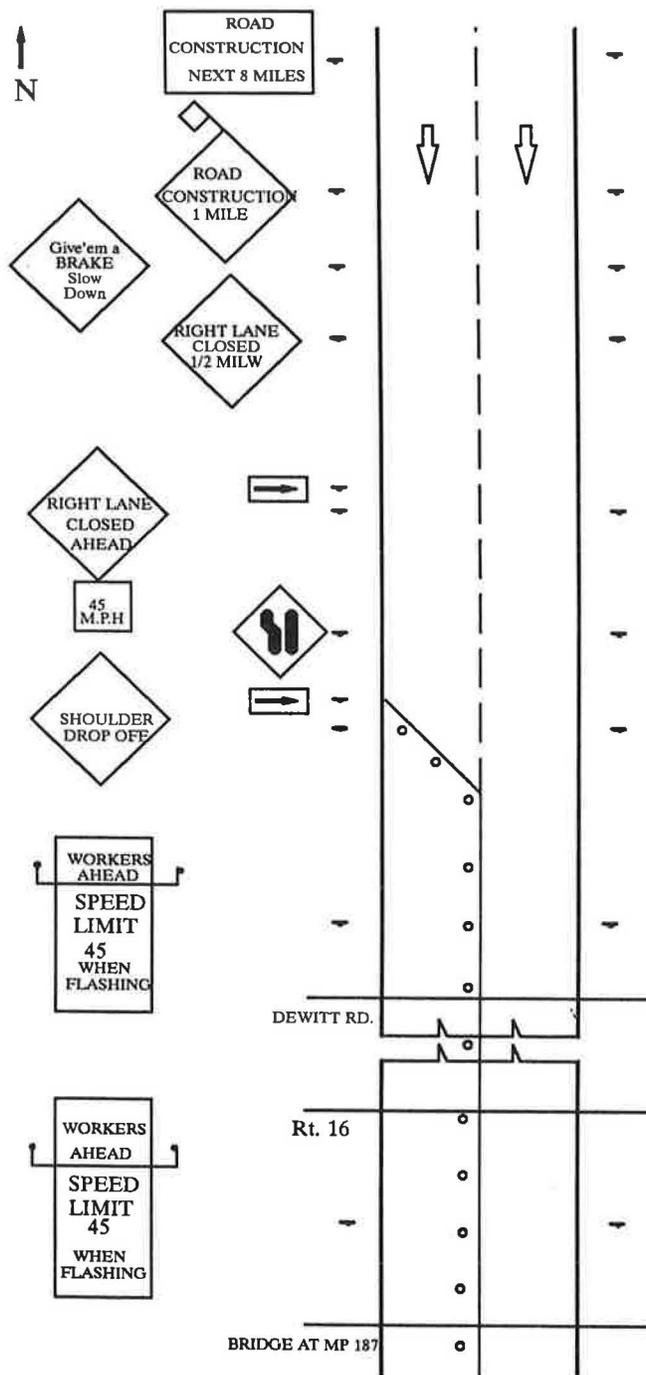


FIGURE 1 Work zone signs on SB I-57 during speed profile study.

There were three sag curves and one crest vertical curve in the study section. The crest curve was approximately 2,800 ft. Proceeding south, the crest curve had a 3 percent uphill slope. The remaining curves had very gentle slopes or short length and would not significantly affect the speed of vehicles. The speed reduction because of the uphill, if any, would be noticeable for truck but not for automobile speeds (10). Speeds of vehicles after completion of the construction project were monitored to assess the effect of the upgrade on speed. The

average speed reductions for 116 automobiles and 104 trucks were 1.00 mph and 4.96 mph, respectively. From the speed profile data, it was not possible to separate the speed reduction effects of the work zone from that of the upgrade. It was assumed that significant portions of the speed changes were mainly caused by the presence of the work zone and not the upgrade.

Data-Collection Approach

The field experiment consisted of obtaining the speed of the vehicles at various locations as they traveled through the construction zone. The speeds were obtained using video images of the vehicles. Although video images of vehicles have been previously used for data collection (11), the data-collection approach of this study is unique. Cameras followed and videotaped the vehicles through the study section.

The study section covered about 1.5 mi of the highway. It was divided into two segments. The first segment was 4,800 ft in length and was videotaped from Camera Location 1. Segment 2 was 5,600 ft in length and was videotaped from Camera Location 2. A 1,600-ft overlapping distance was videotaped from both camera locations.

Each segment was divided into smaller intervals by the road markers. The markers were either of a permanent (e.g., bridge abutment, signs, or light posts) or temporary type. The temporary markers were plastic posts placed on the side of the highway when a permanent marker was not available for some distance. The markers were spaced approximately 400 to 700 ft from each other. A total of 30 markers were established. Normally, 21 markers were used for each vehicle. The remaining 9 markers were considered supplementary, and were used when the time reading for a nearby marker was missing.

Data were collected from May 30 to June 1 of 1990 during weekdays under normal weather conditions. Only vehicles in free-flow conditions were videotaped to eliminate the effects of platooning. The average daily traffic on this section of the freeway was around 12,000, with approximately 22 percent heavy commercial vehicles (12). The data contained video records of 208 vehicles that traveled through the study section.

Data-Collection Teams

There were two data-collection teams. The first team was located at Camera Location 1 and the second team at Camera Location 2. The teams communicated with each other using citizen band radio. The first team identified a free-flowing vehicle that was about to enter the study section and started videotaping it. As the vehicle approached Segment 2, information about the vehicle and its location was given to the second team so that the same vehicle was followed. Both teams videotaped the same vehicle on the overlapping intervals. The overlapping intervals were used to check the speed computed from the two video images and confirm that the same vehicle was used by both teams. A description of each vehicle and the time of the day it traveled in the study section were written on the field notes for later use in data reduction.

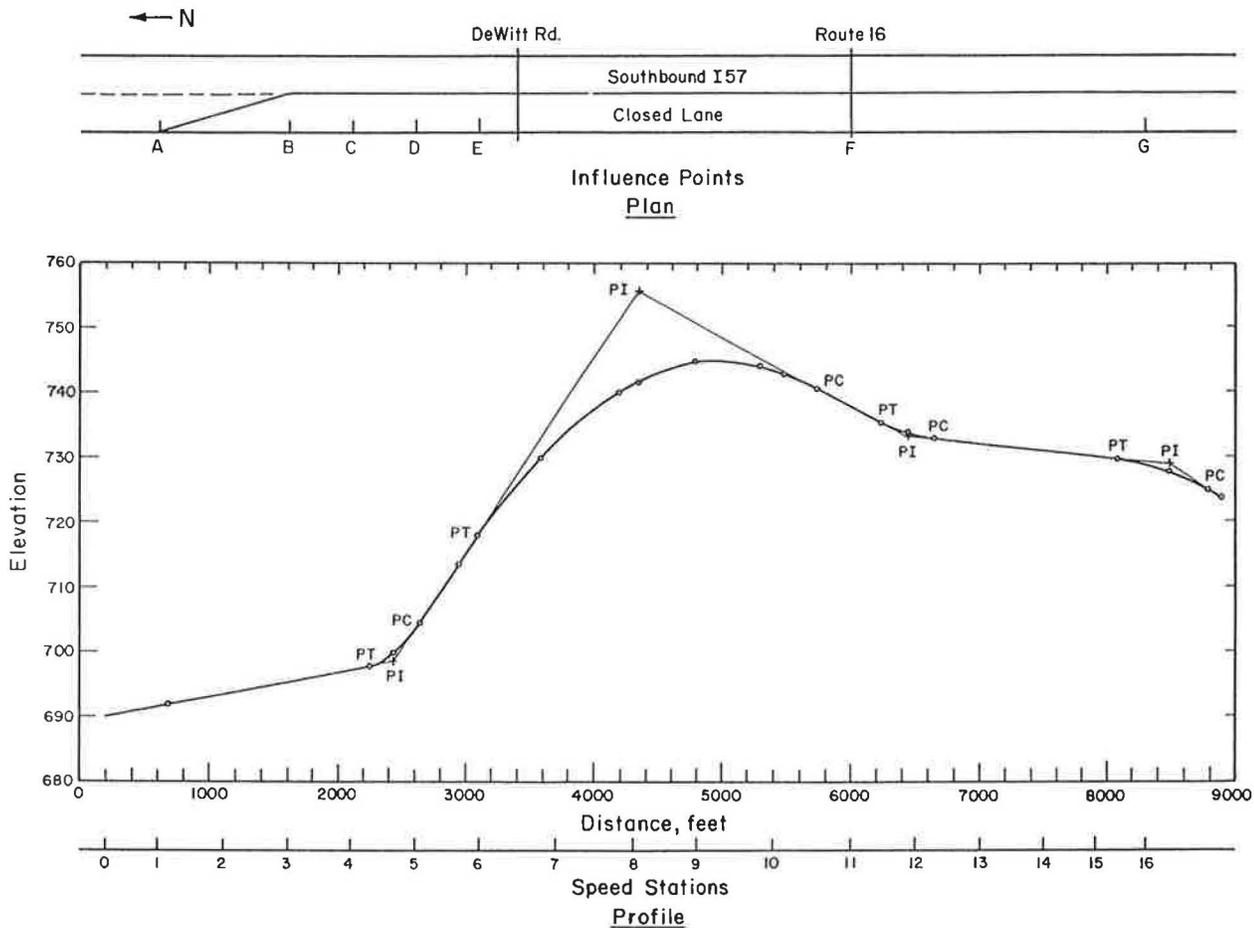


FIGURE 2 Plan, profile, and location of IPs and speed stations.

Camera Locations

Camera Location 1 was on DeWitt Road, which is about 2,600 ft north of Route 16. From Camera Location 1, the vehicles could be seen before entering the lane closure taper until they traveled a distance of 4,800 ft, which is the end of the overlapping intervals and Segment 1. Camera Location 2 was on Route 16. From Camera Location 2 a vehicle could be seen from the time it was on the Dewitt Road overpass, which is the beginning of the overlapping intervals, until the vehicle traveled a distance of 5,600 ft on the highway, which is the end of the study section. Camera locations 1 and 2 were 2,600 and 1,600 ft, respectively, away from I-57.

DATA REDUCTION

The data reduction was very labor intensive. Descriptions of each vehicle were carefully checked, once again, to confirm that the same vehicle was videotaped by the two teams. Also checked was whether this vehicle exited from the ramps or came up on a slow-moving vehicle. This was discerned by watching the videotapes of the vehicle. When it appeared that a taped vehicle was slowed down by another vehicle, the taped vehicle was tagged as suspected for platooning (influenced).

Out of 208 vehicles, 57 vehicles were tagged as influenced vehicles. The remaining vehicles were labeled as uninflu-

enced. The uninfluenced vehicles were divided into three vehicle types: automobiles (*C*), semi-trailer trucks (*T*), and vans and others (*V*). There were 74 automobiles, 49 trucks, and 28 vans and other vehicles in the uninfluenced group. During data collection for this group, no police were present in the work zone, speed limit was 45 mph, and several workers were working on the Route 16 bridge.

The data reduction consisted of the following steps:

1. Recording the travel times,
2. Calculating the distances,
3. Computing the speeds,
4. Finding velocity at speed stations,
5. Computing speeds at the overlapping segments,
6. Determining speeds at the influence points, and
7. Checking errors.

Each of these steps will be briefly described in the following sections. More information about data reduction is given elsewhere (13).

Recording Travel Time

The time a vehicle passed a marker was recorded to the accuracy of $\frac{1}{30}$ of a sec. The time a vehicle spent between two

markers was computed from the recorded data. For each vehicle, at least 21 readings of the time were recorded from the videotapes. Two successive markers identified a speed station.

Distance Calculation

The distance between two markers as an observer sees it on the television monitor is not equal to the actual longitudinal distance between the markers along the highway. The distance a vehicle traveled during the two readings of the time was the distance subtended between the lines connecting the markers to the camera location. The traveled distance is computed using the lateral distances from the markers to the travel path of the vehicle and the angles between the road and the lines from the markers to the camera location. The actual longitudinal distances between the markers were measured using a measuring tape.

Speed Computation

For each vehicle the average speed between two markers was computed by knowing the time and the distance traveled. The speeds for 9 intervals were computed based on the data that were collected at Camera Location 1. Similarly, the speeds were computed for 10 intervals from the data collected at Camera Location 2. The speeds on the two overlapping intervals were computed using the data from both camera locations.

Speed at Speed Stations

A map of the study area was drawn with a scale of 1 in. equal to 100 ft. A line of sight from a camera location to a marker was extended to cross the southbound lanes of the highway. By this method, it was possible to determine the location of the vehicle on the lanes at the time that it appeared to pass the marker. These lines divided the study section along the highway into smaller intervals. The length of each interval is equal to the distance a vehicle traveled between the two markers as seen from the camera locations. The speeds computed in the previous section are for these intervals. The speeds were assumed to correspond to the speeds at or within 100 ft of the midpoints of the intervals, which are called speed stations. Using the computed speeds and the map, the speed of a vehicle at any point on the highway could be determined.

Speed at Overlapping Intervals

There were two overlapping intervals in the middle of the study section. These were from the DeWitt Road abutment to the double-cross pole, and from the double-cross pole to the overhead sign or light post. The speed of a vehicle on an overlapping interval was computed by both teams. The speeds computed by the two teams were very close. For most of the computations the differences were less than 1 mph. Thus it was decided to use the average of the two speeds as the speed on the corresponding overlapping interval.

Speed at Influence Points

Throughout the construction zone, there are traffic control signs and roadway features that may influence the speed of a vehicle. An influence point is defined as a location within the construction zone that may have such a sign or roadway feature. Seven IPs, labeled *A* through *G*, were used in this paper. The distances from the beginning of the study section to the IPs *A* through *G* are 600, 1,600, 2,100, 2,600, 3,100, 6,000, and 8,300 ft, respectively. The speeds of a vehicle at these IPs were determined using the speed profiles.

Measurement Errors

The speed profile of each vehicle was reviewed to check whether there were any noticeable errors (e.g., a sudden increase or decrease in speed). Common sources of noticeable errors could be mistakes in computing time or distance, input errors, or errors caused by missing data. Possible sources of noticeable errors were identified and corrected (*I*). Moreover, computational errors and sensitivity of the computed speed to the input values were examined. The computational errors are caused by the procedures used to compute the speed. Sources of computational errors are such things as errors in the measurement of the longitudinal distances between the markers, the lateral distances from the markers to the highway, the distance between the camera and the road, and errors caused by the vehicle's location in the lane and the width of vehicle (e.g., automobile versus truck). The magnitude of the computational errors were determined. In general, the computed speed could be influenced by 1 mph or less because of these errors (*I*).

STUDY FINDINGS

This study provided information about drivers' speed change patterns as they traveled through the work zone. Such information was not previously available. The focus of this paper is on the analysis of speed profile patterns and speed characteristics. Statistical tests on the data are not presented because of space limitations. The findings reported are based on a sample size of 123 uninfluenced vehicles, made up of 74 automobiles (only) and 49 trucks (vans are not discussed). Almost all of the vehicles included in the truck category are of the tractor semitrailer type. In the following sections, the speed profile patterns and drivers' categories will be discussed first, followed by the analysis of speed characteristics for automobiles and trucks.

SPEED PROFILE PATTERNS AND DRIVER CATEGORIES

Speed Profile Patterns

The review of speed profiles for 74 automobiles and 49 trucks indicated that there are certain speed-reduction patterns that are repeated by many drivers. The common speed profiles for automobiles and trucks were identified separately. It was observed that some automobiles and trucks have similar speed

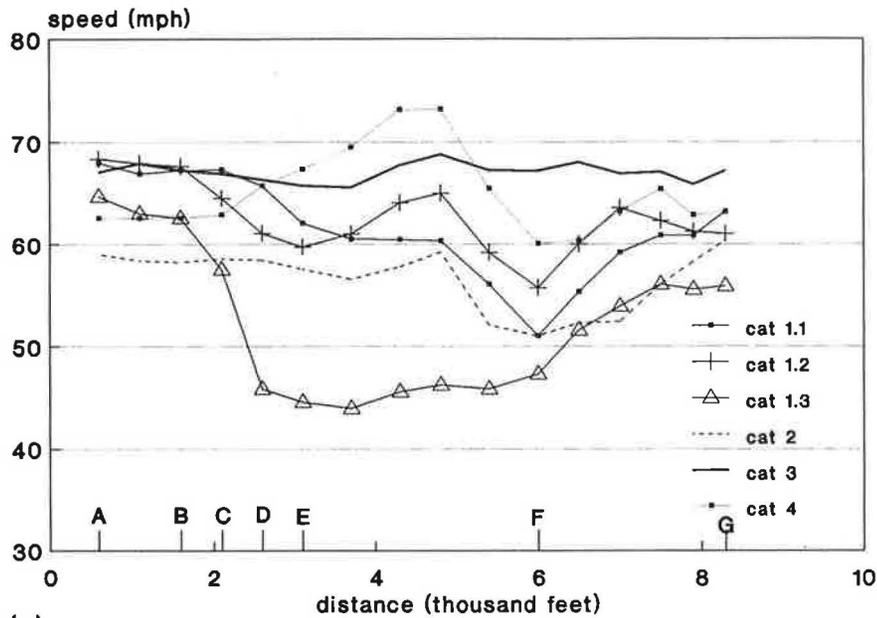
profiles. Based on their speed profile patterns, the drivers were grouped into four general categories. The general description of a category would apply to automobiles as well as to trucks.

The criteria for the classification were the visual examination of the speed change patterns and a quantitative measure of the speed change. Vehicles that showed similar speed profiles were grouped in one category. If the speed change was not noticeable (less than 5 mph for automobiles and 4 mph for trucks), it was attributed to expected speed fluctuation and was not used as a criterion in the classification. The descriptions of these categories are given in the following para-

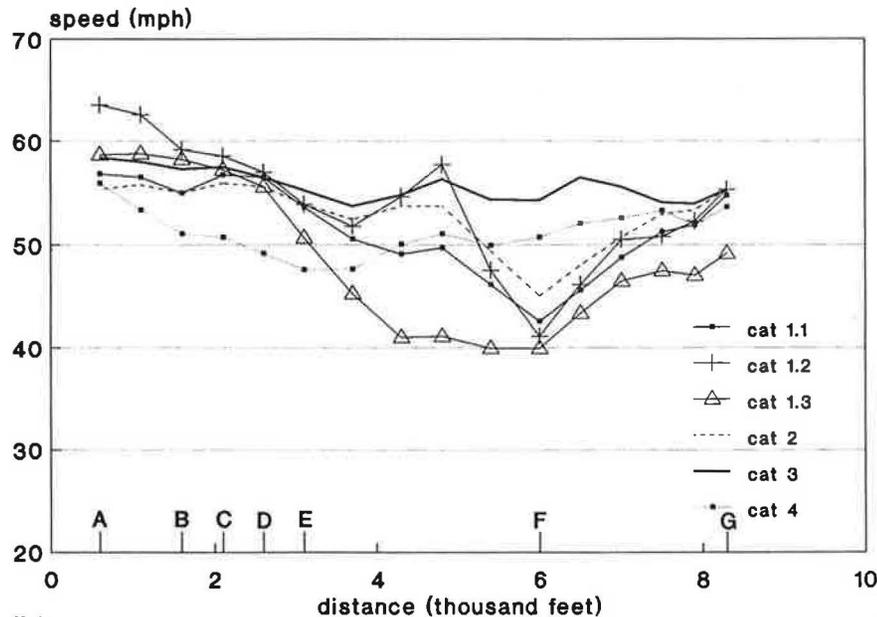
graphs. The speed profiles for typical automobile and truck drivers in each category are shown in Figures 3a and 3b.

Driver Category 1

Category 1 represents those drivers who reduced their speeds noticeably in the beginning of the one-lane section (near the first speed-limit signs). Some drivers in this category had further speed reduction at the work space (over the Route 16 bridge). The drivers in Category 1 are further divided into three sub-categories (groups).



(a)



(b)

FIGURE 3 (a) Typical speed profile for automobiles and (b) typical speed profile for trucks.

Driver Category 1.1

The first group in Category 1 represents the drivers who decreased their speeds near the first work zone speed-limit signs and had further speed reductions at the bridge (work space). Usually, the latter speed reduction was greater than the former. The speed profile for this group was similar to that of automobile No. 197 or truck No. 54. Approximately 22 percent of automobile drivers and 25 percent of truck drivers belong to this group. Generally, the speeds of the automobiles before the bridge, unlike the speeds of the trucks before the bridge, were much higher than 45 mph.

Driver Category 1.2

The second group in Category 1 represents the drivers who slowed down considerably at the first speed-limit signs and at the bridge, but between these two points they increased their speeds. Their speed profiles resembled a "W". The speed profiles for automobile No. 153 and truck No. 126 represent typical speed profiles for this group. About 26 percent of automobile drivers and 20 percent of truck drivers were placed in this group.

Driver Category 1.3

The third group in Category 1 represents the drivers who reduced their speed around the first speed-limit signs and kept traveling at that reduced speed until they passed the bridge. After passing the bridge, some drivers increased their speeds. The speed profile for this group was similar to that of automobile No. 67 or truck No. 60. About 12 percent of automobile drivers and 23 percent of truck drivers belong to this group.

Driver Category 2

The criteria for Category 2 was that the drivers traveled faster than the speed limit and did not have significant speed reduction around the first speed-limit signs (IP *D*). They largely ignored the first speed limit sign, but began to slow down when they arrived at the bridge. The speed profiles for automobile No. 202 or truck No. 201 represent the drivers in Category 2. Nearly 13 percent of automobile drivers and 8 percent of truck drivers were placed in this category.

Driver Category 3

Category 3 includes those drivers who ignored both the first speed-limit signs and the construction activities over the bridge. Examples of the drivers in this category are the drivers of automobile No. 43 and truck No. 192. They drove through the work zone at an almost constant speed that was higher than the 45 mph speed limit. The automobile drivers in this category maintained a speed of about 60 mph or higher, and truck drivers traveled at a speed between 50 and 60 mph. The speed fluctuation for this group was very small (5 mph or

less). About 11 percent of automobile drivers and 10 percent of truck drivers were grouped in this category.

Driver Category 4

The fourth category is called "others," which includes those vehicles that could not be classified into categories 1 to 3. Some of the drivers in Category 4 reduced their speed at the first speed-limit signs, but did not slow down at the bridge. Some of them even increased their speeds while passing through the work space. The speed profiles for automobile No. 26 and truck No. 34 represent this category. About 16 percent of automobile drivers and 14 percent of truck drivers belong to Category 4.

Importance of Categorizing Drivers

Knowing the nature and extent of the speeding problems in a work zone would help in the selection of appropriate countermeasures that may result in more effective traffic control plans. Measures taken to slow down the drivers in Category 3 who ignored the speed-limit signs may be different from the measures for the drivers in Category 1 who reduced their speed, but not to the desired level.

The critical points in a construction zone are the locations in which the drivers slow down or speed up. Knowing these points would help in placing the signs at the appropriate locations. For instance, the traffic control signs to encourage the drivers to maintain the reduced speed should be placed before or at the points where the drivers begin to increase their speeds, whereas the signs to reduce their speed should be at the beginning of the work zone.

The distribution of drivers in the four categories indicates that 63 percent of drivers reduced their speed considerably after the first construction zone speed-limit signs. Category 1.3 represents the desirable speed-reduction pattern, and other drivers should be encouraged to follow this pattern. The effects of placing additional speed-limit signs between the first speed-limit signs and the work space to persuade the drivers in Category 1.1 to slow down further, and to discourage the drivers in Category 1.2 from increasing their speed before the work space, need to be studied.

The speed-reduction patterns of drivers may be used to determine the location of work zone signs that would result in more desirable speed-reduction patterns. The drivers in Category 1.2 may have increased their speeds because they perceived that no work was going on or the work space was too far from the first set of speed-limit signs. The location of the signs and the length of section before the work space should be such that most drivers are encouraged to follow the speed limit. Because 63 percent of drivers reduced their speeds around the first speed-limit signs and 74 percent of all drivers reduced their speeds near the work space, more speed reduction may be achieved if the work space is closer to the beginning of the work zone.

Traffic control plans should be carefully prepared to obtain a higher level of compliance from the drivers. Drivers complain about marking a long stretch of highway as the construction zone without any construction activities (*I*). Such a

practice reduces the credibility of the work zone signs. The speed profiles for the drivers in Category 2 indicate that this group delayed speed reduction until they saw the construction activities. The length of construction zones should be limited, whenever possible, to the section that is actively under construction.

SPEED CHARACTERISTICS FOR AUTOMOBILES

At each IP, the maximum, minimum, average speed, and its standard deviation were computed. These statistics are summarized in Table 1. The mean speed for automobiles reduced from 63 mph at the beginning of the taper (IP A) to 49 mph

at the bridge (IP F), and then increased to 57 mph at the end of the study section (IP G). The speed frequency distributions at four different IPs are shown in Figure 4. The standard deviations were around 7 mph at all locations, except over the bridge where they were 9.23 mph. The large standard deviations indicate that the speed range was high on all IPs and even higher over the bridge. The speeds of automobiles over the bridge were as low as 29 and as high as 67 mph.

Speed Characteristics of Automobiles on Taper

The speed distribution for IP A shows one peak around 63 mph and another around 50 mph (see the modal speeds in

TABLE 1 Speed Statistics for Automobiles and Trucks at Influence Points (in mph)

Influence Points	Min Speed		Max Speed		Mean Speed		Standard Dev	
	Cars	Trucks	Cars	Trucks	Cars	Trucks	Cars	Trucks
A	46.1	45.5	77.3	68.8	62.6	57.0	7.24	5.12
B	43.7	38.3	72.2	66.4	59.9	54.2	7.01	5.86
C	44.8	38.9	70.7	66.3	58.8	54.3	7.31	5.85
D	41.7	40.2	69.8	67.0	57.2	53.6	7.37	5.65
E	39.3	39.8	68.6	65.4	55.6	51.4	7.06	5.38
F	29.3	35.3	67.2	59.7	49.3	45.5	9.28	5.13
G	41.8	40.5	72.8	64.8	56.9	52.3	6.93	5.19

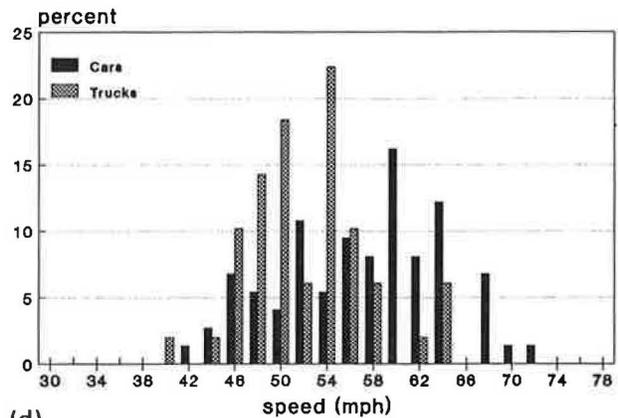
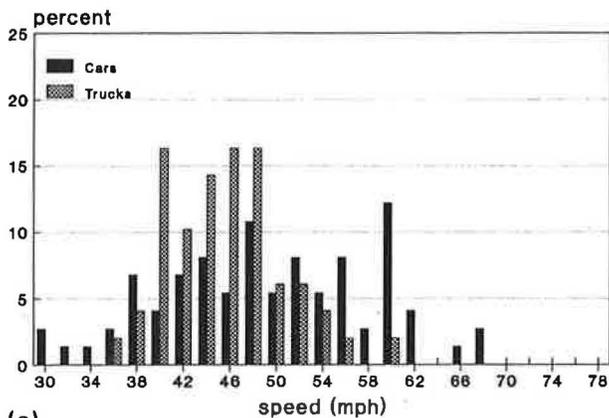
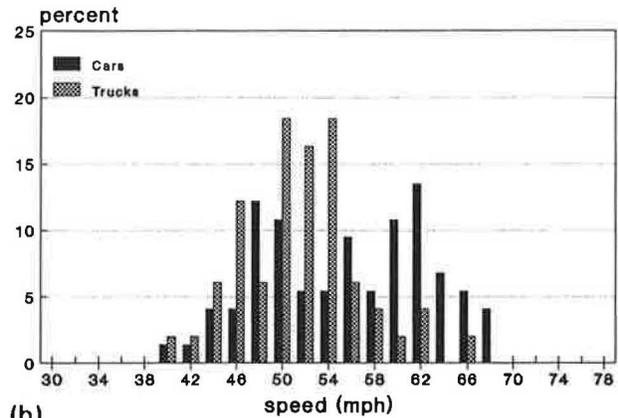
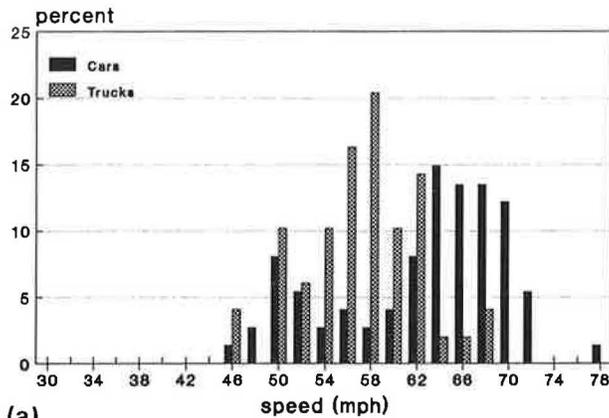


FIGURE 4 (a) Speed distance at IP A, (b) at IP E, (c) at IP F, and (d) at IP G.

Figure 4a). These two modal speeds indicate that there were two general groups of drivers. A small group of drivers was traveling at approximately 50 mph, but the rest of the drivers had a speed in the upper 60s or lower 70s. This distinct pattern became less obvious as the vehicles traveled through the work zone. By the time the automobiles reached the end of the taper (IP *B*), the average, maximum, and minimum speeds had decreased, but still almost all of the vehicles exceeded the speed limit.

Speed Characteristics of Automobiles Near First Speed-limit signs

As the vehicles passed IP *C*, located 500 ft before the first construction speed-limit signs, a small decrease (1 mph) in the average speed was observed. At the first construction zone speed-limit signs (IP *D*), the average speed was 57 mph and 96 percent of the automobiles exceeded the speed limit. After passing the first speed-limit signs, the vehicles continued decreasing their speeds. This reduction can be seen by comparing the average speed and speed distributions at IP *E* with that of IP *A*. The speed distribution at this point (Figure 4b) looks very different than that of IP *A*. The drivers did not use a modal speed, but traveled at a wide range of speed around the mean.

Speed Characteristics of Automobiles at Work Space

The average speed of automobiles over the bridge (IP *F*) was the lowest (49 mph) and speed distributions showed a significant shift toward the lower speeds (see Figure 4c). The range of speed was from 29 to 67 mph, with few drivers traveling near the upper bound of this range. The work space over the bridge was physically separated from the travel lane by 250 ft of concrete safety shape (Jersey) barriers. At this point, the open lane was about 15 ft and did not present the feeling of going through a narrow lane. Although a previous study indicates that the concrete safety shape (Jersey) barriers do not affect highway capacity even when they are closer than 6 ft to the traveled lane (14, p. 3–11), vehicles decreased their speed when they went through this section (work space). The main reason for the speed reduction seems to be the construction activities in the work space and presence of the concrete shape barriers.

Speed Characteristics of Automobiles After Passing Work Space

After passing the bridge, the vehicles increased their speeds and the speed distributions showed a shift toward higher speeds (see Figure 4d). At IP *G*, which was located at the end of the study section, there was a second pair of construction speed-limit signs. The signs at IP *G* were for drivers entering from the ramp as well as for the drivers on I-57.

It should be noted that the average speed and speed distribution at the second speed-limit signs (IP *G*) were very close to those at the first speed-limit signs (IP *D*). The average speed at IP *G* increased to 57 mph, which is equal to the average speed at IP *D*. About the same number of drivers exceeded the speed limit at these two locations.

Percent of Automobiles Exceeding Speed Level

Almost all of the automobile drivers traveled faster than 45 mph at all IPs except at IP *F*, where nearly 70 percent of them went faster than 45 mph. The percentage of automobiles exceeding a given speed decreased over the bridge and increased to the same level as that reached before the drivers had passed the bridge. The percentage of automobiles exceeding 65 mph was 53 percent at the beginning of the taper, 19 percent at the first speed-limit signs, 4 percent at the bridge, and 12 percent at the second set of speed-limit signs. Similar trends were observed at other speed levels, as shown in Figure 5a.

It is important to note that the percentage of automobiles exceeding a given speed at the second set of construction zone speed-limit signs (IP *G*) reached the level of the first speed-limit signs (IP *D*). This indicates that, on the average, the drivers decrease their speeds to the lowest level near the work space, but after passing it they accelerated to speeds as high as they had at the first speed-limit signs.

Figure 5a clearly shows that the percentage of automobiles exceeding a speed level decreased as they approach IP *F* (the bridge on Route 16), but after they had passed it the percentage increased. Although the percentage of automobiles exceeding the speed limit over the bridge (IP *F*) was the lowest compared with other locations, nearly 70 percent of automobiles traveled faster than 45 mph at this location.

SPEED CHARACTERISTICS FOR TRUCKS

For trucks, the maximum, minimum, and average speed, and its standard deviation, are summarized in Table 1. The average speed for trucks was reduced from 57 mph at the beginning of the taper (IP *A*) to 46 mph at the bridge (IP *F*), and then increased to 52 mph at the end of the study section (IP *G*). The speed frequency distributions at four IPs are given in Figure 4. Trucks had only one modal speed contrary to the automobiles that showed two modal speeds at the first few IPs. The range of speed for trucks was narrower than that for the range for automobiles, as reflected by the smaller standard deviation for trucks (it varied between 5.12 and 5.86). Interestingly, the largest variation in speed did not occur over the bridge, but was at the end of the taper and before the first speed-limit signs. Over the bridge, the speed of trucks was as low as 35 mph and as high as 60 mph.

Speed Characteristics of Trucks on Taper

The speed distribution for trucks showed one modal speed, as shown on Figure 4a. Unlike the automobiles, most of the trucks traveled at about the mean speed. By the time the trucks reached the end of the taper, the average speed decreased by 3 mph and the speed distributions were shifted toward lower speeds. At IP *B*, nearly one-quarter of the trucks traveled at the mean speed at this location.

Speed Characteristics of Trucks Near First Speed-limit signs

The speed variance at IP *C* was as large as that of IP *B*, but the other speed indicators (minimum, maximum, and aver-

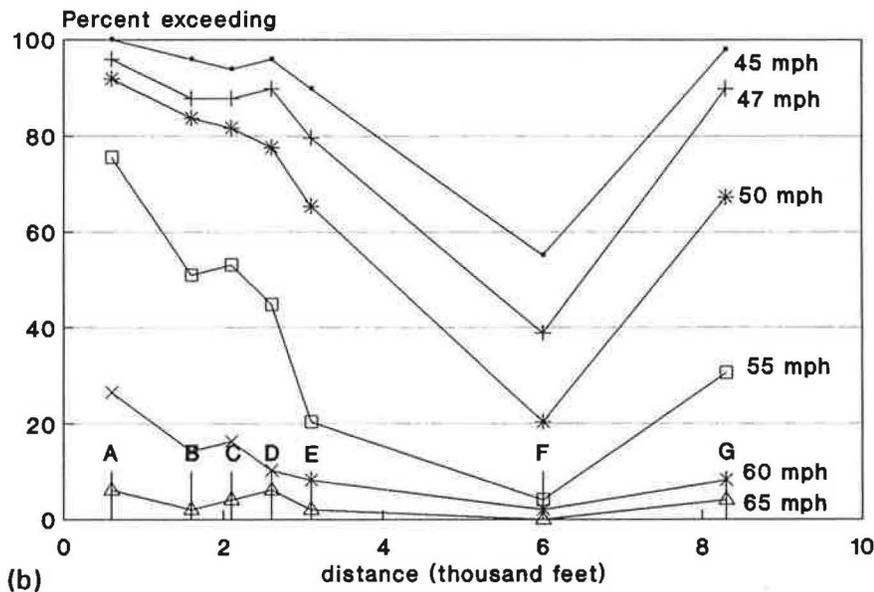
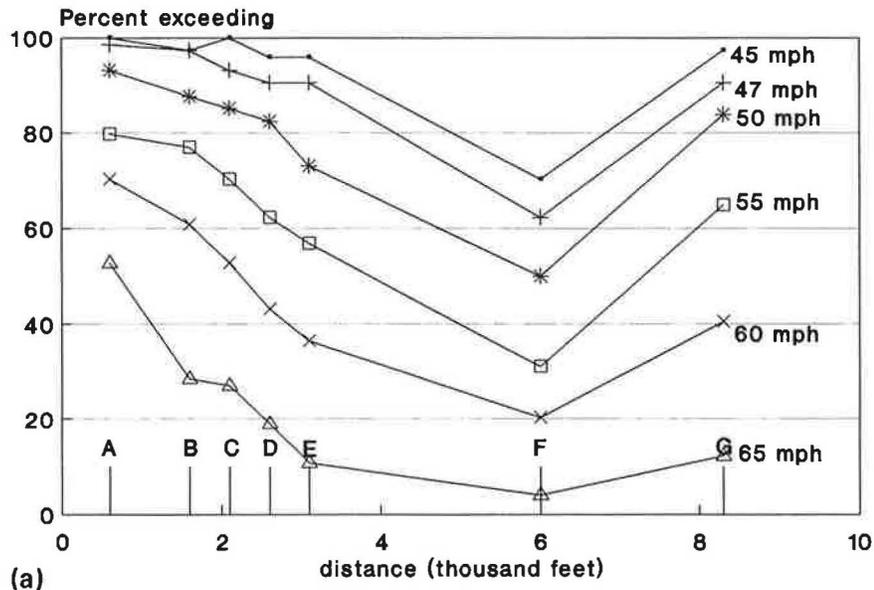


FIGURE 5 (a) Percent of automobiles exceeding a given speed in the work zone, and (b) percent of trucks exceeding a given speed in the work zone.

age) remained the same. At the first work zone speed-limit signs (IP D), the average speed was 54 mph. After passing the first speed-limit signs (IP E), the average speed of the trucks decreased to 51 mph. The speed distributions at this point showed more concentration around the mean speed, as shown in Figure 4b.

Speed Characteristics of Trucks at Work Space

Over the Route 16 bridge (IP F), the average speed for trucks dropped to its lowest value, and the speed distributions showed a significant shift toward the lower speeds (see Figure 4c). The average speed at this point was 46 mph and nearly half of the truck drivers traveled faster than the speed limit. About two-thirds of the truck drivers maintained a speed within 5 mph of the speed limit.

Speed Characteristics of Trucks After Passing Work Space

Like automobiles, the trucks increased their speeds after passing the work space. The average speed increased to 52 mph, even though there was a second pair of work zone speed-limit signs at the IP G. Comparing the speed distribution for point F (Figure 4b) with that of G clearly shows the shift toward the higher speeds.

Percent of Trucks Exceeding Speed Level

The percentage of trucks exceeding a given speed at different locations within the study section is shown in Figure 5b. More than 90 percent of the truck drivers traveled faster than 45

mph at all IPs except at IP *F*, where more than half of them went faster than 45 mph. The percentage of trucks exceeding 65 mph was 6 percent at the beginning of the taper, 6 percent at the first speed-limit signs, 2 percent at the bridge, and 4 percent at the second speed-limit signs. The percentage of trucks exceeding a given speed decreased over the bridge and then generally increased after the bridge to the same levels as those observed before the bridge.

It is important to note that truck drivers decreased their speeds, as did automobile drivers, to the lowest level near the construction activities, but after passing them accelerated to their previously higher speeds. The percentage of trucks exceeding a given speed at the first and second construction zone speed-limit signs (IP *D* and IP *G*) is almost equal.

CONCLUSIONS

In response to roadway geometry and traffic control devices, motorists may change their speeds at different locations within a work zone. This study determined the speed-reduction profiles of vehicles in a work zone. Four categories of drivers were identified on the basis of their speed-reduction profiles. The drivers in different categories showed distinct speed-reduction profiles, but automobiles and trucks in a given category indicated similar speed-reduction patterns. About 63 percent of all drivers reduced their speeds considerably after passing the first work zone speed-limit signs (Category 1). Nearly 11 percent of all drivers reduced their speeds when they neared the location of construction activities (Category 2). About 11 percent of all drivers did not reduce their high speeds (Category 3). The profiles for the remaining drivers did not indicate a pattern (Category 4).

The percentage of vehicles exceeding a speed level decreased as the work space was approached (IP *F*), but after passing it the percentage increased. The percentage of vehicles exceeding a given speed at the second construction zone speed-limit signs (IP *G*) reached the level of that observed at the first speed-limit signs (IP *D*). The drivers decreased their speeds to the lowest level near the work space, but after passing it they accelerated to the higher speeds they had reached at the first speed-limit signs. Although the percentage of vehicles exceeding the speed limit at the work space (IP *F*) was the lowest compared with other locations, nearly 70 percent of automobiles and 55 percent of trucks traveled faster than 45 mph at this location.

RECOMMENDATIONS

The locations where drivers slow down or speed up are critical points in a construction zone. Knowing these points would help to place the signs at appropriate locations. It is recommended that the placement and frequency of the work zone speed-limit signs should be examined using the speed-reduction patterns of the drivers. The effects of placing an additional set of speed-limit signs between the first speed-limit signs and the work space to persuade the drivers in Category 1.1 to slow down further, and to discourage the drivers in Category 1.2 from increasing their speed before the work space, need

to be determined. The location of the signs and the length of section before the work space should be such that most drivers are encouraged to follow the speed limit.

The analysis indicated that the location of a speed-measuring station has to be carefully selected because it would affect the outcome of the measurements. Furthermore, speed distributions as well as the mean speeds should be analyzed to obtain more accurate speed-characteristic data.

The data-reduction stage should be computerized to reduce the human resources needed. The computational errors of this data-collection method are reasonable. This approach, although time consuming in the data-reduction stage, should be used in future studies.

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