40 G, or that many times an individual's body weight.[3] The factor of safety in these stunts would seem to be ample.

It is important to realize, however, that this factor of safety would not be enjoyed by a person sitting in the seat of an automobile, in the event of a collision. As has been pointed out many times before, such persons (especially those in the right-front seat) continue forward at substantially the original velocity, until some portion of their body (unfortunately, usually the head) meets up with some portion of the car's structure which has already been greatly decelerated. The resulting impact generates forces which are highly localized, rather than well-distributed, and may be very destructive.

A chance observation, made possible by the filming of a mishap during another stunt demonstration, and which will be analyzed in detail in another paper, indicates that the impact of the human head on a steering wheel, during crash deceleration from a speed of less than 30 mph., involved forces certainly not less than 50 G, and possibly 100 G or more.

RECOMMENDATIONS

Because of the limitations imposed by analysis of displacement-time data, in an effort to derive valid information on the rapidly-changing decelerations experienced during collisions, it is believed that future studies in this field should utilize instrumentation which will measure deceleration directly. Such instrumentation has been developed in recent years and could be applied without much difficulty to a problem of this nature.

The recent development for the Aero Medical Laboratories at Wright-Patterson Air Force Base, of an anthropometric dummy, designed to simulate the principal physical and mechanical characteristics of the human body, suggests the possibility of utilizing such a dummy in further investigation, to enable study of the behavior of the body during collisions, and measurement, even on an approximate basis, of the impact forces sustained by it.

[3] The symbol G, with a given coefficient n, is used to designate a force, acting on a given mass, which is n times the *weight* of that mass. A force expressed as nG will cause an acceleration (or deceleration) of ng in a given mass, with respect to the coordinate system of the agent exerting the force.

ACKNOWLEDGMENT

The author wishes to gratefully acknowledge the assistance of R. D. Bartlome, G. N. Olsen, and V. Skoro in the film studies and the tabulation and analysis of data.

All of the personnel (other than stunt drivers), instrumentation, and equipment (other than cars), utilized in the research project reported in this paper were provided out of funds and facilities of the Institute of Transportation and Traffic Engineering of the University of California.

EFFECT OF BARRIER-LINE LOCATION AT NO-PASSING ZONES

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SYNOPSIS

A COMPARATIVE study of two types of no-passing-zone markings was conducted during 1949 in cooperation with the Missouri State Highway Department. A 16.5-mi. section of 20-ft. bituminous pavement on US 66 in south-central Missouri was selected. For approximately half this length, the standard pavement marking was applied, i. e., a broken white reflectorized centerline and, at the no-passing zones, a solid yellow reflectorized barrier line adjacent to the center line. On the remaining half (Missouri system) the yellow-reflectorized barrier line was painted in the middle of the driving lane.

Three general classes of information were obtained. The first was a record of speed and transverse placement for vehicles approaching and traveling through a selected single-direction zone on each type of marking and through a two-di-

rection zone of the Missouri design. Speed-placement data were recorded for approximately 11,500 vehicles. A record was kept of the start and completion points for all passings attempted or completed in the direction controlled by the respective test zones. The third class of data resulted from interviewing 1,005 drivers as they left the test section to determine their reactions to the two marking plans. Except for the driver-interview phase of the study, both day and night observations were made. Average daily traffic during the period of study was between 3,500 and 4,000 vehicles, a high percentage of which were vehicles registered in other states.

Speeds of approaching vehicles 500 ft. in advance of each of the zones averaged slightly over 52 mph. At a point 300 ft. within both the national-standard and the Missouri-type zone the average speed level was lower by 2 to 3 mph. The effect of familiarity may account for the fact that the speed reduction upon entering the zone was slightly greater for out-of-state drivers at the Missouri zone and for Missouri drivers at the standard zone.

Extensive study of the transverse placement data was made to isolate significant driver-behavior locations. The studies made 300 ft. within the Missouri zone showed that the average transverse placement of all vehicles in the daytime was 4 71 ft., measured from center of vehicle to centerline of pavement. At the corresponding point on the standard zone, the placement was 4.73 ft. The difference is obviously too small to have significance.

Segregation of the placement information into classes which take into account vehicle types and the nearby presence or absence of other vehicles is somewhat more revealing. Where a vehicle traversing the zone had met or was to meet another vehicle traveling in the opposite direction within 300 ft., the placement of the vehicle in the zone was generally found to be farther from the center line at the national-standard zone than at the Missouri-type zone. Study of the distribution pattern of placements at the test sites 300 ft. within each of the zones indicates that a smaller proportion of the vehicles have placements less than 3.5 or 4.5 ft. on the national-standard zone than is the case on the Missouri zone. This is particularly true of the wider commercial vehicles. In the day studies, only 1.6 percent of all commercial vehicles had placements less than 3.5 ft. and 9.7 percent had placements less than 4.5 ft. while in the national standard zone. The corresponding values in the Missouri zone were 4.3 percent less than 3.5 ft. from the centerline and 27.7 percent less than 4 5 ft. from the center line. Results of the night studies were similar. In practically all cases, the differences between the two systems of marking insofar as placement is concerned is greatest when commercial vehicles or vehicles with opposing traffic are considered.

The average completion point of the passings recorded during the daytime at the standard zone was found to be 86 ft. beyond the beginning of the barrier line. At the Missouri zone, the average completion point was 228 ft. beyond the start of the barrier line, an average of 142 ft. more infringement on the no-passing zone. The difference at night was not as great, but there was still less overrunning of the barrier line at the national-standard zone.

Roadside interviews were conducted with drivers who had just had an opportunity to see both types of marking. Drivers were first asked if they had noticed the two systems of marking no-passing zones and then were asked if they had a preference for either one. All but 66 said they had noticed the two types of marking. Missouri drivers favored the barrier line next to the centerline by an insignificant margin 130 to 124, while 21 had no choice; drivers from states bordering Missouri expressed a 147 to 115 preference for the barrier line in the center of the driving lane, with 12 having no choice; and drivers from all other states voted 227 to 208 for the location next to the centerline and 21 drivers indicated no preference.

The conclusions drawn are that the measured differences in operating characteristics on the national-standard and the Missouri-type no-passing-zone marking are, in general, of small magnitude. In the few areas of analysis where dissimiliarities of some consequence were found, however, the national-standard marking appears to enjoy the advantage of potentially safer operation. The driving public is not in agreement that either marking is superior to the other.

● THE TWO-LANE, two-way highway is the wheel horse of our transportation system. For economic reasons, it will undoubtedly persist as a popular type, despite the operating hazards inherent in its design. Warranted, therefore, are the many researches dedicated to improvements in the traffic capacity, safety, and other functional characteristics of this most common of all highway types.

Vehicle overtaking and passing actions on two-lane highways are essential to maintenance of reasonable capacities and necessary flexibility in traffic flow. Passings can normally be undertaken by the driver at any time he is assured that the left lane will be free of oncoming traffic throughout his maneuver. The presence of opposing traffic that might interfere with passing is obvious when sight distances are adequate, but wherever alignment changes or other factors introduce a short sight-distance condition, the driver has no positive assurance that his passing can be completed without interference. This has led to rather general use of the no-passing-zone pavement marking which defines the limited section throughout which passing is not safe. According to reports of the President's Highway Safety Conference, 27 state highway departments are regularly marking no-passing zones, where needed, on more than 70 percent of the hard-surfaced mileage under their jurisdiction. The remaining states are similarly marking substantial portions of their mileage, and the totals are increasing each year. The value of this control measure is now well established.

STANDARDIZATION OF NO-PASSING-ZONE MARKINGS

What drivers see and understand has a profound effect on their driving actions and reactions and what they do not fully see or understand often bears on their traffic mishaps. Much effort has been directed, therefore, toward standardizing all traffic-control devices, among them the marking design for no-passing zones. Many differences exist among the states. Since no-passing zones are locations of exposure to relatively high hazard, it is vitally important that all drivers quickly and accurately interpret the "line language" of pavement marking. Variations in color, pattern, and in location of the barrier line with respect to the centerline marking subject motorists to possible confusion that may result in abnormal behavior or accident.

Despite the inconsistency in no-passing-zone design mentioned, practically all state and local jurisdictions place the barrier line a few inches to the side of the centerline marking to indicate that passing is prohibited from the lane on that side of the center line. This is the nationally recommended standard.

Drastic exceptions to the national standard are found in Missouri and Iowa where for a number of years the barrier line has been positioned in the center of the driving lane from which passings are prohibited. This marking design was first adopted by Missouri to facilitate maintenance of a serviceable barrier line at a point on the roadway where it would not be subject to the constant grinding and abrasive action created by heavy commercial tires. On narrow pavements, especially those with lip curb, the problem of maintaining a serviceable barrier line near the roadway center was most pronounced. Placing the barrier line at the center of the driving lane produces the economy of longer effective life and in some cases, serviceable characteristics have been retained for as long as three years. Also given consideration in the Missouri decision was the relatively greater hazard of placing lines where the paint-striping vehicle has to straddle the centerline rather than proceed entirely within one lane.

SITE SELECTED FOR COMPARATIVE STUDIES

To evaluate the effect of the two types of no-passing zones on driving practices, the Missouri State Highway Department and the Bureau of Public Roads cooperated in a series of special traffic studies in that state during the summer of 1949. The highway selected was US 66, a principal cross-country route with a high proportion of out-of-state traffic.

A test section 16.5-mi. in length was chosen, extending easterly from Lebanon, Missouri, to the Laclede-Pulaski county line. The pavement there is a 20-ft. bituminous surfacing over old concrete and is flanked by gravel shoulders of adequate width. Approximately half the section length was marked with the national standard no-passing-zone design. The remaining mileage was marked in the Missouri fashion, with the barrier line located in the center of the driving lane.

The terrain traversed by this portion of US

66 is moderately rolling. No-passing zones are relatively frequent. Traveling westbound through the 16.5-mi. section the driver sees 39 no-passing zones, eastbound he traverses 36 zones. The aggregate length of no-passing zone for westbound travel is 6 mi., eastbound it is 5.5 mi. These represent 36.4 percent and 33.3 percent restrictions on passing for westbound and eastbound drivers, respectively. Signs reading, "Do Not Cross Yellow Line When In Your Lane" (see Figure 1) are placed at intervals of 3 to 5 mi. along the route, but none was in the vicinity of the zones selected for special study.

To obtain the uniformity desired in the condition of markings throughout the 16.5 mi., the centerline marking was repainted throughout as a dashed, reflectorized white line. Most of the existing reflectorized yellow barrier lines in the center of the driving lanes had been painted a year or more previous to the study and were not too prominent in daylight. These lines were totally obliterated with asphalt paint on the 9.2 mi. in the easterly portion of the test section and new reflectorized yellow barrier lines were painted next to the centerline marking in accordance with the national standard. On the 7.3 mi. in the western portion, the existing barrier lines were retraced with reflectorized yellow paint.

Two single-direction no-passing zones as nearly identical as could be found were selected for intensive study, one from the eastern, and one from the western portion of the test section. These were designated Sites C and A, respectively. Site C was 4.5 mi. west of the Laclede-Pulaski county line near the middle of the length marked with national standard no-passing zones. Figure 2 is a general view of Site C. The zone studied is on the grade in the background. The location of Site A was 4.4 mi. from the east city limits of Lebanon, also approximately centered in the test length with the Missouri markings. Figure 3 is a photograph of that site, taken from the beginning of the barrier line. The approaches at both sites were on tangent alignment and the sight distance restriction at the no-passing zone was caused in both cases by summit vertical curves. The standard used in Missouri for this route calls for marking no-passing zones at any point where the sight distance, measured from points 4.5 ft. above the road surface, is less than 800 ft. At each of the two study sites the sight distance from the driver's eye to the pavement surface at the beginning of the barrier line was 550 ft. The zone at Site C was marked for westbound traffic and the one at Site A for eastbound traffic. At

Figure 1. Standard informational sign used at 3- to 5-mi. intervals (none near test stations).

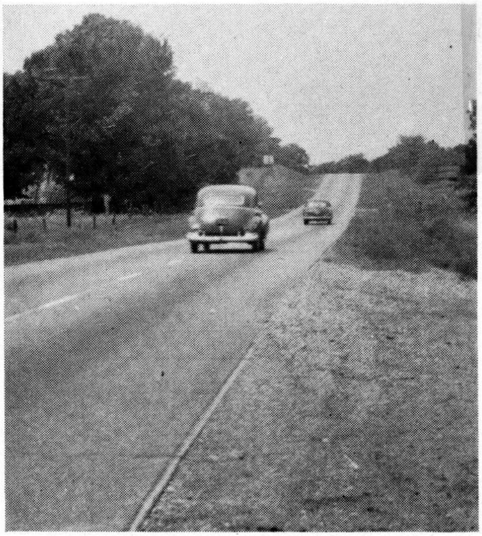

Figure 2. No-passing zone at Site C starts near foot of grade in background.

Site C the grade in the zone was 4.5 percent, at Site A, 4.0 percent.

NATURE OF INFORMATION OBTAINED

Three types of information were assembled. First, and perhaps most significant, was a

vehicle speed and transverse-placement study, during which data were obtained for more than 11,500 vehicles. Second, the start and finish points were recorded for all passings in one direction attempted or completed within 500 ft. each way from the beginning of the barrier line at both the Missouri-standard and national-standard zones. The third class of data resulted from interviewing approximately 1,000 drivers as they left the test section.

Speed and placement data were first recorded for three different locations in the vicinity of each zone, as indicated below and in Figure 4.

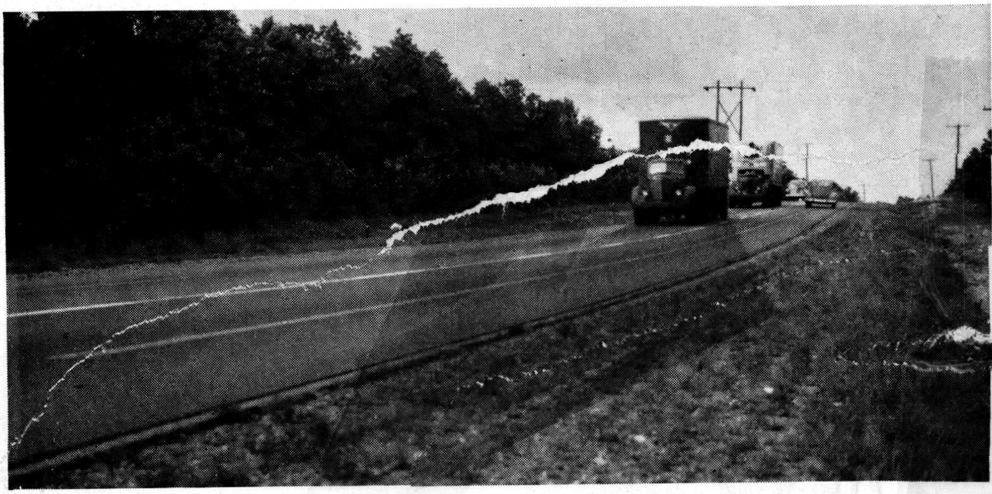

Figure 3. Site A, looking east into no-passing zone from beginning of barrier line.

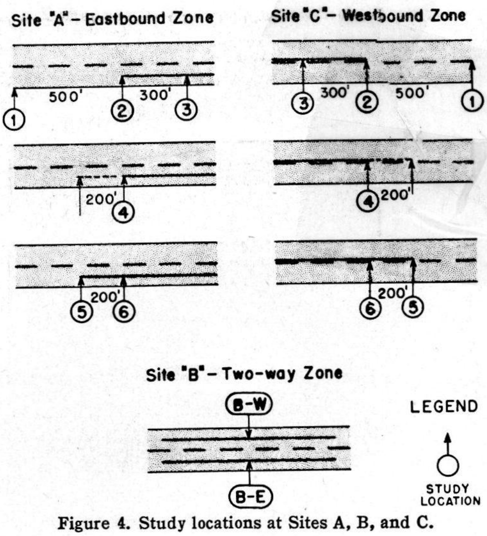

Figure 4. Study locations at Sites A, B, and C.

Study No.	*Location*
1	500 ft. in advance of the start of the barrier line.
2	At the start of the barrier line.
3	300 ft. beyond the start of the barrier line.

During the course of these studies it was decided to experiment with both a dashed and solid extension of the yellow barrier line on the approach end. Following Study 3 a 200-ft. dashed extension was painted at both sites. Later the dashed extension of the barrier line was made solid. Under these two conditions, three additional locations were studied at Sites C and A, as follows:

Study No.	*Location*
4	Same road location as Study 2, but with a 200-ft. dashed extension of barrier line.
5	At the approach end of a 200-ft. solid extension of barrier line.
6	Same road location as Studies 2 and 4, but with the 200-ft. solid extension of the barrier line.

The zones at Sites C and A were both single-direction zones, as previously noted. To measure the effect of having a no-passing zone marked for both directions of travel, in which case there is a barrier line at the center

of both lanes and a line at the center as well, Site B was also chosen for study. This was located in the section marked with the Missouri standard zone 6.1 mi. east from the east city limits of Lebanon. The general conditions at Site B are portrayed in Figure 5.

At each of the study sites observations were made between 3 and 6 P.M. and between 8 and 11 P.M. Speed, transverse placement, and classification of vehicle types were obtained with the automatic-recording speed-placement equipment. This is the same equipment as that described in *Public Roads*[1] except that adding machines were substituted for the graphic recorders to produce a coded record on adding machine tape. For vehicles entering the no-passing zone, special notation was made on the tape if opposing traffic was within 300 ft. of the observed vehicle at the time its placement was recorded. In addition, an observer maintained a record of the start and finish of all passings attempted or completed by traffic traveling toward the zone within a distance of 500 ft. in each direction from the approach end of the barrier line. A series of posts set at 100-ft. intervals with reflectorized stripes, indicating distance from the beginning of the barrier line facilitated these observations, particularly at night. Hourly traffic volumes by direction were read from traffic counters throughout the period of study.

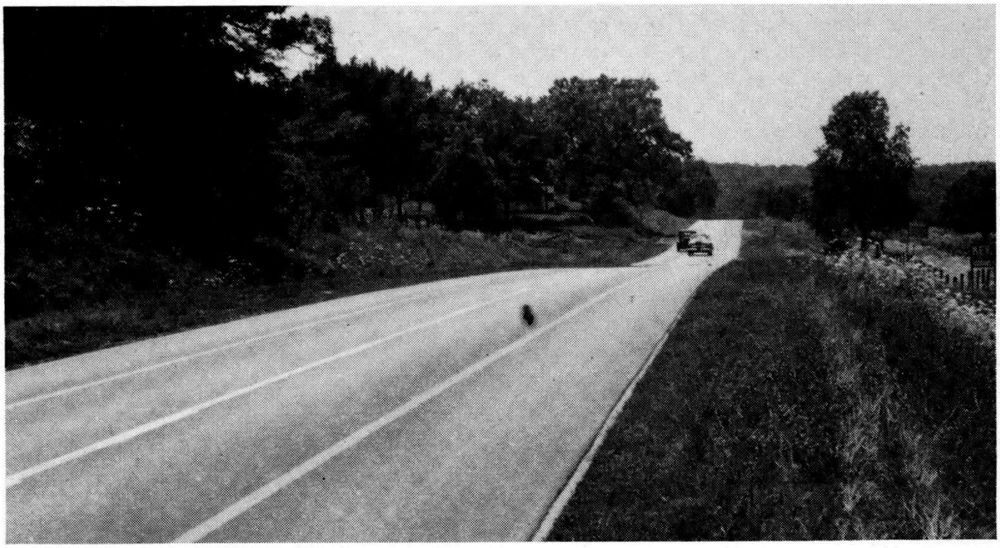

Figure 5. Site B, showing two-direction no-passing zone. Driver passing is in violation.

OUT-OF-STATE DRIVERS ON US 66

The test section carried a daily traffic volume averaging between 3,500 and 4,000 vehicles during the period of the study (June 30 to July 15, 1949). July 4 fell on a Monday, making a long holiday week end, but the traffic flow nevertheless was remarkably uniform throughout the observations. The average traffic for all daytime hours of study on the Missouri standard, Site A, was 251 vehicles per hour and at Site C, 247 vph. Corresponding volumes during the night studies were 130 vph. at Site A and 150 vph. at Site C. The volumes at Site B averaged 280 vph. in the daylight hours and 145 vph. at night. This relative stability in the traffic-volume factor lends reliability to the comparison of driver practices under the several conditions studied. Table 1 shows the hourly variations and the day and night average volumes at each site.

[1] New Techniques in Traffic Behavior Studies, by E. H. Holmes and S. E. Reymere, *Public Roads*, April 1940.

A detailed classification count made on July 5 indicated the following composition:

Vehicle type	Percent of Total Traffic	
	Day (3–6 P.M.)	Night (8–11 P.M.)
Missouri passenger cars	34.5	34.0
Foreign passenger cars	45.5	23.3
Single-unit trucks, including panels and pick-ups	11.1	8.3
Truck combinations	7.8	32.6
Busses	1.1	1.8
	100.0	100.0

Of principal interest is the high percentage of foreign passenger-car traffic, particularly in the daylight hours, and the large proportion of truck combinations at night. The proximity of the holiday undoubtedly accounted in some measure for both conditions, but other observations on this route have consistently shown relatively large percentages of foreign passenger and night-time commercial traffic.

DRIVING SPEEDS IN NO-PASSING ZONE

The information obtained on traffic speeds indicates also that operating conditions at the two principal test sites were substantially similar. The daytime speed at Site A averaged 52.5 mph. for vehicles approaching the no-passing zone, and at Site C the average speed was 52.3 mph. Within the no-passing zone, vehicles averaged 50.1 mph. at Site A and 50.4 mph. at Site C. The slight decrease in speed is accounted for at least in part by the grade of approximately 4 percent that vehicles ascended in passing through the zone. Night-time speeds were slightly lower but followed the same general pattern of decreasing slightly upon entering the no-passing zone.

At Site B, where only a single study within the two-direction zone was made, speeds were found to be about the same as at Sites A and C. The daytime average was 48.4 mph. for eastbound and 47.6 mph. for westbound traffic during daylight hours. Corresponding night speeds were 45.3 and 49.4 mph.

The difference in the effect of the two barrier-line locations on the driving speeds of in-state and out-of-state vehicles is of some importance in appraising the no-passing-zone designs. Table 2 shows that out-of-state drivers travel at a slightly higher average speed than Missouri drivers on the approach to both types of no-passing zones but tend generally to reduce their speed more than Missouri drivers as they travel through the zone. The one exception is the case of out-of-state drivers in the national standard zone at night where their average speed actually increased 0.9 mph.

TABLE 1
HOURLY TRAFFIC VOLUMES AT STUDY SITES

Direction of Travel	P.M. Hours (day)				P.M. Hours (night)			
	3–4	4–5	5–6	Day average	8–9	9–10	10–11	Night average
Site A-1								
Westbound	115	128	101	115	82	54	45	60
Eastbound	182	186	143	170	64	102	92	86
Total	297	314	244	285	146	156	137	146
Site A-2								
Westbound	125	132	157	138	67	31	66	54
Eastbound	123	133	102	119	72	72	50	65
Total	248	265	259	257	139	103	116	119
Site A-3								
Westbound	116	101	109	109	71	55	55	60
Eastbound	110	133	110	118	87	66	50	68
Total	226	234	219	227	158	121	105	128
Site A-4								
Westbound	125	121	92	113	58	62	73	64
Eastbound	119	103	129	117	75	60	48	61
Total	244	224	221	230	133	122	121	125
Site A-5								
Westbound	125	117	121	121	92	65	83	80
Eastbound	111	130	128	123	51	79	49	60
Total	236	247	249	244	143	144	132	140
Site A-6								
Westbound	128	126	147	134	60	61	78	67
Eastbound	117	154	119	130	50	79	37	55
Total	245	280	266	264	110	140	115	122
Site B								
Westbound	139	200	148	162	91	75	72	79
Eastbound	131	122	99	117	65	60	72	66
Total	270	322	247	279	156	135	144	145
Site C-1								
Westbound	132	100	106	113	87	56	69	71
Eastbound	106	103	120	110	69	53	51	57
Total	238	203	226	223	156	109	120	128
Site C-2								
Westbound	130	131	150	137	123	148	156	142
Eastbound	122	130	115	122	77	97	84	86
Total	252	261	265	259	200	245	240	228
Site C-3								
Westbound	160	183	170	171	119	80	72	90
Eastbound	126	159	172	152	83	58	68	70
Total	286	342	342	323	202	138	140	160
Site C-4								
Westbound	120	121	112	118	82	86	84	84
Eastbound	131	135	136	134	52	57	55	55
Total	251	256	248	252	134	143	139	139
Site C-5								
Westbound	132	96	83	104	95	52	83	77
Eastbound	106	115	77	99	47	57	62	55
Total	238	211	160	203	142	109	145	132
Site C-6								
Westbound	122	105	97	108	58	73	52	61
Eastbound	120	127	103	117	42	51	62	52
Total	242	232	200	225	100	124	114	113

Perhaps of most significance is the fact that in every instance the speed change occurring as vehicles travel into the no-passing zone is greater both day and night for Missouri drivers at the national standard zone than for the same drivers at the Missouri zone. Similarly, the speed of out-of-state drivers consistently shows greater change at the Missouri zone than at the national zone. The difference between the reaction of Missouri and foreign-vehicle operators is greater on the Missouri standard than on the national standard. This finding seems logical because Missouri drivers in general would be more familiar with the widely used national standard than other drivers are with the Missouri marking.

TABLE 2
RELATIVE EFFECT OF TWO BARRIER-LINE LOCATIONS ON SPEED OF DRIVERS

Passenger-car Drivers	Missouri Standard			National Standard		
	Approaching zone	Within zone	Difference	Approaching zone	Within zone	Difference
	mph.	*mph.*	*mph.*	*mph.*	*mph.*	*mph.*
Day						
Missouri	52.8	51.6	−1.2	52.8	50.0	−2.8
Out-of-state	53.8	50.1	−3.7	52.9	49.6	−3.3
Night						
Missouri	49.1	48.9	−0.2	48.5	47.2	−1.3
Out-of-state	50.2	47.8	−2.4	49.2	50.1	+0.9

EFFECT OF MARKINGS ON VEHICLE PLACEMENT

The lateral position of vehicles on the roadway is one of the most accurate indications of the differences in traffic operation caused by varying the barrier-line location. Extensive study of the placement data has been made to isolate significant driver-behavior characteristics associated with the two types of marking. The dimension used to identify vehicle placement is the distance in feet from the centerline of the roadway to the center of the vehicle.

A compilation of the average placements of vehicles, segregated by day and night and by vehicle type for each study site, is given in Table 3. As previously indicated, Sites A and B have the barrier line in the center of the driving lane, and Site C has the barrier line next to the centerline marking. Site B is the two-direction zone, Site A is marked only for eastbound traffic, and Site C only for westbound. Since Sites A and C are almost identical in physical conditions, traffic volume and normal speed, the placement of vehicles traveling in the single direction controlled by the respective zones has been selected for analysis.

The values shown in Table 3, therefore, pertain to vehicles traveling eastbound at Site A, westbound at Site C and for each direction separately at Site B. The few vehicles using

TABLE 3
AVERAGE DISTANCE FROM CENTER OF VEHICLE TO CENTERLINE OF ROADWAY

Study Site	Day					Night				
	Missouri passenger cars	Foreign passenger cars	Single-unit trucks	Truck combinations	Total	Missouri passenger cars	Foreign passenger cars	Single-unit trucks	Truck combinations	Total
	ft.	*ft.*	*ft.*	*ft.*	*ft.*	*ft.*	*ft.*	*ft.*	*ft.*	*ft.*
A-1	5.08	5.10	5.33	5.15	5.10	4.61	4.67	4.90	4.90	4.70
C-1	4.16	4.04	4.50	4.60	4.22	3.89	3.82	3.90	4.57	4.09
A-2	4.34	4.19	4.52	4.92	4.34	4.37	3.90	4.20	4.45	4.21
C-2	4.23	4.07	4.43	4.71	4.21	4.18	4.22	4.56	4.76	4.29
A-3	4.73	4.61	4.99	4.80	4.71	4.28	4.71	4.20	4.70	4.57
C-3	4.73	4.61	5.29	5.29	4.73	4.60	4.50	4.50	5.04	4.62
A-4	4.37	4.13	4.68	4.78	4.33	4.20	4.09	4.60	4.57	4.28
C-4	4.16	4.01	4.62	5.03	4.30	4.18	4.04	4.74	4.97	4.45
A-5	4.29	4.08	4.55	4.71	4.25	3.89	4.08	4.10	4.31	4.10
C-5	4.19	3.69	4.35	4.57	4.03	4.07	3.88	4.40	4.56	4.20
A-6	4.52	4.29	4.84	4.73	4.48	4.22	4.21	4.60	4.40	4.30
C-6	4.49	4.20	5.05	4.96	4.50	4.57	4.05	4.80	4.86	4.54
B-E	4.70	4.70	4.65	4.90	4.73	4.66	4.68	4.90	4.80	4.68
B-W	4.42	4.23	4.62	4.60	4.32	4.28	4.27	4.45	4.54	4.28

the left lane for passing in violation of the markings at the several study sites have been omitted from the placement summaries and are treated separately in the section of the report dealing with driver obedience to the no-passing zones.

The relatively close agreement between the average placement values at Locations 2, 3, 4, and 6 on the Missouri and national-standard zones is a feature of Table 3. These four locations are either within the no-passing zone or at the approach end of the normal barrier line, as indicated earlier. Location 5 is at the approach end of the extended barrier line and Location 1 is 500 ft. in advance of the no-passing zone.

TABLE 4
STANDARD DEVIATIONS OF LATERAL PLACEMENT OF PASSENGER CARS

Study Site	Missouri and Foreign Passenger Cars			
	Free moving	With opposing traffic	All others	Total
A-1	0.9063	0 7989	0.8443	0.8511
C-1	1.1385	1.1261	1.6160	1.3260
A-2	0 7611	0.7376	0.7366	0.7521
C-2	1.2147	0.8481	1.0524	1.0571
A-3	0.7994	0.9290	0.6962	0 8085
C-3	0.8943	0.7715	0.8777	0.8921
A-4	0 7150	0.7461	0.6997	0.7367
C-4	0 9442	0.7998	1.0899	1.0318
A-5	0.7516	0.6782	0.7658	0 7754
C-5	1.1995	0.8727	1.0444	1.0253
A-6	0 9203	0.6349	0.7815	0 7796
C-6	0.9834	0.9101	0.8770	0.9128

At this latter point, the average lateral position of all vehicles differs 0.88 ft. on the two systems in the day study and 0.61 ft. at night, and in both cases, the distance from the roadway centerline is greater at the Missouri standard zone. The observations at Site A-1 were made July 4 when the weather was partly cloudy with light showers and the traffic volume was higher than normal. Site A-1 was also slightly beyond the crest of a vertical curve for eastbound drivers who had just left another no-passing zone about 150 ft. before their vehicle placement was recorded. Location 1 at Site C, by contrast, was on a nearly flat section and the nearest no-passing zone for westbound drivers in advance of the study site was approximately ¼ mi. to the east. This range in conditions is the suspected cause of the differences between the two values.

At Site B, the horizontal alignment on the approaches to the observation point varied slightly. Eastbound traffic entered the zone on tangent alignment, while westbound traffic entered on a curve to the left, which condition is believed to account for westbound average placements being consistently closer to the centerline at Site B-W than at B-E. No physical or other differences that might influence vehicle paths were evident at any of the other study locations at Sites A and C.

As will be seen from Table 3, the difference in the average placement values for the two no-passing zone designs is least at Sites A-3 and C-3. In the daytime, the average placement of all vehicles within the Missouri zone is 4.71 ft., measured from center of vehicle to roadway centerline, and on the national standard it is 4.73 ft. The corresponding night values are 4.57 and 4.62 ft. This is at a point 300 ft. within each of the test zones, which is certainly one of the more critical locations.

The data in Table 3 include vehicles moving through the test zones singly, in groups and with and without traffic in the opposing lane. To study these several movement categories independently, the total traffic through the test zones was classified into three groups: (1) free-moving, vehicles at least 6 sec. behind any other vehicle traveling in the same direction and are not within 300 ft. of any vehicle traveling in the opposite direction; (2) with opposing traffic, vehicles that are within 300 ft. of a vehicle traveling in the opposite direction, and (3) all others, vehicles not in the two above classes, except those that are in the left lane to pass.

Because of the marked similarity in average placements, all passenger-car data from the daytime studies were segregated into these three categories and standard deviations computed for each of the comparative studies. Table 4 shows that with a single exception, namely passenger cars with opposing traffic in the national standard zone, Site C-3, the dispersion of placements is greater on the national standard marking than it is on the Missouri marking.

It might be expected that the placement distribution of those vehicles with opposing traffic would always show less dispersion than does the distribution for vehicles in the other

two movement classifications due to the imminent danger of colliding head-on with vehicles in the left lane. At all but one of the studies on the national standard, this was true, but at three of the six studies at the Missouri zone, the dispersion was greater than for one of the other movement classifications. In other words, all passenger-car drivers when using the national zone showed somewhat less precision in following a central path than when traversing the Missouri zone. Nevertheless, the presence of opposing traffic increased the tendency of drivers on the national marking to follow a central path more than on the Missouri design. Furthermore, the precision with which the central path was followed on the national standard was slightly superior to that found on the Missouri marking when passenger cars were 300 ft. into the zone and faced with traffic in the opposite lane.

Figures 6 and 7 show additional comparative data on passenger-car driver practices at the two test zones, under day and night conditions. As previously explained, the placements at Site A-1 appear to have been influenced by local factors and probably should not be compared with those for Site C-1 for that reason. However, after vehicles reached the end of the barrier line and traveled 300 ft. into either type of zone, a definite shift to the right occurs in the vehicle path. This shift ranged from about 0.3 ft. to 0.75 ft. over the 300-ft. section. In the daytime, the amount of the shift is greater on the national standard zone, and at night, it is greater on the Missouri zone. The net difference between the average placement within the two zones, however, was less than 0.05 ft., either day or night. It will be seen that under all conditions the maximum lateral shift between Locations 2 and 3 occurred when oncoming traffic was in the left lane.

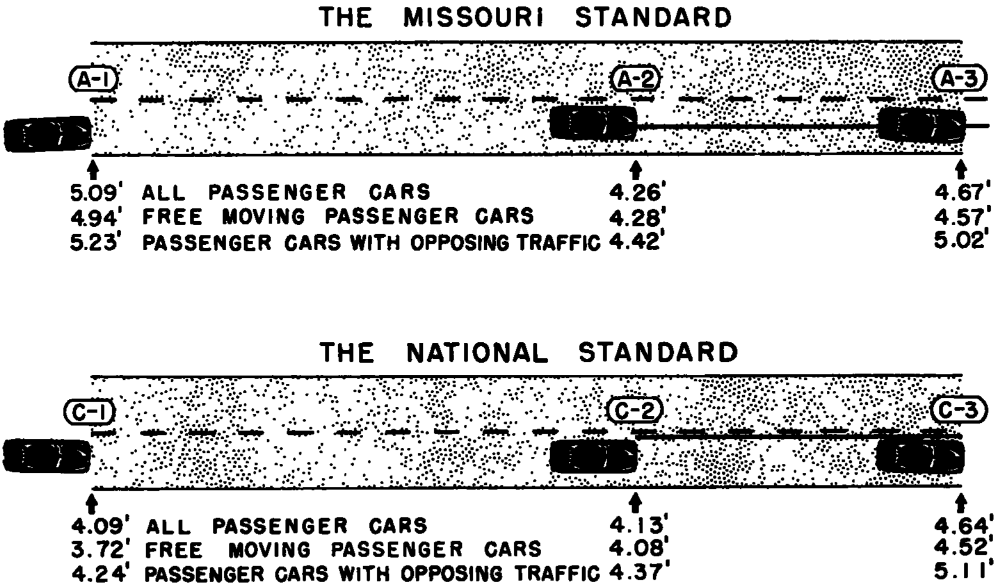

Figure 6. Distance from center of vehicle to centerline of roadway for vehicles entering no passing zones during daytime

Figures 8 through 11 permit more detailed examination of the placement distributions of this important class of traffic at these two points. Passenger cars at the beginning of the national standard barrier line tended to have a more sprawling distribution pattern than at the Missouri standard. This was true both day and night. Within the zone, the distribution of placements was more compact. For both day and night operation within the zone and on either type of marking, about three fourths of all passenger cars were driven with their centers in the range of 3.6 to 5.5 ft. from the roadway centerline.

A measure of the relative effectiveness of the two barrier-line locations in inducing

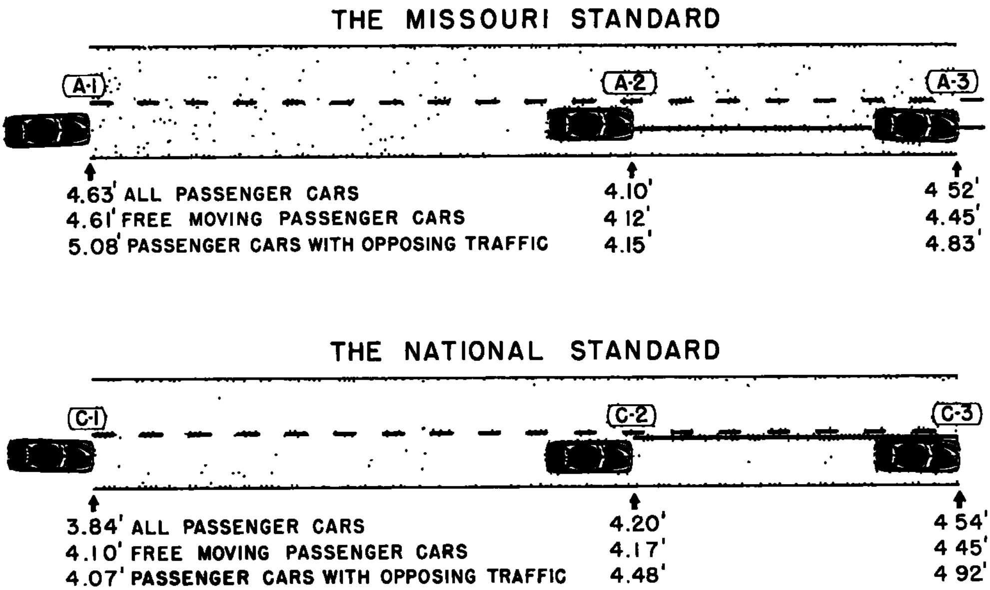

Figure 7. Distance from center line of vehicle to roadway centerline for vehicles entering no passing zone at night.

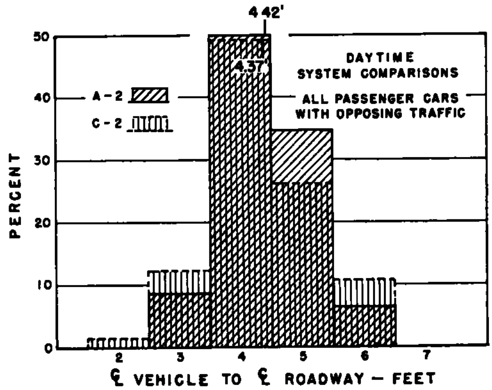

Figure 8.

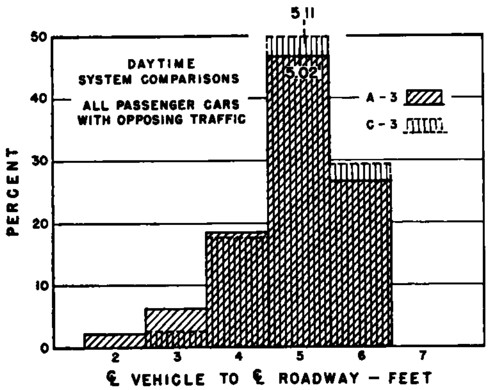

Figure 10.

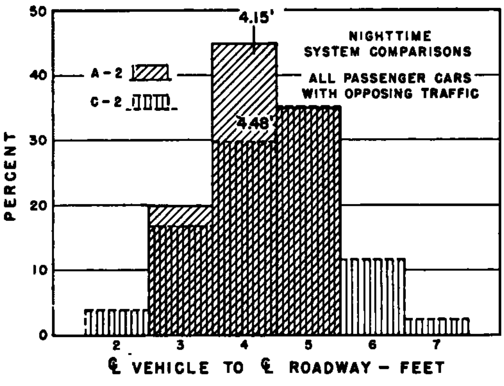

Figure 9.

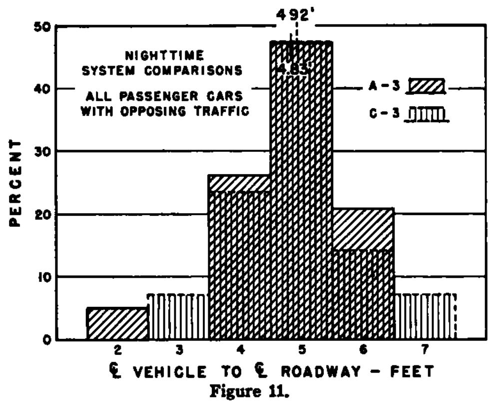

Figure 11.

vehicle drivers to stay a proper distance from the centerline while traversing a no-passing section appears in Table 5. Regardless of light conditions, vehicle type, or the class of vehicle movement, the proportion of vehicles with placements less than 4.5 ft. from the roadway center at the national standard zone was, with several minor exceptions, smaller than on the Missouri zone. Taken as a whole, the proportion within 3.5 ft. of the centerline was slightly smaller on the Missouri standard, but in the significant class of vehicles with opposing traffic, the national standard showed marked superiority in the daytime results and was substantially the same as the Missouri standard at night. A lower percentage of commercial vehicles, in every case, was found within 3.5 or 4.5 ft. of the centerline on the national standard and the average placement, both day and night in that zone, averaged approximately 0.3 ft. farther from the pavement center.

Night time is known to be the critical period for many traffic-control devices. Consequently, special attention has been devoted to day and night comparisons at the two barrier-line locations. Data for study of the differences between average placements of all vehicles day and night are presented in Table 6. Where the barrier line was located in the center of the driving lane, the average placement at night was consistently nearer the roadway center than the daytime average, as can be seen from the predominance of minus signs in the first column. This is not as generally true where the barrier line is located next to the centerline. Previous studies have indicated that on the typical roadway section removed from a no-passing zone, drivers follow a path closer to the centerline at night. That finding is verified by the data obtained in this study at Sites A-1 and C-1.

From Table 6 it is evident that the Missouri no-passing-zone marking offers no effective deterrent to this practice. By comparison, the studies on the national zone show that the average placement at night closely approximates the daytime position. In some instances, the average night driver is even slightly farther away from the centerline than the average daytime driver. At all six study sites compared, the difference between day and night placement averages on the national standard marking was either less than on the Missouri standard or was such as to provide greater clearance from the centerline at night than in the daytime. With the ever-present hazard of sideswipe collisions on narrow pavements, where center-of-the-lane barrier-line marking is contended to be most applicable, this finding is worthy of attention.

TABLE 5

EFFECT OF BARRIER-LINE LOCATION ON PLACEMENT AND PERCENTAGE OF VEHICLES TRAVELING LESS THAN 3.5 AND 4.5 FT. FROM ROADWAY CENTER WHILE IN ZONE

Movement Classification	Passenger Cars						Commercial Vehicles						All Vehicles					
	Average placement		Percent less than 3.5 ft.		Percent less than 4.5 ft.		Average placement		Percent less than 3.5 ft.		Percent less than 4.5 ft.		Average placement		Percent less than 3.5 ft.		Percent less than 4.5 ft.	
	Mo.	Natl.	Mo.	Natl.	Mo.	Natl.	Mo.	Natl.	Mo.	Natl.	Mo.	Natl.	Mo.	Natl.	Mo.	Natl.	Mo.	Natl.
Day																		
Free moving	4.57	4.52	10.5	13.1	48.7	49.2	4.85	5.09	11.8	3.7[a]	35.3	11.1[a]	4.62	4.62	10.8	11.4	46.3	42.9[a]
With oppos. traffic	5.02	5.11	8.2	2.9[a]	26.6	20.6[a]	4.85	5.71	0	0[a]	28.6	0[a]	4.98	5.18	6.4	2.6[a]	27.0	18.4[a]
All others	4.57	4.56	5.0	12.2	49.4	45.4[a]	5.06	5.37	0	0[a]	18.8	7.4[a]	4.64	4.65	4.3	10.8	45.2	41.0[a]
Total	4.67	4.64	7.6	10.9	44.2	42.3[a]	4.92	5.29	4.3	1.6[a]	27.7	9.7[a]	4.71	4.73	7.0	9.7	41.3	37.9[a]
Night																		
Free moving	4.45	4.45	13.8	11.9[a]	62.1	56.6[a]	4.51	5.02	7.1	0[a]	50.0	9.1[a]	4.46	4.53	11.6	10.4[a]	58.1	50.6[a]
With oppos. traffic	4.83	4.92	5.2	7.2	31.6	30.9[a]	4.90	5.02	4.7	0[a]	33.3	8.3[a]	4.86	4.94	5.0	5.6	32.5	25.9[a]
All others	4.43	4.43	11.9	19.1	57.1	52.4[a]	4.48	4.81	17.4	12.0[a]	52.2	40.0[a]	4.45	4.52	13.8	17.5	55.3	49.5[a]
Total	4.52	4.54	11.1	13.8	53.4	49.4[a]	4.64	4.91	10.3	6.3[a]	44.8	25.0[a]	4.57	4.62	10.7	12.3	49.9	44.7[a]

[a] Identifies comparable percentages that are lower (or equal) where barrier line is next to center line (national standard).

DRIVER OBEDIENCE TO NO-PASSING-ZONE MARKINGS

The information recorded on driver compliance with the various types of no-passing-zone markings shows that passings are frequently completed after the barrier line is reached. This may reflect an attitude that the completion of passings is permissible beyond

TABLE 6
DIFFERENCE IN DAY AND NIGHT LATERAL PLACEMENT VALUES

Study Site	Movement Classification	Barrier Line Location	
		Center of lane	Next to center line
		Ft.	*Ft.*
1	Free moving	−.34	+.30
1	With opposing traffic	−.13	−.06
1	All others	−.54	−.50
1	Total	−.40	−.13
2	Free moving	−.16	+.14
2	With opposing traffic	−.05	+.13
2	All others	−.16	−.01
2	Total	−.13	+.08
3	Free moving	−.16	−.09
3	With opposing traffic	−.12	−.24
3	All others	−.19	−.13
3	Total	−.14	−.11
4	Free moving	−.08	+.43
4	With opposing traffic	−.03	+.23
4	All others	+.02	+.10
4	Total	−.05	+.16
5	Free moving	−.17	+.35
5	With opposing traffic	−.06	+.25
5	All others	−.35	+.01
5	Total	−.15	+.17
6	Free moving	−.23	+.14
6	With opposing traffic	+.18	+.29
6	All others	−.27	−.13
6	Total	−.18	+.04

Note: Minus sign (−) indicates night placement was closer to roadway center line than day placement; plus sign (+) indicates night placement was farther away.

the beginning of the barrier line and not that the maneuver must be completed before reaching it. Whatever the typical driver's reasoning, the average return point of pass completions observed in the vicinity of both the Missouri standard and the national standard zones in this study was beyond the start of the barrier line.

Table 7 is a compilation of the comparative obedience data. The average point of completion is calculated from the beginning of the normal length barrier line or, in the case of the extended zones, from the start of the extended barrier line.

In general, the completion point is considerably farther into the no-passing zone when the barrier line is located in the center of the driving lane. For the normal zone, the average is 228 ft. in the day study and 202 ft. at night, as compared with 86 ft. and 172 ft., respectively, on the national standard design. No great difference is evident between Missouri and out-of-state drivers in the daytime results but at night, the latter do not observe either barrier line as well as do the local drivers.

On the extended zones, roughly the same pattern of compliance exists. The additional 200 ft. of length on the advance end of the barrier lines apparently serve only to increase

TABLE 7
EFFECT OF BARRIER-LINE LOCATION ON DRIVER OBSERVANCE OF NO-PASSING ZONES
Normal length zones

Barrier Line Location	Passings Completed in Vicinity of No-Passing Zones by					
	Missouri drivers		Out-of-State drivers		All drivers	
	Number of passings observed	Average completion point[a]	Number of passings observed	Average completion point[a]	Number of passings observed	Average completion point[a]
		ft.		*ft*		*ft.*
Day						
Center of driving lane	20	230	37	227	57	228
Next to center line	28	66	86	93	114	86
Night						
Center of driving lane	14	160	7	286	21	202
Next to center line	31	87	33	252	64	172
Extended zones						
Day						
Center of driving lane	23	404	46	406	69	405
Next to center line	33	280	58	342	91	320
Night						
Center of driving lane	11	413	9	528	20	465
Next to center line	7	307	16	341	23	330

[a] Average completion point is the distance traveled into the no-passing zone before returning to the right lane.

the infringement on the no-passing zones by approximately the same amount.

The data in Table 7 indicate that the number of passings recorded was somewhat greater during the studies on the national standard zone. Aside from the effects of alignment and traffic volume which, as previously stated, were closely comparable, the sight-distance conditions leading to the test sites may have had a relation to the actual frequency of passings recorded. The mile immediately west of Site A has 0.3 mi. of eastbound no-passing zones while the mile east of Site C, by comparison, has 0.45 mi. of westbound no-passing zones. This more severe restriction of sight distance available for passing over the mileage approaching Site C from the east may account for the somewhat greater number of passings recorded at that location. The difference between the average position of the pass completion points on the two types of barrier line marking, however, seems more likely to be related to the difference in barrier-line location than to the factor just mentioned.

When the barrier line is located in the center of the driving lane, it is frequently obscured in part or totally by vehicles on the road ahead. Figure 12 has been constructed to show the comparative conditions of view from the driver's seat when trailing the vehicle ahead at various distances. It assumes that the vehicle ahead is in normal position on a 20-ft. pavement and that the approach to the no-passing zone is on tangent alignment. The driver sees the Missouri-type barrier line only by looking under or through the vehicle ahead, and for all practical purposes his maximum notice of the beginning of the barrier line is the distance between him and the rear of the vehicle ahead. The overtaking and passing studies conducted by the Bureau of Public Roads indicate that the average passing vehicle is approximately 55 ft. behind the car ahead when it starts into the left lane to pass.

With the barrier line next to the centerline, the driver can see to a varying extent around the side of the vehicle ahead and his advance view of the barrier line is considerably longer. If he moves laterally toward the center of the roadway from his normal position, preparatory to passing, his view of the barrier line next to the centerline increases rapidly, as indicated by Figure 12.

Under other conditions of alignment, the comparative distances at which barrier lines at the two locations could be seen will differ, of course, but there is little doubt that the advantage in driver viewing distance will remain with the national standard in the majority of instances. The lack of advance view is believed to be a factor in the relatively poorer observance found at the Missouri zone.

EFFECT ON VEHICLE PLACEMENTS OF EXTENDING BARRIER LINES

As reported previously, the barrier lines were extended to see if this disadvantage of short advance view of the no-passing zone could be overcome. The 200-ft. dashed and solid extensions of the barrier lines did not materially change the average location on the road where passings were completed, but they did influence the average placement of vehicles entering the zones. Table 8 presents the average placements obtained at each zone for three conditions, *viz.*, the normal length zone, the zone extended at the advance end with a 200-ft. dashed line, and the zone extended with a 200-ft. solid line. All three studies were made at the beginning of the normal length barrier line in the two test zones.

The dashed extension on the Missouri zone made no appreciable difference in the average day or night placement. On the national standard with the dashed extension, however, the average position of vehicles with opposing traffic was 0.33 ft. farther away from the roadway center in the day study and 0.43 ft. farther away at night.

On the solid extension, the vehicles with opposing traffic again were affected the most. No great difference was found on the Missouri zone in the daytime but at night, this class of vehicles averaged 0.36 ft. farther away from the centerline. On the national standard the difference was still greater. The placement results with the solid line extension show that vehicles use a path appreciably farther to the right than they do with no extension or with only a dashed line extension, and that a greater effect generally was caused on the national standard than on the Missouri zone.

ROADSIDE INTERVIEWS

The Missouri State Highway Department, using the postcard-questionnaire technique, has solicited driver reaction to their no-passing-zone markings on several occasions. One

of these surveys made a few years ago, in which almost 12,000 cards were passed out to motorists and 3,063 were returned, indicated a 2½ to 1 preference for locating the barrier line in the center of the driving lane.

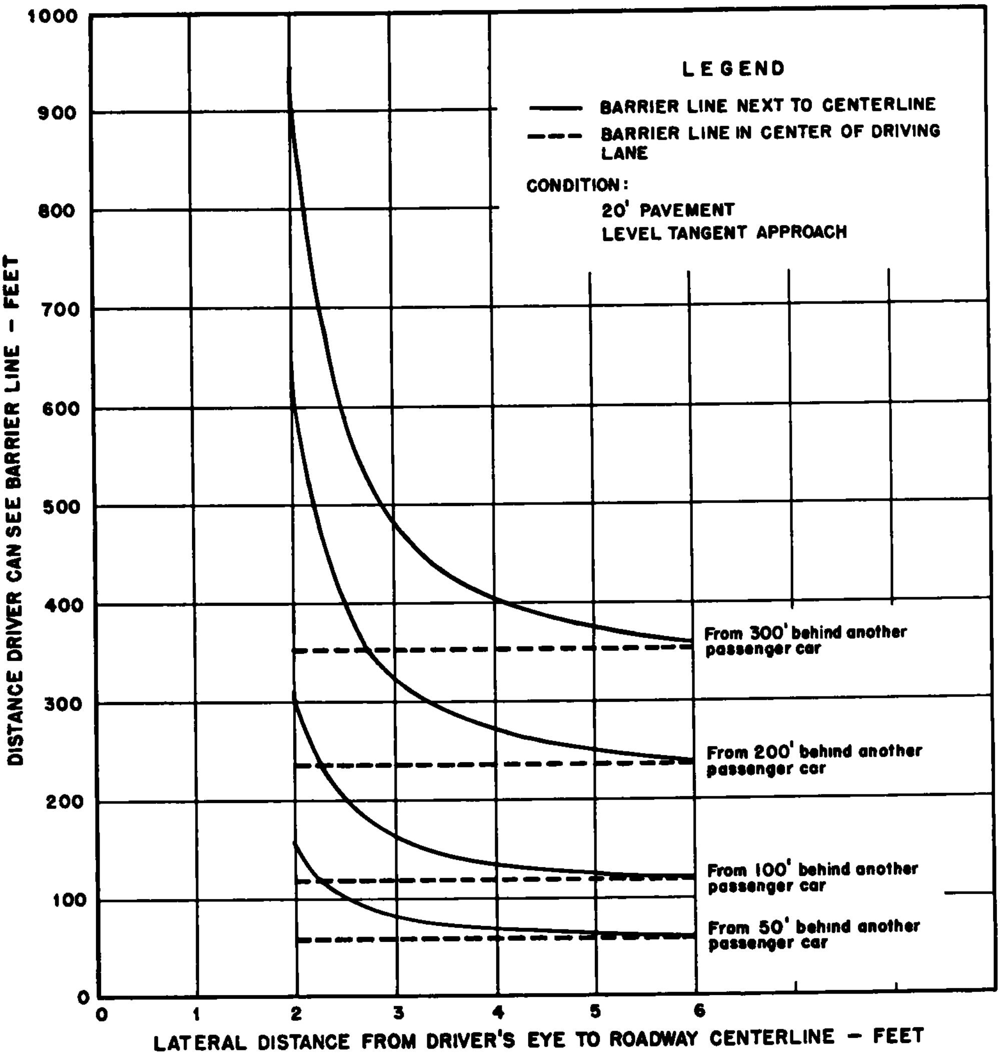

Figure 12.

As a check on this finding, and to eliminate bias caused by motorists who were intrigued by novel traffic controls responding in greater numbers than those not so interested, a 100-percent sample of driver reaction was obtained as a phase of the study. Interviewers stationed at the extremities of the 16.5-mi. test section stopped all outbound traffic and confronted drivers with these questions: (1) Did you notice the two different systems of marking no-passing zones? (2) Do you have a preference for either system? (3) Which system does your state use?

The state of registration of the vehicle was also noted on the interview form. Station A adjoined the national standard, and Station B the Missouri standard.

A summary of the returns from the 1,005 drivers interviewed appears as Table 9. Replies

TABLE 8
EFFECT ON AVERAGE PLACEMENT OF EXTENDING ZONE WITH 200-FT. DASHED AND SOLID BARRIER LINES

Missouri Standard

Movement Classification	Normal Zone Study 2	Dash Extension Study 4		Solid Extension Study 6	
		Average placement	Change from normal	Average placement	Change from normal
	ft.	*ft.*	*ft.*	*ft.*	*ft.*
Day					
All vehicles	4.34	4.33	−.01	4.48	+.14
Free moving	4.36	4.28	−.08	4.43	+.07
With opposing traffic	4.53	4.58	+.05	4.66	+.13
Night					
All vehicles	4.21	4.28	+.07	4.30	+.09
Free moving	4.20	4.20	0	4.20	0
With opposing traffic	4.48	4.55	+.07	4.84	+.36
National Standard					
Day					
All vehicles	4.21	4.30	+.09	4.50	+.29
Free moving	4.14	3.92	−.22	4.29	+.15
With opposing traffic	4.42	4.75	+.33	4.81	+.39
Night					
All vehicles	4.29	4.45	+.16	4.54	+.25
Free moving	4.28	4.35	+.07	4.43	+.15
With opposing traffic	4.55	4.98	+.43	5.10	+.55

Note: Minus sign (−) indicates placement with dashed or solid extension of barrier line was closer to roadway center line than with normal length of barrier line; plus sign (+) indicates placement was farther from center line.

TABLE 9
SUMMARY OF DRIVER QUESTIONNAIRE

Station A—Eastbound drivers on US 66 at the Laclede-Pulaski County line
Friday, July 15, 1949, to Saturday, July 16, 1949

Station B—Westbound drivers on US 66 one mile east of Lebanon, Missouri, city limits
Tuesday, July 12, 1949, to Thursday, July 14, 1949

1. Did you notice the two different systems of marking "No-passing zones"?

	Drivers from Missouri		Drivers from Illinois, Kansas, Oklahoma, and Arkansas		Drivers from Other States	
Station	Yes	No	Yes	No	Yes	No
A	126	5	158	10	192	17
B	135	9	101	5	227	20
A-B	261	14	259	15	419	37

2. Did you have a preference for either system?

Station	Drivers from Missouri			Drivers from Illinois, Kansas, Oklahoma, and Arkansas			Drivers from Other States		
	Yellow line		No choice	Yellow line		No choice	Yellow line		No choice
	Center of driving lane	Next to the center line		Center of driving lane	Next to the center line		Center of driving lane	Next to the center line	
A	56	67	8	85	73	10	76	122	11
B	68	63	13	62	42	2	132	105	10
A-B	124	130	21	147	115	12	208	227	21

3. Which system does your State use?

	Drivers from Illinois, Kansas, Oklahoma, and Arkansas				Drivers from Other States			
Station	Missouri	National	Other	Do not know	Missouri	National	Other	Do not know
A	2	159	3	4	2	202	2	3
B	3	100	0	3	9	225	3	10
A-B	5	259	3	7	11	427	5	13

were segregated by drivers of vehicles registered in Missouri, states bordering Missouri, and all other states to isolate the factor of familiarity. More than 93 percent of all drivers who had traveled over the test section stated that they had noticed the two types of markings. As shown by the reply to the third question, practically every out-of-state driver knew also that his state placed the barrier line next to the centerline.

When asked for an expression of preference, Missouri drivers, border-state drivers, and other drivers were all quite evenly divided between the two systems. Neither interview station was within sight of a no-passing-zone marking, but drivers tended to favor the marking standard they had more recently seen. Missouri drivers at Station A, for example, who had just seen about 9 mi. of the national standard marking, showed a 67 to 56 preference for having the barrier line next to the centerline, while Missouri drivers at Station B, who had just passed about 7½ mi. of the Missouri standard, voted 68 to 63 for having the barrier line at the center of the driving lane.

SUMMARY

The findings of this special study of no-passing-zone marking designs are, of necessity, based on observation and analysis of traffic performance in a state where only one marking design generally prevails. That one design, which prescribes the position of the barrier line at the center of the driving lane, rather than next to the centerline, is the exception rather than the rule among the states. The operating experience from which this report has been prepared may not, therefore, be precisely representative of the performance that would be found if the situation were reversed and the Missouri design were in widespread use. To the extent possible, the effects of familiarity have been explored and discussed so that this factor and the principal data will appear in their proper relation.

The major results derived from comparative study of vehicles traversing the two types of no-passing-zone marking are as follows:

1. Average operating speeds 500 ft. in advance of the no-passing zones compared were almost identical, and slightly over 52 mph. for vehicles proceeding toward the zone. At a point 300 ft. within each of the zones the general average speed level was lower by 2 to 3 mph., and the greater decreases occurred with out-of-state drivers on the Missouri type marking and with Missouri drivers on the national standard marking. The difference between the Missouri and the out-of-state drivers' reaction to the zone, measured in terms of that speed change, was larger at the Missouri zone, probably because Missouri drivers are better acquainted with the conventional barrier-line location than out-of-state drivers are with the center-of-the-lane position used throughout Missouri.

2. A remarkable similarity existed between the average placement obtained in comparable studies at the two sites for all locations at or beyond the start of the barrier line. The least difference between average placements at comparable locations in the two zones was at a point 300 ft. beyond the beginning of the barrier line. Here, on the Missouri marking, the average placement of all vehicles expressed in terms of the distance from vehicle center to roadway center, was 4.71 ft. in the day study and 4.57 ft. at night. Corresponding values for the national standard zone were 4.73 ft. and 4.62 ft.

At the two-direction no-passing zone marked with the Missouri design, the average placement for the direction with a tangent approach was 4.73 ft. in the daytime and 4.68 ft. at night. For the opposite direction, the respective values were 4.32 ft. and 4.28 ft., indicating only a small difference between average placements on the one-direction and the two-direction zones.

3. The average placement of vehicles 300 ft. within both types of no-passing zones was from 0.3 to 0.75 ft. farther from the centerline than for vehicles at the beginning of the barrier line. The maximum differences occurred when opposing traffic was in the left lane. At both types of zones, about three fourths of all passenger cars traveled with their centers in the range of 3.6 to 5.5 ft. of the centerline, when actually within the zone.

4. Detailed analysis of the placement-distribution pattern shows interesting differences between the results obtained at the two test zones. On the national standard, vehicle paths were somewhat more widely dispersed than on the Missouri zone. Statistical measures of dispersion for the placement data show that passenger cars, for example, did not generally

follow a central path as precisely on the national standard as on the Missouri zone. However, it is significant that less dispersion in vehicle placements occurred within the national standard zone than the Missouri zone when oncoming traffic was in the opposing lane.

5. Regardless of light condition, vehicle type, or class of vehicle movement, the percentage of vehicles with their centers within 4.5 ft. of the centerline of the pavement was, with a few minor exceptions, less at a point 300 ft. within the national standard zone than at the corresponding location marked with the Missouri design. The percentage of vehicles that had placements of 3.5 ft. or less was a little lower in the Missouri zone when all classes of vehicle movement were considered together. However, a much smaller percentage of the vehicles with opposing traffic on the national standard had placements in this range than on the Missouri standard during the day. At night the corresponding percentages were approximately equal. Without exception, fewer commercial vehicles were centered within 3.5 or 4.5 ft. of the roadway center. Their average placement was also farther from the centerline, 5.29 ft. on the national standard as compared with 4.92 ft. on the Missouri zone in the daytime, and 4.91 ft. as compared with 4.64 ft. at night.

6. Study of the difference between day-and night-placement data at all comparable sites reveals that the night averages were generally closer to the daytime averages where the barrier line was placed next to the centerline. At a number of the studies on the national standard marking, the night placement actually averaged slightly farther to the right at night than in the daytime. This did not occur at any of the studies on the Missouri zone.

7. The average driver completing a passing maneuver in the vicinity of the test zones overran or violated the Missouri no-passing marking by 228 ft. in the daytime as compared with 86 ft. on the standard zone. At night the difference was not as great, but the national-standard zone was still shown more respect. Extension of the barrier line at the advance end with dashed or solid lines resulted in lengthening the average violations roughly by the amount of the extension, but the extended barrier lines seemed to encourage drivers to drive somewhat farther from the centerline as they approached the zone. This effect also was more pronounced where the barrier line was next to the centerline. The driver's advance view of the beginning of a barrier line located in the center of the lane was definitely hampered by the geometric limitations involved as vehicles trailed one another on the approach to the zone. This factor could easily have been responsible for the relatively poorer observance recorded at the Missouri zone.

8. A 100-percent sample of drivers interviewed immediately after traveling 8 or 9 mi. over each type of marking indicated that their preference was far from being one-sided. Of the 1,005 drivers questioned, 479 preferred the Missouri design; 472 preferred the national standard; and 54 had no choice. The expression of Missouri drivers alone was 130 to 124 for placing the barrier line next to the centerline, while 21 stated they had no preference. The survey revealed too that over 93 percent of the drivers had noticed the two types of marking, and that most out-of-state drivers were aware that their state placed the barrier line adjacent to the centerline, which is the location recommended in the *Manual on Uniform Traffic Control Devices.*

CONCLUSIONS

Based on the data collected and analyzed for this report, the following conclusions are offered:

1. Some of the traffic-operation characteristics on the two marking systems do not appear to differ greatly. Speed values vary only slightly and drivers not familiar with a particular system display only small differences in their speed characteristics at the two zones. However, in an analysis of the more critical conditions for transverse placement, particularly those cases involving vehicles traveling into a no-passing zone in the face of oncoming traffic and those involving the wider vehicles in the commercial class, the findings show that although the differences in placement are small, the advantage is quite consistently with the standard marking design. Drivers of the vehicles in these categories are significantly farther away laterally from potential head-on collisions and sideswipe accidents.

2. The average lateral placement of vehicles at night resembles rather closely the daytime condition on the national standard zone. In the Missouri zone, the difference between day

and night operation is somewhat more marked. It is of interest to note that in each of the six comparative studies on the Missouri zone, the average vehicle was closer to the centerline at night than during the day. On the national standard zone, the night placement for the average vehicle was, in four of the six studies, farther from the centerline than the day placement. In the remaining two studies, the difference between the day and night placement was less than in the corresponding studies on the Missouri zone.

3. Since observance of no-passing zone marking is very largely a voluntary matter, the extent to which drivers comply is a significant measure of the effectiveness of the markings. The average infringement on the no-passing zone area by drivers observed completing passings is greater at the locations where the barrier line is in the middle of the driving lane, and on this count also, the national standard shows superiority.

4. Direct interview of a representative sample of driver opinion, consisting of 1,005 motorists who had just left the test section, reveals no decisive preference for either type of marking. This is as true for Missouri drivers as for drivers from states bordering Missouri and for drivers from other states.

5. Even though some slight improvement in placement occurs when the barrier line is extended with a dashed or solid line, driver observance of the extended zone is poor, and this cannot be termed an effective means of bettering operating conditions, regardless of the type of no-passing zone.

CHARACTERISTICS OF LEFT-TURNING PASSENGER VEHICLES

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SYNOPSIS

GENERAL characteristics of left-turning passenger vehicles have proved to be of current interest to those connected with geometric design. The study locations chosen provided two basic conditions; namely, 90-deg. alignment of the vehicle to the intersecting road, and a zero vehicular speed at the beginning of the turn. Data collection was made by a photographic method. Both rural and urban locations were chosen for the study.

The wider range of turning speeds was found to occur at the urban location. The 85 percentile value at the urban location was found to be 21.4 mph., while at the rural location the 85 percentile value was 16.9 mph.

The maximum acceptable side friction factors displayed a reflection of the speed characteristics in that the frequency distribution curves were of the same general shape as those for speed. This suggested that the minimum radii occurring within each speed group must remain nearly constant for the range of speeds observed at each intersection. It is of importance to note that of the total sample only one third of the drivers used a side friction factor lower than or equal to the generally accepted comfortable value of 0.16.

The paths of the left-turning vehicles could not be expressed mathematically as second- or third-degree equations. Both the front and rear wheel paths took the form of a transitional spiral. Front and rear wheel paths blended from transitional spirals at either end of the turn into a central circular arc. The minimum turning radii were found to occur within the first 30 deg. of the 90-deg. directional change. In all cases the shorter-radii transitional curves were at the beginning of the turn, with the longer-radii transitional curves occurring at the end of the turn.

A correlation of turning paths with speed groups at each intersection proved that the shape of the turning paths remained approximately constant for speed groupings at each intersection. However, comparing similar speed groups at both intersections revealed a difference in the geometric shape of the turning path. This precluded any attempt to make a general formulation that would enable prediction of turning paths on the basis of speed.