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Truck traffic on U.S. Route 10 at Lookout Pass on the Idaho-Montana State line, 62 miles east of Coeur d'Alene, Idaho. Final location of Interstate Route 90 over this pass is under study by the State highway departments. Present alinement to the summit is winding and has sharp curves. The maximum curvature is 28 degrees and the maximum grade is 7 percent; for long stretches the grade is 5 percent.

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U.S. DEPARTMENT OF COMMERCE
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Perceptual and Field Factors Causing Lateral Displacement

BY THE TRAFFIC SYSTEMS RESEARCH DIVISION BUREAU OF PUBLIC ROADS

Reported by [1] RICHARD M. MICHAELS, Chief, Human Factors Research Branch, and LEE W. COZAN, Research Psychologist

An awareness of the existence of the phenomenon of lateral displacement has been extant for many years and much descriptive information has been published on this driving phenomenon. However, the study reported here constitutes what is believed to be a first attempt to determine the process drivers use to locate objects and to define the factors that cause a driver to displace laterally.

The results obtained in a controlled study on a test track showed that drivers locate an object they are overtaking on the basis of the angular velocity of the object. If a driver can detect this lateral movement, he knows that the object cannot be in his path. If there is no such velocity, the object is perceived as an obstruction and the driver must displace. The results also provide a basis for predicting the effects of lateral displacement on lane width, size of objects near the path of travel—fixed or moving—and the speed of the vehicle.

Findings reported here have many implications related to highway transportation and can provide some criteria for design, speed controls, and roadside developments in plans for future highways and improvement of existing ones.

Introduction

WHEN AN object is placed near the path of a driver, a lateral movement away from the object occurs as the driver approaches. The amount of this lateral displacement has been shown to be directly dependent upon the distance of the object from the path of travel (*1, 2*).[2] Thus, Taragin (*2*) has shown that there is a shift in position for objects located up to 6 feet to the right of the driver's path of travel. However, the process that the human operator must carry out in order to locate himself relative to fixed objects in his path has not been specified. The research reported here was an attempt to isolate the variables involved in this location process. Two models were considered; one fits the results obtained in the tests.

From a perceptual standpoint, the transverse location of an object in a driver's path may be considered a problem in trigonometry. The transverse distance a (the lateral distance of an object from the driver) may be derived from the simple trigonometric expression, in which ℓ = location, as:

$$a=\ell \tan \theta$$

These conditions are shown in figure 1. Thus, at any point in space, the observer may determine the transverse distance a by estimating both ℓ and θ. For small angles $\tan \theta = \theta$, and therefore the equation becomes simply $a=\ell\theta$.

However, a problem arises for the driver because of the interaction of distance and angle. At long distances the angle is so small that errors in estimation preclude a solution of sufficient accuracy to determine whether the object is in the driver's path. Similarly, at short distances the angle increases so rapidly that solutions also become inaccurate. Therefore, there should be a range of distance for which drivers judgment of the angle θ is most nearly accurate. On the basis of this angle estimation model, as the driver approaches the object, he eventually moves into an optimum range of discrimination. If the angle is smaller than some critical value, the driver will displace away from the object, the magnitude of the lateral displacement being directly related to the size of the angle at the distance at which the detection of the object is made. According to this model, lateral displacement should begin at some fixed distance from the object, independent of the absolute location of the object and independent of travel speed.

An alternative model exists, however. As the driver is moving continuously toward the object, the angle as well as distance is changing continuously. If the driver tracks the object over a period of time and estimates the rate at which the angle is changing, he also can determine the lateral location of the object in relation to his path of travel. The rate of change of the angle is a nonlinear function of time and is, furthermore, dependent upon the speed of travel. If the driver were to operate on this basis, he would be solving the equation:

$$\frac{d\theta}{dt}=\frac{av}{a^2+\ell^2}$$

Where,

$\frac{d\theta}{dt}$ = rate of change of angle
θ = angle
a = transverse distance
v = velocity of vehicle
ℓ = location of object.

Estimation of the rate of change of the angle between himself and the object in his path has several advantages for the driver. First, his judgment very quickly becomes a simple binary one. If the rate of change does not exceed a critical value regardless of sight distance and object location, the driver can predict a collision course. Second, the driver has a physical anchor for speed judgment and one source of error may be minimized. Third, vehicle speed must be taken into account in any steering inputs imposed upon the vehicle.

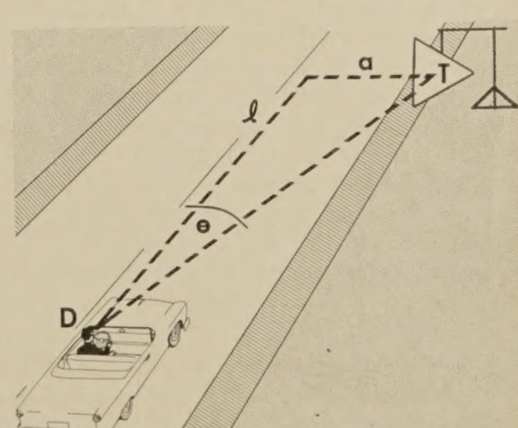

Figure 1.—Geometry of the lateral displacement effect.

[1] Presented at the 42d annual meeting of the Highway Research Board, Washington, D.C., January 1963.

[2] References indicated by italic numbers in parentheses are listed on p. 240.

On the basis of the derivative model a set of hypotheses very different from the angle estimation model may be stated, as: (1) The magnitude of lateral displacement will be directly related to vehicle speed. (2) Lateral displacement will begin at a distance dependent on vehicle speed. (3) The derivative of the visual angle at the point where displacement begins will be independent of speed and object location so long as displacement occurs.

A final consideration that exists in the displacement effect concerns the spatial characteristics of the stimulus object. In the description of both models, it was implicitly assumed that the object was a point in space that served as a simple visual reference. Actually, all practically realized displacing objects have some extension. It would appear reasonable that the nature of the contours of the object would influence the driver's perception of the location of the object. The study of Case et al. (*1*) showed that the size of the object significantly affected displacement.

It might be expected that the angle would be taken to the contour of the object nearest the path of travel. If, however, the shape of the object is of limited extent and has one dominant contour, the driver might be expected to use that as a point of reference; for example, a triangular object having the base oriented perpendicular to the driver's line of vision. It may be expected that when that base is farthest from the roadway (the apex being nearest the travel path), there should be less lateral displacement than when the situation is reversed. Obviously, such an example would be a limited situation for there should be a limit to contour effectiveness if the farthermost border has too great an extent. Within these limits it is reasonable to hypothesize that the dominant figure contours should influence the magnitude of lateral displacement. In the study reported here an equilateral triangle was used to test this hypothesis. In summary, this study was an attempt (1) to isolate the perceptual variables that cause lateral displacement and (2) to discriminate between two alternative models of that process.

Summary

The study reported in this article was made as an attempt to analyze some of the underlying factors that cause the lateral displacement of a vehicle away from a roadside object. The investigation was conducted in daylight and under free field conditions. For several conditions of object location and vehicle speed, the lateral position of the vehicle was measured continuously over a 5,000-foot specially prepared test track.

The findings indicate that lateral displacement is a special case in the field of visual velocity perception. Relative to the observer, the displacing object effectively moves laterally across the retina with a definable angular velocity. Drivers react to this apparent velocity of the object by determining when and how much they should displace on the

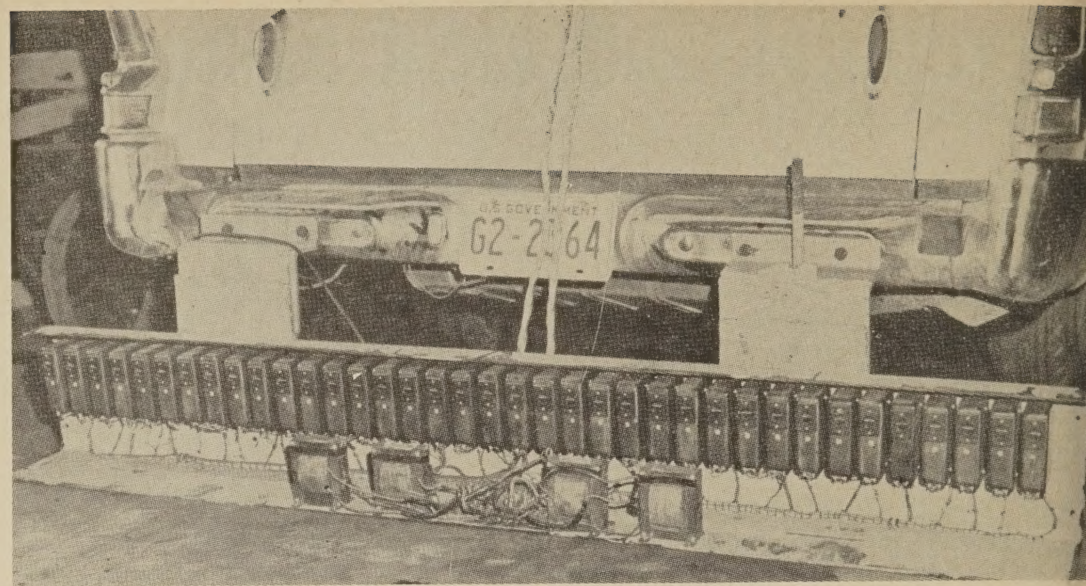

Figure 2.—Lateral displacement detector.

basis of the time and distance at which that velocity exceeds threshold.

The angular velocity model allows an understanding of the effect of the location of roadside objects on highway capacity as well as lateral displacement. In addition, the results suggest that the limitations in driver's judgment of location of objects may markedly increase the probability of certain types of collisions under conditions of low illumination and headlight glare.

Apparatus and Procedure

In order to determine where and when lateral displacement began and its magnitude, it was necessary to devise a method for measuring lateral position continuously. An optical tracking system was developed by Melpar, Inc., for this purpose. It was a housing, anchored on the rear bumper of a vehicle, that contained 37 individual photodetector units mounted to face downward. The detector is shown in figure 2. Each unit contained (1) a light source and lens system to focus the beam on the roadway; and (2) a mirror system that focused light, reflected from a specially prepared road, on a photoresistor. A schematic of the detector unit is shown in figure 3. To get sufficient light reflected to the photoresistor, a 2-inch retroreflective strip was placed on the pavement. With this material, a high proportion of the light from the lamp was reflected into the mirror and hence to the photoresistor.

The photoresistor was connected directly to a transistor amplifier. When the light reflected onto the photoresistor was high, its resistance dropped and sufficient current flowed to close a relay. Thus, whenever one of the detector units passed over the reflective line that detector, and only it, would fire. As the vehicles were moved laterally, a different detector unit was activated. Lateral position could be estimated to the nearest inch as the units were on 2-inch centers. With use of 37 detector units, lateral displacement could be measured over a length of 6 feet.

To record the lateral displacement dat continuously, the digital output of the ampl fier relays was used to switch an appropriat step in a 37-section potentiometer. Th analog voltage was then recorded on a Brus recorder. With this complete system it wa possible to continuously plot the path of vehicle as it traveled down the test track. B leaving 5-foot gaps in the reflective line ever 100 feet, it was possible to determine later placement as a function of distance from th displacing object.

Test track

The test track was a 1-mile section of a j aircraft runway. The concrete runway w 100 feet wide and had an asphalt shoulder feet wide on each side. The runway w made up of four sections of concrete each feet by 20 feet. The maximum vertical curv ture of the test section was less than 0.1 pe cent. A single section nearest the edge of t runway was used. Thus, the travel path w a lane 25 feet wide having limits demarcat by the asphalt shoulder on the driver's rig and the longitudinal joint on his left. T reflective strip was laid in the center of t lane. It was placed so accurately that t deviation from the center was never more th 1 inch over the mile course. The reflecti material was a buff color that was clear visible to the observer. No way was fou to camouflage this line and still retain suf cient retroreflectivity to ensure reliable oper tion of the placement detector. The arrang ment of the test situation is shown in figure

Two identical equilateral triangles, 6 fe on a side, and mounted on a boom, were us as the displacing objects. This boom was feet long, a length sufficient to minimize a effect that the mounting base might have displacement. The boom could be moved or out, and the triangle could be rotated abo its mounting point so that either the base the apex could be placed nearest the path travel. One object was placed 2,000 feet a the other 4,000 feet from the beginning of t course.

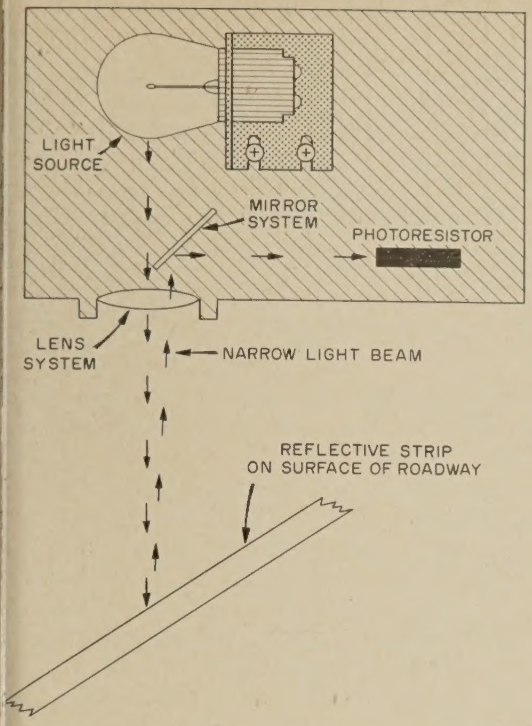

Figure 3.—Photodetector unit.

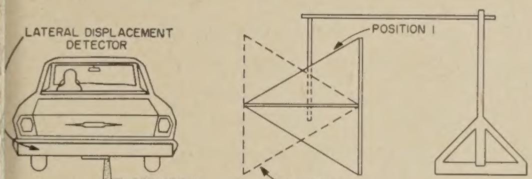

Figure 4.—Road test arrangement.

Four lateral locations for each object were elected. From an analysis of the angle stimation model, the distance at which the angent function began to exhibit an obvious hange in slope was in the order of 200 feet. This model predicts a direct relation between ateral displacement and the size of the angle, ience object location was chosen in units of ingular separation at the distance of 200 feet. The closest location was chosen at this point o subtend an angle of 2 degrees. Three other positions were chosen so that they ubtended angles of 2¼, 2½, and 2¾ degrees, espectively. In lineal distance, the object vas placed 7.0 feet, 7.8 feet, 8.9 feet, and 9.6 eet from the driver. In these experiments, ach object was placed at random in one of hese four locations. The orientation of the riangle also was arranged randomly. Orhogonal latin squares were used for the omplete matrix of test conditions so that any nteractive effects between the two displacing riangles were counterbalanced.

Four vehicle speeds were used—15, 30, 45, and 60 m.p.h. Each test driver was tested at ach speed for all combinations of object ocation and orientation. In total, each driver went through a 4×4×2 factorial design. In addition, the design was replicated four imes.

All the electronic equipment for measuring and recording lateral position, including a 1.5-kv. generator, was installed in a station wagon. A driver and the experimenter were the only occupants of the vehicle. Four assistants to the experimenter adjusted the position and orientation of the displacing objects according to a prearranged schedule. Test drivers were five men whose ages ranged from 25 to 40 years, all were licensed drivers, each having had 5 years or more driving experience. None was told the purpose of the tests. Rather, the drivers were told that the study was aimed at finding out how well each could maintain the vehicle at a constant assigned speed.

Table 1.—Analysis of variance for lateral displacement under 32 experimental conditions

Source of variation	Sum of squares	*d.f.*	Mean square	*F*, ratio
Vehicle speed (v)	2,911.7	3	970.5	[1] 46.88
Object distance (d)	3,658.4	3	1,291.3	[1] 62.38
Object orientation (o)	252.5	1	252.5	[1] 12.20
Driver (D)	9,610.8	4	2,402.7	[1] 116.07
$v \times d$	110.5	9	12.3	------
$v \times o$	135.0	3	45.0	2.13
$v \times D$	2,015.9	12	168.0	[1] 8.12
$d \times o$	240.1	3	80.0	[1] 3.86
$d \times D$	1,979.4	12	164.9	[1] 7.97
$o \times D$	34.9	4	8.7	------
$v \times d \times o$	226.2	9	25.1	1.21
$v \times d \times D$	1,007.2	36	279.8	[1] 13.52
$v \times o \times D$	297.4	12	24.8	------
$d \times o \times D$	637.6	12	53.1	2.06
$v \times d \times o \times D$	796.4	36	22.1	------
Error (within treatments)	9,917.8	480	20.7	------
TOTAL	33,831.8	639	-------	------

[1] Significant with probability less than 0.01.

Table 2.—Analysis of variance for angular change

Source of variation	Sum of squares	*d.f.*	Mean square	*F*, ratio
Between vehicle speeds (v)	17.3	2	8.65	4.62
Between drivers (D)	7.1	4	1.78	----
Interaction: $v \times D$	34.9	8	4.36	2.33
Error (within treatments)	56.2	30	1.87	----
Total	115.5	44	----	----

Results

The maximum lateral displacement was determined for each condition and each driver. These data were subjected to an analysis of variance and the summary is shown in table 1. Differences among the main variables are significant at the 0.01 level. The analysis also shows a significant interaction among these variables.

Figure 5 is a plot of displacement as a function of object location for each of the four speeds; these curves shown include data for the base orientation only. The line shown is the mean displacement for the five subjects. The general form of the curve is the same as that for each individual driver. The straight-line relationship shown is similar to Taragin's data (*2*), but the magnitude of lateral displacement is less. The displacement at each object location increased markedly as speed was increased; this is summarized in figure 6. Again, the four curves are for the base orientation only. The data demonstrate that lateral displacement is directly dependent on travel speed as well as object location.

In the rate of change of angle model, it was hypothesized that lateral displacement would begin at a distance from the object that was directly dependent upon vehicle speed. Figure 7 shows the relation between vehicle speed and the distance at which displacement began. The parameter is the lateral location of the displacing object. The beginning point ranged from approximately 50 feet at 15 m.p.h. to about 275 feet at 60 m.p.h. The data were consistent in showing a significant increase in distance at which displacement started in relation to increase in speed for all four object locations; thus the hypothesis was confirmed.

Test of rate of change of angle

One of the hypotheses derived from the angular change model was that the rate of change of angle at which displacement began would be independent of both object location and vehicle speed. To test this hypothesis, it was necessary to determine the point at which lateral displacement began for each run. This determination was confounded by two factors. First, there was some variability in lateral position for all drivers. Considerable error was possible in judging the start of displacement as it frequently was difficult to determine whether change in position was made in response to the displacing object or was only a random change in position. Second, not all conditions caused a significant displacement and for these conditions no determination of starting distance was possible. This situation occurred when the displacing object was located farthest from the travel path and the test was made at the lowest speed, at 15 m.p.h. In general, lateral displacement occurred reliably for the three highest speeds and the three closest object locations. The distance at which displacement began could reliably be estimated for these conditions. Further analysis was done only on these data. For these combinations of speed and lateral location of the object, the rate of change of angle was determined for each speed and each driver, and an analysis of variance was done on these data; the summary is shown in table 2. As shown, none of the differences were significant. It does seem reasonable to conclude, therefore, that there is a constant rate of change of angle between the driver and the object at the point where displacement is begun.

The final result of this investigation concerns the spatial relations between the contours of the displacing objects. It was hypothesized that displacement would be greater when the base of the triangle was nearest the path of travel than when the apex was so located. The analysis of variance in table 1 shows that there was a significant difference in lateral displacement related to object orientation. In figure 8, displacement is plotted as a function object location for each orientation and for each speed. As may be seen, the difference in displacement related to the base and apex orientation increased with speed of travel and decreased as object

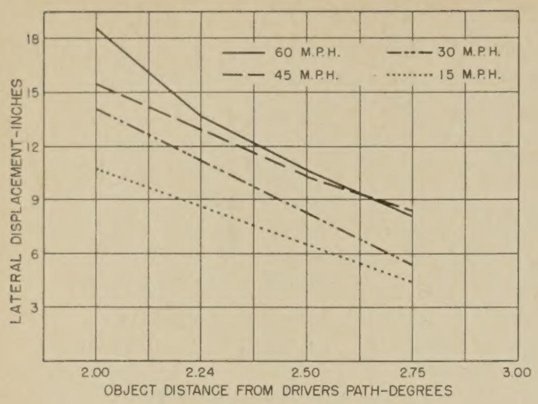

Figure 5.—Lateral displacement as a function of object location at different speeds.

distance increased. Again, the results offered verification for the hypothesis that lateral displacement should be dependent upon the geometric characteristics of the displacing object.

Discussion

The data clearly indicate that a model of lateral displacement based on the rate of change of visual angle best fits the obtained results. The three hypotheses originally specified for this model were validated. Thus, as the model predicts for one hypothesis, a direct relationship between the magnitude of lateral displacement and travel speed was confirmed. A second hypothesis, that lateral displacement would be started at a longitudinal distance functionally related to vehicle speed, was also confirmed by the data. The data for the third hypothesis, that the determining factor in lateral displacement would be constant over all conditions, indicated a strong confirmation.

Threshold for visual velocity

Thus, the study leads to an explanation of lateral displacement that is based upon the driver's ability to detect the rate of change of

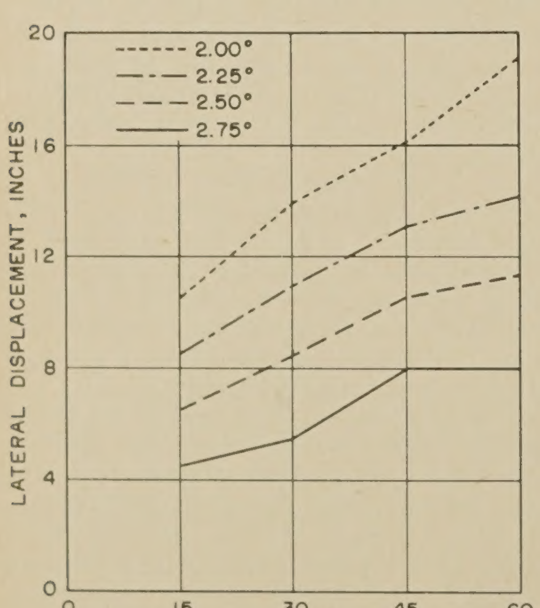

Figure 6.—Lateral displacement as a function of vehicle speed for different object locations.

visual angle of objects near his path of travel. The problem for a driver approaching an object near his path of travel is one, from a perceptual standpoint, in which, phenomenally, the image of the object moves across the retina. This movement is actually a special case in the general field of the visual perception of velocity. The major differences are that (1) the angular velocity of the target in the driving situation is nonlinear, and (2) the visual angle subtended by the object itself increases as the observer approaches.

From this viewpoint, it is worthwhile to compare the angular velocity at which displacement begins with the classical research on the threshold for visual velocity. The work of J. F. Brown (*3*) indicated absolute thresholds in the range of 1.0 to 10.0 minutes of arc per second, and the more recent work by Rock (*4*) indicated an absolute threshold range of 0.2 to 0.5 minute of arc per second when luminance was carefully controlled. In the present experiment the range of angular velocity at the beginning of displacement was from 4 to 40 minutes of arc per second. It is obvious, therefore, that the driver was responding to the presence of an object near his path of travel at a point where its angular velocity approached his absolute threshold.

Within the framework of this model, it is possible to define the process of displacement. If the driver, traveling at a certain speed, increases his fixation distance along the roadway two things occur:

One, the angular velocity of elements in his field of view decreases rapidly. Eventually all elements become subthreshold regardless of their lateral separation.

Two, objects located at increasing lateral separation from the line of sight fall on the eye outside the driver's fovea centralis,[3] which will cause a sharp decrease in sensitivity to velocity. Thus, there exists a visual operating field whose size is determined by a physiological characteristic of the eye and a physical function. This visual operating field is shown in a slightly different way in figure 9. As the driver increases the distance ahead at which he establishes a point of reference, as shown on the abscissa, the lateral distance at which an object must be located in order to generate a detectable velocity increases rapidly. Assuming the visual field is 3 degrees at 60 m.p.h., at a linear distance of 300 feet, objects located laterally more than 16 feet from the driver's path are outside his visual field. Conversely, all objects laterally less than 14 feet from the driver, although within the operating field, have subthreshold angular velocity at this distance. Actually, it is only the lateral locations shown within the hatched area of figure 9 that have a detectable angular velocity at 60 m.p.h. Thus, as a driver approaches an object that is within his visual operating field at 60 m.p.h. at a distance of about 300 linear feet, if there is no detectable component of angular velocity the object will appear to be in his path, and he will begin to displace laterally.

[3] The small area in the eye where form and size discrimination are best.

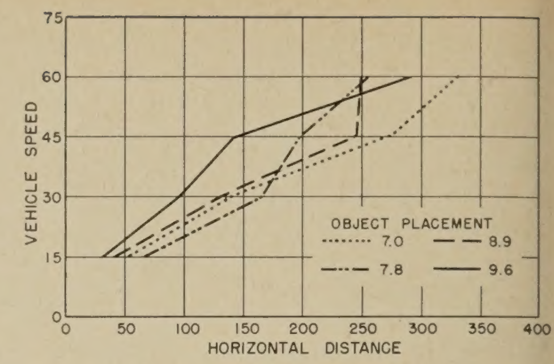

Figure 7.—Effect of speed on distance from object that lateral displacement is started.

The process for detecting lateral position becomes a fairly direct one for the driver. He must adjust his point of fixation to that distance at which there is a sharp decrease in angular velocity for objects at the margins of his visual field. He can determine this point from a variety of cues in the driving environments such as pavement texture, shoulder contrast, etc. As obstructions first enter his visual field, the driver is able to make a simple binary judgment. If the obstruction has a detectable lateral movement it cannot be in his path, and no displacement is necessary. If it has no detectable lateral velocity it is located in his path and hence he begins to displace.

The foregoing considerations indicate that the driver has a very small margin of time and distance within which to operate on objects located laterally along the path of travel. Assuming no restrictions in sight distance, only 3 to 10 seconds are available for the driver's decision as to whether a displacement is necessary and how much is required. By operating near the absolute threshold of angular velocity, the driver not only has a stable reference for detection but also maximum time for object location, as well as maximum time for making compensatory steering responses.

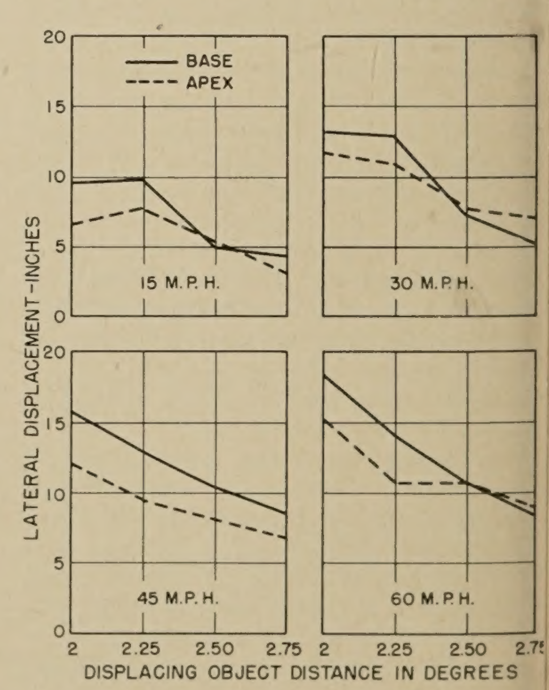

Figure 8.—Lateral displacement for different object orientation for each object distance and for each speed.

It appears reasonable to expect that those factors found from classical research to influence the perception of visual velocity would be applicable to lateral displacement. Thus, the object size may be expected to influence displacement because of the effect of stimulus size on visual velocity (*3*). This factor of size as it affects lateral displacement has been studied by Case et al. (*1*). They found that there was a significant effect on the displacement starting point and also the magnitude of the displacement as a function of the displacing object's size.

It may also be expected that the shape of the stimulus will influence the visual perception of velocity. The results of this study demonstrated that there was a significant reduction in lateral displacement, approximately 15 percent, when the apex of the triangle was oriented toward the driver's path of travel. Phenomenally, of course, these results imply that the apex-oriented object has a higher visual velocity than does the base-oriented one. The higher the speed of travel the less will be displacement as displacement occurs in relationship to perceived velocity of the displacing object in this model.

Effect of shape

The effect of shape has been studied by Motokawa (*5*) by means of electrical stimulation of the eye. His findings bear directly upon the effects on lateral displacement found in this investigation relative to the triangular displacing object orientation. His work suggests that the physiological correlate of visual velocity is the amount of suppression of retinal response exerted on the retinal pathway through which the image of the moving object has passed. This concept, called retrograde suppression, can account for most of the perceptual results in the study of visual velocity. Thus, Motokawa suggests that as a moving stimulus passes across the retina, a field is generated about the object that suppresses activity in the area removed from the immediate vicinity of the stimulus itself. Thus, as a stimulus moves across the retina it generates retinal activity as it proceeds and acts to extinguish or neutralize the retinal activity in the path through which it has already passed. Hence, the lower the velocity the more intense the stimulus, or the larger the object the greater will be the degree of retinal suppression, both causing a perception of lower angular velocity. In essence, the strength of the suppressing stimulus is the correlate of the perception of velocity.

The intensity of the suppression is also related to the nature of the contours of the stimulus. Other experimentation by Motokawa (*6*) has shown that the strength of the field about an object is determined by the contours of that figure as well as its size and brightness. For a triangle, as used in the displacement study reported here, the field of activity is at a minimum at the intersection of the figure contours. Consequently, the strength of the field that acts as a suppressor on trace activity in the retina is at a minimum. The perceived velocity of the figure will be at a maximum when the apex of triangle is oriented to path of travel. It is, then, on the basis of the differences in fields of suppression that the reduction in lateral displacement obtained in this study can be explained when the apex is oriented closest to the driver's path of travel.

APPLICATIONS

Placement of Objects

In the light of this study, it is instructive to examine current practices relative to the location of signs and abutments near the roadway. The *AASHO Manual for Signing and Pavement Marking of the National System of Interstate and Defense Highways, 1961*, requires that no object be placed nearer than 6 feet to the travel lane. At this separation, as may be seen in figure 9, an object will have a detectable angular velocity depending on the driver's visual threshold for distances up to 300 feet ahead of a driver traveling at 60 m.p.h. As the driver's reference distance at this speed is slightly less than 300 feet, such a standard ensures that all objects will have a suprathreshold velocity and hence the driver will locate them outside his travel path. Consequently there will be no displacement.

It is also obvious that this standard is applicable only to highways on which the travel speed averages 60 m.p.h. At higher speeds a greater separation would be required, and at lower speeds a closer spacing may be tolerated. As a matter of fact, the data from this study allow the determination of minimum placement of roadside objects for any desired travel speed. The curve in figure 10 shows this relation for a 12-foot lane and indicates that the minimum lateral location to eliminate displacement increases continuously as travel speed increases. It is also obvious that at low speeds objects actually encroaching a 12-foot travel lane may be tolerated by the driver without his making a lateral displacement.

Every attempt was made to obtain a maximum lateral displacement in the design of this study. It was initially anticipated that the magnitude of displacement in this study would exceed that obtained by Case et al. (*3*) or Taragin (*4*) because an effective 25-foot lane width was employed and no other obstacles were in the driver's path. This prediction was not borne out in the study. Actually, the magnitudes of displacement were a half to a third less than reported in the other field studies. Two reasons may account for this unexpected result. One is in the nature of the displacing objects and the other is the factors affecting the driver's ability to judge his line of travel.

In this study the absolute size of the object was 15 square feet; this object was considerably smaller than the displacing objects used by Case et al. (*3*), which had minimum and maximum sizes of 28 and 64 square feet, respectively. In Taragin's study (*4*) two of the objects were considerably larger than the triangles used in this experiment. In terms of the model of displacement proposed in this article, it would be expected that the apparent velocity of the displacing object will be greater for the smaller object and hence appear farther from the driver's path of travel.

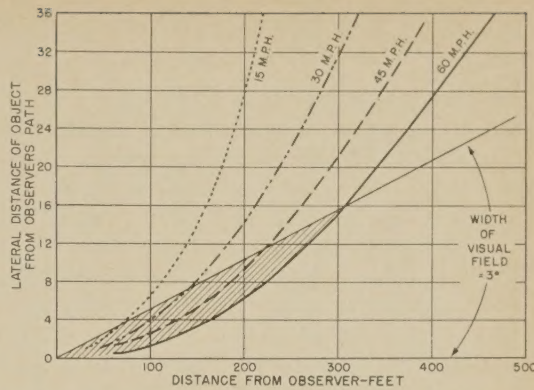

Figure 9.—Visual velocity threshold contours at four speeds.

In relation to the factors influencing the driver's ability to judge his line of travel accurately, in this study the reflective strip that was placed on the pavement to measure lateral position was clearly visible to the driver. All five drivers appeared to orient themselves relative to this marking so that it was nearly centered under the vehicle. The striping apparently served as a direct reference by which the driver could define his path of travel. By having a stable reference at which the driver may fixate, the detection of movement of an object near his projected path should be improved. With no such reference for fixation, the driver's line of vision may be expected to vary laterally. This should reduce the accuracy of his estimation of the apparent velocity of the object and hence add ambiguity about the judgment of object location. It seems reasonable that such uncertainty would amplify a driver's response to the displacing object, and the result would be a greater magnitude of displacement. If this explanation is valid, it should be possible to reduce the magnitude of lateral displacement in a field situation by providing a tracking reference line for the driver. A test of such an hypothesis is currently underway at the Bureau of Public Roads.

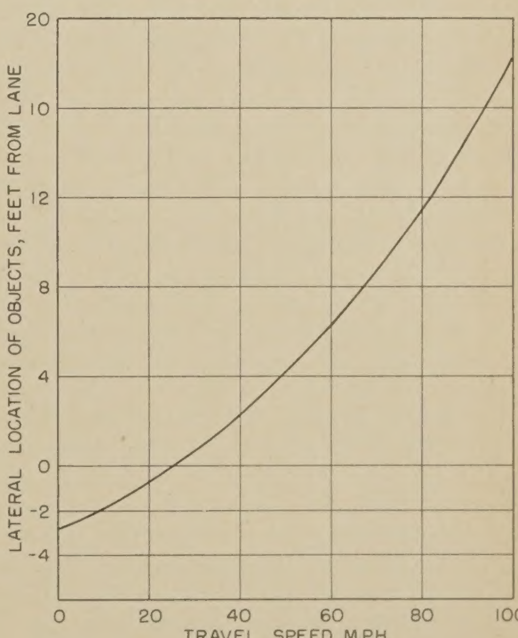

Figure 10.—Nearest placement of roadside objects that causes no lateral displacement.

Speed Control

From this study, it is clear that a driver can exercise control over the magnitude of his lateral displacements by reducing vehicle speed. Conversely, it should be possible to cause a speed reduction by strategically placing objects relative to a travel path within which the driver has little freedom to displace. Such situations occur in construction areas and special channelization situations. From the data presented here it is possible to develop a relation between lateral location of objects near the path of travel and the travel speed through the section.

Three conditions must be met in order to control speed in this fashion. First, there must be no possibility of shifting from the travel lane. Second, a desired terminal speed must be selected. Third, a maximum acceptable deceleration must be specified. The last two determine the length of the speed transition zone. For example, if the input speed is 50 m.p.h. and it is desired to reduce speed to 15 m.p.h. and have deceleration not to exceed 1 m.p.h. per second, then approximately a 1,100-foot transition section must be used. Given these three conditions it is possible to use the two curves shown in figure 11 to determine the lateral location of the objects (curve 1) and their separation from one another (curve 2).

The use of these curves may be shown by an example. Suppose that travel speed approaching a construction zone is 50 m.p.h. and that it is desired to reduce the speed of approaching traffic in a 12-foot lane to 15 m.p.h. and have a deceleration not to exceed 2 m.p.h. per second. Assuming an initial sight distance greater than 500 feet, a cone would be placed relative to the lane so that the driver would decrease his speed over this 500 feet to 40 m.p.h. Curve 1 in figure 11 specifies this placement relative to the driver at approximately 11 feet. Assuming the approaching vehicle is located in the left of the lane, then the cone should be placed 1 foot in from the edge of the lane. The next cone should be located at a distance from the first as determined from curve 2, also for 40 m.p.h. This requires that the second cone be placed 180 feet beyond the first and one-half foot from the edge of the lane. In order to cause a speed reduction to 30 m.p.h., a third cone should be placed 3½ feet from the edge of the lane, 140 feet from the second cone, this should then be repeated and a fourth cone placed 140 feet beyond. To reduce speed to 20 m.p.h. the lateral position for the next cone, determined from curve 1, should be 6 feet from the driver or 4½ feet in from the edge of the lane. The fifth cone should be placed, as shown in curve 2, 85 feet beyond the fourth cone. A sixth cone repeats the spacing for the fifth cone 85 feet beyond the fifth. Finally to reduce speed to 15 m.p.h., a seventh cone should be placed 5½ feet in from the edge of the lane 70 feet beyond the sixth cone.

Thus, by using a minimum of seven cones placed as described, a smooth reduction of speed can be brought about as a natural consequence of the placement of objects in the travel lane. Obviously, more cones could be used, being placed according to the relation with speed shown in curve 1 of figure 11. This approach to traffic speed control would offer several advantages over existing techniques if it actually holds in the field situation. It would allow a specific definition and prediction of the speed of traffic and would ensure a smooth speed transition. It may also permit a far more reliable means of control than can possibly be obtained with construction signing. Hence, this approach could lead to safer traffic movement through a hazardous area.

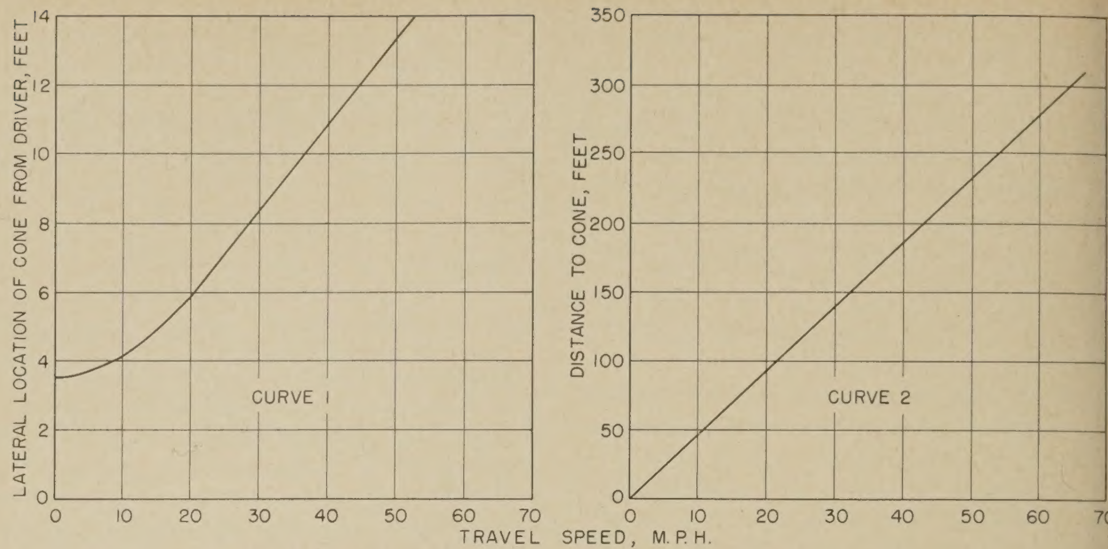

Figure 11.—Placement and spacing functions of objects for speed reduction.

Effect of Truck Width on Traffic

The effect of vehicle width on traffic has received considerable discussion. One aspect concerns the influence of trucks on traffic and safety. The problem essentially is one of definition of how the size of a vehicle influences traffic, if it does. One criterion of influence that may be used is: When two vehicles approach, neither shall by its presence in its own lane cause the other to change its placement in its lane. Such a criterion has three advantages: (1) Forced changes in placement of a stream of traffic may be expected to cause turbulence in flow and hence affect the efficiency of traffic movement. (2) A shift in placement forced on a driver implies that the driver predicted himself on a collision course. This may be perceived by such a driver as an unsafe situation. (3) It is possible to operationally define such a criterion.

Using this criterion, the problem basically is a variation of the lateral displacement effect. It may be treated as if one vehicle were a fixed object on the driver's left and the other vehicle were overtaking at a velocity (v) equal to the sum of the two speeds. Any lateral shift under these conditions will be caused by the driver's perception that the angular velocity of the oncoming vehicle is below threshold. From the data in this study, the factor influencing this perception is the speed of the affected vehicle, which determines the length of the driver's field of view. Thus, to calculate the influence of a vehicle *B* on another vehicle *A*, it is necessary to determine whether the angular velocity for driver of *A* exceeds the threshold for the particular conditions of v_A, v_A+v_B, and lateral separation. By using the threshold value for angular velocity developed in this study, it is possible to derive the relation between lateral separation of the two vehicles and the combined velocity v_A+v_B for different values of v_A. This is shown in figure 12. In this set of curves, the ordinate is the lateral separation, the abscissa is the combined speed, and the parameter is the speed of the influenced vehicle, v_A. For each curve, all points lying to the right of each v_A curve generate a supra-threshold angular velocity and hence will not cause a displacement.

Example

As an example, assume a lateral separation equal to 4 feet, and v_A equal to 60 m.p.h. At what combined speed, v_A+v_B, will there be no influence of *B* on *A?* Using the 60 m.p.h. curve, find the point at which lateral separation of 4 feet intersects this speed curve. From the abscissa, the combined speeds ($v_{AB}+v_B$) required to generate a supra-threshold velocity is 184 feet per second (f.p.s.). As v_A is known to be 88 f.p.s., v_B must be 96 f.p.s. In other words, the speed of the influencing vehicle, *B*, must be 64 m.p.h. or more if vehicle *B* is *not* to influence vehicle *A*. Conversely if v_B is actually less than 64 m.p.h., *B* will not generate a threshold angular velocity, hence vehicle *B* will be perceived in the path of the approaching driver *A* who will displace to the right.

From data on vehicle placement as a function of lane width (*7*), it is possible to specify the conditions that exist on a highway when one vehicle overtakes another. The data show that 90 percent of the time, separations from trucks that are 96 inches wide will be no less than 4 feet. For trucks 102 inches wide, it may be expected that separations would be no less than 3.5 feet. If the 85th centile speed on 2-lane rural highways is about 60 m.p.h., it is possible to determine the effect of these two different truck widths on opposing traffic on roads of different lane widths. This is shown in figure 13. It

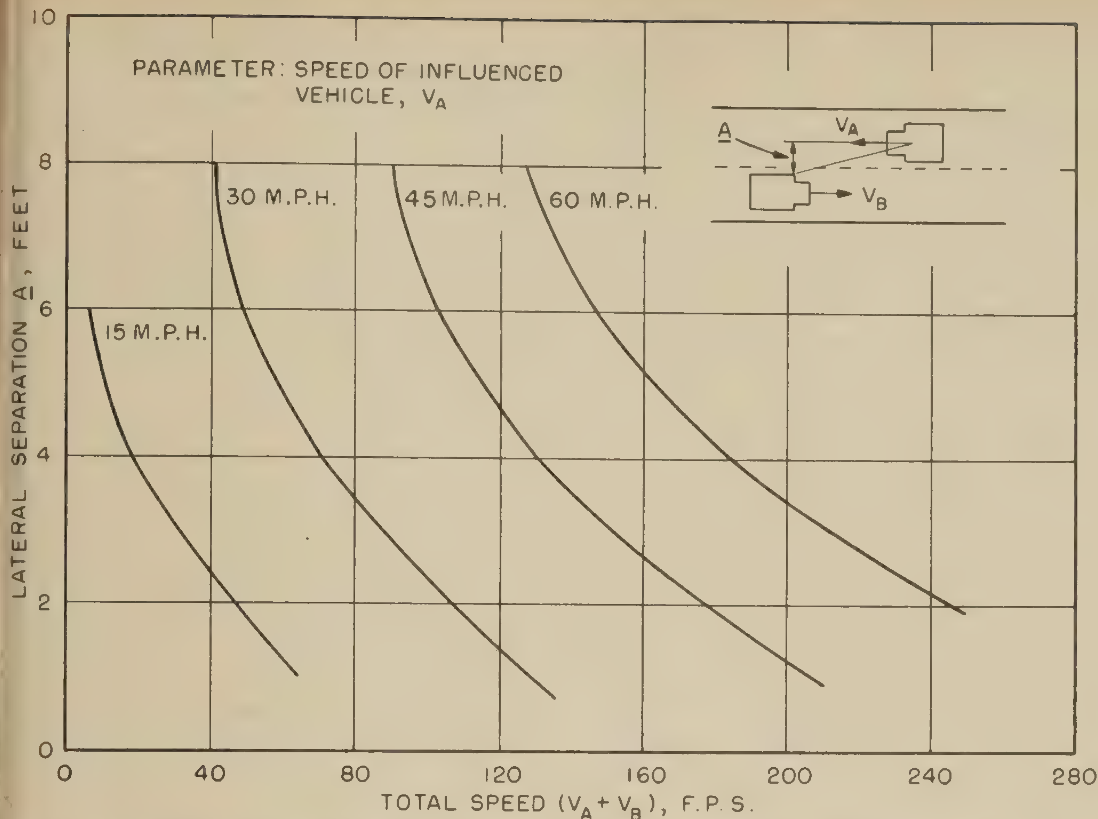

Figure 12.—Lateral separation and speed functions that influence approaching vehicles.

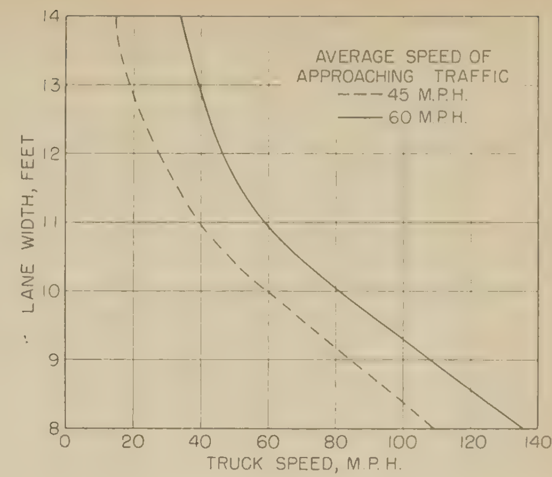

Figure 13.—Minimum speed of a 96-inch wide truck that has no influence on approaching vehicles as a function of lane width.

may be seen that with a 12-foot lane width the 96-inch wide vehicle must, at the 4-foot separation, be traveling at a speed in excess of 64 m.p.h. if it is not to influence opposing traffic. For the 102-inch wide truck, its speed must exceed 74 m.p.h. at the 3½-foot separation to ensure no displacement effect on the opposing traffic. From figure 13, it is possible to determine these relationships for any combination of speed and lane width.

The two factors of speed and lane width in relation to width of truck are the main influences on magnitude of displacement. Influence on traffic varies inversely with the speed of the truck and directly with the speed of the approaching vehicle. In general, truck speeds on main rural highways are significantly lower than that of passenger cars. At higher speeds of the approaching vehicles, truck speed must be nearly the same or higher to avoid causing displacement of the oncoming vehicles. The less the initial separation the greater must be the truck speed. Although truck speeds have increased, keeping pace with increased passenger car speed, it is apparent that as the speed trend of passenger cars increases, a constant difference in speed between the truck and passenger-car will cause ever-increasing displacement of the passenger car approaching the truck. Increased truck width will markedly increase this cross-stream effect and to an ever greater extent as traffic speed rises.

The second aspect is related to lane width. Lane width is one determinant of placement and hence a determinant of lateral separation between opposing streams of traffic. The narrower the lane, the greater must be the cross-stream displacing effects. This may be seen in figure 13. Here the mean placement of the opposing streams in their lanes is used. For example, on a 10-foot lane, a 96-inch truck would have to travel 81 m.p.h. to ensure no displacement, and a 102-inch truck would have to travel at 94 m.p.h. when the approaching cars have an average traffic speed of 60 m.p.h. At a 45 m.p.h. average speed for approaching cars, the speeds of the 96-inch and 102-inch trucks must be 59 and 71 m.p.h., respectively. Thus, small changes in lane width or truck width generate large changes in cross-traffic effects.

This analysis has not considered several variables that can influence the effects of truck width, such as the sight distance, other traffic, or pavement markings. The last of these especially should act to reduce these cross-stream effects. Pavement markings provide a significant additional cue to the driver for locating opposing traffic. Indeed, a center line marking allows a driver to use an additional perceptual process for judgment of position. He now has available a basis for employing visual acuity or, more specifically, minimum separable acuity for making judgments of position. If the driver can detect a gap between the pavement marking and the nearest contour of the truck, then he knows that the truck cannot be in his path. This cue, of course, may be at variance with the angular velocity cue and what a driver does may depend on the magnitude of the disparity between the two. However, it may be expected that, in general, the added cue of pavement markings will reduce cross-stream effects. This will be tested in future research.

The Effects on Lane Capacity of Shoulder Objects

It is well known that an object located near a travel lane will reduce lane capacity. An understanding of why this happens may be had from the lateral displacement effect shown in the study reported here. As a driver approaches a fixed object he is detecting its location at the farthest point in his visual field at which he can detect angular velocity. The distance at which such detection is made and the magnitude of the displacement are directly dependent on travel speed. If a driver is in a line of traffic traveling at 30–40 m.p.h. and traffic is also approaching, one way he can reduce the magnitude of displacement from a shoulder object is to reduce his speed. A slight reduction in speed will not only give him more time for locating a shoulder object but also will minimize the magnitude of displacement. However, at or near lane capacity, slight reductions of speed must reduce the lane capacity.

In addition, at lane capacity, the headways maintained will cause a leading vehicle to limit the forward view of a following driver. This will markedly influence the angular velocity of shoulder objects as they become visible for they will enter a driver's field of vision at a closer distance than in free flow. If a driver detects the presence of a shoulder object before he can detect its location—as will normally be the case—he may be expected to adopt a greater headway in order to improve his detection of location. This increase in headway will obviously begin considerably before the actual location of the shoulder object. Under these conditions, headways will increase and lane capacities measured at the object will be lower than they would be if there were no object. The presence of a shoulder object will markedly affect the speed-spacing relationships in a queue of traffic and will be most evident at or near lane capacity where displacement must be limited because of traffic in adjacent lanes. To maintain adequate control, the driver is forced to compromise in speed and/or headway. This should lead to a reduction in capacity when the highway is operating at or near capacity. If the changes in speed or headways in a queue are to be detected, measurement of these variables must be made considerably in advance of the object causing them, where will depend upon the visibility of the obstructing object.

Night Visibility and Collision Avoidance

This investigation also has relevance for the more general problem of the visibility of stationary objects on or near the highway. This problem, especially acute at night, has received considerable attention in the safety field for many years. In general, it has been conceived primarily as a problem in object detection. From the results obtained in this study, it would seem reasonable that not only the detection of an object is important but also the ability of the driver to locate that object relative to the path of travel. For, even if the driver detects the object, it is also necessary to ascertain whether it is in or near his path of travel. Obviously, the brightness of the object or its contrast with its surroundings, its size, and its shape, and fundamental factors in this dynamic localizing process. In this context, two classes of collision situations may be considered: collisions with a fixed object and head-on collisions.

In approaching a fixed object in or near the travel lane, a driver is faced with two problems. One is the detection of presence of an obstruction and the other is the detection of its location. The former problem has been studied and many of the determinants of visibility have been defined. It would appear that visibility (detection of the presence of an object in a driver's path) alone cannot account for the frequency of collisions with fixed objects. Only under extreme operating conditions will visibility be so compromised that collisions will occur because drivers do not see an object.

On the other hand, many of the factors that influence visibility also influence localization. These factors of size, shape, contrast, and brightness have as much of an effect on detection of angular velocity as they do on visibility. Thus, for example, from Blackwell's data (*8*) an object 6 feet wide having a contrast with its surroundings of 0.010 at an adapting brightness of 0.1 footlambert would be detected at about 800 feet from the observer. From the data collected in the study reported here, the driver cannot make localization detection at distances much beyond 300 feet for speeds under 60 m.p.h. Hence, it would seem far more reasonable to look at errors in location as a basis for fixed object collisions.

Because of the limitations in localization detection, one obvious prediction is that collisions with fixed objects should increase more than other types of accidents from day to night driving. Data from accidents on main rural highways indicate that the total accident rate doubles from day to night, but the rate for collisions with fixed objects more than triples. It is also predictable that the probability of such collision should rise as the effective size of a fixed object decreases. In this context, effective size refers to the area of an object that is continuously above the threshold of visibility for the approaching driver. This relation would exist because the apparent angular velocity of an object decreases with increasing size. Hence, the smaller the size of the object the greater is its apparent velocity. In terms of localization, this could mean that smaller objects more likely would be located outside the driver's path of travel than would larger ones, all other things being equal. It is reasonable to predict on this basis that highway lighting may reduce collisions with shoulder objects but not those occurring within the traffic stream.

Effective size can obviously be translated into other dimensions of the visual stimulus and the same sort of relations predicted. Thus the brightness of the object or its contrast with its surroundings will all effect localization in expected directions. Glare, which reduces the contrast, will also markedly raise localization thesholds.

Examination of the factors influencing collisions with fixed objects indicates that this problem involves far more than simple detection of the presence of an object. Although accident reports on this type of collision frequently quote the driver as not seeing the object, it would appear that these reports more usually refer to a driver's not seeing the object's position relative to his path of travel. It is apparent, therefore, that any thorough analysis of this problem must be concerned not only with absolute visibility but also with the accuracy of roadside object location and the driver's ability to locate himself in his path of travel.

The problem of head-on collisions may also be viewed within the context of the localization problem. Here the problem for the driver is to locate an approaching vehicle relative to his path of travel. The same factors determining displacement relative to truck size apply here. The conditions are far more severe at night, however, than in daylight for many of the cues present in daytime are eliminated at night. Thus cues to vehicle size are almost completely missing because of headlight glare. The localization cues using pavement markings also are almost eliminated. Thus, at night, a driver must localize approaching vehicles on the basis of the angular velocity contributed by the headlights. In effect, a driver has only a dominating glare source to use as a cue to localization.

Localization judgments are made at distances under about 300 feet. At these distances normal separations between approaching vehicles is 1.6 degrees. On low beams, the effective intensity at an approaching driver's eye is of the order of 17,000 footlamberts. The size of the source is 5 inches. Thus, the approaching driver is faced with an extremely bright source of extremely small size. The two complement to generate a high apparent angular velocity. To the approaching driver this implies a large separation between himself and the vehicle he's approaching.

In addition, the glare from the approaching headlights sharply reduces the cues available to the driver for locating himself in his own lane. Consequently, in the approaching situation, conditions are conducive for a driver making maximum errors in locating an approaching vehicle relative to his own path of travel, which should increase the probability of head-on collisions. Accident data from main rural highways do, in fact, indicate that the rate for this type of collision rises more at night than does any other type of collision, except those with fixed objects. Thus, where the rates for angle and rear-end collisions increase about one-half from day to night, head-on collision rates rise 2.5 times. In part, at least, this increase may be attributed to the degradation in localization detection because of the extreme conditions existing in these approaching situations.

One advantage of medians becomes readily apparent from these considerations. Medians effectively eliminate the entire problem of the location of approaching vehicles. From the data in this study, medians of only 5 to 10 feet are needed. However, in darkness, the higher figure will minimize not only errors in detection of location but will also leave some brightness contrast in the median area. That is, there will amost always be some detectable contrast between pavement and median that will improve localization for the driver. It is also obvious that the effects of a wide grass median may be obtained with a fence or glare screen and a narrow separation between opposing lanes. From the standpoint of localization detection, any object such as this will function as an interposition cue that will almost completely eliminate any uncertainty as to location of an approaching vehicle. Thus, either wide grass median or a divider providing an unambiguous cue to separation may be used to prevent localization errors. From the drivers' standpoint either would be effective.

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The Automobile in American Daily Life

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Data pertinent to the ownership and use of the automobile in daily life in America have been compiled from several motor-vehicle-use studies and summarized and analyzed in this article. State motor-vehicle-use studies, a Nationwide Automobile-Use Study conducted by the Bureau of the Census for the Bureau of Public Roads, and other Census and Public Roads statistical studies provided the source material for this article. The analysis presented here is expected to be useful to highway planners in assuring that future highway construction will be adequate for the area to be served.

Although all States did not participate in the motor-vehicle-use studies, the characteristic factors of automobile ownership and use presented in this article may be considered representative of all sections of the United States. This was substantiated by comparison of the results from the State studies with the findings obtained in the national study conducted by the Bureau of the Census. However, when detailed pertinent local information on the characteristics of ownership and use of automobiles and travel is needed to supplement other planning and research work, the basic data must come from a State study such as the motor-vehicle-use study.

Introduction

THE PRIMARY purpose of this article is to present summary data on the characteristics of ownership and use of automobiles [1] based on the findings of a number of studies. Data on ownership and use from studies in 18 States have been added to the results reported in *Motor-Vehicle-Use Studies in Six States* (*1*).[2] Complete reports are not available from all the more recent studies, but sufficient data have been obtained to permit expansion and updating material in the earlier report.

In addition to the State motor-vehicle-use studies, the Bureau of the Census under contract with the Bureau of Public Roads has collected national data on some characteristics of automobile use. These data have been correlated with economic data that Census collects, such as that for income and composition of families.

Information is presented here on distribution of automobile ownership by occupational groups, distribution of drivers by age and sex, mode of travel used for home-to-work trips, and purpose of travel. Data are also presented on automobile ownership by income group and by purpose of travel for each trip for each day of the week. Some comparisons have been made between the data provided in the motor-vehicle-use studies conducted by most of the State highway departments at different times between 1935 and 1940 and the studies conducted since 1951.

Background

No great battery of classified data need be marshaled to support the conclusion that the automobile, no less than the motortruck, has been a dominant shaper of the American way of life. The extent of dependence on the automobile has long been recognized by the Bureau of Public Roads and others; it was stated as long ago as 1949 by Wilfred Owen (*2*) in introducing his study of automotive transportation. He said in part:

"Automotive transportation is the most extensive medium of passenger movement in the United States, dwarfing all other agencies of transport combined. . . . The importance of passenger car transportation in the family budget is . . . indicated by the fact that after food, housing, and clothing, automobile transportation outlays are fourth in order of magnitude among consumer expenditures. . . .

"The effects of the automotive age on the average American may be seen in the location of his home and his work, his occupation, his recreation, and in the enlarging radius of his social and business activities. . . . Today it is difficult to visualize the American economy before the advent of the motor vehicle, so completely has the Nation become geared to the workings of internal combustion.

"There is indication that the far-reaching effects of the motor vehicle on our industry and living habits have only begun to be felt."

The growth and influence of the use of private automobiles has been almost entirely a 20th-century phenomenon, the automobiles registered at the beginning of the century numbered a mere 8,000. In 25 years the number registered had risen to 17 million, in 50 years the number increased to 40 million (*3*), and by 1961 registered automobiles numbered more than 63 million (*4*). The number of registered automobiles is expected to continue to increase and by 1966 total an estimated 75 million and by 1976 reach an estimated 95 million (*5*). In 1961 more than 89 million operator licenses were estimated to be in force (*6*). The advent of the automobile has greatly enlarged the area within which people can live and work. For people who lived 3 miles from the heart of the city in 1890, from 30 to 45 minutes was required to get downtown by a streetcar. The competition between the public transportation systems and private automobiles was noticeable by 1920. People had found that they could live farther from their places of employment and get to work by automobile, even over unpaved roads, in 10 to 15 minutes (*7*). Thus a chain of circumstances was set in motion that has had and continues to have great economic and social implications. One of the more recent effects is the number of outlying shopping areas and medical centers that have been developed to service people living from a few miles to 15 or 20 miles from the central business districts. The evidence suggests that people living in outlying areas are willing to travel farther to get to their places of work than to get to shopping and service areas.

The resultant influx of automobiles into the downtown business areas from the mass home-to-work movement of workers has created problems. State and local governments have been faced with the necessity of building urban expressways. At the same time provisions for parking have been necessary; parking lots and parking meters have been established throughout most business districts.

Data from the motor-vehicle-use studies of 21 States show that 53.7 percent of gainfully employed persons requiring transportation to work drove their automobiles and 14.8 percent were passengers; thus 68.5 percent of this group traveled to work in automobiles. According to table 94 (*8*), "Means of Transportation to Work of Workers During the Census Week, for the United States, Urban and Rural: 1960," automobiles were used for transportation to place of employment by 69 percent of the workers.

State motor-vehicle-use studies

Recognizing the need for up-to-date information on the characteristics of ownership

[1] The terms "automobile" and "passenger car" are used synonymously in this article.

[2] References indicated by italic numbers in parentheses are listed on p. 255.

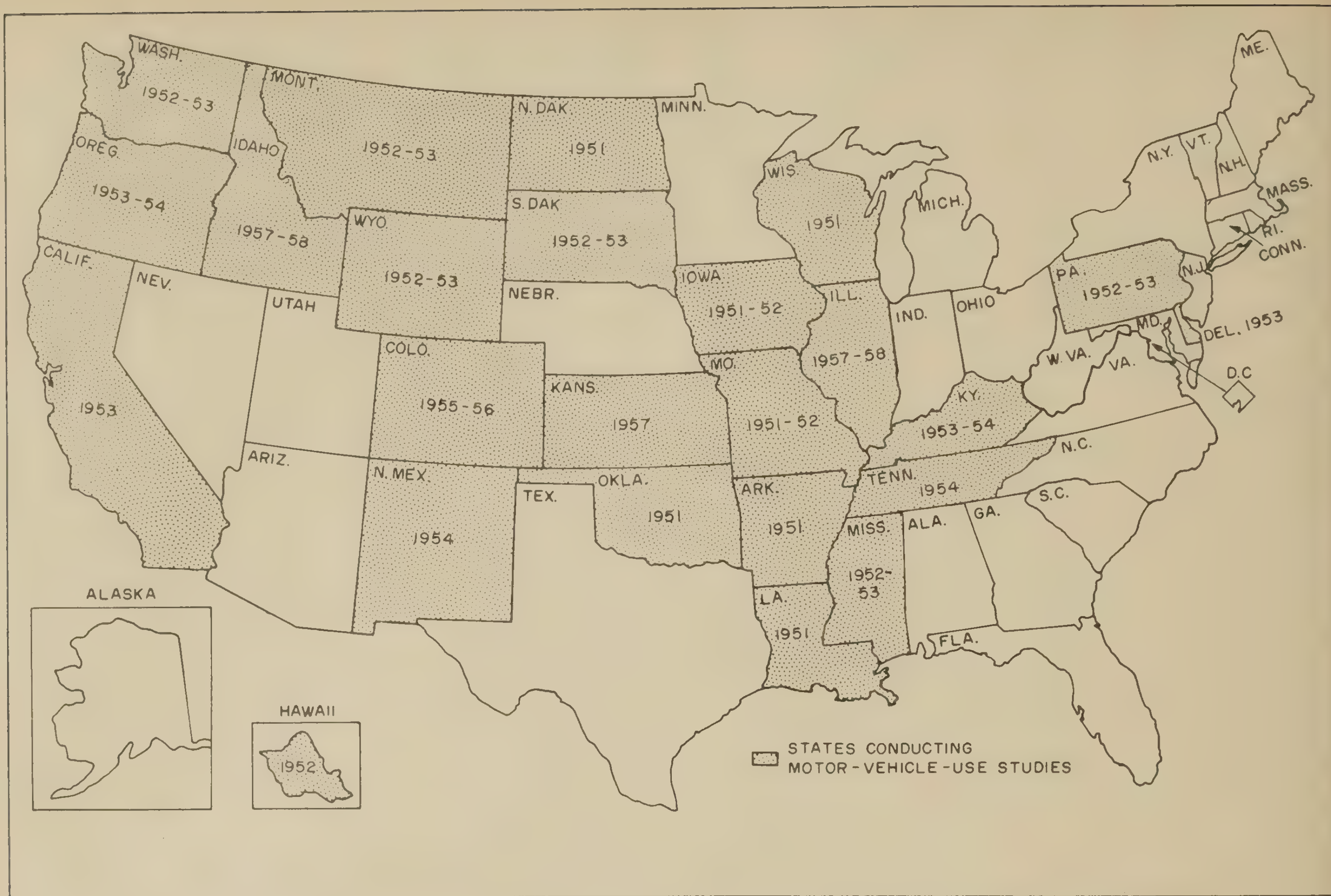

Figure 1.—States participating in the motor-vehicle-use studies and year of study.

and travel by automobiles and trucks, 24 State highway departments in cooperation with the Bureau of Public Roads have conducted State motor-vehicle-use studies. These studies, made at different times between 1951 and 1958, were designed to provide information, not available from regular traffic count surveys, about the characteristics of ownership and use of motor-vehicles, trip-length distributions, occupational groupings of members of households, mode of transportation used for home-to-work trips, purpose of travel, and age and sex of motor-vehicle operators. Data from similar studies conducted by most State highway departments between 1935 and 1940 have permitted historical comparisons to be made by State for the distribution of data on travel for business and pleasure.

Nationwide automobile-use study

In the fall of 1959 and the spring of 1961, the Bureau of the Census, under contract with Public Roads, collected data on a national basis on characteristics of ownership and use of automobiles. Because the Bureau of the Census surveyed the same households (approximately 4,000) from which other economic data had been obtained, the automobile information collected for Public Roads could be correlated with economic information on family income and age composition of the households.

Applications of Data

The results of the 24 State studies and the national study have been used for many different purposes at all levels of government. At the national level, the basic data available from these studies have been used by congressional committees studying highway legislative affairs, by civil defense planning officials, by national and regional planning officials, and by other government agencies. State, city, and county planning agencies have used the travel data on the different highway systems to enable administrators to plan for the future demands for highway transportation. State legislative committees have adapted the motor-vehicle-use data for use in determination of the equity of the present tax structure and proposed revisions. These data have also proved to be useful in developing mathematical models for forecasting traffic.

Information on the distribution of travel by purpose and trip-length groupings and travel on the different highway systems by rural and urban residents is also useful to research and trade associations. These data are used by industry and marketing researc staffs of the automotive, fuel, and tire manu facturing groups for estimating the needs fo highway services.

Summary

Some of the principal findings from con sideration of data obtained in the Stat studies and Census survey are summarized i the following paragraphs.

Distribution of automobiles

Automobile ownership by occupied dwellin unit was reported in both the State motor vehicle-use studies and the Census survey Automobiles were reported for occupants o more than 80 percent of the dwelling units i unincorporated places, about 60 percent o those in incorporated places having a popula tion of 100,000 or more, and 75 percent o those in incorporated places having popula tions of less than 25,000. The relation betwee automobile ownership and family income wa a feature of the Census survey conducted i the spring of 1961. Of the families havin an annual income of more than $5,000, 9 percent or more reported owning automobiles When the annual income was less than $2,00 fewer than 40 percent of the families ha automobiles.

Motor-vehicle operators

According to the State motor-vehicle-use studies, about four-fifths of all males and two-fifths of all females of driving age were licensed operators, and more than two-thirds of all persons between the ages of 21 and 50 were licensed operators. About 90 percent of all males and slightly more than 53 percent of all females between the ages of 21 and 39 were licensed operators, and 68 percent of all males and 20 percent of all females between the ages of 60 and 69 were licensed operators.

Travel to and from work

The automobile was the principal means of transportation to and from work according to data collected in the State studies. Two out of every three workers traveled to work in automobiles and one in seven workers was a passenger in an automobile. Fifteen percent of all workers used public transportation and 12 percent walked to work. Among different occupational groups, 40 percent of the personal service workers and almost 80 percent of the craftsmen and skilled laborers traveled to work by automobile. One-half of all workers living less than 1 mile from their place of employment walked to work. Eleven percent of those living from 1 to 2 miles from work also walked. More than 70 percent of the workers living from 1 to 5 miles from work traveled by private automobile.

Use characteristics for passenger cars

The number of trips and vehicle-miles of travel reported in the State motor-vehicle-use studies are discussed in the following paragraphs.

Forty-six percent of all trips and 44 percent of all miles traveled in passenger cars were related to earning a living. For residents of incorporated places, a higher proportion of passenger-car trips and total miles of travel was for trips related to earning a living than the proportion for residents in unincorporated areas.

Trips for family business accounted for 29 percent of all trips and 19 percent of all travel; 18 percent of all trips and 34 percent of all travel was for social and recreational purposes. The average length of one-way trips for all purposes was 8 miles; the range in length among the different purposes was from 4.1 miles for educational, civic, and religious purposes to 6.4 miles for work trips and to 296 miles for vacations.

The average occupancy rate for all trips was 1.7 persons per trip. Average occupancy per trip for different purposes was: 1.3 for trips related to earning a living, 1.9 for trips for family business, and 2.4 for trips for educational, civic, religious, social, and recreational activities. Principal operators of the automobiles were responsible for 88 percent of all vehicle-miles traveled and 86 percent of all trips. Housewives drove for 10 percent of all reported passenger-car vehicle-miles.

The following information was obtained from the Census survey conducted in the spring of 1961. The average trip length for all days of the week was 8 miles; the range in length among the days of the week was from 7 miles on Thursday to 10.6 miles on Sunday. The largest proportion of the trips and travel related to earning a living were made by automobile on Mondays and Fridays. The largest proportion of trips for shopping were made on Saturdays. Almost half of all trips and three-fifths of all travel for social and recreational purposes was accomplished on weekends.

Description and Status of Studies

Motor-vehicle-use studies are designed to obtain information about the characteristics of ownership and use of motor vehicles and were first conducted in most States during the years 1935 to 1940. As the number of vehicles manufactured has increased and their characteristics have changed substantially since the earlier studies, more nearly current information has been needed for research and planning purposes. State and national automobile-use studies were conducted to obtain this needed data.

State motor-vehicle-use studies

The State motor-vehicle-use studies are conducted by the State highway departments as projects under the highway planning program and have the technical cooperation and financial assistance of the Bureau of Public Roads. The basic purpose of these studies is to assemble more detailed information about the characteristics of ownership and use of motor vehicles than can be obtained from the regular traffic count surveys. The types of information collected include:

- Ownership of automobiles and/or trucks related to population size of the owners' places of residence.
- Distribution of motor-vehicle operators according to age and sex.
- Mode of transportation used for home-to-work travel related to distance, occupation, and population size of the automobile owners' places of residence.
- Travel by type of highway system related to population size of the automobile owners' places of residence.
- Trips made and miles traveled in passenger cars according to purpose of the individual trip and population size of the automobile owners' places of residence.
- Average length of passenger-car trips according to purpose of individual trips.
- Automobile ownership by year model and population size of the owners' places of residence.
- Estimated travel made in passenger cars according to car-year model.
- Estimated fuel consumption by passenger cars and trucks.
- Annual vehicle-miles of travel by trucks (visual classification) on each highway system.

Essentially, the motor-vehicle-use study was based on recognized statistical processes in which sampling techniques are used wherein selections are made on a probability basis. The data for each household were obtained by personal interviews with occupants of the sample dwelling units. The sample design included consideration of both rural and urban characteristics of the State. The procedure followed in all but the earlier studies provided for a full year coverage of ownership and travel data: the interview sample in each population group was divided into four equal segments, and a sampling was taken each season.

The interviewers were selected, trained, and supervised by State highway planning personnel. The sample units were preselected by the study supervisors and the interviewers were not permitted to make substitutions. A few State highway departments contracted with the U.S. Bureau of the Census to perform some phases of the study, including preparation of the sample design, accomplishment of interviews, and contributions of other technical assistance. The services performed by Census varied from State to State. These State studies in which Census participated were not the same as the nationwide automobile-use study, which was conducted in its entirety by the Bureau of the Census under contract to Public Roads. Since 1951, the 24 States shown in figure 1 have conducted motor-vehicle-use studies. Partial or complete reports have been received from all of them. A few States have prepared popularized versions of the reports for general distribution.

Nationwide automobile-use study

In 1959 the Bureau of Public Roads contracted with the Bureau of the Census to collect on a nationwide interview-sample basis specific information on characteristics of ownership and use of automobiles. Although almost half of the States had conducted motor-vehicle-use studies, Public Roads desired confirmation of the findings and additional data. Reliable information was needed to establish benchmark data and to determine factors for estimating future trends in automobile ownership, vehicle mileage, and revenues from motor-vehicle user taxes. This information was also urgently needed on a national and regional basis for the Highway Cost Allocation Study required by section 210 of the Federal Highway Revenue Act of 1956 (70 Stat. 387), as amended by section 2 of the Act approved August 28, 1958. Census conducted the first survey in the fall of 1959 and the second in the spring of 1961. The principal purpose of the spring 1961 survey was to measure patterns of use in the spring in comparison with patterns of use determined in the survey of fall 1959 and to obtain some socio-economic-location information related to households.

Principal items of motor-vehicle-use information collected in the Census surveys were:

- Households classified by density of automobile ownership, total family income, and number of adults in households.
- Distribution of automobile trips generated from places of each population-size group and classification of automobile trips according to length and purpose of each trip.
- Distribution of automobile vehicle-miles generated from places of each population-size group and classified as to length and purpose of each trip.

Table 1.—Distribution of automobile ownership per occupied dwelling unit, classified by location and data from three surveys [1]

Location of dwelling units	Automobile ownership per occupied dwelling unit														
	1			2			3 or more			1 or more			None [2]		
	Motor-vehicle-use	National auto-use 1959	National auto-use 1961	Motor-vehicle-use	National auto-use 1959	National auto-use 1961	Motor-vehicle-use	National auto-use 1959	National auto-use 1961	Motor-vehicle-use	National auto-use 1959	National auto-use 1961	Motor-vehicle-use	National auto-use 1959	National auto-use 1961
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Unincorporated areas	67.6	64.3	61.9	12.4	15.6	20.4	0.9	1.8	2.3	80.9	81.7	84.6	19.1	18.3	15.4
Incorporated places, populations:															
Less than 5,000	65.2	59.8	59.5	9.1	15.1	15.4	0.7	2.1	1.7	75.0	77.0	76.6	25.0	23.0	23.4
5,000–24,999	63.2	61.0	55.0	10.8	14.9	19.5	0.9	1.0	1.7	74.9	76.9	76.2	25.1	23.1	23.8
25,000–99,999	63.0	51.4	57.2	10.3	15.0	15.0	1.0	1.6	1.0	74.3	68.0	73.2	25.7	31.9	26.8
100,000 and more	52.9	50.2	44.9	8.6	9.6	9.2	0.7	0.6	0.8	62.2	60.4	54.9	37.8	39.6	45.1
TOTAL	61.8	57.4	56.0	10.4	13.6	16.4	0.8	1.3	1.7	73.0	72.3	74.1	27.0	27.7	25.9

[1] Motor-vehicle-use data based upon summary information from 23 State studies. Data from the national automobile-use studies based upon fall 1959 and spring 1961 studies by the Bureau of the Census for Public Roads.
[2] For motor-vehicle-use data, "none" indicates no vehicles of any kind; for national auto-use surveys, "none" refers only to automobile ownership.

Table 2.—Density of automobile ownership related to percentage of dwelling units by location [1]

Location of dwelling units	Total dwelling units	Density of automobile ownership			
		1	2	3 or more	None [2]
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Unincorporated areas	31.9	34.9	37.9	33.7	22.6
Incorporated areas, populations:					
Less than 5,000	12.5	13.1	10.9	10.6	11.5
5,000–24,999	14.6	15.0	15.2	16.5	13.7
25,000–99,999	11.9	12.1	11.8	14.6	11.4
100,000 and over	29.1	24.9	24.2	24.6	40.8

[1] State motor-vehicle-use data based upon summary information from 23 States: studies were conducted between 1951 and 1958.
[2] No automobiles or trucks.

The sample used by Census for these studies was one CPS (Current Population Survey) rotating panel, or approximately 4,000 dwelling units. The CPS is conducted each month by the Bureau of the Census with a scientifically selected sample representing the noninstitutional civilian population. The main purpose of the survey is to obtain current information on employment, unemployment, and related data, which are compiled monthly. During a designated week in each month, interviewers visit the sample households and obtain the needed information.

For the national automobile-use survey, the Census interviewers obtained the needed information on automobile use from a sample of the households included in the regular CPS panel. The selected households were surveyed by mail or by personal interview and were asked to keep a travel log for 3 assigned days on each automobile owned by members of the household. This travel log provided space for recording separately each trip made, the major purpose of the trip, and the mileage. When the interviewer picked up the completed travel logs, he also filled out an interview form for each household. The interview form was used to record information such as mode of transportation to work, distance to nearest public transportation to work, and distance to nearest public transportation to main business district of the town. As the households surveyed for the automobile-use study had previously been surveyed to obtain other economic data, Census provided information on such economic items as income and composition of families, which is not available from the standard State motor-vehicle-use studies.

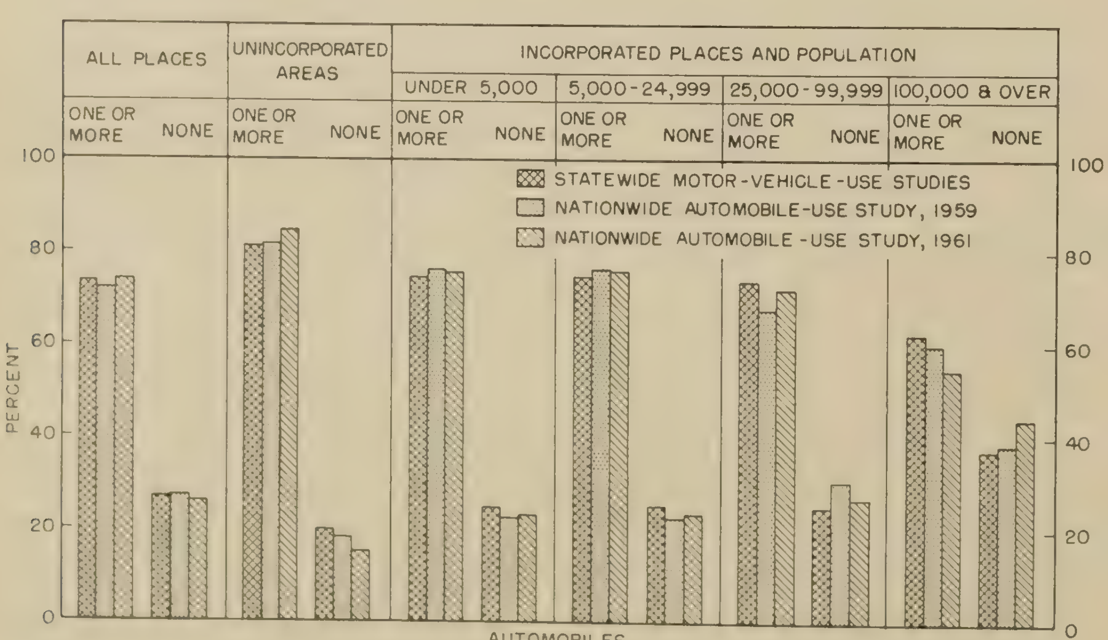

Figure 2.—Distribution of automobile ownership based on motor-vehicle-use studies and national automobile-use surveys.

Characteristics of Ownership of Motor Vehicles

Distribution of automobiles

The relative density of automobile ownership related to occupied dwelling units was reported in both the State motor-vehicle-use studies and the two national surveys conducted for Public Roads by the Bureau of the Census. Table 1 and figure 2 show a comparison between the results of these surveys. Between the years of the earlier motor-vehicle-use studies, 1951–58, and the national studies conducted in the fall of 1959 and the spring of 1961, ownership patterns may have changed appreciably. Although the percentage of all occupied dwelling units for which occupants had one or more automobiles was substantially the same in the three sets of data, ranging from 72.3 to 74.1 percent, the evidence of increasing multiple ownership of automobiles can be perceived. Percentage distribution of passenger cars in relation to occupied dwelling units was highest in the unincorporated areas and decreased steadily as the size of the incorporated places increased.

Dwelling units whose occupants had only one automobile comprised 61.8 percent of the total according to the motor-vehicle-use studies, but only 57.4 and 56.0 percent, respectively, as reported in the 1959 and 1961 national automobile-use surveys. Similar information collected by the Bureau of the Census during census week in 1960 (*9*) indicated that in 57.0 percent of the occupied dwelling units, ownership was reported for only one automobile.

The percentage of the total occupied dwelling units for which occupants reported ownership of two or more automobiles suggests a possible growth pattern. The motor-vehicle-use studies conducted between 1951 and 1958 showed that for 11.2 percent of the dwelling units occupants had two or more automobiles, and the 1959 and 1961 surveys showed occupants of 14.9 and 18.1 percent, respectively, of the dwellings as owning two or more. Information collected during census week in 1960 (*9*) indicated that occupants of 21 percent of the dwelling units had two or more automobiles. Multiple-car ownership was highest per dwelling unit for those located in the unincorporated areas. In general, the larger the population of the incorporated place, the percentage of dwelling units for which ownership of more than one automobile was reported decreased.

Table 2 shows the percentage distribution of automobile ownership per dwelling unit in each population-size group. The data shown in this table substantiate the assumption of greater density of automobile ownership for persons living in unincorporated areas and incorporated places having populations of less than 100,000 than for those in places where the population is greater. For example, 32 percent of all dwelling units were located in the unincorporated areas where only 23 percent of the households reported no automobiles. But for the 29 percent of the dwelling units in places having a population of more than 100,000, 41 percent of the households reported no automobiles.

Distribution by occupational groups

Table 3 and figure 3 show the distribution of automobiles, trips, and travel by the occupational-group classification of the head of the household. This information is based on the findings of the national automobile-use studies.

Table 3.—Percentage distribution of trips, travel, vehicle-miles, and automobiles for labor force, classified in groups, according to occupation of head of household

Occupation of head of household	Distribution of—						
	Persons[1] in labor force, 1959	Automobiles [2]		Trips [2]		Travel [2]	
		1959	1961	1959	1961	1959	1961
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Professional, technical, and kindred workers	10.9	11.8	16.6	13.2	19.4	11.6	19.3
Farmers and farm managers	4.6	7.7	5.7	7.1	5.1	8.1	5.8
Managers (except farm), officials and proprietors	10.6	15.6	17.3	16.8	16.4	16.1	16.5
Craftsmen, foremen, and kindred workers	13.1	21.0	20.0	20.7	20.4	21.1	19.3
Subtotal	39.2	56.1	59.6	57.8	61.3	56.9	60.9
Clerical and kindred sales workers	20.9	14.5	13.3	14.4	13.1	15.4	14.4
Operatives and kindred workers, laborers, and farm laborers	27.6	24.6	21.1	23.8	20.4	24.4	19.1
Private household and service workers	12.3	4.8	6.0	4.0	5.2	3.3	5.6
Subtotal	60.8	43.9	40.4	42.2	38.7	43.1	39.1
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[1] Employment and Earnings, Department of Labor, Bureau of Labor Statistics.
[2] National automobile-use studies fall of 1959 and spring of 1961; trips and vehicle-miles reported by heads of households who were not in labor force, members of the Armed Forces, and did not report their occupations have been omitted.

As shown in table 3, persons listed in the first four occupational groups—(1) professional, technical, and kindred workers; (2) farmers and farm managers; (3) other managers, officials, and proprietors; and (4) craftsmen, foremen, and kindred workers—proportionately performed more trips and travel and owned more vehicles than other groups of workers in the labor force. These four occupational groups represented 39 percent of the labor force and performed from 57 to 60 percent of the total travel. The other groups of workers—(1) clerical and sales workers, (2) operatives and laborers, and (3) household and service workers—owned proportionally fewer vehicles, made fewer trips, and traveled less. The relatively low ownership of vehicles by household and service workers probably is the result of their economic status.

Distribution by family income groups

Table 4 shows the distribution of automobile ownership by family income groups. This information was derived from the national automobile-use survey conducted in the spring of 1961. These figures clearly demonstrate that as the income goes up, the density of automobile ownership increases. As the yearly family income rises to more than $2,000, the percentage of the income group having automobiles increases sharply. The percentage of families in the income groups having automobiles rose steadily, reaching 98.4 percent for the group having an income of $15,000 and more. The families reporting ownership of two automobiles were concentrated in the family income groups of $6,000 and more and the families having three or more automobiles were concentrated in the family income groups of $10,000 and more.

Although income is an important consideration in automobile ownership, in many of the larger cities such factors as the lack of parking facilities and adequate public transportation systems also affect automobile ownership. And families living and working in rural areas, where there is no adequate public transportation system, must depend upon the automobile for work, shopping, and other necessary purposes even though the individual family income may be low. Table 5 shows data useful for a comparison by States between the percentage of occupied dwelling units for which ownership of vehicles, automobiles and/or trucks was reported, and the per capita personal income rank in 1960. Vehicle ownership data in this table were compiled from State motor-vehicle-use studies.

Reports from five States (Tennessee, Kentucky, Arkansas, Mississippi, and Louisiana) showed that occupants of less than 70 percent of their dwelling units had vehicles; also,

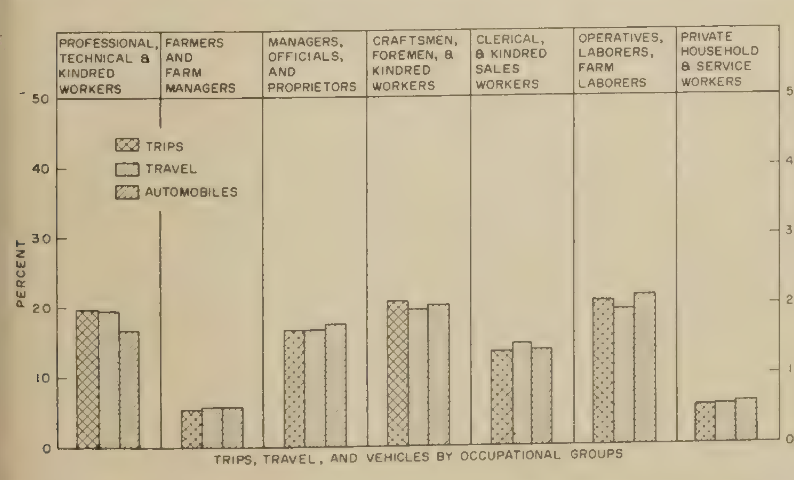

Figure 3.—Distribution of trips, travel, and vehicles classified by occupation of head of household, 1961.

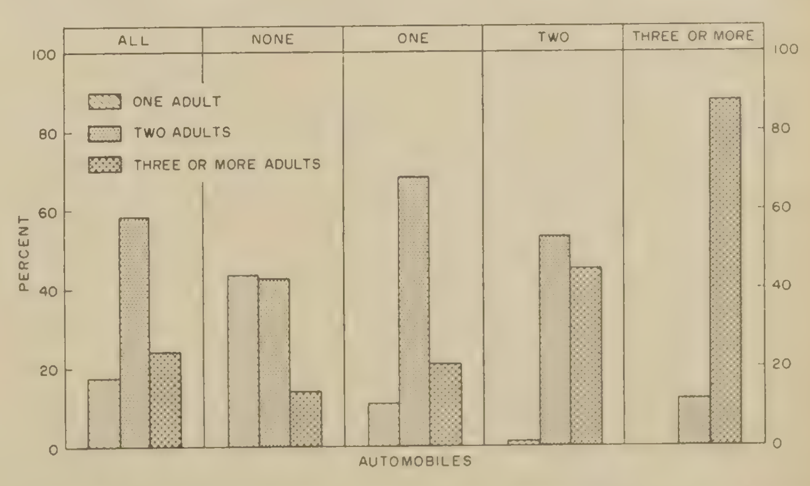

Figure 4.—Distribution of automobile ownership by number of adults in household.

Table 4.—Distribution of automobile ownership [1]

Total family income		Automobile ownership			
		1	2	3 or more	None
DISTRIBUTION OF OWNERSHIP BY FAMILIES					
Income groups	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Under $1,000	8.3	4.2	1.3	1.2	21.9
$1,000–$1,999	8.7	5.2	1.5	--------	21.5
$2,000–$2,999	8.4	8.1	3.2	--------	13.0
$3,000–$3,999	8.8	9.3	4.9	4.1	10.4
$4,000–$4,999	8.6	10.1	5.2	5.4	7.7
$5,000–$5,999	10.3	14.1	7.3	6.7	4.1
$6,000–$7,499	13.8	17.0	17.9	11.6	4.5
$7,500–$9,999	9.3	10.5	15.9	13.6	2.3
$10,000–$14,999	9.3	8.9	22.0	25.1	1.3
$15,000 and more	2.6	1.7	7.7	21.3	0.2
Income not reported	11.9	10.9	13.1	11.0	13.1
TOTAL	100.0	100.0	100.0	100.0	100.0
DISTRIBUTION OF OWNERSHIP WITHIN INCOME GROUP					
Under $1,000	100.0	28.4	2.7	0.2	68.7
$1,000–$1,999	100.0	33.3	2.8	--------	63.9
$2,000–$2,999	100.0	54.0	6.1	--------	39.9
$3,000–$3,999	100.0	59.4	9.2	0.8	30.6
$4,000–$4,999	100.0	65.9	9.9	1.0	23.2
$5,000–$5,999	100.0	76.9	11.6	1.1	10.4
$6,000–$7,499	100.0	68.9	21.3	1.4	8.4
$7,500–$9,999	100.0	63.1	28.1	2.4	6.4
$10,000–$14,999	100.0	53.2	38.7	4.5	3.6
$15,000 and more	100.0	36.3	48.5	13.6	1.6
Income not reported	100.0	51.6	18.2	1.5	28.7
TOTAL	100.0	56.0	16.4	1.7	25.9

[1] National automobile-use study, spring 1961.

Table 5.—Percentage of dwelling units whose occupants owned vehicles, per capita personal income rank, and year of motor-vehicle-use study

State	Percent of dwelling units whose occupants owned vehicles [1]	Per capita [2] personal income rank 1960	Year
North Dakota	96.0	39	1951
Wyoming	89.9	18	1952–53
Idaho	89.1	40	1957–58
South Dakota	88.8	34	1952–53
Oregon	85.7	17	1953–54
Kansas	84.2	27	1957
Colorado	81.7	15	1955–56
New Mexico	81.3	41	1954
Wisconsin	81.1	23	1951
Montana	81.0	28	1952–53
Iowa	80.3	29	1951–52
Washington	79.3	14	1952–53
Hawaii	77.2	22	1952
California	76.9	6	1953
Oklahoma	75.8	38	1951
Missouri	73.8	20	1951–52
Illinois	72.9	9	1957–58
Pennsylvania	71.3	16	1952–53
Delaware	70.1	1	1953
Tennessee	69.0	46	1954
Kentucky	67.9	47	1953–54
Arkansas	62.8	50	1951
Mississippi	55.7	51	1952–53
Louisiana	55.1	43	1951

[1] Motor-vehicle-use studies include automobiles and/or trucks.
[2] Data from National Industrial Conference Board. Income ranged from a low of about $1,200 in Mississippi to a high of almost $3,100 per capita in Delaware. U.S. average was $2,242.

average per capita personal income in these States ranked relatively low. This would seem to infer that income influenced vehicle ownership. However, the three States of North Dakota, South Dakota, and Idaho reported relatively low per capita personal income but a high proportion of vehicle ownership in relation to number of dwelling units. Thus, per capita personal income may not be the only factor influencing car ownership. However, the results shown in table 5 may have been affected by the fact that the State motor-vehicle-use studies were conducted between 1951 and 1958 but the per capita personal income rank shown was for 1960. Between 1951 and 1960 the per capita personal income rank for a particular State may have changed appreciably, particularly in the agricultural States.

Distribution by number of adults in households

The number of persons old enough to operate motor vehicles (persons 16 years of age or older) in a household tends to help set the pattern for the number of automobiles owned in a household. Table 6 and figure 4 show for each automobile ownership class the number of these potential operators in a household. A high proportion, 54 percent, of the households for which ownership of two automobiles was reported were the two-adult

Table 6.—Distribution of automobile ownership by number of adults in the household[1]

Number of automobiles owned	Distribution of sample of households	Number of adults in household [2]			
		1	2	3 or more	Unknown
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
None	25.9	43.5	42.6	13.9	-----
1	56.0	10.8	68.2	20.9	0.1
2	16.4	1.1	53.6	45.3	-----
3 or more	1.7	----	12.1	87.9	-----
TOTAL	100.0	17.5	58.3	24.2	-----

Nationwide automobile-use survey, spring 1961.
[2] 16 years of age or older.

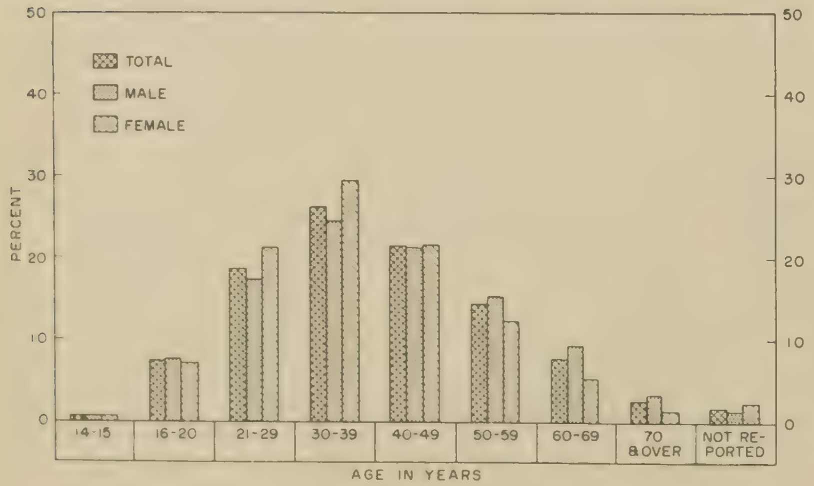

Figure 5.—Distribution of licensed motor-vehicle operators by age group and sex.

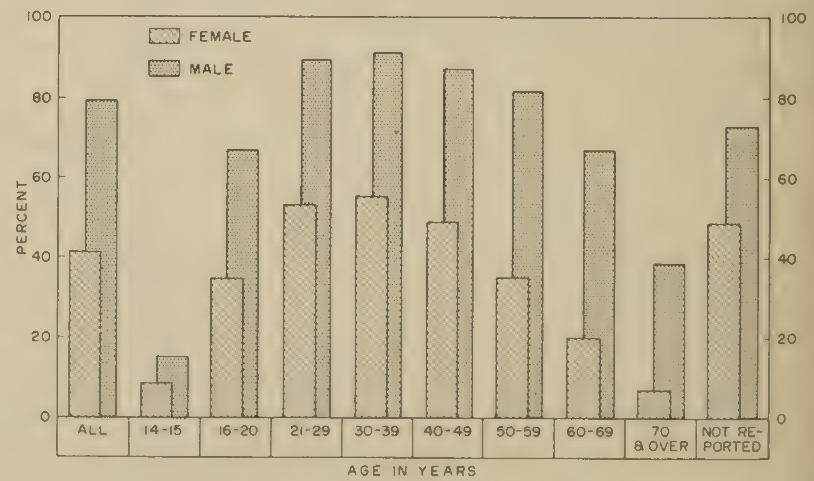

Figure 6.—Proportion of population in each age and sex group licensed as motor-vehicle operators.

Table 7.—Age distribution of licensed motor-vehicle operators and the proportion of the total population of operators in each age group [1]

Age	Distribution of licensed operators			Proportion of total population licensed as operators		
	Male	Female	Total	Male	Female	Total
Years	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
14–15	0.3	0.3	0.3	15.1	8.1	11.7
16–20	7.5	7.0	7.3	66.8	34.3	50.4
21–29	17.3	21.3	18.7	89.2	52.5	69.6
30–39	24.4	29.3	26.1	91.2	55.6	72.5
40–49	21.1	21.3	21.2	87.6	48.4	67.8
50–59	15.5	12.2	14.3	81.8	34.8	57.9
60–69	9.3	5.2	7.9	67.5	20.0	43.1
70 and over	3.3	1.1	2.5	39.4	7.1	22.5
Not reported	1.3	2.3	1.7	73.1	48.4	58.4
ALL	100.0	100.0	100.0	79.1	41.1	59.4

[1] Motor-vehicle-use studies conducted in 22 States: Arkansas, California, Colorado, Idaho, Illinois, Iowa, Kansas, Kentucky, Louisiana, Mississippi, Missouri, Montana, New Mexico, North Dakota, Oklahoma, Oregon, Pennsylvania, South Dakota, Tennessee, Washington, Wisconsin, and Wyoming.

household. For households where ownership of three or more automobiles was reported, the modal household had three or more adults.

Motor-Vehicle Operators

Information about motor-vehicle operators is important to Federal, State, and local officials in the highway taxation and planning fields. Forecasts must be made of the number of drivers who may be operating vehicles on the Nation's highways in 5, 10, or even 25 years. The proportion of drivers to the total population in the driving-age groups is expected to increase appreciably in the next few years. This increase probably will be accompanied by a proportional increase in the number of automobiles being driven for the different purposes.

In 1961 (*6*) it was estimated that almost 89 million persons were licensed to operate motor vehicles. This represented an average of 1.2 operators' permits for each registered motor vehicle; the range for licensed operators among the different States was from 105,000 in Alaska and 175,000 in Nevada to 7 million in New York and 9 million in California. The ratio of the number of licenses issued to the number of vehicles registered ranged from less than one operator per vehicle in Montana and Nevada (more vehicles registered than licenses in force) to 1.3 operators per vehicle in Massachusetts. By 1966, 131 million persons are expected to be eligible to drive, according to age requirements (*5*, p. 264). Even if the proportion of drivers to the total population remains constant, although it is expected to increase, there will be about 91 million licensed motor-vehicle operators in 1966.

Table 7, which is based on the State motor-vehicle-use studies, shows the distribution of licensed motor-vehicle operators separately for males, females, and all persons, and the proportion of the total population in each age group licensed as motor-vehicle operators. These data are shown also in figures 5 and 6.

The highest proportion of licensed operators were in the 30–39 age group; 24 percent of all male drivers and 29 percent of all female drivers were in this age group. The age groups from 21–29 and 40–49 years also had a high proportion of licensed drivers. A high proportion of persons in the age groups from 21 through 49 are expected to retain their licenses to operate a vehicle as they become older. If States enact legislation that would require a periodic reexamination for drivers, some potential drivers may be lost, particularly in the higher age groups.

Table 7 also shows the proportion of the total population in each age group that is licensed to operate a motor vehicle. Again the highest proportion, 72 percent, of licensed operators is in the 30–39 age group; 91 percent of all males and 56 percent of all females in this age group are licensed operators. An interesting statistic is the relative stability of the percentage of total males licensed to drive in the four age groups from 21 to 59 years of age; 82 to 91 percent of the males in these age groups are licensed operators. For females the stability carries only from ages 21 through 49, where from 48 to 56 percent of the females are licensed drivers. Only 20 percent of the females in the 60–69 age group and 7 percent of the females over 70 years of age are licensed operators. Many of the females in the older age groups probably never did learn to drive.

Travel To and From Work

Most workers today have the problem of commuting to work. Joining the rush-hour traffic to get to and from work is now an accepted part of the routine of urban living. As the population and the number of workers grow and more and more families settle in the suburban areas, the distance necessary to be traveled to work tends to be increased.

Based upon summary data developed from 21 State motor-vehicle-use studies, 80 percent of all gainfully employed workers use some form of travel to get to work. Independent data collected by the Bureau of the Census in 1960 showed that 93 percent of all workers required transportation to work. Some of the differences in these two sets of data are traceable to differences in definition of "work at home." In the motor-vehicle-use studies, a person is considered as being gainfully employed at home if he regularly conducts his business from his place of residence; this includes a doctor, plumber, or traveling salesman. In the survey conducted at 10-year intervals by the Bureau of the Census, a doctor or salesman who uses an automobile in connection with work, even though operating his business from his place of residence, would be reported as using an automobile for transportation to work. Other differences in the results of these two studies may be the result of the difference in time of survey. The 21 State motor-vehicle-use studies were conducted in different years, between 1951 and 1958. The Census study was national in scope and was conducted for a week in April 1960.

Table 8 and figure 7 show by occupational and population groupings the percentage of workers requiring transportation to get to work. For residents of all places the range was from 46 percent for proprietors, managers, and officials (including farmers and farm managers) to 96 percent for store and office clerks. Fifty-nine percent of all workers in

Table 8.—Percentage of workers in each occupational group required to travel [1] **to get to work, classified by residence of operator** [2]

Occupational group of operator	Residence of principal operator						
	All places	Unincorporated areas	Incorporated places having populations of—				
			Less than 5,000	5,000–24,999	25,000–99,999	100,000 and more	Total
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Professional and semiprofessional	87.9	88.0	82.4	90.8	92.4	86.5	87.8
Proprietors, managers, and officials, including farmers and farm managers	46.4	20.1	78.5	86.5	89.2	85.3	84.6
Store and office clerks, salesmen (excluding traveling salesmen)	95.9	94.4	92.1	94.6	97.4	97.6	96.3
Traveling salesmen, agents	85.1	79.0	77.0	82.8	88.6	89.7	86.3
Craftsmen, foremen, skilled laborers	94.4	93.1	91.0	94.7	96.5	96.0	95.0
Operatives, semiskilled workers, unskilled workers, laborers	89.1	77.7	91.8	94.7	96.3	97.7	95.7
Protective services workers	61.4	46.0	76.6	54.7	88.1	71.8	69.7
Personal service workers	87.3	80.8	85.7	87.1	86.7	90.6	88.7
Miscellaneous [3]	63.9	61.8	62.4	52.1	79.5	67.3	64.0
TOTAL	80.4	59.4	86.9	89.9	93.7	92.9	91.4

[1] Includes walking.
[2] Motor-vehicle-use studies conducted in 21 States: Arkansas, California, Delaware, Idaho, Illinois, Iowa, Kansas, Kentucky, Louisiana, Mississippi, Missouri, Montana, New Mexico, North Dakota, Oklahoma, Oregon, Pennsylvania, South Dakota, Tennessee, Washington, and Wyoming.
[3] Includes workers not reporting occupation.

Table 9.—Distribution of workers traveling from home to work classified by mode of travel within each occupational group—residents of all places, all unincorporated areas, and all incorporated places [1]

Residence location and occupational group	Automobile			Public transportation	Automobile and public transportation	Walk	All other means and not reported
	Driver	Passenger	Total				
All places:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Professional and semiprofessional	58.8	12.6	71.4	13.0	2.4	10.6	2.6
Proprietors, managers, officials [2]	71.0	6.2	77.2	5.8	1.5	11.9	3.6
Store and office clerks, salesmen	40.4	18.1	58.5	24.9	2.4	12.4	1.8
Traveling salesmen, agents	71.3	4.6	75.9	12.8	3.7	4.8	2.8
Craftsmen, foremen, skilled laborers	65.7	13.5	79.2	10.1	1.3	7.0	2.4
Operatives, workers, and laborers	49.2	19.2	68.4	14.2	1.0	13.6	2.8
Protective services workers	63.3	11.7	75.0	10.1	1.5	6.4	7.0
Personal service workers	25.2	14.8	40.0	31.3	2.0	24.3	2.4
Miscellaneous [3]	33.3	12.0	45.3	12.1	2.1	9.5	31.0
ALL OCCUPATIONS	53.7	14.8	68.5	15.1	1.7	11.8	2.9
Unincorporated areas:							
Professional and semiprofessional	67.6	15.5	83.1	6.8	1.6	5.0	3.5
Proprietors, managers, officials [2]	72.0	6.0	78.0	2.0	1.2	13.7	5.1
Store and office clerks, salesmen	54.2	25.1	79.3	11.0	2.5	5.2	2.0
Traveling salesmen, agents	80.8	7.4	88.2	4.4	3.5	2.5	1.4
Craftsmen, foremen, skilled laborers	74.1	15.7	89.8	3.0	1.3	3.4	2.5
Operatives, workers, and laborers	60.0	23.4	83.4	3.7	0.9	8.4	3.6
Protective services workers	68.4	11.6	80.0	4.4	0.8	6.9	7.9
Personal service workers	44.1	26.3	70.4	10.2	1.4	14.2	3.8
Miscellaneous [3]	38.5	12.3	50.8	10.2	6.0	4.9	28.1
ALL OCCUPATIONS	64.2	18.6	82.8	4.9	1.4	7.3	3.6
All incorporated places:							
Professional and semiprofessional	56.6	11.8	68.4	14.6	2.5	12.1	2.4
Proprietors, managers, officials [2]	70.6	6.4	77.0	7.2	1.6	11.3	2.9
Store and office clerks, salesmen	37.4	16.6	54.0	27.9	2.4	14.0	1.7
Traveling salesmen, agents	69.6	4.1	73.7	14.3	3.8	5.2	3.0
Craftsmen, foremen, skilled laborers	62.3	12.7	75.0	13.0	1.3	8.4	2.3
Operatives, workers, and laborers	44.1	17.3	61.4	19.1	1.0	16.0	2.5
Protective services workers	61.6	11.8	73.4	12.0	1.7	6.2	6.7
Personal service workers	21.5	12.6	34.1	35.3	2.2	26.2	2.2
Miscellaneous [3]	31.3	11.9	43.2	12.9	0.5	11.3	32.1
ALL OCCUPATIONS	50.1	13.5	63.6	18.6	1.8	13.4	2.6

[1] 21 State motor-vehicle-use studies: Arkansas, California, Delaware, Idaho, Illinois, Iowa, Kansas, Kentucky, Louisiana, Mississippi, Missouri, Montana, New Mexico, North Dakota, Oklahoma, Oregon, Pennsylvania, South Dakota, Tennessee, Washington, and Wyoming.
[2] Includes farmers and farm managers who traveled to work.
[3] Includes workers not reporting occupation.

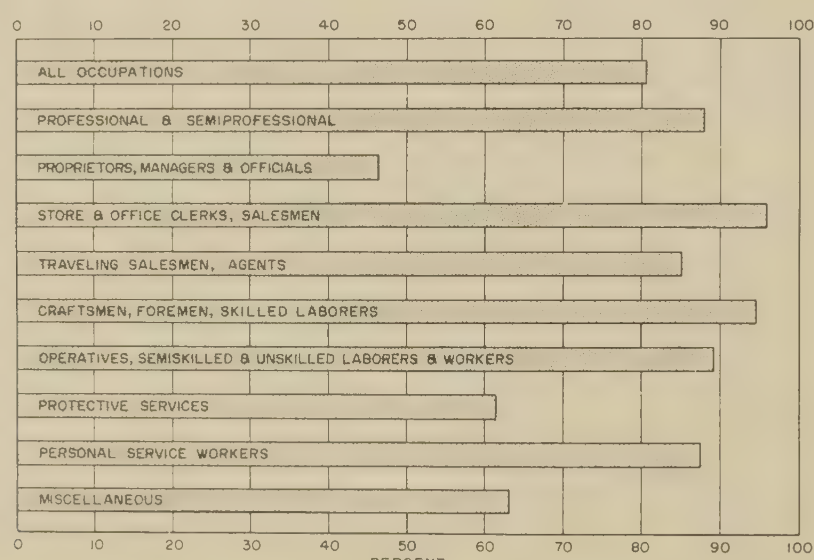

Figure 7.—Percentage of workers in each occupational group that requires travel to reach place of employment.

the unincorporated areas traveled to work as compared with 91 percent in the incorporated places.

Modes of travel to and from work

According to the motor-vehicle-use studies, 68 percent of all workers travel to and from work by automobile, either as the driver or as a passenger. An additional 15 percent use public transportation. Table 9 indicates the extent of use of different modes of transportation by each occupational group for residents of all places. In addition, table 9 shows comparable data separately for residents of unincorporated areas and incorporated places. For residents of all places, workers using automobiles for home-to-work travel ranged from 40 percent for personal service workers to 79 percent for craftsmen, foremen, and skilled laborers. Almost one-third of all the personal service workers used public transportation to get to work.

A relatively high proportion of store and office clerks, 25 percent, also used public transportation to get to and from work. However, less than 6 percent of the occupational group, including proprietors, managers, and officials, went to work by public transportation. About 12 percent of all workers walked to work. The number of walkers among the principal occupational groups ranged from 6 percent for workers in the protective services to 24 percent for the personal service workers.

Workers using a combination of methods to get to work, that is automobile and public transportation or some other combination, accounted for a relatively small percent of the total modes of travel.

Relation of Distance to Work and Mode of Travel

The mode of travel to work is influenced by such factors as distance, type and convenience of public transportation, and occupation. Usually the workers who live in the rural areas have less public transportation available. Table 10 shows the mode of travel used by workers grouped according to distance.

Walking was the most popular method of getting to work where the individuals lived less than 1 mile from work; more than half of all workers in that mileage group walked to work and 43 percent went by private automobile. Where the distance to work was more than 2 miles, few walked. Workers using a combination of passenger cars and public transportation to get to work are included mainly in the 13-miles-and-more distance groups. The highest percentage, 6.6 percent, of workers using a combination method of transportation lived 25 miles or more from their work.

Public transportation was the most popular method of travel for those living 2 to 9 miles from work; 20 to 25 percent of the workers in this distance group used public transportation. As people live farther from work, particularly when the distance is more than 15 miles, public transportation is used less, possibly because of inconvenient scheduling of public transportation.

A high proportion of automobile drivers or riders is shown in all mileage groupings. Except for those workers living less than 1 mile from work, more than 70 percent of the workers went to work by private automobile. Also, more than 80 percent of the workers living more than 11 miles from work either rode or drove in automobiles. Only 7.8 percent of persons living less than 1 mile from work were passengers in private automobiles. Where the distance was from 1 to 14 miles, from 15 to 17 percent of persons were reported as being automobile passengers. More than 20 percent of the persons living 14 miles and more from work were passengers in private automobiles. This may reflect the influence of car pooling from the more distant points and the lack and/or inadequacy of public transportation.

Use Characteristics for Automobiles

Travel to and from work accounts for more than one-third of all automobile trips and more than one-fourth of all passenger-car travel, according to the motor-vehicle-use studies. Planners of urban highway facilities know only too well that such travel is responsible for the morning and evening rush-hour traffic peaks and accompanying congestion that provide their most knotty problems. However, the other two-thirds of the automobile trips and three-fourths of travel require attention too, especially in connection with the planning of interstate and intercity facilities, and rural feeder and access roads.

Purpose of travel

As table 11 and figure 8 data indicate, more than 46 percent of all automobile trips and almost 44 percent of all travel is related to earning a living. The proportion of total trips and travel made that is related to earning a living by residents of incorporated places is somewhat higher than the proportions for persons residing in unincorporated areas. For residents of all places, passenger cars are used for commuting to and from work on one-third of all one-way trips and more than one-fourth of all travel. Persons living in the unincorporated areas perform proportionally fewer work trips than persons living in cities having a population of 100,000 and more. Persons living in all other incorporated places travel about the same proportion of their total miles for work trips as do residents of unincorporated areas.

Trips made for purposes of family business accounted for nearly 29 percent of all trips and 19 percent of all travel. Persons living in the unincorporated areas accounted for a higher proportion of their trips and travel for such purposes than residents of incorporated places. Residents of incorporated places are usually nearer to shopping and medical service

Table 10.—Distribution of workers classified by mode of travel to work, according to distance to work[1]

Distance to place of employment	Automobile: Driver	Automobile: Passenger	Automobile: Total	Public transportation	Automobile and public transportation	Walk	All other means and not reported
Miles	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
0.1–0.9	35.0	7.8	42.8	3.1	0.4	52.4	1.3
1.0–1.9	55.4	16.7	72.1	14.9	0.9	11.1	1.0
2.0–2.9	55.8	16.3	72.1	23.4	1.2	1.9	1.4
3.0–3.9	57.0	14.5	71.5	25.8	1.0	0.5	1.2
4.0–4.9	57.0	15.8	72.8	24.6	1.2	0.2	1.2
5.0–5.9	59.7	15.4	75.1	21.9	1.3	0.2	1.5
6.0–6.9	60.2	15.4	75.6	21.6	1.7	--------	1.1
7.0–7.9	62.0	15.8	77.8	18.6	1.9	--------	1.7
8.0–8.9	59.9	15.6	75.5	21.1	2.4	--------	1.0
9.0–9.9	65.3	17.9	83.2	13.1	2.1	--------	1.6
10.0–10.9	61.9	16.9	78.8	17.1	2.6	--------	1.5
11.0–11.9	65.8	17.1	82.9	13.9	2.2	--------	1.0
12.0–12.9	65.9	17.2	83.1	14.0	2.0	--------	0.9
13.0–13.9	67.3	17.2	84.5	10.1	4.2	--------	1.2
14.0–14.9	60.6	20.3	80.9	13.4	4.2	--------	1.5
15.0–19.9	65.3	20.4	85.7	9.1	3.4	--------	1.8
20.0–24.9	64.3	21.1	85.4	7.0	5.9	--------	1.7
25.0 and more	61.8	22.2	84.0	7.5	6.6	--------	1.9
Not reported	36.4	9.1	45.5	7.4	1.0	17.6	28.5
ALL DISTANCES	53.7	14.8	68.5	15.1	1.7	11.8	2.9

[1] Motor-vehicle-use studies conducted in 21 States: Arkansas, California, Delaware, Idaho, Illinois, Iowa, Kansas, Kentucky, Lousiana, Mississippi, Missouri, Montana, New Mexico, North Dakota, Oklahoma, Oregon, Pennsylvania, South Dakota, Tennessee, Washington, and Wyoming.

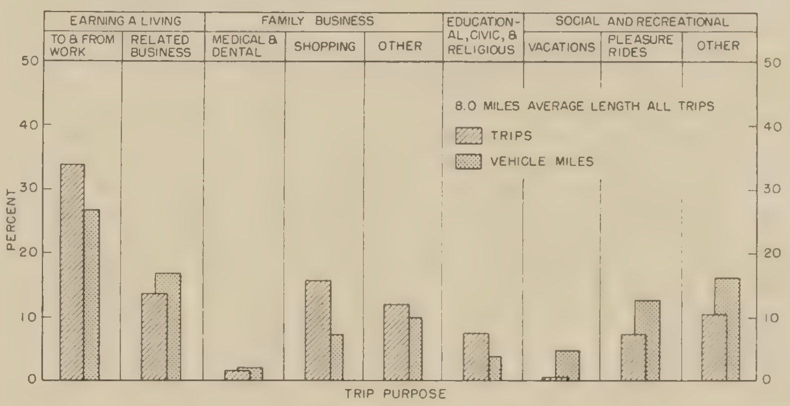

Figure 8.—Automobile trips and travel classified by major purpose of trip.

Table 11.—Distribution of automobile trips and travel by purpose and population groups[1]

Purpose of trip[2]	All population groups: Trips	All population groups: Travel	Unincorporated areas: Trips	Unincorporated areas: Travel	Under 5,000: Trips	Under 5,000: Travel	5,000–24,999: Trips	5,000–24,999: Travel	25,000–99,999: Trips	25,000–99,999: Travel	100,000 and more: Trips	100,000 and more: Travel	Total incorporated: Trips	Total incorporated: Travel
					Incorporated places and populations									
Earning a living:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
To and from work	33.3	26.8	27.6	25.1	33.4	24.2	34.1	25.1	35.2	24.3	39.0	33.4	35.9	27.8
Related business	13.2	16.8	15.2	16.2	14.3	19.3	11.6	18.7	11.2	18.3	12.4	14.5	12.3	17.2
Subtotal	46.5	43.6	42.8	41.3	47.7	43.5	45.7	43.8	46.4	42.6	51.4	47.9	48.2	45.0
Family business:														
Medical and dental	1.6	1.9	1.8	2.7	1.6	2.5	1.4	1.3	1.3	1.1	1.6	1.1	1.5	1.5
Shopping	15.4	7.2	17.4	10.4	14.6	6.7	15.7	5.4	15.1	5.5	13.3	4.7	14.5	5.4
Other	11.6	9.9	11.8	10.2	10.9	8.8	11.5	10.2	12.7	9.8	11.0	9.7	11.5	9.6
Subtotal	28.6	19.0	31.0	23.3	27.1	18.0	28.6	16.9	29.1	16.4	25.9	15.5	27.5	16.5
Educational, civic, and religious	7.2	3.7	8.1	4.9	6.5	3.1	7.0	2.7	7.5	3.0	6.3	3.0	6.8	2.9
Social and recreational:														
Vacations	0.1	4.9	0.1	3.3	0.1	4.2	0.2	5.0	0.2	8.5	0.1	6.0	0.1	5.9
Pleasure rides	7.1	12.7	6.9	11.6	9.1	15.5	7.7	13.4	7.7	15.9	5.8	10.8	7.3	13.4
Other	10.5	16.1	11.1	15.6	9.5	15.7	10.8	18.2	9.1	13.6	10.5	16.8	10.1	16.3
Subtotal	17.7	33.7	18.1	30.5	18.7	35.4	18.7	36.6	17.0	38.0	16.4	33.6	17.5	35.6
ALL PURPOSES	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

(Column groups are headed "Residence of principal operator"; the Under 5,000 through Total incorporated columns fall under "Incorporated places and populations".)

[1] Motor-vehicle-use studies conducted in 22 States: Arkansas, California, Colorado, Idaho, Illinois, Iowa, Kansas, Kentucky, Louisiana, Mississippi, Missouri, Montana, New Mexico, North Dakota, Oklahoma, Oregon, Pennsylvania, South Dakota, Tennessee, Washington, Wisconsin, and Wyoming.
[2] A trip is defined as a one-way movement from a starting place to the first stop for one of the purposes shown.

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Table 12.—Average length of one-way trips by major purpose of trip in selected States[1]

State	All purposes	Earning a living		Family business			Educational, civic, and religious	Social and recreational		
		To and from work	Related business	Medical and dental	Shopping	Other		Vacations	Pleasure rides	Other
	Miles	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*
Arkansas	8.7	4.9	13.3	8.5	3.6	9.1	5.7	156.6	15.3	11.9
California	7.9	7.4	8.5	8.1	3.5	6.7	4.3	205.4	21.8	11.8
Colorado	7.9	5.7	7.0	5.7	3.5	6.5	3.7	269.8	18.6	12.1
Idaho	8.3	4.9	9.6	9.9	5.8	7.6	4.2	80.9	31.6	14.9
Illinois	7.0	6.5	9.5	7.1	3.4	7.0	3.1	747.9	12.0	9.2
Iowa	8.2	3.6	11.8	15.5	4.6	6.8	4.7	535.4	13.7	----
Kansas	6.2	4.6	6.2	8.0	3.6	6.1	4.3	94.1	11.1	11.8
Kentucky	10.2	6.4	15.5	10.3	4.1	7.8	5.3	654.4	12.5	15.7
Louisiana	9.3	7.6	11.9	15.4	8.8	8.8	4.5	171.4	11.9	12.3
Mississippi	8.6	6.1	14.0	13.1	4.8	6.8	3.9	408.2	15.3	11.2
Missouri	8.2	5.9	9.5	9.3	4.0	4.4	4.2	641.5	22.9	14.9
Montana	9.3	3.8	17.2	21.0	4.7	10.1	6.2	472.5	16.1	12.6
New Mexico	8.2	4.4	12.6	20.5	3.6	4.7	2.9	377.7	11.1	3.5
North Dakota	12.9	5.3	16.1	34.8	6.3	8.3	9.3	538.9	12.9	16.4
Oklahoma	8.3	6.1	9.8	11.9	3.7	----	7.1	265.9	13.4	16.5
Oregon	8.7	6.9	10.0	15.5	4.2	6.7	4.4	320.2	14.7	6.9
Pennsylvania	9.0	6.9	14.2	9.1	3.9	7.5	3.8	111.1	16.2	14.4
South Dakota	10.2	3.4	13.8	25.9	7.1	7.1	5.4	1,031.2	14.0	16.1
Tennessee	8.1	7.1	8.6	8.1	3.6	13.5	5.2	287.5	12.6	11.1
Washington	8.9	6.7	14.8	11.3	4.1	6.7	3.9	106.8	13.7	3.9
Wisconsin	7.9	5.3	9.3	23.4	3.8	6.3	3.7	264.3	15.2	11.2
Wyoming	14.7	6.4	57.0	23.6	6.5	28.4	5.5	318.9	23.6	23.3
AVERAGE	8.0	6.4	10.2	9.7	3.8	6.8	4.1	296.0	14.2	12.3

[1] Motor-vehicle-use studies conducted in each State.

areas and other places for conducting family business than persons living in the unincorporated areas. Shopping trips accounted for 15 percent of all trips but only 7 percent of all the travel. Trips made for medical and dental purposes were responsible for less than 2 percent of the trips and travel. But, trips for family business other than medical, dental, and shopping accounted for 12 percent of the trips and 10 percent of the travel. These trips included those for such purposes as to see a lawyer, insurance agent, hairdresser, or a barber.

Trips made for social and recreational purposes accounted for 18 percent of the trips and 34 percent of the travel. Persons living in either incorporated or unincorporated areas performed about the same proportion of the trips, but residents of incorporated places performed a higher proportion of their travel for social and recreational purposes than persons living in the unincorporated areas. Thirty-six percent of the travel by residents of incorporated places was for social and recreational purposes, while only 30 percent of the travel by unincorporated area residents was for such purposes. Only 0.1 percent of the trips were made for vacations but these accounted for 5 percent of the total travel.

Table 12 shows the average one-way-trip length by purpose of trips in each of 22 States. For the 22 States combined, the average one-way-trip length for all purposes was 8.0 miles, it ranged from 6.2 miles in Kansas to 14.7 miles in Wyoming. Trips to and from work were relatively short trips, the average being 6.4 miles, and ranged from 3.4 miles in South Dakota to 7.6 miles in Louisiana.

Related business trips averaged 10.2 miles for the 22 States. Nine States reported an average business trip length of less than 10 miles, nine States between 10 and 15 miles, three States between 15 and 17 miles, while Wyoming reported an average trip length of 57 miles.

Trips for shopping purposes were relatively short, averaging less than 4 miles. Similarly, trips for educational purposes averaged less than 5 miles. Vacation trips averaged almost 300 miles one way, with a wide difference in averages among the various States. One reason for the range in the averages reported among the States was the definitions used for vacations and pleasure rides. For example, in some States an overnight trip was considered a pleasure ride while in other States it was considered a vacation. Another factor probably was the availability of the major vacation areas within the State and/or adjacent States.

Comparison With Earlier Studies

Between 1935 and 1940 most State highway departments conducted road-use studies that were designed to provide more information about the characteristics of motor-vehicle use than was then available. These studies were somewhat similar to the motor-vehicle-use studies that have been conducted since 1951.

Both types of studies were based on samples. However, in the earlier studies the universe in most instances was the motor-vehicle registrations of the previous complete year. The universe for the passenger-car data in the current motor-vehicle-use studies was the total number of dwelling units in the State being studied.

The information in both groups of studies was collected through personal interview with the respondents. In a few States, the road-use data needed were obtained through the so-called "school method." In States adopting this method the study was set up as a school project in classes in selected high schools.

The interviewers employed in the more recent motor-vehicle-use studies were given no latitude in selecting persons to be interviewed. In the earlier road-use studies, quotas within areas were established and the interviewers were instructed to make their selections on a more or less random basis. Some controls were established, however, including the requirement that urban interviews be distributed according to the distribution of workers among the different occupations. In the earlier studies, an attempt was made to obtain trip information for an entire 12-month period, generally the 12-month period immediately preceding the date of the interview. The more recent studies are designed to obtain data only for trips reported on the most recent workday and Saturday and Sunday. Further, the procedures for the motor-vehicle-use studies conducted since 1952 provided that one-fourth of the interviews shall be obtained in each area sampled in each of the four seasons of the year. These changes in procedures are expected to reduce memory bias or unreliability in the information obtained and to provide uniform seasonal coverage of the areas sampled.

Despite differences in the procedures used in the two studies, it is still possible to make some significant comparisons between the two. Table 13 shows by State and population groups the percentage of total travel assignable to business and pleasure. Two sets of data are presented for each population group. The first reports the percentage of travel assignable to business and pleasure as developed from the road-use studies conducted during the late 1930's. The second set of data shows the results of the motor-vehicle-use studies conducted in the different States from 1951 through 1958.

Business travel in both studies includes travel to and from work and for related business and family business trips, such as for shopping, medical, and dental purposes. The travel shown for pleasure purposes includes the travel for social and recreational activities plus that for educational, civic, and religious purposes. Although it is difficult to draw conclusions from these two sets of data, a few general observations can be made. Most of the States shown, which are generally considered as being somewhat rural in character, reported less travel for business purposes in the motor-vehicle-use studies than in the earlier road-use studies. Also, in the major cities having a population of 100,000 or more, the more recent studies show a higher percentage of travel for business purposes than the earlier studies. This could possibly have been caused by decentralization of commercial and industrial firms. The motor-vehicle-use study results showed that people in the unincorporated areas generally drove less of their total mileage for business purposes than results reported in the earlier studies.

Automobile Occupancy

Information on automobile occupancy is essential as a base for computing passenger miles of travel in private automobiles. The data are of general interest also to highway

Table 13.—Comparison by State between distribution of travel for business and pleasure as reported in the road-use studies [1] and the motor-vehicle-use studies [2]

Purpose of travel by State	Residence of principal operator													
	All places		Unincorporated areas		Incorporated places populations									
					Less than 5,000		5,000–24,000		25,000–99,999		100,000 and more		Total	
	Road-use	Motor-vehicle-use	Road-use	Motor-vehicle-use	Road-use	Motor-vehicle-use	Road-use	Motor-vehicle-use	Road-use	Motor-vehicle-use	Road-use	Motor-vehicle-use	Road-use	Motor-vehicle-use
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Arkansas:														
Business	71.6	60.0	76.9	62.0	71.5	59.7	61.9	62.6	62.6	51.5	----	58.4	66.6	58.8
Pleasure	28.4	40.0	23.1	38.0	28.5	40.3	38.1	37.4	37.4	48.5	----	41.6	33.4	41.2
Colorado:														
Business	62.6	53.9	72.5	60.2	60.2	50.0	61.5	31.0	50.3	65.9	56.9	77.3	57.9	51.4
Pleasure	37.4	46.1	27.5	39.8	39.8	50.0	38.5	69.0	49.7	34.1	43.1	22.7	42.1	48.6
Idaho:														
Business	66.8	56.1	73.2	55.1	62.2	62.1	60.1	52.9	----	57.2	----	----	61.2	57.1
Pleasure	33.2	43.9	26.8	44.9	37.8	37.9	39.9	47.1	----	42.8	----	----	38.8	42.9
Illinois:														
Business	48.1	69.7	60.3	65.4	49.5	67.5	43.5	71.9	43.4	69.7	48.1	73.1	46.3	71.1
Pleasure	51.9	30.3	39.7	34.6	50.5	32.5	56.5	28.1	56.6	30.3	51.9	26.9	53.7	28.9
Iowa:														
Business	57.8	55.3	67.4	56.8	56.4	56.8	38.8	50.1	61.6	55.1	48.7	53.0	54.3	54.5
Pleasure	42.2	44.7	32.6	43.2	43.6	43.2	61.2	49.9	38.4	44.9	51.3	47.0	45.7	45.5
Kansas:														
Business	56.2	61.2	66.5	62.1	51.3	60.9	53.4	59.5	52.2	58.5	50.8	62.5	52.0	60.5
Pleasure	43.8	38.8	33.5	37.9	48.7	39.1	46.6	40.5	47.8	41.5	49.2	37.5	48.0	39.5
Kentucky:														
Business	64.6	52.5	66.2	49.7	65.4	51.8	65.9	67.3	59.8	57.7	61.3	54.0	63.1	56.5
Pleasure	35.4	47.5	33.8	50.3	34.6	48.2	34.1	32.7	40.2	42.3	38.7	46.0	36.9	43.5
Louisiana:														
Business	70.1	61.2	80.0	61.9	71.2	70.3	68.5	61.9	70.7	57.2	59.2	54.4	64.6	60.6
Pleasure	29.9	38.8	20.0	38.1	28.8	29.7	31.5	38.1	29.3	42.8	40.8	45.6	35.4	39.4
Mississippi:														
Business	67.2	67.2	70.9	73.2	66.9	61.5	64.1	67.4	61.8	59.0	----	----	65.2	62.2
Pleasure	32.8	32.8	29.1	26.8	33.1	38.5	35.9	32.6	38.2	41.0	----	----	34.8	37.8
Missouri:														
Business	63.0	62.8	73.6	71.5	67.9	61.9	59.1	63.2	65.1	52.9	57.2	58.1	60.0	59.5
Pleasure	37.0	37.2	26.4	28.5	32.1	38.1	40.9	36.8	34.9	47.1	42.8	41.9	40.0	40.5
Montana:														
Business	63.0	58.8	76.8	64.6	56.5	51.9	55.1	61.6	53.1	50.6	----	----	55.4	54.1
Pleasure	37.0	41.2	23.2	35.4	43.5	48.1	44.9	38.4	46.9	49.4	----	----	44.6	45.9
New Mexico:														
Business	55.6	61.6	55.6	69.9	54.4	67.3	56.4	55.0	55.7	55.1	----	----	55.5	57.2
Pleasure	44.4	38.4	44.4	30.1	45.6	32.7	43.6	45.0	44.3	44.9	----	----	44.5	42.8
North Dakota:														
Business	62.4	53.3	68.9	59.8	59.8	47.8	56.9	58.5	53.7	24.2	----	----	57.8	48.4
Pleasure	37.6	46.7	31.1	40.2	40.2	52.2	43.1	41.5	46.3	75.8	----	----	42.2	51.6
Oklahoma:														
Business	70.8	59.1	77.4	68.4	69.7	42.3	72.6	55.6	63.7	51.7	61.0	63.9	66.9	53.9
Pleasure	29.2	40.9	22.6	31.6	30.3	57.7	27.4	44.4	36.3	48.3	39.0	36.1	33.1	46.1
Oregon:														
Business	55.4	62.6	64.3	68.5	52.6	57.8	48.7	58.3	37.3	48.9	52.4	57.2	51.2	56.9
Pleasure	44.6	37.4	35.7	31.5	47.4	42.2	51.3	41.7	62.7	51.1	47.6	42.8	48.8	43.1
South Dakota:														
Business	56.8	57.3	65.8	56.8	54.6	63.5	51.9	47.7	48.2	62.2	----	----	53.3	57.8
Pleasure	43.2	42.7	34.2	43.2	45.4	36.5	48.1	52.3	51.8	37.8	----	----	46.7	42.2
Tennessee:														
Business	63.8	56.1	68.7	62.3	65.0	53.5	57.4	56.4	62.7	49.3	60.0	46.2	60.9	49.6
Pleasure	36.2	43.9	31.3	37.7	35.0	46.5	42.6	43.6	37.3	50.7	40.0	53.8	39.1	50.4
Washington:														
Business	62.1	63.1	67.7	65.2	62.3	54.2	58.1	63.2	56.7	63.4	60.1	62.3	59.5	61.3
Pleasure	37.9	36.9	32.3	34.8	37.7	45.8	41.9	36.8	43.3	36.6	39.9	37.7	40.5	38.7
Wisconsin:														
Business	49.6	59.3	54.5	69.6	50.2	67.7	48.8	53.1	50.7	47.5	41.9	44.1	48.2	52.8
Pleasure	50.4	40.7	45.5	30.4	49.8	32.3	51.2	46.9	49.3	52.5	58.1	55.9	51.8	47.2
Wyoming:														
Business	56.4	50.7	67.0	69.0	51.0	49.4	49.3	34.9	----	38.2	----	----	50.0	43.1
Pleasure	43.6	49.3	33.0	31.0	49.0	50.6	50.7	65.1	----	61.8	----	----	50.0	56.9

[1] Road-use studies conducted during the 1930's.
[2] Motor-vehicle-use studies conducted since 1951.

Table 14.—Average occupancy in automobile trips, classified by location of travel, major purpose of travel, by selected population groups [1]

Population group of residence of principal operator and location of travel	Occupants and major purpose of travel												
	All purposes	Earning a living			Family business				Educational, civic, and religious	Social and recreational			
		To and from work	Related business	Total	Medical and dental	Shopping	Other	Total		Vacations	Pleasure rides	Other	Total
All population groups:													
All trips	1.7	1.3	1.3	1.3	2.0	1.9	1.8	1.9	2.4	2.7	2.5	2.4	2.4
Trips partially within an incorporated place and partially rural	1.9	1.3	1.4	1.4	2.2	2.1	2.0	2.1	2.5	2.8	2.7	2.5	2.6
Trips entirely within an incorporated place [2]	1.6	1.2	1.2	1.2	1.8	1.8	1.7	1.8	2.3	2.3	2.3	2.2	2.2
Trips entirely outside incorporated places	1.9	1.3	1.4	1.4	2.0	1.9	1.9	1.9	2.7	2.9	2.6	2.5	2.5
Unincorporated areas:													
All trips	1.9	1.3	1.5	1.4	2.2	2.0	1.9	2.0	2.6	3.1	2.7	2.5	2.6
Trips partially within an incorporated place and partially rural	1.9	1.3	1.5	1.4	2.3	2.1	1.9	2.1	2.6	3.2	2.7	2.5	2.6
Trips entirely within an incorporated place [2]	1.8	1.3	1.4	1.3	2.0	1.9	2.0	2.0	2.5	3.8	2.6	2.5	2.5
Trips entirely outside incorporated places	1.9	1.3	1.5	1.4	2.0	1.9	1.8	1.9	2.7	2.6	2.6	2.5	2.5
All incorporated places:													
All trips	1.7	1.2	1.3	1.2	1.9	1.8	1.8	1.8	2.3	2.7	2.5	2.3	2.4
Trips partially within an incorporated place and partially rural	1.9	1.3	1.4	1.3	2.0	2.1	2.0	2.1	2.4	2.7	2.7	2.5	2.6
Trips entirely within an incorporated place [2]	1.6	1.2	1.2	1.2	1.8	1.8	1.7	1.8	2.3	2.2	2.3	2.1	2.2
Trips entirely outside incorporated places	1.8	1.3	1.3	1.3	2.5	1.8	2.4	2.2	2.3	3.1	2.9	2.8	2.9

[1] Motor-vehicle-use studies in 16 States: California, Colorado, Idaho, Illinois, Iowa, Kansas, Kentucky, Mississippi, Montana, New Mexico, Oregon, Pennsylvania, South Dakota, Tennessee, Washington, and Wyoming.
[2] Or within contiguous incorporated places.

Table 15.—Distribution of automobile trips by purpose of trip and location of travel [1]

Purpose of trip	Distribution by purpose	Distribution of travel		
		Trips partially within an incorporated place and partially rural	Trips entirely within an incorporated place [2]	Trips entirely outside incorporated places
Earning a living:	*Percent*	*Percent*	*Percent*	*Percent*
To and from work	33.6	36.7	56.3	7.0
Related business	12.2	42.3	46.0	11.7
TOTAL	45.8	38.2	53.6	8.2
Family business:				
Medical and dental	1.6	48.4	48.3	3.3
Shopping	15.8	30.7	58.0	11.3
Other	12.1	36.4	53.8	9.8
TOTAL	29.5	34.1	55.7	10.2
Educational, civic, and religious	7.6	28.1	57.8	14.1
Social and recreational:				
Vacations	0.1	83.9	8.3	7.8
Pleasure rides	7.2	54.6	36.1	9.3
Other	9.8	48.5	40.4	11.1
TOTAL	17.1	51.3	38.3	10.4
ALL PURPOSES	100.0	38.4	52.0	9.6

[1] Motor-vehicle-use studies conducted in 16 States: California, Colorado, Idaho, Illinois, Iowa, Kansas, Kentucky, Mississippi, Montana, New Mexico, Oregon, Pennsylvania, South Dakota, Tennessee, Washington, and Wyoming.
[2] Or within contiguous incorporated places.

Table 16.—Proportion of driving done by principal operator according to occupation and population group of residence [1]

Occupational group of principal operator	All places		Unincorporated areas		All incorporated places	
	Vehicle-miles	Trips	Vehicle-miles	Trips	Vehicle-miles	Trips
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Professional and semiprofessional workers	97.1	94.8	97.4	96.0	97.0	94.4
Proprietors, managers, and officials:						
Farmers and farm managers	87.3	93.6	87.8	94.5	82.5	83.9
Other proprietors, managers, and officials	90.4	89.8	97.2	91.8	88.5	89.4
Store and office clerks	92.3	90.3	94.1	88.3	91.8	90.9
Traveling salesmen	100.0	100.0	100.0	100.0	100.0	100.0
Craftsmen, foremen, and skilled laborers	90.5	95.0	97.8	97.8	87.3	93.8
Operatives, semiskilled, and unskilled laborers	93.4	93.2	93.9	91.5	93.1	94.0
Protective services workers	96.8	89.0	93.9	76.9	97.7	91.8
Military personnel	76.7	88.1	100.0	100.0	76.1	87.4
Personal service workers	91.3	91.0	82.8	75.8	93.4	93.7
Retired persons	89.3	95.1	92.1	90.0	88.6	96.3
Housewives	63.0	57.5	52.0	51.5	70.0	60.3
Unemployed persons	86.9	79.4	83.3	71.1	88.9	83.3
Students	65.9	70.6	73.0	69.1	60.4	71.5
ALL OCCUPATIONS	88.0	86.4	88.0	85.5	87.9	86.9

[1] Special analysis of 24,000 trips reported on motor-vehicle-use study interview forms from Colorado, Delaware, Kansas, and Tennessee. This represented a subsample of motor-vehicle-use study interview forms.

planners and city officials for estimating the number of automobiles that may travel on a given highway if an industrial plant or shopping center is located within any specified area and for comparing with data on other modes of transportation.

The average occupancy for all trips was 1.7 persons per trip, as shown in table 14 and figure 9. For trips that were confined entirely to an incorporated place or to contiguous places, occupancy averaged 1.6 persons per trip, but when the trip was made entirely outside of incorporated places or partially

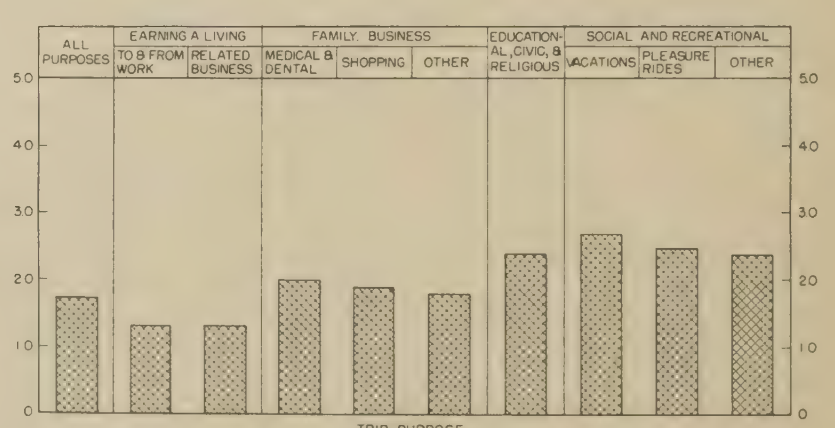

Figure 9.—Average occupancy of automobile classified by purpose of trip.

Table 17.—Proportion of travel performed by each occupational group of drivers [1]

Occupational group of driver	Proportion of travel performed by driver	Proportion of vehicle-miles driven by each occupational group as—	
		Principal operator	Other than principal operator
	Percent	*Percent*	*Percent*
Professional and semiprofessional workers	12.1	88.4	11.6
Proprietors, managers, and officials:			
Farmers and farm managers	9.9	82.6	17.4
Other proprietors, managers, and officials	10.7	91.6	8.4
Store and office clerks	11.6	90.3	9.7
Traveling salesmen	2.3	97.3	2.7
Craftsmen, foremen, and skilled laborers	16.8	95.0	5.0
Operatives, semiskilled, and unskilled laborers	16.6	92.4	7.6
Protective services workers	1.4	94.6	5.4
Military personnel	2.2	96.8	3.2
Personal service workers	1.8	90.2	9.8
Retired persons	1.1	96.0	4.0
Housewives	10.6	59.8	40.2
Unemployed persons	0.9	98.9	1.1
Students	2.0	98.6	1.4
ALL OCCUPATIONS	100.0	88.0	12.0

[1] Special analysis of 24,000 trips reported from motor-vehicle-use studies in 4 States: Colorado, Delaware, Kansas, and Tennessee. This represented a subsample of motor-vehicle-use study interview forms.

Table 18.—Average length of one-way trip by purpose of travel and day of week [1]

Day	All trips	Earning a living			Family business				Educational, civic, and religious	Social and recreational
		To and from work	Related business	All work trips	Medical and dental	Shopping	Other family business	All family business		
	Miles	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*
Monday	7.5	7.4	14.7	8.3	6.8	3.9	6.0	5.2	5.9	12.1
Tuesday	7.6	7.3	18.7	8.6	5.6	4.9	6.9	5.9	4.1	10.8
Wednesday	7.8	7.3	20.6	8.8	4.8	4.7	7.8	6.3	4.2	10.5
Thursday	7.0	7.4	17.3	8.3	9.3	4.4	5.5	5.3	6.3	6.7
Friday	7.7	7.0	15.6	8.0	12.3	4.3	6.5	5.7	6.0	12.9
Saturday	8.3	6.3	13.1	7.3	8.8	5.1	8.1	6.5	7.5	13.9
Sunday	10.6	8.1	16.1	9.9	7.4	4.0	8.8	7.3	4.1	18.8
ALL DAYS	8.0	7.2	16.7	8.3	7.9	4.6	7.0	6.0	5.0	13.6

[1] National automobile-use study conducted by the Bureau of the Census for Public Roads, spring 1961.

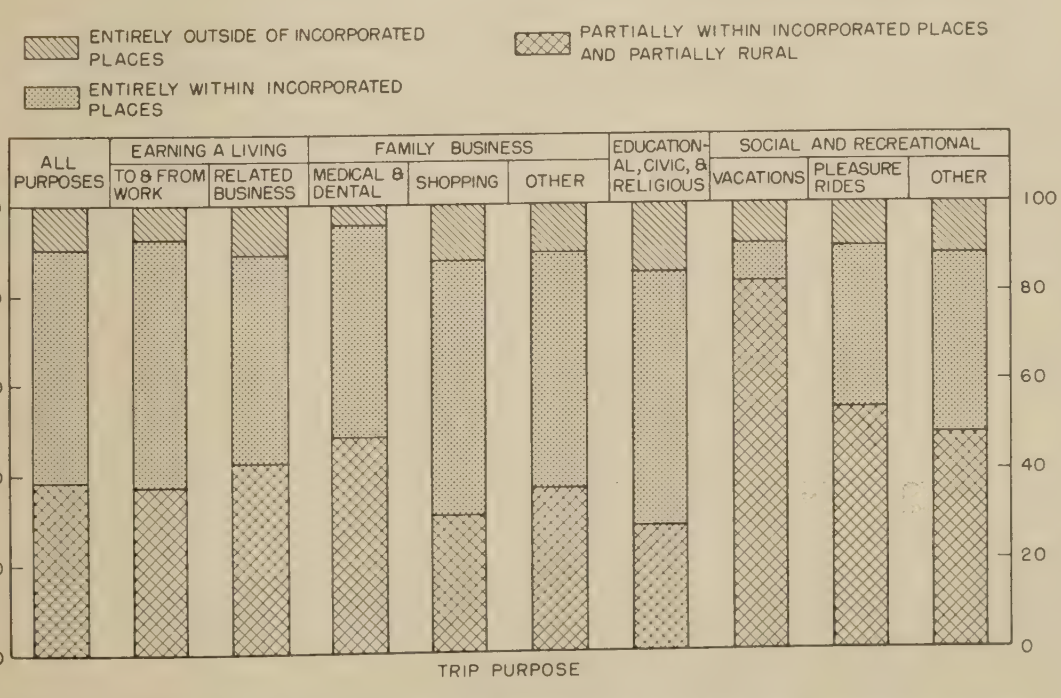

Figure 10.—Automobile trips classified by purpose of each trip and location of travel.

within an incorporated place and partially in a rural area, the average occupancy rate was 1.9 persons per vehicle. On trips made by unincorporated area residents, occupants generally averaged more persons per trip than for the trips made by residents of all incorporated places.

The average occupancy rate for trips related to earning a living was 1.3 persons per trip for all population groups combined. Residents of all incorporated places reported an average occupancy of 1.2 persons per trip, while residents of unincorporated areas reported 1.4 occupants per trip.

On trips made for medical and dental purposes, occupants averaged 2.0 per trip, and 2.2 occupants per trip by residents of unincorporated areas and 1.9 occupants per trip by residents of incorporated places were reported. Where the trip was made partially through an incorporated place and partially through a rural area, the average occupancy per trip was somewhat higher. Other trips made in connection with family business followed somewhat the same pattern as trips for medical and dental purposes, but the average occupancy rate was a little lower: 1.9 persons per trip for shopping purposes and 1.8 persons per trip for other family business.

For trips related to educational, civic, and religious purposes, occupancy averaged 2.4 persons per trip for residents of all places, and 2.6 and 2.3 for residents of unincorporated areas and incorporated places, respectively. The largest number of occupants per trip, an average of 2.7 persons was reported for vacation trips. Unincorporated area residents reported an average occupancy of 3.1 persons for vacation trips, and residents of all incorporated places reported an average occupancy of 2.7 persons per trip. For trips for pleasure rides and other social and recreational purposes, average occupancy was 2.5 and 2.4 persons, respectively.

Distribution of Automobile Trips by Purpose and Location of Travel

As shown in table 15 and figure 10 more than half of all passenger-car trips were made entirely within an incorporated place or within contiguous places. An additional 38 percent of all trips was classified as trips partially within incorporated places and partially in rural areas. These latter trips probably approximate the so-called intercity travel, although some of the trips are undoubtedly not truly intercity.

Fifty-six percent of all to-and-from-work trips was confined entirely within a single incorporated place or contiguous places. Half or more of the trips for purposes other than social and recreational was also urban in character. Eight percent of all vacation trips was taken entirely within incorporated places; the bulk of such travel was reported by California, Kansas, Illinois, and Pennsylvania. Eighty-four percent of all vacation trips involved travel both within incorporated places and in rural areas. Similarly, only a small proportion of trips for any purpose were made completely outside an incorporated place (in

Table 19.—Distribution of trips and travel by day of week for each purpose of travel [1]

Day	All purposes		Earning a living		Family business								Educational, civic, and religious		Social and recreational	
					Medical and dental		Shopping		Other family business		Total					
	Trips	Travel	Trips	Travel	Trips	Travel	Trips	Travel	Trips	Travel	Trips	Travel	Trips	Travel	Trips	Travel
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Monday	15.2	14.1	19.7	19.5	21.5	18.5	12.6	10.6	13.0	11.0	13.4	11.5	13.5	16.1	9.2	8.2
Tuesday	13.4	12.6	16.7	17.3	14.1	10.0	11.2	11.9	13.2	12.9	12.3	12.3	11.4	9.4	8.9	7.1
Wednesday	13.3	12.9	16.3	17.3	16.4	10.1	11.2	11.6	13.5	14.9	12.6	13.3	10.7	9.0	9.4	7.2
Thursday	13.4	11.7	15.9	15.8	16.1	19.0	12.1	11.6	14.0	10.8	13.2	11.8	9.9	12.7	10.6	5.2
Friday	16.5	15.8	18.7	18.1	16.0	25.0	19.9	18.8	16.2	14.9	17.9	17.2	10.5	12.6	12.9	12.2
Saturday	15.4	16.0	9.6	8.4	14.0	15.6	28.3	31.4	20.1	23.0	23.6	25.4	5.6	8.4	20.6	21.0
Sunday	12.8	16.9	3.1	3.6	1.9	1.8	4.7	4.1	10.0	12.5	7.0	8.5	38.4	31.8	28.4	39.1

[1] National automobile-use study conducted by the Bureau of the Census for Public Roads, spring 1961.

a rural area), the greatest number, 14.1 percent, being made for educational, civic, and religious purposes.

Who Does the Driving

Car manufacturers are concerned about their potential market. Thus, it follows that they need to know who drives the vehicles. For example, if the housewife does a high proportion of all the driving, manufacturers undoubtedly will want to give consideration to women when designing new automobiles.

The standard interview form for the motor-vehicle-use studies asks for the occupational group of the principal operator of a vehicle and also the occupational group of the driver for each trip. For the standard tabulations prepared from these studies, all trips and travel were classified according to the occupation of the person shown as the principal operator. To determine the proportion of trips and travel performed by each occupational group according to the principal operator and other than the principal operator, a special analysis was made of a subsample of interview forms from Colorado, Delaware, Kansas, and Tennessee. This analysis showed that 88 percent of all travel and 86 percent of all trips were performed by the persons reported as the principal operators.

Table 16 shows the proportion of travel and trips performed by the principal operator according to occupational groups for residents of all places, all unincorporated areas, and all incorporated places. Traveling salesmen performed all the trips and travel in the vehicles for which they were reported as the principal operators. Persons engaged in the protective services and those in the professional and semi-professional groups reported a very large percentage of the vehicle-miles and trips in the vehicles for which they were reported as being the principal operators. Housewives, however, performed only 63 percent of the travel and 58 percent of the trips in automobiles in which they were reported as the principal operators.

Table 17 shows the proportion of travel performed according to the occupational group

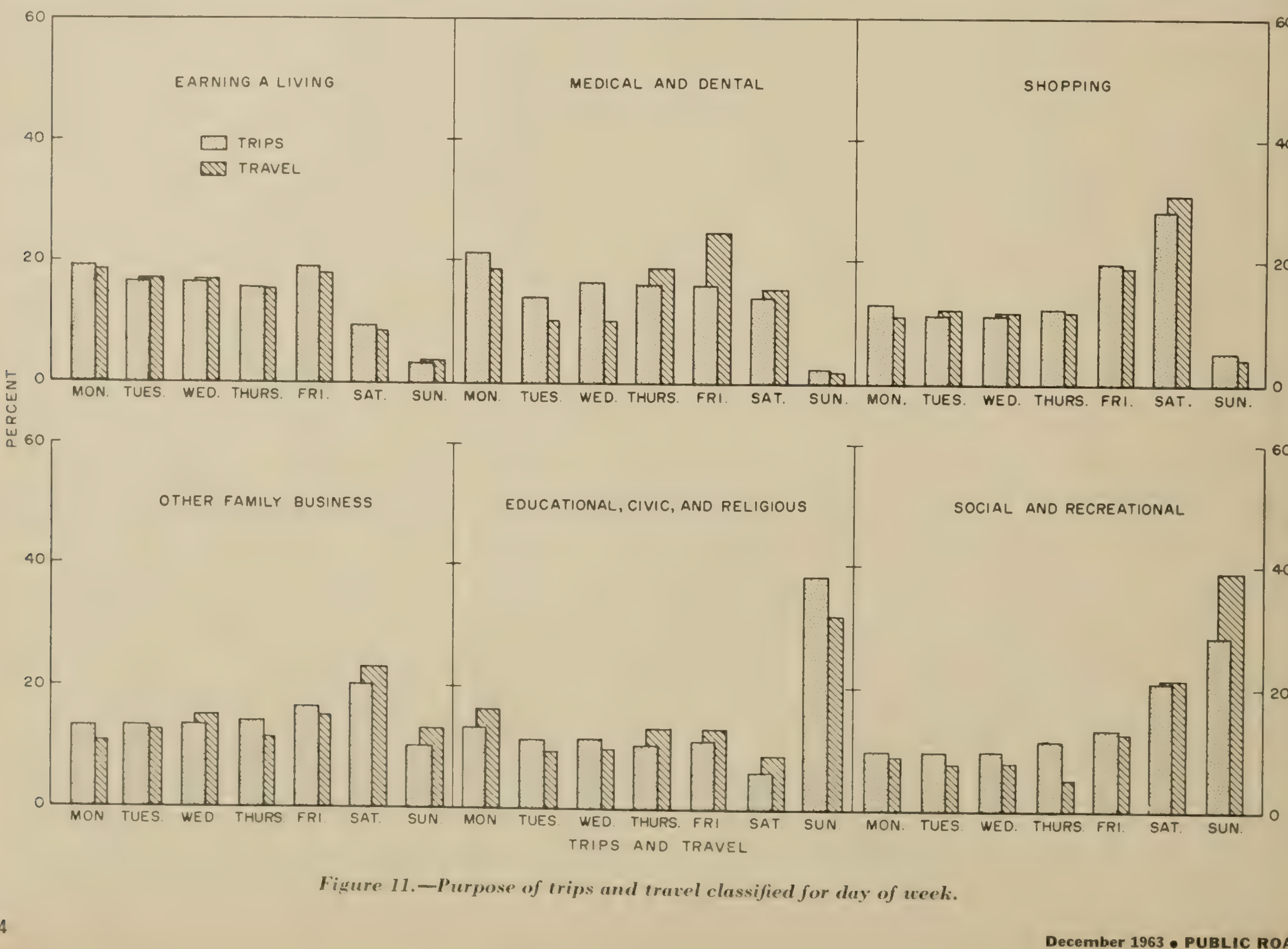

Figure 11.—Purpose of trips and travel classified for day of week.

of the driver. Also, this table shows, by occupational groups, the proportion of travel performed as the principal operator and as other than the principal operator. Skilled and unskilled laborers (including craftsmen, foremen, and operatives) performed one-third of the total travel. Persons in the protective services, traveling salesmen, military personnel, and personal service workers performed a small proportion of the total travel; they also accounted for only a small proportion of the total workers.

Housewives accounted for a high proportion of driving (40.2 percent) in automobiles for which they were not reported as the principal operators. Farmers and farm managers and professional and semiprofessional workers also reported that a high proportion of their driving was done in vehicles in which they were not reported as the principal operator.

Trips and Travel by Day of Week

The average one-way-trip length by passenger cars owned by residents as determined from the study conducted by the Census Bureau for Public Roads was 8.0 miles. This finding agrees with similar data developed from State motor-vehicle-use studies. The tabulations prepared by the Census Bureau give data showing trips and travel for each day of the week. Table 18 shows that trips made on weekdays for all purposes combined were shorter than trips made on weekends. Length of trips made on weekdays averaged 7.0 to 7.8 miles, trips made on Saturdays averaged 8.3 miles, and trips made on Sundays averaged 10.6 miles. Sunday trips made for purposes of earning a living and for social and recreational purposes tended to be longer than trips made for the same purposes on other days. For example, persons who made trips to and from work on Sundays drove an average of 8.1 miles, as compared with from 7.0 to 7.4 miles on weekdays and 6.3 miles on Saturdays.

Table 19 and figure 11 show the distribution of all trips and travel by the day of week for selected purposes of travel. The highest proportion of all trips was made on Fridays and the highest proportion of all travel on Sundays. There were wide variations in the distribution of trips and travel by day of week. The lowest proportion of all trips related to earning a living or family business was made on Sundays. The highest proportion of all trips and travel related to earning a living was made on Mondays, the next higher proportion being reported on Fridays.

Although many persons do shop during the weekdays, approximately 30 percent of all trips and travel for shopping are made on Saturdays. Because many stores are open at least some evenings during the week, it might be anticipated that a smaller proportion of trips and travel for shopping would be made on Saturday. One possible reason for the large number of shopping trips on Saturdays may be that many workers are paid on Fridays and Saturdays. Also, it is possible that the type of shopping done on Saturdays may be different from that done on the weekday shopping trips.

More than 38 percent of all trips and almost 32 percent of all travel for educational, civic, and religious purposes were made on Sunday. This naturally follows as Sunday is the principal day for trips to church. However, it would be expected that trips and travel performed for civic and educational purposes would bulk large on weekdays and would tend to pull these percentages down. Sunday was also the most popular day for social and recreational trips; 28 percent of all such trips and 39 percent of all such travel were made on this day.

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(*4*) *Highway Statistics 1961*, by Bureau of Public Roads, 1963, table MV–1, p. 14.

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Interstate System Accident Research

BY THE TRAFFIC SYSTEMS RESEARCH DIVISION BUREAU OF PUBLIC ROADS

By STANLEY R. BYINGTON, Highway Research Engineer

This article reports the initial findings of a study comparing the traffic accident experience on completed portions of the Interstate Highway System with that on nearby highways, which formerly carried the largest percentage of interstate traffic. Included are data from 16 States for more than 1,000 miles of both Interstate System and nearby highways.

Results of the comparison show that accident rates on the Interstate System are about half as great as those on nearby highways and injury and fatality rates are about one-third as great. Data also show that the Interstate Highway System produced the greatest net reduction in accident rates in the more densely populated areas and the greatest reduction in fatality rates in rural areas. As these areas normally have, respectively, the highest accident and fatality rates, the safety benefits of the Interstate Highway System in terms of accident and fatality reductions are greatest where the need is greatest.

A preliminary estimate has been made that 8,000 lives a year may be saved upon completion of the Interstate Highway System. The article emphasizes that this estimate is preliminary and is based on limited data.

Information collected on the effect of traffic volume, an analysis by manner of collisions, and the importance of access control also are summarized in this article.

Introduction

IN 1939 AND again in 1944, the Bureau of Public Roads reported to the Congress the need for a special system of interregional highways and the necessary connections through and around cities. Legislation passed in 1944 authorized such a System and legislative acts of 1956 and following years have assured the construction of this system, a 41,000-mile network, commonly called the Interstate System.

The need for this System has been expressed in terms of social, economic, and defense benefits. In addition, it has been estimated by different sources that completion of the Interstate System would save from 5,000 to 9,000 lives a year.[1] Accident data are currently being collected by a number of States in a study designed to measure the actual safety benefits that can be attributed to the completion of portions of this system. Accident experience on the Interstate System is being compared with accident experience on nearby highways, hereafter referred to as "existing highways," that Interstate System traffic formerly had to traverse. For brevity, references to data collected prior to construction of the Interstate System are labeled "before" and data collected after its construction "after." When Interstate and existing highway "after" data are combined, reference is made to the Interstate corridor.

This article, which is introductory in scope, describes the study techniques and summarizes the findings based on data collected for 1,130 miles of the Interstate System and 1,000 miles of existing highways. As additional data are collected, more extensive analyses will be made and additional reports will be prepared. Plans for future reports include a more detailed examination of property damage costs associated with accidents occurring on each highway system and the interaction of different design and traffic variables.

Summary

The following paragraphs contain a summary of the principal findings from the first group of data collected in the Interstate System Accident Research Study.

. On the average, accident rates on the Interstate System were slightly more than one-half those on nearby existing highways, either before or after the Interstate System was opened to traffic.

. Injury and fatality rates on the Interstate System were slightly more than one-third as great as those on existing highways.

. The accident and injury rates on the existing highways did not change much after the Interstate System was opened and some traffic was diverted from these highways to the Interstate System. However, fatality rates on existing highways in rural areas declined by more than one-half after opening of the Interstate System.

. The more densely populated urban areas had the greatest net reduction in accident and injury rates, as shown in the comparison of existing highways "before" and the Interstate corridor. Also, the net reduction in injury rates for rural areas followed closely that of the highly urbanized areas. Fatality rates in rural areas were reduced by 71 percent as compared with 24 percent for urban areas.

. The accident rate generally increased as traffic volume increased; this trend was particularly evident for existing highways.

. As expected, head-on, opposite-direction sideswipes, angle, and pedestrian collisions were nearly eliminated on Interstate highways. About one-third of all collisions on these highways were of the rear-end or same direction sideswipe types, and nearly all of the remaining accidents involved only a single vehicle.

. Although control of access is the most important single factor contributing to the excellent safety record of the Interstate System, there is an indication that other elements of modern highway design, such as wide medians, easy curvature and gradient, and long sight distances, are also important.

Study Techniques

In May 1960, all States except Alaska, which had no Interstate System mileage, were invited to participate in an accident study designed to measure the safety benefits that construction of the Interstate System would provide. Up to the present time, 43 States have indicated that they will participate in this research study, and 36 States are already collecting data. This article presents an analysis of the accident data compiled by the 16 States shown in figure 1. As of the closing date selected for summarizing the data, these States had advanced their studies sufficiently to permit at least a limited analysis. Eventually, it is expected that much of the Interstate System mileage plus an equivalent mileage of existing highways will be included in the study.

Study Sections

Mileage on three types of highways was included in this study of highways: Interstate, existing, and control. Existing highways are those highways within the Interstate System corridors that formerly carried the greatest proportion of the present Interstate traffic. Figure 2 illustrates Interstate and existing highway study sections in Iowa.

Whenever an Interstate highway replaced an existing highway on the same location, an effort was made to select a control highway for

[1] *Future Highways and Urban Growth*, by Wilbur Smith & Associates under commission from the Automobile Manufacturers Association. Feb. 1961, p. vii. *Life Saving Benefits of the Interstate System*, by Charles W. Prisk. PUBLIC ROADS, vol. 31, No. 11, Dec. 1961, pp. 219–220.

Table 1.—Number of study sections included in the analysis, length of study sections, and vehicle-miles of travel, by State and type of highway

Types of highways	Arizona	Florida	Georgia	Indiana	Iowa	Kansas	Minnesota	Missouri	New Mexico	New York	North Dakota	Rhode Island	Utah	Vermont	Virginia	Wyoming	Total
Existing highways "before":																	
Number of study sections	6	8	(1)	2	22	7	1	4	35	114	7	4	2	1	8	8	229
Length of sections ..... miles	68.0	22.5	(1)	11.7	67.7	59.1	8.2	25.3	248.4	340.8	32.8	19.1	16.8	7.9	11.1	61.1	1,000.5
Vehicle-miles 100,000	1,440	716	(1)	316	2,513	1,399	293	1,663	10,167	13,645	663	714	2,122	87	420	1,143	37,301
Existing highways "after":																	
Number of study sections	------	8	8	2	22	5	1	4	5	139	6	4	1	1	8	4	218
Length of sections ..... miles	------	22.5	35.2	13.4	67.7	39.2	8.2	25.1	29.0	424.7	30.6	19.1	8.2	7.9	11.1	11.1	753.0
Vehicle-miles 100,000	------	490	4,453	340	472	335	87	729	53	29,692	93	412	287	87	270	119	37,919
Control highways "before":																	
Number of study sections	6	------	------	------	------	------	------	------	7	------	1	------	1	------	------	------	15
Length of sections ..... miles	69.3	------	------	------	------	------	------	------	33.5	------	2.5	------	9.0	------	------	------	114.3
Vehicle-miles 100,000	1,318	------	------	------	------	------	------	------	1,717	------	12	------	171	------	------	------	3,218
Control highways "after":																	
Number of study sections	6	------	------	------	------	------	------	------	7	------	1	------	1	------	------	------	15
Length of sections ..... miles	69.3	------	------	------	------	------	------	------	33.5	------	2.5	------	9.0	------	------	------	114.3
Vehicle-miles 100,000	793	------	------	------	------	------	------	------	1,383	------	1.3	------	36	------	------	------	2,225
Interstate highways, type 5: [2]																	
Number of study sections	6	9	------	2	2	7	1	4	------	13	6	2	2	1	2	8	65
Length of sections ..... miles	68.0	21.3	------	11.7	27.6	59.1	8.0	29.6	------	130.8	30.6	8.1	16.9	7.5	12.2	61.7	493.1
Vehicle-miles 100,000	809	513	------	477	208	626	248	1,575	------	9,013	587	234	478	140	174	505	15,587
Interstate highways, type 6: [3]																	
Number of study sections	------	------	5	1	------	------	------	------	9	23	------	------	------	------	------	------	38
Length of sections ..... miles	------	------	32.2	6.4	------	------	------	------	52.5	310.1	------	------	------	------	------	------	401.2
Vehicle-miles 100,000	------	------	8,294	806	------	------	------	------	1,054	50,579	------	------	------	------	------	------	60,733
Interstate highways, type 7: [4]																	
Number of study sections	------	------	1	------	3	------	------	------	26	------	------	1	------	------	------	------	31
Length of sections ..... miles	------	------	5.2	------	24.7	------	------	------	195.9	------	------	9.4	------	------	------	------	235.2
Vehicle-miles 100,000	------	------	1,849	------	298	------	------	------	8,213	------	------	755	------	------	------	------	11,115

[1] Interstate System study sections were opened to traffic in 1958. No information is presented for comparable existing "before" study sections because accident data were not available prior to 1958.

[2] Study sections were fully improved to Interstate standards. Data included on sections in which the roadway, structures, ramps, guardrails, etc., were accepted from the contractor by the State and opened to traffic. Such work as seeding, signing, striping, and other minor items may or may not havebeen completed.

[3] Study sections include highways that were under construction or completed before July 1, 1956. Such facilities may have substandard shoulders, ramps, median, or other characteristics that may or may not be scheduled for improvement under the current Interstate program.

[4] Study sections include highways that had some minor at-grade intersections. Facilities were not in accordance with AASHO Geometric Design Standards for the National System of Interstate and Defense Highways.

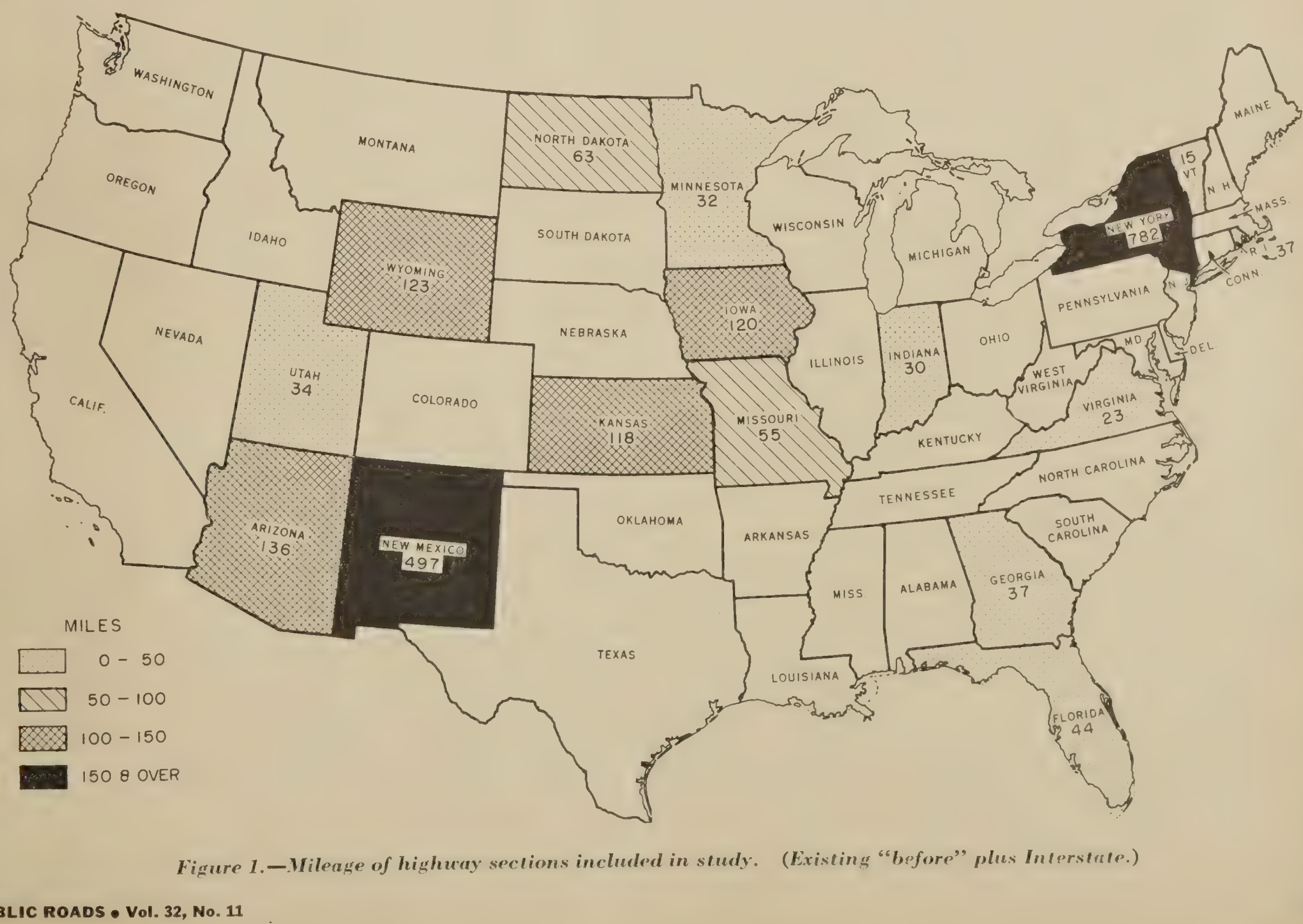


Figure 1.—Mileage of highway sections included in study. (Existing "before" plus Interstate.)

study. Control highways are those routes in reasonable proximity to the obliterated highways that have design, roadside development, and average daily travel characteristics similar to the replaced sections. All three types of highways were divided into study sections for purposes of analysis. These sections were homogeneous with respect to average daily traffic, roadside development, type of area, and number of traffic lanes.

Table 1 shows the number of study sections, their length, and vehicle-miles of travel applicable to the study sections for each of the 16 States for which data are analyzed in this article. Travel data are the summation of vehicle-miles applicable to all study sections for a different number of years before or after the opening of Interstate System sections. A total of 1,000 miles of existing highways, 114 miles of control highways, and 1,130 miles of Interstate highways constituted the lengths of sections under study. A more general geographical distribution of study section mileages would have been desirable in this analysis, as the findings were influenced considerably by data compiled in two States—New Mexico and New York.

Figure 3 is a facsimile of the form used by the States in compiling all of the basic information for the study. One year of data for each study section was recorded on the form.

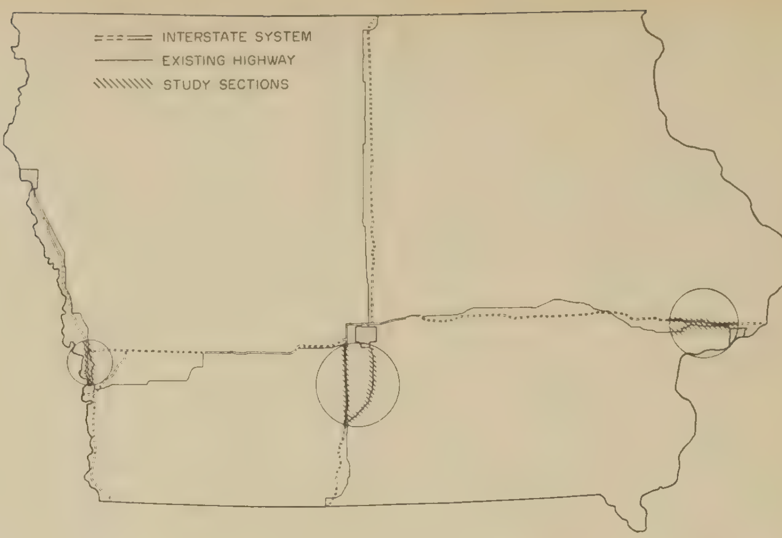


Figure 2.—Illustration of Interstate System and existing parallel highway study sections (encircled) in Iowa. (Broken lines indicate proposed location of Interstate System.)

Highway Data

The highway data collected for each study section consisted of length of section, degree of access control, roadside development, number of at-grade intersections, type of area, and type of highway as shown in items 6–10 of figure 3. The length for each section was determined to the nearest one-tenth mile through the use of "as-built" construction plans, road mileage logs, or odometer readings.

Traffic Data

Average daily traffic volumes were determined for each study section by one of the following described methods: (1) one continuous 24-, 48-, or 96-hour count; (2) four continuous 24-hour counts taken at four different times during the year; or (3) one continuous 7-day count plus one 24-hour count at another time of the year. In the first method, a section's average daily traffic was determined to the nearest 100 vehicles by adjusting the measured volumes for seasonal and daily variations through control station counts. When either of the other two methods were employed, average daily traffic was determined to the nearest 100 vehicles by an averaging process of the measured volumes.

The data from regular traffic counting programs were utilized to the extent possible. Where the regular counting programs did not meet the requirements of the study or no counting programs were in progress, special counts had to be made. The scope of the traffic counting operation may be reduced in the future when data on seasonal fluctuations and general trends appear to be fairly well established.

Accident Data

Wherever possible, accident and related data were obtained for existing highways 4 to 6 years before the opening of the Interstate highway. Accident data obtained for each study section included the total number of accidents reported to State or local authorities, number of persons injured, number of persons killed, and estimated costs of property damage. The number of accidents reported were distributed by types of collision. Accidents that occurred at intersections (at grade) and interchanges, on frontage roads, and on Interstate grade-separated crossroads not having interchanges were included in the study. At interchanges, crossroad accidents were included if they occurred within the limits of 100 feet "outboard" of the ramp terminals. On Interstate grade-separated crossroads not having interchanges, accidents were included when they occurred within 100 feet of the structure or on the structure. The different subgroupings of estimated property damage costs and types of collisions are shown as items 13 and 16 of figure 3. Most accident data were obtained from the States' central accident record files. Depending on the State, these files are maintained by the State highway patrol, the State records division, or a State agency or department of motor vehicles, public safety, law enforcement, or revenue. Other accident data were obtained from records of the city police, county sheriff offices, and toll authorities.

Accident data are being collected for all study sections on a continuing basis. Analyses of these accident data will help to define possible trends that may develop as adjacent sections of the Interstate System are completed and traffic volumes increase.

Property Damage Costs

All accidents for each study section were classified into one of four categories, based on property damage cost information shown on accident records of State or local authorities: (1) less than $100, (2) $100 to $499, (3) $500 or over, and (4) property damage cost not known.

Analysis of Data

The data lent itself to two general types of analysis: group and individual. In the group

Table 2.—Comparison of accidents, injuries, and fatalities occurring on existing highways "before" and "after," with those on Interstate highways.

Item of comparison	Existing highways "Before"	Existing highways "After"	Interstate highways only	Interstate highways plus existing highways "after"
Number of accidents	8,892	9,881	11,829	21,710
Vehicle-miles ... millions	3,730	3,792	8,744	12,536
Accidents per 100 million vehicle-miles	238	261	135	173
Difference in accident rates [1]		23	−103	−65
Percentage change in accident rates [1]		9.7	−43.3	−27.3
Number of injuries	4,968	5,372	4,343	9,715
Injuries per 100 million vehicle-miles	133	142	50	78
Difference in injury rates [1]		9	−83	−55
Percentage change in injury rates [1]		6.8	−62.4	−41.4
Number of fatalities	362	193	247	440
Fatalities per 100 million vehicle-miles	9.7	5.1	2.8	3.5
Difference in fatality rates [1]		−4.6	−6.9	−6.2
Percentage change in fatality rates [1]		−47.4	−71.1	−63.9

[1] Numerical difference or percentage change in rates when compared to existing highways "before."

analysis, comparisons of accident data were made between highway sections having similar traffic volumes. For example, accidents on existing highway sections having traffic volumes between 4,000 and 8,000 vehicles per day were compared with those on Interstate sections, regardless of location, which carried similar traffic volumes. For the individual analysis, comparisons were made only on accident data collected for existing highways and the nearby Interstate study sections. For example, accidents on existing highway sections were compared with those on parallel Interstate sections regardless of the design characteristics of the two types of highways.

Within the two types of analysis, accident rate comparisons were possible for (1) existing highway sections "before" compared with Interstate System sections; (2) existing highway sections "before" compared with existing highway sections "after"; and (3) existing highway sections "before" compared with Interstate plus existing highway sections "after." When sufficient control section data are obtained, a comparison can be made between accidents on control highway sections and existing highway sections "before" with accidents on control highway sections "after" and Interstate System sections. All of the preceding comparisons were included in the analysis of data described in subsequent sections of this article, except control highway comparisons. In the analysis in this article, control highway section data were reported by only 4 of the 16 States, and the limited mileage did not provide a basis for meaningful comparisons. In the analysis consideration was given to such variables as average daily traffic volume, type of study area, degree of access control, number of traffic lanes, and types of accident or collision.

Accident, Injury, and Fatality Rates

In table 2, the number of accidents and the number of persons injured and killed are related to travel on the basis of 100 million vehicle-miles. This accident rate for Interstate highways was 135 accidents per 100 million vehicle-miles, as compared to 238 and 261 accidents per 100 million vehicle-miles respectively, for existing highways "before" and existing highways "after." Thus, the accident rates on Interstate highways were 43 and 48 percent below those of the existing highways "before" and "after," respectively.

Similar comparisons of injury and fatality rates show even greater percentage reductions in these rates on the Interstate highways. Fatality rates on existing highways were reduced 47 percent after the Interstate highways were opened to traffic. The rate of 9.7 fatalities per 100 million vehicle-miles on existing highways "before" was nearly double

ITEM		DO NOT USE THIS SPACE
1. STATE		1, 2
2. SECTION NO. *(1 to 999)*		3, 4, 5
3. YEAR *(12 months ending)*		6, 7
HIGHWAY DATA		8
4. TYPE OF SECTION *(Check one box only)*		
EXISTING HIGHWAY — 1. BEFORE INTERSTATE HIGHWAY OPENED TO TRAFFIC		
2. AFTER INTERSTATE HIGHWAY OPENED TO TRAFFIC		
CONTROL SECTION — 3. BEFORE INTERSTATE HIGHWAY OPENED TO TRAFFIC		
4. AFTER INTERSTATE HIGHWAY OPENED TO TRAFFIC		
INTER-STATE HIGHWAY — 5. FULLY IMPROVED TO INTERSTATE STANDARDS		
6. IMPROVED SUBSTANTIALLY TO INTERSTATE STANDARDS		
7. FULLY OR SUBSTANTIALLY IMPROVED TO INTERSTATE STANDARDS EXCEPT THAT ONE OR MORE INTERSECTIONS ARE AT-GRADE		
5. COMPARABLE SECTION NUMBER OR NUMBERS		9, 10, 11
IF INTERSTATE HIGHWAY IS ON SAME LOCATION AS EXISTING HIGHWAY, CHECK HERE	1 ☐	12
6. LENGTH OF SECTION *(Miles and tenths)*		13, 14, 15
7. DEGREE OF ACCESS CONTROL (AASHO DEFINITION) *(Check one)* 1 ☐ FULL 2 ☐ PARTIAL 3 ☐ NONE		16
8. ROADSIDE DEVELOPMENT AND INTERSECTIONS *(Approximate number of)*		
COMMERCIAL OR BUSINESS ESTABLISHMENTS HAVING DIRECT ACCESS TO THE HIGHWAY		17, 18, 19
AT-GRADE INTERSECTION		20, 21
9. TYPE OF AREA *(Check one)*		22
1. WITHIN A PLACE OF 50,000 POPULATION OR OVER		
2. WITHIN A PLACE OF 5,000 - 50,000 POPULATION		
3. WITHIN A PLACE OF LESS THAN 5,000 POPULATION		
4. WITHIN SUBURBAN FRINGE OF 50,000 POPULATION OR OVER		
5. WITHIN SUBURBAN FRINGE OF LESS THAN 50,000 POPULATION		
6. RURAL		
10. TYPE OF HIGHWAY *(Check one)*		23
1. 2-LANE; 4. 4-LANE DIVIDED; 7. PAIR OF ONE-WAY STREETS		
2. 4-LANE UNDIVIDED; 5. 6-LANE DIVIDED; 8. OTHER *(Specify)*		
3. 6 OR MORE LANE UNDIVIDED; 6. 8 OR MORE LANE DIVIDED		
TRAFFIC DATA		24, 25, 26, 27
11. AVERAGE DAILY TRAFFIC *(To nearest 100 vehicles)*		
ACCIDENT DATA		28, 29, 30
12. TOTAL NUMBER OF ACCIDENTS		
13. NUMBER OF ACCIDENTS WITH PROPERTY DAMAGE		31, 32, 33
LESS THAN $100		
$100 - $499		34, 35, 36
$500 OR OVER		37, 38, 39
AMOUNT OF PROPERTY DAMAGE NOT KNOWN		40, 41, 42
14. TOTAL NUMBER OF PERSONS INJURED		43, 44, 45
15. TOTAL NUMBER OF PERSONS KILLED		46, 47
16. MANNER OF COLLISION - NUMBER OF ACCIDENTS		48, 49, 50
REAR-END OR SIDESWIPE, SAME DIRECTION		
HEAD-ON OR SIDESWIPE, OPPOSITE DIRECTION		51, 52, 53
ANGLE COLLISION		54, 55, 56
COLLISION WITH PEDESTRIAN		57, 58, 59
OTHER COLLISION		60, 61, 62
NON-COLLISION		63, 64, 65
OTHER AND NOT KNOWN		66, 67, 68

Figure 3.—Form used in tabulating accident data for each study section.

Table 3.—Mean rates and ranges in rates of accident occurrence, based on 2 methods of computation

Item of comparison	Summation method [1]			Average method [2]		
	Existing highways		Interstate highways	Existing highways		Interstate highways
	"Before"	"After"		"Before"	"After"	
	MEAN RATE, ALL STATES			MEAN RATE, ALL STUDY SECTIONS [2]		
Accidents per 100 million vehicle-miles	238	261	135	319	344	147
Injuries per 100 million vehicle-miles	133	142	50	174	201	62
Fatalities per 100 million vehicle-miles	9.7	5.1	2.8	11.0	9.3	3.8
	RANGE IN RATES, BY STATE			RANGE IN RATES, BY STUDY SECTION		
Accidents per 100 million vehicle-miles	114–719	115–819	66–208	0–3,914	0–3,392	0–1,142
Injuries per 100 million vehicle-miles	82–347	35–269	36–143	0–2,740	0–2,740	0– 571
Fatalities per 100 million vehicle-miles	0–16.6	0–18.9	0–9.9	0– 449	0– 276	0– 73

[1] Total accidents, injuries, and fatalities occurring on each type of highway were divided by total travel on the respective highways.
[2] Rates were determined by averaging the computed rates for each year of study section data.

Table 4.—Standard error of estimates for comparisons of accidents and injury rates by years and accident rates by average daily traffic volumes

Figure number and title	Standard error of estimate (accidents or injuries per 100 million vehicle-miles)		
	Existing highways "before"	Existing highways "after"	Interstate System highways
Figure 5: Accident rates by years before and after opening of the Interstate System	19.2	7.9	8.1
Figure 5: Injury rates by years before and after opening of the Interstate System	5.5	5.6	3.6
Figure 10: Accident rates by average daily traffic volumes before and after opening of the Interstate System	118.4	66.3	48.1

that of the national average. The generally poor performance of the existing highways undoubtedly was one of the major factors considered in the early scheduling of Interstate System construction.

The question may be asked, What is the total benefit in terms of accident reduction in the Interstate System corridor? To answer this question, the number of accidents occurring on the Interstate System and on existing highways "after" were combined, as shown in table 2. Similarly, the vehicle-miles of travel were combined and a rate computed. This rate of 173 accidents per 100 million vehicle-miles established for the Interstate corridor indicates a decrease of 27 percent or 65 accidents per 100 million vehicle-miles when compared with the accident rate for existing highways "before." In other words, for every 100 million miles of travel in the Interstate System corridor, there were 65 fewer accidents than there would have been in the same corridor if the Interstate System had not been built and if all travel had been confined to existing highways. The foregoing comparison assumes that the accident rate on existing highways would remain constant if the Interstate System were not built, an unlikely assumption as the accident rate tends to increase with increases in traffic volumes (figs. 4 and 10).

Rate Calculation Methods

Two approaches were used in calculating the rates for accidents and injuries and fatalities. In the summation method, the mean accident, injury, and fatality rates were computed by dividing total accidents, injuries, and fatalities occurring on each type of highway by total vehicle-miles traveled on the respective highways. This method was used in determining the rates shown in table 2. Readers are cautioned against general application of these data because States have studied only a limited mileage. Also, a multitude of variables were present in each of the computed rates, such as average daily traffic volumes, number of traffic lanes, rural-urban characteristics, degree of access control, and roadside development.

In the average method, the smallest data breakdown possible was employed as a single observation; that is, data for a single study section for 1 year. This method also has certain limitations. Although study sections are located in similar areas and have similar design characteristics, their average daily traffic volumes may vary throughout the year. Furthermore, the varying amount of travel on each study section causes an imbalance between observations.

As indicated in table 3, the accident rate on the Interstate System was 135 accidents per 100 million vehicle-miles. This rate was computed on the basis of total accidents and total travel on all Interstate System sections (summation method). When each year of data for each study section of the Interstate System was treated separately and the individual accident rates averaged, the resultant accident rate was 147 accidents per 100 million vehicle-miles (average method). The difference in the mean accident rates for the preceding example seems relatively small. However, if accidents on existing highways "before" had been selected for comparison, the difference would have been considerably greater.

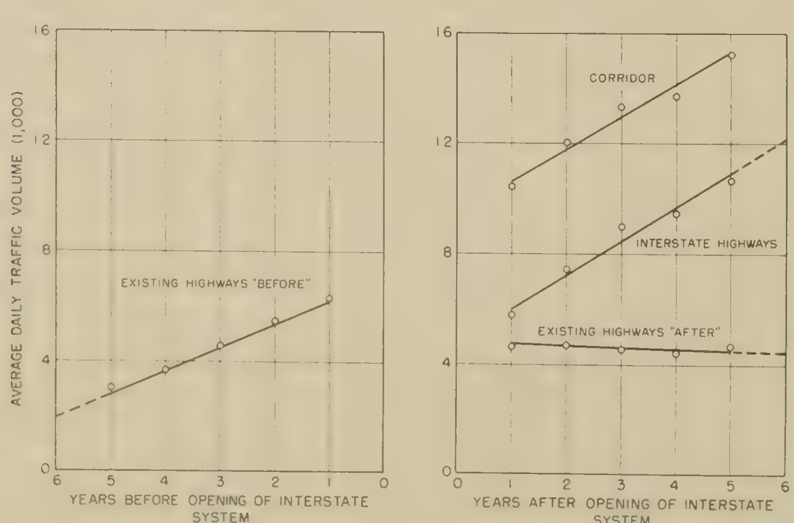


Figure 4.—Average daily traffic volumes, by years, for highway study sections before and after opening of Interstate System.

Statistical reliability

As an indication of the limitations of both methods, table 3 shows the range of accident rates by State for the summation method of computation and the range of rates by study section for the average method. The range of rates indicates that careful consideration must be given to the many design and traffic variables present for the different highway types before generalizations can be made concerning accident experience. However, on the basis of the mean rates and statistical significance curves, a logical conclusion is that the accident rates on the same section of highway. However, there is some justification for their use because highways of the Interstate System corridor carry most of the traffic formerly carried by existing highways "before." Furthermore, if the accident rate does rise as traffic volumes increase to the highway's design capacity, as shown to be true in subsequent discussion of figure 10, then the combined "after" accident data on the Interstate System would be expected to be on the high side. As shown in figure 4, the availability of Interstate highways has generated additional travel.

Figure 4 shows an upward trend in average daily traffic volumes on the existing highways before the Interstate highways were opened to traffic. This growth averaged 17 percent annually in the 2 years before the opening of the Interstate System sections, as compared to only 4 percent each year for highways, generally. This is to be expected because sections selected for initial Interstate construction were probably those indicating the poorest performance because of traffic overloads.

After the Interstate System was opened to traffic, an initial drop occurred in average daily traffic volumes on the existing highways, this volume changed little thereafter. As

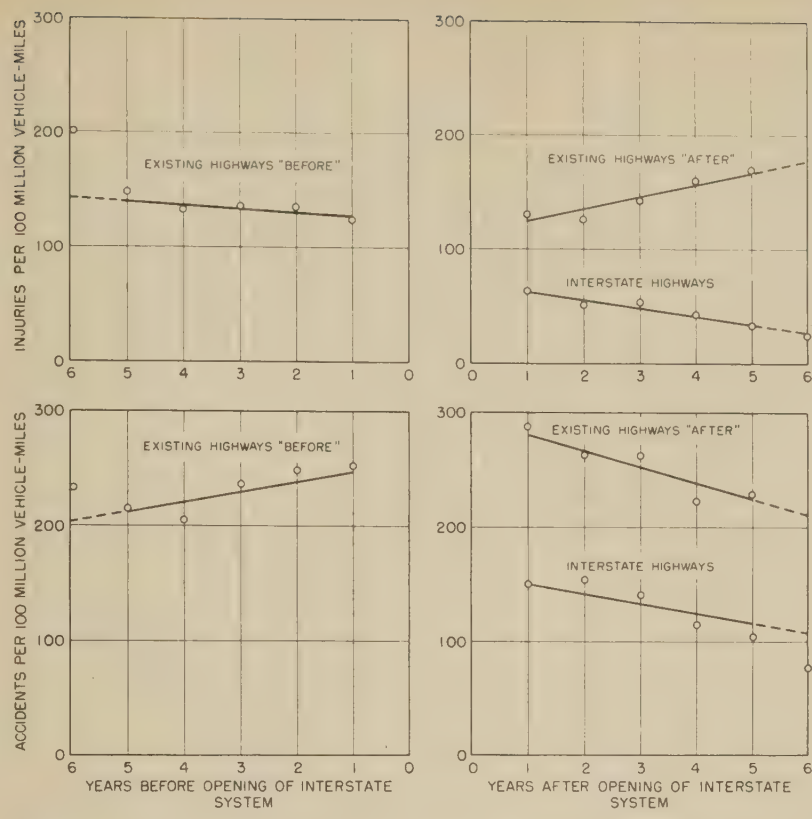


Figure 5.—Accident and injury rates, by years, for highway study sections before and after opening of Interstate System.

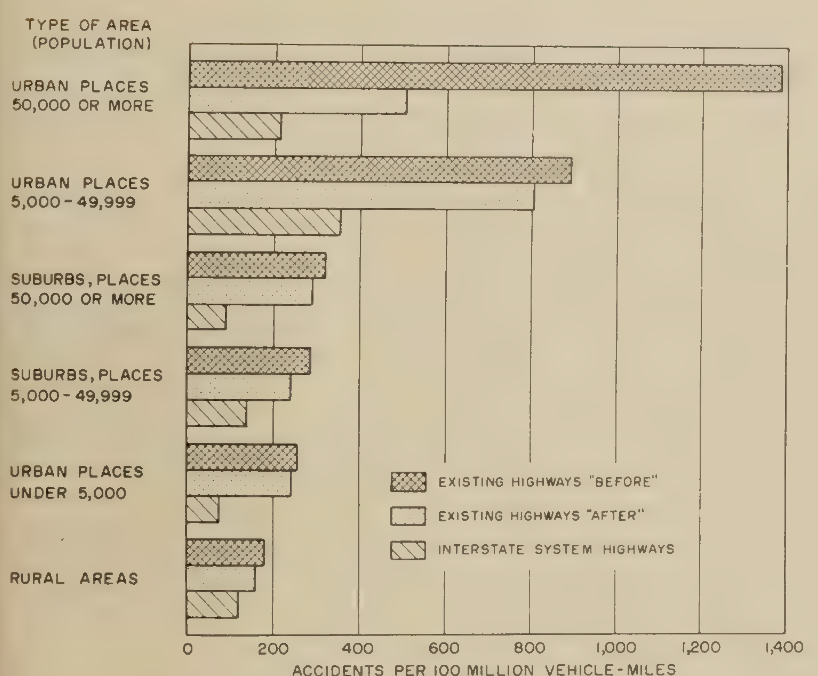


Figure 6.—Accident rates by type of area and class of highway study sections.

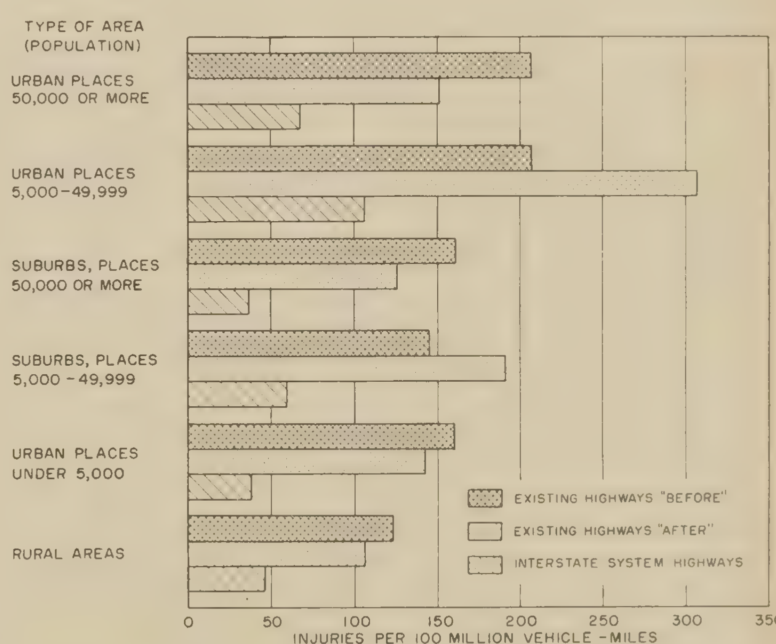


Figure 7.—Injury rates by type of area and class of highway study sections.

combined Interstate System and existing highways "after" are safer than the existing highways "before." [2]

As the accident and injury rates on the "before" and "after" sections of existing highways were nearly the same, all the benefits of accident and injury reduction were traceable to the use of Interstate highways. A Chi Square test indicates that the accident, injury, and fatality rates for the Interstate corridor were significantly lower that the rates for existing highways "before" at the 5-percent level of significance. In contrast, a comparison of rates for the existing "before" and existing "after" sections by means of the Chi Square test curve indicates that only the fatality rate is significantly different.

Readers may well question the use of the statistical curves developed by Michaels as they were designed to test before and after

might be expected, traffic on the Interstate highways increased much more rapidly in absolute volumes than on the existing highways before the Interstate System was opened to traffic. Also of interest is the growth in traffic in the Interstate corridor; that is, the combined traffic on the Interstate highways and on the existing highways "after." The absolute yearly increase in traffic in the Interstate corridor was greater after the Interstate System was opened to traffic than on the existing highways "before." However,

[2] *Two Simple Techniques for Determining the Significance of Accident-Reducing Measures*, by Richard M. Michaels PUBLIC ROADS, vol. 30, No. 10 Oct. 1959, pp. 238–239.

Table 5.—Number of accidents, injuries, and fatalities before and after the opening of Interstate System study sections, by type of area

Type of area (population)	Existing highways "Before"	Existing highways "After"	Interstate System only	Interstate System corridor [1]	Existing highways "Before"	Existing highways "After"	Interstate System only	Interstate System corridor [1]	Reduction [2] Number	Reduction [2] Percent
	NUMBER OF ACCIDENTS				ACCIDENTS PER 100 MILLION VEHICLE-MILES					
Urban places, 50,000 or more	402	2,102	2,226	4,328	1,386	505	213	294	1,092	78.7
Urban places, 5,000–49,999	1,245	1,475	708	2,183	892	805	357	572	320	35.9
Suburban fringe, places of 50,000 or more	291	641	538	1,179	321	289	91	145	176	54.8
Suburban fringe, places under 50,000	1,353	1,586	759	2,345	287	239	140	195	92	32.1
Urban places, under 5,000	591	1,138	93	1,231	258	242	74	207	51	19.8
All urban places	3,882	6,942	4,324	11,266	404	355	173	253	151	37.4
Rural areas	5,010	2,939	7,505	10,444	181	160	120	129	52	28.7
	NUMBER OF INJURIES				INJURIES PER 100 MILLION VEHICLE-MILES					
Urban places, 50,000 or more	60	635	708	1,343	207	152	68	91	116	56.0
Urban places, 5,000–49,999	289	562	210	772	207	307	106	202	5	2.4
Suburban fringe, places of 50,000 or more	146	281	217	498	161	126	37	61	100	62.1
Suburban fringe, places under 50,000	684	1,266	317	1,583	145	191	59	131	14	9.7
Urban places, under 5,000	368	674	48	722	160	143	38	121	39	24.4
All urban places	1,547	3,418	1.500	4,918	161	175	60	110	51	31.7
Rural areas	3,421	1,954	2,843	4,797	123	106	46	59	64	52.0
	NUMBER OF FATALITIES				FATALITIES PER 100 MILLION VEHICLE-MILES					
Urban areas	49	107	66	173	5.1	5.5	2.6	3.9	1.2	23.5
Rural areas	313	86	181	267	11.3	4.7	2.9	3.3	8.0	70.8

[1] Existing highways "after" plus Interstate System.
[2] Existing highways "before" rate minus Interstate System corridor rate.

the percentage increases were less, ranging from 8 to 11 percent each year.

Accident Experience by Years

In any attempt to predict safety benefits that will result from construction of the Interstate System, the variation in accident and injury rates over time must be considered for the different types of highways. Figure 5 shows the accident and injury rates by years for each of the highway systems included in the study. Fatality rates are not shown accordingly because of the limited fatality data available.

Table 6.—Comparison of the effect of access control on accident and injury rates in urban and rural areas, from 2 studies

Highway access control	Urban areas: Controlled-Access Study [1]	Urban areas: Interstate System Accident Study	Rural areas: Controlled-Access Study [1]	Rural areas: Interstate System Accident Study
	ACCIDENTS PER 100 MILLION VEHICLE-MILES			
Full control of access	186	161	151	122
Partial control of access	496	264	211	94
No control of access	526	380	322	169
	FATALITIES PER 100 MILLION VEHICLE-MILES			
Full control of access	2.6	2.5	3.3	2.3
Partial control of access	4.6	3.3	6.1	6.6
No control of access	4.0	5.5	8.7	8.4

[1] *Federal Role in Highway Safety*, House Document 93, 86th Cong., 1st sess., 1959, p. 58.

Trend lines illustrated in figure 5 were developed by the Least Squares method, assuming a straightline trend. It is recognized that a straight line of regression does not always satisfactorily describe accident and injury rate trends. However, the straightline relationship appears reasonable because of the low standard errors of estimate shown in table 4 for the three types of highways.

The accident and injury trend lines in figure 5 reveal relationships described in the following paragraphs:

An upward trend in accident rates is shown for existing highways "before," but the injury rates show a slight decline. Increasing traffic congestion and corresponding decreases in average speeds may have accounted for the declining injury rate.

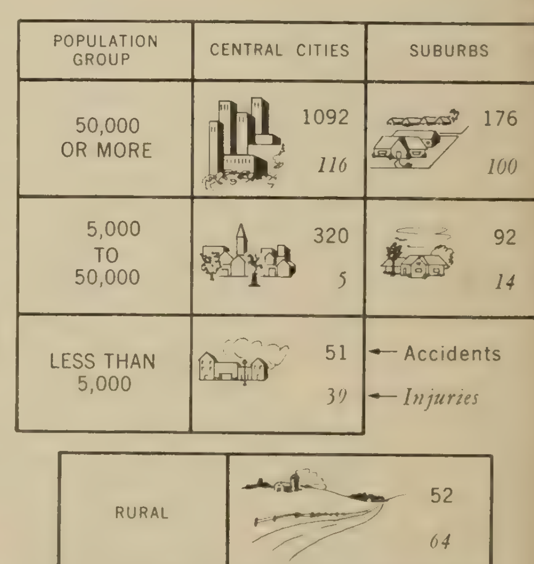
After the opening of Interstate highways, the accident rates on existing highways "after" declined whereas the injury rates increased.

Most noteworthy are the lower accident and injury rates on the Interstate System as compared to those on existing highways "before" and "after," and the declining rates of accidents and injuries on Interstate highways in the years following the opening of these facilities.

To determine the influence of certain design and traffic variables on accident and injury rates, subsequent sections of this article are devoted to accident comparisons made on the basis of type of area, degree of access control, and average daily traffic volumes.

Accident and Injury Rates, by Type of Area

Accident and injury rates for three types of highways located in urban places of different population sizes and in rural areas are shown in figures 6–7. Both accident and injury rates for Interstate System highways were lower than those for existing highways in rural areas and in urban areas, regardless of the population size of urban places. Accident rates were also less for the existing highways after the Interstate highways were opened to traffic. Injury rates declined on existing highways after construction of Interstate routes, except in urban places having populations from 5,000 to 50,000; no reason is apparent for the increase in injury rates in these places.



Reduction In Accidents And Injuries Per 100 Million Vehicle-Miles

Figure 8.—Reduction in accident and injury rates, by type of area, after Interstate System study sections were opened to traffic.

The reduction in accident and injury rates brought about by the construction of Interstate System highways is evident when the rates for existing highways "before" are compared with those for the Interstate corridor (Interstate highways plus existing highways "after"). Such a comparison is given in table 5. The numerical values in figure 8 represent the reduction, after the Interstate highways were built, in accidents and injuries per 100 million vehicle-miles of travel. The greater the population density, the greater the benefits in accident reduction. Injury rate reductions were greatest in the large metropolitan areas and in rural areas. The beneficial effects that Interstate construction had on the fatality rates are also shown in table 5. In rural areas, fatality rates dropped from 11.3 to 3.3, a reduction of 8.0 fatalities per 100 million vehicle-miles. In urban areas, the net reduction was 1.2 fatalities per 100 million vehicle-miles.

On the basis of data collected in this study, valid estimates cannot be made as to the possible number of lives that will be saved when the Interstate System is completed. The reliability of these data is questioned because sections of the Interstate may have been programed for early construction in areas where existing highways had poorest performance and high fatality rates. Preliminary but unpublished data for 26 States and the District of Columbia collected for the "Interstate System Traveled-Way Study" tend to support these conclusions on Interstate programing. This latter study is a cooperative undertaking of all State highway departments and the Bureau of Public Roads. Data collected for the study reported here and the traveled-way study are compared in the following paragraphs.

In the present study, the fatality rates for 1,000 miles of existing highways "before" were 5.1 deaths per 100 million vehicle-miles in urban areas and 11.3 in rural areas. All of this mileage has now been superseded by Interstate System improvements. In the traveled-way study, 17,000 miles of highways planned to be relieved of traffic by future Interstate construction had comparable fatality rates of 3.7 deaths per 100 million vehicle-miles in urban areas and 7.0 in rural areas. By combining the data from the two studies, preliminary estimates of the number of lives that may be saved upon completion of the Interstate System in 1972 may be developed.

Fatality Rates

	Urban	Rural
Existing highways "before" (2 studies combined) . .	4. 1	8. 1
Interstate System corridor (current study only, see table 5)	3. 9	3. 3
Reduction in fatality rates	0. 2	4. 8

The fatality rates for existing highways "before" are based on the assumption that: the rates obtained in the study reported here were representative of the first one-quarter of the existing mileage programed for construction, and the fatality rates obtained in the traveled-way study were representative of the remaining mileage of existing highways. Thus, the rates for the current study were given a weight of unity; and the traveled-way study, a weight of three.

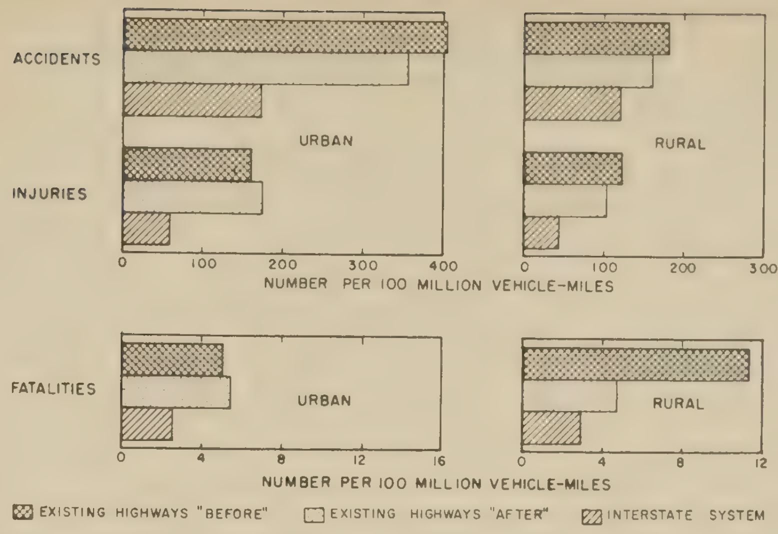


Figure 9.—Accident, injury, and fatility rates by class of highway within urban and rural areas.

Annual travel on the Interstate System at its completion in 1972 is estimated to be 240 billion vehicle-miles and total travel in the Interstate corridor is estimated at 300 billion vehicle-miles. During 1972, travel in the Interstate System corridor has been estimated, in the Highway Cost Allocation Study, at approximately 64 percent rural and 36 percent urban. In *Future Highways and*

Table 7.—Number of accidents, injuries, and fatalities and their corresponding rates by type of highway and access control

Access control by types of highways	Accidents		Injuries		Fatalities	
	Number	Number per 100 million vehicle-miles	Number	Number per 100 million vehicle-miles	Number	Number per 100 million vehicle-miles
RURAL AREAS						
Full control of access:						
Interstate highways	6, 502	122	2, 187	41	125	2. 3
Existing highways "after"	33	140	17	72	--------	--------
Existing highways "before"	5	(1)	3	(1)	1	(1)
Partial control of access:						
Interstate highways	458	91	327	65	32	6. 3
Existing highways "after"	30	231	23	177	2	(1)
No control of access:						
Interstate highways	545	135	329	81	24	5. 9
Existing highways "after"	2, 876	160	1, 914	106	84	4. 7
Existing highways "before"	5, 005	181	3, 418	123	312	11. 3
URBAN AREAS, LESS THAN 50,000 POPULATION						
Full control of access:						
Interstate highways	1, 560	181	575	67	24	2. 8
No control of access:						
Existing highways "after"	4, 199	319	2, 502	190	81	6. 1
Existing highways "before"	3, 189	379	1, 341	160	45	5. 4
URBAN AREAS, 50,000 OR MORE POPULATION						
Full control of access:						
Interstate highways	2, 177	150	802	55	34	2. 3
Partial control of access:						
Interstate highways	587	318	123	67	8	(1)
Existing highways "after"	279	194	106	74	3	(1)
No control of access:						
Existing highways "after"	2, 464	498	810	164	23	4. 6
Existing highways "before"	693	579	206	172	4	(1)

[1] Too few accidents, injuries, or fatalities to be significant.

Urban Growth, it was estimated that 40 percent of the travel in the Interstate System corridor would be rural and 60 percent urban. The differences in these estimates are attributed to the method of estimating. For purposes of this study, it has been assumed that 55 percent of the Interstate System corridor travel during 1972 will be in rural areas and 45 percent in urban areas. Application of the reduction in fatalities (4.8 rural and 0.2 urban) to the estimated travel figures shows that in 1972 approximately 8,000 lives may be saved by virtue of operation of the Interstate System. It should be emphasized that the estimate of lives to be saved is based on limited data. As more information becomes available from the two continuing studies, more reliable estimates will be possible. Figure 9 illustrates accident, injury, and fatality rates in urban and rural areas for the three types of highways, based on the current analysis.

Effect of Degree of Access Control

For several years the Bureau of Public Roads has been conducting studies of the effects of access control on accidents and fatalities. Accident and fatality rates obtained for the controlled-access study and the current Interstate System accident study are shown in table 6. The results of both studies definitely demonstrate that full control of access should be used wherever possible to minimize accidents and resultant fatalities. The principal difference in comparing the data for the two studies was related to highways having partial control of access. Findings of the controlled-access study indicated that partial access control on highways in urban areas contributed little in safety benefits. Interstate System study shows that both accident and fatality rates for highways having partial access control were considerably below the rates for highways having no access control. The differences in data collected in the two studies may have been the result of the interpretation as to what constitutes partial control of access. In subsequent reports collected for this study, the effect of partial control of access will be considered in more detail.

Accident, injury, and fatality rates, distributed on the basis of extent of access control and as to rural or urban location, are shown in table 7. The benefits of modern highway design, in both rural and urban areas, are plainly evident when accident, injury, and fatility rates for highways having full control of access are compared with those having no control of access. However, for accident and injury rates, greater benefits accrue to fully controlled-access facilities located in urban areas than those in rural areas. Fatality rates on highways having full control of access in both rural and urban areas were considerably below those for highways that had no control of access; the rate decreased by approximately two-thirds in rural areas and about one-half in urban areas.

Table 8.—Number of accidents and accident rates before and after the opening of Interstate System study sections, by type of highway and average daily traffic volume

Highway	Accidents and accident rates for highways by average daily traffic volumes—						
	Under 2,000	2,000–3,900	4,000–7,900	8,000–15,900	16,000–31,900	32,000–63,900	64,000 and more
NUMBER OF ACCIDENTS							
2-lane highways:							
Existing highways "before"	122	2,242	1,929	1,439	1,065	------	------
Existing highways "after"	364	701	2,600	1,367	29	------	------
3-lane highways:							
Existing highways "before"	------	250	363	99	------	------	------
Existing highways "after"	3	395	198	28	------	------	------
4-lane undivided highways:							
Existing highways "before"	------	53	198	736	------	------	------
Existing highways "after"	19	166	781	1,159	57	------	------
4-lane divided highways:							
Existing highways "before"	------	45	120	------	------	------	------
Existing highways "after"	50	198	79	302	------	------	------
Interstate System highways	45	804	3,807	4,556	605	1,059	------
6-lane divided highways:							
Interstate System only	------	------	415	------	16	271	351
ACCIDENTS PER 100 MILLION VEHICLE-MILES							
2-lane highways:							
Existing highways "before"	157	172	228	265	475	------	------
Existing highways "after"	276	181	201	294	196	------	------
3-lane highways:							
Existing highways "before"	------	352	179	412	------	------	------
Existing highways "after"	120	188	288	566	------	------	------
4-lane undivided highways:							
Existing highways "before"	------	294	472	353	------	------	------
Existing highways "after"	316	392	354	284	241	------	------
4-lane divided highways:							
Existing highways "before"	------	157	111	------	------	------	------
Existing highways "after"	176	136	188	244	------	------	------
Interstate System highways	99	108	153	104	161	263	------
6-lane divided highways:							
Interstate System only	------	------	630	------	67	180	343

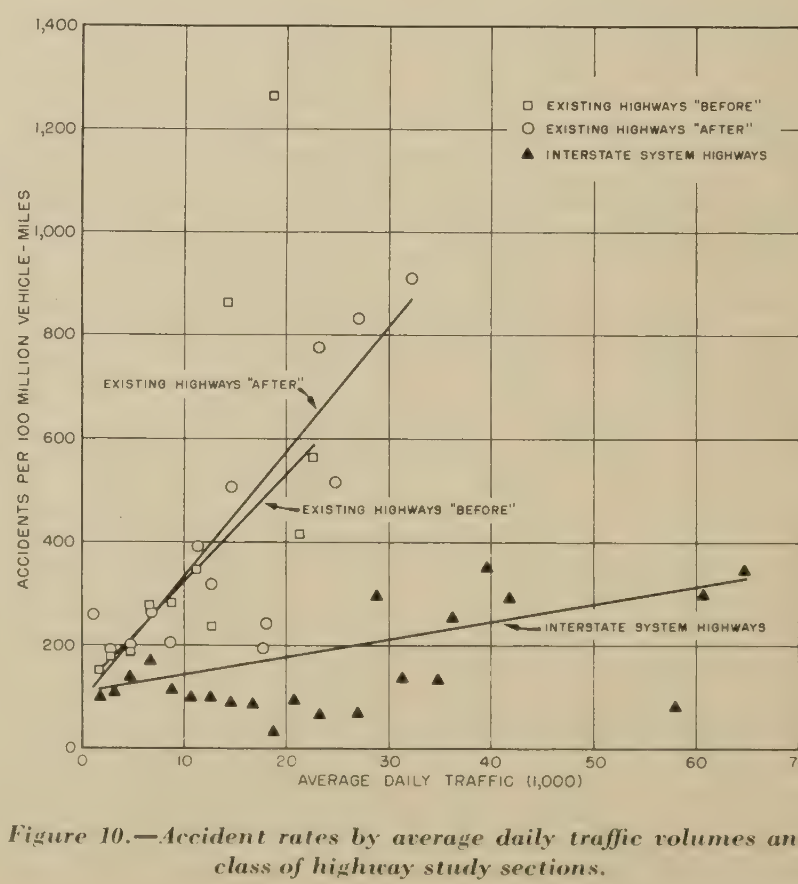


Figure 10.—Accident rates by average daily traffic volumes and class of highway study sections.

Table 9.—Comparison of accident rates, by type of collision, before and after the opening of Interstate System study sections

Type of collision or accident	Existing highways, "before"		Existing highways, "after"		Interstate System highways		Ratio (existing highways "before"÷Interstate System highways)
	Accidents per 100 million vehicle-miles	Percent of total	Accidents per 100 million vehicle-miles	Percent of total	Accidents per 100 million vehicle-miles	Percent of total	
Collision:							
Head-on or sideswipe, opposite direction	34	14	24	9	1	1	34.0:1
Angle	32	13	56	21	4	3	8.0:1
Collision with pedestrian	4	2	6	3	1	(1)	4.0:1
Rear-end or sideswipe, same direction	94	39	106	41	47	35	2.0:1
Other	37	16	51	19	49	36	0.8:1
Noncollision accidents	37	16	18	7	33	25	1.1:1
ALL ACCIDENTS	238	100	261	100	135	100	1.8:1

[1] Less than 0.5 percent.

Table 10.—Number of accidents occurring in rural and urban areas, by type of highway and property damage cost intervals

Property damage cost intervals	Existing highways "Before"		Existing highways "After"		Interstate System only		Interstate System corridor [1]	
ACCIDENTS IN RURAL AREAS								
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Under $100	484	9.7	367	12.5	2,041	27.2	2,408	23.1
$100–$499	2,152	42.9	944	32.1	3,432	45.7	4,376	41.9
$500 and more	1,884	37.6	505	17.2	1,962	26.2	2,467	23.6
Cost unknown	490	9.8	1,123	38.2	70	.9	1,193	11.4
TOTAL	5,010	100.0	2,939	100.0	7,505	100.0	10,444	100.0
ACCIDENTS IN URBAN AREAS								
Under $100	861	22.2	1,019	14.7	725	16.8	1,744	15.5
$100–$499	1,614	41.6	1,817	26.2	974	22.5	2,791	24.8
$500 and more	612	15.7	679	9.8	469	10.8	1,148	10.2
Cost unknown	795	20.5	3,427	49.3	2,156	49.9	5,583	49.5
TOTAL	3,882	100.0	6,942	100.0	4,324	100.0	11,266	100.0

[1] Interstate System plus existing highways "after."

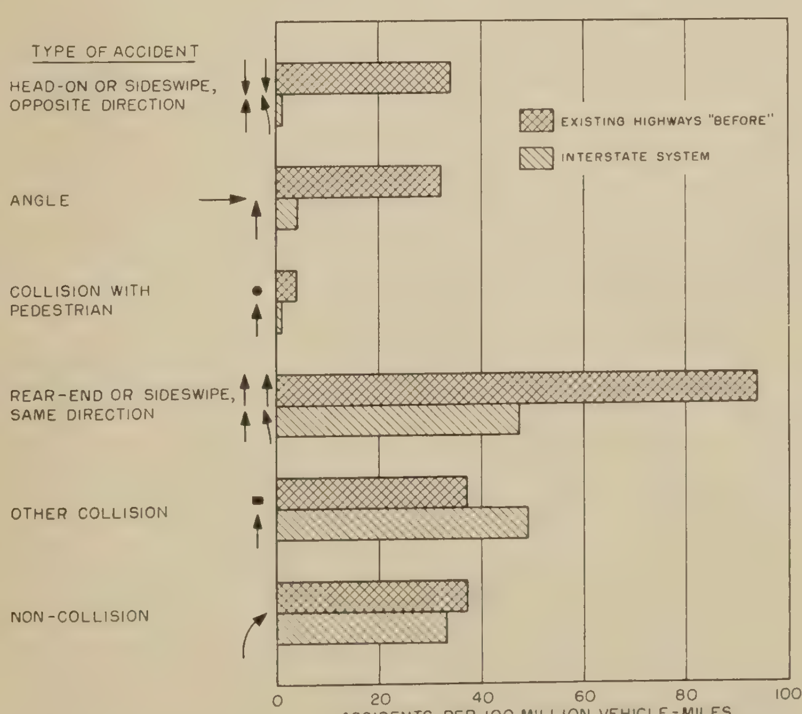


Figure 11.—Accident rates by type of accident and class of highway study section.

The extent to which access to highways is controlled is perhaps the most important design factor in terms of accident reduction. However, other features of modern design practices are also important. In rural areas, Interstate highways had lower accident and injury rates than existing highways "before" and "after," regardless of the degree of access control. This finding indicates that other design features such as wide medians, easy curvature and gradient, and long sight distances may have also contributed to the improved safety record of the Interstate System.

In initiating construction of the Interstate System, the States have concentrated their efforts in different areas. Some States have constructed their initial Interstate System mileage in congested metropolitan areas, whereas other States have built their initial mileage in rural areas. But, regardless of the type of area in which the Interstate System is constructed safety benefits accrue. The Interstate System is particularly effective in reducing the frequencies of accidents and injuries in highly urbanized areas and fatalities in rural areas.

Although type of area and control of access greatly influence incidence of accidents, the ability of the roadway to accommodate traffic or its capacity is another significant factor. Two variables closely associated with capacity are averge daily traffic volume and type of highway; that is, number of traffic lanes and whether opposing traffic is separated by a median. Other studies [3] have shown a definite relationship between average daily traffic volumes and accident rates. The study reported here confirms the relationship. Regardless of whether average daily traffic volumes are considered separately or in conjunction with types of highways, the answer is the same: traffic volumes do influence accident rates.

Tests of Independence and Linearity of Regression for regression coefficients, accident rates and ADT, were made for each of the types of highways shown in table 8. In making these tests, different average daily traffic groups were used from those shown in the table. Average daily traffic volumes in intervals of 2,000 vehicles per day were used in the tests: 0–2,000, 2,000–4,000, 4,000–6,000, and so forth. Results of the tests indicated that accident rates were dependent on average daily traffic volumes for all types of highways, except 3-lane existing "before" highways. For all highway types except 4-lane undivided existing "before" 4-lane divided existing "after," and 6-lane Interstate, the group mean accident rates followed a straightline relationship. No attempt was made to determine the de-

[3] *Effects of Average Speed and Volume on Motor-Vehicle Accidents on Two-Lane Tangents,* by D. M. Belmont, Highway Research Board Proceedings, 1953, vol. 32 p. 383–395. *The Interstate Highway Accident Study,* by M. S. Raff, PUBLIC ROADS, vol. 27, No. 8, June 1953, pp. 170–186. *The Influence of Major Highway Improvements on Traffic Accidents,* by A. H. Vey, Civil Engineering, vol. 7, No. 3, Mar. 1937, p. 213.

gree of correlation between average daily traffic volumes and accident rates for those highways whose rates did not follow a straight-line trend.

Figure 10 shows the relationship between average daily traffic and accident rates. For each of the three systems, existing "before" and "after" and Interstate, the accident rate increased as traffic volumes increased. The graph also shows that as the traffic volumes increased, Interstate safety benefits also increased, as measured by the distance between the trend lines of existing and Interstate highways. This relationship is particularly significant in that the accident rates for existing highways, as derived for the graph, included many highway types—2-lane 3-lane, and 4-lane divided and undivided. Table 4 shows the standard errors of estimate for the curves illustrated in figure 10.

Accidents by Type of Collision

Three types of collision—head-on, opposite direction sideswipe, and angle—are practically eliminated by modern design standards of the Interstate System. This finding would be expected because of the separation of opposing streams of traffic and the grade separation of intersecting highways. Table 9 and figure 11 show the frequencies of accident occurrence, by type of collision, for existing highways and Interstate highways.

Accident rates for rear-end and same direction sideswipe collisions on Interstate highways were approximately one-half those for existing highways "before" and "after." Other accident rates by type of collision, principally collision with fixed objects and noncollision accident rates, were similar for existing highways and Interstate routes.

Perhaps the most meaningful comparision of accident rates, by type of collision or accident, for Interstate highways with those for existing highways "before" is given in the extreme right column of table 9. Ratios provided therein indicate that only one type of collision happened on Interstate highways more frequently than on existing highways "before"—collisions classed as "other." The latter classification includes principally single-vehicle collisions with fixed objects. The proportion of angle collisions on the existing highways increased more than 50 percent after the Interstate System was opened to traffic. Conversely, the proportion of head-on or sideswipe (opposite direction) accidents and the proportion of noncollision accidents were reduced by approximately one-half. The diversion of through traffic to the Interstate System may have influenced these changes in accident patterns on the existing highways.

Property Damage Costs Associated With Accidents

Accident rates on the Interstate System are much lower than on other highways. Although it is not possible to make precise cost comparisons, the evidence does indicate that property damage costs for accidents on Interstate highways were no greater than those on existing highways. Table 10 summarizes property damage costs data obtained in the study. It is emphasized that data on costs other than property damage were not obtained in this study. Moreover, a high proportion of the property damage costs were reported as "unknown."

Future Reports

As more study data are collected, further analyses will be made of accidents in relation to the variables being studied: average daily traffic volumes, type of area, degree of access control, number of business or commercial establishments per mile, number of at-grade intersections per mile, type of collision, and property damage costs per accident. Such analyses will include: (1) correlations of two or more of the variables; (2) an expansion of the different highway systems' accident, injury, and fatality rate trends; (3) a more comprehensive cost analysis as accident cost study data are refined; (4) development of accident, injury, fatality, and cost equations in conjunction with future travel forecasts.

NEW PUBLICATIONS

Highway Bond Financing . . . An Analysis 1950–1962

Highway Bond Financing . . . An Analysis 1950–1962, a 45-page publication in which are reviewed the highway borrowing practices of the States, and to a lesser extent, of the local governments during the 1950–62 period, has been issued by the Bureau of Public Roads. This publication may be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402, at 35 cents a copy.

In this publication, highway debt is examined in terms of its magnitude, its relation to other types of debt, and its comparative costs to the highway user by means of guaranteed or revenue bond financing The effects of constitutional limitations upon creation of debt are measured and evaluated; these limitations are shown to have been largely ineffectual in restricting highway borrowing.

Some of the other facets of highway bond financing discussed include: development and impact of the authority device in financing highways by revenue bonds; comparison of interest costs and scheduled maturities of revenue bonds with other types of highway bonds; specific bond financing programs developed in selected States; resurgence in toll-road financing; and use of the authority device to finance toll-free highway programs.

The conclusion points out that the method of financing accelerated highway programs depends upon the decision to pay-as-you-go or resort to credit financing and that the use of guaranteed bonds, highway tax bonds, or short-term financing in lieu of revenue bonds can hold the costs of borrowing for highway construction to a minimum consistent with the public interest.

Estimated Travel by Motor Vehicles in 1962

BY THE CURRENT PLANNING DIVISION
BUREAU OF PUBLIC ROADS

Reported by THEODORE S. DICKERSON,
Highway Engineer

MOTOR-VEHICLE travel in the United States in 1962 totaled 767.8 billion vehicle-miles, an increase of 4.1 percent over the travel in 1961. The travel data were compiled from information supplied by the State highway departments and toll authorities. Total travel for 1963, based on information for the first 9 months of the year is estimated at 798 billion vehicle-miles, a 4-percent increase over 1962.

The proportions of travel by road system and by vehicle type changed little from 1961 to 1962. Of the 1962 travel, 40 percent was on main rural roads comprising 14 percent of the Nation's total of 3.6 million miles of roads and streets. Another 46 percent of the travel was on urban streets, which comprise only 13 percent of the total mileage. Local rural roads accounted for only 14 percent of the travel but make up 73 percent of the total mileage.

Passenger cars represented 83.5 percent of the vehicles registered and accounted for 81.8 percent of the travel in 1962; trucks and truck combinations accounted for 16.1 percent of the vehicles registered and 17.6 percent of the travel. Buses accounted for 0.4 percent of all vehicles registered and for 0.6 percent of total travel.

Average vehicle performance in 1962 differed very little from that reported for 1961. The average motor vehicle traveled 9,635 miles in 1962, almost half of it in cities, and consumed 774 gallons of fuel at a rate of 12.44 miles per gallon. The average passenger car traveled 9,435 miles and consumed 654 gallons of fuel at a rate of 14.42 miles per gallon. The average truck traveled a little more and the average commercial bus a little less in 1962 than in 1961, but their average rates of fuel consumption did not change appreciably.

The travel and related information for 1962 is shown in table 1 by road system and vehicle type. Such data have been reported in PUBLIC ROADS magazine for a number of years; the latest, for 1961, appeared in vol. 32, No. 7, April 1963, p. 180.

Table 1.—Estimated motor-vehicle travel in the United States and related data for calendar year 1962 [1]

Vehicle type	Motor-vehicle travel					Number of vehicles registered	Average travel per vehicle	Motor-fuel consumption		Average travel per gallon of fuel consumed
	Main rural road travel	Local rural road travel	Total rural travel	Urban travel	Total travel			Total	Average per vehicle	
	Million vehicle-miles	*Million vehicle-miles*	*Million vehicle-miles*	*Million vehicle-miles*	*Million vehicle-miles*	*Thousands*	*Miles*	*Million gallons*	*Gallons*	*Miles/gallon*
Passenger cars [2]	242,521	82,099	324,620	303,619	628,239	66,589	9,435	43,570	654	14.42
Buses:										
Commercial	915	165	1,080	1,776	2,856	75.5	37,828	609	8,066	4.69
School and nonrevenue	656	694	1,350	270	1,620	209.7	7,725	229	1,092	7.07
ALL BUSES	1,571	859	2,430	2,046	4,476	285.2	15,694	838	2,938	5.34
All passenger vehicles	244,092	82,958	327,050	305,665	632,715	66,874	9,461	44,408	664	14.25
Trucks and combinations	66,092	21,460	87,552	47,507	135,059	12,809	10,544	17,288	1,350	7.81
ALL MOTOR VEHICLES	310,184	104,418	414,602	353,172	767,774	79,683	9,635	61,696	774	12.44

[1] For the 50 States and District of Columbia.
[2] Includes taxicabs; also motorcycles (660,400 registered).

PUBLICATIONS
of the Bureau of Public Roads

A list of the more important articles in PUBLIC ROADS *and title sheets for volumes 24–31 are available upon request addressed to Bureau of Public Roads, Washington, D.C., 20235.*

The following publications are sold by the Superintendent of Documents, Government Printing Office, Washington, D.C., 20402. Orders should be sent direct to the Superintendent of Documents. Prepayment is required.

ANNUAL REPORTS

Annual Reports of the Bureau of Public Roads:

1951, 35 cents. 1955, 25 cents. 1958, 30 cents. 1959, 40 cents. 1960, 35 cents. 1962, 35 cents. (Other years, including 1961 report, are now out of print.)

REPORTS TO CONGRESS

Factual Discussion of Motortruck Operation, Regulation and Taxation (1951). 30 cents.

Federal Role in Highway Safety, House Document No. 93 (1959). 60 cents.

Highway Cost Allocation Study:

First Progress Report, House Document No. 106 (1957). 35 cents.

Final Report, Parts I–V, House Document No. 54 (1961). 70 cents.

Final Report, Part VI: Economic and Social Effects of Highway Improvement, House Document No. 72 (1961). 25 cents.

The 1961 Interstate System Cost Estimate, House Document No. 49 (1961). 20 cents.

U.S. HIGHWAY MAP

Map of U.S. showing routes of National System of Interstate and Defense Highways, Federal-Aid Primary Highway System, and U.S. Numbered Highway System. Scale 1 inch equals 80 miles. 25 cents.

PUBLICATIONS

Aggregate Gradation for Highways: Simplification, Standardization, and Uniform Application, and A New Graphical Evaluation Chart (1962). 25 cents.

America's Lifelines—Federal Aid for Highways (1962). 15 cents.

Classification of Motor Vehicles, 1956–57 (1960). 75 cents.

Design Charts for Open-Channel Flow (1961). 70 cents.

PUBLICATIONS—Continued

Federal Laws, Regulations, and Other Material Relating to Highways (1960). $1.00.

Financing of Highways by Counties and Local Rural Governments: 1942–51 (1955). 75 cents.

Highway Bond Calculations (1936). 10 cents.

Highway Bond Financing . . . An Analysis, 1950–1962. 35 cents.

Highway Capacity Manual (1950). $1.00.

Highway Statistics (published annually since 1945):

1955, $1.00. 1956, $1.00. 1957, $1.25. 1958, $1.00. 1959, $1.00. 1960, $1.25. 1961, $1.00.

Highway Statistics, Summary to 1955. $1.00.

Highway Transportation Criteria in Zoning Law *and* Police Power and Planning Controls for Arterial Streets (1960). 35 cents.

Hydraulics of Bridge Waterways (1960). 40 cents.

Increasing the Traffic-Carrying Capability of Urban Arterial Streets: The Wisconsin Avenue Study (1962). 40 cents. Appendix, 70 cents.

Interstate System Route Log and Finder List. 10 cents.

Landslide Investigations (1961). 30 cents.

Manual for Highway Severance Damage Studies (1961). $1.00.

Manual on Uniform Traffic Control Devices for Streets and Highways (1961). $2.00.

Part V—Traffic Controls for Highway Construction and Maintenance Operations (1963). 25 cents.

Parking Guide for Cities (1956). Out of print.

Peak Rates of Runoff From Small Watersheds (1961). 30 cents.

Road-User and Property Taxes on Selected Motor Vehicles, 1960. 30 cents.

Selected Bibliography on Highway Finance (1951). 60 cents.

Specifications for Aerial Surveys and Mapping by Photogrammetric Methods for Highways, 1958: a reference guide outline. 75 cents.

Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects, FP-61 (1961). $2.25.

Standard Plans for Highway Bridges (1962):

Vol. I—Concrete Superstructures. $1.00.
Vol. II—Structural Steel Superstructures. $1.00.
Vol. III—Timber Bridges. $1.00.
Vol. IV—Typical Continuous Bridges. $1.00.

The Identification of Rock Types (revised edition, 1960). 20 cents.

The Role of Aerial Surveys in Highway Engineering (1960). 40 cents.

Traffic Safety Services, Directory of National Organizations (1963). 15 cents.

Transition Curves for Highways (1940). $1.75.

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