

# DEPARTMENT OF TRAFFIC AND OPERATIONS

## Driver Behavior as Affected by Objects on Highway Shoulders

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A PASSENGER car, highway maintenance truck, or a barricade was placed on the shoulder at the pavement edge and at 3 feet and 6 feet from the pavement edge. Observations of the effect were recorded on two-lane and four-lane divided highways.

During light-to-moderate traffic volumes on the wider two-lane highways and on four-lane highways, vehicle speeds were affected little, if at all, by the objects on the shoulder. However, on two-lane pavements 20 feet or less in width, speeds averaged approximately 3 mph. lower with vehicles or barricades on the shoulder.

The transverse positions were affected only for those vehicles moving in the lane adjacent to the shoulder on which the vehicle or barricade was placed. The narrower the pavement and the closer the object to the pavement edge, the greater was the lateral displacement of vehicles from their normal path. An object placed at the edge of an 8-foot lane of a two-lane highway caused vehicles to travel 3.3 feet farther from the pavement edge than when the object was not present.

On a 12-foot lane the corresponding value was 1.8 feet. Objects on the shoulder of a four-lane divided highway had a slightly lesser effect than on two-lane highway. When the vehicle or barricade was placed 6 feet from the pavement edge, no significant effect on the transverse positions of moving vehicles was found. A car, truck, or barricade parked on the shoulder each had about the same effect on vehicle speed and lateral position, except for the slightly lesser effect of the barricade on the four-lane highway.

● SHOULDERS along a highway are needed for several reasons. They add to the comfort of the drivers and increase safety. Wide shoulders provide a storage space outside the traffic lanes for disabled vehicles and for short-time parking of vehicles as may be desired by drivers. They also serve as a space to avoid an accident in case of emergency.

It is generally believed that vehicles standing along the traveled way of a highway either by choice of the drivers or due to mechanical failure influence the behavior of vehicles on the highway. It is the purpose of this article to report the results of studies made to determine the extent to which traffic is influenced by vehicles parked on the shoulders, or

other objects, at various distances from the edges of the traffic lanes.

Vehicle speeds and placements were recorded on two-lane highways carrying light to moderate traffic volumes and on a four-lane divided highway carrying volumes as high as 3,400 vehicles per hour in one direction.

### STUDY PROCEDURE

A description of the sites selected for study for two-lane operations is given in table 1. These sites were studied in cooperation with the Oregon State Highway Department and were on level tangent sections with no restrictive sight distances in either direction of travel. A yellow dashed centerline separated

TABLE 1  
DESCRIPTION OF THE TWO-LANE HIGHWAYS STUDIED IN OREGON

| Site No. | Route Number and Location   | Pavement    |      | Shoulders   |      |             |        | Number of Vehicles Observed |       |
|----------|-----------------------------|-------------|------|-------------|------|-------------|--------|-----------------------------|-------|
|          |                             | Width       | Type | Paved       |      | Other       |        | Day                         | Night |
|          |                             |             |      | Width       | Type | Width       | Type   |                             |       |
|          |                             | <i>feet</i> |      | <i>feet</i> |      | <i>feet</i> |        |                             |       |
| 1        | US 99E, 7 miles S. of Salem | 16          | PCC. | 2           | Bit. | 5           | Gravel | 6,600                       |       |
| 2        | US 99W, S. of Tigard        | 20          | PCC. | —           | —    | 7           | Gravel | 10,246                      | 2,997 |
| 3        | US 99, 6 miles N. of Eugene | 22          | PCC. | —           | —    | 9           | Gravel | 9,144                       | 1,985 |
| 4        | US 99E, 1 mile S. of Brooks | 26          | Bit. | —           | —    | 5           | Gravel | 10,694                      |       |

the two traffic lanes, and the pavements were flanked by well-maintained gravel shoulders. The 16-foot concrete pavement at site 1 was flanked by 2-foot bituminous shoulders beyond which were the 5-foot gravel shoulders.

The study of four-lane operations was conducted during September 1953, on a level tangent at the north end of the Shirley Highway, a freeway connecting the Pentagon Network and Woodbridge, Virginia. The section studied has two 12-foot lanes in each direction, of portland cement concrete with shoulders 10 feet wide. A 30-foot grass median separates the vehicles traveling in the opposing directions. The posted speed limit at this location is 50 miles per hour for passenger cars and 45 miles per hour for trucks.

The speeds and transverse positions of vehicles were first recorded at all locations under normal conditions, that is, with the shoulders clear of any object. Similar data were then recorded with the various objects placed on the shoulder at various distances from the pavement edge. The data for normal conditions were used as a base to determine the effect of each of the several objects on driver behavior. They cannot be used, however, to compare driver behavior on various surface widths, because other design elements and traffic conditions were not the same at the different locations included in this study. The results of another study based on extensive data for comparable locations show the effect of roadway width on driver behavior.<sup>1</sup>

#### OBJECTS PLACED ON ONE SHOULDER

The objects placed on the shoulder included a passenger car, a highway maintenance

truck, and a barricade. Studies were conducted with each of these objects at the pavement edge, 3 feet from the edge, and 6 feet from the edge of the pavement. Data were recorded during a period of 3 hours for each condition at each location. Driver behavior data were thus obtained for nine different conditions in addition to the normal condition at each study location. Figure 1 shows the type and position of the objects studied on the two-lane highways. Pictures of the four-lane study location are shown by figure 2. The three lines across the pavement in the foreground of each frame in these pictures are the speed and placement detectors which were connected to recording instruments that were well hidden from the drivers.

The total hourly volume in both directions of travel on the two-lane roads during each of the studies is shown by table 2. Table 2 shows that the traffic volumes were moderate at all the 2-lane locations and not widely different for each shoulder condition at any one location. Thus the effect of traffic volume or density was eliminated from the consideration of the effect that the objects had on the drivers.

Data were analyzed separately for passenger cars and commercial vehicles traveling in each of the two traffic lanes. For the two-lane studies, the data were also analyzed separately for free-moving vehicles, meeting vehicles, and all other vehicles. Free-moving vehicles are those that were not influenced by other traffic on the highway whereas meeting vehicles are those that might be influenced by opposing traffic. Vehicles overtaking and passing other vehicles on the two-lane roads have been omitted from the analysis because they were of too small a number during the study periods to be considered.

<sup>1</sup> "Effect of Roadway Width on Vehicle Operations," by A. Taragin, *Public Roads*, October-November-December, 1945.

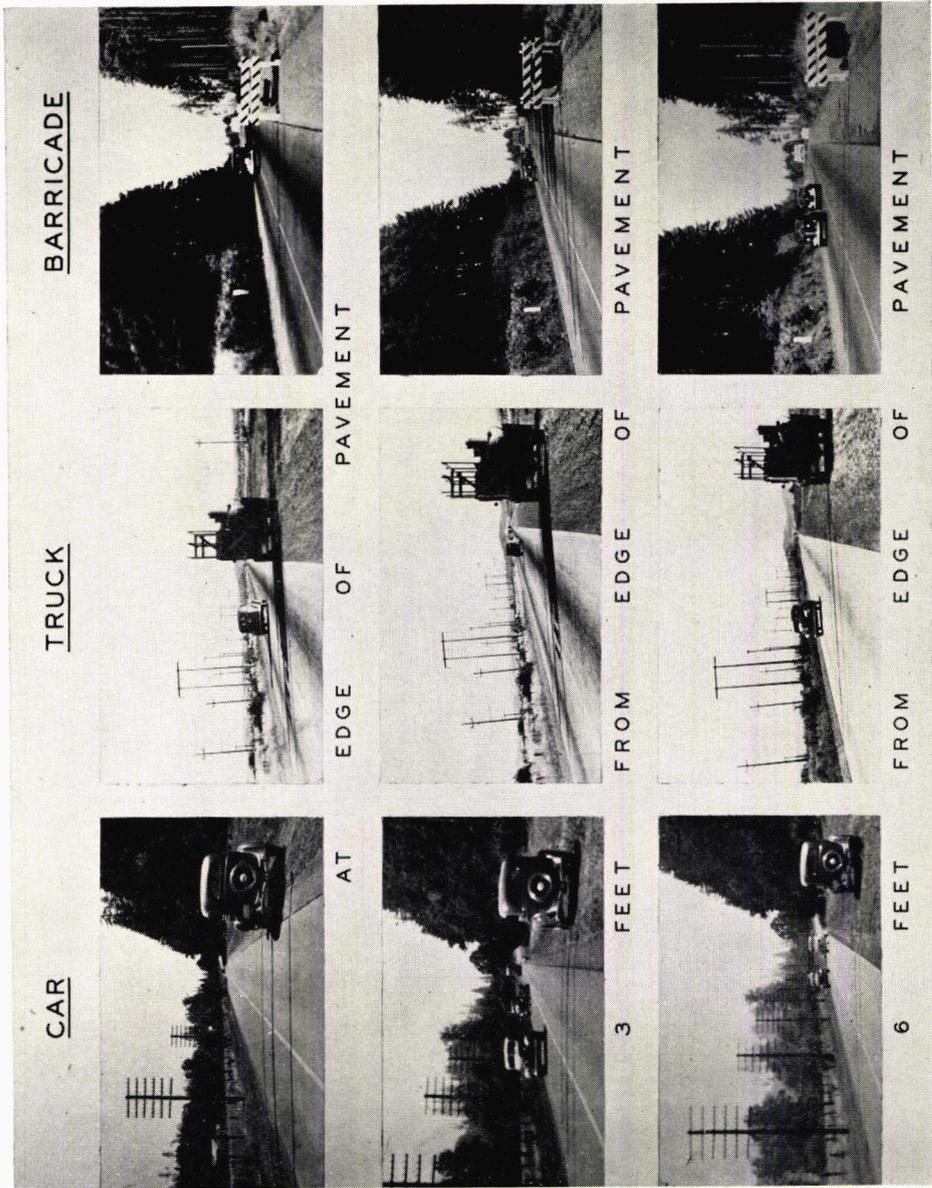


Figure 1. Type and position of objects placed on shoulder, 2-lane highways.

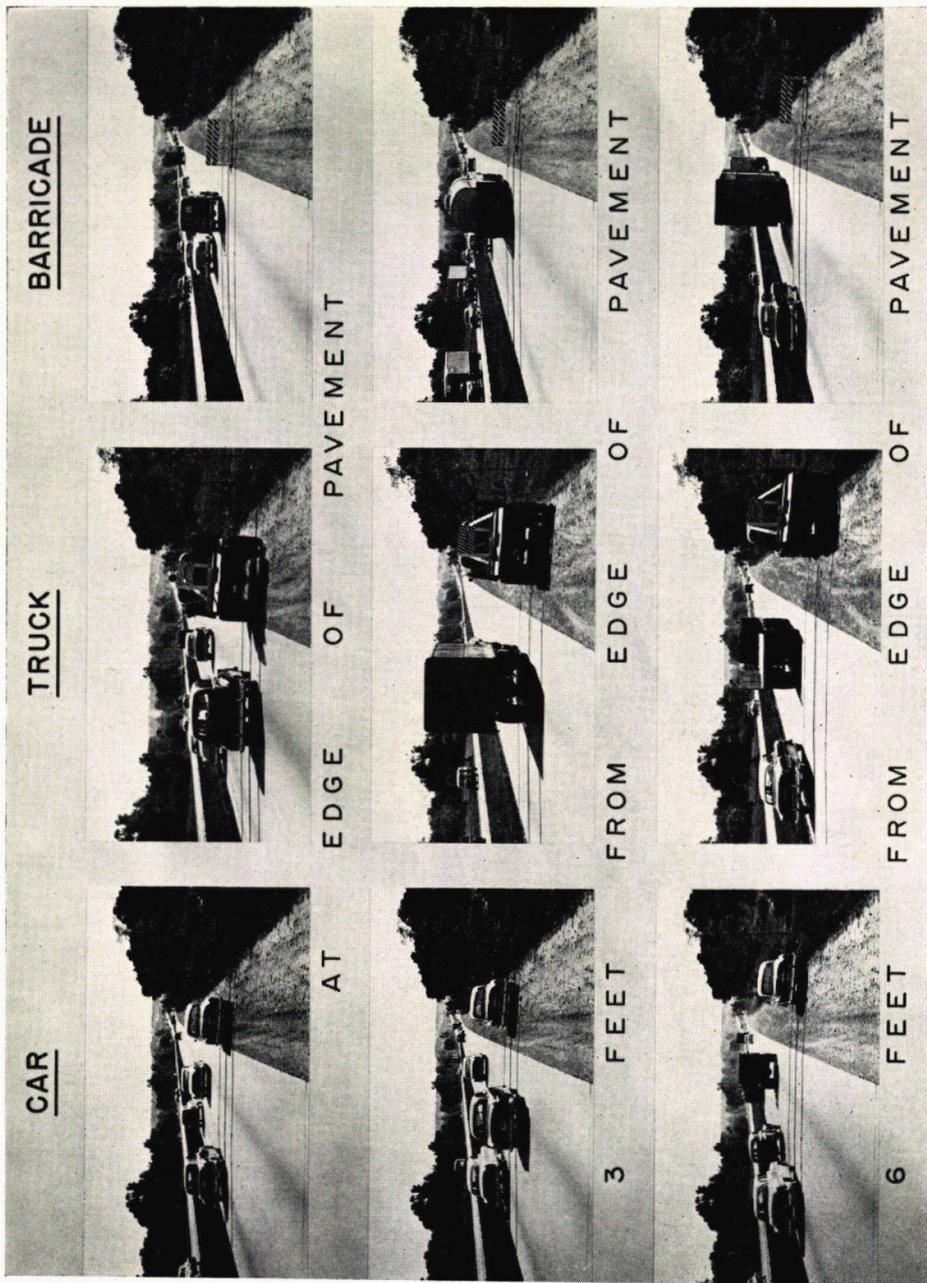


Figure 2. Type and position of objects placed on shoulder, 4-lane divided highway.

NORMAL SPEEDS

Average passenger car speeds during the normal condition in daytime at the different locations on the two-lane roads varied from 42.9 to 48.9 miles per hour (table 3). Under similar conditions, the average speeds of commercial vehicles (dual-tired only) were from 37.6 to 43.2 miles per hour (table 4). At individual locations, however, commercial vehicles traveled, on an average, 3.9 to 8.3 miles per hour slower than passenger cars. In addition to the speeds for normal conditions, tables 3 and 4 show average speeds while each of the objects was on the shoulder at the various distances from the pavement edge.

On the four-lane divided highway during the normal condition, and at volumes below 2,000 vehicles per hour in one direction, passenger cars averaged about 50 miles per hour in the left lane and 43 miles per hour in the right lane. Commercial vehicles under similar conditions traveled about 2 miles per hour slower than passenger cars. The average speed on this 4-lane highway while operating at volumes above 2,000 vehicles per hour was far more dependent on other conditions which could not be held constant than on the shoulder condition. For this reason, therefore, analysis of the effect of an object on the shoulder on vehicle speeds on the four-lane road was confined to volumes below 2,000 vehicles per hour.

EFFECT ON SPEEDS

A vehicle or a barricade parked on the shoulder of the two-lane highways included in this study had a general tendency to reduce vehicle speeds. The reduction, however, was not consistently greater for one of the objects than for another. Also, the reduction was not consistently greater when the object on the shoulder was adjacent to the edge of the pavement than when located 3 or 6 feet from the edge although there was some tendency in this direction.

These are not surprising results because a number of other studies have shown that speeds are not reduced as much as one would expect by unusual conditions. A study of speeds at short, narrow, two-lane bridges,<sup>2</sup> for example, showed that drivers did not reduce their speeds appreciably as they approached

TABLE 2  
HOURLY TRAFFIC VOLUMES DURING STUDY PERIODS ON TWO-LANE HIGHWAYS

| Type and Position of Object on Shoulder     | Day time            |            | Nighttime  |            |            |            |
|---|---------------------|------------|------------|------------|------------|------------|
|   | Pavement width—feet |            |            |            |            |            |
|   | 16                  | 20         | 22         | 26         | 20         | 22         |
|   | <i>vph</i>          | <i>vph</i> | <i>vph</i> | <i>vph</i> | <i>vph</i> | <i>vph</i> |
| Shoulder clear—normal operation             | 179                 | 233        | 192        | 282        | 152        |            |
| Car at edge of pavement.....                | 201                 | 349        | 220        | 323        | 214        |            |
| Car 3 feet from edge of pavement.....       | 176                 | 364        | 169        | 263        | 116        | 107        |
| Car 6 feet from edge of pavement.....       | 196                 | 258        | 213        | 469        | 107        | 151        |
| Truck at edge of pavement.....              | 164                 | 269        | 214        | 310        |            |            |
| Truck 3 feet from edge of pavement.....     | 216                 | 325        | 232        | 287        |            |            |
| Truck 6 feet from edge of pavement.....     | 211                 | 268        | 229        | 344        |            |            |
| Barricade at edge of pavement.....          | 247                 | 344        | 280        | 321        | 146        | 189        |
| Barricade 3 feet from edge of pavement..... | 211                 | 307        | 257        | 394        | 167        | 99         |
| Barricade 6 feet from edge of pavement..... | 228                 | 483        | 288        | 364        | 115        | 88         |

the bridges although the drivers did make a considerable change in the lateral positions of their vehicles—shying away from the bridge railings or parapet walls. The changes in speed caused by placing the three different types of objects on the one shoulder at various distances from the pavement edge are shown by tables 5 through 11. The following statements are based on a study of the data shown by these tables:

1. There is only a slight tendency for passenger car drivers to reduce their speeds when traveling in the lane adjacent to the shoulder which was not occupied. On an average, the reduction in speed was less than 1 mile per hour, with the surface width, the type of object, or its location on the other shoulder making little difference.

2. The average passenger car driver traveling in the lane adjacent to the occupied shoulder reduced his speed an average of 3 miles per hour on two-lane pavements 16 and 20 feet wide and an average of 1 mile per hour on pavements 22 and 26 feet wide. There was a somewhat greater tendency under these conditions for the drivers to reduce their speeds with a barricade on the shoulder than with a truck or passenger car parked on the shoulder. The distance that the object was from the pave-

<sup>2</sup> "Influence of Bridge Widths on Transverse Positions of Vehicles," by W. P. Walker, Highway Research Board Proceedings, 1941.

TABLE 3  
AVERAGE SPEEDS OF ALL PASSENGER CARS OBSERVED DURING STUDIES ON TWO-LANE HIGHWAYS

| Type and Position of Object on Shoulder | Daytime             |            |            |            |            |            |            |            | Nighttime  |            |            |            |
|---|---------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
|   | Pavement width—feet |            |            |            |            |            |            |            |            |            |            |            |
|   | 16                  |            | 20         |            | 22         |            | 26         |            | 20         |            | 22         |            |
|   | Near*               | Far†       | Near       | Far        |
| <i>mph</i>                              | <i>mph</i>          | <i>mph</i> | <i>mph</i> | <i>mph</i> | <i>mph</i> | <i>mph</i> | <i>mph</i> | <i>mph</i> | <i>mph</i> | <i>mph</i> | <i>mph</i> | <i>mph</i> |
| Shoulder clear—normal operation         | 47.1                | 42.9       | 45.2       | 43.8       | 48.7       | 48.9       | 45.9       | 46.1       | 43.1       | 41.1       |            |            |
| Car at edge of pavement                 | 45.0                | 43.9       | 42.6       | 44.2       | 47.0       | 48.0       | 45.6       | 45.2       | 40.8       | 41.6       |            |            |
| Car 3 feet from edge of pavement        | 45.8                | 43.2       | 42.5       | 42.9       | 49.9       | 48.5       | 45.8       | 44.9       | 43.5       | 41.8       | 46.3       | 48.0       |
| Car 6 feet from edge of pavement        | 46.5                | 44.4       | 41.8       | 43.0       | 49.2       | 47.6       | 42.9       | 42.1       | 43.7       | 45.0       | 44.9       | 43.9       |
| Truck at edge of pavement               | 40.9                | 43.7       | 42.4       | 41.8       | 48.0       | 48.6       | 44.4       | 44.4       |            |            |            |            |
| Truck 3 feet from edge of pavement      | 45.9                | 43.9       | 42.4       | 43.4       | 48.4       | 48.7       | 45.8       | 46.0       |            |            |            |            |
| Truck 6 feet from edge of pavement      | 45.3                | 43.2       | 43.4       | 44.3       | 49.2       | 49.1       | 44.6       | 44.3       |            |            |            |            |
| Barricade at edge of pavement           | 42.6                | 42.4       | 40.6       | 43.4       | 47.1       | 47.0       | 42.0       | 43.2       | 41.7       | 44.6       | 40.6       | 42.2       |
| Barricade 3 feet from edge of pavement  | 44.4                | 43.3       | 40.7       | 42.1       | 48.0       | 44.2       | 44.0       | 42.0       | 39.2       | 39.9       | 42.6       | 43.9       |
| Barricade 6 feet from edge of pavement  | 44.3                | 42.9       | 39.6       | 42.2       | 47.8       | 45.2       | 44.6       | 44.9       | 40.7       | 40.6       | 44.7       | 44.8       |

\* Near indicates the speeds of vehicles traveling in the lane adjacent to the occupied shoulder.  
† Far indicates the speeds of vehicles traveling in the lane adjacent to the clear shoulder.

TABLE 4  
AVERAGE SPEEDS OF ALL COMMERCIAL VEHICLES OBSERVED DURING STUDIES ON TWO-LANE HIGHWAYS

| Type and Position of Object on Shoulder | Daytime             |            |            |            |            |            |            |            | Nighttime  |            |            |            |
|---|---------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
|   | Pave ent width—feet |            |            |            |            |            |            |            |            |            |            |            |
|   | 16                  |            | 20         |            | 22         |            | 26         |            | 20         |            | 22         |            |
|   | Near*               | Far†       | Near       | Far        |
| <i>mph</i>                              | <i>mph</i>          | <i>mph</i> | <i>mph</i> | <i>mph</i> | <i>mph</i> | <i>mph</i> | <i>mph</i> | <i>mph</i> | <i>mph</i> | <i>mph</i> | <i>mph</i> | <i>mph</i> |
| Shoulder clear—normal operation         | 43.2                | 38.1       | 38.5       | 37.6       | 40.8       | 42.4       | 37.6       | 39.1       | 35.6       | 36.2       |            |            |
| Car at edge of pavement                 | 40.8                | 37.5       | 37.6       | 37.2       | 38.6       | 42.9       | 41.7       | 39.0       | 35.2       | 34.6       |            |            |
| Car 3 feet from edge of pavement        | 42.3                | 39.7       | 36.9       | 38.5       | 42.9       | 41.2       | 37.6       | 37.4       | 36.4       | 37.6       | 44.2       | 37.8       |
| Car 6 feet from edge of pavement        | 42.4                | 38.7       | 34.4       | 38.5       | 40.3       | 42.0       | 37.8       | 37.4       | 37.0       | 37.7       | 40.3       | 41.0       |
| Truck at edge of pavement               | 38.4                | 37.3       | 36.9       | 36.5       | 40.5       | 41.6       | 39.6       | 40.8       |            |            |            |            |
| Truck 3 feet from edge of pavement      | 41.8                | 41.5       | 36.9       | 37.0       | 42.3       | 43.3       | 37.4       | 38.5       |            |            |            |            |
| Truck 6 feet from edge of pavement      | 40.4                | 35.1       | 37.8       | 39.5       | 42.0       | 41.9       | 38.1       | 38.3       |            |            |            |            |
| Barricade at edge of pavement           | 40.8                | 38.0       | 34.1       | 36.8       | 43.4       | 39.6       | 37.6       | 37.6       | 35.5       | 40.3       | 37.6       | 37.7       |
| Barricade 3 feet from edge of pavement  | 42.3                | 39.0       | 35.4       | 39.1       | 40.7       | 41.9       | 38.0       | 36.8       | 31.2       | 37.2       | 38.5       | 37.5       |
| Barricade 6 feet from edge of pavement  | 44.0                | 40.6       | 40.4       | 40.3       | 41.0       | 42.5       | 40.7       | 34.5       | 33.8       | 34.2       | 36.9       | 38.9       |

\* Near indicates the speeds of vehicles traveling in the lane adjacent to the occupied shoulder.  
† Far indicates the speeds of vehicles traveling in the lane adjacent to the clear shoulder.

ment edge, however, made no consistent difference.

3. Truck drivers, regardless of the lane in which they were traveling, were influenced by the shoulder condition even less than passenger car drivers.

4. The average passenger car driver who met another vehicle traveling in the opposite direction at the same place on the highway as the object was located on the shoulder reduced his speed 2.3 miles per hour if in the lane adjacent to the occupied shoulder and 1.5 miles per hour if in the other lane. Under

these conditions the type of object, its location on the shoulder, or the width of pavement made little difference.

5. On the four-lane highway there was no consistent tendency for drivers of vehicles in either lane under any of the study conditions to change their speeds with respect to those under normal conditions.

EFFECT OF OBJECTS ON LATERAL POSITIONS, TWO-LANE HIGHWAYS

Numerous studies have shown that the effect on driver behavior when any geometric

TABLE 5  
CHANGE IN AVERAGE SPEEDS DUE TO AN OBJECT ON ONE SHOULDER OF A TWO-LANE HIGHWAY COMPARED WITH NORMAL SPEEDS

All passenger cars traveling in lane adjacent to the clear shoulder

| Type of Object on Shoulder | Distance to Object from Pavement Edge | Pavement Width—Feet |            |            |            |            |
|----------------------------|---------------------------------------|---------------------|------------|------------|------------|------------|
|                            |                                       | 16*                 | 20         | 22         | 26         | Average    |
|                            | <i>feet</i>                           | <i>mph</i>          | <i>mph</i> | <i>mph</i> | <i>mph</i> | <i>mph</i> |
| Car                        | 0                                     | 1.0                 | 0.4        | -0.9       | -0.9       | -0.1       |
|                            | 3                                     | 0.3                 | -0.9       | -0.4       | -1.2       | -0.6       |
|                            | 6                                     | 1.5                 | -0.8       | -1.3       | -4.0       | -1.2       |
| Truck                      | 0                                     | 0.8                 | -2.0       | -0.3       | -1.7       | -0.8       |
|                            | 3                                     | 1.0                 | -0.4       | -0.2       | -0.1       | 0.1        |
|                            | 6                                     | 0.3                 | 0.5        | 0.2        | -1.8       | -0.2       |
| Barricade                  | 0                                     | -0.5                | -0.4       | -1.9       | -2.9       | -1.4       |
|                            | 3                                     | 0.4                 | -1.7       | -4.7       | -4.1       | -2.5       |
|                            | 6                                     | 0                   | -1.6       | -3.7       | -1.2       | -1.6       |
| Average                    | 0.5                                   | -0.8                | -1.5       | -2.0       | -0.9       |            |

By type of object on shoulder

|           |     |      |      |      |      |
|-----------|-----|------|------|------|------|
| Car       | 0.9 | -0.4 | -0.9 | -2.0 | -0.6 |
| Truck     | 0.7 | -0.6 | -0.1 | -1.2 | -0.3 |
| Barricade | 0   | -1.2 | -3.4 | -2.7 | -1.8 |

By distance object was from pavement edge

|        |     |      |      |      |      |
|--------|-----|------|------|------|------|
| 0 feet | 0.4 | -0.7 | -1.0 | -1.8 | -0.8 |
| 3 feet | 0.6 | -1.0 | -1.8 | -1.8 | -1.0 |
| 6 feet | 0.6 | -0.6 | -1.6 | -2.3 | -1.0 |

\* 16 feet of portland cement concrete with 2-foot bituminous shoulders.

feature of the cross section of a highway is changed will generally be reflected in a change in the lateral position of the vehicles. For this purpose, lateral positions have usually been a more definite criterion than vehicle speeds or any other characteristic of driver behavior that can be measured.

Neither the parked car, truck, nor barricade had any effect on the lateral position of vehicles traveling in a traffic lane which was not adjacent to the shoulder on which these objects were located. The differences between the lateral positions of the vehicles in this lane under normal conditions and when the objects were located on the shoulder are shown by table 12. In nearly all cases the values in this table, representing the change in lateral positions, are 0.3 of a foot or less, the precision to which the lateral positions were measured. They have no consistent tendency to be larger or smaller for the narrower surfaces than

TABLE 6  
CHANGE IN AVERAGE SPEEDS DUE TO AN OBJECT ON ONE SHOULDER OF A TWO-LANE HIGHWAY COMPARED WITH NORMAL SPEEDS

All commercial vehicles traveling in lane adjacent to the clear shoulder

| Type of Object on Shoulder | Distance to Object from Pavement Edge | Pavement Width—Feet |            |            |            |            |
|----------------------------|---------------------------------------|---------------------|------------|------------|------------|------------|
|                            |                                       | 16*                 | 20         | 22         | 26         | Average    |
|                            | <i>feet</i>                           | <i>mph</i>          | <i>mph</i> | <i>mph</i> | <i>mph</i> | <i>mph</i> |
| Car                        | 0                                     | -0.6                | -0.4       | 0.5        | -0.1       | -0.2       |
|                            | 3                                     | 1.6                 | 0.9        | -1.2       | -1.7       | -0.1       |
|                            | 6                                     | 0.6                 | 0.9        | -0.4       | -1.7       | -0.2       |
| Truck                      | 0                                     | -0.8                | -1.1       | -0.8       | 1.7        | -0.3       |
|                            | 3                                     | 2.6                 | -0.6       | 0.9        | -0.6       | -0.6       |
|                            | 6                                     | -3.0                | -1.9       | -0.5       | -0.8       | -1.6       |
| Barricade                  | 0                                     | -0.1                | -0.8       | -2.8       | -1.5       | -1.3       |
|                            | 3                                     | 0.9                 | 1.5        | -0.5       | -2.3       | -0.1       |
|                            | 6                                     | 2.5                 | 2.7        | 0.1        | -4.6       | 0.2        |
| Average change             | 0.4                                   | 0.1                 | -0.5       | -1.3       | -0.3       |            |

By type of object on shoulder

|           |      |      |      |      |      |
|-----------|------|------|------|------|------|
| Car       | 0.5  | 0.5  | -0.4 | -1.2 | -0.2 |
| Truck     | -0.4 | -1.2 | -0.1 | 0.1  | -0.4 |
| Barricade | 1.1  | 1.1  | -1.1 | -2.8 | -0.4 |

By distance object was from pavement edge

|        |      |      |      |      |      |
|--------|------|------|------|------|------|
| 0 feet | -0.5 | -0.8 | -1.0 | 0    | -0.6 |
| 3 feet | 1.7  | 0.6  | -0.3 | -1.5 | 0.1  |
| 6 feet | 0    | 0.6  | -0.3 | -2.4 | -0.5 |

\* 16 feet of portland cement concrete with 2-foot bituminous shoulders.

for the wider surfaces or for one type or location of object than for another type or location of object.

The objects on the shoulder did, however, have a very definite effect on the lateral positions of vehicles traveling in the lane adjacent to the shoulder on which the objects were parked, as shown by table 13. This table also shows that the changes in the lateral positions due to an object on the shoulder were greater for the narrow surfaces than for the wider ones, and that they were greater the closer the objects on the shoulder were to the pavement edge.

The type of object, however, had no consistent effect on the results. An analysis of the clearances between vehicles when meeting on the two-lane highways also showed that there was relatively little difference between the results obtained with either the car, the truck, or the barricade. For this reason, the following

**TABLE 7**  
**CHANGE IN AVERAGE SPEEDS DUE TO AN OBJECT ON ONE SHOULDER OF A TWO-LANE HIGHWAY COMPARED WITH NORMAL SPEEDS**  
 All passenger cars traveling in lane adjacent to the occupied shoulder

| Type of Object on Shoulder | Distance to Object from Pavement Edge | Pavement Width—Feet |            |            |            |            |
|----------------------------|---------------------------------------|---------------------|------------|------------|------------|------------|
|                            |                                       | 16*                 | 20         | 22         | 26         | Average    |
|                            |                                       | <i>feet</i>         | <i>mph</i> | <i>mph</i> | <i>mph</i> | <i>mph</i> |
| Car                        | 0                                     | -2.1                | -2.6       | -1.7       | -0.3       | -1.7       |
|                            | 3                                     | -1.3                | -2.7       | 1.2        | -0.1       | -0.7       |
|                            | 6                                     | -0.6                | -3.4       | 0.5        | -3.0       | -1.6       |
| Truck                      | 0                                     | -6.2                | -2.8       | -0.7       | -1.5       | -2.8       |
|                            | 3                                     | -1.2                | -2.8       | -0.3       | -0.1       | -1.1       |
|                            | 6                                     | -1.8                | -1.8       | 0.5        | -1.3       | -1.1       |
| Barricade                  | 0                                     | -4.5                | -4.6       | -1.6       | -3.9       | -3.6       |
|                            | 3                                     | -2.7                | -4.5       | -0.7       | -1.9       | -2.4       |
|                            | 6                                     | -2.8                | -5.6       | -0.9       | -1.3       | -2.6       |
| Average change...          |                                       | -2.6                | -3.4       | -0.4       | -1.5       | -2.0       |

By type of object on shoulder

|                 |      |      |      |      |      |
|-----------------|------|------|------|------|------|
| Car .....       | -1.3 | -2.9 | 0    | -1.1 | -1.3 |
| Truck .....     | -3.1 | -2.5 | -0.2 | -1.0 | -1.7 |
| Barricade ..... | -3.3 | -4.9 | -1.1 | -2.4 | -2.9 |

By distance object was from pavement edge

|              |      |      |      |      |      |
|--------------|------|------|------|------|------|
| 0 feet ..... | -4.3 | -3.3 | -1.3 | -1.9 | -2.7 |
| 3 feet ..... | -1.7 | -3.3 | 0.1  | -0.7 | -1.4 |
| 6 feet ..... | -1.7 | -3.6 | 0    | -1.9 | -1.8 |

\* 16 feet of portland cement concrete with 2-foot bituminous shoulders.

graphs for two-lane roads which show the effect that an object parked on a shoulder has on the lateral position of a vehicle traveling in the adjacent lane are applicable when the parked object is either a car, truck, or barricade.

The change in the lateral position of passenger cars caused by a vehicle or barricade being parked on the shoulder adjacent to the traffic lane in which the passenger car was traveling is shown by figure 3. Similar information is shown for commercial vehicles by figure 4. The change in the lateral positions in these and all subsequent figures is shown in terms of the movement to the left of the position that the vehicle occupied under normal conditions. In other words, it is the distance that the average vehicle, of a certain group of vehicles, shifted its position toward the centerline of the highway and away from the shoulder due to the vehicle or barricade which was parked on the shoulder.

**TABLE 8**  
**CHANGE IN AVERAGE SPEEDS DUE TO AN OBJECT ON ONE SHOULDER OF A TWO-LANE HIGHWAY COMPARED WITH NORMAL SPEEDS**  
 All commercial vehicles traveling in lane adjacent to the occupied shoulder

| Type of Object on Shoulder | Distance to Object from Pavement Edge | Pavement Width—Feet |            |            |            |            |
|----------------------------|---------------------------------------|---------------------|------------|------------|------------|------------|
|                            |                                       | 16*                 | 20         | 22         | 26         | Average    |
|                            |                                       | <i>feet</i>         | <i>mph</i> | <i>mph</i> | <i>mph</i> | <i>mph</i> |
| Car                        | 0                                     | -2.4                | -0.9       | -2.2       | 4.1        | -0.4       |
|                            | 3                                     | -0.9                | -1.6       | 2.1        | 0          | -0.1       |
|                            | 6                                     | -0.8                | -4.1       | -0.5       | 0.2        | -1.3       |
| Truck                      | 0                                     | -4.8                | -1.6       | -0.3       | 2.0        | -1.2       |
|                            | 3                                     | -1.4                | -1.6       | 1.5        | -0.2       | -0.4       |
|                            | 6                                     | -2.8                | -0.7       | 1.2        | 0.5        | -0.4       |
| Barricade                  | 0                                     | -2.8                | -4.4       | 2.6        | 0          | -1.2       |
|                            | 3                                     | -0.9                | -3.1       | -0.1       | 0.4        | -0.9       |
|                            | 6                                     | 0.8                 | 1.9        | 0.2        | 3.1        | 1.5        |
| Average change...          |                                       | -1.8                | -1.8       | 0.5        | 1.1        | -0.5       |

By type of object on shoulder

|                 |      |      |      |     |      |
|-----------------|------|------|------|-----|------|
| Car .....       | -1.4 | -2.2 | -0.2 | 1.4 | -0.6 |
| Truck .....     | -3.0 | -1.3 | 0.8  | 0.8 | -0.7 |
| Barricade ..... | -1.0 | -1.9 | 0.9  | 1.2 | -0.2 |

By distance object was from pavement edge

|              |      |      |     |     |      |
|--------------|------|------|-----|-----|------|
| 0 feet ..... | -3.3 | -2.3 | 0   | 2.0 | -0.9 |
| 3 feet ..... | -1.1 | -2.1 | 1.2 | 0.1 | -0.5 |
| 6 feet ..... | -0.9 | -1.0 | 0.3 | 1.3 | -0.1 |

\* 16 feet of portland cement concrete with 2-foot bituminous shoulders.

The drivers of free-moving passenger cars, or those drivers who were not influenced by the presence of other traffic on the highway, made the greatest shift toward the centerline and away from their normal position due to the objects on the right-hand shoulder, whereas the drivers of passenger cars who were meeting a truck or bus at the same time that they were adjacent to the vehicle or barricade parked on the shoulder made the smallest change from their normal paths. Under this latter condition, however, the movement to the left was 1 foot when the object was parked at the edge of a 13-foot lane and 2.5 feet when the object was at the edge of an 8-foot lane. The only drivers that did not change their lateral positions due to the objects on the shoulders were those who met commercial vehicles when the objects were 6 feet from the edge of the pavement.

The objects on the shoulders generally caused the trucks to veer farther than passen-

TABLE 9

CHANGE IN AVERAGE SPEEDS DUE TO AN OBJECT ON ONE SHOULDER OF A TWO-LANE HIGHWAY COMPARED WITH NORMAL SPEEDS

Passenger cars traveling in lane adjacent to the clear shoulder and meeting other vehicles

| Type of Object on Shoulder | Distance to Object from Pavement Edge | Pavement Width—Feet |            |            |            |            |
|----------------------------|---------------------------------------|---------------------|------------|------------|------------|------------|
|                            |                                       | 16*                 | 20         | 22         | 26         | Average    |
|                            |                                       | <i>feet</i>         | <i>mph</i> | <i>mph</i> | <i>mph</i> | <i>mph</i> |
| Car                        | 0                                     | 2.1                 | -0.3       | -0.2       | -1.5       | 0          |
|                            | 3                                     | -2.3                | -1.1       | 0          | -4.4       | -2.0       |
|                            | 6                                     | 1.4                 | -2.0       | 0.5        | -5.9       | -1.5       |
| Truck                      | 0                                     | 1.7                 | -2.7       | 1.3        | -3.6       | -0.8       |
|                            | 3                                     | -0.1                | -1.9       | -0.5       | -1.6       | -1.0       |
|                            | 6                                     | 0.4                 | -1.0       | 3.2        | -4.3       | -0.4       |
| Barricade                  | 0                                     | -0.9                | -1.5       | 0.4        | -5.5       | -1.9       |
|                            | 3                                     | 0.4                 | -4.3       | -4.6       | -5.7       | -3.6       |
|                            | 6                                     | -1.1                | -2.0       | -2.5       | -5.3       | -2.7       |
| Average change             |                                       | 0.2                 | -1.9       | -0.3       | -4.2       | -1.5       |

By type of object on shoulder

|           |      |      |      |      |      |
|-----------|------|------|------|------|------|
| Car       | 0.4  | -1.1 | 0.1  | -3.9 | -1.2 |
| Truck     | 0.7  | -1.9 | 1.3  | -3.2 | -0.7 |
| Barricade | -0.5 | -2.6 | -2.2 | -5.5 | -2.7 |

By distance object was from pavement edge

|        |      |      |      |      |      |
|--------|------|------|------|------|------|
| 0 feet | 1.0  | -1.5 | 0.5  | -3.5 | -0.9 |
| 3 feet | -0.7 | -2.4 | -1.7 | -3.9 | -2.2 |
| 6 feet | 0.2  | -1.7 | -0.4 | -5.2 | -1.5 |

\* 16 feet of portland cement concrete with 2-foot bituminous shoulders.

ger cars from their normal paths. (Figures 3 and 4.) There were, however, some exceptions such as the effect on free-moving vehicles when the objects were either 3 or 6 feet from the surface. Under these conditions, the passenger cars veered away from the objects more than did the trucks.

*Clearance Between Vehicles*

Two-lane roads carrying two-directional traffic should be of sufficient width to provide adequate clearance between the bodies of vehicles traveling in opposite directions when they meet. The results of previous studies have shown that 3 feet is the minimum desirable lateral clearance for this condition and that clearances of less than 3 feet occur infrequently on two-lane roads with 12-foot traffic lanes and adequate shoulders. This study shows, however, that when an object such as a car, a truck, or a barricade was parked on one shoulder

TABLE 10

CHANGE IN AVERAGE SPEEDS DUE TO AN OBJECT ON ONE SHOULDER OF A TWO-LANE HIGHWAY COMPARED WITH NORMAL SPEEDS

Passenger cars traveling in lane adjacent to the occupied shoulder and meeting other vehicles

| Type of Object on Shoulder | Distance to Object from Pavement Edge | Pavement Width—Feet |            |            |            |            |
|----------------------------|---------------------------------------|---------------------|------------|------------|------------|------------|
|                            |                                       | 16*                 | 20         | 22         | 26         | Average    |
|                            |                                       | <i>feet</i>         | <i>mph</i> | <i>mph</i> | <i>mph</i> | <i>mph</i> |
| Car                        | 0                                     | -5.6                | -2.6       | -3.3       | -2.0       | -3.4       |
|                            | 3                                     | 0.1                 | -1.5       | 1.5        | 0          | 0          |
|                            | 6                                     | 0.6                 | -3.0       | -1.9       | -4.3       | -2.2       |
| Truck                      | 0                                     | -5.5                | -1.5       | -2.0       | -1.9       | -2.7       |
|                            | 3                                     | -1.8                | -3.5       | -1.6       | -1.4       | -2.1       |
|                            | 6                                     | -1.3                | -3.7       | -3.2       | -1.1       | -2.3       |
| Barricade                  | 0                                     | -6.8                | -2.9       | -2.0       | -5.1       | -4.2       |
|                            | 3                                     | -2.5                | -3.2       | -2.5       | -1.4       | -2.4       |
|                            | 6                                     | -0.1                | -3.0       | -2.0       | -1.8       | -1.7       |
| Average change             |                                       | -2.5                | -2.8       | -1.7       | -2.1       | -2.3       |

By type of object on shoulder

|           |      |      |      |      |      |
|-----------|------|------|------|------|------|
| Car       | -1.6 | -2.4 | -1.2 | -2.1 | -1.9 |
| Truck     | -2.9 | -2.9 | -2.3 | -1.5 | -2.4 |
| Barricade | -3.1 | -3.0 | -2.2 | -2.8 | -2.8 |

By distance object was from pavement edge

|        |      |      |      |      |      |
|--------|------|------|------|------|------|
| 0 feet | -6.0 | -2.3 | -2.4 | -3.0 | -3.4 |
| 3 feet | -1.4 | -2.7 | -0.9 | -0.9 | -1.5 |
| 6 feet | -0.3 | -3.2 | -2.4 | -2.4 | -2.1 |

\* 16 feet of portland cement concrete with 2-foot bituminous shoulders.

der at the edge of a two-lane road with a 24-foot surface, 30 percent of the passenger cars had a clearance of 3 feet or less as they met other passenger cars (figure 5). On surfaces with 11-foot traffic lanes the corresponding figure is 46 percent. Surfaces with traffic lanes 8 feet wide are obviously too narrow for modern vehicles and speeds since 56 percent of the meetings of passenger cars took place with clearances of 3 feet or less although the average clearance exceeded 3 feet under normal conditions when the shoulders were clear. Placing a car, a truck, or a barricade on one of the shoulders, however, increased this percentage from 56 to 94 percent and decreased the average clearance between vehicles from 3.2 feet to 1.3 feet (figure 5).

Figure 6, which is similar to figure 5, shows clearances between bodies of passenger cars and trucks as they met. In figure 6 the average clearances are less and the percentage of vehicles with clearances of 3 feet or less are

TABLE 11  
CHANGE IN AVERAGE SPEEDS DUE TO AN OBJECT ON THE SHOULDER OF A FOUR-LANE DIVIDED HIGHWAY

Volumes less than 2,000 vehicles per hour in the two lanes

| Type and Position of Object on Shoulder   | Left Lane  |                | Right Lane |                |
|---|------------|----------------|------------|----------------|
|   | Pass. cars | Comm. vehicles | Pass. cars | Comm. vehicles |
|   | <i>mph</i> | <i>mph</i>     | <i>mph</i> | <i>mph</i>     |
| Car at pavement edge                      | 0.1        | 1.9            | -0.7       | 0              |
| Car 3 feet from pavement edge             | 0.4        | -0.9           | -1.1       | -0.4           |
| Car 6 feet from pavement edge             | 0.7        | 1.3            | -1.1       | -1.3           |
| Truck at pavement edge                    | -0.5       | 1.5            | -0.4       | -1.3           |
| Truck 3 feet from pavement edge           | -0.6       | 0.7            | 3.0        | 3.0            |
| Truck 6 feet from pavement edge           | -3.5       | -2.7           | 0.6        | 1.0            |
| Barricade at pavement edge                | -0.9       | -1.1           | 0          | -0.8           |
| Barricade 3 feet from pavement edge       | -1.0       | -1.1           | 1.6        | 0.5            |
| Barricade 6 feet from pavement edge       | -2.0       | -3.4           | 0.4        | 1.2            |
| Average change                            | -0.8       | -0.4           | 0.2        | 0.2            |
| By type of object on shoulder             |            |                |            |                |
| Car                                       | 0.4        | 0.8            | -1.0       | -0.6           |
| Truck                                     | -1.5       | -0.2           | 1.1        | 0.9            |
| Barricade                                 | -1.3       | -1.9           | 0.7        | 0.3            |
| By distance object was from pavement edge |            |                |            |                |
| 0 feet                                    | -0.4       | 0.8            | -0.4       | -0.7           |
| 3 feet                                    | -0.4       | -0.4           | 1.2        | 1.0            |
| 6 feet                                    | -1.6       | -1.6           | 0          | 0.3            |

greater than in figure 5. This is to be expected because trucks are wider than passenger cars.

*Objects on Shoulder Cause Crossing of Centerline*

The average position of both passenger cars and trucks under normal conditions is to the right of the centerline of a two-lane two-directional pavement even though it is only 16 feet wide. Figures 7A through 7H show, however, that when a car, a truck, or a barricade was placed on one shoulder next to the edge of a 16 or 20-foot pavement, vehicles which normally traveled entirely in the lane adjacent to the occupied shoulder, encroached on the lane used by oncoming traffic. This was the case even in the face of oncoming traffic on a 16-foot surface with the result that oncoming traffic was forced to use the other shoulder. (Figure 7B)

When the objects were 6 feet from the edge of the pavement, regardless of the pavement width, they caused little change in the lateral positions of the vehicles (figures 7A through 7H). As an object on the shoulder was brought closer than 6 feet from the edge of the pavement, there was an increasing effect on the lateral positions with a decrease in the distance the object was from the edge. This is true for all pavement widths but applies to a greater degree on the narrower than on the wider two-lane pavements. This is further il-

TABLE 12  
CHANGE IN LATERAL POSITION OF VEHICLES DUE TO AN OBJECT ON ONE SHOULDER OF A TWO-LANE HIGHWAY

Vehicles traveling in lane adjacent to clear shoulder

| Pavement Width, feet   | Distance Object Was from Edge of Pavement |      |           |      |        |      |           |      |        |      |           |      |
|--|---|------|-----------|------|--------|------|-----------|------|--------|------|-----------|------|
|  | 0 feet                                    |      |           |      | 3 feet |      |           |      | 6 feet |      |           |      |
|  | Type of object                            |      |           |      |        |      |           |      |        |      |           |      |
|  | Car                                       | Tk.  | Barricade | Avg. | Car    | Tk.  | Barricade | Avg. | Car    | Tk.  | Barricade | Avg. |
| Increased distance from shoulder on which object was placed—feet |   |      |           |      |        |      |           |      |        |      |           |      |
| Effect on passenger cars   |   |      |           |      |        |      |           |      |        |      |           |      |
| 16   | 0.1                                       | 0.2  | 0.1       | 0.1  | 0.1    | 0.1  | -0.2      | 0    | 0.1    | 0.2  | -0.1      | 0.1  |
| 20   | -0.3                                      | -0.2 | -0.2      | -0.2 | -0.5   | -0.3 | -0.3      | -0.4 | -0.6   | -0.3 | -0.4      | -0.4 |
| 22   | -0.1                                      | 0.4  | 0.2       | -0.2 | -0.1   | 0.1  | 0.1       | 0    | -0.1   | 0.1  | 0.1       | 0    |
| 26   | -0.2                                      | 0.1  | 0.3       | -0.1 | 0      | -0.1 | 0.3       | 0.1  | 0      | 0    | 0.2       | 0.1  |
| Effect on trucks and buses                                       |   |      |           |      |        |      |           |      |        |      |           |      |
| 16   | 0.6                                       | 0.4  | 0.4       | 0.5  | 0.3    | 0.1  | 0         | 0.1  | 0.4    | 0.1  | -0.1      | 0.1  |
| 20   | 0.2                                       | 0    | -0.1      | 0    | -0.1   | -0.1 | -0.4      | -0.2 | -0.2   | -0.2 | -0.2      | -0.2 |
| 22   | -0.3                                      | 0.2  | 0.1       | 0    | -0.2   | -0.1 | -0.2      | -0.2 | -0.3   | 0    | -0.1      | -0.1 |
| 26   | -0.1                                      | 0.3  | 0.4       | 0.3  | -0.2   | 0    | 0         | -0.1 | -0.1   | 0.1  | 0.1       | 0    |

TABLE 13  
CHANGE IN LATERAL POSITION OF VEHICLES DUE TO AN OBJECT ON ONE SHOULDER OF  
A TWO-LANE HIGHWAY  
Vehicles traveling in lane adjacent to occupied shoulder

| Pavement Width,<br>feet  | Distance Object Was from Edge of Pavement |     |                |      |        |     |                |      |        |     |                |      |  |
|--|---|-----|----------------|------|--------|-----|----------------|------|--------|-----|----------------|------|--|
|  | 0 feet                                    |     |                |      | 3 feet |     |                |      | 6 feet |     |                |      |  |
|  | Type of object                            |     |                |      |        |     |                |      |        |     |                |      |  |
|  | Car                                       | Tk. | Barri-<br>cade | Avg. | Car    | Tk. | Barri-<br>cade | Avg. | Car    | Tk. | Barri-<br>cade | Avg. |  |
| Increased distance from shoulder on which object was placed—feet |   |     |                |      |        |     |                |      |        |     |                |      |  |
| Effect on passenger cars   |   |     |                |      |        |     |                |      |        |     |                |      |  |
| 16   | 3.0                                       | 3.7 | 3.4            | 3.4  | 1.3    | 1.3 | 0.9            | 1.2  | 0.6    | 0.6 | 0.1            | 0.4  |  |
| 20   | 2.1                                       | 2.6 | 2.1            | 2.3  | 0.4    | 1.1 | 0.4            | 0.6  | 0.3    | 0.1 | 0.2            | 0.2  |  |
| 22   | 2.6                                       | 2.8 | 2.0            | 2.5  | 1.0    | 1.5 | 0.9            | 1.1  | 0.5    | 0.7 | 0.2            | 0.5  |  |
| 26   | 1.0                                       | 1.7 | 1.6            | 1.4  | 0.5    | 0.8 | 0.6            | 0.6  | 0.3    | 0.5 | 0              | 0.3  |  |
| Effect on trucks and buses                                       |   |     |                |      |        |     |                |      |        |     |                |      |  |
| 16   | 3.4                                       | 3.9 | 3.8            | 3.7  | 0.8    | 1.4 | 1.1            | 1.1  | 0.4    | 0.6 | 0.5            | 0.5  |  |
| 20   | 2.4                                       | 3.0 | 2.2            | 2.5  | 0.7    | 1.2 | 0.5            | 0.8  | 0.3    | 0.1 | 0.3            | 0.2  |  |
| 22   | 2.6                                       | 3.0 | 2.3            | 2.6  | 1.0    | 1.6 | 0.9            | 1.2  | 0.5    | 0.7 | 0.7            | 0.6  |  |
| 26   | 1.2                                       | 1.9 | 1.8            | 1.6  | 0.7    | 0.9 | 0.8            | 0.8  | 0.3    | 0.8 | 0.4            | 0.5  |  |

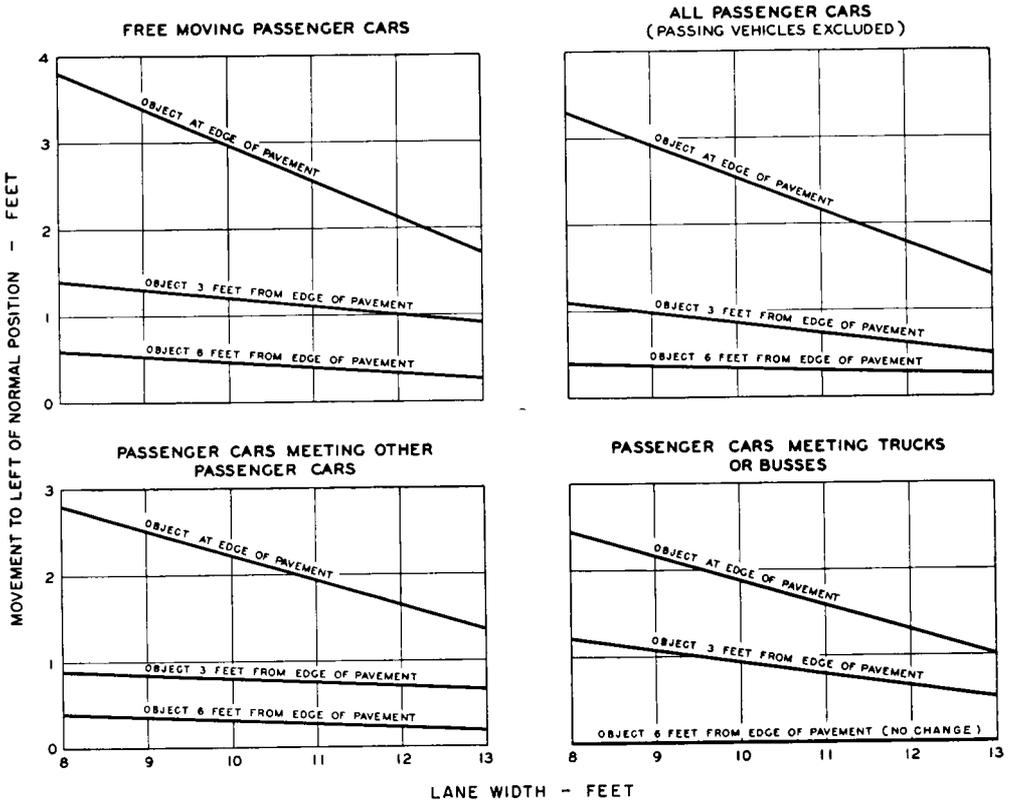


Figure 3. Effect of objects on the lateral position of passenger cars traveling in lane adjacent to occupied shoulder.

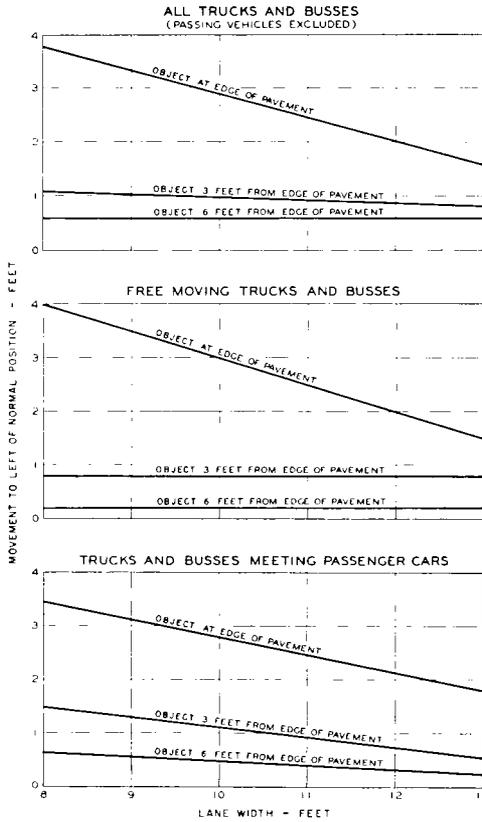


Figure 4. Effect of objects on the lateral position of trucks and buses traveling in lane adjacent to occupied shoulder.

illustrated by the graph at the top of figure 8 which combines the information in figures 3 and 4 in a somewhat different form to represent average traffic conditions during the study periods on the two-lane roads.

The graph at the top of figure 8 shows the change in lateral positions which the objects caused. When an object was 6 or more feet from the pavement edge, the distance between a vehicle in the traffic stream and the pavement edge was increased by 0.4 of a foot if the traffic lanes were 8 feet wide and about 0.25 of a foot if the lanes were 13 feet wide. These correspond to only 5 percent and 2 percent, respectively, of the lane widths, as shown by the graph at the bottom of figure 8. From these figures and from the shape of the curves on figure 8, it can be concluded that, for all practical purposes, objects 6 or more feet from

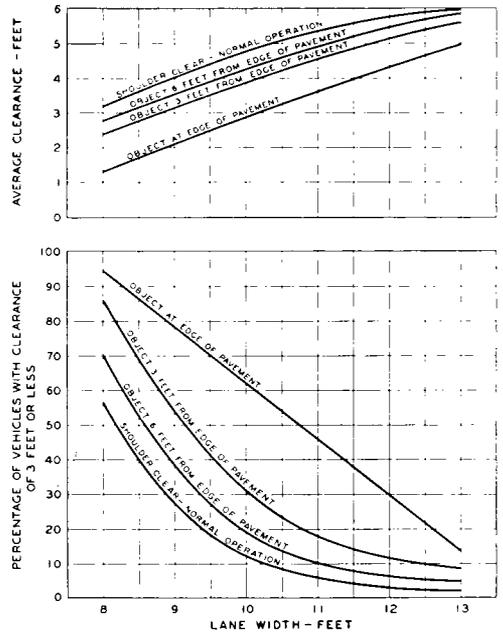


Figure 5. Clearances between bodies of passenger cars when meeting.

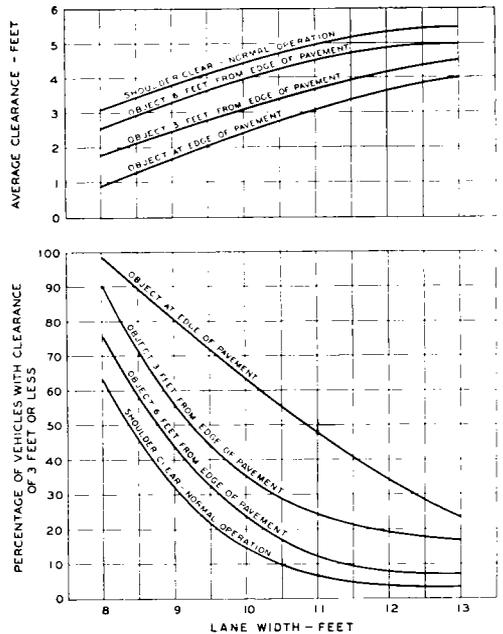


Figure 6. Clearances between bodies when passenger cars meet trucks or buses.

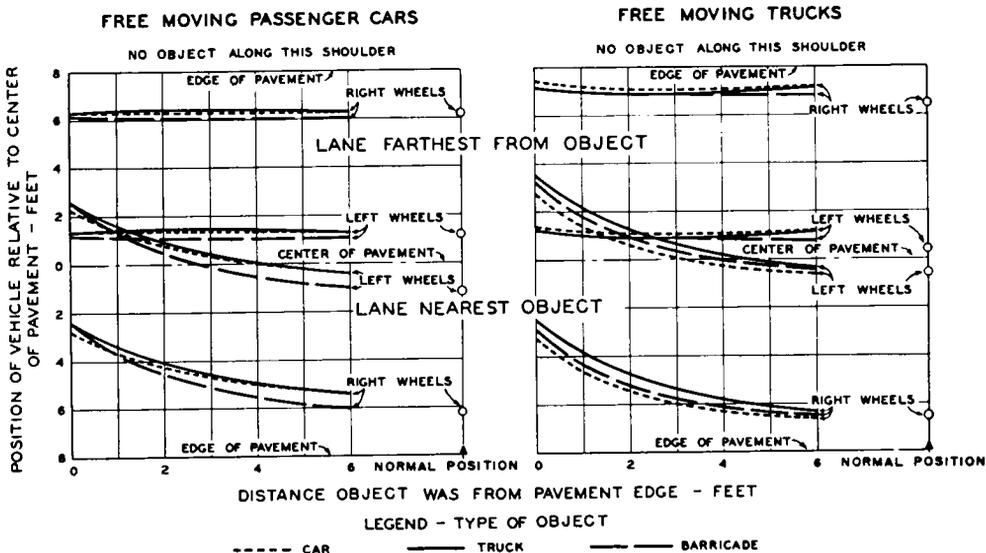


Figure 7A. Average position of free moving vehicles on a 16-foot concrete pavement with various objects on the shoulder.

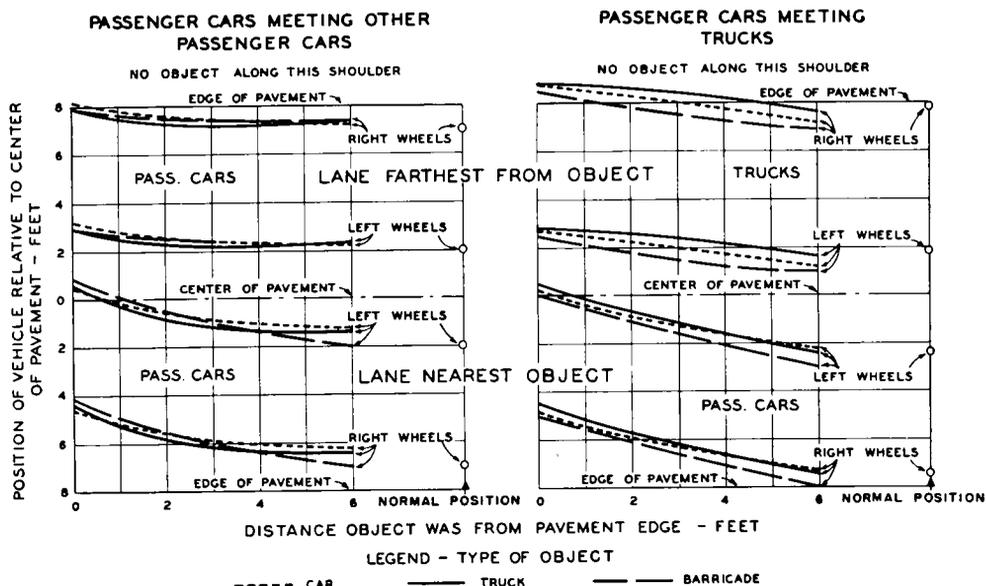


Figure 7B. Average position of vehicles meeting other vehicles on a 16-foot concrete pavement with various objects on the shoulder.

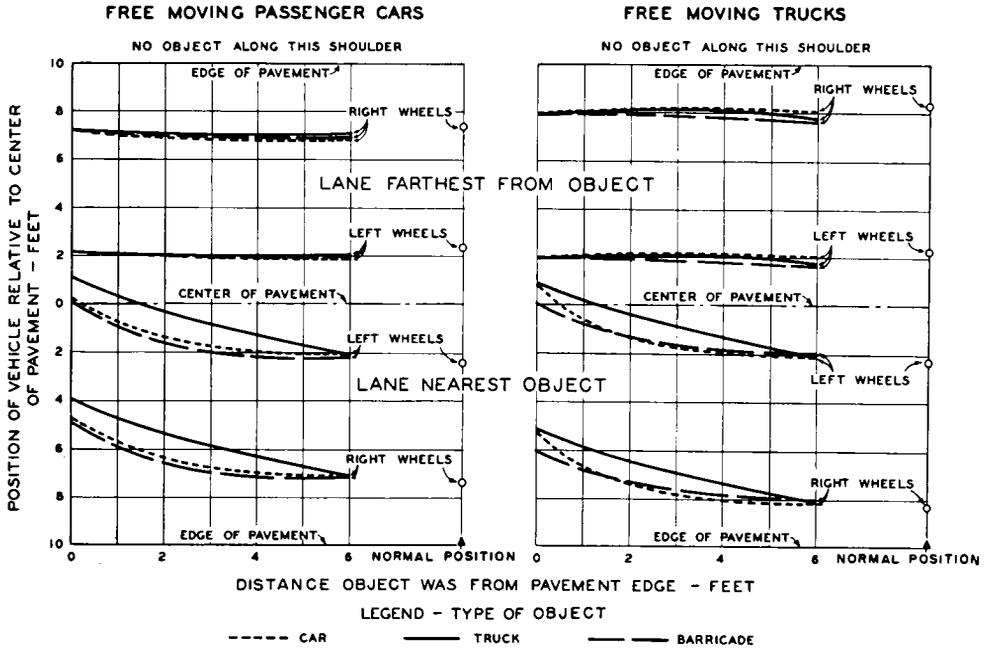


Figure 7C. Average position of free moving vehicles on a 20-foot concrete pavement with various objects on the shoulder.

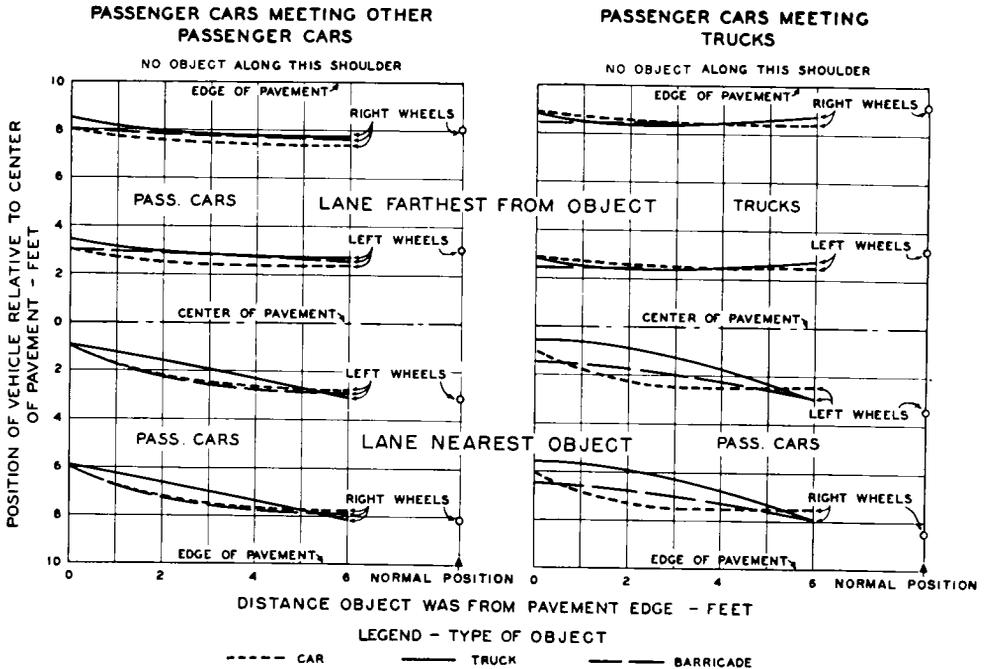


Figure 7D. Average position of vehicles meeting other vehicles on a 20-foot concrete pavement with various objects on the shoulder.

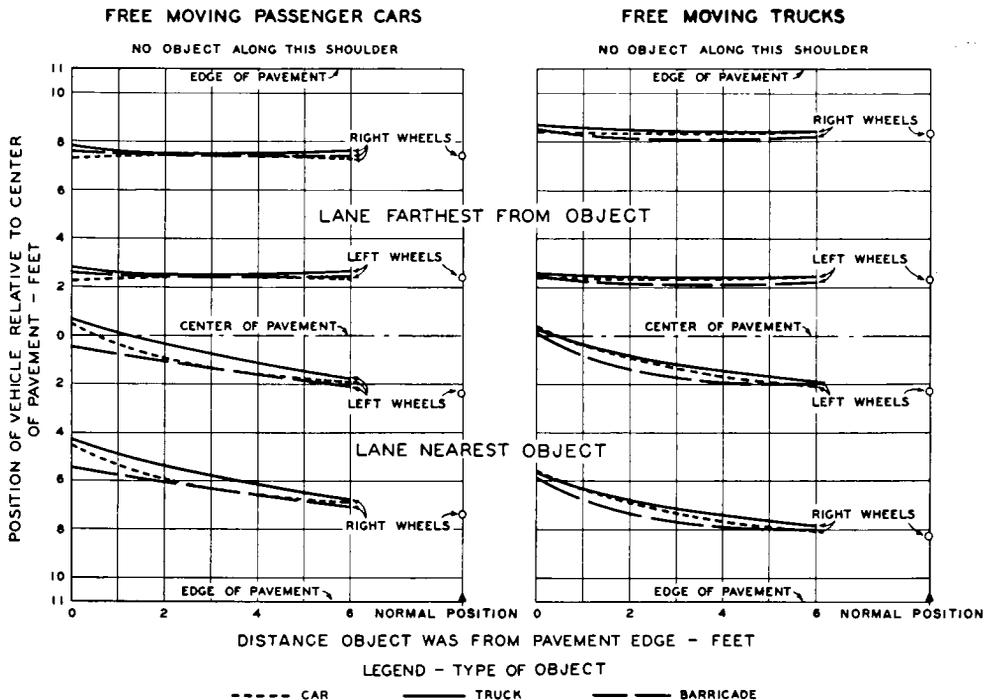


Figure 7E. Average position of free moving vehicles on a 22-foot concrete pavement with various objects on the shoulder.

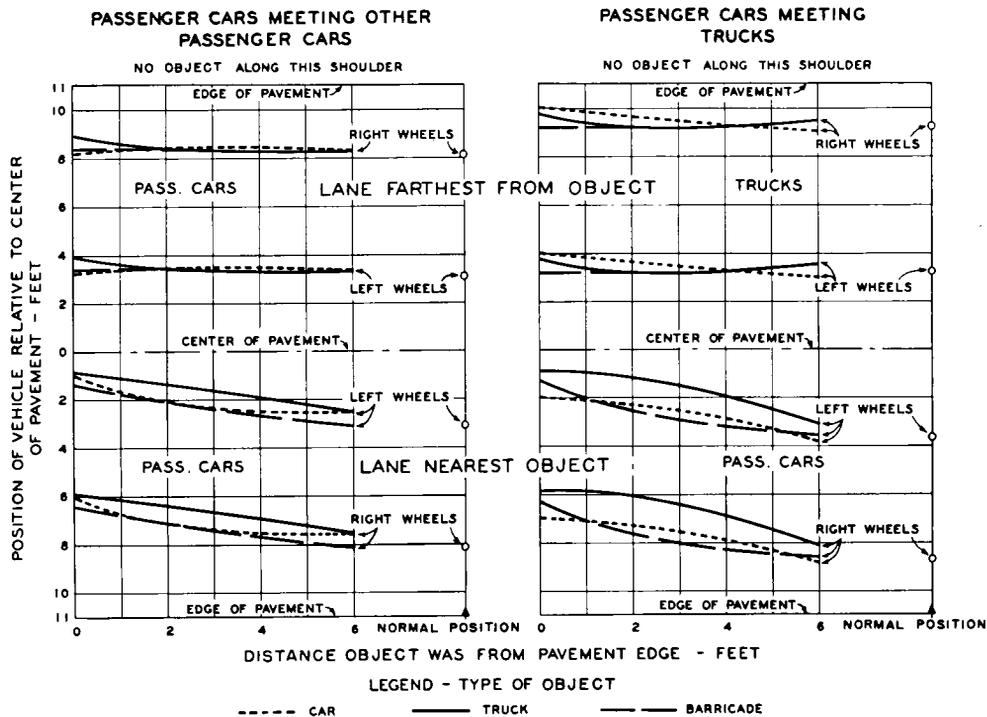


Figure 7F. Average position of vehicles meeting other vehicles on a 22-foot concrete pavement with various objects on the shoulder.

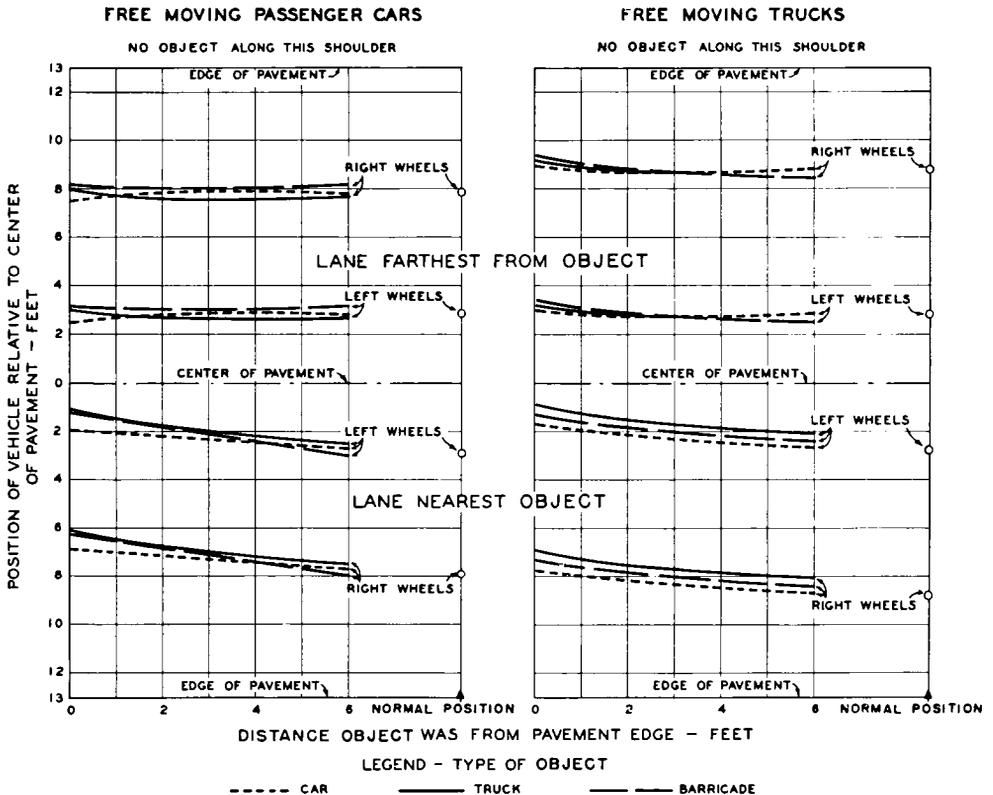


Figure 7G. Average position of free moving vehicles on a 26-foot bituminous pavement with various objects on the shoulder.

the edge of the pavement of a two-lane road of any width have an insignificant effect on driver behavior. The effect of an object at the edge of a two-lane surface of any width is very significant and especially so for the narrower surfaces. Regardless of the surface width, however, an object 2 feet from the edge has only half the effect of an object at the edge of the surface.

EFFECT OF OBJECTS ON LATERAL POSITIONS, FOUR-LANE HIGHWAYS

The traffic volumes on the four-lane facility included in this study varied from 1,000 to over 3,500 vehicles per hour in one direction of travel. It is interesting to see how the normal pattern of vehicle placements on this highway varied with traffic volumes. This is shown by figures 9 and 10. As the volume increased, figure 9 shows that passenger cars in the right lane, on an average, traveled closer to the

shoulder and those in the left lane traveled closer to the median. Furthermore, the average lateral position and hourly volume are linearly related. Similar results were obtained for commercial vehicles (figure 10).

In order to eliminate the effect of volume and to obtain only the effect of the objects on vehicle placement, comparisons of placement values were made at the same hourly volume. For this purpose it was necessary to draw graphs showing average placements against the recorded volumes. The desired data were thus obtained for each 500-vehicle-per-hour increment within the range of observed volumes.

Traffic in Left Lane Unaffected by Object on Shoulder

Table 14 shows the effect that the objects placed on the shoulder had on the lateral position of vehicles traveling in the left lane. The

PASSENGER CARS MEETING OTHER PASSENGER CARS

PASSENGER CARS MEETING TRUCKS

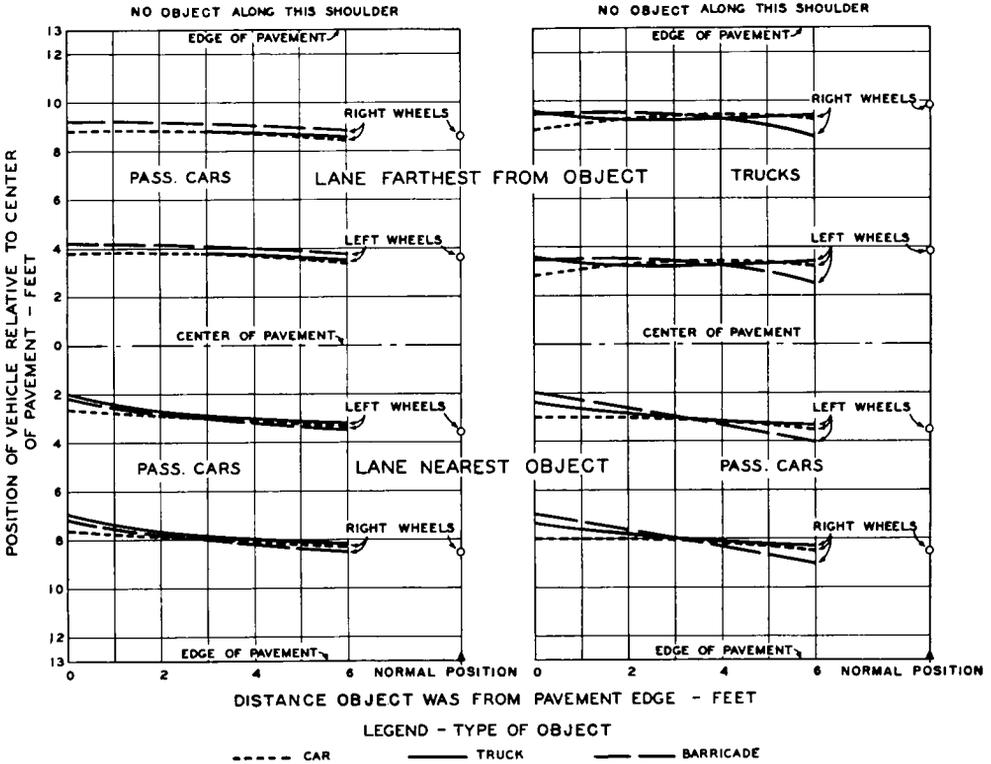
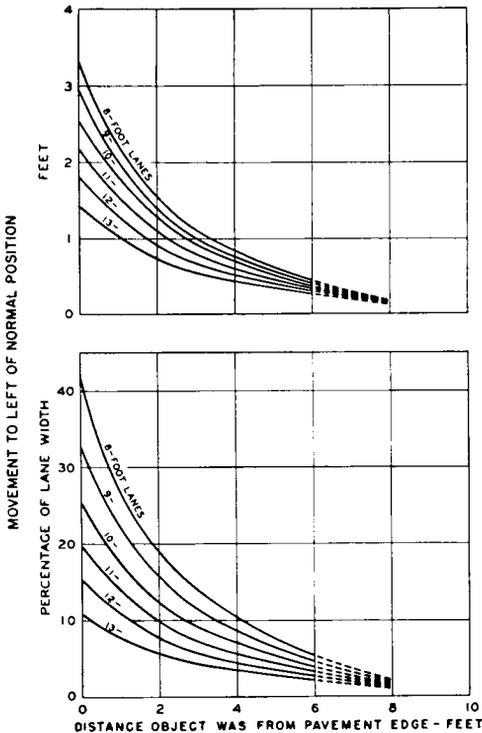


Figure 7H. Average position of vehicles meeting other vehicles on a 26-foot bituminous pavement with various objects on the shoulder.



← Figure 8. Lateral movement of traffic for various distances object was from pavement edge by lane widths (weighted for traffic consisting of 10 percent commercial vehicles during volumes of 200 to 400 vehicles per hour).

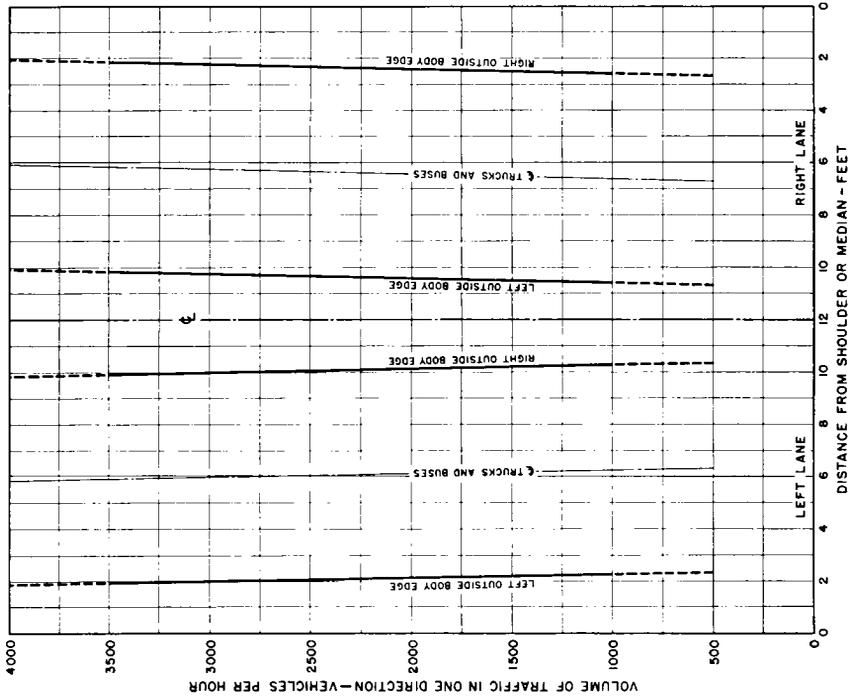


Figure 10. Average position of commercial vehicles during different traffic volumes (normal condition on 4-lane divided highway).

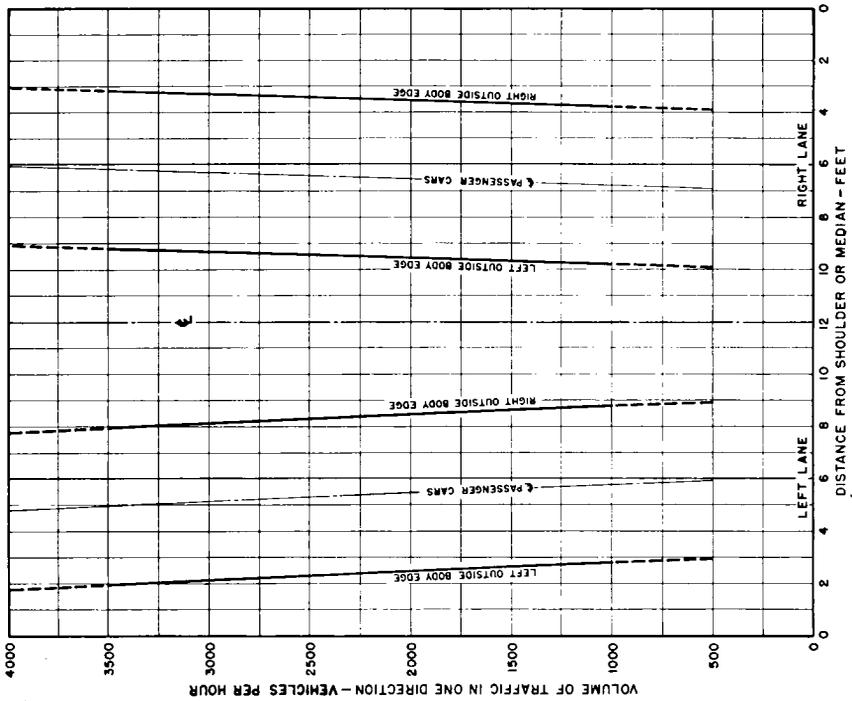


Figure 9. Average position of passenger cars during different traffic volumes (normal condition on 4-lane divided highway).

TABLE 14  
CHANGE IN LATERAL POSITION OF VEHICLES DUE TO AN OBJECT ON ONE SHOULDER OF  
A FOUR-LANE HIGHWAY  
Vehicles traveling in left lane

| Total Hourly Volume, vph   | Distance Object was from Pavement Edge |      |                |      |        |     |                |      |        |      |                |      |
|--|--|------|----------------|------|--------|-----|----------------|------|--------|------|----------------|------|
|  | 0 feet                                 |      |                |      | 3 feet |     |                |      | 6 feet |      |                |      |
|  | Type of object                         |      |                |      |        |     |                |      |        |      |                |      |
|  | Car                                    | Tk.  | Barri-<br>cade | Avg. | Car    | Tk. | Barri-<br>cade | Avg. | Car    | Tk.  | Barri-<br>cade | Avg. |
| Increased distance from shoulder on which object was placed—feet |  |      |                |      |        |     |                |      |        |      |                |      |
| Effect on passenger cars   |  |      |                |      |        |     |                |      |        |      |                |      |
| 1,000  | 0.1                                    | 0.1  | 0.2            | 0.2  | 0      | 0.1 | -0.1           | 0    | 0.2    | -0.1 | 0              | 0    |
| 1,500  | 0.1                                    | 0.1  | 0.1            | 0.1  | 0      | 0.1 | -0.1           | 0    | 0.1    | -0.1 | 0              | 0    |
| 2,000  | 0.1                                    | 0.1  | 0              | 0.1  | 0.1    | 0.1 | -0.1           | 0    | 0.1    | -0.1 | -0.1           | 0    |
| 2,500  | 0.1                                    | 0    | 0              | 0    | 0.1    | 0.1 | -0.1           | 0    | 0.1    | -0.1 | -0.1           | 0    |
| 3,000  | 0                                      | 0    | -0.1           | 0    | -0.1   | 0.1 | -0.1           | -0.1 | 0      | -0.2 | -0.1           | -0.1 |
| 3,500  | -0                                     | 0    | -0.2           | -0.1 | -0.2   | 0.1 | -0.2           | -0.1 | 0      | -0.2 | -0.1           | -0.1 |
| All  | 0.1                                    | 0.1  | 0              | 0    | -0.1   | 0.1 | -0.1           | 0    | 0.1    | -0.1 | -0.1           | 0    |
| Effect on trucks and buses                                       |  |      |                |      |        |     |                |      |        |      |                |      |
| Below 2000   | -0.2                                   | 0.2  | -0.8           | -0.2 | 0      | 0.1 | 0.2            | 0.1  | 0.3    | 0.2  | 0.3            | 0.2  |
| 2000 and over  | 0.4                                    | -0.1 | 0              | 0.1  | 0.5    | 0.4 | 0              | 0.3  | 0.4    | 0.3  | 0.5            | 0.4  |
| All  | 0.1                                    | 0.1  | -0.4           | 0    | 0.2    | 0.2 | 0.1            | 0.2  | 0.3    | 0.2  | 0.4            | 0.3  |

TABLE 15  
CHANGE IN LATERAL POSITION OF VEHICLES  
DUE TO AN OBJECT ON ONE SHOULDER  
OF A FOUR-LANE HIGHWAY  
Vehicles traveling in right lane

| Total Hourly Volume, vph   | Distance Object Was from Pavement Edge |     |                |     |        |                |      |     |                |     |     |                |
|--|--|-----|----------------|-----|--------|----------------|------|-----|----------------|-----|-----|----------------|
|  | 0 feet                                 |     |                |     | 3 feet |                |      |     | 6 feet         |     |     |                |
|  | Type of object                         |     |                |     |        |                |      |     |                |     |     |                |
|  | Car                                    | Tk. | Barri-<br>cade | Car | Tk.    | Barri-<br>cade | Car  | Tk. | Barri-<br>cade | Car | Tk. | Barri-<br>cade |
| Increased distance from shoulder on which object was placed—feet |  |     |                |     |        |                |      |     |                |     |     |                |
| Effect on passenger cars   |  |     |                |     |        |                |      |     |                |     |     |                |
| 1,000  | 0.9                                    | 1.1 | 0.4            | 0.4 | 0.7    | 0.2            | 0.2  | 0   | 0.1            | 0.2 | 0.2 | 0              |
| 1,500  | 0.9                                    | 1.1 | 0.4            | 0.4 | 0.6    | 0.2            | 0.2  | 0   | 0.1            | 0.2 | 0.2 | 0              |
| 2,000  | 0.9                                    | 1.0 | 0.5            | 0.4 | 0.4    | 0.2            | 0.2  | 0.1 | 0              | 0.2 | 0.2 | 0.1            |
| 2,500  | 0.9                                    | 1.0 | 0.5            | 0.4 | 0.3    | 0.2            | 0.2  | 0.1 | 0              | 0.2 | 0.2 | 0.1            |
| 3,000  | 0.9                                    | 0.9 | 0.5            | 0.4 | 0.2    | 0.2            | 0.2  | 0.1 | 0              | 0.2 | 0.2 | 0.1            |
| 3,500  | 0.8                                    | 0.9 | 0.5            | 0.3 | 0.1    | 0.2            | 0.1  | 0.2 | 0              | 0.1 | 0.2 | 0              |
| All  | 0.9                                    | 1.0 | 0.5            | 0.4 | 0.4    | 0.2            | 0.2  | 0.1 | 0              | 0.2 | 0.2 | 0.1            |
| Effect on trucks and buses                                       |  |     |                |     |        |                |      |     |                |     |     |                |
| 1,000  | 1.0                                    | 1.1 | 0.4            | 0.1 | 0.6    | 0              | 0.2  | 0   | 0.1            | 0.2 | 0.2 | 0              |
| 1,500  | 1.0                                    | 1.1 | 0.4            | 0.1 | 0.5    | 0              | 0.1  | 0   | 0.1            | 0.2 | 0.2 | 0              |
| 2,000  | 0.9                                    | 1.0 | 0.4            | 0.1 | 0.3    | 0              | 0    | 0.1 | 0              | 0.1 | 0.1 | 0              |
| 2,500  | 0.9                                    | 0.9 | 0.4            | 0.1 | 0.2    | -0.1           | 0    | 0.1 | 0              | 0.1 | 0.1 | 0              |
| 3,000  | 0.8                                    | 0.8 | 0.4            | 0.1 | 0.1    | -0.1           | -0.1 | 0.2 | 0              | 0.1 | 0.1 | 0              |
| 3,500  | 0.8                                    | 0.7 | 0.4            | 0.1 | 0      | -0.1           | -0.2 | 0.2 | 0              | 0.1 | 0.1 | 0              |
| All  | 0.9                                    | 0.9 | 0.4            | 0.1 | 0.3    | -0.1           | 0    | 0.1 | 0              | 0.1 | 0.1 | 0              |

figures in the table are the differences between the lateral positions during normal conditions and those while an object was on the shoulder. It can readily be seen that neither the type of object nor the distance that the object was from the pavement had any significant effect on lateral positions of passenger cars traveling in the left lane. Very few commercial vehicles traveled in the left lane. A detailed analysis of the effect of objects on these vehicles, therefore, could not be made. The limited data, however, do indicate that trucks in the left lane of a four-lane highway were also unaffected by objects placed on the shoulder.

*Vehicles in Right Lane Veer Away from Objects on Shoulder*

Objects on the shoulder do affect the lateral positions of vehicles traveling in the right lane of a four-lane divided highway. The differences between the lateral positions of vehicles during normal conditions and those while an object was on the shoulder are shown by table 15. A truck parked at the edge of the pavement or 3 feet away had a slightly greater effect on traffic than a parked car when the total hourly volume was 1,500 or less. Generally, however, the effect of the truck was about the same as

that of the car. A barricade placed on the shoulder had considerably less effect both on passenger cars and commercial vehicles than a parked car or truck under all volume conditions.

When the total hourly volume in both traffic lanes was 1,000 vehicles per hour, passenger cars in the right lane traveled about a foot farther from the edge of the pavement when a truck or a car was parked at the pavement edge than when no object was on the shoulder. As the traffic volume increased, the effect of the parked truck or car decreased slightly.

A barricade at the edge of the surface had only about half the effect of a parked truck or car in causing passenger cars in the right-hand lane to veer away from the shoulder. Objects on the shoulder but 3 feet from the pavement edge had only half the effect as the same objects placed at the pavement edge. Any of the three objects placed 6 feet from the pavement edge had almost a negligible effect on passenger cars traveling in the right-hand lane.

During low traffic volumes, commercial vehicles traveling in the right-hand lane were affected to approximately the same extent as passenger cars by objects at the pavement edge. At the higher volumes, the effect on commercial vehicles was slightly less than the effect on passenger cars. The lateral positions of commercial vehicles were not influenced by a barricade placed either 3 or 6 feet from the pavement or by a truck or car parked 6 feet from the pavement.

Although the lateral positions of vehicles in the right-hand lane were affected by objects on the shoulder, the objects did not cause a

change in the distribution of traffic between the two lanes. The objects on the shoulder did, however, cause an increase in the percentage of commercial vehicles that straddled the lane line.

#### CONCLUSIONS

From studies of driver behavior with and without objects on two-lane and on four-lane divided highways it may be concluded that:

1. Vehicle speeds were affected little if at all by objects on the shoulder during light to moderate traffic volumes. This confirms earlier studies of speeds on narrow pavements and at narrow bridges and other obstructions.

2. Objects parked on one shoulder affected the lateral position of only those vehicles traveling in the lane adjacent to the occupied shoulder. The effect was greatest when the object on the shoulder was at the pavement edge, and diminished rapidly with an increase in the distance that the object was located from the edge of the pavement.

3. The narrower the pavement, the greater was the shift of traffic to the left or away from the object on the shoulder. On a two-lane highway with a 16-foot surface, the shift was 3.3 feet, and on one with a 24-foot surface the shift was 1.8 feet.

4. A car, a truck, or a barricade parked on the shoulder had about the same effect on the lateral positions of vehicles on two-lane highways. On the four-lane highway a truck had about the same effect as a car, but a barricade caused a lateral movement about one-half as great as the car or truck.