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FEDERAL HIGHWAY ADMINISTRATION
BUREAU OF PUBLIC ROADS

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Route interchange of Interstate Highways 59 and 65 in Birmingham, Ala.

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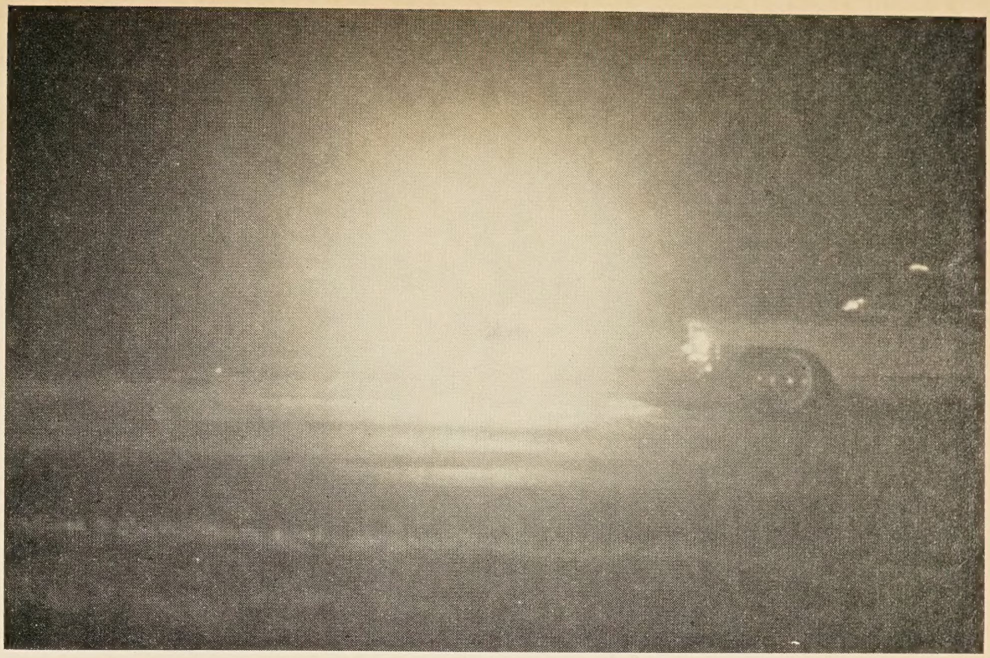


The speed of an oncoming vehicle and its distance away are difficult factors to estimate at night because of headlight glare.

Driver Judgments as Influenced by Vehicular Lighting at Intersections

Reported by [1] NICHOLAS G. TSONGOS, Highway Research Engineer, and RICHARD SCHWAB, Electrical Engineer Traffic Systems Division

The effects of headlight glare on drivers' judgments and decisions at a right-angle, nonsignalized intersection were examined in an experiment conducted in a dark rural environment on an airport runway. Twenty male drivers, in two age groups of 10 drivers each, were exposed to different degrees of glare from both conventional and polarized headlights and were asked repeatedly either to judge the last safe moment to start across the intersection ahead of an approaching test vehicle on the crossroad or to actually perform the crossing maneuver.

Statistical analyses of the results of the experiment, reported here, indicate that different lighting modes produced significant differences in drivers' reactions. Under the more glaring conditions, longer gap-acceptance times were required, and there was more variance in the data. According to the drivers' evaluations of glare discomfort, the two polarized high-beam systems studied were superior to conventional high beams, but conventional low beams were least bothersome.

Introduction

THE DRIVER'S behavior at a street intersection is a complex series of judgments and decisions. As he approaches or waits at a nonsignalized intersection, the driver visually searches the other legs of the intersection for oncoming vehicles. If a vehicle is approaching, he probably estimates the distance and speed of that vehicle and the maneuver that its driver is likely to make at the intersection. He then weighs these judgments and decides whether or not it is safe to enter the intersection.

These judgments become more complicated at night. The lighted headlamps may make it easier to detect the presence of the oncoming vehicle, but glare from them makes speed and distance estimates more difficult. When no fixed source illumination is present at the intersection, details of the surrounding environment are lacking, and the oncoming headlights will aggravate the visual task, which is already difficult.

In the last quarter century, several improvements have been suggested to control headlamp beams and improve the night driving environment. One of the most promising methods for reducing headlight glare and improving night visibility is to use linear polarizers on the headlamps, positioned 45 degrees from horizontal, and a parallel analyzer or viewer through which the driver views his surroundings. As two vehicles so equipped approach each other head-on, the polarizer on the headlamps of the one vehicle is crossed with the analyzer on the other vehicle, and no direct glare is transmitted to the driver. Most of the research on polarized headlighting has dealt with target detection and other visibility-type situations of head-on encounters between two vehicles. Little or no attention has been given to right-angle situations at intersections where glare alone may be the most important variable affecting driver behavior. Yet as the driver moves from the rural environment into the suburban environment, the frequency of these right-angle encounters increases. In the suburban environment, gap acceptance is a critical parameter for headlamp design because speeds are lower and the sight distance requirements are less critical.

[1] Presented at the 49th Annual Meeting of the Highway Research Board, Washington, D.C., January 1970.

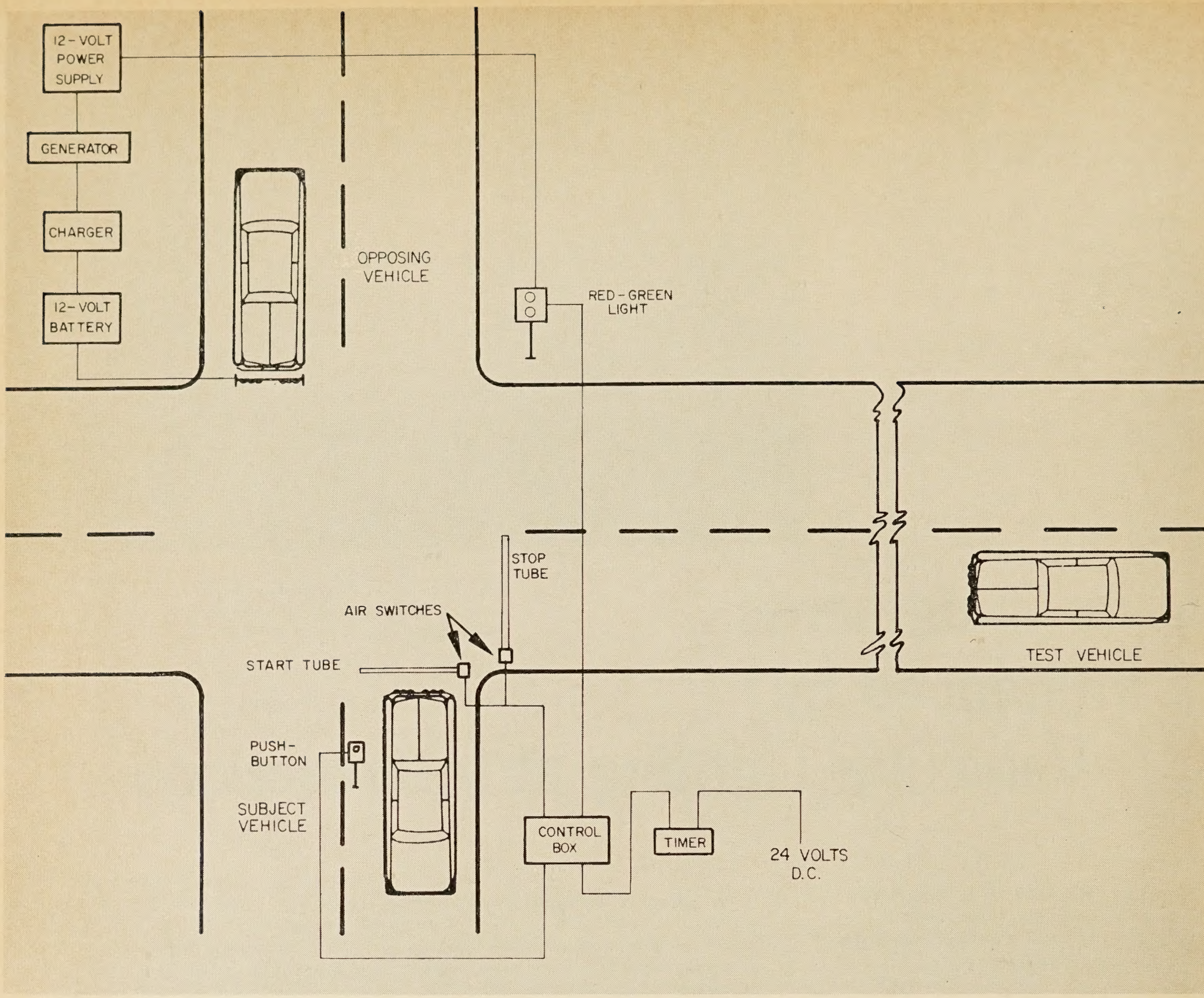


Figure 1.—Layout of experimental intersection.

In a recent study by Tsongos and Weiner (*1*)[2] an isolated, unlighted, suburban intersection was observed both during the day and at night. Differences in the driver's day and night gap-acceptance probability were noted, particularly near the ends of the gap-size distribution. The nighttime driver was more likely to reject a very short gap (2 to 3 seconds) than his daytime counterpart. It is at this part of the encounter that the disability-glare phenomenon approaches its maximum and that even small errors in judgment can become critical.

Because almost all the vehicles observed in that study were using low beam headlamps, it was not possible to determine whether glare was indeed a factor in the rejection of short gaps. However, with at least one of the common analyzer designs suggested for a polarized headlighting system, glare would be increased in the right-angle situation. The purpose then of the experiment reported here was to control the degree of glare exposure, using both conventional headlamps and polarized lighting with two different types of analyzer systems, and evaluate driver behavior while gap-acceptance judgments were being made.

[2] Italic numbers in parentheses identify the references listed on page 15

Test Procedures

The experiment was conducted on the two runways of the airport operated by the U.S. Department of Agriculture at the Beltsville Agricultural Research Center. As this airport was closed at night, environmental conditions for the experiment could be closely controlled. The environment was that of a dark rural area with no extra-vehicular light sources. The test was performed only in a clear atmosphere and on a dry road surface.

A highway intersection was simulated at a point near the intersection of the two runways, each of which was approximately ¾ of a mile long. The running surfaces had recently been repaved with a black asphalt overlay on which two 12-foot lanes had been outlined with 4-inch nonreflective, white, solid edge markings and a dashed centerline. A part of one runway consisted of a 3,200-foot-long, constant-grade approach on the subject driver's right side.

The subject driver was stationed in a vehicle sitting at the intersection, as shown in figure 1. A test vehicle was stationed on the 3,200-foot, constant-grade approach at the right end of the runway. On command, the test driver turned on his vehicle's lights, accelerated to constant speed, and traveled down the lane nearest the subject, approaching the subject vehicle at a right angle. Once the test driver had passed the subject vehicle, he returned to the starting point and set up for the next run. Mobile radios provided communication between the test driver and the experimenter.

Table 1.—Driver age and vision characteristics

Driver [1]	Age [2]	Vision characteristics					
		Phoria		Acuity			Stereopsis (depth)
		Vertical	Lateral	Right eye	Left eye	Both eyes	
Younger group							
	Years						*Percent*
1	23	0.17	−0.66	20/20	20/17	20/18	88.5
2	21	.17	.33	20/33	20/29	20/25	76.5
3	20	.17	.33	20/20	20/18	20/18	102.4
4	23	.50	4.33	20/22	20/29	20/22	96.0
5	20	.17	1.33	20/20	20/18	20/20	96.0
6	21	.50	−.66	20/20	20/22	20/20	88.5
7	20	.17	2.33	20/20	20/18	20/17	106.5
8	21	.50	1.33	20/18	20/18	20/18	102.4
9	19	.17	2.33	20/17	20/20	20/20	96.0
10	20	.17	2.33	20/22	20/25	20/22	88.5
Older group							
1	62	0.50	−1.66	20/22	20/20	20/18	103.6
2	60	.17	−1.66	20/18	20/18	20/18	102.4
3	70	.17	7.33	20/29	20/40	20/29	56.6
4	60	1.00	5.33	20/25	20/22	20/22	76.5
5	53	.17	.33	20/20	20/18	20/18	56.6
6	51	.17	1.33	20/20	20/22	20/18	84.4
7	57	.50	4.33	20/22	20/20	20/18	103.6
8	54	.17	1.33	20/25	20/25	20/29	76.5
9	50	.17	3.33	20/20	20/20	20/18	76.5
10	54	.50	−.66	20/17	20/17	20/17	96.0

[1] Average driving experience: Younger group—4.5 years; older group—35.8 years.
[2] Average age: Younger group—20.8 years; older group—57 years.

In the first of two procedures used in the experiment, the judgment series, the subject was asked to judge the *last safe moment* to start across the intersection ahead of the test vehicle and to signal his decision by pushing a large 6-inch-diameter metallic button located on a stand just outside his window. In this procedure, the subject kept his vehicle stationary while reacting. In the second procedure, called the performance series, the subject actually performed the crossing maneuver. Which one of the two procedures was to be used for a given run was signaled to the subject by one of two lights located across the intersection, which was switched when the approaching test vehicle was 1,600 feet from the intersection. A red light was used to indicate a judgment run and a green light to indicate an actual crossing.

It was believed that the semidynamic procedure would allow for better control of the stimulus condition and would have less inherent variability. Accordingly, it was possible to use fewer subjects under more experimental conditions. The fully dynamic performance procedure did have a higher degree of realism, more closely paralleling the real-world driving situation, but it also involved some accident risks. For this reason, the semidynamic judgment procedure with only one car moving, was used to carry out the bulk of the experiment. Eight fully dynamic runs with both vehicles moving were interspersed with the semidynamic runs in a random pattern that kept the subject's responses realistic.

When the red light was on and the subject signaled his decision by touching the large metallic pushbutton, an electrical pulse started a transistorized timer, which continued to operate until the test vehicle, on entering the intersection, crossed a pneumatic tube connected to an air switch (fig. 1). The elapsed time between the moment of decision and the arrival of the test vehicle at the intersection was thus recorded to the nearest millisecond. The gap size was measured in seconds, and this measurement was converted to distance based on the constant speed of the test vehicle. Because the test vehicle had obtained this predetermined velocity before the 1,600-foot point, the constant speed assumption was valid.

When the signal light was green for the performance run, the subject vehicle crossed a pneumatic tube placed immediately in front of its front tires to start the timer. Otherwise, the instrumentation was the same.

To provide an additional stresser to the experimental situation, an opposing vehicle was placed across the intersection from the subject vehicle. During all the performance runs and half the judgment runs, the headlamps of the opposing vehicle were turned on. These headlamps were operated in the same mode—the modes will be described later—as those of both the subject and test vehicles. At the start of an experimental run the subject was required to observe the signal lamp approximately 15 feet to the left of the opposing vehicle, as shown in figure 2. At this time some of the headlamp operational modes subjected him to considerable glare, and his visual adaptation was somewhat elevated. But when the test vehicle was 1,600 feet away, and the signal lamp was turned on, he could shift his visual attention toward the test vehicle and, consequently, was no longer influenced directly by the headlamp glare from the opposing vehicle.

Figure 2.—Test vehicle with high beam approaching intersection during experiment.

DISCOMFORT GLARE EVALUATION

Driver:__________ Age:_____ Date:________

Set No:_____ Run No.:_______

No Problem ☐

Bothersome ☐

Very Uncomfortable ☐

Blinding ☐

Figure 3.—Subjective evaluation form.

The first group of drivers were primarily college students in their early twenties who had a minimum of 2 years driving experience. The second group, mainly nonengineering personnel from two local highway departments, was selected to evaluate the effect of driver's age on the experiment. All drivers in this group were more than 50 years of age.

Berg (*2*) has shown that older drivers are much more sensitive to glare than younger drivers. Both contrast threshold and recovery time after exposure to glare are relatively constant among individuals until they reach approximately age 40 to 45, after which both characteristics deteriorate rapidly. It was therefore hypothesized that the older group,

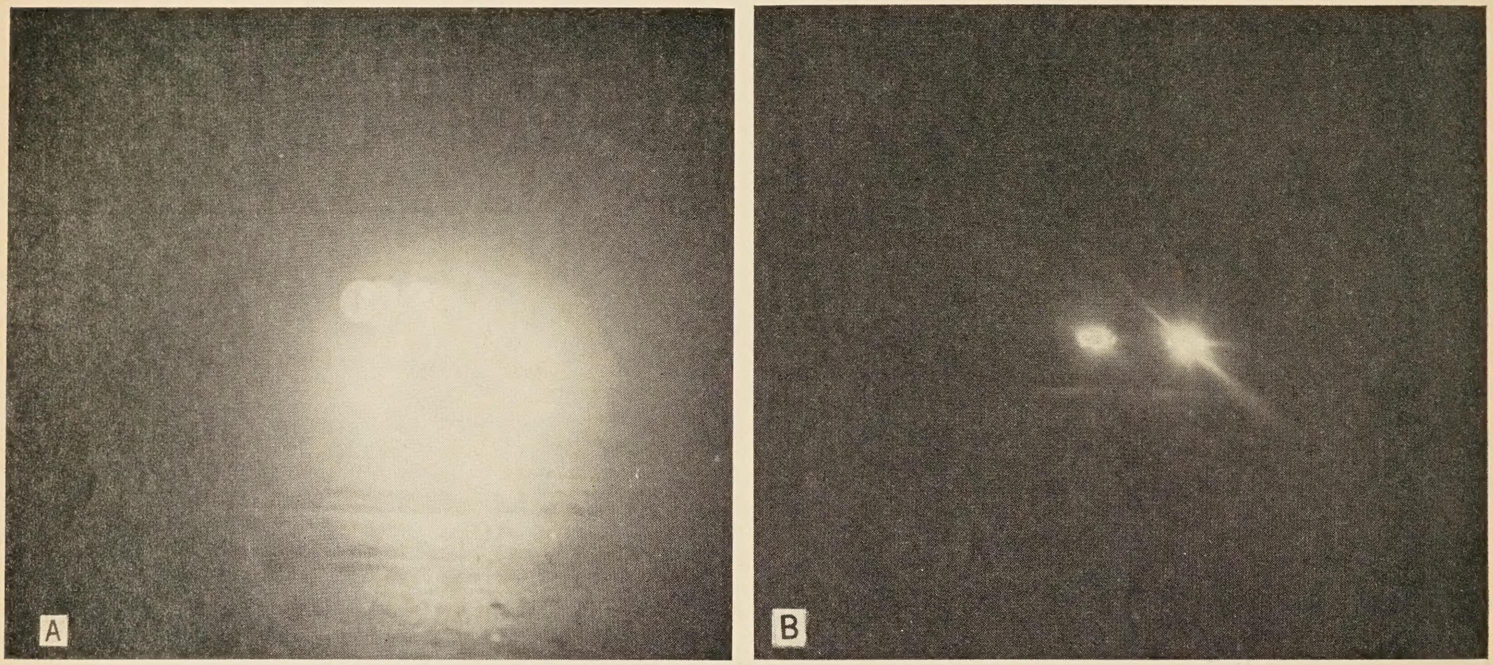


Figure 4.—High intensity headlamps—(a) without analyzer, (b) with analyzer.

The test vehicle was driven at a constant speed for each experimental run. To avoid having to use distance cues, four test vehicle speeds—20, 30, 45, and 60 m.p.h.—were used for judgment runs, and two test vehicle speeds—20 and 45 m.p.h. for the performance runs. The order of the runs was completely random. To minimize the effects of repetitive learning and of fatigue on the results, no subject knew the type of test to be run until he received his order to react. A total of 40 experimental runs was made by each subject.

Upon completion of each experimental run, the subject was asked to complete a subjective evaluation of his discomfort caused by the glare to which he was just exposed. A sample of the evaluation form is shown in figure 3.

Experimental Drivers

Two groups of 10 licensed male drivers were recruited to participate in the experiment. Except for two drivers, one from each group who required 2 nights, each driver completed all 40 of his experimental runs in 1 night.

Figure 5.—Test vehicle.

although having more driving experience, would do relatively poorly as a group in visually judging and reacting to the types of situations in these tests.

On the day that he was scheduled to participate, each subject arrived at the test site after dark and was taken immediately to a trailer parked about a half mile from the intersection where he received a standardized vision test. The results of the 20 vision tests are shown in table 1. Any subject who normally used eyeglasses when driving used them in all the test phases. Before the subject left the trailer, some biographical information was obtained from him, and he was given a set of written instructions on his participation in the tests. He was taken to the intersection only after the equipment was set up and operating. Each subject was given two practice runs, one performance and one judgment, before the actual experiment began.

Vehicular Lighting Modes

Each of the three vehicles used in the experiment was equipped with the following four types of lighting systems or modes: Conventional low beam, conventional high beam, polarized high beam with visor, and polarized high beam with glasses. Only one system was employed at a time, and all vehicles displayed the same mode during each run.

Polarized light looks like ordinary light when it is received by the naked eye, but when it is viewed through a suitable analyzer, it behaves differently. As early as 1920, F. Short and L. W. Chubb pointed out that a polarized-type headlighting system was possible (*3*). Their approach would provide a *light-lock* system with adequate illumination for objects on the road between approaching vehicles to be visible, but from which neither driver would receive glare directly from the headlamps of the other vehicle. Viewed through a crossed polarizer, the approaching vehicle's headlamps would be perceived as very dim spots of light about as noticeable as parking lamps (fig. 4b). In a recent series of studies by Roger H. Hemion, et al. (*4, 5, 6*), polarized lighting systems were investigated and shown to provide more effective illumination for the highway vehicle-meeting situation than conventional systems.

Because it was the purpose of the experiment reported here to study gap-acceptance behavior under different degrees of glare, a polarized system and two types of analyzers were used to control glare. One of the analyzers, a form of visor, was attached to the normal sun visor to give the subject good glare protection as he looked straight ahead at the signal light and opposing vehicle; of course when he looked at the test vehicle, the subject's vision was exposed to a glaring intensity similar to that of the conventional high beam. The other analyzer, in the form of a pair of eyeglasses, was worn by the subject and moved with his head. The degree of protection afforded by the second type of analyzer reduced the glare from the test vehicle to nearly that of a conventional low beam for this right-angle situation.

Each vehicle used in the experiment was equipped with the standard 12-volt, 5.75-inch-diameter, type 4001 and 4002, sealed beam headlamp system. The low-beam and high-beam filaments respectively required 50 and 37.5 watts for operation. The headlamps were conventionally mounted on a horizontal line to conform to Motor Vehicle Safety Standard No. 108. Two additional 5.75-inch-diameter, type 4001 headlamps, rated at 100 watts, were mounted just inside the other lamps and, for the polarized system, replaced the lower-wattage 4001 unit. A photograph of the test vehicle taken shortly after completion of the study is

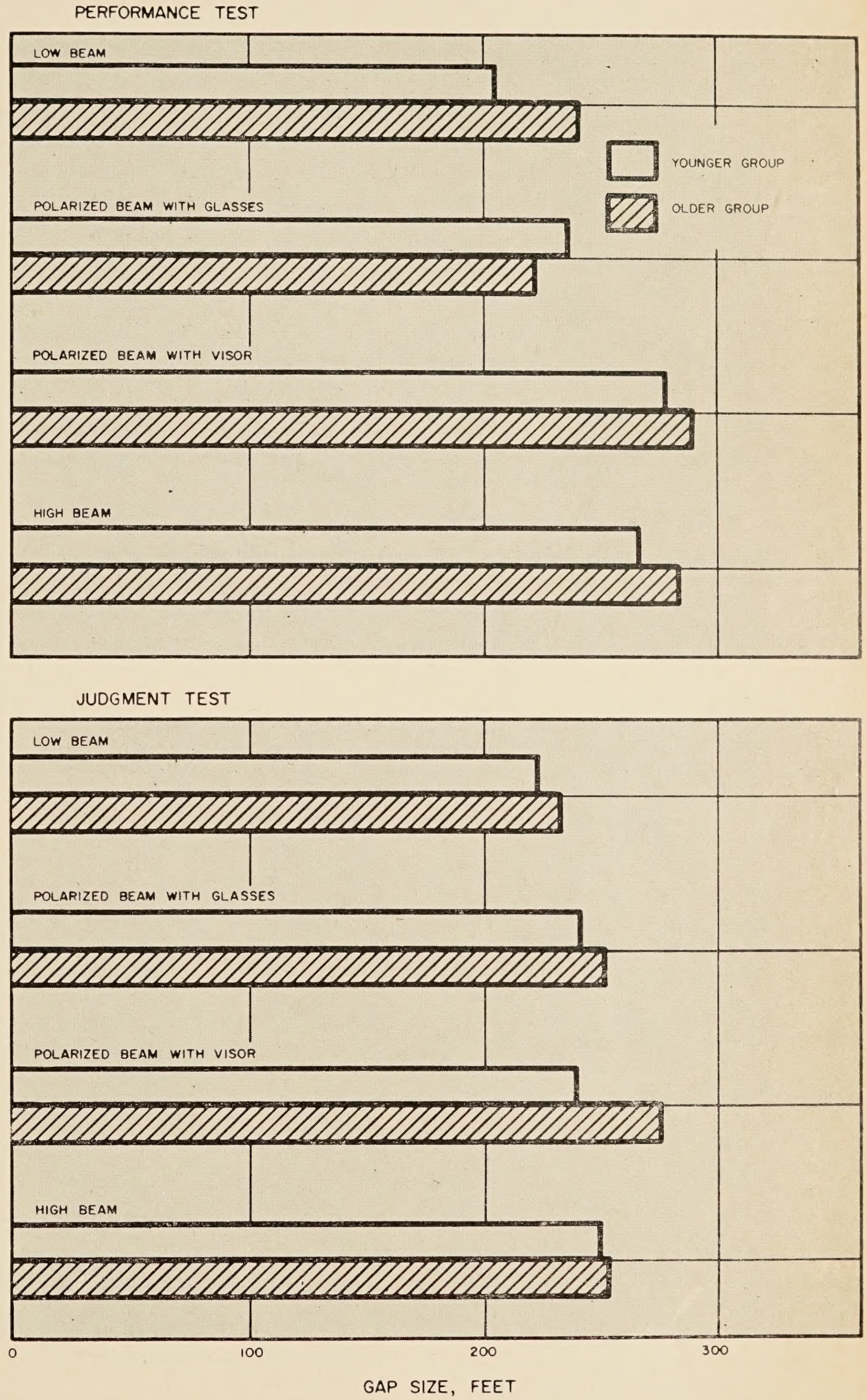


Figure 6.—Mean gap-acceptance distance for each lighting mode and age group, 20 and 45 m.p.h.

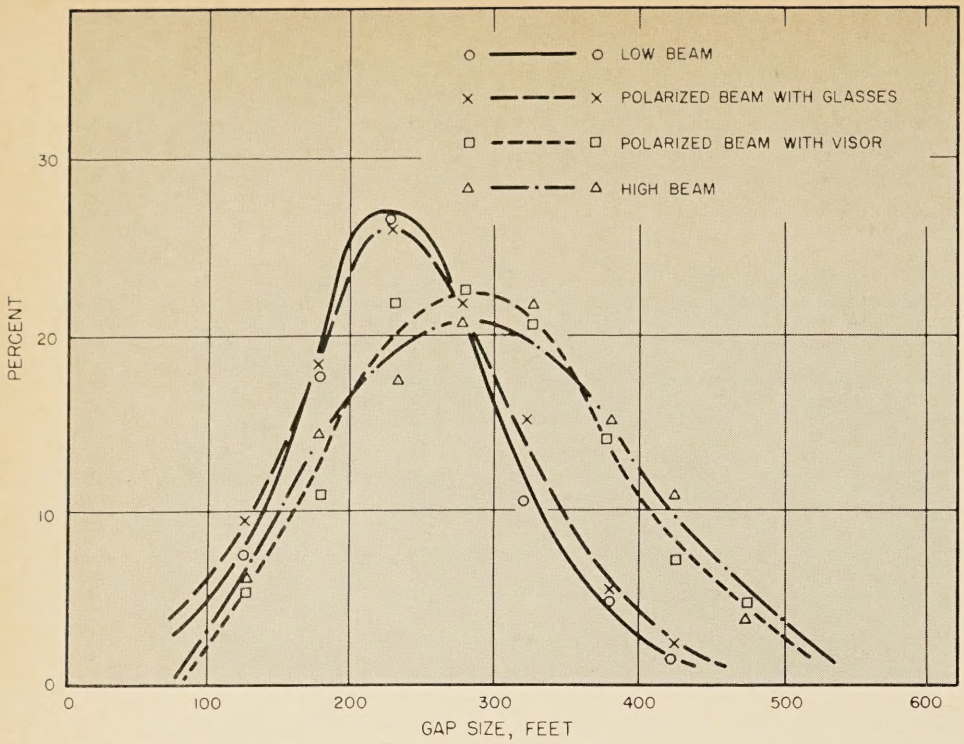


Figure 7.—Distribution of gap acceptance for each lighting mode, performance tests.

Table 2.—Summary of analyses of variance, lighting mode combinations

Test	Source of variation [1]					
	L & H	L & G	L & V	H & G	H & V	G & V
Judgment:						
F ratio	3.02	1.58	4.44	0.176	0.190	0.670
Significant at 5 percent level (2.97)	yes	no	yes	no	no	no
Performance:						
F ratio	4.67	0.033	6.13	4.52	0.16	7.57
Significant at 5 percent level (4.41)	yes	no	yes	yes	no	yes

[1] L=Low beam.
H=High beam.
G=Polarized beam with glasses.
V=Polarized beam with visor.

shown in figure 5. The additional lamp just to the right of the license plate had not yet been installed when the experiment was conducted. For practical reasons, the lamps of the opposing stationary vehicle were mounted on a test stand directly in front of the vehicle, instead of on the vehicle itself. These stationary lamps were powered by a 12-volt battery, which was charged continuously to maintain the same intensity of illumination throughout the experiment. To produce polarized beams, dichroic filters were placed in front of the headlamps and alined to set the vibration plane of the emergent light at 45 degrees to the horizontal plane. The axis of the analyzer had the same orientation and, therefore, was perpendicular to that of opposing headlamps.

Results

To combine the data from the runs at different speeds, the gap-size data—elapsed time between the action taken (decision) by the subject driver and the arrival of the approaching test vehicle at the intersection—was first transformed into distance, based on the appropriate test vehicle speed. An analysis of variance was performed on each experimental series to determine whether the observed differences in gap-acceptance means were real differences or were due to variance in the experimental situations. As expected, there were significant differences not only between lighting modes in both the judgment and performance tests but also between age groups in the performance test.

Lighting mode

The data were further analyzed to ascertain which of the lighting modes contributed to these differences. A summary of these analyses is given in table 2. The data from both the performance and judgment tests indicated statistically significant differences at the 5 percent level of confidence between the low-beam–high-beam combination and between the low-beam–polarized-beam-with-visor combinations. The data from the performance test alone showed significant differences between the high-beam–polarized-beam-with-glasses combination and between the polarized-beam-with-visor–polarized-beam-with-glasses combination. The latter differences are probably due to the driver's alertness during the performance runs and the stimulation from the involved risks, as the tests had been performed under more realistic conditions.

In general, it can be concluded that the drivers required a slightly longer gap in traffic to enter the intersection when the glare level was highest—high beam and polarized beam with visor. This difference in gap acceptance usually was no more than 50 feet. (See table 3.) For the performance run, the mean values for all 10 drivers of each age group are given in figure 6. Comparable data from the 20- and 45-m.p.h. judgment run are also shown in figure 6. These two sets of data

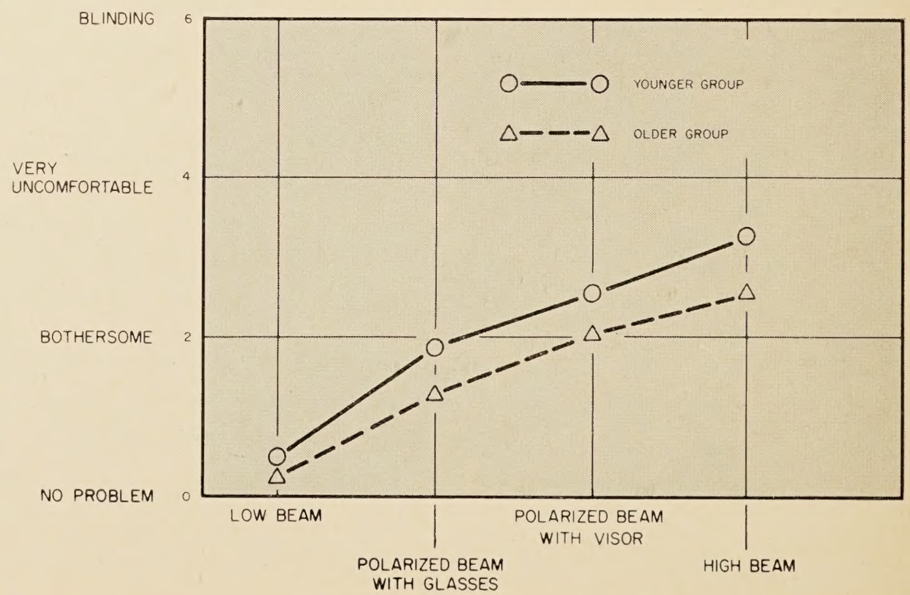


Figure 8.—Discomfort-glare evaluation for each lighting mode.

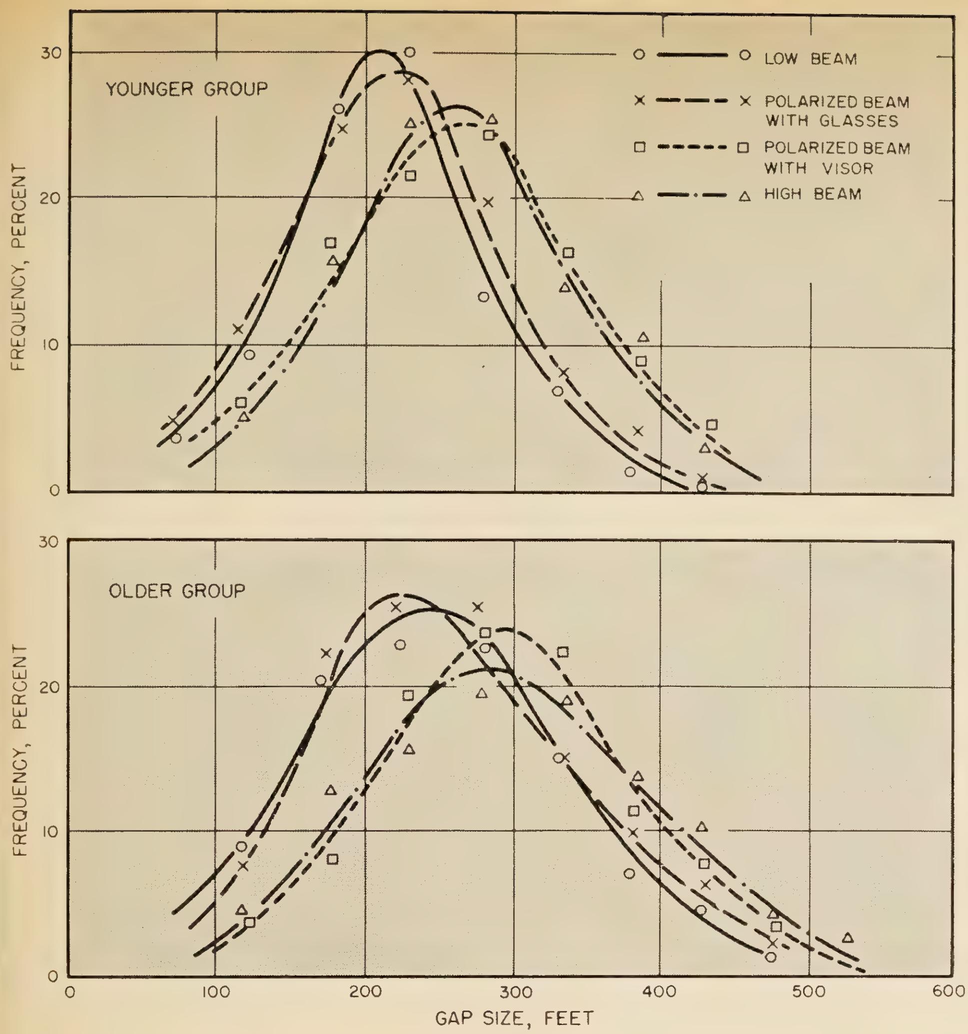


Figure 9.—Gap-acceptance distribution for each lighting mode and age group, performance tests.

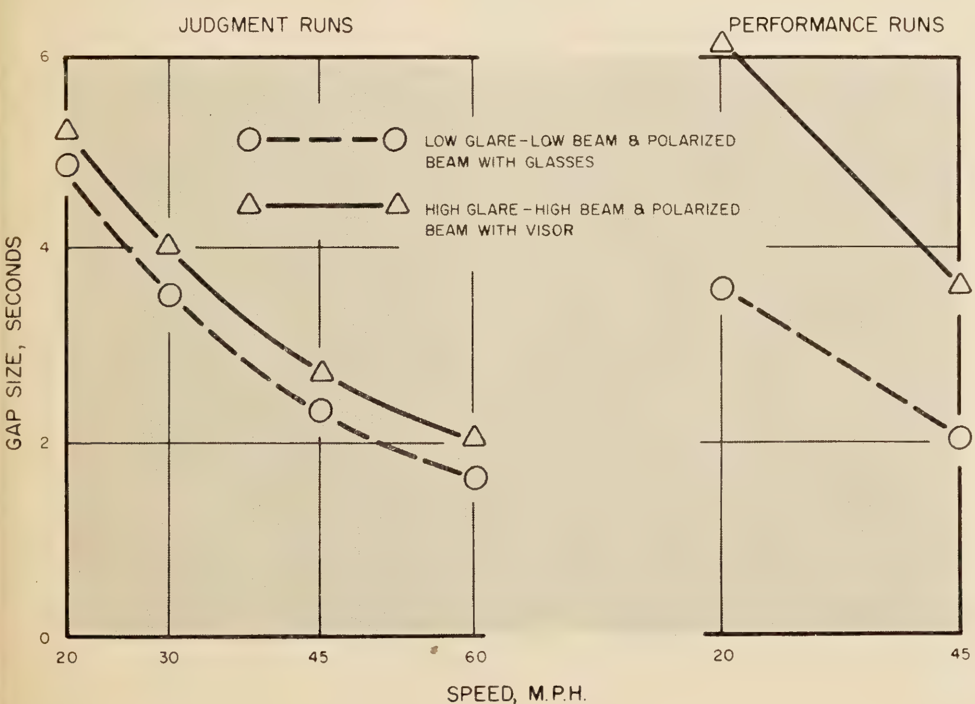


Figure 10.—Mean gap-acceptance times for each speed.

show similar trends; the small differences in the judgment runs were due largely to the experimental situation.

As shown in figure 7 for the performance runs, the high beam and polarized beam with visor produced almost identical distributions of gap size. Greater variability was observed in runs using these two lighting modes (table 3 and fig. 7). The data for low beam and polarized beam with glasses, although again clustered about the same points, demonstrated much less variability. The data from the judgment runs were much the same, but the differences were less striking.

The test situation was developed to determine the effect of glare from an approaching vehicle oriented 90 degrees to the subject's vehicle. The visor in the subject's vehicle was mounted on the sun visor and protected the subject only from glare directly ahead. When the subject turned his head to look at the test vehicle approaching from his right, he was no longer protected by the visor and, consequently, received approximately the same glare intensity as that of the high beam. The glasses, on the other hand, provided protection regardless of which way the driver turned his head. Accordingly, it would seem that glare level was the prime factor that caused the differences in test results of the four lighting-mode conditions.

Discomfort ratings

As mentioned previously, the subjects were asked to evaluate their discomfort at the completion of each run. The results of their evaluations are shown in figure 8. As expected, in both age groups, the low-beam condition was rated best, the high-beam condition worst, and the two polarized conditions in between. In all probability the polarized condition with glasses would have received lower discomfort scores had the drivers been able to aline the axis of their glasses perpendicular to the axis of the polarizers on the approaching vehicle. Such alinement is easy to accomplish in a head-on situation, but when the approaching vehicle is at 90 degrees, the normal tilt of the driver's head makes alinement more difficult. Two of the 20 drivers, both in the older group, objected to the polarized glasses and used them hesitantly in the runs. Their objections probably were due to the general hesitancy of older people to wear glasses.

Contrary to expectation, the numerical rating of discomfort was somewhat lower in the older group of subjects. Individuals more than 50 years old generally have a higher sensitivity to glare; consequently, it was expected that they would experience more discomfort. One explanation for the lower rating is that these subjects over compensated in their subjective evaluations, due to the fact that they usually have more difficulties with night driving. Another possibility is that this particular group was not typical of the over-50 category.

It was much more difficult to recruit the older subjects, and it is likely that the selected individuals in the older group had better visual abilities than would be suggested by the normative data published for that age group.

Statistically significant differences were shown by the performance runs of the two age groups. In figure 9 the distributions of the two age groups for each lighting mode are compared. The older group had a higher variability and possibly required somewhat longer distances to perform the task.

Speed

The effect of speed on gap acceptance was examined for the four speeds used during the experiment.

In the judgment runs, the difference between lighting modes at different speeds was not significant, but on the performance runs, the interaction of speed and lighting-mode differences was statistically significant.

According to figure 10, gap acceptance times associated with high-glare lighting modes were longer during the performance runs. The lower speeds produced longer gap times, which presumably was due to the driver's uncertainty in judging the speeds of the oncoming vehicle.

Discussion and Summary

The study reported here was designed primarily to determine the effect of approaching vehicles' headlight glare on gap-acceptance behavior at a right angle intersection. In general, the four vehicular lighting systems employed could be divided into two subgroups—those that produced at the eye of the subject driver a low level of glare and those that produced a high level of glare. There was a consistent pattern of differences between the lighting modes, especially under the fully dynamic test condition in which the subject was forced to take risks. Under the more glaring conditions, the subject drivers required a longer gap-acceptance time and there was more variance in the data, although the variance was not large enough to cause the two distributions to overlap completely. When exposed to the high-glare conditions, the subjects never accepted gaps quite as short as those that were accepted in the extreme low-glare conditions. Therefore, the high-glare conditions appeared to make drivers behave more conservatively and to induce a somewhat greater margin of safety.

The advantage of low glare headlight systems in terms of gap acceptance was significant, but whether the relation has any practical significance is questionable. In the tests, the gap-acceptance differences were small; however for the older group of subjects in the performance study, differences in mean values between extreme conditions were as much as 100 feet or more (table 3). Such large gap requirements might have an adverse effect on traffic flow, particularly when a high volume exists, as during the evening peak hours on the main road. If a polarized headlight system is employed to obtain the superior forward, head-on visibility that other studies have shown it to have, then more effort should be concentrated on the design of a better analyzer or viewer system to give drivers glare protection from the side. This may be especially desirable for older drivers, although it has been shown in several studies that older drivers drive little after dark.

There was evidence from the study that a satisfactory analyzer could be designed for use in a polarized headlight system. A polarized system in which a visor protected the driver only from oncoming glare produced much the same gap acceptance distribution as the high beam mode, because the visor was ineffective for sidewise glare protection. The situation was improved by use of glasses which did provide protection from the sides also.

In the performance studies, the younger age group usually had lower gap-acceptance values and showed less variability in their performance than the older group. In the judgment studies, the differences were less sharply defined; both groups had the same pattern of acceptance values for the four lighting modes. For the right-angle approach situation studied, the majority of drivers in both groups expressed the opinion that either polarized lighting system was better than conventional high-beam lamps, but that low-beam lamps were least bothersome of all.

No significance difference among vehicular lighting modes at the different speeds was shown by the experiment. As might be expected, the minimum distances that the subjects considered safe for gap acceptance at low speeds were less than those accepted at higher speeds, however, in terms of time gaps, the gaps were somewhat larger at lower speeds.

A comparison of the data obtained under the two methods of study—performance and judgmental—indicated that only the fully dynamic test situation gave valid results for the type of complex behavioral situation studied. Until a subject is exposed to a realistic situation that he assumes is a normal risk-taking situation, the results, though perhaps showing appropriate trends, will not necessarily be indicative of *real world* performance. Future investigations of the effect of vehicle lighting systems at intersections, accordingly, should be conducted under fully dynamic test conditions.

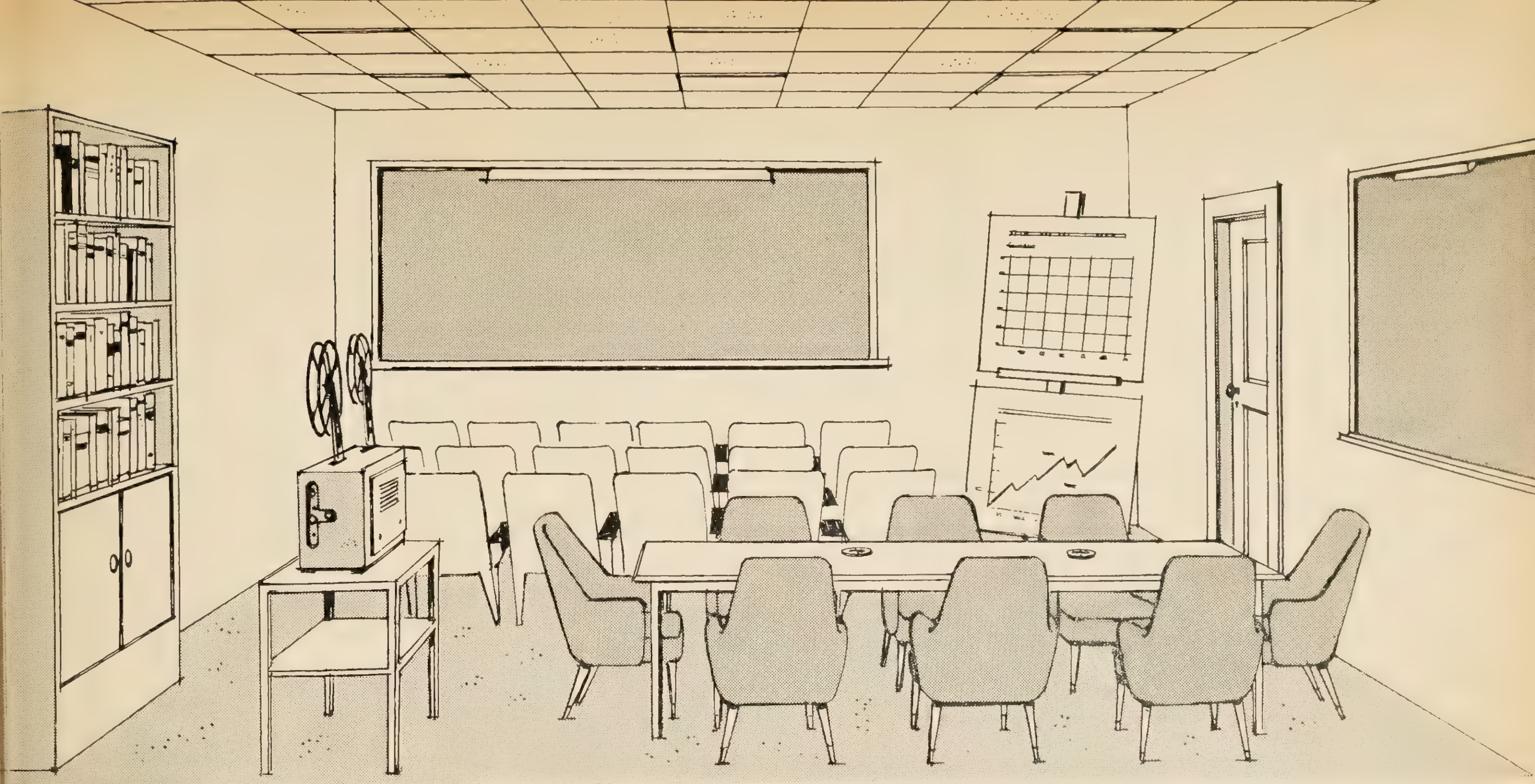
Conclusions

- The distance interval accepted by drivers as a minimum safe gap in which to cross an intersection was somewhat longer under conditions of forward vehicular illumination that produced more glare. The more glaring conditions also produced more variance.
- If a polarized headlighting system is to be employed, it is desirable to provide the driver with an analyzer system that protects his vision when he encounters vehicles from the side as well as those from head-on.
- Younger drivers had shorter gap acceptance values with less variable performance than older drivers over 50 years of age.
- Subjective discomfort glare evaluation indicated, for the situations studied, that both polarized systems were superior to conventional high beams but that low beams were least bothersome.
- The minimum time gap was somewhat larger at lower speeds.
- If the effect of vehicle lighting at intersections should be further investigated, a fully dynamic test procedure should be used.

(*Continued on p. 15*)

Table 3.—Mean gap acceptances and standard deviations

Speed and age group	Lightning mode							
	Low beam		Polarized beam				High beam	
			Glasses		Visor			
	Mean gap	Standard deviation	Mean gap	Standard deviation	Mean gap	Standard deviation	Mean gap	Standard deviation
Performance test								
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
20 and 45 m.p.h.:								
Both age groups	223.2	73.81	227.1	76.89	285.0	82.12	277.2	86.10
18–30 years old	206.1	75.40	234.3	70.62	279.5	87.33	270.5	82.05
More than 50 years old	240.3	72.31	220.0	88.15	290.6	103.52	284.0	91.26
20 m.p.h.:								
18–30 years old	160.2	66.59	186.2	72.68	242.6	58.25	239.3	60.85
More than 50 years old	185.2	64.22	198.3	71.98	272.6	88.52	224.4	80.54
45 m.p.h.:								
18–30 years old	252.0	67.37	282.4	79.26	316.4	98.19	301.7	94.08
More than 50 years old	295.4	91.63	241.7	80.89	308.6	74.96	343.7	110.63
Judgment test								
20, 30, 45 and 60 m.p.h.:								
Both age groups	253.2	65.4	273.5	61.4	285.4	96.4	279.2	88.8
18–30 years old	256.0	78.5	280.3	78.9	281.2	108.8	283.2	89.0
More than 50 years old	250.1	71.5	266.7	66.2	289.7	89.4	274.0	79.2
20 m.p.h.:								
18–30 years old	195.8	65.66	190.7	50.80	185.9	55.13	186.8	56.65
More than 50 years old	204.2	54.60	225.3	59.90	243.4	76.37	231.7	57.47
30 m.p.h.:								
18–30 years old	236.4	73.57	265.4	95.57	271.3	131.87	270.3	110.81
More than 50 years old	232.7	80.08	249.6	74.90	272.1	69.79	255.4	80.92
45 m.p.h.:								
18–30 years old	254.4	85.54	294.2	90.49	295.2	106.74	313.8	103.24
More than 50 years old	264.9	89.74	276.6	74.87	304.8	91.06	285.0	88.16
60 m.p.h.:								
18–30 years old	339.8	92.72	370.9	105.53	372.3	129.49	375.3	128.12
More than 50 years old	300.1	98.30	315.3	68.63	338.5	125.65	324.2	124.01



State Highway Department Management

Part 2.—Training and Manpower Development

BY THE OFFICE OF
RESEARCH AND DEVELOPMENT
BUREAU OF PUBLIC ROADS

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This is the second part of a report on management studies that were conducted in several States to upgrade the quality of highway administration. The findings related to highway department organization, or structure, were presented in the February 1970 issue of PUBLIC ROADS, vol. 35, No. 12. Additional findings of other aspects of highway department management will be presented in a future issue.

The information in this part is not intended as a comprehensive guide for developing training and manpower programs. It reports on the significant findings of the State-conducted studies that might be of general interest to highway department personnel who deal with training and manpower-development matters. Although many of the findings have general application, some are specifically suited to the State that conducted the study.

Introduction

ONE of the obvious needs of contemporary State highway departments is a greater mphasis on the training and development of ighway personnel. This need was clearly lemonstrated by several State highway lepartments that undertook studies in a rogram that dealt with specific aspects of ersonnel training and development to ttempt to improve highway department dministration and management. Highlights rom these studies are presented here hopeully to motivate other State highway departnents to review the basic studies and apply hose findings that are adaptable to their ituations. Those areas of training and levelopment determined to be of general ignificance or interest to the management unction are dealt with primarily.

Although the subject areas and problems f the participating States were frequently elated, it was difficult, and sometimes imossible, to extract applicable generalizations rom the individual studies, largely because ach of the individual studies had specific objectives that differed from those of the other studies, as well as problems to solve that were peculiar to the particular State. Consequently, most of the solutions and findings were suited to the State conducting the study.

Because of the many divergencies—organization, size, population patterns, political climate, and training needs—that exist throughout the States, the conclusions presented are not necessarily the best or only solutions, but are the ones that were gleaned from the studies conducted by the participating States.

Manpower and Training Needs

In recent years training needs of State highway departments have increased for all employee levels and categories, owing to the upsurge of expansion being experienced by all State highway departments. Although somewhat a result of the increase in the total mileage of the State highway systems, this expansion is primarily a product of the planning, construction, and maintenance of new roads in the Interstate and Defense Highway System. Construction especially has increased, as indicated in Minnesota (*1*) [1] where construction expenditures have increased 2.4 times in the 1955–64 period. According to a study in the State of Washington (*2*), highway construction is predictable, at an accelerated pace, with reasonable accuracy through completion of the current Interstate road program. Projecting beyond completion of the Interstate program the Washington study assumed that other highway programs will be undertaken, probably at a cost of about 75 percent of the projected Interstate volume.

Since commencement of the Interstate program, there has been a substantial increase in total highway expenditures, owing largely to emphasis on Interstate-System construction. In Minnesota (*1*), Federal aid in 1966 constituted about 50 percent of the highway department's entire budget. Large expansion of this type, with subsequent increased expenditures, has resulted in monumental increases in the workloads of State highway departments. Moreover, additional increases in workloads have been caused by new technology and by the complexity of highway operations, as well as by the increased number of departmental activities—traffic safety, data processing, planning and programing, management services, etc. In keeping with the general overall amplification of highway operations, highway department staffs have been increased, but the staff increases have not kept pace with the expanded workloads, and numerous management problems have been created.

These relatively recent problems have resulted in expanding program needs, rising State expectations, additional financial needs, and requirements for more effective public relations for a variety of reasons:

- Construction of the Interstate System.
- Need for more roads—to meet future requirements.
- Increased maintenance requirements.
- Safety programs—as traffic increases and becomes more complex.
- Growing State populations—requiring more and better highways to meet their growth potential.
- Need for additional funding—to meet expansion.
- Need for good working relations with the public—to obtain needed funds.

Highway managers will need to keep aware of both changing State requirements and changing expectations of highway users. They must also be prepared to manage a larger and continually expanding program. The highway departments will need a plan of organization that is matched to the rapidly changing and developing programs. Highway department executives will need to adopt improved and more sophisticated operating methods and management controls. Manpower and facilities will need to be used effectively. The total amount of manpower that highway departments can command will always be limited; consequently, effective use of available staff will be necessary. Shortages of qualified executives and technicians will necessitate particularly effective supervision of those available and development of those capable of assuming greater executive and technical responsibility. Changing requirements and expectations must be studied continuously to provide goals that meet them, to provide a source of directed action for highway departments, and to provide a cohesive team approach for all the geographically separated elements of departments.

[1] Italic numbers in parentheses identify the references listed on p. 15.

Selected State Study Findings

Most highway department training programs neglect the management aspects that are extremely necessary to the modern administrator. Many of the State studies indicated the need for training in administration and management as well as in technical skills. In the Minnesota report (*1*), it was stated that a higher degree of managerial skill will be required in the future because of larger, more complex programs, and that to prepare future executives with the necessary background, the department should undertake a management development program. Despite the pervasive tendency to specialization, men capable of manning higher caliber positions than those taken immediately after graduation can be developed and the interests of both the individual and the highway department can be better served by giving the trainee at least an initial program of managerial training to prepare him for future leadership.

It is evident, however, that many of the recent additional highway functions are technical even though they are not necessarily compatible with traditional skills. In several of the State studies it was noted that additional training is needed in specialized technical areas, including, safety, traffic and highway control, finance, and computer application. It was also noted that training is warranted in any specific technical area in which a trainee is deficient. In fact, many trainees and managers need instruction in basic communication skills, both written and oral.

There is a very definite need for training programs dealing with supervisory and managerial knowledge and skills. Management personnel, as well as potential management personnel, should be acquainted with techniques that have been proved effective in managing large operations. Highway management cannot use outmoded techniques to build modern highways, but must take full advantage of current management methods dealing with manpower utilization, planning and programing, data processing, and policy and procedure. Because of ever increasing expenditures, management also must have an understanding of long-range financial planning and cost control. Work scheduling can be made more effective with the application of new electronic-computer techniques like PERT and Critical Path Method.

A knowledge of working relations, both internal and external, also is necessary in training effective managers. Internally, the administrator must be aware of department organization and of how the different bureaus and offices are related. He must also have an understanding of basic personnel and contractural relations. External relations include the general public; other units of the State government, including the governor and the legislature; and other governmental entities like counties, municipalities, and the Federal Government.

Although heretofore the need for management training and development has been stressed, the limitations to the effectiveness of training in the overall scheme of manpower development must be recognized. Determining management needs is an operation that must account not only for training but also for the more comprehensive management development problems. For example, in the Indiana study (*3*), several steps to continue the improvement of employee training and management development, were outlined as follows:

- Perform a continuing study of the highway commission's managerial, supervisory, and technical personnel. Inventory manpower periodically to provide the data necessary for this study—employee qualifications, performance, promotion potential, and development needs. Include employees in all classifications under the career employment policy on this inventory.
- Develop a system to catalog the inventory data so that it will be readily accessible and usable.
- Develop a continuous, 5-year projection of manpower needs to consider anticipated attrition or any contemplated organizational changes, and base the projection on an established program of future highway improvements. Review and update the projection annually.

These steps were implemented by the consultant who conducted the Indiana study, and as a result, the following information is continually available:

- Short and long-range managerial personnel needs are known before they occur.
- Specific capable individuals who are worthy of promotion to higher positions, as well as those who possess potential ability to advance in the future, have been identified.
- A sound basis has been provided to plan and conduct personnel training and individual development activities to meet definite needs and to qualify for advancement those persons having promotion potential.

This management development program now serves as a guide for planning future training and development requirements.

Training is only one of the tools that can be used to strengthen the skills of new and old personnel alike; in fact it is often an inadequate solution to acquiring new skills. Nothing can take the place of experience in making sound judgments nor can anything replace satisfactory work performance. Training therefore is just an aid to management development and rates with other factors like experience, maturity, and responsibility.

There is a great need for a system that requires superiors to appraise their subordinates periodically and to review the appraisals with the individuals involved not only to let them know how they are doing and what their strong and weak points are, but also to provide counseling as to how weaknesses may be overcome and overall performance improved. Some of the descriptive terms for qualities and characteristics that often need improvement are: diplomacy, tact, consideration of others, forcefulness, aggressiveness, initiative, ambition, self-confidence, self-reliance, control of emotions, tolerance and patience, and job interest. Many of these characteristics can be corrected or improved if the individual is made aware of his deficiencies and is told how they are affecting his performance. Without a system that requires periodic appraisals and reviews by superiors, subordinates' performances will not be openly discussed, as supervisors tend to avoid the seemingly unpleasant tasks of discussing individuals' deficiencies.

Minnesota

Progress from the beginning-level positions is not enough to insure competent future management because too much strain is put on the highway department to develop and identify the beginning employees who have potential for advancement. In the Minnesota study (*1*), this problem was noted and it was recommended that more emphasis be given to manpower planning and development. It was also noted that the personnel systems and procedures of the Department of Highways were oriented toward meeting the requirements of civil service practices and policies regarding recruitment, placement, classification, evaluation, and promotion. In these areas, the Department of Highways had only limited options, and a number of prerogatives that were not fully exercised in the system were pointed out:

- Manpower planning was limited to itemizing personnel needs for inclusion in the biennial budget. No effort was made to translate the construction program into its long term personnel requirements.
- The personnel requirements included in the budget expressed needs in terms of additional positions and titles. The Department did not develop its requirements in terms of skill shortages and position vacancies caused by retirements, transfers, and turnover.
- The training activity of the Department tended to focus on beginning technical positions and made only limited provision for administrative and management positions.
- Development of future managers in the Department was left to the initiative of individual supervisors. There was no process for identifying potential managers and for strengthening their skills for responsible future positions.

On the basis of these observations, the following recommendations were offered: (1) Make manpower planning an integral part of the Department's 5-year program (2) establish a management-development program to identify and train future highway executives, and (3) broaden the training and development program to encompass nontechnical areas and to include positions above the starting level. These recommendations are discussed in the following three paragraphs.

Manpower planning—To prepare its 5-year program, the Department must establish its future workload, therefore, each operating unit should be able to translate its workload into manpower requirements. The office of personnel services should be responsible for compiling the approved manpower requirements of the departmental units to develop the overall manpower requirement plan of the first recommendation. The plan should identify anticipated departmental staffing levels for each year included in the plan, the staffing levels of each unit, and the type and proficiency of required skills. The plan also should guide the recruiting and training activities of the offices. Additional information on manpower planning will be presented in a future issue of this journal.

Management development—In the Minnesota personnel system, career progress from beginning level positions is emphasized, and consequently, the Department has a heavy responsibility for identifying and developing the beginning employees who have potential for advancement. It does not concentrate on this responsibility, however, and leaves career progress largely to individual intitiative and ability to pass promotional examinations. In future years the problem of managment succession will become even more serious than it is today. Employees who entered the Department during the 1930's are retiring in large numbers and the salaries and benefits offered by private industry make it difficult to find suitable replacements. The Minnesota report, accordingly, recommended that the Department undertake a managment development program that would include the following basic elements, or development guides, which in turn should be used as the basis to formulate the content of the training and development program:

- Develop a set of performance criteria for each job in the Department.
- Have supervisors suggest names of individuals who should be included in the initial group to be trained for more managerial responsibility.
- Gather data on each individual's background, education, and experience.
- Develop an appraisal form by which each supervisor can evaluate the present job performance and managerial potential of his suboridnates. The appraisal should identify strengths and development needs.
- Have the professional personnel staff interview each of the employees to obtain an objective evaluation of the employee's interest, strengths, development needs, and career potential.
- Develop for each employee a career development guide from the material collected and from the interview notes. The guide should identify the employee's potential and the area in the organization where he is best suited to work, as well as recommend a training program to help the employee fulfill his potential.

Broadening training and development—It was recommended in the Minnesota report that the content of the training program be broadened to include the following areas and needs:

- Technical training to provide the skills necessary to do the job for which a person is hired.
- Supervisory training to prepare employees to direct groups of other employees. This training should include labor relations, work planning, work methods, budgeting, and manpower controls.
- Management training to provide employees with the sophisticated control techniques necessary to manage large scale operations such as work scheduling, PERT and Critical Path analysis, project control techniques, and management reporting.
- Job rotation among the Department's units to expose individuals to the total operation and increase their grasp of the magnitude of the management task.
- Formal specialized university courses for selected individuals who require additional education in areas of interest to the Department.

As pointed out in this discussion of the Minnesota study, the training of new management and other personnel must be inclusive enough to produce men capable of higher caliber positions than those usually occupied by trainees immediately after graduation. Training is a major requirement in any organization and an effective training program for highway departments should be given top priority and consideration. The major aspects of the management development program recommended in the Minnesota study have been implemented largely through the impetus of the management study.

Indiana

The need for increased emphasis on manpower training was illustrated by the Indiana State Highway Commission's study (*3*). It was shown in this study that in 1964, there were 5 percent fewer engineers in the 41–55-age bracket, in which personnel were seasoned and experienced, than in the over-55-age bracket, in which personnel were approaching retirement. It was also shown that 19 percent of the Department's engineers were expected to retire during the next 5 years.

According to the study, recruitment of engineers in quantity was not a large problem, but because successors to prospective retirees were often in the same age bracket as the prospective retirees themselves and because experienced young men capable of promotion were few, the normal line of succession provided little backup for key positions. This disclosure indicated that promotion opportunities were available mostly to younger inexperienced men and pointed up the need of a training and development program for managers. The consultant who performed this study reported that uncovering this situation moved the Highway Commission to employ a professionally qualified personnel director and establish a training function in the Personnel Division. The Commission further provided for a qualified training director to develop an effective training program, which will be described later.

As previously mentioned, improved technology and complex highway operations have added many new functions to the highway program and increased the number of skills necessary for efficient operation. For this reason any effective management training program must have clearly defined objectives to provide:

- Highly qualified persons for each position.
- A reservoir of skills to improve organization and program effectiveness.
- A means of appraisal to select individuals for promotion.

These training objectives must be compatible with the overall department objectives, but they must also be flexible enough to permit fitting the training to the trainee's needs, interests, and qualifications, as well as to the needs of the department. Goals are necessary for a training program both to pinpoint additional needed areas of training and to help eliminate time that might be used to develop skills already considered adequate.

Virginia

Traditionally there has been little deviation in the training of new engineers who will eventually assume management positions. What might be considered a typical program to train engineers for management positions was described in a report prepared from a study of Virginia's graduate engineer training program (*4*).

The Virginia Department of Highways, the first State highway organization in this country to begin a formal training program for graduate engineers, began its engineer training program in 1945. The originally announced intention of the program was to provide a 4-year on-the-job course specifically designed to meet a pressing demand for assistant resident engineers. The program was divided into six basic areas: surveys, location and design, bridge design, materials control, construction, and administration. It also provided for a possible further research assignment. During the period 1945–63, trainee losses were greater than anticipated, and the Virginia Department of Highways initiated the aforementioned study to investigate the effectiveness of the program and determine ways to better serve the aims of the program. As one of the conclusions of this study was that the 4-year training program was too long, the overall length of the program was reduced from 4 years to 30 months.

Louisiana

A comprehensive study of the State highway-maintenance organizational structure and of its operating policies and practices was conducted by the Louisiana Department of Highways (*5*). The study consisted of several parts, each of which produced results that reflected the findings, developments, and recommendations of a specific research area. One of the specific areas, *Manpower Inventory and Training Needs Analysis*, was completed in 1967 and uncovered some unique training needs and limitations on personnel training.

The situation in Louisiana was unique in that both French and Cajun languages were used by maintenance personnel in addition to English. Large differences in the educational levels of supervisors and potential supervisors were revealed. Of the supervisors, 34 percent had fewer than 8 years of education, and only 32 percent had graduated from high school. Only 7 percent of the supervisors had attended college, and only 3 percent had graduated from college. Of the potential supervisors, 63 percent had fewer than 8 years of education and only 11 percent had graduated from high school.

These differences in educational attainments among persons of the same training population indicated a need for carefully prepared training materials that could be understood by all personnel without reducing the motivation of better educated individuals. Any training program would have to include basic courses that would be prerequisites to technical courses for persons with limited educations, and training materials would have to be developed in at least two languages. The study concluded that basic training policies reflecting the needs of the Department should be adopted, that maintenance training materials should be developed from the activities performed in the maintenance function, and that development of these materials should consider variations in age, education and experience, limited capacities of persons to work with abstract matters and, the capacities of persons to work with maintenance-related problems.

The Department of Highways has developed a training program that includes maintenance training. The subject matter for maintenance training is developed and approved by experts from the maintenance organization, and a training specialist then converts the approved subject materials into training manuals, which are subsequently used by the Department after they have been appropriately tested.

Typical Training Problems

Management training is never completed, because requirements, situations, and people seldom are static in a progressive, dynamic organization. The problem therefore is to determine what kind of training is required, where it is needed, and what the best means are of accomplishing it. To be successful, the training program must have clearly defined goals that are formulated for compatability with department objectives so that training can be fitted to the changing needs of the organization it serves.

The content and goals of the program must not only be carefully outlined and clear to both training staff and the trainees, but they must be understood and used to the best advantage by the department. Often when the aims are not understood, resistance to the training program develops. For example, maintenance type training programs, in which poorly educated, less knowledgeable maintenance employees fail to recognize the intended benefits of management training, may be resisted because personnel are reluctant to risk comparisons of their backgrounds with those of better educated, more knowledgeable individuals. In such situations, a training program that permits the employee to learn at his own pace, spares the embarrassing exposure of his lack of knowledge to other trainees and to instructors. In the report of the Louisiana study (*5*), which dealt with the training of maintenance personnel, it was stated in one of the conclusions that the maintenance function should continue employment of existing supervisory personnel with limited learning potential while it develops more capable supervisors from other personnel with adequate learning potential. It was further stated that any employer who demonstrates such a lack of interest in his employees that he would take steps to reduce the rank of a significant number of employees, to isolate them, or to terminate them because of changes in personnel standards, can expect difficulty in recruiting and retaining personnel who meet new standards.

One form of resistance to on-the-job training is the giving of preference to workloads rather than to training. When the workload is overemphasized, the training program is not fully effective and is being used most inefficiently. Moreover, supervisors can sacrifice training and use trainees to complete jobs. In the Mississippi study (*6*) it was noted that on-the-job training is often made more difficult when the trainee is assigned a new job experience. This occurs when construction activity is at its peak and experienced personnel, who assist with training, are spread to the limit. Therefore, if on-the-job type training is to be fully effective, training should have priority over workloads, except in emergency situations.

A functional and effective training program must have an aggressive training administration with capable supervisors for on-the-job training as well as professional training personnel. The training supervisors should be authorized to obtain qualified employees from the department to assist in developing effective manuals and to serve as instructors. Training manuals must be written in language that is at the trainee's level of comprehension. Instructors must be given sufficient advance notice of their instruction schedule to permit them to prepare their training materials well enough to give the trainees full benefit of their knowledge and experience. Also, in maintenance training, and in other types of training to be performed at district and field levels, it is necessary to have the program developed and administered at headquarters to insure high and uniform standards of training throughout the department.

The success of a training program is also dependent on other factors. For instance, the length of a formal training program is very important. It must be long enough to cover adequately the various aspects and phases of the program, but be brief enough to be practical and interesting to the trainee. The Virginia training program for graduate engineers was too long according to many of the engineers who had completed the program, and the basic formal training program was shortened from 48 months to 30 months.

A good orientation phase is also important to a well designed training program. It helps both to acquaint the trainee with the aims of the training and to make the trainee feel at home in the department. Orientation is especially important for trainees recently recruited for formal training programs. These factors and several others will be further discussed later when retention is considered.

The Virginia study was designed to revamp the existing graduate engineer training program to increase its effectiveness and the retention rate of graduates. The study proposed a new curriculum to solve some of the problems of the old one—mainly reduction of material devoted to construction matters. Interspersed in the new program are varied short periods devoted to introduction to the training policy and orientation. However, even after shortening the overly long program, a considerable portion is still devoted to construction matters, and administrative training has been shortened instead of increased. From evidence in several of the State studies, it would seem that administrative and management aspects should be increased rather than decreased because of the ever increasing demand being placed on all levels of both supervisory technicians and professional personnel.

Organizing and planning a training program is not a prearranged or set process. Attention must be given to the objectives and goals of the Department as well as to training needs. In attempting to solve old problems, no new problems should be created. Before the formulation of a program is attempted, each aspect of organized training must be studied thoroughly by professional training personnel and by experts from the various disciplines. The final product, an effective training program, necessarily must be a composite of the best solutions for each problem defined by the needs, limitations, and peculiarities of the particular department.

Types and Methods of Training

It is often effective to use more than one type of training in a training program. The most important consideration is that the most effective type of training be selected for each requirement. In many situations formal on-the-job training has proved to be the most effective way to develop a new engineer. It is especially effective in smaller organizations in which development of a sophisticated classroom and work activity would be virtually impossible. On-the-job training has the advantage of giving the trainee both the necessary technical skills and a working knowledge of his impending job. Also, simply by informal job rotation, the individual can be exposed at least to the total operation and magnitude of the organization.

However, many of the new management techniques are too complicated to be efficiently taught while its trainees are on the job. Most management presentations require classroom training, which is harder to justify because it removes the individual from his regularly assigned work and increases the workload of others, even though the training is necessary. This problem can be partly solved by conducting classes during slack work periods.

Management techniques often can be taught more effectively outside of the organization because of a lack of qualified instructors in the organization. In the Washington study (*2*) it was suggested that formal management training be offered outside of the department at various training seminars or programs available through universities and associations. This method of training can even include such programs as subsidized study at a recognized graduate school of business. In the Indiana study (*3*) use of an annual road school, a cooperative venture between the State Highway Commission and Purdue University, was utilized. This school is held annually at Purdue University for State, city, and county highway personnel, as well as for contractors, materials and equipment suppliers, and others involved with highway matters. Papers on various technical subjects are presented at many of the sessions held at the school. Other sessions are discussion type seminars on various subjects suggested by the attendees. Highway Commission attendance usually consists of high management personnel and a few engineers from the different districts.

In some States, formal out-service training is encouraged by reimbursing employees for all or part of their tuition and fees for courses of study taken on their own time. Of course, the studies must be adjudged beneficial to both the employee and the highway organization.

Indiana also has an interesting arrangement in which two men alternately attend work and school while earning their degrees in civil engineering. The two men share a given job in the State Highway Commission and alternate their attendances at school and work for specified periods—one man is on campus while the other is on the job.

Informal training and self-improvement should be encouraged as a supplement to formal training. Informal training might take several forms, one of which could consist of trainees passing on to associates and subordinates knowledge gained in formal training courses. Forms of self-improvement could be memberships in professional associations, self-advancement through the study of professional journals, and self-study to qualify for licensing by professional boards.

The types and methods of training are many and varied such as formal, informal, in-service, and out-service. For any modern highway organization, a program that envelops all types is necessary to keep pace with changing requirements and demands. The problem is to determine the types needed for different requirements and how best to marshal the means to conduct the training. A highway organization should overlook no type of training that can contribute to a program that fulfills its needs.

Recruitment

Recruitment as it relates to obtaining qualified trainees for formal management-level training programs and positions is dealt with here. Often recruitment will take place within the organization, but for certain high-level management positions, recruitment must be directed to outside sources where qualified trainees and personnel are available. The subject of recruitment as it relates to the personnel function will be discussed in more depth in a future issue of this journal.

One of the increasingly difficult tasks of highway organizations today is the recruitment of qualified personnel to be trained for management level positions. It was indicated in several of the State studies that such recruitment in the past was limited largely to engineering personnel, but it is becoming increasingly apparent that top management requires training in other disciplines as well.

In the Indiana study (*3*) it was recommended that recruiting be broadened to include candidates with other than civil engineering backgrounds. This recommendation, which was adopted and implemented, refers particularly to the Commission's college recruiting program. It was the consultants' opinion that the recruiting of civil engineers was being overemphasized although it was recognized that the Commission's task was strongly engineer oriented because of its technical nature. However, according to the consultants, an organization as large and diverse in its activity as the Indiana State Highway Commission needed a greater variety of talent than was being employed at that time. Although the predominate need was for civil engineers, other positions could be filled as well or better by persons other than civil engineers with nonengineering or nontechnical qualifications.

It was also disclosed in the Indiana study that a number of civil engineers were employed as technicians, administrators, nonengineering specialists, and even clerks. The consultant concluded that because the organization had tended to operate without a long-range plan, insofar as manpower needs were concerned, there had been little attempt to analyze and determine the best kind of education and background for particular positions. He also concluded that improper use of civil-engineering talent leads to erroneous conclusions about true engineer needs, contributes to the shortage of such talent, and deprives the organization of the contributions by persons with other knowledge and ability.

Effective recruiting can be aimed at both recent college graduates and private industry. The Washington study (*2*) emphasized that particular attention should be given to the methods of recruiting for management-level positions in administration and engineering. It recommended, for the State of Washington, that the college recruitment program be expanded so that capable college graduates

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with interests and talents in administration and engineering could be identified and encouraged to consider highway-department employment. It was noted that, in the past, this program had been restricted largely to civil engineering graduates.

In the West Virginia study (*7*), a recruiting source heretofore largely overlooked in highway recruiting, was noted. This study stated that a major criterion for a recruitment plan is the selection of an area that is becoming industrially depressed and where qualified people, many with outstanding experience, are available.

Both in colleges and in industry, the highway organization must attempt to get top quality candidates for its training programs by screening, by making offers to qualified candidates, and by developing followup programs to obtain candidates' acceptance. Many factors influence an individual's acceptance of employment for a training program. The Virginia study (*4*), which investigated the Department of Highways training program, examined this matter and disclosed the following important reasons why trainees accepted employment with the Department:

• The merits of the program itself—location, security, benefits, pay, recruitment program, and advancement opportunities.

• The experience to be gained in varied assignments.

• Interest in a highway engineering career.

• Prior highway experience—full or part time. This is especially effective in recruiting college graduates.

• Short term employment before armed-services commitment cr an interim employment.

• On the job training and/or refresher-course possibilities.

Because of an ever increasing shortage of qualified candidates for employment and training, highway organizations have encountered stiff competition with industry and often lose top candidates owing to lower pay and less security than is being offered by industry. The salary scales of trainees, as well as of regular employees, must be kept competitive not only with other highway organizations but with industry as well. Job security and a well administered personnel program must be assured.

Many States have a well administered personnel—civil service system, but other States not only have no system but other factors, like political patronage, are detrimental. In Indiana, for instance, there was no career employment policy and little job security. But in the Indiana study (*3*), the consultant developed and recommended a career employment policy that specified position classifications to be included in the parameters of existing legislation and established the conditions and procedures for installing and administering a merit-type system, which included more than 100 classifications in the engineering, nonengineering, professional, administrative, supervisory, and technical categories. The career employment policy was approved by the State Highway Commission and the Indiana State Department of Administration and placed into effect by executive order of the governor. Besides correcting the problem of job security for management, the career employment policy provided other benefits such as:

• Better employee performance, which improved considerably when it became apparent that job security and tenure was no longer tied primarily to political factors.

• Better qualified individuals were employed to fill vacancies as new recruitment sources were used and some selectivity in screening applicants' qualifications became possible.

• A new tool was available to attract qualified applicants. Persons who formerly would not consider employment with the Commission were now doing so.

• Training plans were initiated to further upgrade employee's capabilities instead of ignoring this important activity because of anticipated wholesale dismissals after changes of administration.

• A basis was now available to plan and develop a longer range personnel program, including training, as future needs were better known.

In competing with industry State highway organizations must offer benefits and security similar to those in industry if they are to attract well qualified trainees for top management and training programs. The trainee not only must be attracted to the work and its opportunities, but he must be motivated by them to have an active, positive attitude toward his career.

Retention

The success of a training program is measured by how well an organization can retain its trainese and graduates of training programs.

Of course, this measure of success can be applied to retention of all levels and categories of employees. However the following discussion is based largely on retention as it applies to trainees. A good retention rate indicates satisfaction with the training program and the organization itself. Many factors both inside and outside of a training program directly influence the rate of employee attrition. The following discussion, which is summarized largely from the findings of the Virginia study (*4*), deals with the more important reasons for trainees' resignations from the Department of Highways both during training and immediately following it. Also some reasons for a favorable retention rate in Virginia, as well as in other States, are mentioned.

Dynamic program goals and efficient planning not only influence employee retention directly, but these factors also help to establish nearly all the other related factors. For example, during the Virginia study a questionnaire was sent to the highway departments of other States to obtain comparative statistical and policy data relating to their current training programs. Response from Florida reported that the State has a relatively high trainee-retention rate for the following reasons:

• The program is established and well defined, and the content of each phase of training is described in detail.

• Although the training program is an in-service one, each trainee is a working employee who is expected to perform his assigned job on the same basis as any other employee. Training is given preference, and when the allotted time is up on any phase, the trainee is transferred to the next phase.

• Usually, each trainee is visited at 3-month intervals or at least once during each phase either by the Engineer of Research and In-Service Training or by his Director of In-Service Training.

• Trainee transferring is kept to a minimum.

Realistic training objectives are only partly adequate unless they can be communicated to the trainee and modified to fit the program and the changing needs of the trainee and of the highway organization. Communication is accomplished through orientation, evaluation, and counseling. Often a highway organization can seem large and impersonal, and orientation—introduction to the training program and to highway organization—is important not only to introduce goals to the trainee but also to provide the important favorable first impression. Response from Arizona to the Virginia questionnaire emphasized the importance of the personal touch that makes the trainee feel at home and treats him as an individual and potential leader.

Personal counseling and communication are even more essential than orientation in developing this feeling. Several States responding to the Virginia questionnaire indicated that visits at periodic intervals by upper echelon personnel from the organization instilled in the trainee a feeling of importance and prestige.

Organized counseling likewise is essential to the trainee in developing a long range assignment plan as well as in career planning. Within the sphere of counseling, trainee evaluation, as well as trainee planning, can be accomplished to some extent using devices like progress interviews. Other methods of evalutating trainees and training received reported by States having high retention rates were monthly progress reports by the trainee and monthly progress evaluation reports by immediate training supervisors. These evaluation reports can help determine the extent of training, degree of trainees' success, and areas of potential program improvement, all of which have a direct bearing on the trainee retention rate.

The length of the training program and the amount of employee relocation both affect the retention rate. The training program must be no longer than the minimum time required to adequately cover all aspects. Excessive moving, especially on short notice, must be kept to a minimum. Individual training schedules help the trainee anticipate major moves in advance. In Pennsylvania it was reported that trainees select the District they prefer, which is likely to be the location of their permanent assignment after they complete their training. Selection of the work location not only satisfies the trainee but it also tends to improve the quality of training received, as the district engineer is then responsible for training his own future permanent employees.

Monetary remuneration that is competitive with industry is extremely important to successful trainee recruitment. Salaries both during training and afterward must be adequate. Long-range income, as well as advancement possibilities, must seem attractive to the trainee. Although not directly related to training, these factors together with fringe benefits, which are becoming increasingly more appealing to employees, are directly related to retention rates.

Military obligations also influence retention rates, but this factor is one over which a highway department has no control. A new draft policy may help mitigate this factor.

The training and the work assigned after training must be challenging. The variety and type of work and training, the results of a job well done, and the feeling of accomplishment and responsibility are important factors influencing continued employee retention. As with any responsible person, the trainee likes to feel that his time is spent productively and that his education and training are being used to advantage. By stressing the value of continued education and development, the trainee also can be made to understand that his future role will be an important one.

Every effort should be made to promote a positive trainee-retention rate without sacrificing the goals of the training program. A training program that leaves the trainee with a positive, enthusiatic attitude toward the program and the organization is of the utmost importance to effective highway management.

Evaluation of Training Programs

One of the prerequisites of a successful training program is an effective evaluation procedure. To understand the needs of the trainee and to plan an efficient training program around these needs, both management personnel and new trainees must be evaluated and rated periodically. Management personnel need to be evaluated to determine their promotion potential. Also the organization must provide the means to develop and groom employees who have promotion potential. Evaluation should include such factors as job performance, professional knowledge, judgment and decision-making ability, interest, cooperation, and leadership.

From a manpower inventory survey, the consultant in the Indiana study (*3*) concluded that the State needed a system that requires superiors to appraise their subordinates periodically. This conclusion, equally applicable to the evaluation of trainees, stated that appraisal should be reviewed with the individual being appraised who should be told how he is doing and what his strong and weak points are. Moreover, the superior should counsel the individual as to how his weaknesses may be overcome and his overall performance improved, based on a variety of descriptive terms indicating qualities and characteristics such as diplomacy, tact, forcefulness, initiative, ambition, self-confidence, tolerance, patience, and job interest.

Concerning the training program itself, the training progress should be checked and reviewed regularly to insure adherence to the training plan and to discourage the use of trainees to offset workloads. According to the Virginia study (*3*), progress of trainees in that State had not been properly and regularly reviewed, and individual counseling for the most part was lacking. Furthermore, communication channels to express satisfaction or dissatisfaction were not clearly defined. Consequently, because of recommended corrective action, counseling sessions are now held with individual trainees at least every 3 months, and the system for evaluating trainees has been improved.

Effective evaluation is an invaluable basis for formulating the content of a training and development program, as well as for guiding the program itself. Evaluation also helps management in many other ways. For instance, evaluation criteria can produce a guideline to judge qualifications of new employees and applicants. It can also be used to develop a comprehensive management-development program that includes training but is not limited to it. After training has been completed, training evaluations can prove valuable in appraising managerial potential. Furthermore, as mentioned earlier, employee evaluation and counseling both during and after training can serve as a training device and be corrective in itself. Just giving an individual an awareness of problems concerning his many personal characteristics will help his self-improvement.

Evaluation then is seen to play a very important role in the overall plans of manpower development, specifically of training. It also influences the retention of trainees as discussed in the previous section.

Conclusions

This presentation was not intended as an exhaustive dissertation on all aspects of highway department training and development, but rather as the product of the findings of several State-conducted studies that dealt wholly or partly with the subject. Each of these State studies was devoted to a particular problem being encountered by the individual State. Therefore, comprehensive answers to the manpower problems of every State could not be given. Reports on the basic studies listed in the references contain specific information on these problems in the respective States who sponsored the studies.

The conclusions expressed here are more than a repetition of what others have disclosed. The findings helped to compile an outline of the different manpower and training aspects covered, and this article is meant to help draw those aspects into focus and demonstrate what must be considered in organizing and administering a manpower development and training program. The conclusions and findings were developed for particular States that may have had unique or unusual training and manpower problems and must be judged accordingly. Thus considered, the material presented and the knowledge gained will be helpful in seeking answers to highway department manpower and training matters.

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Driver Judgments as Influenced by Vehicular Lighting at Intersections

(*Continued from p. 8*)

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Table 2.—Vehicle-miles of travel in 1968 on all roads and streets, free and toll, by State and highway system—estimated by State highway departments

[Table VM-2 from *Highway Statistics*, 1968]

(Millions)

Division	State	Federal-aid highway system																		Not on Federal-aid systems						
		Interstate rural			Interstate urban			Sub-total Inter-state	Other primary			Secondary					Total Federal-aid rural	Total Federal-aid urban	Total Federal-aid					Sub-total rural	Sub-total urban and munici-pal	Total
		Final	Traveled-way 1/	Total rural	Final	Traveled-way 1/	Total urban		Rural	Urban	Total	State rural	State urban	Local rural	Local urban	Total				Other State rural	Other State urban and munici-pal	Local rural	Local urban and munici-pal			
		01	31		02	32			03	04		05	06	07	08					09	10	11	12			
New England	Connecticut	623	235	858	2,081	464	2,545	3,403	1,205	1,760	2,965	914	760	9	47	1,730	2,986	5,112	8,098	213	1,641	249	4,736	3,448	11,489	14,937
	Maine	536	48	584	66	70	136	720	1,456	447	1,903	872	144	-	-	1,016	2,912	727	3,639	895	299	335	373	4,142	1,399	5,541
	Massachusetts	1,350	86	1,436	1,690	802	2,492	3,928	2,607	4,467	7,074	628	538	1,090	1,345	3,601	5,761	8,842	14,603	149	900	726	6,776	6,636	16,518	23,154
	New Hampshire	435	54	489	66	41	107	596	1,104	284	1,388	722	133	3	2	860	2,318	526	2,844	152	192	123	494	2,593	1,212	3,805
	Rhode Island	72	107	179	549	179	728	907	207	1,174	1,381	218	414	16	203	851	620	2,519	3,139	52	125	125	915	797	3,560	4,357
	Vermont	244	185	429	35	73	108	537	791	141	932	361	6	136	11	514	1,717	266	1,983	46	2	202	219	1,965	487	2,452
	Total	3,260	715	3,975	4,487	1,629	6,116	10,091	7,370	8,273	15,643	3,715	1,995	1,254	1,608	8,572	16,314	17,992	34,306	1,507	3,160	1,760	13,513	19,581	34,665	54,246
Middle Atlantic	New Jersey	343	392	735	1,961	1,973	3,934	4,669	2,531	5,642	8,173	38	87	1,346	2,308	3,779	4,650	11,971	16,621	1,422	2,237	4,481	12,956	10,553	27,164	37,717
	New York	2,820	193	3,013	5,937	645	6,582	9,595	8,300	12,055	20,355	1,767	1,150	2,819	1,416	7,152	15,899	21,203	37,102	43	59	7,919	17,203	23,861	38,465	62,326
	Pennsylvania	3,821	1,041	4,862	2,085	752	2,837	7,699	8,491	6,990	15,481	6,050	3,751	51	102	9,954	19,454	13,680	33,134	3,446	4,460	4,317	11,519	27,217	29,659	56,876
	Total	6,984	1,626	8,610	9,983	3,370	13,353	21,963	19,322	24,687	44,009	7,855	4,988	4,216	3,826	20,885	40,003	46,854	86,857	4,911	6,756	16,717	41,678	61,631	95,288	156,919
South Atlantic (North)	Delaware	60	-	60	163	85	248	308	888	700	1,588	330	210	-	-	540	1,278	1,158	2,436	-	-	95	79	1,373	1,237	2,610
	Dist. of Col.	-	-	-	212	149	361	361	-	1,055	1,055	-	-	-	510	510	-	1,926	1,926	-	-	-	805	-	2,731	2,731
	Maryland	1,025	64	1,089	2,189	554	2,743	3,832	2,967	2,376	5,343	1,577	866	452	421	3,316	6,085	6,406	12,491	668	82	3,156	2,391	9,909	8,879	18,788
	Virginia	2,815	860	3,675	757	532	1,289	4,964	5,189	2,394	7,583	3,183	705	2,065	446	6,399	14,112	4,834	18,946	104	470	1,833	3,194	16,049	8,498	24,547
	West Virginia	441	448	889	86	186	272	1,161	1,812	735	2,547	1,404	143	1,079	40	2,666	5,184	1,190	6,374	9	29	374	1,439	5,567	2,658	8,225
	Total	4,341	1,372	5,713	3,407	1,506	4,913	10,626	10,856	7,260	18,116	6,494	1,924	3,596	1,417	13,431	26,659	15,514	42,173	781	581	5,458	7,908	32,893	24,003	56,901
South Atlantic (South)	Florida	1,808	803	2,611	1,300	722	2,022	4,633	5,301	3,913	9,214	4,483	2,794	240	54	7,571	12,635	8,783	21,418	1,402	1,084	2,228	8,706	16,265	18,573	34,838
	Georgia	1,970	1,229	3,199	1,753	155	1,908	5,107	5,782	2,007	7,789	2,631	554	1,301	471	4,957	12,913	4,940	17,853	138	405	1,854	5,801	14,905	11,146	26,051
	North Carolina	1,451	1,229	2,680	417	341	758	3,438	4,478	1,848	6,326	9,003	2,316	3	209	11,531	16,164	5,131	21,295	1,844	584	28	2,361	18,036	8,076	26,112
	South Carolina	1,116	809	1,925	118	105	223	2,148	4,541	1,535	6,076	3,293	469	114	5	3,881	9,873	2,232	12,105	333	1,015	360	378	10,566	3,625	14,191
	Total	6,345	4,070	10,415	3,588	1,323	4,911	15,326	20,102	9,303	29,405	19,410	6,133	1,658	739	27,940	51,585	21,086	72,671	3,717	3,088	4,470	17,246	59,772	41,420	101,192
East North Central	Illinois	2,699	1,475	4,174	4,238	935	5,173	9,347	8,441	7,558	15,999	1,092	621	2,179	545	4,437	15,886	13,897	29,783	1,538	3,827	2,857	14,134	20,281	31,858	52,139
	Indiana	2,568	778	3,346	1,021	665	1,686	5,032	6,132	2,682	8,814	2,872	648	1,899	756	6,175	14,249	5,772	20,021	115	183	1,184	6,100	15,548	12,055	27,603
	Michigan	3,017	183	3,200	2,700	1,509	4,209	7,409	7,068	6,318	13,386	1,403	519	6,929	1,124	9,975	18,600	12,170	30,770	24	58	4,502	12,690	23,126	24,918	48,044
	Ohio	4,200	252	4,452	4,146	1,340	5,486	9,938	7,985	6,479	14,464	4,271	1,823	2,267	2,340	10,701	18,975	16,128	35,103	107	437	4,701	12,486	23,783	29,051	52,834
	Wisconsin	1,457	191	1,648	643	174	817	2,465	5,595	2,441	8,036	1,625	513	1,644	978	4,760	10,512	4,749	15,261	44	67	1,178	5,639	11,734	10,455	22,189
	Total	13,941	2,879	16,820	12,748	4,623	17,371	34,191	35,221	25,478	60,699	11,263	4,124	14,918	5,743	36,048	78,222	52,716	130,938	1,828	4,572	14,422	51,049	94,472	108,337	202,809
West North Central	Iowa	1,484	282	1,766	356	89	445	2,211	4,785	1,403	6,188	-	-	1,537	324	1,861	8,088	2,172	10,260	92	60	904	2,523	9,084	4,755	13,839
	Kansas	919	189	1,108	333	82	415	1,523	3,716	1,039	4,755	573	25	1,470	438	2,506	6,867	1,917	8,784	65	67	1,077	2,557	8,009	4,541	12,550
	Minnesota	477	525	1,002	954	727	1,681	2,683	5,447	2,260	7,707	1,143	35	2,878	173	4,229	10,470	4,149	14,619	26	112	1,242	3,900	11,738	8,161	19,899
	Missouri	2,330	918	3,248	1,779	447	2,226	5,474	5,593	2,075	7,668	2,394	417	20	38	2,869	11,255	4,756	16,011	151	670	1,852	6,107	13,258	11,533	24,791
	Nebraska	766	121	887	82	30	112	999	3,048	641	3,689	653	33	640	81	1,407	5,228	867	6,095	4	-	994	1,860	6,226	2,727	8,953
	North Dakota	335	127	462	13	22	35	497	1,127	162	1,289	207	5	442	13	667	2,238	215	2,453	1	2	676	417	2,915	634	3,549
	South Dakota	446	290	736	22	12	34	770	1,562	220	1,782	255	30	404	29	718	2,957	313	3,270	24	7	581	428	3,562	748	4,310
	Total	6,757	2,452	9,209	3,539	1,409	4,948	14,157	25,278	7,800	33,078	5,225	545	7,391	1,096	14,257	47,103	14,389	61,492	363	918	7,326	17,792	54,792	33,099	87,891
East South Central	Alabama	588	1,193	1,781	118	866	984	2,765	4,373	1,889	6,262	1,491	313	932	113	2,849	8,577	3,299	11,876	28	24	1,053	3,549	9,658	6,872	16,530
	Kentucky	1,274	606	1,880	742	294	1,036	2,916	4,021	1,471	5,492	3,549	504	255	60	4,368	9,705	3,071	12,776	1,108	658	1,150	2,067	11,963	5,796	17,759
	Mississippi	762	365	1,127	142	422	564	1,691	3,816	716	4,532	896	87	1,073	195	2,251	6,912	1,562	8,474	19	19	636	1,450	7,567	3,031	10,598
	Tennessee	1,323	824	2,147	1,056	437	1,493	3,640	4,992	2,269	7,261	975	168	687	50	1,880	8,801	3,980	12,781	51	3	1,866	4,123	10,718	8,106	18,824
	Total	3,947	2,988	6,935	2,058	2,019	4,077	11,012	17,202	6,345	23,547	6,911	1,072	2,947	418	11,348	33,995	11,912	45,907	1,206	704	4,705	11,189	39,906	23,805	63,711
West South Central	Arkansas	859	226	1,085	325	25	350	1,435	2,791	1,018	3,809	2,230	332	272	61	2,895	6,378	1,761	8,139	57	67	718	1,249	7,153	3,077	10,230
	Louisiana	711	1,173	1,884	588	357	945	2,829	2,687	1,496	4,183	3,633	588	12	1	4,234	8,216	3,030	11,246	664	375	705	2,362	9,585	5,767	15,352
	Oklahoma	1,187	396	1,583	858	308	1,166	2,749	4,464	1,445	5,909	1,069	290	757	277	2,393	7,873	3,178	11,051	221	87	988	3,702	9,082	6,967	16,049
	Texas	3,463	1,826	5,289	6,662	1,614	8,276	13,565	11,814	7,754	19,568	7,921	2,267	-	-	10,188	25,024	18,297	43,321	1,288	1,016	2,445	14,118	28,757	33,431	62,188
	Total	6,220	3,621	9,841	8,433	2,304	10,737	20,578	21,756	11,713	33,469	14,853	3,477	1,041	339	19,710	47,491	26,266	73,757	2,230	1,545	4,856	21,431	54,577	49,242	103,819
Mountain	Arizona	1,045	1,263	2,308	388	191	579	2,887	1,250	324	1,574	575	51	656	1,907	3,189	4,789	2,861	7,650	196	16	572	1,608	5,557	4,485	10,042
	Colorado	908	490	1,398	607	224	831	2,229	2,044	1,746	3,790	908	186	-	-	1,094	4,350	2,763	7,113	23	50	1,253	2,605	5,626	5,418	11,044
	Idaho	460	321	781	33	62	95	876	1,183	218	1,401	339	23	317	90	769	2,620	426	3,046	2	2	652	512	3,274	940	4,214
	Montana	242	549	791	30	23	53	844	1,412	236	1,648	410	55	-	-	465	2,613	344	2,957	-	-	737	456	3,350	800	4,150
	Nevada	477	161	638	30	70	100	738	629	245	874	279	67	92	181	619	1,638	593	2,231	21	20	98	629	1,757	1,242	2,999
	New Mexico	924	518	1,442	158	213	371	1,813	1,439	565	2,004	820	137	6	*	963	3,707	1,073	4,780	78	490	420	710	4,205	2,273	6,478
	Utah	153	1,031	1,184	149	405	554	1,738	846	561	1,407	512	402	97	163	1,174	2,639	1,680	4,319	34	138	404	644	3,077	2,462	5,539
	Wyoming	543	269	812	23	14	37	849	855	122	977	250	9	14	9	282	1,931	177	2,108	2	3	348	336	2,281	516	2,797
	Total	4,752	4,602	9,354	1,418	1,202	2,620	11,974	9,658	4,017	13,675	4,093	930	1,182	2,350	8,555	24,287	9,917	34,204	356	719	4,484	7,500	29,127	18,136	47,263
Pacific	California	3,432	4,635	8,067	11,155	4,699	15,854	23,921	10,113	14,537	24,650	2,662	1,105	4,394	4,910	13,071	25,236	36,406	61,642	472	1,107	11,474	31,375	37,182	68,888	106,070
	Oregon	1,445	113	1,558	733	29	762	2,320	2,350	1,369	3,719	1,061	306	758	488	2,613	5,727	2,925	8,652	34	26	1,433	1,889	7,194	4,840	12,034
	Washington	936	752	1,688	1,735	451	2,186	3,874	2,374	1,495	3,869	1,010	555	1,539	1,030	4,134	6,611	5,266	11,877	17	149	2,727	4,253	9,355	9,668	19,023
	Total	5,813	5,500	11,313	13,623	5,179	18,802	30,115	14,837	17,401	32,238	4,733	1,966	6,691	6,428	19,818	37,574	44,597	82,171	523	1,282	15,634	37,517	53,731	83,396	137,127
Total - All Divisions		62,360	29,825	92,185	63,284	24,564	87,848	180,033	181,602	122,277	303,879	84,552	27,154	44,894	23,964	180,564	403,233	261,243	664,476	17,422	23,325	79,832	226,823	500,487	511,391	1,011,878
	Alaska	-	-	-	-	-	-	-	316	93	409	107	40	-	-	147	423	133	556	-	-	114	238	537	371	908
	Hawaii	20	114	134	141	281	422	556	552	407	959	141	30	42	30	243	869	889	1,758	10	-	457	638	1,336	1,527	2,863
United States Total		62,380	29,939	92,319	63,425	24,845	88,270	180,589	182,470	122,777	305,247	84,800	27,224	44,936	23,994	180,954	404,525	262,265	666,790	17,432	23,325	80,403	227,699	502,360	513,289	1,015,649

1/ Traveled-way includes travel on highways in the Interstate System status of completion group 2. This group consists of mileage which is adequate for present traffic but will need further construction and improvement to bring it to full Interstate standards. In some instances these are divided highways with full control of access and in others they are two, three or four-lane undivided highways with no access control.

* Less than 0.5 million vehicle-miles.

Note: For this table travel on frontage roads has been placed in systems 11 and 12. The numerical codes which are shown above for all 14 administrative highway systems are used for identification purposes in analyses of travel, mileage, and accident data based on these systems.

[Table VM-2 from *Highway Statistics,* 1968]

(Millions)

Division	State	Federal-aid highway system: Interstate rural: Final 01	Interstate rural: Traveled-way 1/ 31	Interstate rural: Total rural	Interstate urban: Final 02	Interstate urban: Traveled-way 1/ 32	Interstate urban: Total urban	Sub-total Inter-state	Other primary: Rural 03	Other primary: Urban 04	Other primary: Total	Secondary: State rural 05	Secondary: State urban 06	Secondary: Local rural 07	Secondary: Local urban 08	Secondary: Total	Total Federal-aid rural	Total Federal-aid urban	Total Federal-aid	Not on Federal-aid systems: Other State rural 09	Other State urban and munici-pal 10	Local rural 11	Local urban and munici-pal 12	Sub-total rural	Sub-total urban and munici-pal	Total
New England	Connecticut	541	162	703	1,821	398	2,219	2,922	1,160	1,618	2,778	864	754	7	44	1,669	2,734	4,635	7,369	218	1,623	240	4,564	3,192	10,822	14,014
	Maine	482	48	530	63	60	123	653	1,374	491	1,865	827	148	-	-	975	2,731	762	3,493	798	276	274	383	3,803	1,421	5,224
	Massachusetts	1,047	174	1,221	1,288	540	1,828	3,049	2,418	4,501	6,919	611	523	1,059	1,306	3,499	5,309	8,158	13,467	145	873	705	6,579	6,159	15,610	21,769
	New Hampshire	393	59	452	61	37	98	550	1,094	295	1,389	730	125	3	2	860	2,279	520	2,799	135	170	109	437	2,523	1,127	3,650
	Rhode Island	59	44	103	489	103	592	695	237	1,139	1,376	206	390	16	206	818	562	2,327	2,889	79	157	125	911	766	3,395	4,161
	Vermont	210	185	395	30	72	102	497	754	133	887	319	6	137	10	472	1,605	251	1,856	44	2	197	212	1,846	465	2,311
	Total	2,732	672	3,404	3,752	1,210	4,962	8,366	7,037	8,177	15,214	3,557	1,946	1,222	1,568	8,293	15,220	16,653	31,873	1,419	3,101	1,650	13,086	18,289	32,840	51,129
Middle Atlantic	New Jersey	325	370	695	1,849	1,861	3,710	4,405	2,385	5,320	7,705	37	83	1,269	2,177	3,566	4,386	11,290	15,676	1,340	2,111	4,227	12,219	9,953	25,620	35,573
	New York	3,020	221	3,241	5,424	738	6,162	9,403	8,228	11,581	19,809	1,740	1,130	2,776	1,399	7,045	15,985	20,272	36,257	42	58	7,940	16,434	23,967	36,764	60,731
	Pennsylvania	3,613	1,171	4,784	2,205	894	3,099	7,883	7,789	5,908	13,697	5,516	3,326	46	93	8,981	18,135	12,426	30,561	3,164	4,010	3,996	10,392	25,295	26,828	52,123
	Total	6,958	1,762	8,720	9,478	3,493	12,971	21,691	18,402	22,809	41,211	7,293	4,539	4,091	3,669	19,592	38,506	43,988	82,494	4,546	6,179	16,163	39,045	59,215	89,212	148,427
South Atlantic (North)	Delaware	55	-	55	148	102	250	305	845	657	1,502	320	220	-	-	540	1,220	1,127	2,347	-	-	93	77	1,313	1,204	2,517
	Dist. of Col.	-	-	-	192	155	347	347	-	1,025	1,025	-	-	-	492	492	-	1,864	1,864	-	-	-	779	-	2,643	2,643
	Maryland	744	154	898	1,911	413	2,324	3,222	2,431	2,758	5,189	1,451	1,048	439	405	3,343	5,219	6,535	11,754	556	69	3,049	2,395	8,824	8,999	17,823
	Virginia	2,523	1,056	3,579	656	643	1,299	4,878	4,514	2,179	6,693	2,993	569	2,041	403	6,006	13,127	4,450	17,577	92	419	1,675	2,878	14,894	7,747	22,641
	West Virginia	308	523	831	78	192	270	1,101	2,030	719	2,749	1,491	116	850	31	2,488	5,202	1,136	6,338	7	24	286	1,120	5,495	2,280	7,775
	Total	3,630	1,733	5,363	2,985	1,505	4,490	9,853	9,820	7,338	17,158	6,255	1,953	3,330	1,331	12,869	24,768	15,112	39,880	655	512	5,103	7,249	30,526	22,873	53,399
South Atlantic (South)	Florida	1,598	1,484	3,082	1,251	1,165	2,416	5,498	4,608	3,414	8,022	4,293	2,565	206	33	7,097	12,189	8,428	20,617	861	1,462	2,151	6,729	15,201	16,619	31,820
	Georgia	1,743	1,267	3,010	1,504	267	1,771	4,781	5,536	1,891	7,427	2,514	532	1,179	452	4,677	12,239	4,646	16,885	167	394	1,575	5,261	13,981	10,301	24,282
	North Carolina	1,311	1,062	2,373	350	338	688	3,061	4,369	1,715	6,084	8,661	2,036	3	196	10,896	15,406	4,635	20,041	1,413	602	27	2,487	16,846	7,724	24,570
	South Carolina	985	716	1,701	85	159	244	1,945	4,200	1,383	5,583	3,083	440	117	5	3,645	9,101	2,072	11,173	307	926	345	335	9,753	3,333	13,086
	Total	5,637	4,529	10,166	3,190	1,929	5,119	15,285	18,713	8,403	27,116	18,551	5,573	1,505	686	26,315	48,935	19,781	68,716	2,748	3,384	4,098	14,812	55,781	37,977	93,758
East North Central	Illinois	2,299	1,562	3,861	4,334	758	5,092	8,953	8,202	6,901	15,103	1,072	587	2,105	498	4,262	15,240	13,078	28,318	1,479	3,673	2,779	13,536	19,498	30,287	49,785
	Indiana	1,801	1,124	2,925	865	742	1,607	4,532	7,718	2,173	9,891	3,174	575	1,433	180	5,362	15,250	4,535	19,785	189	136	1,234	6,471	16,673	11,142	27,815
	Michigan	2,591	552	3,143	2,852	1,146	3,998	7,141	6,383	6,082	12,465	1,297	468	6,321	942	9,028	17,144	11,490	28,634	26	45	4,126	12,223	21,296	23,758	45,054
	Ohio	3,571	495	4,066	3,379	1,386	4,765	8,831	7,725	6,173	13,898	4,195	1,756	2,221	2,224	10,396	18,207	14,918	33,125	105	417	4,644	12,072	22,956	27,407	50,363
	Wisconsin	1,346	131	1,477	484	66	550	2,027	5,393	2,317	7,710	1,543	463	1,562	911	4,479	9,975	4,241	14,216	46	60	1,172	5,437	11,193	9,738	20,931
	Total	11,608	3,864	15,472	11,914	4,098	16,012	31,484	35,421	23,646	59,067	11,281	3,849	13,642	4,755	33,527	75,816	48,262	124,078	1,845	4,331	13,955	49,739	91,616	102,332	193,948
West North Central	Iowa	1,397	161	1,558	194	88	282	1,840	4,943	1,367	6,310	-	-	1,522	313	1,835	8,023	1,962	9,985	80	51	886	2,471	8,989	4,484	13,473
	Kansas	822	198	1,020	312	80	392	1,412	3,650	1,002	4,652	562	24	1,436	412	2,434	6,668	1,830	8,498	65	65	1,080	2,442	7,813	4,337	12,150
	Minnesota	371	599	970	805	751	1,556	2,526	4,661	2,269	6,930	1,055	76	2,761	163	4,055	9,447	4,064	13,511	24	87	1,364	3,675	10,835	7,826	18,661
	Missouri	1,926	963	2,889	1,423	696	2,119	5,008	5,379	2,017	7,396	2,281	387	19	36	2,723	10,568	4,559	15,127	126	642	1,848	6,034	12,542	11,235	23,777
	Nebraska	675	185	860	59	46	105	965	2,852	638	3,490	636	39	635	71	1,381	4,983	853	5,836	4	-	1,002	1,865	5,989	2,718	8,707
	North Dakota	327	125	452	11	22	33	485	1,103	147	1,250	196	4	430	13	643	2,181	197	2,378	1	2	662	401	2,844	600	3,444
	South Dakota	399	271	670	20	11	31	701	1,548	208	1,756	238	28	396	25	687	2,852	292	3,144	23	7	579	390	3,454	689	4,143
	Total	5,917	2,502	8,419	2,824	1,694	4,518	12,937	24,136	7,648	31,784	4,968	558	7,199	1,033	13,758	44,722	13,757	58,479	323	854	7,421	17,278	52,466	31,889	84,355
East South Central	Alabama	495	1,095	1,590	104	778	882	2,472	4,200	1,724	5,924	1,430	277	1,360	221	3,288	8,580	3,104	11,684	40	51	875	3,300	9,495	6,455	15,950
	Kentucky	1,094	676	1,770	575	345	920	2,690	3,829	1,320	5,149	3,379	457	215	48	4,099	9,193	2,745	11,938	1,023	632	1,085	1,895	11,301	5,272	16,573
	Mississippi	517	472	989	118	470	588	1,577	3,595	652	4,247	803	82	970	182	2,037	6,357	1,504	7,861	18	13	636	1,293	7,011	2,810	9,821
	Tennessee	1,062	989	2,051	969	668	1,637	3,688	4,848	2,062	6,910	934	169	657	47	1,807	8,490	3,915	12,405	47	4	1,804	3,911	10,341	7,830	18,171
	Total	3,168	3,232	6,400	1,766	2,261	4,027	10,427	16,472	5,758	22,230	6,546	985	3,202	498	11,231	32,620	11,268	43,888	1,128	700	4,400	10,399	38,148	22,367	60,515
West South Central	Arkansas	629	383	1,012	287	38	325	1,337	2,596	923	3,519	2,075	318	260	37	2,690	5,943	1,603	7,546	55	107	666	1,374	6,664	3,084	9,748
	Louisiana	618	1,179	1,797	473	568	1,041	2,838	2,554	1,340	3,894	3,412	542	11	1	3,966	7,774	2,924	10,698	616	375	661	2,289	9,051	5,588	14,639
	Oklahoma	1,120	386	1,506	746	283	1,029	2,535	4,365	1,319	5,684	1,032	287	728	256	2,303	7,631	2,891	10,522	215	109	971	3,346	8,817	6,346	15,163
	Texas	3,018	1,656	4,674	6,036	1,544	7,580	12,254	11,261	7,349	18,610	7,626	2,079	-	-	9,705	23,561	17,008	40,569	1,250	920	2,473	13,790	27,284	31,718	59,002
	Total	5,385	3,604	8,989	7,542	2,433	9,975	18,964	20,776	10,931	31,707	14,145	3,226	999	294	18,664	44,909	24,426	69,335	2,136	1,511	4,771	20,799	51,816	46,736	98,552
Mountain	Arizona	853	1,354	2,207	382	207	589	2,796	1,174	285	1,459	499	48	473	1,899	2,919	4,353	2,821	7,174	185	15	373	1,468	4,911	4,304	9,215
	Colorado	1,048	332	1,380	444	375	819	2,199	2,052	1,624	3,676	918	156	-	-	1,074	4,350	2,599	6,949	14	44	1,266	2,567	5,630	5,210	10,840
	Idaho	397	304	701	27	68	95	796	1,191	203	1,394	325	24	303	52	704	2,520	374	2,894	3	2	707	530	3,230	906	4,136
	Montana	206	547	753	27	23	50	803	1,340	224	1,554	375	52	-	-	427	2,468	326	2,794	-	-	730	418	3,198	744	3,942
	Nevada	514	216	730	20	84	104	834	630	230	860	262	63	86	165	576	1,708	562	2,270	22	20	101	600	1,831	1,182	3,013
	New Mexico	792	570	1,362	140	208	348	1,710	1,375	519	1,894	803	129	6	*	938	3,546	996	4,542	72	437	396	674	4,014	2,107	6,121
	Utah	349	764	1,113	487	76	563	1,676	771	565	1,336	508	380	92	142	1,122	2,484	1,650	4,134	38	151	384	603	2,906	2,404	5,310
	Wyoming	446	321	767	21	16	37	804	813	125	938	210	7	13	9	239	1,803	178	1,981	2	3	275	321	2,080	502	2,582
	Total	4,605	4,408	9,013	1,548	1,057	2,605	11,618	9,346	3,775	13,121	3,900	859	973	2,267	7,999	23,232	9,506	32,738	336	672	4,232	7,181	27,800	17,359	45,159
Pacific	California	2,772	4,523	7,295	10,356	3,784	14,140	21,435	11,374	14,412	25,786	2,457	844	3,547	3,799	10,647	24,673	33,195	57,868	594	1,197	6,927	32,886	32,194	67,278	99,472
	Oregon	1,344	112	1,456	693	30	723	2,179	2,251	1,333	3,584	1,034	283	723	456	2,496	5,464	2,795	8,259	36	14	1,370	1,886	6,870	4,695	11,565
	Washington	560	804	1,364	1,236	527	1,763	3,127	2,089	1,224	3,313	937	489	1,432	884	3,742	5,822	4,360	10,182	1,116	135	2,648	3,660	9,586	8,155	17,741
	Total	4,676	5,439	10,115	12,285	4,341	16,626	26,741	15,714	16,969	32,683	4,428	1,616	5,702	5,139	16,885	35,959	40,350	76,309	1,746	1,346	10,945	38,432	48,650	80,128	128,778
Total - All Divisions		54,316	31,745	86,061	57,284	24,021	81,305	167,366	175,837	115,454	291,291	80,924	25,104	41,865	21,240	169,133	384,687	243,103	627,790	16,882	22,590	72,738	218,020	474,307	483,713	958,020
	Alaska	-	-	-	-	-	-	-	305	101	406	106	35	-	-	141	411	136	547	-	-	107	219	518	355	873
	Hawaii	16	108	124	105	262	367	491	473	362	835	234	42	-	-	276	831	771	1,602	-	-	404	654	1,235	1,425	2,660
United States Total		54,332	31,853	86,185	57,389	24,283	81,672	167,857	176,615	115,917	292,532	81,264	25,181	41,865	21,240	169,550	385,929	244,010	629,939	16,882	22,590	73,249	218,893	476,060	485,403	961,553

1/ Traveled-way includes travel on highways in the Interstate System status of completion group 2. This group consists of mileage which is adequate for present traffic but will need further construction and improvement to bring it to full Interstate standards. In some instances these are divided highways with full control of access and in others they are two, three or four-lane undivided highways with no access control.

* Less than 0.5 million vehicle-miles.

Note: For this table travel on frontage roads has been placed in systems 11 and 12. The numerical codes which are shown above for all 14 administrative highway systems are used for identification purposes in analyses of travel, mileage, and accident data based on these systems.

Table 4.—Comparison of preliminary estimates of vehicle registrations and highway use of motor fuel and relationships of these items to each other and to total travel, 1968

[From table TA-1 [1] with published estimates by the Bureau of Public Roads]

Division	State	Vehicles registered, thousands		Annual miles per vehicle		Motor fuel, million gallons		Gallons per vehicle		Miles traveled per gallon	
		Preliminary estimate 2/ 5/	Table MV-1 3/	Preliminary estimate 2/	Based on tables MV-1 and VM-2 3/ 4/	Preliminary estimate 2/	Table MF-21 3/	Preliminary estimate 2/	Based on tables MV-1 and MF-21 3/	Preliminary estimate 2/	Based on tables MF-21 and VM-2 3/ 4/
New England	Connecticut	1,624	1,626	9,198	9,186	1,149	1,148	708	706	13.00	13.01
	Maine	480	480	11,542	11,544	443	438	923	912	12.50	12.65
	Massachusetts	2,490	2,336	9,326	9,912	1,855	1,957	745	838	12.51	11.83
	New Hampshire	355	353	10,718	10,779	300	304	845	861	12.68	12.52
	Rhode Island	447	452	9,682	9,639	325	321	723	709	13.39	13.57
	Vermont	210	207	11,677	11,845	191	191	910	925	12.84	12.84
	Total	5,606	5,454	9,676	9,946	4,263	4,359	760	799	12.72	12.44
Middle Atlantic	New Jersey	3,498	3,334	11,162	11,313	2,739	2,704	811	811	13.77	13.95
	New York	6,482	6,310	9,615	9,877	5,042	5,022	778	796	12.36	12.41
	Pennsylvania	5,587	5,547	10,172	10,253	4,238	4,279	758	771	13.42	13.29
	Total	15,567	15,191	10,080	10,330	12,019	12,005	772	790	13.06	13.07
South Atlantic (North)	Delaware	278	283	9,388	9,223	233	244	837	861	11.21	10.70
	Dist. of Col.	258	257	10,585	10,626	246	246	953	956	11.11	11.10
	Maryland	1,709	1,704	10,994	11,026	1,424	1,423	833	835	13.19	13.20
	Virginia	2,048	2,048	11,986	11,986	1,897	1,890	926	923	12.94	12.99
	West Virginia	810	805	10,155	10,217	658	659	810	819	12.54	12.48
	Total	5,103	5,097	11,150	11,164	4,458	4,462	874	875	12.76	12.75
South Atlantic (South)	Florida	3,635	3,628	9,584	9,603	2,805	2,804	772	773	12.42	12.42
	Georgia	2,338	2,324	11,142	11,210	2,140	2,142	915	922	12.18	12.16
	North Carolina	2,572	2,573	10,152	10,148	2,206	2,195	858	853	11.84	11.90
	South Carolina 6/	1,250	1,250	11,353	11,353	1,113	1,113	890	891	12.75	12.75
	Total	9,795	9,775	10,331	10,352	8,264	8,254	844	844	12.24	12.26
East North Central	Illinois	5,007	4,990	10,413	10,449	4,198	4,224	838	847	12.42	12.34
	Indiana	3,020	2,739	9,140	10,078	2,364	2,386	783	871	11.76	11.57
	Michigan	4,308	4,317	11,153	11,129	3,748	3,798	870	880	12.82	12.65
	Ohio	5,390	5,442	9,802	9,709	4,254	4,322	789	794	12.42	12.22
	Wisconsin	2,184	2,027	9,615	10,947	1,690	1,695	774	836	12.42	13.09
	Total	19,909	19,515	10,187	10,392	16,254	16,425	816	842	12.48	12.35
West North Central	Iowa	1,699	1,703	8,145	8,126	1,326	1,321	780	776	10.44	10.48
	Kansas	1,502	1,501	8,356	8,361	1,101	1,114	733	742	11.40	11.27
	Minnesota	2,082	2,086	9,558	9,539	1,623	1,615	780	774	12.26	12.32
	Missouri	2,474	2,345	10,019	10,572	2,151	2,167	869	924	11.52	11.44
	Nebraska	909	909	9,849	9,849	723	720	795	792	12.38	12.43
	North Dakota	414	414	8,572	8,572	274	272	662	658	12.95	13.05
	South Dakota	411	411	10,487	10,487	317	319	771	776	13.60	13.51
	Total	9,491	9,369	9,260	9,381	7,515	7,528	792	804	11.70	11.68
East South Central	Alabama	1,815	1,806	9,107	9,153	1,470	1,473	810	816	11.24	11.22
	Kentucky	1,685	1,691	10,522	10,502	1,335	1,335	792	790	13.28	13.30
	Mississippi	1,077	1,061	9,840	9,989	982	982	912	926	10.79	10.79
	Tennessee	1,926	1,907	9,774	9,871	1,674	1,698	869	891	11.24	11.09
	Total	6,503	6,465	9,797	9,855	5,461	5,488	840	849	11.67	11.61
West South Central	Arkansas	1,033	1,023	9,913	10,000	935	912	906	892	10.94	11.22
	Louisiana	1,663	1,662	9,224	9,237	1,391	1,398	836	841	11.03	10.98
	Oklahoma	1,609	1,610	9,975	9,968	1,286	1,289	800	800	12.48	12.45
	Texas	6,170	6,180	10,079	10,063	5,572	5,581	903	903	11.16	11.14
	Total	10,475	10,475	9,911	9,911	9,184	9,180	877	876	11.30	11.31
Mountain	Arizona	977	944	10,278	10,638	807	796	826	844	12.44	12.62
	Colorado	1,278	1,300	8,642	8,495	895	959	700	738	12.34	11.52
	Idaho	469	471	8,985	8,947	339	347	723	736	12.42	12.14
	Montana	464	463	8,944	8,963	359	367	774	793	11.56	11.31
	Nevada	314	303	9,551	9,898	291	289	927	953	10.30	10.38
	New Mexico	585	589	11,074	10,998	550	551	940	934	11.78	11.76
	Utah	624	571	8,868	9,701	443	469	709	821	12.51	11.81
	Wyoming	226	226	12,376	12,376	233	233	1,031	1,031	12.00	12.00
	Total	4,937	4,867	9,573	9,711	3,917	4,011	793	824	12.07	11.78
Pacific	California	11,125	11,123	9,534	9,536	8,506	8,535	764	767	12.42	12.43
	Oregon	1,241	1,242	9,697	9,689	988	983	796	791	12.18	12.24
	Washington	1,987	1,987	9,574	9,574	1,442	1,433	726	721	13.19	13.27
	Total	14,353	14,352	9,554	9,555	10,936	10,951	762	763	12.54	12.52
Total - All Divisions		101,739	100,560	9,946	10,062	82,271	82,663	809	822	12.30	12.24
	Alaska	120	123	7,320	7,382	76	76	610	613	12.00	11.95
	Hawaii	354	355	8,089	8,065	204	203	578	573	14.00	14.10
United States Total		102,213	101,038	9,937	10,052	82,551	82,942	808	821	12.30	12.25

1/ "Table TA-1.--Statewide mileage, travel and nonfatal and fatal injury accidents" is submitted to the Bureau of Public Roads by the State highway departments early in April each year, while the final Bureau of Public Roads estimates are not usually completed until midsummer.
2/ Data source: Table TA-1, 1968 for the 50 States and the District of Columbia.
3/ Data sources: Vehicle registrations, highway use of motor fuel, and drivers licenses in force from tables MV-1, MF-21, and DL-1, respectively, 1968, Highway Statistics Division, Bureau of Public Roads; population from "Current Population Reports," Series P-25, No. 414, January 28, 1969.
4/ All travel related items were calculated using State estimates of total travel as shown in table VM-2 for 1968.
5/ Excludes motorcycles.
6/ Published figures used in the preliminary estimate columns since the State did not estimate these items.
Note: Totals may not add to the same totals given in tables MV-1, MF-21, DL-1, or Current Population Reports, series P-25, No. 414, due to rounding.

ehicle-miles for each road section—a long, iborious process. Another good approach is sample randomly certain road sections on ach system and obtain an average figure for ehicle-miles per mile on each system, from hich the vehicle-miles can be calculated.

Most often, one of the following methods, a combination of them, is used to arrive at tal travel: (1) The product of vehicle regis- ations and an estimated annual miles per ehicle; (2) the product of fuel consumption d an estimated miles-per-gallon figure;) the product of the population and an esti- ated annual miles-per-capita figure. Of these, e second is the most frequently used be- use there is a more direct relationship be- veen travel and gallons of fuel used than etween travel and any other variable.

For many years, estimates and forecasts of avel have been very important for highway anning. They are needed for urban trans- ortation studies, statewide transportation udies, studies of highway needs and financ- g, etc. Travel estimates have been used in ese studies as base year data for forecasts, compare service provided among highway stems, and to compare different modes of ansport. Although the greatest accuracy ossible, within practical limits, is always de- red for these purposes, consistency is as im- ortant, or even more important, than accu- cy. The basic estimates can be high or low, ut as long as consistency between the factors maintained, decisions based on these factors ill be correct.

Distributing travel among the systems in e proper proportions is essential. Even if the ase year travel estimate and the related ctors of miles per gallon and annual miles er vehicle are in error, forecasts of fuel con- umption and vehicle registrations for highway eeds and revenue studies will not be adversely fected as long as consistent relations among ese factors are maintained throughout the recast period.

Because of the increased emphasis on high- ay safety programs in the last few years, avel estimates are acquiring even more im- ortance. Reliable travel estimates are needed ot only by highway systems but also by ehicle type, age and sex of driver, weather nditions, road condition, day or night, etc., properly evaluate State-to-State accident perience. This need for increased detail in avel estimates brings with it a need for creased accuracy.

As more detail is required in the breakdown total travel, the relative positions of the arious elements become less dependable and ss useful, and the absolute values more portant. The greater the number of parts at total travel is divided into, the lesser the kelihood that proper relationships between ements will be maintained. To properly sess the accident-causation potential of the ifferent combinations of driver-vehicle-road- ay-weather interrelations, reliable accident tes under these conditions must be known. ccident rates are functions of accident umbers and of exposure—exposure being the mount of travel produced under given nditions. Accordingly, two things are neces- sary to develop accurate accident rates: accurate reporting of accidents and reliable detailed travel estimates. Because of this increasing need for accurate and detailed travel estimates, estimates of some of the factors that contribute to travel estimating will be explained.

Vehicle registrations, highway use of motor fuel, drivers' licenses in force, and population are listed in tables 4 and 5 in which comparisons of preliminary estimates and later published estimates, as well as the relationships of the listed items to each other and to total travel are shown. Variations between preliminary estimates and published estimates usually were small, as illustrated by the small number of States with estimates that varied by more than 2 percent from the published figures—vehicle registrations, nine States; highway use of motor fuel, five States; population, nine States; and drivers' licenses in force, 17 States. The State estimates are reported for the preceding year in table TA–1, which is submitted in April of each year. Preliminary estimates of vehicle registrations, population, and particularly fuel consumption, are near enough to the published values to be used in estimating travel when final data are not available. However, drivers' licenses in force has not been as reliable a figure. Because of differences in administrative procedures and in extent of enforcement, the significance of the numbers of drivers' licenses varies among the States. The relations of drivers' licenses in force to other variables are even more erratic among the States.

Vehicle registrations and fuel consumption are published each year in the Public Roads publication *Highway Statistics* (see list of publications inside back cover), which is based on actual State figures that have been adjusted to achieve consistency in reporting. Thus, figures used in estimating are never obsolete by more than 1 year, and errors should be slight. Although actual population counts are made only in the decennial census, populations in all States are estimated each year by the Bureau of the Census and are based on data that can be quantified on a consistent basis.

The items that relate known variables to the unknown variable, travel, cannot be quantified with the same assurance. For this reason, three of these items, miles per gallon, annual miles per vehicle, and gallons per vehicle, will be discussed in more detail. Of these three, gallons per vehicle can be more reliably ascertained as it is derived from the vehicle registrations and the figures for fuel consumed. The gallons-per-vehicle figure is useful in analyzing the consistency of forecasts of vehicle registrations, fuel consumption, and travel. When the figures from the different States are compared, the comparison can provide a clue to help identify those States that have a high or low proportion of fuel purchases by out-of-State vehicles.

Miles per gallon

As stated previously, the most common method used to estimate total travel in a State is to multiply the number of gallons of fuel consumed for highway use by a miles-per-gallon figure. As a very close estimate of fuel consumption can be obtained, the accuracy of the resulting travel estimate is dependent on the miles-per-gallon figure.

Nationally, miles traveled per gallon, which had remained fairly stable at 12.47–12.49 from 1963 through 1966, dropped to 12.38 in 1967, and to 12.25 in 1968. These decreases can be

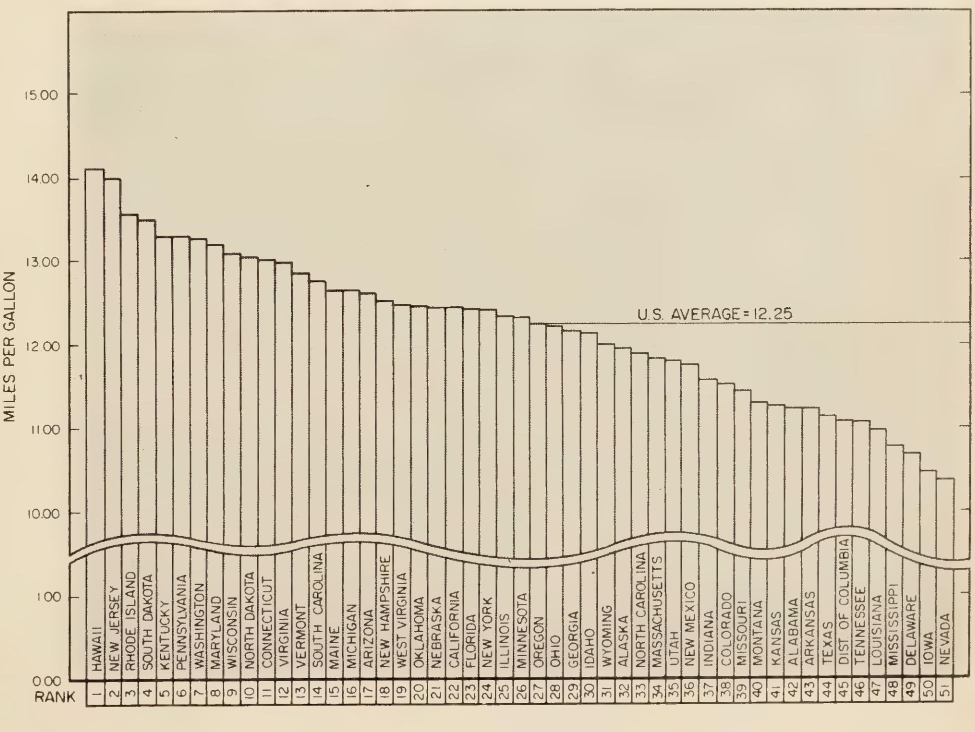

Figure 1.—Miles traveled per gallon of fuel consumed in 1968.

Table 5.—Comparison of preliminary estimates of population, and drivers licenses in force and relationships of these items to each other and to total travel, 1968

[From table TA-1 [1] with published estimates by the Bureau of the Census and the Bureau of Public Roads respectively]

Division	State	Population, thousands		Drivers licenses in force, thousands		Drivers licenses in force, percent population		Persons per vehicle		Drivers licenses in force, per vehicle		Annual travel per capita, miles		Travel per drivers license in force, miles	
		State estimate 2/	Census Bureau P-25, No. 414 3/	Preliminary estimate 2/	Table DL-1 3/	Preliminary estimate 2/	Based on Census and table DL-1 3/	Preliminary estimate 2/	Based on Census and table MV-1 3/	Preliminary estimate 2/	Based on tables MV-1 and DL-1 3/	Preliminary estimate 2/	Based on Census and table VM-2 3/ 4/	Preliminary estimate 2/	Based on tables VM-2 and DL-1 3/ 4/
New England	Connecticut	2,965	2,963	1,983	1,983	66.88	66.93	1.83	1.82	1.22	1.22	5,038	5,041	7,533	7,533
	Maine	982	976	491	491	50.00	50.31	2.05	2.03	1.02	1.02	5,642	5,677	11,283	11,285
	Massachusetts	5,525	5,469	2,845	2,850	51.50	52.11	2.22	2.34	1.14	1.22	4,203	4,234	8,162	8,124
	New Hampshire	704	702	413	390	58.66	55.56	1.99	1.99	1.17	1.10	5,405	5,420	9,213	9,756
	Rhode Island	914	914	480	480	53.00	52.52	2.04	2.02	1.09	1.06	4,767	4,767	9,077	9,077
	Vermont	422	425	215	224	50.94	52.71	2.01	2.05	1.02	1.08	5,811	5,769	11,405	10,946
	Total	11,512	11,449	6,427	6,418	55.83	56.06	2.05	2.10	1.15	1.18	4,712	4,738	8,440	8,452
Middle Atlantic	New Jersey	7,320	7,093	3,783	3,733	51.68	52.63	2.17	2.13	1.12	1.12	5,153	5,317	10,090	10,104
	New York	18,830	18,078	7,950	7,983	42.21	44.16	2.90	2.86	1.23	1.27	3,310	3,448	7,840	7,807
	Pennsylvania	11,800	11,728	6,074	6,076	51.47	51.81	2.11	2.11	1.09	1.10	4,820	4,850	9,364	9,361
	Total	37,950	36,899	17,807	17,792	46.92	48.22	2.44	2.43	1.14	1.17	4,135	4,253	8,812	8,820
South Atlantic (North)	Delaware	536	534	303	312	56.52	58.43	1.93	1.89	1.10	1.10	4,879	4,888	8,559	8,365
	Dist. of Col.	809	809	346	343	42.77	42.40	3.14	3.15	1.34	1.33	3,376	3,376	7,893	7,962
	Maryland	3,804	3,754	1,972	1,925	51.84	51.28	2.23	2.20	1.15	1.13	4,939	5,005	9,527	9,760
	Virginia	4,693	4,595	2,307	2,307	49.16	50.21	2.29	2.24	1.13	1.13	5,231	5,342	10,640	10,640
	West Virginia	1,802	1,802	839	828	46.55	45.95	2.22	2.24	1.04	1.03	4,574	4,564	9,764	9,934
	Total	11,644	11,494	5,767	5,715	49.53	49.72	2.28	2.26	1.13	1.12	4,887	4,950	9,867	9,956
South Atlantic (South)	Florida	6,202	6,151	3,746	3,425	60.40	55.68	1.71	1.70	1.03	0.94	5,617	5,664	9,300	10,172
	Georgia	4,584	4,568	2,279	2,279	49.71	49.89	1.96	1.97	0.97	0.98	5,683	5,703	11,431	11,431
	North Carolina	5,122	5,122	2,600	2,548	50.76	49.75	1.99	1.99	1.01	0.99	5,098	5,098	10,043	10,248
	South Carolina	2,664	2,664	1,326	1,326	49.77	49.77	2.13	2.13	1.06	1.06	5,327	5,327	10,702	10,702
	Total	18,572	18,505	9,951	9,578	53.58	51.76	1.90	1.89	1.02	0.98	5,449	5,468	10,169	10,565
East North Central	Illinois	10,999	10,991	5,966	5,972	54.24	54.34	2.20	2.20	1.19	1.20	4,740	4,744	8,739	8,731
	Indiana	5,044	5,061	3,198	2,573	63.40	50.84	1.67	1.85	1.06	0.94	5,472	5,454	8,631	10,728
	Michigan	8,728	8,739	4,966	4,572	56.90	52.32	2.03	2.02	1.15	1.06	5,505	5,498	9,675	10,508
	Ohio	10,529	10,588	5,860	5,860	55.66	55.35	1.95	1.95	1.09	1.08	5,018	4,990	9,016	9,016
	Wisconsin	4,228	4,221	2,361	2,361	55.84	55.93	1.94	2.08	1.08	1.16	4,965	5,257	8,895	9,398
	Total	39,528	39,600	22,351	21,338	56.54	53.88	1.99	2.03	1.12	1.09	5,131	5,121	9,074	9,505
West North Central	Iowa	2,758	2,774	1,597	1,598	57.90	57.61	1.73	1.63	1.06	0.94	5,018	4,989	8,666	8,660
	Kansas	2,281	2,293	1,396	1,396	61.20	60.88	1.52	1.53	0.93	0.93	5,502	5,473	8,990	8,990
	Minnesota	3,646	3,647	2,071	2,078	56.80	56.98	1.75	1.75	0.99	1.00	5,458	5,456	9,608	9,576
	Missouri	4,625	4,625	2,526	2,450	54.05	52.97	1.87	1.97	1.02	1.04	5,360	5,360	9,813	10,119
	Nebraska	1,502	1,439	886	886	58.98	61.57	1.65	1.58	0.97	0.97	5,961	6,222	10,105	10,105
	North Dakota	627	627	333	333	53.11	53.11	1.51	1.51	0.80	0.80	5,660	5,660	10,658	10,658
	South Dakota	656	656	388	398	59.15	60.67	1.60	1.60	0.94	0.97	6,570	6,570	11,108	10,829
	Total	16,095	16,061	9,197	9,139	57.14	56.90	1.70	1.71	0.97	0.98	5,461	5,472	9,556	9,617
East South Central	Alabama	3,558	3,558	1,664	1,614	46.77	45.36	1.96	1.97	0.92	0.89	4,646	4,646	9,934	10,242
	Kentucky	3,229	3,220	1,477	1,477	45.74	45.87	1.92	1.90	0.88	0.87	5,491	5,515	12,003	12,024
	Mississippi	2,344	2,344	1,005	1,010	42.88	43.09	2.18	2.21	0.93	0.95	4,521	4,521	10,545	10,493
	Tennessee	3,983	3,975	2,010	2,010	50.46	50.57	2.07	2.08	1.04	1.05	4,726	4,736	9,365	9,365
	Total	13,114	13,097	6,156	6,111	46.94	46.66	2.02	2.03	0.95	0.95	4,858	4,865	10,349	10,426
West South Central	Arkansas	1,968	1,986	1,051	1,051	53.40	52.92	1.91	1.94	1.02	1.03	5,198	5,151	9,734	9,734
	Louisiana	3,726	3,726	1,677	1,677	45.01	45.01	2.24	2.24	1.01	1.01	4,117	4,120	9,147	9,154
	Oklahoma	2,520	2,520	1,500	1,461	59.52	57.98	1.57	1.57	1.07	0.91	6,369	6,369	10,699	10,985
	Texas	11,605	10,977	5,627	5,627	48.49	51.26	1.88	1.78	0.91	0.91	5,359	5,665	11,052	11,052
	Total	19,819	19,209	9,855	9,816	49.73	51.10	1.89	1.83	0.94	0.94	5,238	5,405	10,535	10,577
Mountain	Arizona	1,700	1,663	1,079	1,004	63.47	60.37	1.74	1.76	1.10	1.06	5,907	6,038	9,307	10,002
	Colorado	2,068	2,043	1,306	1,261	63.15	61.72	1.62	1.57	1.02	0.97	5,340	5,406	8,456	8,758
	Idaho	712	703	435	473	61.01	67.28	1.52	1.49	0.93	1.00	5,919	5,994	9,687	8,909
	Montana	693	693	392	392	56.60	56.57	1.49	1.50	0.84	0.85	5,988	5,988	10,587	10,587
	Nevada	548	449	330	327	60.22	72.83	1.75	1.48	1.05	1.08	5,473	6,679	9,088	9,171
	New Mexico	1,006	1,006	540	540	53.68	53.68	1.72	1.71	0.92	0.92	6,439	6,439	11,996	11,996
	Utah	1,041	1,034	650	513	62.43	49.61	1.67	1.81	1.04	0.90	5,320	5,357	8,521	10,797
	Wyoming	315	315	216	216	68.57	68.57	1.39	1.39	0.96	0.96	8,879	8,879	12,949	12,949
	Total	8,083	7,906	4,948	4,726	61.21	59.78	1.64	1.62	1.00	0.97	5,847	5,978	9,552	10,001
Pacific	California	19,782	19,300	11,234	11,324	56.79	58.67	1.78	1.74	1.01	1.02	5,362	5,496	9,442	9,367
	Oregon	2,008	2,008	1,235	1,157	61.50	57.62	1.62	1.62	0.99	0.93	5,993	5,993	9,748	10,401
	Washington	3,276	3,276	1,881	1,788	57.42	54.58	1.65	1.65	0.95	0.90	5,807	5,807	10,113	10,639
	Total	25,066	24,584	14,350	14,269	57.25	58.04	1.75	1.71	1.00	0.99	5,471	5,578	9,556	9,610
Total - All Divisions		201,383	198,804	106,809	104,902	53.04	52.77	1.98	1.98	1.05	1.04	5,025	5,090	9,474	9,646
	Alaska	253	274	115	115	40.35	41.97	2.30	2.23	0.93	0.93	3,186	3,314	7,896	7,896
	Hawaii	778	780	379	375	48.74	48.08	2.20	2.20	1.07	1.06	3,678	3,671	7,546	7,635
United States Total		202,414	199,858	107,303	105,392	53.01	52.73	1.98	1.98	1.05	1.04	5,018	5,082	9,465	9,637

1/ "Table TA-1.--Statewide mileage, travel and nonfatal and fatal injury accidents" is submitted to the Bureau of Public Roads by the State highway departments early in April each year, while the final Bureau of Public Roads estimates are not usually completed until midsummer.
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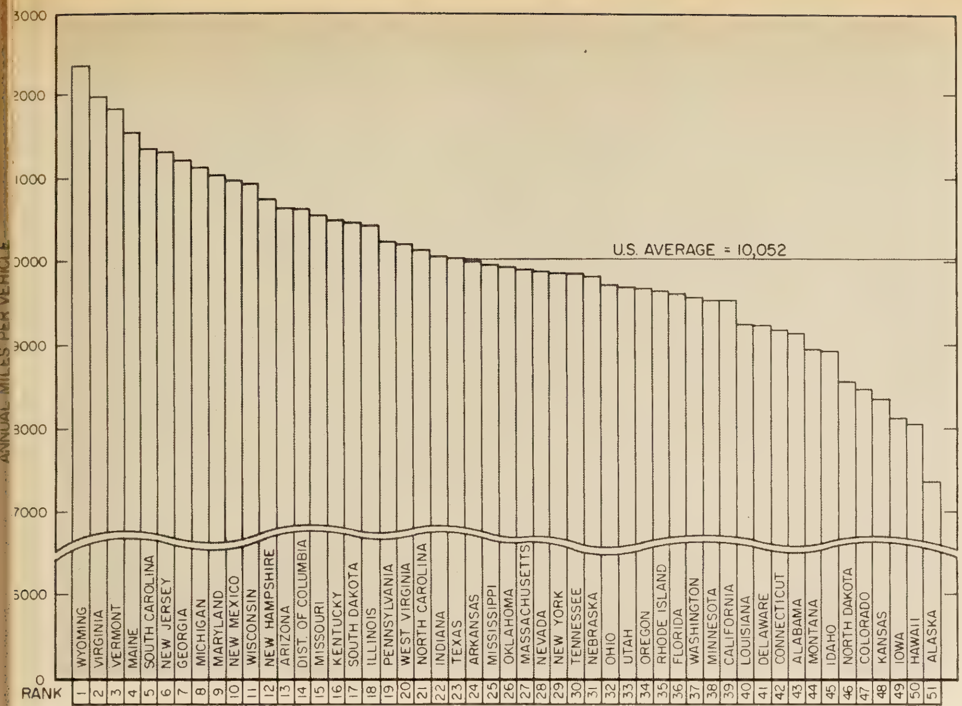
4/ All travel related items were calculated using State estimates of total travel as shown in table VM-2 for 1968.



ure 2.—Annual miles traveled per registered vehicle (excluding motorcycles) in 1968.

ributed to several causes. The proportion new cars purchased with power steering, ver brakes, and air conditioning continues ncrease, and Federal standards now require t all new cars have emission-control devices. these devices place additional demands on engine, reduce the effective power transmit- to the wheels, and thus decrease the miles reled per gallon of fuel consumed. In speed dies conducted jointly by the State highway artments and the Bureau of Public Roads, vas shown that from late 1945—after the rld War II speed limit of 35 miles per hour rescinded—to 1968, the average speeds of -moving vehicles increased by 15 miles per r. As speed increases above about 40 miles hour, so does the amount of fuel consumed mile traveled.

Miles-per-gallon figures differed consider- y among the States in 1968, as shown in le 4 and figure 1. Hawaii had the most miles veled per gallon at 14.10, and Nevada had least at 10.38. This difference does not n that vehicles in Nevada are less efficient n those in any other State. The miles-per- on figure is obtained simply by dividing al travel in the State by the number of lons of fuel purchased in the State for high- y use. Some of the fuel in Nevada was pur- sed for vehicles from the San Francisco and thern California areas and was consumed in Nevada but on California highways ing the return trip. The opposite situation sts in many States that have high miles-per- lon figures. States like New Jersey, Rhode and, Maryland, and Connecticut, all of ich reported fuel consumption rates in ex- of 13 miles per gallon, may be affected by lging traffic. The bridge effect adds travel the State's highways that is not reflected gasoline purchases in the State. The bridge effect would apply only to those States that could be traversed in one dimension on one tankful of gasoline, or less, and would normally be significant only if there were one or more heavy traffic corridors in the bridge direction.

Other factors that affect the fuel-consumption rate in a State are distribution of traffic by vehicle type, average speeds, percentages of urban travel to total travel, and altitude. A higher miles-per-gallon figure would be more likely in a State that has a low percentage of heavy-truck travel than in a State that has a high percentage of heavy-truck travel. States with low speed limits, rigidly enforced, would probably show higher miles-per-gallon rates than States with high speed limits or more relaxed enforcement. States that have high percentages of urban travel would be expected to have lower miles-per-gallon rates than those States that have little urban travel and are less affected by the traffic congestion. Engines tuned for operation at low elevations lose efficiency at much higher altitudes.

Indications are that miles-per-gallon figures may be high in some States; studies in several States usually have lowered the figures for total travel and miles-per-gallon. For example, the *Montana Vehicle Classification Study, 1965–66* showed that average fuel consumption for all vehicles in Montana was 11.56 miles per gallon compared to the national average at that time of 12.45 miles per gallon. As accurate total travel and miles-per-gallon figures are developed in other States, national totals and averages, which are but composites of the State figures, will be adjusted accordingly.

Annual miles per vehicle

Figures reported by the States in 1968 for annual miles per vehicle ranged from a low of 7,382 in Alaska to a high of 12,376 in Wyoming (table 4 and fig. 2). As shown in table 4, the average for the Nation is 10,052 which differs from the figure of 9,847 in table 1 because registration data used to develop the annual

(Continued on p. 24)

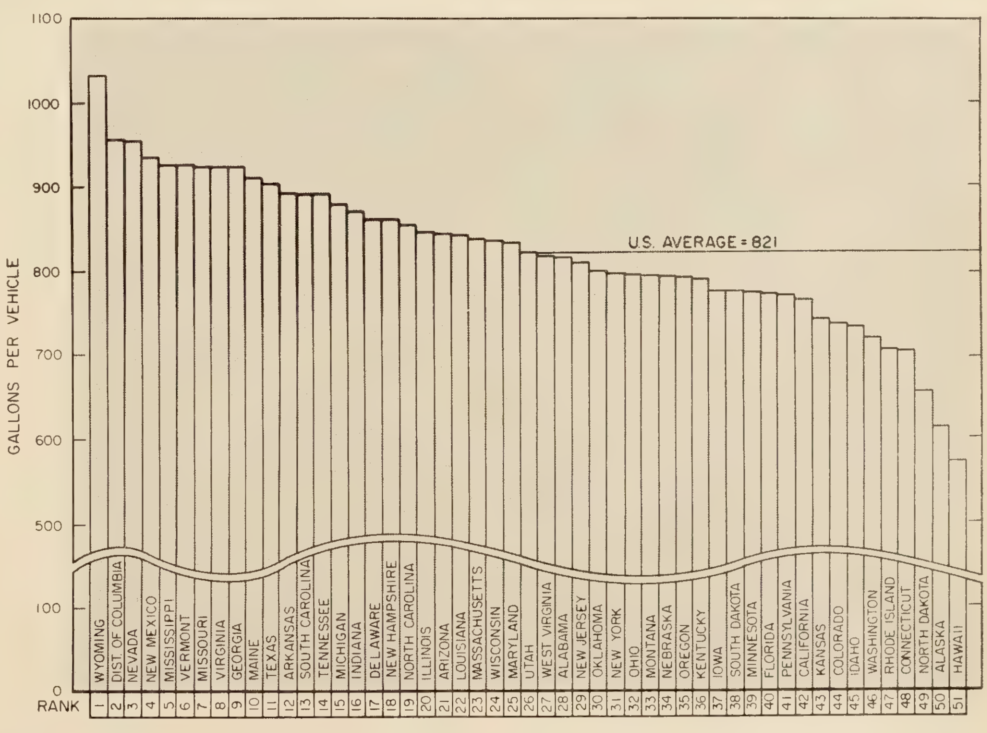


Figure 3.—Average gallons of fuel sold for highway use per registered vehicle (excluding motorcycles) in 1968.

Fatal Collisions With Fixed Objects on Completed Sections of the Interstate Highway System, 1968

Harold R. Hosea and J. N. McDonald, Office of Traffic Operations, Bureau of Public Roads

Investigations of fatal accidents on completed sections of the Interstate Highway System during 1968 [1] disclosed that two out of every five persons killed were occupants of vehicles that ran off the road and collided with one or more fixed objects. Certain of the more common series of events or accident patterns in these single-vehicle, off-the-road collisions are described in the analysis here, which is based on police investigation reports on 1,208 such accidents that resulted in the deaths of 1,400 persons.

In nearly two-fifths (37 percent) of these crashes, the vehicle struck one or more fixed objects after its first collision. In a slightly larger proportion of the crashes, the vehicle also overturned, frequently ejecting occupants. Some of the single-vehicle accident patterns are given in general terms by the data in the accompanying table.

For example, in 30 percent of the 1,208 accidents, the vehicle first struck a guardrail. In three of every five of these accidents, the vehicle subsequently struck at least one other object, most frequently a bridge or overpass structure. In two out of five accidents in this category, the vehicle also overturned—a significant number of the overturns occurring prior to the second impact as a result of initial impacts with guardrails. In many accidents, however, the vehicles were deflected by the guardrail, or vaulted it, and then overturned on embankments or slopes.

These statistics support the conclusion that guardrail itself is a roadside hazard and that on projects under construction, and on future projects, it should be determined initially whether guardrail is actually necessary. Moreover, the necessity for guardrail should be reviewed on existing mileage. Where possible, rigid sign supports, open cross-drainage channels, raised inlets, and other safety hazards should be changed or improved, and the existing guardrail removed. Where guardrail is definitely required, it should, according to present standards, have proper height, increased strength by closer post spacing, adequate blockouts, proper flares and/or turned-down end sections.

The single-vehicle accident data also reveal that 18 percent of the 1,208 vehicles collided initially with a bridge or overpass structure. In these accidents, relatively few subsequent impacts with other objects or overturns occurred obviously owing to the characteristics of the objects first struck. Again it is evident that guardrail installations should be modified by upgrading the guardrail, extending it beyond bridge piers, and securing it to bridge parapets and/or curbs.

Curbs were the first object struck in many off-the-road accidents in which disproportionate numbers of overturns and the largest percentage of subsequent collisions with other objects occurred. Guardrails, bridge elements, and light standards, in that order, were the objects struck most frequently following initial impacts with curbs and, frequently, after overturns, indicating a need to minimize the use of curbs adjacent to main lanes, in gore areas, and even on outer edges of shoulders. Temporary curbs, often constructed on the outer edge of shoulders to control erosion on new fill slopes, should be removed after vegetation has adequately covered the slopes. Also, in a combined installation in which guardrail is located behind curbs, the face of the guardrail should be installed in virtually the same vertical plane as the face of the curb to negate the possibility of a vehicle striking the curb and vaulting over the guardrail.

Accidents in which vehicles ran into ditches resulted in the most overturns. Overturns were also frequent in accidents in which an embankment or backslope was the first object struck, which points out the need to use flatter slopes, both foreslopes and backslopes, to provide an adequate recovery area. Well rounded or swale-type ditches should be signed and constructed to carry the nor roadway drainage. However, where it necessary to provide channels parallel to roadway that carry more than normal r way drainage, they should be located pre ably beyond the normal right-of-way line construction easements, or at least near normal right-of-way line, to provide a w recovery area between the pavement edge the channel.

A third of the vehicles that struck me barriers subsequently struck a second obj most frequently a guardrail. In some of t accidents, the vehicle was deflected across lanes by the barrier and struck the guar on the right. In others, especially where c or chain link dividers were in place, the v cles penetrated the median and struck gu rails at the far side of the opposing la These accident patterns amplify the rec mendations contained in the *Yellow Book* [2] t median barriers should be designed to pre penetration and also to minimize deflectio the vehicle.

[1] *Fatal Accidents on Completed Sections of the Interstate Highway System, 1968*, PUBLIC ROADS, A JOURNAL OF HIGHWAY RESEARCH, vol. 35, No. 10, October 1969, pp. 217–224.

[2] *Highway Design and Operational Practices Relat Highway Safety*, A Report of the Special AASHO T Safety Committee, February 1967.

Characteristics of single-vehicle, off-the-road fatal accidents in which fixed objects w struck on completed sections of the Interstate Highway System, 1968

Fixed object	All accidents				Overturns			
	First object struck		Second object struck		All accidents		Second object stru	
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Perce*
Guardrail	364	30.1	213	58.5	152	41.8	90	59.2
Bridge or overpass	217	18.0	36	16.6	40	18.4	17	42.5
Sign	97	8.0	21	21.6	22	22.7	6	27.3
Embankment	86	7.1	28	32.6	62	72.1	21	33.9
Curb	72	6.0	56	77.8	40	55.6	27	67.5
Divider	71	5.9	24	33.8	21	29.6	10	47.6
Light pole	63	5.2	19	30.2	13	20.6	5	38.5
Ditch	57	4.7	9	15.8	51	89.5	8	15.7
Culvert	51	4.2	13	25.5	25	49.0	4	16.0
Fence (right-of-way)	28	2.3	19	67.9	16	57.1	9	56.3
Tree	26	2.2	5	19.2	4	15.4	1	25.0
Other	76	6.3	5	6.6	34	44.7	6	17.6
Total	1,208	100.0	448	37.1	480	39.7	204	42.5

Travel By Motor Vehicles in 1968

(*Continued from p. 23*)

miles per vehicle in table 1 included motorcycles and the registrations shown in table 4 did not. Annual miles per vehicle reported by 24 States ranged from 9,500 to 10,500, or within 5 percent plus or minus of the national average.

Actually, the annual-miles-per-vehicle figure, which is a ratio of total travel in the State to total number of vehicles registered in the State, does not give a true indication of the annual miles traveled by the average vehicle in a State. If travel in the State by out-of-State vehicles were balanced by an equal amount of travel out of the State State-registered vehicles, the ratio of tra to-vehicles would equal the average n traveled by vehicles registered in the S But this is not always true, as some St contain large national parks, scenic won well-known historic sites, or other locatio interest and attract more tourist travel other States. The greater the attra and the smaller the State's population t the more out-of-State travel affects State's total travel. The high annual r per vehicle, of 12,376 in Wyoming, ref significance of travel by out-of-State icles. Yellowstone and Grand Teton tional Parks together draw approximately ,00,000 visitors to Wyoming annually; 1968, the State population was 315,000.

llons per vehicle

he State-by-State figures for gallons per icle in table 4 are based on vehicle registions that exclude motorcycle registrations. onsistent with its high annual-miles-per-icle figure, Wyoming showed the highest lons per vehicle at 1,031, and Hawaii wed the lowest at 573. The national aver- was 821. As indicated in the discussion of nual miles per vehicle, a large part of the vel in Wyoming is performed by out-of-te vehicles, and consequently, much of the oline purchased in Wyoming is for out-of-te vehicles that do not appear in the nber of registered vehicles used in calcu-ng the gallons-per-vehicle figure.

nsistency of Relationships Among the Factors

onsistency among the factors of miles per lon, miles per vehicle, and gallons per hicle, mentioned previously for a few of the reme deviations, is explained in more detail e. It is not within the scope of this article analyze completely the factors discussed l of the other factors that affect them, either ectly or indirectly, nor are sufficient data ilable to permit such an analysis. Neither t possible to conclude that values for any e State are correct or incorrect. The purpose this general discussion is to indicate some he conditions that should be considered in ging the reasonableness of these factors and the travel estimates or forecasts to which y are related.

n figures 1, 2, and 3, the States are ranked lescending order on miles per gallon, annual es per vehicle, and gallons per vehicle, pectively.

)f the States that are least influenced by -of-State travel, Hawaii ranked first of the States and District of Columbia in miles veled per gallon at 14.10, but ranked 50th annual miles per vehicle at 8,065, and 51st gallons per vehicle at 573. The consistency ween these items is obvious; a State having high miles-per-gallon figure and a low nual-miles-per-vehicle figure would be ex-ted to have a low value for gallons per icle. It is not surprising that Hawaii ranks t in gallons per vehicle and 50th in annual es per vehicle. As the State consists of nds there is no motor vehicle travel across te lines, and maximum trip lengths are ch shorter than in the continental United tes. This results in lower average travel vehicle and lower fuel consumption per icle.

laska, though not an island State like waii, is similar to Hawaii because its ation from the remainder of the continental ited States makes the effect of out-of-State ffic insignificant. Also the few highway tes of significant length result in relatively short average trip length and low travel per vehicle. Alaska's 7,382 annual miles per vehicle figure is the lowest of all the States. In gallons per vehicle, Alaska at 613 ranks 50th. In these two items, the two States are similar, yet Alaska ranks 32d on miles per gallon at 11.95 compared to Hawaii's highest rank at 14.10.

Part of the dissimilarity in miles traveled per gallon of fuel consumed between these two States, which are so close in the other two factors, can be explained by the difference in the composition of travel by vehicle type. According to data available from truck weight studies and classification counts, truck travel constitutes more than 30 percent of the total travel in Alaska but only about 15 percent in Hawaii. What about the other factors involved? Does Hawaii have a higher proportion of small cars in its vehicle population than Alaska? Are the average speeds lower in Hawaii than in Alaska? What effect does the relatively stable temperature and humidity in Hawaii have compared to the greater range found in Alaska.?

These questions apply also to the 48 contiguous States, except that in these States the effects are modified by out-of-State travel. Some States are affected by bridging travel, yet some of the States reporting a high miles-per-gallon figure could not be considered bridge States. These include States like North Dakota, South Dakota, Pennsylvania, Washington, and Wisconsin.

It was attempted to relate the high and low miles-per-gallon values to the percentage of urban travel, and to average free-flowing speeds for main rural roads from *Traffic Speed Trends*, but no consistent relations could be established. Several States that had miles-per-gallon values of more than 13 had average speeds of 4–10 miles per hour lower than the national average. These States also ranked higher in percentage of urban travel. The higher percentage of stop and go conditions in urban travel would imply lower miles-per-gallon rates, and tend to offset the advantages gained from lower average speeds, but some States that had low miles-per-gallon figures also had a low percentage of urban travel, and were close to the national average in speeds.

Speed data, as reported are of limited value for these analyses. Speed observations, on which these data were based, were made at points where the traffic was free flowing and drivers could drive at their desired speeds. Thus, a true average speed or operating speed could not be determined from these data.

Summary

There is an increasing need for accuracy and detail in travel estimates. When sufficient vehicle-count data are available, highly reliable travel estimates can be made without other factors. Usually, manpower and time are not available to obtain these data so factors that relate travel to known variables like vehicle registrations, fuel consumed for highway use, and population must be used. It is imperative, therefore, that these relations be evaluated as accurately as possible and factors that influence these relations in each State must be determined, and to what extent. This requires independent estimates of travel for each highway system.

New Publications

The Bureau of Public Roads has recently published two documents. These publications may be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, prepaid. The following paragraphs give a brief description of each publication and its purchase price.

Highway Statistics, 1968

Highway Statistics, 1968 ($1.75 a copy), a 191-page bulletin, is the 24th in the annual series presenting statistical and analytical tables of general interest on motor fuel, motor vehicles, highway-user taxation, State and local highway financing, road and street mileage, and Federal aid for highways.

The *Highway Statistics* series has been published annually beginning with the year 1945, but most of the earlier editions, except 1965, 1966, and 1967, are now out of print. However, much of the information presented in earlier editions is summarized in *Highway Statistics, Summary to 1965*, which may be purchased from the Superintendent of Documents for $1.25.

Highway Research and Development Studies, Using Federal-Aid Research and Planning Funds

The 1969 issue of *Highway Research and Development Studies Using Federal-Aid Research and Planning Funds* ($1.50 a copy) lists studies approved in the Office of Research and Development, Bureau of Public Roads, FHWA, for fiscal year 1970 and calendar year 1969, as of July 1, 1969.

The information has been grouped by the seven major technical goals of the National Program of Research and Development in Highway Transportation. An eighth grouping includes miscellaneous projects of local, regional, or national importance. Data are also presented on the objective of each study, the conducting agency, and the funding for each study.

Available reports on Federal-aid highway research studies are listed and the makeup and operation of the Federal-aid highway research and development program is explained. The publication is intended not only for Federal Highway Administration personnel, but also for those outside the Government who are interested in the program and may desire to participate in it.

Highway Research and Development Reports Available From Clearinghouse for Federal Scientific and Technical Information

The following highway research and development reports are available from the Clearinghouse for Federal Scientific and Technical Information, Sills Building, 5285 Port Royal Road, Springfield, Va. 22151. Paper copies are priced at $3 each and microfiche copies at 60 cents each. To order, send the stock number of each report desired and a check or money order to the Clearinghouse. Prepayment is required.

Highway research and development reports available from the Clearinghouse are also listed by subject in Public Roads annual publication Highway Research and Development Studies *(see inside back cover) according to the goals and projects of the national program of highway research and development.*

Stock No.	
PB 179251	Statistical Approach to the Quality Control of Plant Mix Pavement.
PB 179257	Creep and Creep Recovery for Plain Concrete.
PB 179258	Time-dependent Deflection of a Box Girder Bridge.
PB 179259	Traffic Systems Reviews and Abstracts—July Issue, 1968.
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PB 179262	The Economic Benefits Accruing From the Scenic Enhancement of Highways.
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PB 179273	Interim Progress Report on Supplementary Studies in Highway Illumination.
PB 179274	The Socio-Economic Impact of the Capital Beltway on Northern Virginia.
PB 179275	Highway and Land-use Relationships in Interchange Areas.
PB 179276	Current Laws and Practices.
PB 179277	Illinois Interchange Area Development.
PB 179278	Case Studies of Selected Interchange Areas.
PB 179287	Description and Evaluation of Ramp Control on Hollywood Blvd. and Sunset Blvd. On-Ramps.
PB 179288	Fatigue Tests of Hybrid Plate Girders Under Combined Bending and Shear.
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PB 179320	Electronic Computer Program for Coordinate Transformations (BPR Program Number SU-4).
PB 179392	Joint Seal Materials—Final Report.
PB 179402	Economic and Social Effects of a Highway Bypass, American Fork, Utah. Vol. I
PB 179403	Vol. III
PB 179416	Development of a Procedure for the Design of Hot Mix Asphaltic Concrete Mixtures for Use on West Virginia Highways.
PB 179417	Investigation of Structural Grade Expanded Sucarnoochee (Porter's Creek) Clay as Highway Construction Aggregate.

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PB 179437	Traffic Systems Reviews and Abstracts—August Issue, 1968.
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PB 179568	A Study of Variability in Production, Sampling and Testing Bituminous Concrete Base—Part III, The 1966–67 Study.
PB 179582	A Regional Analysis of the Economic and Social Impact of Interstate Highways in the Employment and Retail Markets Served by Birmingham, Ala. Report No. 31-A.
PB 179583	Report No. 31-B.
PB 179584	Report No. 31-C.
PB 179585	Determination of Accuracies in Earthwork Quantities from Photogrammetrically Made Surveys.
PB 179586	Highway Drainage Study—Annual Report for Fiscal Year 1968.
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