HIGHWAY RESEARCH BOARD

Bulletin 244

Effects of Traffic Control Devices

**National Academy of Sciences—
National Research Council**

publication 730

HIGHWAY RESEARCH BOARD

Officers and Members of the Executive Committee

1960

OFFICERS

Executive Committee

Editorial Staff

N.R.C. HIGHWAY RESEARCH BOARD

Bulletin 244

Effects of Traffic Control Devices

Presented at the
38th ANNUAL MEETING
January 5-9, 1959

1960
Washington, D. C.

Department of Traffic and Operations

Donald S. Berry, Chairman
Professor of Civil Engineering
Northwestern University
Evanston, Illinois

COMMITTEE ON HIGHWAY CAPACITY

O.K. Normann, Chairman
Deputy Assistant Commissioner for Research
Bureau of Public Roads

Arthur A. Carter, Jr., Secretary
Highway Research Engineer
Bureau of Public Roads

W.R. Bellis, Chief, Traffic Design and Research Section, New Jersey State Highway Department, Trenton
Robert C. Blumenthal, Partner, Bruce Campbell and Associates, Boston, Massachusetts
Kenneth W. Crowley, Assistant Highway Planning Engineer, Port Development Department, The Port of New York Authority, New York
Gordon K. Gravelle, Deputy Commissioner, Department of Traffic, New York,
Frank V. Houska, Assistant Engineer of Research and Planning, Illinois Division of Highways, Springfield
Charles J. Keese, Texas Transportation Institute, Texas A & M College, College Station
James H. Kell, Assistant Research Engineer, Institute of Transportation and Traffic Engineering, University of California, Berkeley
Jack E. Leisch, Chief Highway Engineer, DeLeuw, Gather and Company, Chicago, Illinois
Eugene Maier, Director, Department of Traffic and Transportation, Houston, Texas
Karl Moskowitz, Assistant Traffic Engineer, California Division of Highways, Sacramento
Charles M. Noble, Cherry Valley Road, Princeton, New Jersey
Walter S. Rainville, Jr., Director of Research, American Transit Association, New York,
Edmund R. Ricker, Traffic Engineer, New Jersey Turnpike Authority, New Brunswick
Richard I. Strickland, Assistant Chief, Traffic Engineering Division, The Port of New York Authority, New York,
S.S. Taylor, General Manager, Department of Traffic, Los Angeles, California
Alan M. Voorhees, Traffic Planning Engineer, Automotive Safety Foundation, Washington, D.C.

William P. Walker, Chief, Geometric Standards Branch, Highway Design Division, Bureau of Public Roads, Washington, D.C.

Leo G. Wilkie, Traffic Engineer, Cook County Highway Department, Chicago, Illinois

COMMITTEE ON TRAFFIC CONTROL DEVICES

William J. Miller, Jr., Chairman
Deputy Chief Engineer
Delaware State Highway Department
Dover

W.C. Anderson, Chief Research and Development Engineer, Union Metal Manufacturing Company, Canton, Ohio

Edward S. Barber, Bureau of Public Roads and University of Maryland

William F. Bauch, Jr., Engineer of Design, State Toll Highway Commission, Chicago, Illinois

Frederick E. Behn, Assistant Engineer, Office of the Engineer of Research, Ohio Department of Highways, Columbus

Louis E. Bender, Traffic Engineer, The Port of New York Authority, New York,

C.E. Billion, Principal Civil Engineer, Bureau of Highway Planning, New York State Department of Public Works, Albany

Donald E. Cleveland, Research Associate, Yale Bureau of Highway Traffic, New Haven, Connecticut

Leon W. Corder, Traffic Engineer, Missouri State Highway Department, Jefferson City

F.B. Crandall, Traffic Engineer, Oregon State Highway Department, Salem

J.E.P. Darrell, Traffic and Planning Engineer, Minnesota Department of Highways, St. Paul

Robert D. Dier, City Traffic Engineer, Long Beach, California

D.L. Gerlough, Ramo-Wooldridge, 5500 West El Segunda Boulevard, Los Angeles, California

James R. Halverson, Chief Traffic Engineer, State Road Commission of Utah, Salt Lake City

H.H. Harrison, Engineer of Traffic, Illinois Division of Highways, Springfield

J. Al. Head, Assistant Traffic Engineer, Oregon State Highway Commission, Salem

J.T. Hewton, Operations Engineer, Toronto Traffic Engineering Department, Toronto, Canada

E.H. Holmes, Assistant Commissioner for Research, Bureau of Public Roads, Washington, D.C.

George W. Howie, Director of Public Utilities, Cincinnati, Ohio

Matthew J. Huber, Research Associate, Bureau of Highway Traffic, Yale University, New Haven, Connecticut

R.C. Kasser, Manager, Structural Section, Sales Development Division, Aluminum Company of America, New Kensington, Pa.

James H. Kell, Assistant Research Engineer, Institute of Transportation and Traffic Engineering, University of California, Berkeley
Holden M. LeRoy, Traffic Control Engineer, Department of Streets and Traffic, Detroit, Michigan
J. Carl McMonagle, Director of Field Services, Highway Traffic Safety Center, Michigan State University, East Lansing
Walter Q. Macnee, Traffic Engineer, Ontario Department of Highways, Ontario, Canada
Milton Male, U.S. Steel Corporation, Pittsburgh, Pennsylvania
Philip S. Mancini, State Traffic Engineer, Rhode Island Department of Public Works, Providence
Fred J. Meno, II, Electrical Engineer, Public Lighting Commission, Detroit, Michigan
J.P. Mills, Jr., Traffic and Planning Engineer, Virginia Department of Highways, Richmond
James V. Musick, Traffic Engineer, Ohio Department of Highways, Columbus
LeRoy T. Oehler, Physical Research Engineer, Highway Research Laboratory, Michigan State University, East Lansing
G.S. Paxson, Assistant State Highway Engineer, Oregon State Highway Commission, Salem
A.R. Pepper, Traffic Engineer, Colorado Department of Highways, Denver
C.W. Prisk, Highway Transport Research Engineer, Bureau of Public Roads, Washington, D.C.
Edmund R. Ricker, Traffic Engineer, New Jersey Turnpike Authority, New Brunswick
Carlton C. Robinson, Automotive Safety Foundation, Washington, D.C.
Charles B. Smith, Associate Professor, Civil Engineering, Ohio State University, Columbus
Jerry Sorrentino, Chief Engineer, Pfaff and Kendall, Newark, N.J.
Rex G. Still, Traffic Engineer, Washington State Highway Commission, Transportation Building, Olympia
Asriel Taragin, Chief, Traffic Performance Branch, Bureau of Public Roads, Washington, D.C.
William T. Taylor, Jr., Assistant Traffic and Planning Engineer, Louisiana Department of Highways, Baton Rouge
James P. Thompson, Codes and Specifications Section, National Bureau of Standards, Washington, D.C.
G.S. Vincent, Bureau of Public Roads, Washington, D.C.
Charles O. Pratt, Associate Traffic Engineer, Wilbur S. Smith and Associates, New Haven, Connecticut
George M. Webb, Traffic Engineer, California Division of Highways, Sacramento
Arthur M. White, Traffic Control and Safety Engineer, Mississippi State Highway Department, Jackson
K.M. Wilkinson, Assistant Traffic and Planning Engineer, Virginia Department of highways, Richmond

R. M. Williston, Senior Highway Engineer, Connecticut State Highway Department, Hartford
David K. Witheford, Planning Engineer, Delaware State Highway Department, Dover

COMMITTEE ON ROAD USER CHARACTERISTICS

T. W. Forbes, Chairman
Highway Traffic Safety Center
Michigan State University
East Lansing

Terrence M. Allen, Department of Psychology and Highway Traffic Safety Center, Michigan State University, East Lansing
Earl Allgaier, Research Engineer, Traffic Engineering and Safety Department, American Automobile Association, Washington, D. C.
Siegfried M. Breuning, Civil Engineering Department, Michigan State University, E. Lansing
Leon Brody, Director of Research, Center for Safety Education, New York University, New York
Harry W. Case, Department of Engineering, University of California, Los Angeles
William G. Eliot, 3d, Highway Engineer, Bureau of Public Roads, Washington, D. C.
Bernard H. Fox, Accident Prevention Program, U. S. Public Health Service, Washington, D. C.
Gordon K. Gravelle, Deputy Commissioner, Department of Traffic, New York
William Haddon, Jr., Director, Driver Research Center, New York State Department of Health, Bureau of Motor Vehicles, Albany
Fred W. Hurd, Director, Bureau of Highway Traffic, Yale University, New Haven, Connecticut
Joseph Intorre, Administrative Assistant, Institute of Public Safety, Pennsylvania State University, University Park, Pa.
Merwyn A. Kraft, Research Coordinator, Flight Safety Foundation, Inc., New York,
A. R. Lauer, Professor of Psychology, Driver Research Laboratory, Iowa State College, Ames
David B. Learner, Human Factors Research Group Research Laboratories, General Motors Corporation, Detroit, Michigan
James L. Malfetti, Executive Officer, Safety Education Project, Teachers College, Columbia University, New York, N. Y.
Alfred L. Moseley, Moseley and Associates, Boston, Massachusetts
Charles W. Prisk, Director, Highway Safety Study, Bureau of Public Roads, Washington, D. C.
Robert V. Rainey, Driver Research Project, University of Colorado Medical Center, Denver
David W. Schoppert, Automotive Safety Foundation, Washington, D. C.

Virtus W. Suhr, Accident Research Analyst, Illinois Division of Highways, Bureau of Traffic, Springfield
Clifford O. Swanson, Chief, Research and Statistics, Iowa Department of Public Safety, Des Moines
Julius E. Uhlaner, The Research Manager, Personnel Research Branch, Department of the Army, Washington, D.C.
George M. Webb, California Division of Highways, Sacramento

COMMITTEE ON SPEED CHARACTERISTICS

Harold L. Michael, Chairman
Assistant Director
Joint Highway Research Project
Purdue University, Lafayette, Indiana

J.E. Baerwald, Assistant Professor of Traffic Engineering, University of Illinois, Civil Engineering Hall, Urbana
J. Stannard Baker, Director of Research and Development, The Traffic Institute, Northwestern University, Evanston, Illinois
W.J. Bartels, 131 Colight Avenue, New Rochelle, N.Y.
C.E. Billion, Principal Civil Engineer, Bureau of Highway Planning, New York State Department of Public Works, Albany
J.E.P. Darrell, Traffic and Planning Engineer, Minnesota Department of Highways, St. Paul
H.M. Edwards, Associate Professor or Civil Engineering, Queen's University, Kingston, Ontario, Canada
J.E. Johnston, State Road Commission of Utah, Salt Lake City
James H. Kell, Assistant Research Engineer, Institute of Transportation and Traffic Engineering, University of California, Berkeley
W.A. McConnell, Technical Assistant, Vehicles Testing, Ford Motor Company, Dearborn, Michigan
Robert L. Meyer, Traffic Engineer, Nebraska Department of Roads, Lincoln, Nebraska
Edmund R. Ricker, Traffic Engineer, New Jersey Turnpike Authority, New Brunswick
David Solomon, Highway Transport Research Engineer, Bureau of Public Roads, Washington, D.C.
K.A. Stonex, Assistant Director, General Motors Proving Grounds, Milford, Michigan
Joseph L. Wehmeyer, Engineer of Safety and Traffic, Wayne County Road Commissioners, Detroit, Michigan
W.E. Zierer, Experimental Engineer, Chrysler Corporation, Highland Park, Michigan

Contents

Effect of Curb Parking on Intersection Capacity

ANTHONY J. GALIOTO, The Port of New York Authority

To increase the traffic capacity through signalized intersections, many traffic engineers have resorted to complete prohibition of parking on heavily traveled arteries. As a consequence, appropriate regulations have been adopted under which parking can be restricted for various reasons.

This paper attempts to show, through quantitative evaluation, the effects on intersection capacity, of varying lengths of clear distance adjacent to an intersection. By controlling conditions at the study intersection, factors influencing capacity, such as pedestrian and parking maneuvers, are kept to a minimum in order to more accurately establish the relationship between clear distance and intersection capacity.

The intersection selected for study consists of a three-lane one-way street intersecting a two-lane two-way street. Blocking off nearly a full lane first on one side of the one-way approach and then on the other side, and then allowing vehicles to utilize varying lengths of clear distance in the curb lanes, it was possible to obtain sufficient data to suggest a relationship between clear distance in the curb lane and intersection capacity.

The relationship is tested statistically by the students "t" method and correlation by ranks.

The results as they pertain to the specific intersection involved are that maximum volumes of traffic can be moved through an intersection without complete prohibition of parking, and that on the approach the clear distance adjacent to the intersection required for maximum volumes is related to the percentage of turning movements.

● IN AN ATTEMPT to move as much traffic as possible through areas subject to high volumes of vehicular movements, many traffic engineers apparently believe strongly in the importance of complete prohibition of parking on heavily traveled streets. As a consequence, appropriate regulations have been adopted under which parking can be restricted for various reasons.

Parking and parking restrictions are known to affect traffic capacity of intersections, as evidenced by reported studies in the Highway Capacity Manual (1). Typical values for capacities under various physical and traffic conditions include parking, turning movements, location of intersection with respect to downtown areas, and factors for increasing or decreasing capacities as a result of changing these conditions to suit a particular problem. The sources of these data are reports of traffic volumes observed at many intersections in several cities throughout the United States.

The stated values in the manual apply to complete parking permitted or prohibited conditions. A correction factor is applied for conditions of partial parking. The factor is determined by the formula P (D-20)/5G percent where P is the total percentage of turns (1). D is the distance in feet from the crosswalk and G the seconds of green per signal cycle. Maximum values for P and D are limited by 30 and (5G-20), respectively. In addition, the manual states that prohibition of parking in advance of an intersection for a distance in feet equal to five times the green period is equivalent to a complete prohibition of parking.

THE PROBLEM

The purpose of this report is to determine the effect on the intersection capacity of a one-way street by varying the length of curb parking adjacent to the intersection.

To examine the effect of varying the length of clear distance on intersection capacity, data were taken at an intersection approach operating under saturated traffic conditions. Observations were made without parking and then by coning off a traffic lane so that it was possible to obtain data for clear distances in multiples of 22 ft, a unit parking space length. Data were collected on the number of vehicles entering the intersection in each cycle as measured from the start of the GO period for each curb lane. In addition, the number of vehicles stored in the curb lane was recorded before each GO period. Mean discharge per cycle under different lengths of clear distance were compared and tested statistically for significant differences. Significant differences indicate whether or not intersection capacity is affected by the length of clear distance.

Parking and unparking maneuvers contribute to a reduction in intersection capacity but these factors have not been included in this study. In addition, the presence of traffic cones are assumed to have the same influence as a line of parked cars on the approaching vehicles.

STUDIES CONDUCTED

Definitions of Terms Used

Left Curb Lane. For the purpose of this paper, the left curb lane is defined as that lane adjacent to the left curb on the approach to the intersection.

Right Curb Lane. That lane adjacent to the right curb on the approach to the intersection.

Center Lane. That lane situated between the left and right curb lanes.

Clear Distance. That distance in feet measured in either curb lane from suitable reference points to the first parked car or, as applicable in this paper, to the first cone on the approach side of the intersection.

Initial Study at Prospect and Grove Streets

In order to acquaint the author with first hand field conditions to be faced in undertaking a study such as the one described in this project, a pilot study was made at the intersection of Prospect and Grove Streets in New Haven, Connecticut on October 11 and 13, 1956. The leg considered was the southbound approach of Prospect Street, 36 ft wide curb-to-curb with a painted centerline dividing the two-way roadway into two 18-ft legs.

Normally, traffic approaches the intersection in one lane with right-turn vehicles frequently stacking up parallel to the through- or left-turn movements after each GO period.

For these initial observations, attempts were made to place a single parked car at varying distances from the intersection. Data were recorded under conditions of saturated flow; that is, a continuous reservoir of vehicles waiting to enter the intersection.

The single parked car presented a hazard to traffic by reducing the effective width of the leg from 18 to 10 ft, thereby forcing some vehicles to cross over into the opposite traffic lane. In addition, its position in the roadway necessitated dangerous weaving maneuvers for those vehicles approaching the intersection in the curb lane. Consequently, limited data were taken, precluding quantitative evaluation and, therefore, excluded in the analysis.

Inasmuch as the single parked car was obstructing the free movement of traffic and causing inconvenience to motorists, it was decided to abandon further study of this intersection. Furthermore, heavy pedestrian volumes and far side curb parking introduced elements which would have presumably influenced the results of this experiment.

On the basis of the experience gained from the initial study, it was felt desirable to select an intersection which, by virtue of actual or imposed regulations, would have eliminated these factors.

Study Site at Springdale Avenue and North Service Road

The North Service Road of the Garden State Parkway at Springdale Avenue in East Orange, New Jersey, was selected as the site for this experiment. The service road is under the jurisdiction of the Garden State Parkway Authority and signals thereon, within city limits, are under the jurisdiction of the City of East Orange. Arthur T. Brokaw, City Engineer, and his staff extended their full assistance to aid in this project.

The North Service Road is 40 ft wide, curb-to-curb, at its intersection with Springdale Avenue. Parking is not specifically prohibited by posting on either approach. Particular care was taken during recording of data to insure that parking on the far approach was non-existent. In this manner, interference with traffic flow through the intersection was kept at a minimum. No driveways or houses front on the east side of the service road; a retaining wall is present on the west side.

Under normal operation, three lanes of traffic move northbound along the service road to enter or cross Springdale Avenue. The service road is 30 ft wide on the approach, and a left turn bulb is provided at the intersection. For purposes of this study, the left turn bulb was considered non-existent since it was coned off while data were recorded.

On the northbound service road, coning off what is normally used for parking, some 8 ft, would block off one full lane of traffic. In this manner, the approach would be physically reduced to 22 ft. Differences in traffic movement between no parking and various parking conditions would be more sharply marked than presumably would be the case if the restriction blocked less than a full traffic lane. Under conditions of this study it was not possible for three lanes of traffic to move along to service road.

The intersection selected for study is controlled by a fixed-time three -light signal. The cycle length is 90 sec and the traffic controller is in a progressive system which includes the intersection of Arlington Avenue and the service road. Referring to Figure 1, the major portion of traffic using this section of the service road is fed from the Arlington Avenue off-bound ramp from the Garden State Parkway. The parkway is restricted to passenger cars throughout the area studied. Normally, traffic flows along the service road through the progressive system very smoothly and the signal splits favor Springdale Avenue. The service road, under normal operation, is given 25 sec of green and 3 sec of amber.

Volume counts made during the selected period of study revealed a heavy left turn movement in the magnitude of 40 percent while the right turns were less than 5 percent of the total approach volumes.

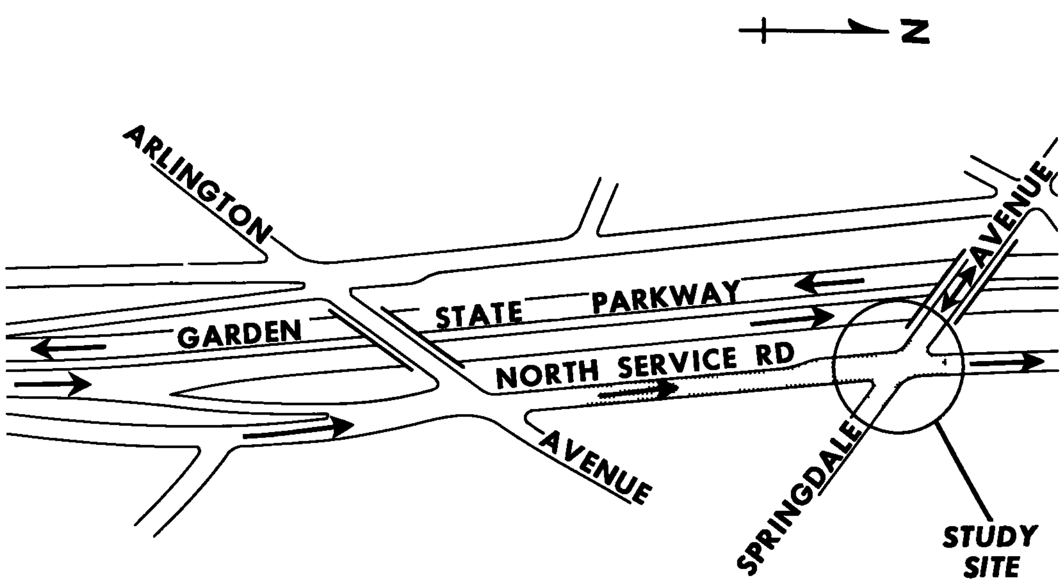


Figure 1. Location plan.

METHOD OF STUDY

To permit quantitative evaluation of the effects of varying lengths of clear distances on capacity, data were collected on the number of vehicles entering from each lane for each cycle under different parking conditions. Hand denominators mounted on clip boards were used to facilitate recording the data. Cones were set up 8 ft from the curb and 22 ft apart along the entire approach leg. In this manner, removal of one cone at a time produced the desired clear distances and prevented vehicles from approaching the intersection in the coned-off lane. As a consequence, the hazards of weaving induced by the single parked car technique were eliminated. Figures 2 and 3 depict the manner in which the curb lanes were coned off during data taking periods.

Collection of Data

The intersection selected for study, as previously indicated, is normally part of a progressive system, and under usual traffic conditions operates efficiently. Since it was felt desirable to conduct this study under conditions of saturated flow, the green time alloted to the service road was reduced from 25 sec to 16.5 sec and 20.0 sec on the two days of observations. In this manner, it was possible to destroy the progression, creating conditions of saturated flow and causing the approach to fill up rapidly with vehicles. Once this condition was obtained, data were taken.

With the green time reduced to 16.5 to 20.0 sec for both right and left curb parking conditions, it was possible to maintain saturated conditions for periods of 3 hr on each day of data taking.

Occasionally, the back up would overflow to the preceding intersection and danger of blocking the exit ramp from the parkway was present. To avoid this latter condition, the signal splits were periodically readjusted by a signal technician who was present throughout the field study. During this period, data were not taken.

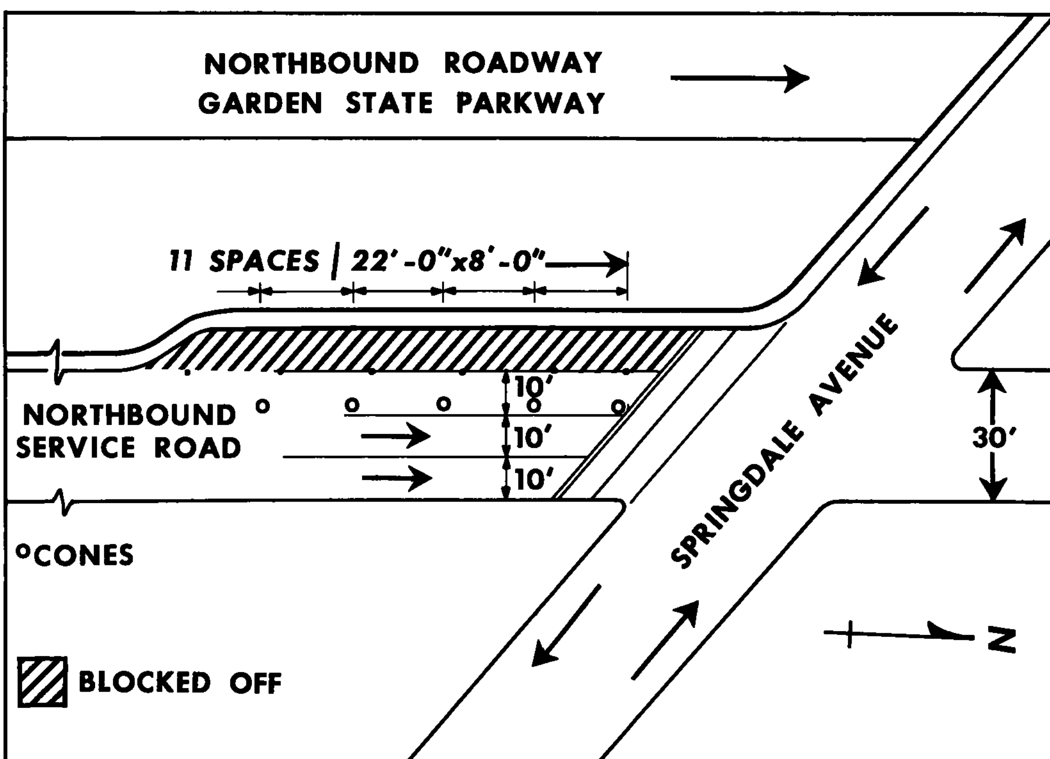


Figure 2. Left curb lane parking conditions.

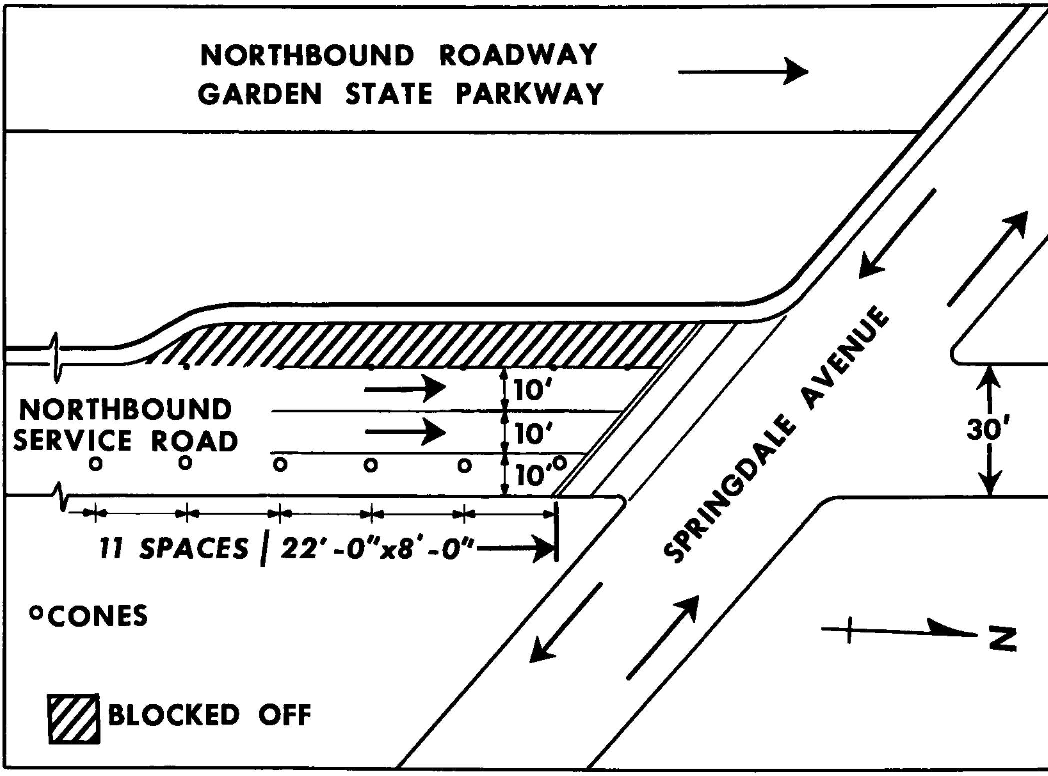


Figure 3. Right curb lane parking conditions.

Cycles during which the intersection was blocked by a stalled or stopped vehicle were noted and omitted from analysis, as well as cycles during the period when the splits were changed in order to avoid overflow of back up onto the parkway. Pedestrian traffic was non-existent during the survey period and hence could not have influenced the results of the study.

Data-taking periods were scheduled in order to obtain between 5 and 10 cycles for each clear distance, in multiples of 22 ft, up to approximately 250 ft from the intersection for each curb lane. All cycles were recorded under saturated intersection conditions.

Observations were made first with the right lane coned off on October 22 and then with the left lane coned off on November 5. Weather was cool and clear on both days.

ANALYSIS OF DATA

Study of Left Curb Lane Parking Conditions

Table 1 summarizes the mean discharge, expressed in vehicles per cycle, in addition to the observed storage in the left curb lane just before the signal turned green.

From Table 1, it is apparent that the storage is a function of the clear distance back from the intersection and the relationship is approximately linear.

The discharge from the left lane, between 44 and 110 ft from the intersection, lies within the range of 0.0 and 9.6 vehicles per cycle with an average discharge of 4.8 vehicles per cycle. Beyond 110 ft the discharge from the left lane is within the range of 8.8 and 9.9 vehicles per cycle with an average discharge of 9.4 vehicles per cycle.

Discharge from the center lane decreases from a maximum of 9.6 vehicles per cycle at 44 ft to a minimum of 5.6 vehicles per cycle at 110 ft and then begins to rise beyond 110 ft. It is interesting to note that the decrease in the center lane takes place at the same time that the discharge from the left lane increases.

TABLE 1

SUMMARY OF DATA—LEFT LANE PARKING CONDITIONS

Clear Distance (ft)	Storage Left Curb Lane-Veh	Mean Discharge—Veh/Cycle Left Lane	Center Lane	Right Lane	Total All Lanes
44	0	0.0	9.6	7.8	17.4
66	2	3.0	7.8	10.4	21.2
88	3.2	7.8	6.2	9.6	23.6
110	3.8	9.6	5.6	9.8	25.0
132	5.0	9.0	6.6	9.0	24.6
154	5.2	8.8	7.0	9.0	24.8
176	5.6	9.6	7.0	9.3	25.9
198	6.0	9.4	7.8	7.8	25.0
220	6.2	9.1	8.2	7.6	24.9
242	8.0	9.9	8.0	7.8	25.7

This relationship is better illustrated in Figure 4 where both the left curb lane and center lane are plotted. This characteristic appears to be due in part to the fact that when the left lane is almost entirely coned off, drivers are forced to make left turns from the center lane. As the clear distance is increased, those desirous of turning left could use the curb lane and drivers going through the intersection will use both the remaining center and right lanes. As a consequence, gaps are left in the center lane resulting in a decrease of discharge.

Discharge from the right lane does not appear to be affected by the varying offset in the left lane.

Relationship Between Intersection Capacity and Clear Distance

The hypothesis that intersection capacity is proportional to the length of clear distance adjacent to the intersection was tested by the "t" statistical method. Provision of only 22 ft in the left curb produced significant effects on the total volumes discharged up to 88 ft.

Table 2 depicts the values of "t" for the difference in mean volumes between offsets of 44 and 66 and 66 and 88 ft from the intersection.

Significance levels 0.01 and 0.01 are noted. This indicates that the hypothesis of equal means would be rejected at a significance level of 0.01 or lower.

On the basis of the results shown in Table 2, it is unlikely that the volumes observed came from the same population or that the difference in means could be attributed to variations in turning movements.

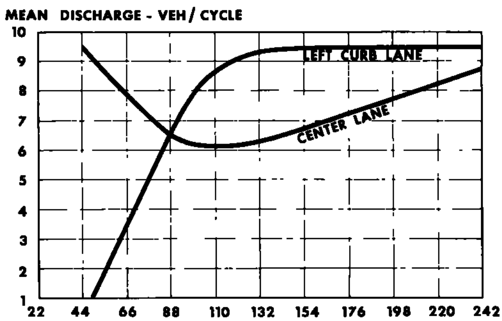


Figure 4. Discharge—left and center lane left lane parking conditions.

Rank Correlation Analysis

A rank correlation analysis (6) was made to ascertain the degree of correlation between clear distance and the mean discharge per cycle. The coefficient of correlation was found to be 0.86 with a probable error of 0.06. The high correlation

TABLE 2

COMPARISON OF MEAN VOLUMES LEFT LANE PARKING CONDITIONS

Clear distance (ft)	44		66		88
Number of cycles	8		7		7
Mean discharge (veh/cycle)	17.4		21.2		23.6
Value of "t"		4.50		3.75	
Significance level (3)		0.01		0.01	

value of 0.86 indicates the relationship that the length of clear distance is proportional to intersection capacity.

Figure 5 shows the relationship of total discharge per cycle and clear distance adjacent to the intersection. The volume discharged increases linearly to approximately 23.5 vehicles per cycle when a clear distance of 88 ft was provided adjacent to the intersection. The maximum mean discharge was approximately 25.5 vehicles per cycle and at 110 ft the mean discharge observed was 25.0 vehicles per cycle.

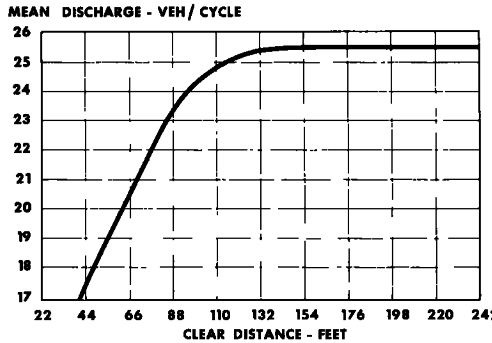


Figure 5. Discharge— all lanes—left lane parking conditions.

Study of Right Curb Lane Parking Conditions

Table 3 summarizes the mean discharge expressed in vehicles per cycle when the right curb lane was coned off in intervals of 22 ft. Shown also is a breakdown by lane of the total discharge.

TABLE 3

SUMMARY OF DATA—RIGHT LANE PARKING CONDITIONS

Clear Distance (ft)	Mean Discharge—Veh/Cycle			
	Left Lane	Center Lane	Right Lane	Total All Lanes
22	6.6	6.8	0	13.4
44	7.3	6.8	0.2	14.3
66	7.2	7.5	0.2	14.9
88	7.3	7.8	1.1	16.2
110	7.4	8.2	0.6	16.2
132	7.7	7.6	3.1	18.4
154	7.4	7.5	3.0	17.9
176	7.8	8.4	4.4	20.6
198	7.2	7.7	4.9	19.8
220	7.1	8.3	4.2	19.6
242	7.0	7.2	4.5	18.7

While there is an increase in total discharge in a manner similar to the study conducted when the left lane was coned off, the slope of the increase is considerably less steep.

In comparison to the condition where the left lane was coned off, it was demonstrated that from 44 ft from the intersection to 110 ft an increase of 7.6 vehicles per cycle followed, as compared to an increase of 14.3 to 20.6, or 6.3 vehicles per cycle, in an aggregate distance of 176 ft less 44, or 132 ft.

Notwithstanding a 3.5 sec difference in green time for both conditions, it appears that this difference could be attributed to the higher percentage of left turns and the absence of right turns. Had parking been retained on the far side of the intersection, this difference could have been partially attributed to this condition. However, as brought out earlier in this report, parking was not permitted on the far side of the intersection.

Since this was the case, it appears that the low discharge in the right curb lane could be attributed to driver reluctance to use the right lane as a through lane.

This is more clearly shown in Figure 6. It is evident that the increase in discharge from the right curb lane is very gradual and only amounts to approximately 5.0 vehicles per cycle. The mean discharge from the center lane is relatively constant and varies from approximately 7.0 to 8.0 vehicles per cycle, as opposed to the dip from a high of 9.6 to a low of 5.6 vehicles per cycle and then a gradual increase under the left curb lane parking conditions described.

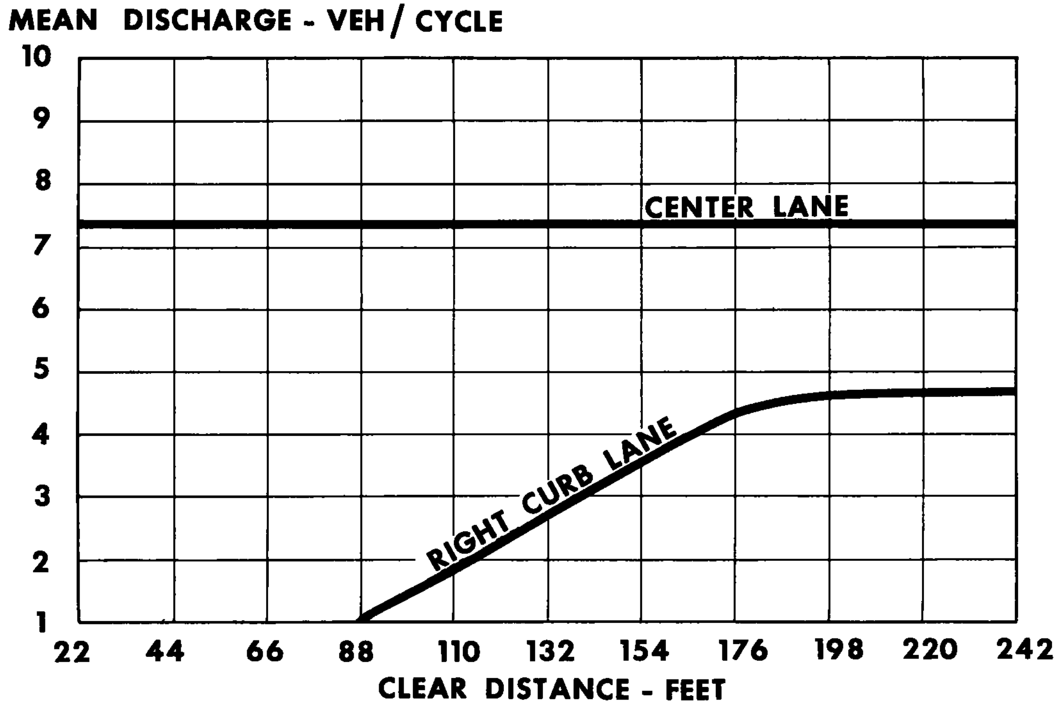


Figure 6. Discharge—right and center lane right lane parking conditions.

The total mean discharge for the conditions of this study is shown in Figure 7. The general shape of the curve very nearly approaches that of the curve for the study with the left lane coned off and there can be no doubt that as the clear distance increases, the mean discharge increases. This increase takes place until there is a gradual leveling off of the total mean discharge, until the effect of curb parking is not apparent in the discharge at the intersection.

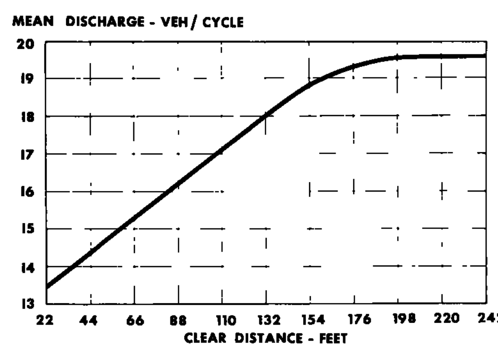


Figure 7. Discharge—all lanes—right lane parking conditions.

Relationship Between Intersection Capacity and Clear Distance

A "t" statistical analysis was made to test the significance of the difference in mean discharge for the study with the right lane coned off in intervals of 22 ft. The results are shown in Table 4.

An analysis of the results of the "t" test indicate that for the right lane clear distances of 88 and 66 ft were necessary to detect significant differences in mean discharge per cycle. The study with the left lane coned off showed that distances of as little as 22 ft caused significant differences in mean discharge per cycle.

TABLE 4

COMPARISON OF MEAN VOLUMES RIGHT LANE PARKING CONDITIONS

Clear distance (ft)	22		110		176
Number of cycles	8		9		5
Mean discharge (veh/cycle)	13.4		16.2		20.6
Value of "t"		2 27		3.25	
Significance level (3)		0.05		0.01	

As brought out previously, the high percentage of left turns as opposed to a very negligible number of right turns could have made the difference.

Rank Correlation Analysis

A rank correlation analysis (6) was also made to ascertain the degree of correlation between the curb offsets in the right lane and the mean discharge. The coefficient of correlation was found to be 0.87 with a probable error of 0.05 . The high correlation of 0.87 supports the contention that the length of clear distance is proportional to intersection capacity.

Comparison of Calculated and Maximum Observed Capacity

A clear distance of approximately 110 ft in the left curb lane yielded a maximum volume of 1,000 vehicles per hr. In the right curb lane, approximately 132 ft was required to yield a maximum volume of 750 vehicles per hr.

TABLE 5

RELATIONSHIP OF CALCULATED AND MAXIMUM OBSERVED CAPACITY—VEH/HR OF GREEN

Lane	Calculated	Maximum Observed	% Difference
Left lane parking conditions	835	1,000	+16.5
Right lane parking conditions	685	750	+ 8.7

These comparisons are depicted in Table 5. Observed traffic volumes on this intersection approach are somewhat higher than the theoretical capacities calculated on the basis of maximum volumes observed and stated in the Traffic Engineering Handbook (4).

CONCLUSIONS

For both conditions of parking studied, capacity through the intersection increased in proportion to the length of clear distance. The increase in capacity for the left curb lane parking conditions was apparent up to a distance of about 110 ft. No significant increase in discharge was evident beyond this distance. This finding very closely agrees with the statements made in the Highway Capacity Manual, that is, a distance in feet equal to five times the green period in seconds is equivalent to complete prohibition of parking in regard to capacity. The right curb lane parking conditions, on the other hand, required a distance of 132 ft beyond which no significant increase in discharge was noted. For this condition, agreement with the Highway Capacity Manual is not noted. As indicated in the analysis, this may be due to the absence of right turns in addition to driver reluctance to use the curb lane as a through lane.

Significant increases were found in the volume discharged per cycle when additional clear distance at the intersection was available for moving traffic in both cases tested by the t-statistic. While additional clear distances of 22 ft provided significant effects in the left lane, a distance of approximately 80 ft was required when the right lane was coned off. This difference also appears to be attributable to the high percentage of left turns as opposed to a very small percentage of right turns in addition to driver reluctance to use the curb lane for through movements.

A correlation analysis between the clear distance adjacent to the intersection and the discharge resulted in a high correlation coefficient for both parking conditions. This finding supports the hypothesis that capacity through an intersection will increase in proportion to an increase in clear distance.

COMPARISON OF OBSERVATIONS WITH THOSE OF PREVIOUS STUDIES

Bartle's Observations

Bartle's paper (2) presented the results of a similar study at a four-lane two-way intersection. In this study the restrictive effect of a single car was studied at two distances from the intersection. Bartle found the effect of the single car to be significant, although the difference in absolute volumes was small. He attributes the small difference in absolute volumes to the fact that an entire traffic lane was not blocked off. It is further suggested that single cars parked at mid-block locations between signalized intersections may have no restrictive effect on capacity, based on the two distances of parking from the intersection.

Wickstrom's Observations

Wickstrom's thesis (5) offers a more direct comparison in a study of a similar nature at an intersection of a one-way street in a downtown area. Wickstrom's study included observations at and below saturated capacity. The characteristics of the curves for both conditions are similar. While the study described herein was conducted during saturated conditions, the similarity of the relationship between observed volumes and clear distance is noteworthy. Both studies suggest that the maximum volumes through a signalized intersection occur when the clear distance, in feet, is approximately equal to five times the green time when turning volumes are in the neighborhood of 30 to 40 percent of the total approach volumes.

APPLICATION OF RESULTS

The experiment described in this paper has demonstrated that maximum volumes of traffic can be moved through an intersection without complete prohibition of parking. It has further been shown that the clear distance required for maximum volumes is a function of the percentage of turns. It is realized that the effect of vehicles maneuvering during parking operations constitutes a detriment to traffic approaching an intersection. This effect was not measured in this study.

In applying the findings presented herein, consideration should be given to the parking characteristics of the intersection studied. Where turning volumes are low and parking on the far side on an intersection is not a factor, perhaps proper signing will encourage greater utilization of the clear distance.

Need for Further Research

While only one street width was considered in this project, the findings suggest a possible relationship between street width, percentage of turning movements and volumes of traffic. Similar studies on streets of different widths and turning movements will be a valuable contribution in determining whether such a relationship exists. In this manner, it would be possible to more fully understand the effect of curb parking on intersection capacity.

REFERENCES

1. Committee on Highway Capacity, Department of Traffic and Operations, HRB Highway Capacity Manual, U.S. Government Printing Office (1950).
2. Bartle, R.M., "Effect of Parked Vehicle on Traffic Capacity of Signalized Intersection." HRB Bull. 112 (1956).
3. Arkon, H., and Colton, R., "Tables for Statisticians." Barnes and Noble, Inc., New York (1953).
4. Institute of Traffic Engineers, Traffic Engineering Handbook, The Institute, New Haven, Conn. (1950).
5. Wickstrom, G.V., "The Effect of Curb Use on Intersection Capacity." Student Thesis, Bureau of Highway Traffic, Yale University (1956).
6. Arkon, H., and Colton, R., "Statistical Methods." Barnes and Noble, Inc., New York (1955).

Effect of Edge Striping on Traffic Operations

I. L. THOMAS, JR., Traffic and Planning Engineer; and
W. T. TAYLOR, JR., Assistant Traffic and Planning Engineer,
Louisiana Department of Highways

During 1956, the Louisiana Department of Highways, in conjunction with the Bureau of Public Roads conducted a number of research studies on US 71 near LeBeau to determine the effect of pavement edge striping on the lateral placement of vehicles on 24-ft tangent highways. Results of the study indicated that a continuous edge stripe or line had no effect on vehicle placement during the day, but at night the continuous line tended to move vehicles slightly toward the centerline.

During the summer of 1957, the department, again in cooperation with the Bureau of Public Roads, repeated the placement study on 24-ft tangent highways in a different part of the state in an effort to verify findings of the initial study.

In addition, the scope of the study was broadened to include a study of a section of tangent 20-ft roadways, a section of 20-ft roadways on a 4-deg curve, and a section of 4-lane divided highway with 12-ft lanes in one direction and 10-ft lanes in the other. In all cases, shoulders were in color contrast to the through roadways.

●THE BUREAU of Public Roads furnished the department an electromechanical speedmeter and placement detector with technicians to supervise collection of field data. This device recorded vehicle speeds by use of electrical circuits wired to pens recording on a tape moving at a constant rate. Lateral placement of vehicles was measured by electrical contacts placed across the roadway spaced at 1-ft intervals. Placement of vehicles was measured to within 6-in. maximum, and generally within 3 in.

In the 24-ft tangent roadway study, a 4-mi section of US 190, bituminous surfaced, located just east of Albany was selected for sampling. The study was limited to the hours 12 noon to 12 midnight with the exception of the twilight hour which was not studied. The study location was approximately midway the 4-mi section. All equipment and personnel were off the highway and hidden from the motorists.

The "before" study was conducted with the roadway marked along the centerline with a 15-ft white-reflectorized 4-in. wide centerline on 40-ft centers. A total of 7,939 veh was sampled in all of the "before" studies. Vehicle placement was observed by type of vehicle; direction of travel; and maneuver (free moving, meeting, etc.).

The "after" study was conducted with all of the conditions listed above plus a 4-in. wide reflectorized stripe or line placed 6 in. from the outside edge of both sides of the pavement. A total of 9,480 veh was sampled in the "after" study. Both the "before" and "after" study were conducted for three consecutive weekdays.

VEHICLE PLACEMENT ON 24-FT TANGENT ROADWAYS

Figure 1 shows the average distance from the centerline to the nearest edge of the vehicle for free flowing passenger cars and for commercial vehicles by each direction of travel during the day and night.

Again, in this study as in the initial study, the trend for free flowing vehicles to travel nearer the centerline after painting of the continuous outside edge line is noted. As expected, commercial vehicles, because of their increased size, travel closer to the center line than passenger cars.

A comparison of the results found during the 1956 and 1957 study for both directions of travel combined for passenger cars and commercial vehicles is shown in Figure 2.

A study of this figure shows the findings during the 1956 study are repeated almost identically by the 1957 findings. It is interesting to note that in all cases the presence of the continuous line along the outside edge of the pavement moved the vehicles slightly toward the centerline. These two studies conducted on Louisiana highways in different parts of the State and separated by a time interval of a year indicate strongly that free flowing vehicles on a 24-ft highway marked with both a centerline and an outside continuous line will, of their own free will, travel several inches closer to the centerline.

Figure 3 shows the clearance between inner edge of meeting vehicles. Here again, both passenger cars meeting passenger cars, or passenger cars meeting commercial vehicles have less clearance between the passing vehicle after the continuous line had been installed. Noteworthy is the finding that there is a greater distance between passenger cars meeting at night than those meeting in the daytime. This is true with or without the continuous edge line. However, meeting vehicles traveling during the day or night after the highway had been marked with a continuous stripe are some 6 to 8 in.

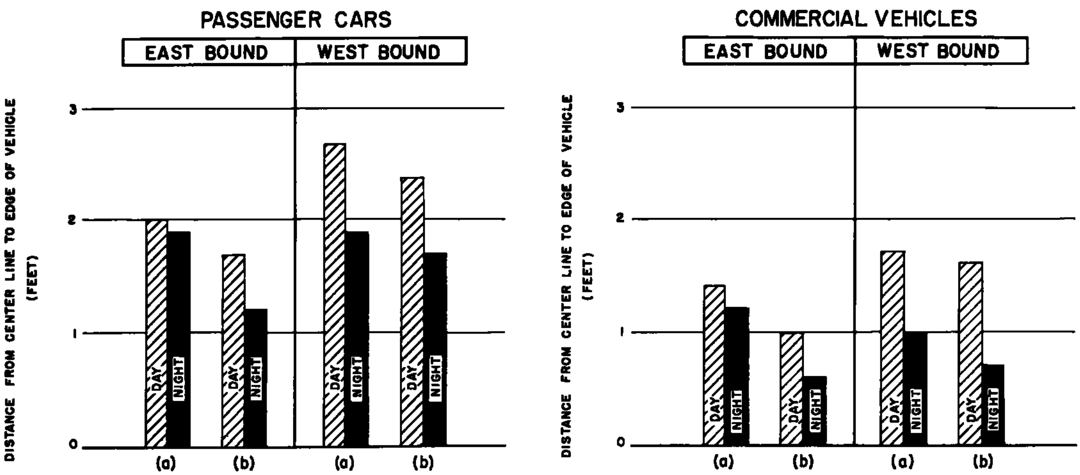


Figure 1. Lateral placement of free moving vehicles on 24-ft tangent highway; (a) no edge stripe; (b) continuous edge stripe.

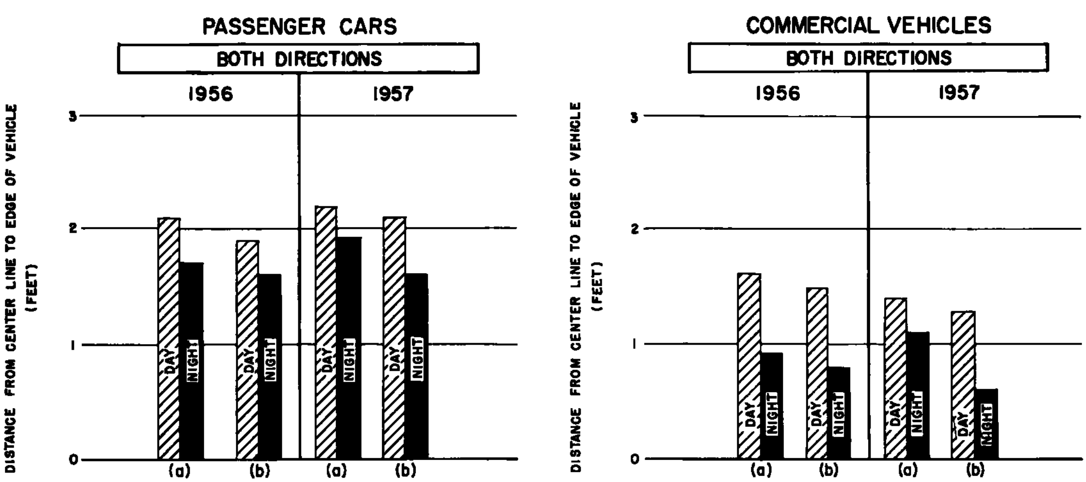


Figure 2. Comparison of lateral placement of free moving vehicles on 24-ft tangent highway 1956-1957; (a) no edge stripe; (b) continuous edge stripe.

nearer each other than those meeting on the highway prior to placement of the stripe.

VEHICLE PLACEMENT ON 20-FT TANGENT ROADWAYS

The second phase of the study was conducted on a 20-ft tangent bituminous highway in a manner similar to that described for the 24-ft section. Results for free flowing vehicles found in this study which are shown in Figure 4 are almost identical to those observed on the 24-ft study sections. The vehicles are traveling nearer to the centerline since the roadway is narrower, but the trend to move toward the centerline after painting of the continuous edge line is noted by both the free moving passenger cars and commercial vehicles.

Figure 5 indicates that this tendency to move nearer the centerline after painting of the continuous edge line is also present when passenger cars meet other passenger cars.

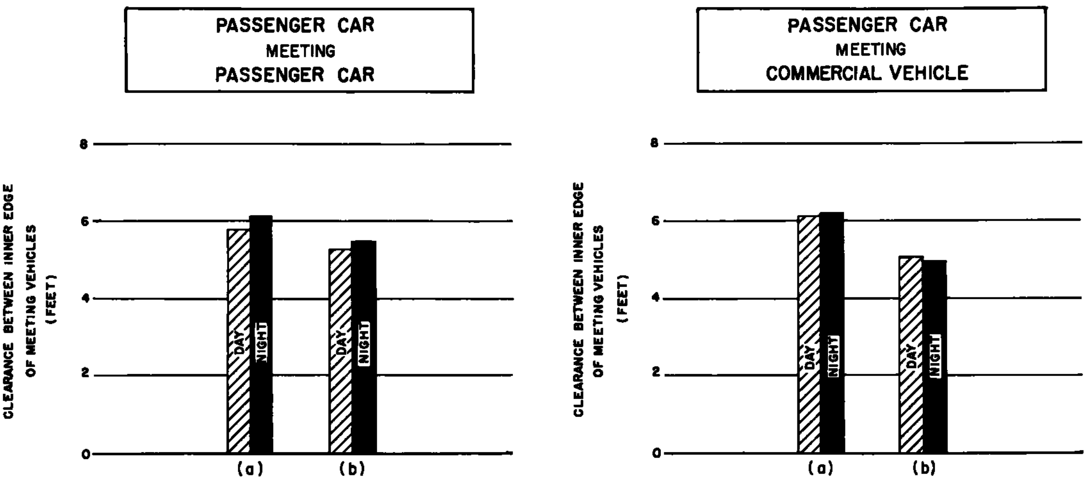


Figure 3. Clearance between inner edge of meeting vehicles on 24-ft tangent highway; (a) no edge stripe; (b) continuous edge stripe.

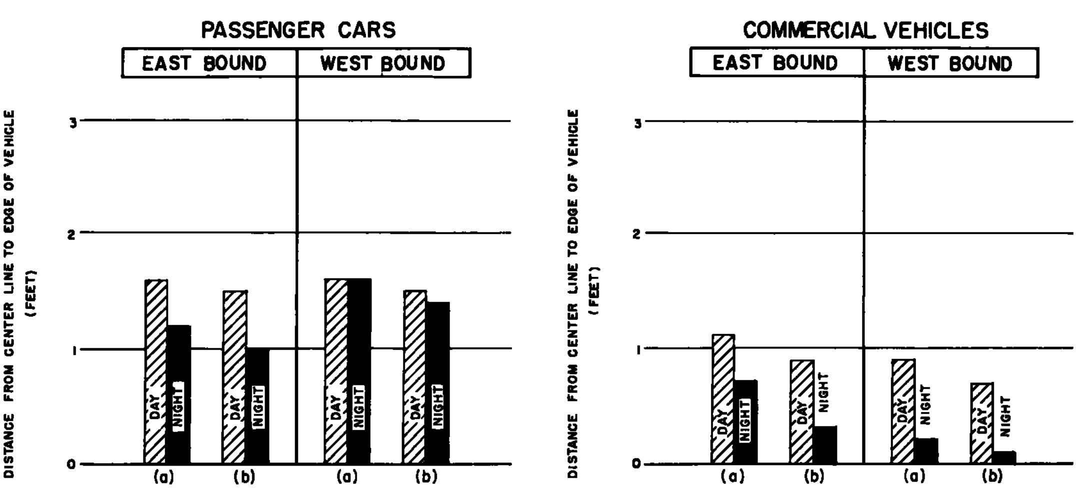


Figure 4. Lateral placement of free moving vehicles on 20-ft tangent highway; (a) no edge stripe; (b) continuous edge stripe.

VEHICLE PLACEMENT ON CURVES ON 20-FT ROADWAYS

A third phase of the study deals with lateral placement of vehicles on a 20-ft roadway in a 4-deg curve. Conditions for the study were the same as those described for the other two phases. The westbound traffic moved over the inside of the curve while eastbound traffic was on the outside of the curve. The entire curve was in a marked no passing zone, utilizing standard double yellow markings.

Figure 6 shows the lateral placement of free moving passenger cars before and after outside edge markings were applied.

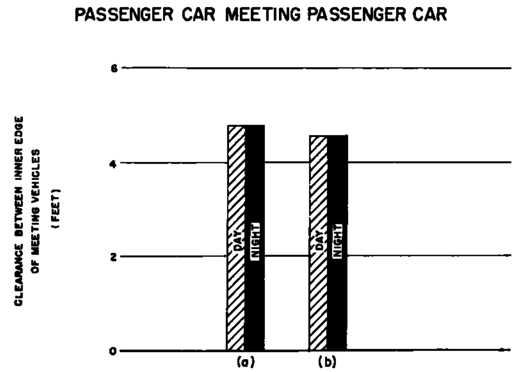


Figure 5. Clearance between inner edge of meeting vehicles on 20-ft tangent highway; (a) no edge stripe; (b) continuous edge stripe.

The minus values recorded during the night observations indicate that vehicles in the outside or eastbound lane are crossing the no passing stripe and the centerline stripe when negotiating this curve. The continuous outside edge stripe at night moved these eastbound vehicles slightly to the left, increasing the distance that they crossed the centerline by 0.1 of a foot. This move to the left was even greater in the daytime, averaging 0.6 ft. However, in the daytime the vehicles on the outside of the curve did stay in their lane, evidently obeying the yellow no passing line; even though they were nearer the centerline

The same general pattern was followed by eastbound commercial vehicles, except that the movement to the left was even more pronounced, with vehicles crossing the centerline in the daytime.

Westbound traffic also showed a tendency to move away from the edge of the roadway and toward the centerline. However, this movement for passenger cars averaged only 0.2 ft during the day and 0.1 ft at night. The lateral movement for commercial vehicles during the day was also slight; however, at night this movement toward the centerline after edge striping was almost a foot.

VEHICLE PLACEMENT ON 4-LANE DIVIDED HIGHWAYS

The final phase of the study was conducted to determine the effect continuous edge line striping has on vehicle placement on 4-lane divided highways.

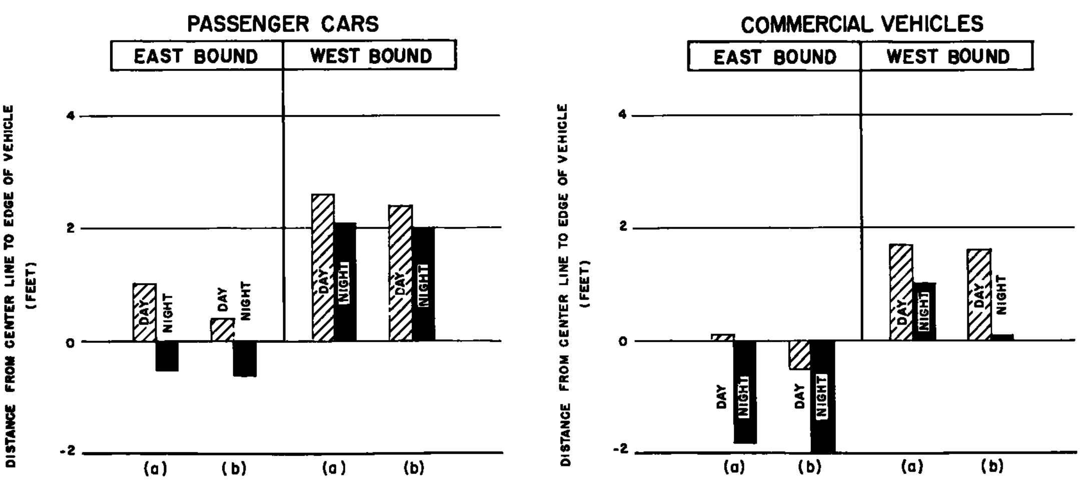


Figure 6. Lateral placement of free moving vehicles on 20-in. highway in 4-deg curve; (a) no edge stripe; (b) continuous edge stripe.

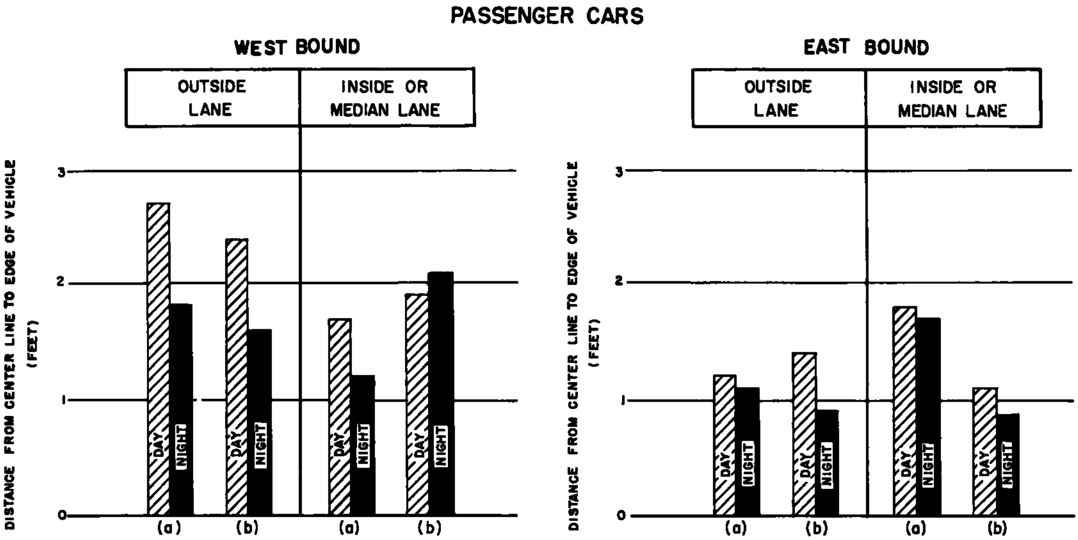


Figure 7. Lateral movement of free moving passenger cars on 4 lane divided highway; (a) no edge stripe; (b) continuous edge stripe.

A tangent 4-mi section of US 190 some 8 mi west of Baton Rouge was selected for study. The westbound lanes were 12-ft concrete while the eastbound lanes were 10-ft bituminous overlay. Roadways were separated by a 4-ft raised concrete median. Ten-ft grass shoulders were provided on each side. The statutory speed limit of 60 mph for passenger cars and 45 mph for trucks was in effect. This section of highway served an average traffic volume of 9,000 veh daily.

In the "before" study, the only marking was standard lane lines—15-ft white 4-in. reflectorized line on 40-ft centers. For the "after" study continuous edge lines were applied along the outside edge of the pavement and along the edge of the median.

Figure 7 shows results of the study dealing with free flowing passenger cars; it is interesting to note that completely different findings were observed for vehicles moving in the 12-ft lanes as compared to those in the 10-ft lanes.

With the 12-ft lanes, the continuous edge stripe moved vehicles in the outside or right hand lane toward the lane line; however, the continuous line along the median moved the vehicles away from the lane line and toward the median. This movement was quite significant at night, measuring almost a foot.

On the 10-ft lanes, the edge stripes along the outside edge of the pavement and along the median moved both the inside and outside lanes of night traffic toward the lane line; that is, the center of the travelway for that direction of travel; and although the movement in the median lane was almost a foot, it was just the reverse of that found on the 12-ft lanes.

Based on results of these studies, it has been recommended and the Louisiana Department of Highways has adopted a policy of edge striping all 24-ft, 2-lane highways, but will not mark 2-lane highways that are narrower than 24 ft.

Four-lane divided highways with 12-ft lanes are edge striped only under certain conditions of high traffic volumes, high speed in suburban or urban areas. Edge striping will be applied on all divided highways where stabilized shoulders with little or no color contrast are provided.

Effectiveness of Symbols for Lane Control Signals

T.W. FORBES and EDWARD GERVAIS, Highway Traffic Safety Center, Michigan State University; and TERRENCE ALLEN, Michigan State Highway Department

A need was indicated for improved signals for control of individual lanes on freeways and bridges in cases where accidents, maintenance, or unbalanced flow requires closing or reversing of a lane. Five criteria for more satisfactory signals than are now available for such use included (a) positive indication without false direction in malfunctioning, (b) distinctive appearance, (c) visibility and legibility, (d) ready understanding by most motorists, and (e) economic feasibility in the field. A series of different symbols was considered by the Michigan Highway Department from which the "red X" and "green-arrow-up" were thought to fulfill qualifications a, b, c, and e, and to be most promising for qualification d.

To test the readiness of understandability by the majority of motorists, research was carried out in two parts. Part 1 was an engineering psychology approach, which measured the types of meaning most commonly associated with six different possible symbols. To reverse or clear a lane, the desired motorist interpretation would not be "stop," but would be "do not drive in this lane" or "move into another lane." A total of 253 graduate and undergraduate students viewed signal presentations by means of colored slides showing the signals as if in place on the Mackinac Bridge and gave a total of about 4,200 reactions to the critical signal. Part 1 was a laboratory study and Part 2 a check of actual motorist reaction to the most effective signals when installed on the bridge.

Three experiments in Part 1 showed a consistent advantage for the "red X" as most often associated with the desired interpretation and least often with the undesired "stop." This advantage was most marked in the first experiment, where some indication of possible meanings of the signals was given. The standard red bullseyes, on the other hand, showed consistently a lesser proportion of the desired response and the largest proportion of "stop" responses. The latter would be undesirable where a lane is being reversed or cleared in order to get tow trucks or ambulances to a broken-down vehicle or to an accident. The laboratory study, therefore, confirmed the hypothesis that for most motorists the "red X" possessed advantageous natural associations with the desired meanings.

Part 2 consisted of checks of actual effects on bridge traffic of the "red X" and "green-arrow-up." A simple experimental setup employed a light wooden barrier and red flag in the right-hand lane beyond the signals. The red X was turned on for this lane during every alternate 5-min period. Comparisons of the point at which the weave was started showed that motorists were responding to the red X signal.

Thus, the "red X" and "green-arrow-up" not only showed the advantage of natural association with a desired meaning as shown in the laboratory, but also produced the desired motorist reaction in actual traffic.

● THE NEED for a satisfactory, clear and effective set of lane control signals has been pointed out by Gervais (1). On multi-lane facilities where it may be necessary or desirable to clear or reverse a lane to bring in a tow car or to accommodate unbalanced traffic flow in different directions the need is greatest. It was pointed out that the signals must satisfy five requirements, as described in Part 3.

To carry out these purposes, lane control signals were developed consisting of a red X and a green arrow pointing upward, together with speed indications. Prototypes were erected and viewed on full scale installation by the Michigan Highway Department on an experimental installation on the University campus.

It was hypothesized that they would satisfy requirement 4; that is that they would be readily understood by the motorist, even it a stranger to the signal system. However, it was desirable to evaluate experimentally this question. To do this a two-part study was undertaken. Part 1 describes a laboratory study of the psychological effectiveness of symbols in terms most naturally associated with the desired driver behavior. Part 2 reports a check under actual traffic conditions of the selected signals in use on the Mackinac Straits bridge described in Part 3.

PART 1—LABORATORY STUDY OF SYMBOL EFFECTIVENESS

Engineering Psychology Approach

Engineering psychology studies in related fields such as design of aviation instrument panel displays have shown experimentally that certain natural associations exist for the majority of people which tend to make some displays more effective than others. If certain types of symbols or controls lead the majority of a group of people toward more accurate or safer action, it is important that this be known and that designs be planned accordingly.

The standard red "stop" signal or "bullseye" when used for lane control may be ambiguous and may cause drivers to stop and clog a lane when it is necessary to clear the lane. To facilitate towing off a disabled vehicle or getting ambulances to an accident, stopping in the land under control would not be the desired driver behavior. The hypothesis was that certain other symbols might be more naturally associated with the "do not use this lane" idea when closing or reversing a lane on a bridge or freeway than the standard red bullseye.

The international symbol using a red arrow with a slash indicating a negative might be one such additional symbol. However, this is not yet familiar to most U.S. drivers and may have poorer legibility. A red X, on the other hand, was proposed as both more legible and probably indicating the general negative or "do not travel" association for the majority of people. In addition, red-arrows-up, red-arrows-down and a horizontal red bar and vertical green bar were suggested as worthy of try-out. Accordingly, the hypothesis that certain of these would show a more natural association to the desired prohibition of travel in a given lane was put to the test by psychological laboratory methods.

Experimental Method

Three different experiments were run using groups of subjects in undergraduate and graduate university classes. The procedure was similar for each of the three except that different amounts of information concerning the possible meaning of the signals were given. In this way not only a measure of ambiguity of the signals and of their association with the desired action but also a suggestion of the possible importance of a preceding informative sign were obtained. The procedure for the first group will be described and deviations from this procedure will be indicated for the second and third experiments.

A total of 253 different subjects in graduate and undergraduate classes gave a total of about 4,200 reactions to sets of colored slides depicting various combinations of the experimental signals on a sign truss on the Mackinac Bridge.[1]

[1] Prepared through the cooperation of the Michigan State University Audio-Visual Center from photographs of the bridge, a truss, and the experimental symbols.

First Experiment—Alternatives Indicated

This group was given an indication of possible meanings of the symbols in the form of six possible driver actions for each lane as follows: (a) stop in this lane; (b) go in this lane; (c) do not drive in lane; (d) slow in lane; (e) warning in lane; and (f) drive indicated speed in lane.

Procedure.— Two classes of students in a course in Industrial Psychology were used as subjects. One class had 58 students and the other 38. Slides using the different symbols were presented, and subjects recorded their interpretation of the meaning of the symbols for each lane. Instructions were given as follows:

> We are studying how drivers interpret signs and signals. You are to pretend you are driving on the Mackinac Bridge, and are to be confronted with various types of signs and signals. You are to write down your interpretation of what they mean.

At this point a color slide was shown on the screen, and instructions continued as follows:

> Here we have the Mackinac Bridge, and a truss with no signs or signals mounted on it. Because of traffic conditions to be expected on the bridge, and because traffic lanes may be blocked by accidents, traffic in either direction may be directed to any lane. The median divider in the center of the pavement is a low rounded curb which can be crossed easily.
>
> For each slide you are shown, you are to write on your answer sheet the letter corresponding to what you think the signals mean for each lane. Additional comments are to be written in the space provided.

Each student recorded an action for each lane on this answer sheet. These answers formed the data of the experiment.

Examples of the signals used in the experiment are shown in the Appendix. A different order of presentation of various signal combinations was used for the two groups of subjects. The more important combinations appeared twice in each case. For each group, the first set was composed of standard traffic signals with the right two lanes green and the left two red, to give a "mental" set like that of a driver who had passed through a town using standard traffic signals. The standard signals also occurred later with a different combination of lanes, so that results could be checked. The 5-lane combinations (green in the right hand lanes 1 and 2, 2 and 3, 1 only, 3 only, and 1, 2, and 3) were presented in random order.

Second Experiment—Completely Free Responses

In this experiment a second group of subjects was shown the colored slides presenting different combinations of signals on the Mackinac Bridge, as before, but without any multiple choice answers. It was desired to see whether these alternative responses acted as information concerning the meaning of the signals. If so, completely free responses on the part of the subjects might be expected to give somewhat different results.

Procedure. — The subjects were given blank sheets of paper on which they marked four columns corresponding to the four lanes. They were instructed to write for each slide the meaning of the signal over each lane by a word, phrase, or sentence indicating what they thought the signals indicated. Otherwise, the procedure was the same as for the previous experiment. Two groups totaling 48 subjects participated.

The written-in responses were classified into categories like the responses of the previous study. The number in each category gave a response score for each signal.

Third Experiment—Free Response on Action in Designated Lane

The responses of subjects in the second experiment were in some cases rather indefinite and difficult to classify and many omissions occurred. Therefore, a third group of subjects was shown the experimental slides and asked what they would do if they were driving in a certain lane and responding to the signals shown. This set of instructions was designed to put the subjects more into a driving frame of mind.

Procedure. — The third study differed from the previous ones in these ways: (1) pairs of slides presented (a) a certain combination of signals followed by (b) the same signals but with a changed indication in one lane; (2) the subjects were asked to state what they would do if they were driving in a certain lane; and (3) the designated (lane 1 or 2) was the one in which the signal changed in the second slide of each pair.

The series balanced the order of presentation of the different symbols and the use of lanes 1 and 2 as the designated lane. One group of 48 subjects was given one order of presentation and a second group of 61 (in two different classes) was given another order to achieve this balancing.

Analysis of Data

Statistical significance tests were made to determine whether differences in responses to the signals were sufficiently reliable to use as a basis for conclusions. The common chi-square tests were not applicable to these data, so the sign test (2) was used as follows: for every observer, the percent of "don't drive" responses given for the red X was compared to the percent for each other signal. Each observer for whom the red X percent was better was scored a plus in the sign test, and each observer for whom the other signal was better was scored a minus. The same procedure was repeated for the "stop" responses. From these, the probability of obtaining such differences by chance was computed.

Results

Results from the laboratory presentations are shown in Figures 1, 2 and 3. The red X was either highest in "don't drive in this lane" or lowest in "stop" responses or both except for Experiment 2. Here the pattern was somewhat similar but responses

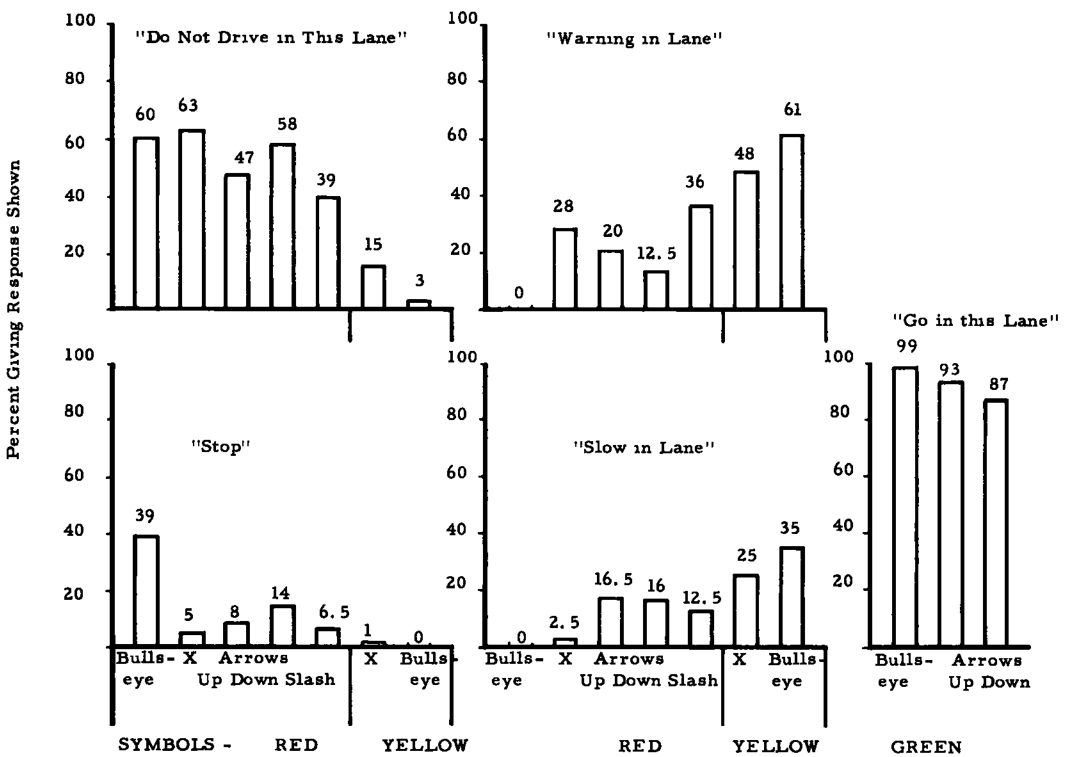


Figure 1. Interpretations of lane control symbols— laboratory experiment 1.

by the group were less consistent and complete as noted above. Note that "go" was the almost unanimous interpretation of all green symbols. Therefore, one must be chosen which differentiates between the "everybody go" and "this lane go" ideas.

The statistical analysis of results for Experiment 1 showed that in percent of "don't drive" responses, the red X was significantly better than the up-arrow, the slashed-arrow, and the amber signals. In the percent of "stop" responses, the red X was significantly better than the red bullseye and the down-arrow. So, in terms of either the "don't drive" responses or the "stop" responses, the red X was superior to each of the other signals tested.

From the second experiment it was thought that although results were not essentially different from results of the first experiment, however, differences between signals were not statistically reliable enough to permit definite conclusions.

From the third experiment results were again similar in direction to those of Experiment 1. The significance test, applied as previously, showed the red X significantly better than the red bullseye in terms of both "move over" and "stop" responses, and differences between the red X and the red bar were almost statistically significant. Other differences were not large enough to be statistically significant. The statistical test was applied to the results of all three experiments combined. For the percent of "don't drive" or "move over" responses, the red X was significantly better than the up-arrow, the slashed-arrow and the amber signals. In terms of "stop" responses, the red X was better than the red bullseye, the down-arrow, and the red bar. So, by one criterion or the other, the red X was significantly better than each of the other signals tested.

Discussion of Laboratory Results

The results of the three laboratory experiments together show that there was a consistent advantage accruing to the red X signal with the "slash arrow" and "arrow-up" coming next with the standard red bullseye ranking last in producing the desired reaction

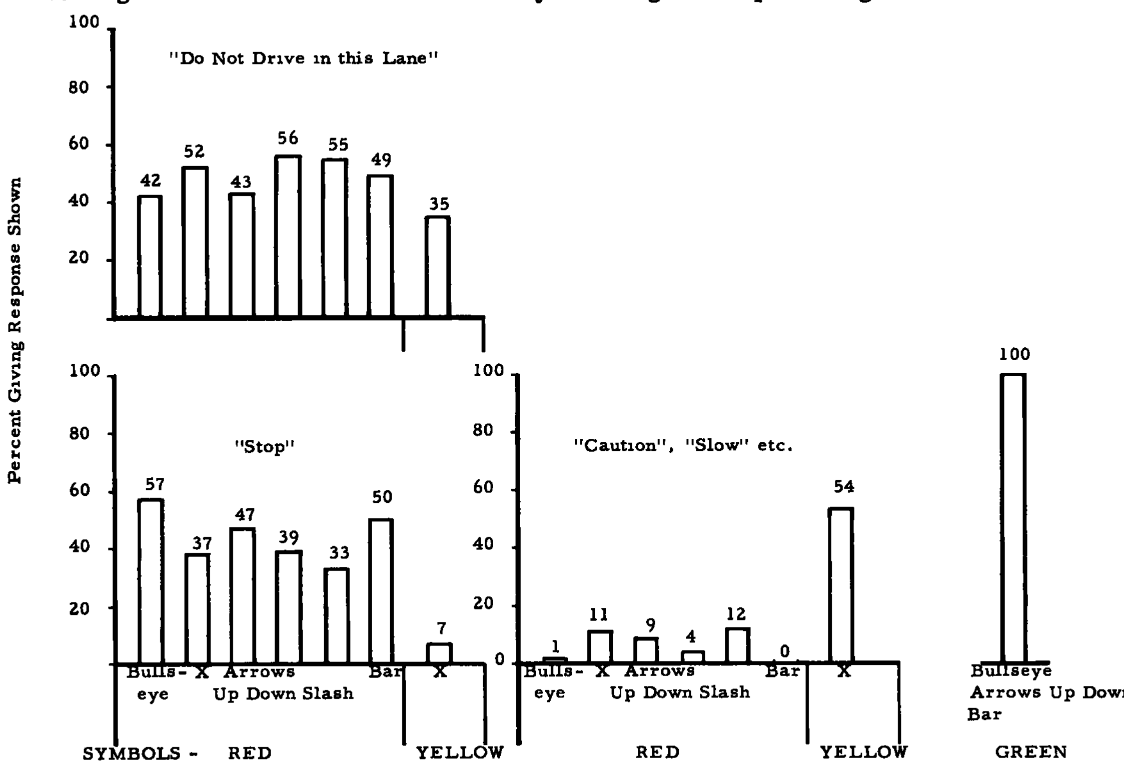


Figure 2. Interpretation of lane control symbols—laboratory experiment 2.

"do not drive in this lane" or "move into another lane." The reverse relationship was consistently shown for the undesired "stop" reaction.

The most clear-cut advantage was shown in the first experiment where some knowledge about the possible meaning of the different signal symbols was given by means of the alternate answers provided. The advantage was reduced or less consistent where no information at all about meaning of the signals was given (as in the second completely free answer case and in the third experiment).

Analysis of the comments and discussion with subjects revealed that they considered the slashed arrows very confusing. They considered the red arrows confusing also. To some subjects the red arrows downward clearly indicated "stop right here."

These results indicated (a) an advantage for the red X in association with the proper behavior when a lane is being closed or reversed and (b) the importance of giving the motorist minimum information on the purpose of signals (perhaps).

The differences ranged from 3 to 34 percent of responses. It is important that these

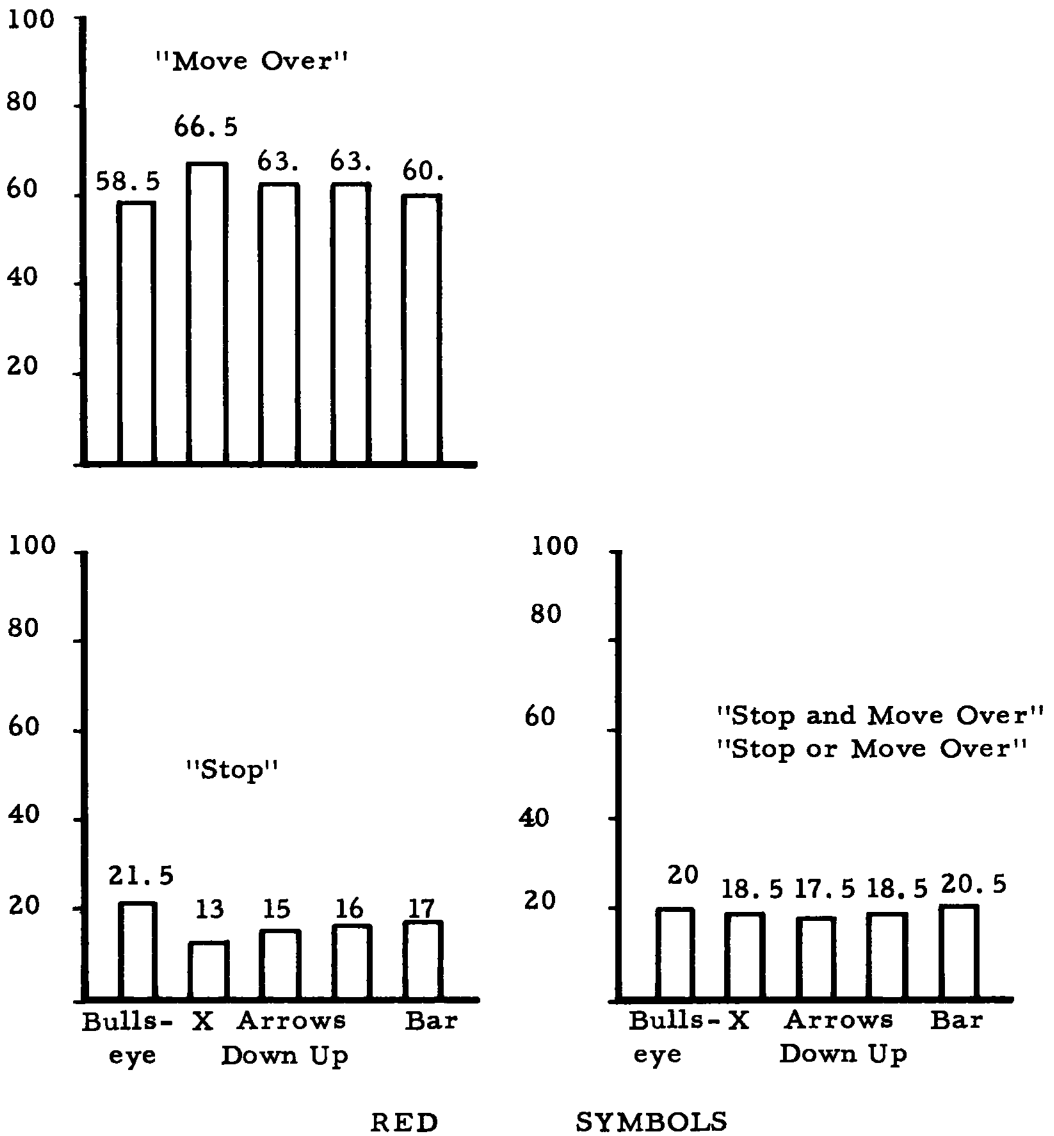


Figure 3. Interpretation of lane control symbols—laboratory experiment 3.

individuals were entirely unfamiliar with such signal symbols. General use of the red X can be expected to increase its advantage; that is, reduce the possible double meaning now given the red bullseye.

The "green-arrow-up" distinguishes between "everybody go" and "cars in this lane go" and also has certain possible consistency advantages if map symbol destination signs are used.

PART 2—EFFECTIVENESS OF LANE SIGNALS ON BRIDGE

Purpose

The purpose of this part of the study was to check in actual traffic the effectiveness of the lane signals indicated by the laboratory results. Individual lane control signals were installed on the Mackinac Bridge, as described in Part 3. Mounted over each lane were the red X shown to be advantageous in the laboratory study and the green-arrow-up.

It was not possible because of practical considerations to test all of the different symbols, but it was highly important to find out (a) to what extent drivers responded with the desired change of lane to the red X and (b) whether an advance information sign increased effectiveness.

Experimental Method. — A simple experimental situation was developed and records of driver-and-vehicle responses were made by visual observation and by photographic recording. A wooden barrier bearing a red flag and light enough to present little hazard if hit by a car was set up in the right hand, northbound lane 300 ft beyond the third signal bridge (located just north of the north bridge anchor). This set of signals was put on local control. During each alternate five min the red X was switched on over the right hand lane while the green arrow showed during intervening 5-min periods. Observers were stationed in a parked car on the concrete bridge anchor, a location where other cars were parked at the south end of the bridge in connection with painting operations at that end. The car and observers were relatively inconspicuous.

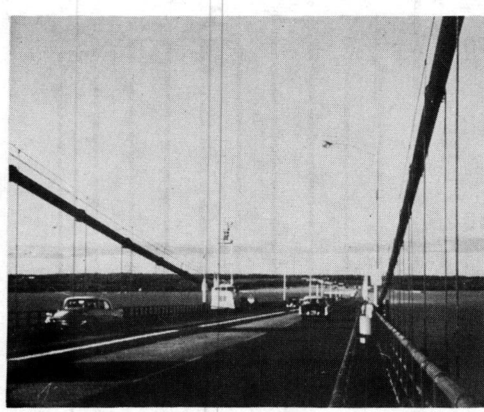


Figure 4. Tower truck under luminaire on southbound lane as seen by northbound drivers.

A tower truck was parked under a luminaire 750 ft south of the signal bridge and its tower extended as if for work on the luminaire. Time lapse photographs were made from a camera stationed on this tower. Figures 4 and 5 show the setup on the bridge.

Aluminum markers were placed at 150-ft intervals on the bridge center strip opposite each light standard and these were used as scale points to assist the accuracy of visual observations. Two observers made independent estimates of the point at which the left wheel of approaching vehicles crossed the lane dividing line as vehicles started to weave from the right lane to avoid the barricade. The barricade

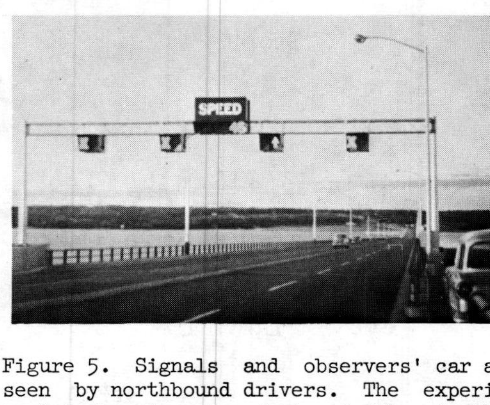


Figure 5. Signals and observers' car as seen by northbound drivers. The experimental barrier is just visible in the distance in right lane.

with its red flag was sufficiently visible for safety but was not conspicuous for any great distance.

Traffic on the bridge was traveling at from 15 to 40 mph, for the most part, even though the speed limit was set continuously at 45 mph on the signal bridge. This low speed resulted from the desire of drivers and passengers to view the scenery and is a consistent characteristic of the traffic on this bridge.

Experimental Design

The experimental design was based on the hypothesis that if the normal average turn-out point for the barrier (green-arrow showing) was beyond the signal bridge, any effect of the red X on driving behavior should produce a weave at an earlier point as the car approached. Second, any variations in traffic would be equalized by displaying the red X in alternate 5-min periods. Comparisons could then be made in the analysis between these periods and the intervening 5-min periods in which the green-arrow-up was showing.

Finally, it as planned to make observations on two weekends. The first would be without any explanatory sign on the bridge approach and the second would be after installation of an explanatory sign. Statistical comparisons of the relative effectiveness of the red X on these two weekends would then be expected to show whether or not the explanatory sign was of importance, as suggested by the laboratory results. Unfortunately, weather conditions made this last comparison somewhat less than conclusive.

Statistical Analysis

The visual estimates of starting point of each weave were recorded in feet from a zero point 300 ft south of the sign bridge as estimated from the 150-ft markers. These observations were analyzed to compare the average starting point for each half-hour interval of the respective time periods when the red X and the green-arrow-up were showing. In addition, the statistical significance of the differences between averages was tested to estimate the probability of their occurrence by chance.

Results

Analysis of the photographic records provided spot checks of the visual estimates. (The time lapse photographs were analyzed by the method reported by Forbes and Fairman (3) and modified by a further grid derivation for a 4-in. telephoto lens employed on the bridge.) Also, the visual estimates proved to be of high statistical reliability and are believed to be satisfactory for this study. The correlation between the individual estimates of the two observers on the same group of cars was 0.949. A reliability coefficient of this magnitude is ordinarily indicative of highly consistent and reliable estimates.

Analysis of the estimates and comparison between red X and green-arrow-up for each half-hour showed statistically reliable effects of the red X in the hypothesized direction. The observation averages are shown in Figure 6. The first set was made on October 18 and 19, and the second set on November 8 and 9. The figure shows that the weaves were longer for both the red X and the green-arrow-up on the second weekend. In both sets of observations the average starting point was earlier with the red X showing.

Differences between the red X and green arrow means for each of the half-hour periods were significant at the 0.01 level, with one exception for the first weekend. For the second weekend, the differences recorded between 8:30 and 10:30 were significant at $p = 0.05$ or less, but those for earlier and later half hours were not statisticaly significant. This was probably due to fewness of observations since the difference was statistically significant when all hours were combined.

Interpretation of Results

The observations from both weekends showed that in actual traffic the motorists responded to the red X signal by starting their weave definitely earlier. Even without the explanatory sign at the bridge approach on the first weekend, the red X signal was effective. It was even more effective on the second weekend.

The results for the second weekend showed a similar effect, but the starting point of the weave was earlier for both the red X and the green-arrow-up periods. It is probable that this was due to the weather on this weekend, which was overcast and rainy. A shift of operating behavior is characteristic of rainy and slippery weather and is well known in many other types of traffic observations and surveys. Also, early and late comparisons were not statistically reliable as noted above. Since both weather and the sign on the bridge approach may have played a part, it was impossible to separate out the possible effect of information on the sign explaining the red X symbol.

Figure 6 shows that on the first weekend the red X was much more effective in the earliest and latest half-hour periods. During the middle of the day it had less effect in producing an early weave. This was probably the effect of "sun phantom" in the bright sunshine on this first weekend. Reflection of the sun from the green plastic was especially noticeable, and at a distance might give drivers the impression that the green arrow was showing even when the red X was being displayed. This was because of the greater brightness of the green reflection and a triangular shape caused by the sun vizor shadow. Steps are being taken to remedy this condition.

The figure indicates less of this change in effectiveness in midday the second weekend, which is consistent with the fact that observations were taken under overcast and rainy conditions with very little bright sunshine to be reflected from the green plastic.

PART 3—MACKINAC BRIDGE SIGNALS

Lane control can serve a very important purpose in obtaining efficient and safe bridge or expressway operation and directional control of traffic lanes. If a lane of an expressway is closed to the movement of traffic due to an accident, maintenance, construction or traffic stagnation, it is important to give the driver immediate knowledge of the condition at a sufficient distance down the roadway so he can alter his travel path. In the case of reversing lanes of a multilane bridge or expressway, the need of a lane

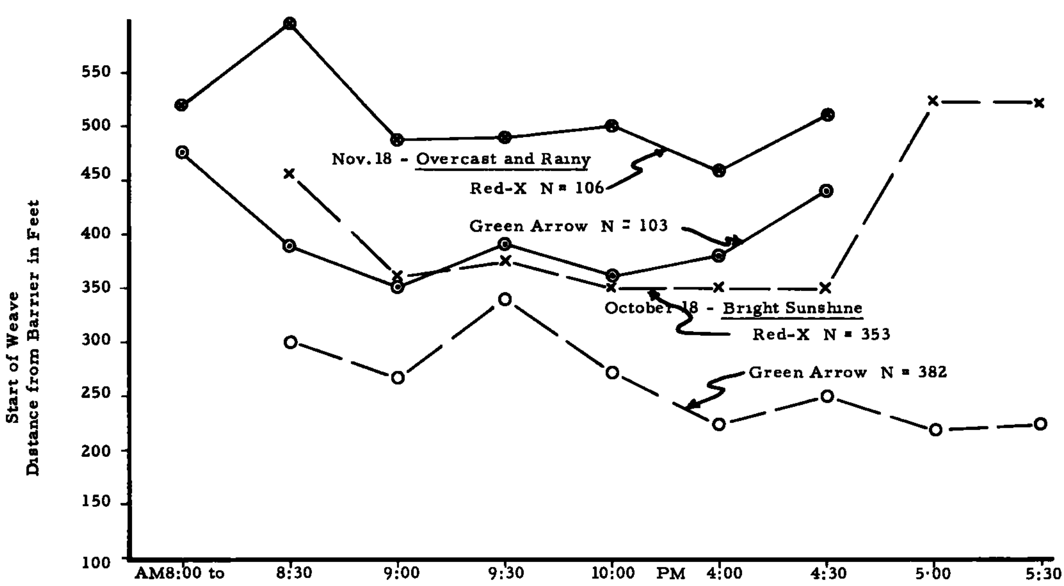


Figure 6. Effect of red X signal on start of weave. Averages for red X and green arrow displayed during alternate 5-min periods. Red X signal gave earlier weave. Less effective in midday probably due to green sun phantom on sunny week-end. All weaves longer on rainy week-end but red X still increased average distance.

control signal system to properly inform drivers of lane assignment to their direction of travel is quite obvious.

The problem of conveying information to the driver regarding lane and speed control is filled with complications and needs very careful study. Variable speed control is the simplest of the two and the biggest problem is the determination of the number of different speeds which may be needed for a certain roadway. The less speed values used, the simpler the construction of the speed sign and the control. There should be enough speed values to satisfy the number of conditions which require a definite speed band. In the initial tests three speeds were decided on which would be indicative of normal driving speed, heavy traffic and emergency speed. The problem of determining the need of different speeds for individual lanes was dismissed for the initial tests due to several considerations which will be discussed in a later publication.

The problem of conveying information to a driver on whether he may drive on a lane or keep off has complications when it is appreciated that each lane must give a message independent of that on an adjacent lane. This means there are as many messages as there are lanes for each control point. If a legend were used to convey this information, the simplest possible would be one which reads either "use lane" or "keep off lane." When it is considered that legend letter sizes on high-speed roadways should be approximately 16 in. vertical height with corresponding horizontal dimensions in order to be effective, the result would be a very sizeable sign. Since a variable-legend sign would by necessity be electrical, the problem is increased.

These considerations made it very desirable to consider signals which would have faces displaying symbols that would convey the proper lane information but be simple in construction. The determination of the proper lane symbol signals is set as one of the first objectives.

The signals which would be used for lane control would have to satisfy the following conditions:

1. The signals will be positive in their action and malfunctioning will not give false directions to the motorist.
2. The signals in relation to one another will be distinctive in their appearance.
3. They will be clearly visible and legible under the greatest range of conditions to the largest number of motorists.
4. Their message will be readily understood by the motorist—even if a stranger to the signal system.
5. The cost of the signal system will be economically feasible for adaptation in the field.

Under the first requirement, a two-way signal is practically dictated since one signal gives the motorist the permission to use a lane while the opposite signal denies him the privilege. This system is practically fool-proof since the only way a motorist could receive a false signal by mechanical failure would be for one signal to burn out while the counter signal was receiving a false electrical feed. Good circuit design would render such an occurrence practically nil.

The second condition will be best satisfied if the two signals have distinctive shape, color and mounting position. Since there is a restriction in the shape of the signal due to manufacturing difficulties, this shape can be acquired by a distinctive symbol legend on each signal which minimizes any possibility of confusion with one another. A further condition which must be satisfied in this respect is that the symbols chosen do not conflict with established symbols used for purposes other than lane control. In order to obtain distinctive contrast in the two signals by color, one must be chosen in the so-called "hot" color range which is the yellow to red and the other in the "cool" color range which is the violet to green. The "hot" color should be the prohibitory signal because of common usage and better bad weather visibility. Improper action on the driver's part while it is being displayed could lead him to an accident. Misunderstanding the signal permitting lane use would merely restrict his use of a lane. Mounting position can be utilized to distinguish the two signals by always mounting the prohibitory signal on the left side of the action signal.

The visibility of the signals to the motorist can best be acquired by their size, intensity of illumination and distinctiveness of symbol. The fact that a bigger signal has greater visibility is axiomatic and needs little discussion. The combination of intensity and distinctiveness of legend does have complications and must be carefully treated. The greatest difference of appearance in the two chosen symbols will be obtained if one signal has a distinctive vertical shape while the other is basically horizontal. The intensity of the light must be balanced so that adequate visibility is given the signal in the sunlight while detrimental visual spreading is not caused during darkness.

Part 2 of the study logically called for the field evaluation of the signals. The recently completed Mackinac Bridge offered a splendid opportunity to study the effectiveness of the signals under practical operating conditions. The Mackinac Bridge is a 4-lane bridge spanning an open water area approximately 5 mi in length. It consists of a combination of causeway, span truss sections and a huge suspension span in the center which is the longest ever constructed from anchorage to anchorage. There are four aluminum truss spans mounted over the roadway on the bridge. The maximum distance between spans is approximately 8,500 ft while the shortest distance is 3,600 ft. Availability of mounting positions for the signal spans made this variation in spacing necessary, but the roadways and type of bridge construction along these lengths were uniform, which gives some justification for the arrangement. For study purposes this gives a further advantage since it permits an evaluation of the maximum distance permissible between control points.

A span was placed at the Mackinac City side of the bridge in which the signals faced only the direction of traffic approaching the bridge from the south. Traffic leaving the bridge was departing from the control area and did not require signalization. Spans in which signals faced both directions of travel were placed at both of the concrete anchor piers of the suspension bridge and at the beginning of the trestle section of the bridge located 3,600 ft north of the north anchor pier. There is a distance of 3,600 ft between this latter signal span and the beginning of the bridge causeway to the north. It is not necessary to have a lane control signal span north of the causeway section since traffic moving south must enter the bridge through the toll gates. They can be moved into their

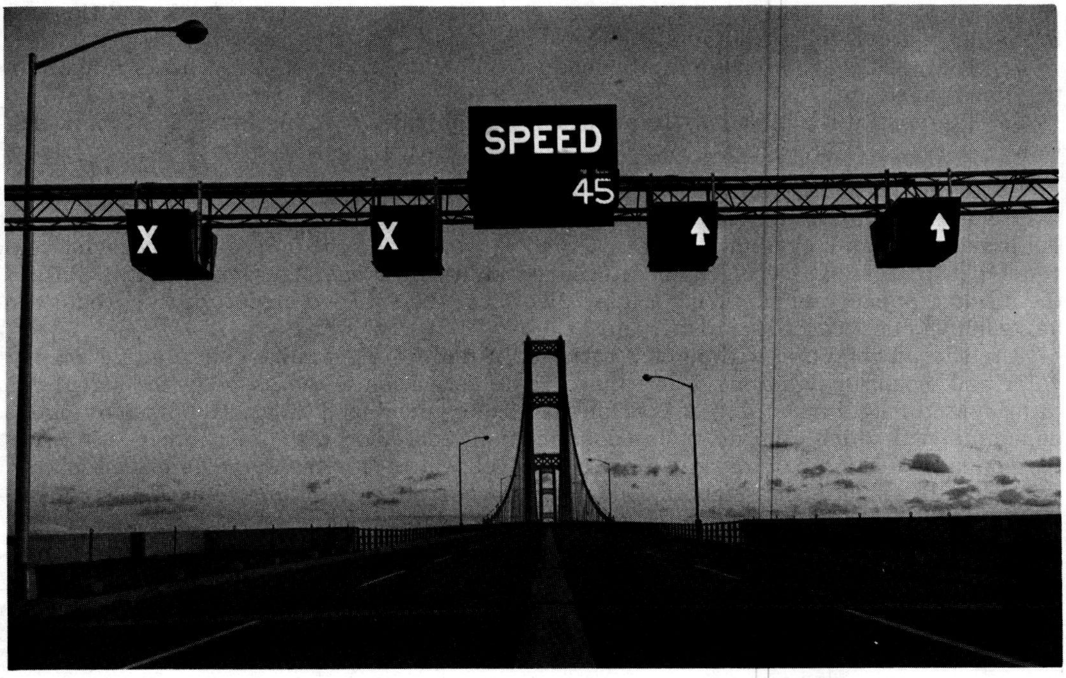


Figure 7. View of signals on Mackinac Bridge showing design of red X, green arrow and speed signals.

proper lanes by traffic cones set south of the toll gates. Speed control is still needed, however, so a variable speed control sign facing southbound traffic is erected at the roadside just south of the toll gate area.

The lane control signals employed at the bridge (Fig. 7) are blank-out signals with high-intensity neon tubing providing internal illumination. The use of neon tubing is required by the size of the signals (17 by 28 in.) and the need of high-intensity lighting for the purpose of providing an effective blank-out signal. One pair of signals is mounted over each lane of the roadway. This makes a total of eight lane signals facing each direction. Inasmuch as there are seven signalized directions, there is a total of 56 signals.

The speed control signals are mounted over the center of each lane control signal span. Three different speed messages were chosen for the Mackinac Bridge which are "15, 30, and 45." The 45 is the normal operating speed while the 30 is used for heavy traffic and semi-emergency conditions. The 15 is utilized for emergency conditions.

The 3-speed messages are grouped horizontally with the lowest speed to the right and the highest to the left. The word "speed" in 16-in. molded plastic letters internally illuminated is placed over the 3-speed messages. The sign reads either "Speed-45" or one of the other messages at any one time. This has already proven effective and there has been no misunderstanding as to the speed limit being in miles per hour. Since there are seven overhead speed sign units and one roadside installation, there are 24 different speed signals. Other details of the signals and their control will be described elsewhere.

Importance for Expressway as Well as Bridge Operation

The experiments reported showed that the red X symbol has certain inherent advantages for use in lane control signals. It was more frequently associated with the "do not use this lane" idea and less often associated with the "stop here" idea. The signals using the red X and the green-arrow-up were shown to be effective in actual traffic in influencing driver behavior.

The differences in driver behavior which were induced and the percentage of advantage in the natural association with the desired driver interpretation resulted when the red X was completely unfamiliar to the people responding. Greater familiarity from use of the red X symbol with a brief explanatory sign on more highway facilities should greatly increase the advantage gained by the use of this signal. Furthermore, restricting the use of the red bullseye to the "stop here" idea would make more definite and clear-cut the meanings intended for both signals. It is, therefore, suggested that use of the red X wherever the meaning "don't travel in this lane" is intended should be given further consideration and experimental usage.

The signal combination tested and in use on the Mackinac Bridge would also be of value in the operation of freeways. In fact, the original consideration of such signals included both freeway and bridge use wherever with multiple lanes, the possibility of reversing lanes, or the need for closing and clearing one lane was involved. The results reported here indicate the suitability of these signals for both types of lane control operation. The distance values furnish at least an initial guide for experimental location of sign and signal bridges on freeways.

An additional problem has also been considered for the freeway operation case which is not present in the bridge requirements. This is destination sign design based on the same engineering psychology approach which has been used for the lane signal design. Here certain other variables enter such as the need for identifying the interchange, directions of connecting routes and the like. The experimental approach developed in this study modified to include the additional variables can evaluate word and symbol combinations for best effectiveness in a somewhat similar way.

ACKNOWLEDGMENTS

Part 1, the Laboratory Study, was supported by Michigan State University. Part 2, was a joint research project by Michigan State University and the Michigan State Highway Department with the participation of the U.S. Bureau of Public Roads.

The observations of Part 2 were carried out with supervisory assistance of Frank DeRose.

It is a pleasure to acknowledge the fine cooperation and assistance of the personnel of the Mackinac Bridge Authority.

The modification was developed with the assistance of Frank DeRose and Norman Overbeek. The effective work of Robert Campbell, Charles Kiesler, Norman Overbeek and William Zilch, in carrying out the observations and analysis under supervision, is acknowledged with appreciation. The laboratory presentations and analysis were carried out under the supervision of Dr. Allen.

REFERENCES

1. Gervais, E., "An Expressway Lane Control System." Traffic Division, Michigan Highway Department (September 1957). Also report to Technical Committee 7-J, Institute of Traffic Engineers by Gervais and Forbes (November 1958).
2. Siegel, S., "Non-Parametric Statistics." McGraw-Hill (1956).
3. Forbes, T.W., and Fairman, G.W., "An Improved Method for Determining Vehicle Speeds from Spaced Serial Photos." Research Report, No. 9-2, Inst. of Transp. and Traf. Engr., University of California (1951).

Appendix

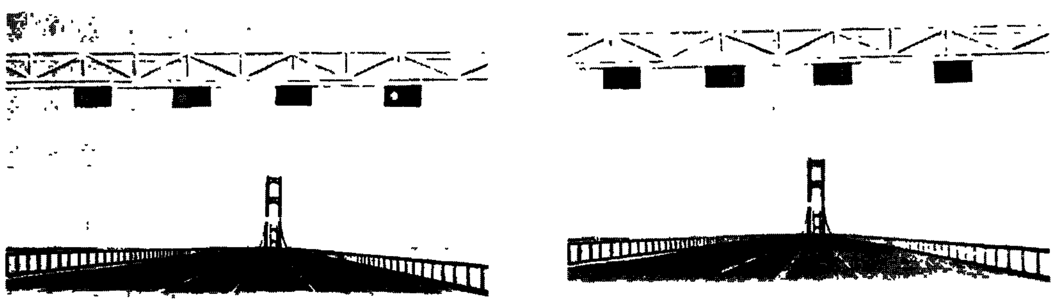


Figure 8. Examples of laboratory presentations from colored slides used in experiment. Pictorial representation of bridge and different symbols used to test associated meaning of symbols. See Figure 7 for actual signal designs. Left—bullseye signals—red over lanes 1, 3 and 4, green over lane 2. Right—red x over lanes 1 and 4, green arrow over lanes 2 and 3.

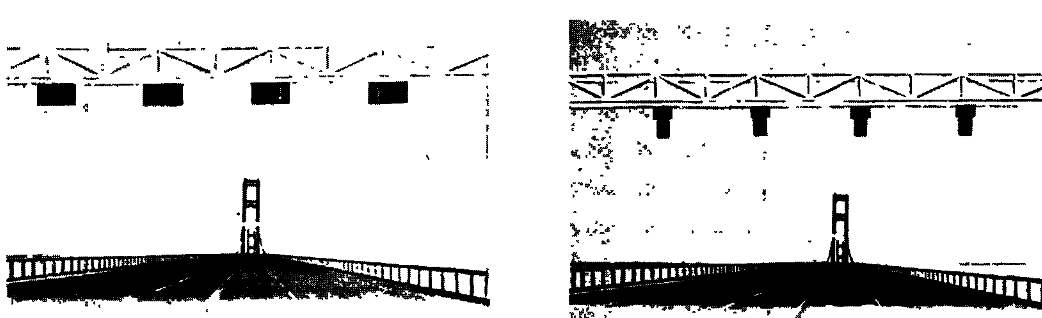


Figure 9. Other examples of laboratory presentations from colored slides used in experiment. Pictorial representation of bridge and different symbols used to test associated meaning of symbols. See Figure 7 for actual signal designs. Left—red slash-arrow and green arrow. Right—red bar over lanes 1, 3 and 4, green bar, lane 2.

TABLE 1

STATISTICAL SIGNIFICANCE LEVELS FOR INTERPRETATION OF LANE SIGNAL SYMBOLS—LABORATORY RESULTS—SIGN TEST ANALYSIS RED X VS OTHER SYMBOLS

	Experiment 1					
	"Don't Drive" Responses			"Stop" Responses		
Signal Symbols	N[1]	X[1]	α[2]	N	X	α
Red bullseye	71	35	0.500	57	50	< 0.001[3]
Red—arrow-up	71	49	0.001[3]	22	13	0.262
Red—arrow-down	66	35	0.356	28	20	0.019[3]
Slashed-arrow	62	51	<0.001	18	10	0.407
Amber-X	77	72	<0.001	10	1	0 999
Amber-bullseye	82	80	<0.001	11	1	0.999
	Experiment 2—Differences not Statistically Significant					
	Experiment 3					
	"Don't Drive" Responses			"Stop" Responses		
	N	X		N	X	
Red bullseye	45	31	0.009[3]	47	34	0.002[3]
Red—arrow-up	43	22	0.500	43	21	0.500
Red—arrow-down	41	22	0.378	43	24	0.271
Red-bar	41	26	0.059	44	28	0.049
	Combined Results Experiments 1, 2, 3					
	"Don't Drive" Responses			"Stop" Responses		
	N	X		N	X	
Red bullseye	124	71	0.064	114	91	<0.001[3]
Red—arrow-up	124	76	0.008[3]	75	41	0.245
Red—arrow-down	116	60	0.390	79	48	0.036
Red-bar	51	32	0.047	54	35	0.021[3]
Slashed-arrow	71	54	<0.001[3]	26	9	0.915

[1] N = number of subjects less ties: X = number of subjects for which Red X was better.
[2] α = one tailed significance level (probability of chance occurrence).
[3] Red X significantly better at 0.05 level or better, two-tailed test.

TABLE 2

EFFECT OF RED X SIGNAL ON START OF WEAVE-SUNSHINE-NO SIGN STATISTICAL SIGNIFICANCE OF DIFFERENCE OF MEAN STARTING POINTS VISUAL OBSERVATIONS OCTOBER 18 AND 19, 1958

	Zero Point 300 ft Ahead of Signals					
Time	$M_{\uparrow}$	M_X	Diff.	t	df	P
8:30- 9:00	295.0	101.6	193.4	4.10	59	< 0.01[1]
9:00- 9:30	328.1	205.0	123.1	4.31	120	< 0.01[1]
9:30-10:00	260.1	195.8	64.3	2.03	157	< 0.05[1]
10:00-10:30	326.1	210.5	115.6	4.17	59	<0.01[1]
4:00- 4:30	373.8	202.8	171.0	5 51	55	<0.01[1]
4:30- 5:00	357.0	202.4	154.6	5.74	133	<0.01[1]
5:00- 5:30	243.4	32.4	211.0	6.97	100	<0.01[1]
5:30- 6:00	378.8	33.0	345.8	6.92	36	<0.01[1]
Green arrow Sat. morn. and Sun. morn.	297.6	291.2	6.4	0.26	190	>0.05
Red X Sat. morn. and Sun. morn.	202.9	172.2	30.7	1.15	209	>0.05
X vs Arrow Both days all hours	310.	160.	150.	11.54	733	<0.01[1]

[1] = Significance at 0.05 level or better.

TABLE 3

EFFECT OF RED X SIGNAL ON START OF WEAVE-RAINY-SIGN ON BRIDGE APPROACH STATISTICAL SIGNIFICANCE OF DIFFERENCE OF MEAN STARTING POINTS VISUAL OBSERVATIONS NOVEMBER 8 AND 9, 1958

	Zero Point 300 ft Ahead of Signals					
Time	$M_{\uparrow}$	M_X	Diff.	t	df	P
8:00- 8:30	125.0	85.7	39.3	0.80	15	>0.05
8:30- 9:00	268.8	-23.3	292.1	5.97	29	< 0.01[1]
9:00- 9:30	240.0	118.0	122.0	2.72	43	<0.01[1]
9:30-10:00	209.2	112.5	96.7	2.09	56	<0.05[1]
10:00-10:30	243.8	100.0	143.8	3.32	57	<0.01[1]
4:00- 4:30	220.8	138.9	82.9	1.77	40	>0.05
4:30- 5:00	164.6	93.8	70.8	0.84	18	>0.05
Green arrow Sat. morn. and Sun. morn.	219.6	216.3	3.3	0.10	101	>0.05
Red X Sat. morn. and Sun. morn.	97.1	86.1	11.0	0.34	104	>0.05
X vs arrow Both days all hours	219.5	96.2	123.3	6.35	270	<0.001[1]

[1] Significance at 0.05 or better.

Some Principles of Freeway Directional Signing Based on Motorists' Experiences

DAVID W. SCHOPPERT, Automotive Safety Foundation,
KARL MOSKOWITZ, California Division of Highways; and
SLADE F. HULBERT and ALBERT BURG, Institute of Transportation and Traffic Engineering, University of California, Los Angeles

●FREEWAYS offer the highest level of highway service available to the nation's motorists. To be consistent with the high level of engineering design which is represented in these highways, a similarly high degree of planning and design is necessary in presenting information to the motorist. This requires thorough knowledge of the type of information that will best meet his needs. This research project had as its goal the development of such knowledge with the following specific objectives:

1. To determine the signing and marking aids sought by motorists in the use of freeways, particularly in urban areas.
2. To determine how well existing standards and practices provide these aids and what, if any, changes could reasonably be made in existing practices to provide the aids sought by motorists.

The need for a study of this kind has been emphasized by the completion of relatively long sections of freeway routes. Research on legibility, illumination, reflectorization, background and message color, and so on, has been reported from a number of sources; however, there has been little study in terms of the needs of motorists, the guides they seek, their interpretation of certain messages or even their relative success with the system of signing now in use. In other words, much attention has been devoted to how to say something, but very little research has been done on what to say.

The growing freeway systems, particularly in urban and metropolitan areas, have underscored the need for new knowledge on which to base signing practice. An extreme case, but an important one, is the Los Angeles metropolitan area. This vast urban complex composed of 85 incorporated cities and an even greater number of communities depends greatly on the freeway system for motor vehicle transportation.

A substantial proportion of freeway users are motorists who are unfamiliar with the area. Each year four million tourists visit Los Angeles, and 3,000 new families settle in the area each month. Even the six million permanent residents, in moving about the over 2,000 sq mi area serviced by the local freeway system, frequently find themselves off their beaten path and therefore with the same need for signing information as unfamiliar motorists. The problem is not trivial from the standpoint of either hazard or economy and convenience.

Directional signing is an essential part of each new freeway. Its adequacy is a major determinant of the adequacy of the freeway itself.

> Commuters who drive a highway or an urban artery every day may learn to drive it without the assistance of signs and markings and may even make good use of a poor design (from the operation point of view). However, a very small portion of drivers, unfamiliar with the situation, often misinterpret, misjudge or make unexpected moves which interfere with the efficiency and safety of traffic flow. Therefore, fundamental data on behavior of the driver who is unfamiliar with the situation are of greatest importance since he represents the critical case.
>
> In the same way and for the same reason, observations or reactions of the design or traffic engineer himself are usually not representative of those of the critically important strange driver (1).

The present study, a joint project of the California Division of Highways; the Automotive Safety Foundation; and the Institute of Transportation and Traffic Engineering of the University of California, was undertaken to determine the essential elements of adequate directional signing. Research started in July 1957 with pilot studies in San Luis Obispo and Sacramento. Data collection continued in Fresno and Los Angeles during late 1957 and early 1958.

Information was collected both by analyzing signing locations and by interviewing drivers about their experiences on the freeway system. Two interviewing techniques were used: roadside interviews which were necessarily brief, and off-the-road extended interviews which were more extensive. The roadside interviews were conducted at locations exemplifying certain signing conditions. Field trips were made to analyze the signing situations mentioned in the interviews. In all, three pilot surveys and two major studies were conducted, involving nearly 12,000 motorists and numerous signing locations. Sufficient biographical data were collected to assay the degree of representativeness of each sample of drivers, and the sample groups were found to be not radically different from the populations from which they were drawn.

The study findings clearly support the existence of certain basic principles of directional signing which, if followed, will help make sign messages of maximum value to motorists. In addition to general principles, it is possible to describe certain factors important to good sign practice in specific situations. The data obtained by the techniques used are definitely limited to a description of the experience of motorists under the existing system. It is not possible to learn directly from them the "best" or "desired" message for each specific location. Drivers can tell how they reacted to the existing system, but they cannot describe how they might react to a new situation which they never have experienced. Thus, in any but the most simple situations it is not possible to say how motorists will react to a new, specific message. This can only be determined by experimentation or experience.

CONCLUSIONS AND APPLICATIONS

General

Most of the signing deficiencies observed during the course of the study would be corrected if the signs in the field were changed to conform to the present design practice of the California Division of Highways (2, 3). The locations where signing is deficient, although they probably constitute a relatively small proportion of all the signing locations on the California highways, nevertheless demonstrate the need for a continuous program to bring existing signing into agreement with certain basic principles of directional signing.

It is evident that most motorists find their way with little inconvenience most of the time. Nevertheless, the fact that a sizeable proportion of motorists have difficulty at one time or another indicates that a higher level of service could be provided.

The studies yielded:

1. A description of the users and the way they use the system (including examples of successful and unsuccessful use).
2. Insight into the reasons for successful or unsuccessful use of the system.
3. A set of general principles for signing practice and a check list for applying them.
4. Suggestions for signing to freeways.

The users can be described best in terms of the type of trip they make. In general, there are three different types of trips:

1. General touring, such as long trips from one city or place to another. The interviews showed that motorists making this type of trip relied to a large extent on route numbers to identify their route, and place names to verify their decisions. For a long trip most of them selected route numbers to identify their path, and place names to identify control points, verify direction of travel, and position them on their path. The distances to places along the route were used for orientation and estimating times of arrival.
2. Metropolitan area movement, which usually involved use of a system of freeways.

Here, the same general concepts apply as were found for touring, except that paths were identified by freeway names rather than route numbers, and place names assumed less importance for either verification of route or identification of control points.

3. Urban driving, usually consisting of shorter trips within one city. The study showed that in purely urban travel, control points along the path were almost invariably identified by intersections, not by place name. Highways and streets were identified by name, seldom by route number.

Every route is used by a variety of motorists making different types of trips, seeking different cues, and having greatly varying familiarity with the route. Within practical limits, directional signing must provide for all of these motorists. Although this is not always possible, it must be recognized that these differences in familiarity and trip purpose, in addition to the differences in individual preferences and expectations, make it necessary to provide more than one type of information at most locations.

The importance of highway signing to a driver depends on his familiarity with the trip, not on his place of residence. Motorists making a trip for the first time are usually regarded, with good reason, as most in need of directional signing. Those repeating a trip they make only occasionally (having some familiarity) are less dependent on signing. Motorists repeating a trip they make regularly generally do not have trouble finding their way. Since all of these motorists are subjected to the same traffic conditions, yet vary greatly in their degree of success, the differences among them are worth studying.

ORIENTATION AND DECISION

"Repeat" motorists have learned from experience where to turn or change routes but, more importantly, when to expect to turn. They know where they are at all times and consequently are prepared to take the proper action. Under present conditions, unfamiliar motorists usually are advised of their whereabouts only by signing located at or shortly preceding the points where a decision is required. Thus they lack the basic ingredient to success, namely, orientation.[1] Lacking orientation, they are falsely prepared to act when there is no need and unprepared when there is such a need. They frequently arrive at control points sooner, or later, than they expect, and therefore make many of their decisions under pressure. Their natural desire to do well, and the realization of the possible undesirable consequences of errors, often adds to this pressure. This pressure, and possibly related driving errors, can best be reduced by providing unfamiliar motorists with cues which constantly tell them where they are, when to relax, and when to be alert. An oriented motorist is continually prepared for the next decision he must make. His "advance notice" is continuous.

Directional signing must be designed to let the motorist know where he is along his entire route, as well as at points of decision.

UNIFORMITY AND BASIC PRINCIPLES

A great number of situations can be covered by standard sets of signs. However, situations that confront motorists are of such complexity and variety that it is impractical to attempt to develop a standard set of signs that specify the exact message content, size, style, and location to be used in all situations. The motorist can be served better by signing designed to fit individual conditions at each location, and such signing should be governed by uniform application of a few basic principles rather than nonuniform use of a few standard signs.

The development and use of basic principles which allow sufficient latitude for the application of sound engineering judgment is preferable to rigid adherence to handbook rules. This concept may appear to some as inconsistent with the concept of uniformity.

---

[1] Orientation as used in this text implies knowledge of both the direction of travel and geographic location within the area.

Actually, the reverse is true. By definition, uniformity means treating similar situations similarly. Hence, different, novel and unique situations must be treated individually. The application of standard treatments to non-standard situations violates this definition of uniformity and the result is usually a less-than-adequate product. Thus, signing uniformity should be a uniformity of basic principles designed to provide motorists with information necessary to achieve two goals: to follow a pre-selected route with an absolute minimum of uncertainty; and to maintain orientation with respect to prominent points along that route.

BASIC PRINCIPLES

Following are six basic principles offered as a guide to be used in the design, installation and maintenance of directional signing. They were derived from an analysis of the experiences of the drivers interviewed in this study. The findings demonstrate the existence of the principles and the need for their application. In view of the size and representativeness of the sample, it is clear that these principles have general application to signing situations in other areas and on other types of highways.

1. Interpretation

All possible interpretations and misinterpretations must be considered in phrasing sign messages (words and symbols).

Messages must be complete and clearly stated. Cryptic messages, which are easily misinterpreted, must be avoided. The difference between two alternatives must be emphasized and, where possible, choices offered must be between things of the same kind, for example, two route numbers. Care must be exercised to avoid giving more information than can be read and comprehended in the time available.

There are two important general points to be remembered. The first is that a motorist's interpretation of a sign message is based not only on what the message says but also on what it does not say. The second point to be kept in mind is that literal interpretation results in the motorist doing exactly what the sign indicates exactly at the sign location. For example, drivers reported turning into alleys and driveways by mistake because the on-ramp sign appeared to direct them to do so.

2. Continuity

Each sign must be designed in context with those which precede it so that continuity is achieved through relatively long sections of highway.

The driver should be expected to evaluate not more than one new alternative at any advance sign. At the decision point he should never be given new information about either the through route or the turnoff. For example, sometimes several communities (or streets) are served by one turnoff. The advance sign will say "Orangevale Exit 2 Miles," the next sign, "Orangevale Exit 1 Mile," and finally, at the exit the sign says "Orangevale, Jamestown." The "Jamestown" on the third sign violates the principle of continuity and throws the motorist for a loss. He says to himself, "I wonder if this is the exit they have been referring to as the one for Orangevale, or is this just an alternate route to Orangevale?" For another example, the advance signs say "Castro Blvd 1 Mile," then "Castro Blvd ½ Mile," and finally, at the exit, "Castro Blvd." Then a few seconds later the driver comes upon a sign like the one shown in Figure 1. He is totally unprepared for this new information. He has 8 sec to digest it, visualize a map, mentally turn the map upside down if he is southbound, and finally take action.

3. Advance Notice

Signing must prepare the driver ahead of time for each decision he has to make.

The term "advance notice" is frequently used by traffic engineers and motorists, but is practically never analyzed. Essentially, when the motorist is surprised to

Figure 1.

find that he has to make a decision, he assumes that he was not told about it ahead of time. Very large signs, and signs well in advance of decision points, have been in place on California freeways for many years and still there are many surprised motorists. In almost all of the cases investigated during this study where the motorist said he did not have advance notice such signing did, in fact, exist. This signing, however, did not adequately prepare the driver for his decision.

The real point is that the motorist does not want to learn suddenly about the decision, regardless of how far ahead he is told or how vividly (that is, how big the letters are). He wants to know where he is located in relation to the point of decision throughout the trip. This is the only advantage that repeat motorists have over unfamiliar motorists.

A single advance sign can easily be missed, as can one sign of any kind, especially in dense traffic (cf. principle 5, below). Two advance signs can also be missed, although the probability is not as great. Of course, the size of the sign and the distance in advance have a bearing on this problem, but more "advance notice" cannot be achieved merely by increasing the size or distance or both.

4. Relatability

Sign messages should be in the same terms as information available to the driver from other sources, such as touring maps and addresses given in tourist information and advertising.

To insure this result, maps used by engineers as the basis for sign design should also include some which correspond in scale to touring maps. Outside of large metropolitan areas, signs should relate to a state road map. In a city represented on the map by a small circle or dot, signs preparing the driver for an important junction within the city should take into consideration that there will be many turnoffs from the main route to other streets, while the map may show only the one junction. In metropolitan areas, he must be expected to receive more detailed information than a state map can show.

5. Prominence

The size and position, as well as the number of times a sign or message is repeated, should be related to the competition from other demands on the driver's attention.

These demands can come from other visual aids, other signs or parts of the message, as well as the task of driving. One huge sign in a group or one huge word in a message tends to attract so much attention that the other signs or the rest of the message may not be comprehended. Thus, it often happens that the sign designer defeats his very purpose.

When the road is very wide, the traffic very dense, and there are numerous competing "spectacular" commercial signs or buildings (as is typical of a downtown urban freeway), the directional signs must be very large, well-illuminated and well-placed, even if this means costly overhead installations. There is no certainty that a motorist will, in the face of such competition (particularly dense traffic on curves) see a given sign no matter how large it is. Repetition suggests itself, not only for "advance notice," but for initial notice. On the other hand, the use of a gigantic sign in a sparsely settled rural area where there is no visual competition will serve to lessen the impact of using extra large signs where they are really necessary.

On city streets, where proper signing is just as important to the motorist as is signing on a freeway, the signs do not have to be as large, but the competition is much greater. Trees, poles, parked cars, signs on buildings, and traffic regulation signs all make it difficult to find the essential sign saying how to get to the freeway. Although standardization of color, shape, and style (uniformity) is one way to make the essential sign distinctive, it should not be relied on too heavily. Location, size, and contrast with surroundings are more important factors.

6. Unusual Maneuvers

Signing must be specially designed at points where the driver has to make a movement which is unexpected or unnatural.

The driver's natural inclination to turn a certain way frequently will lead him to do the wrong thing. Clarity in signing wins the driver's confidence and helps him avoid mistakes resulting from instinctive movements. Although cloverleaf interchanges are becoming more prevalent, the unfamiliar driver never knows whether or not the next interchange is a cloverleaf, and if it is, whether or not it has a collector-distributor road. Standard directional arrows used for near-side turnoffs cannot be used successfully to prepare a first-time user for the series of decisions he must make within a short time interval if his proper course of action is to take the far-side turnoff.

Where the driver is asked to do something contrary to his natural inclination or his learned reactions, the signing must be specifically designed to overcome his natural inclinations. An example of this was found in Fresno, where southbound motorists destined for downtown Fresno concluded that they should have turned off the freeway at the first exit. They did so because the freeway appeared to be turning away from the city and was obviously leading them toward sparsely populated country. Their apprehension led them to leave the freeway too soon, at a point where they would have difficulty finding downtown Fresno.

Additional instances were recorded in Los Angeles, particularly where circuitous unnatural routes had to be followed in order to reach a freeway entrance.

REPORTED TROUBLES ATTRIBUTABLE TO VIOLATION OF PRINCIPLES

The percentage of the reported troubles attributable to signing which resulted in whole or part from violation of each principle in sign messages was calculated (Table 1). Not included in this tabulation are those troubles encountered at locations (usually freeway entrances) where there were no directional signs for any of the movements possible at that location.

In addition to specific troubles encountered on a trip they described, many respondents mentioned other locations where signing was deficient. A separate analysis at these locations (approximately 400) also revealed violations of the general principles. The pattern of these violations was almost identical with that shown in Table 1.

At all locations where difficulties attributable to signing were reported, one or more of the six principles was violated. Furthermore, these findings did not indicate the existence of additional general principles. However, the preservation of good signing is dependent on continuous maintenance and periodic re-evaluation of physical installations, as well as periodic revision of standards. It is just as essential that the basic principles be applied throughout these efforts as in the initial development and application. In fact, many deficiencies observed during the study were the result of failure to observe the principles during the post-installation period. The tests described above should be applied to re-signing in the same way as they would be applied to new installations.

CHECK LIST

The following questions can be applied to a particular signing installation as a test to determine whether all of the principles are complied with.

1. Is there enough information to prevent a motorist from being led astray by assumptions based on information that is not given?

The sign shown in Figure 2 illustrates how this test can be applied to an actual case. This was the advance sign for the northbound approach to the southernmost exit from US 99 to Fresno, but was found deficient and has since been changed.

TABLE 1

PERCENTAGE DISTRIBUTION OF VIOLATIONS OF THE BASIC PRINCIPLES WHICH RESULTED IN RECORDED DIFFICULTIES ATTRIBUTABLE TO SIGNING[1]

Principle	Los Angeles	Fresno
Interpretation	34	42
Continuity	6	11
Advance Notice	24	12
Relatability	6	9
Prominence	17	7
Unusual Maneuvers	13	19
	100	100

[1] Troubles frequently resulted from violations of more than one principle, in those cases the appropriate principles were credited. Difficulties at locations where no signs were posted were excluded.

The absence of any information about prominent cities north of Fresno led many to mistakenly conclude that they should leave at this exit in preference to staying on the freeway. "Sacramento" has since been added to the message (on the left side of the sign).

2. If a motorist does exactly what the sign tells him to do, will he do the right thing, at the right time?

This question is particularly appropriate to advance signs which point to the right or left in advance of the actual point where the turn is to be made. Motorists reported turning into driveways, alleys and streets in obedience to such signs near freeway entrances, and similarly mistook bus turnouts and emergency bays for freeway exits.

3. Is the difference between alternatives clearly emphasized?

The application of this test is illustrated on two signs, Figures 2 and 3. In Figure 2 there is no obvious difference in physical appearance between the freeway continuation and the turnoff. This was corrected by adding the word "Freeway" above the route shield on the left panel. In Figure 3 the sign at the top gave complete information but had to be replaced with the one on the bottom because the difference between the routes was not made clear.

4. Is no more than one choice presented at the same time?

It is a recognized principle that human error increases rapidly with increased number of choices per unit time, and although there are situations where design conditions will make it necessary to present more than one choice at a time, careful signing should minimize the difficulties for the motorist. Figure 3 (bottom photo) shows such a situation. For the driver who relies on place names for his orientation, the choice is between San Francisco and San Jose. For the one who is following route numbers, there is US 101 and US 101 Bypass. The names present a clear choice, and the extra large "Bypass" makes the other choice possible to discern, although it would clearly be preferable to offer a choice between two different route numbers.

5. Is the message too cryptic because of the use of symbols or words which are either ambiguous or meaningless to a certain portion of the motoring public?

This test is a difficult one to apply but extremely important. The necessity for keeping messages short encourages brief messages, but brevity carried to an extreme results in misinterpretation. As an example, the use of "South" to mean "Southbound" was interpreted by some motorists as meaning the south half of a split route when displayed with a route shield. Also, symbols are sometimes difficult for a motorist to interpret. An excellent case in point was the route shield arrow which was tested in the Sacramento study. See Table 12 for results.

6. Is the motorist confronted with too much information to comprehend at one location, either by having too much on one sign or too many signs?

The presence of too many signs can divide the motorist's attention and thus be harmful, as many motorists pointed out in the interviews, even though not asked.

7. Are the various items of information emphasized (by their size, position, color, etc.) in accordance with their importance to the motorist?

Figure 3 shows a signing installation where this question must be answered negatively. The route shields in the upper sign are so small that they are over-shadowed by the place names on the same panel. These were subsequently enlarged in the revision (lower sign). On very large sign panels, route information may be dwarfed by long words. Signs are often replaced by larger ones as a routine maintenance act, and the new sign then dwarfs other signs in the vicinity, thereby throwing the installation out of balance. Size and importance appear to be related for most motorists; they tend to read the largest sign or the most prominent message first and to assume that it is the most important information.

8. Is the signing sufficiently prominent to overcome the competition for the motorists' attention from other sources?

These sources of competition include not only the driving task but prominent structures such as buildings and signs (both official and commercial). The driving task may be unusually demanding at certain locations as a result of such conditions as narrow lanes, sharp curvature, prolonged grades where speeds are high, merging and weaving movements and heavy traffic.

Figure 2.

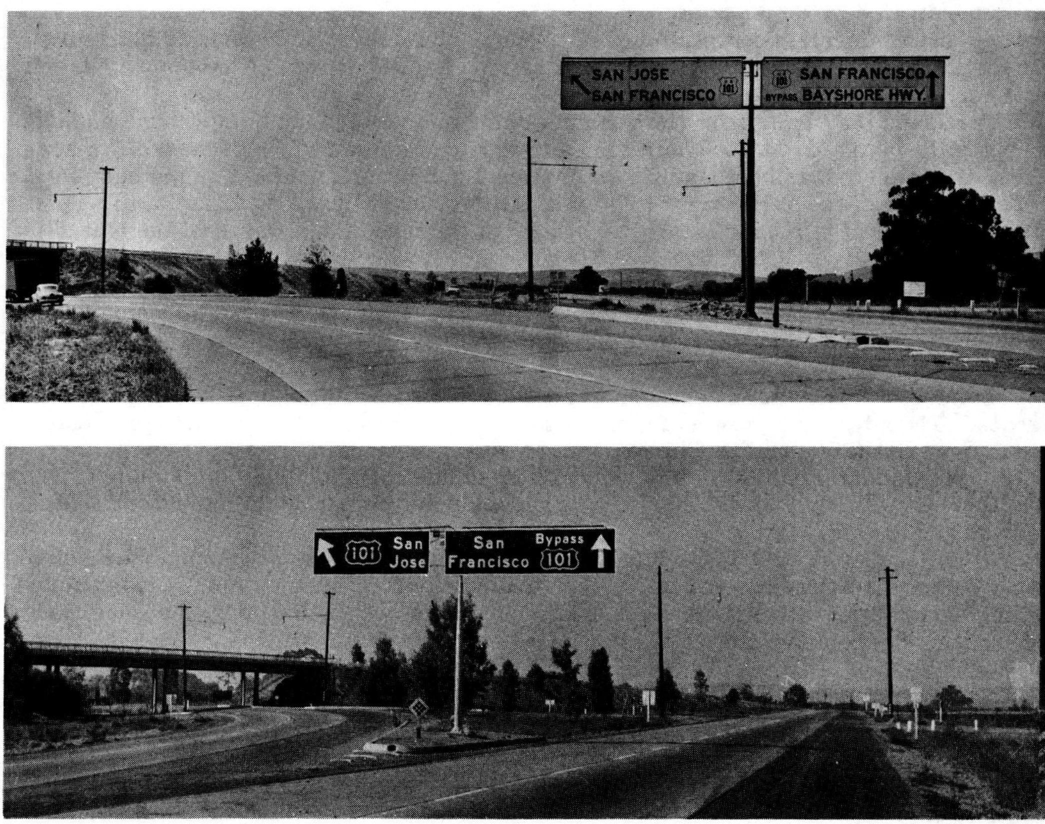


Figure 3. The sign in the upper photo gave complete information but had to be replaced with one (lower photo) which accentuates the differences between choices available to the driver.

The demands of the driving task naturally have first priority on a motorist's attention. A surprising variation in these demands exists on a freeway system. The items listed above are the most common sources of competition mentioned by the motorists interviewed.

9. Does the information presented at this sign installation preserve the continuity established by previous signing?

This test should be applied particularly to place names. The continuity between orientation and decision information should be carefully maintained. A major city (not a minor place name) should be used for through movement signing, not only because of its easier identification but also because it does not have to be changed as often over long sections of highway.

10. Does the information presented relate to that available to the motorist from other sources?

Although road maps are the major source of information for unfamiliar drivers, the natural expectations of motorists must be recognized. For example, motorists expect connections between numbered routes; if none are provided the best available routes should be signed. As another example, motorists expect connections between freeways and major thoroughfares; where these connections are not included in the design, signing should direct the motorist over the best available route. A good example of relatability is to be found in Figure 2. Madera is not a major city and many unfamiliar motorists simply do not know where it is or that it is on the way to Sacramento or San Francisco. Further examples were found in San Luis Obispo, where the junction of two numbered routes represented as a dot on the map was preceded by minor street connections. The fact that there are many exits, not just one as shown on the map, was not indicated by the signing.

11. Is the information repeated often enough and far enough in advance to assure that the motorist will see it and reach a decision well in advance of the point where he must act?

It was found that many motorists simply did not see or did not comprehend some of the signs they passed. Although this may have been the fault of the sign itself in some cases, in others it was obvious that the motorist had been distracted or too busy to read and comprehend the sign (if he saw it at all). In Fresno a situation of this sort was corrected when another large overhead sign was added in advance of the exit shown in Figure 2.

12. Has presentation of new information at the point of decision been avoided?

In the context intended here "new information" can take the form of an added message, or a repeated message stated in a different way, or even failure to repeat a part of a message.

Examples of failure to observe this criterion were found at ramps serving two streets. The advance sign would name both, but the gore sign would name only one. To the motorist this constituted essentially "new" information.

13. Is this sign installation the same as those used at other locations where similar conditions exist? By "conditions" is meant alignment, permissible movements, decisions required, etc., or:

14. Do the conditions at this location demand custom-designed signing because unusual, unnatural or unexpected maneuvers are required of the motorist? This special signing need not result in bizarre treatment; it can be accomplished by the imaginative application of accepted practices.

SIGNING TO FREEWAYS

Deficiencies in signing to freeways (as opposed to signing on or from freeways) were observed in both the Fresno and Los Angeles surveys and merit separate discussion here. The studies conclusively demonstrated the great need for improvement in this type of signing.

The different types of movements which motorists, especially first-time users, make in starting their freeway trips were important findings of both surveys.

Motorists who approach a freeway can be classified into three groups:

1. Those making an initial step in a freeway trip.
2. Those attempting to enter as part of a return trip.
3. Those attempting to re-enter to continue a trip after an intermediate stop.

First-time users in Group 1 approach the freeway without a particular reference point. Although they may have a good concept of the freeway location or even be able to see it, the street by which they approach may not be served by a freeway entrance accommodating the movement they want to make.

First-time users in Groups 2 and 3 have established a reference point between the freeway and the street system. This reference point is the freeway exit they used in the first part of the trip. Consequently they usually return to that exit to begin their search for an entrance. If ramps for all directional movements were available at all interchanges, the signing requirements would be rather simple. The fact is that they are not.

Signing to a freeway is required in a relatively narrow band along the facility. The band should extend to the nearest important intersection of major streets leading to the freeway and, in some cases, to the nearest major street paralleling the facility. In other cases, it should extend to a highway route replaced by the freeway. The width of the band should be determined by the street network in the freeway vicinity, and therefore cannot be pre-established.

Within this band, the signing must be custom-designed to the conditions. The sign locations and messages depend on both the movements required of the three groups of motorists and on the street and freeway layout. Following are several rules which elaborate on, but do not supersede the basic principles and which have been developed to govern the location and message content of this type of signing.

1. Access to the freeway can be provided only at widely spaced locations, in terms of city blocks. Many motorists approach the general vicinity of the freeway with only a vague knowledge of its specific location, and having arrived in the narrow band described above, they start groping for the nearest entrance in the proper direction. The signing to the entrances must therefore be continuous along this band, especially whereever the freeway can actually be seen from the intersecting surface streets.
2. The proper lane for each movement should be indicated in advance of the point where the turn must be made.
3. Advance notice signs should clearly state what the motorist must do to reach the entrance.
4. The signs at the entrance should be positioned uniformly with respect to the point where the turn from the street to the entrance must be made.

At locations where the motorist must use a street other than the one he is on to reach the freeway entrance, special emphasis is necessary to impart the information to him that the freeway can be reached only by turning onto that other street. At locations where the motorist must make a movement which appears illogical, the signing should be particularly clear and well-positioned, both in advance of the actual turning point and at the point where the turn is to be made.

STUDY PROCEDURES

General

At the outset it was evident that the freeway user would be the basic source of information. Furthermore, the demonstrated way to obtain this type of information is to have drivers describe their actual experience rather than give opinions. Interviews with a representative sample of travelers over freeways was the method selected. Therefore, first consideration of the study staff was developing suitable interview forms and techniques.

In the absence of previous published studies of this sort, it was necessary to conduct several pilot surveys to determine the feasibility of different methods for use in the more extended studies. Three pilot surveys were undertaken, one utilizing roadside interviews, another using extended interviews, and a third using questionnaires which motorists could complete and return. The first two techniques proved quite successful; the third showed promise but was not used in the major studies because of certain weaknesses in the method, and lack of time to pursue the subject matter with which it treated. After the pilot studies, the techniques were improved and used in two major studies which developed the bulk of the data. The several studies are identified by the names of the locations at which they were conducted. They were as follows:

Pilot Studies. — San Luis Obispo, California State Fair and West Sacramento.
Major Studies. — Fresno and Los Angeles.

The methodology of each study is discussed separately in the following sections.

SAN LUIS OBISPO STUDY

The first pilot study was undertaken in San Luis Obispo, a city of 14,000 population located on US 101 about 200 mi north of Los Angeles and 230 mi south of San Francisco. A popular stopping place for tourists on heavily traveled US 101 and State Sign Route 1, the city was ideal for a pilot study. A 4-lane freeway to carry US 101 traffic through the city had been open to traffic for about 2 yr. The location of the freeway and the city street network are shown in Figure 4.

Selection of the Interview Sample

Motorists were interviewed at the freeway ramps serving northbound traffic. An interviewing bay was marked out at each ramp, and one or two interviewers were stationed there, depending on the volume of traffic. Rather than attempt to secure a representative sample of the entire traffic stream, a sample was taken only of those drivers unfamiliar with the area. A flagman stopped all traffic and asked each driver: "Have you used this ramp before?" Those who answered "no" were directed to the interview bay; those who answered "yes" were by-passed. While the interviewers were occupied all traffic was by-passed without stopping.

Selection and Training of Interviewers

The interviewers were regular employees of the Division of Highways familiar with the San Luis Obispo area and freeway layout. They were experienced in the techniques of stopping and interviewing motorists. In this respect, the technique of this study followed the Division of Highways' established procedure of Origin-Destination studies.

During certain interviews it was necessary to skip selected questions in light of information obtained from the previous answers. The interviewers were given sufficient experience in the use of the questionnaire so that they could recognize these occasions and act accordingly. They were instructed to record any additional comments made by the motorist regardless of their own opinion of its relevance.

The Interview Form

Prior to the actual interviewing, several interview forms were tested at one interchange. Questions were added, deleted or revised accordingly. Finally, the forms shown in Figures 5 and 6 were adopted, interviewers were trained, and the study was conducted on all ramps serving northbound traffic. Interviewing time ranged from 2 to 4 min with the average about 2½ min. The individual questions are not discussed here in detail because the interview forms are believed to be self-explanatory.

CALIFORNIA STATE FAIR STUDY

The limited amount of information at San Luis Obispo using a roadside interview illustrated the limitations and values of that type of study. Interviews in more relaxed surroundings where time is not so pressing appeared desirable if more detailed information was to be collected. Several possibilities were considered. For example,

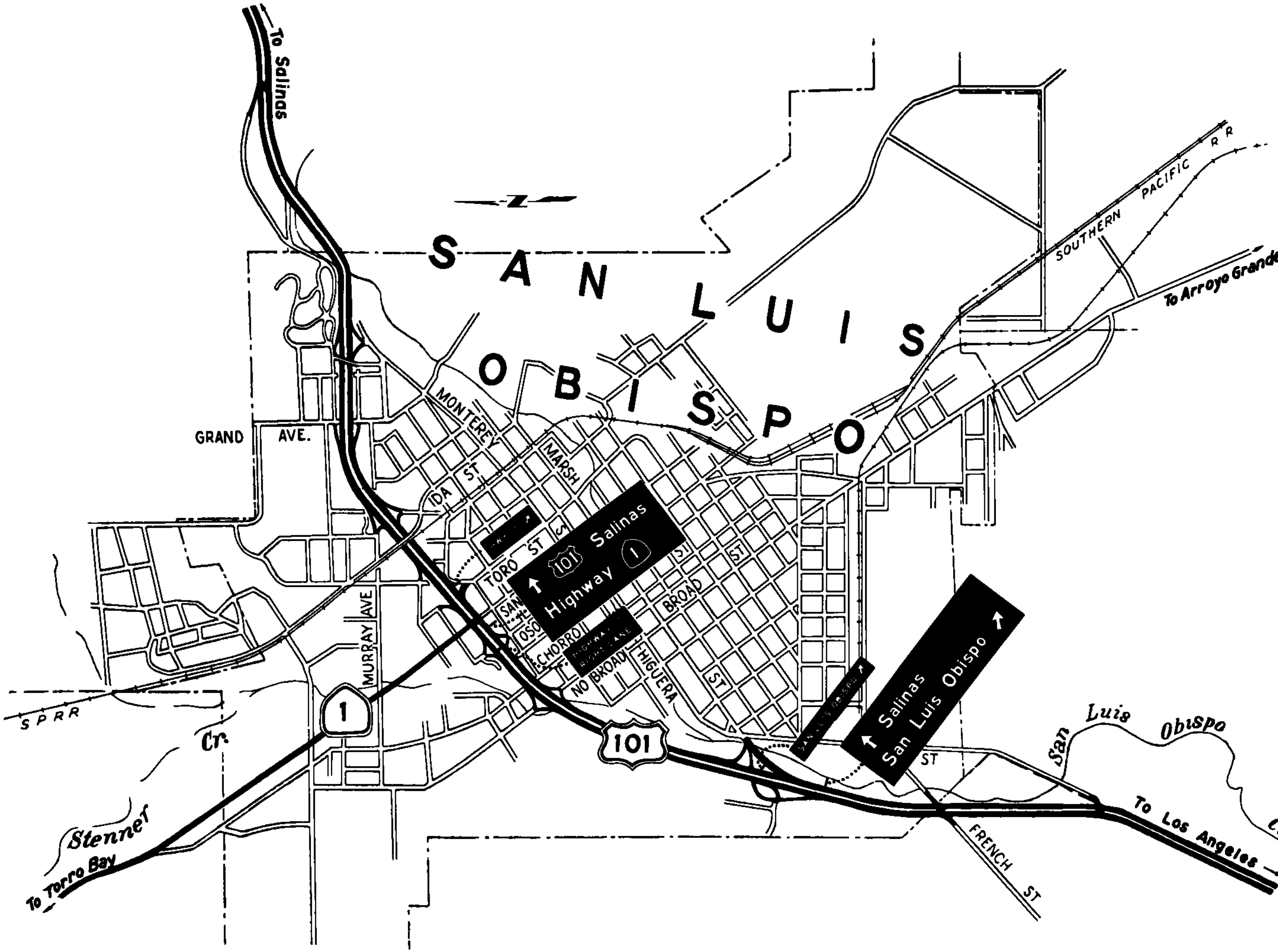


Figure 4. Map of San Luis Obispo.

ROADSIDE INTERVIEW FORM

Pilot Sign Study - San Luis Obispo

Date ________ ___, 1957 Hour beginning 1 2 3 4 5 6 7 8 9 10 11 12 ▱ AM ▱ PM
Month Day

"ON" Ramp number ____________

Where did you stop in San Luis Obispo? ____________

Why did you stop in S.L.O.?

1. Food
2. Lodging
3. Vehicle Service
4. Business
5. Visit
6. Other

How did you locate this particular entrance to the freeway?

____

1. Business route shields (old 101 etc.) 2. Asked directions

Where did your trip begin? ____________

Where will it end? ____________

Have you made use of a road map on this trip? ▱ Yes ▱ No

Did someone give you directions for this trip before you started ▱, or on the road ▱ No ▱

As you know highway signs show:

	strong	weak
route numbers	▱	▱
or city names	▱	▱

Which have you found most useful? ▱ both

Remarks: ____________

Do you have any suggestions for improving highway signing?

____

Asked directions Yes ▱ No ▱

Remarks: ____________ G F P

California ▱ Other ▱

Figure 5. San Luis Obispo interview form for "on" ramps.

ROADSIDE INTERVIEW FORM

Pilot Sign Study - San Luis Obispo

"OFF" Ramp ___________

Date__________ ____, 1957 (Month, Day)

Hour Beginning: 1 2 3 4 5 6 7 8 9 10 11 12 — AM ☐ PM ☐

Where did this trip begin?

Where will this trip end?

Where are you going in S.L.O.?

Why are you stopping in S.L.O.?

1. Food
2. Lodging
3. Vehicle Service
4. Business
5. Visit
6. Other
7. Unintentional
8. Sightseeing

Remarks:

There are several turnoffs from the freeway. What did you see that caused you to turn off here?

1. Route number
2. Street name
3. City name
4. Advertising sign
5. First turnoff
6. Missed last turnoff
7. Could see destination
8. Chance

Remarks:

Have you made use of a road map on this trip? Yes ☐ No ☐

Did someone give you directions before you started ☐, or on the road ☐ No ☐

As you know, highway signs show:

	Strong	Weak
route numbers	☐	☐
or names of cities	☐	☐
Which have you found most useful?	Both ☐	

Do you have any suggestions for improving highway signing?

Asked directions Yes ☐ No ☐

Remarks: ____________________ G F P

California ☐ Other ☐

Figure 6. San Luis Obispo interview form for "off" ramps.

travelers who had spent the day driving could be interviewed at motels or hotels where they were staying for the night.

First, it was necessary to determine whether such a technique would obtain the type of data desired and whether it would be possible to obtain a sufficient number of interviews to justify the cost.

Preliminary interviews in San Luis Obispo motels indicated that such a technique might have value and helped in the development of a questionnaire. The California

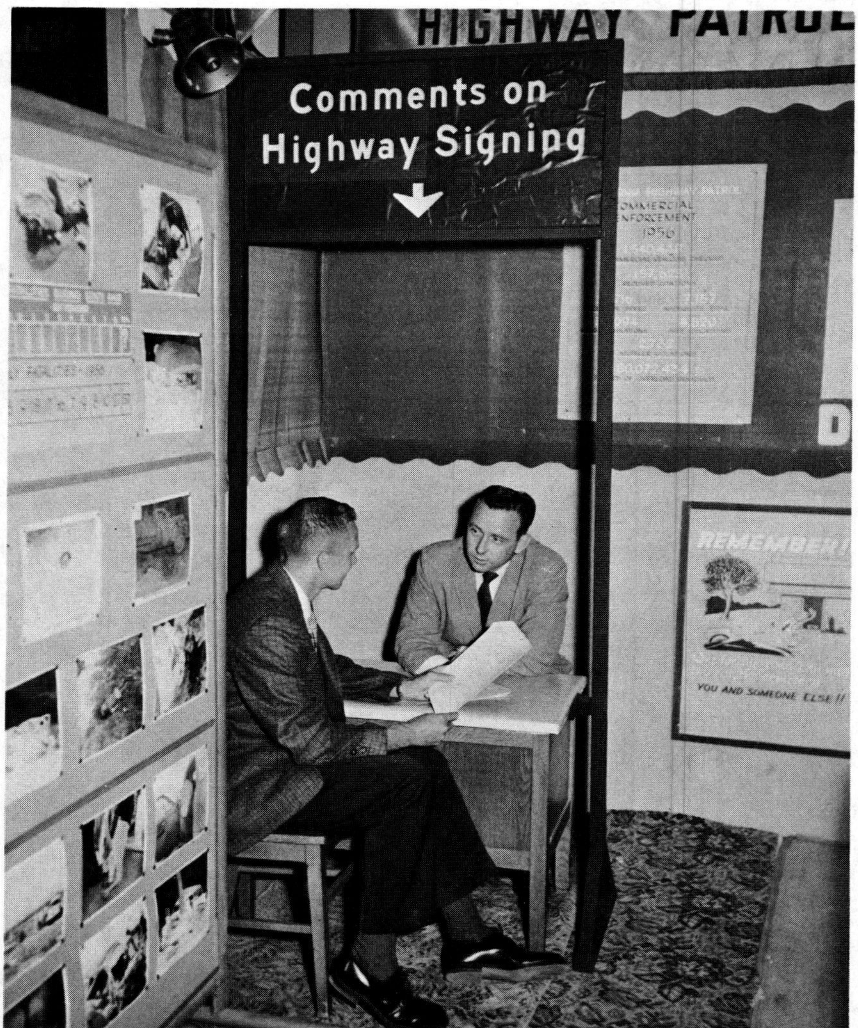


Figure 7.

State Fair presented an excellent opportunity to make a pilot study of this sort. Arrangements were made with the California Highway Patrol to conduct interviews in its booth (Fig. 7).

Selection of the Interview Sample

All of the interviewees were visitors to the California Highway Patrol Booth. The interviewer remained near the desk in the booth, and visitors who asked questions about the exhibits or expressed interest in the sign above the booth were asked if they would like to answer some questions about driving or highway signing. Those who volunteered were asked if they had made a trip during the preceding summer or if they had come to Sacramento from some distance. A trip was considered suitable if it had been about 100 mi or more in length, preferably requiring more than one day to complete. The principal criterion was that the trip was made during the recent past so that the person could remember it rather well. Highway Patrol officers on duty in the booth frequently referred people to the interviewer, so that the interviewer generally was not idle for more than a few minutes between interviews.

Selection and Training of Interviewers

The interviewers used for this study were drawn from the headquarters of the California Division of Highways. In total, five interviewers were used, all of whom were familiar with the questionnaire and the purpose of each of the questions. They were also thoroughly familiar with the State Highway System and signing practices in the state.

The Interview Form

Figure 8 shows the interview form used. Most of the questions are self-explanatory. The respondent was given a copy of the questionnaire and asked to read along with the interviewer. This reduced interviewing time considerably and helped the respondent understand the meaning of the questions.

After recording age, sex and annual travel, the specific trip to be discussed was established and the respondent was instructed to answer all succeeding questions in reference to that particular trip until otherwise instructed.

Questions 2, 15 and 16 were asked only if the trip ended in Sacramento. For Question 20, the respondent was shown 8- x 10-in. cards containing reproductions of the signs in question. In order to keep the time to a minimum, each respondent was shown only half the signs except that every respondent was shown the "Roadside Business," "Frontage Road" and "Yield" signs. The interviewer recorded the respondent's statement for these three signs but merely marked O.K. or N.G. for the others. After completion of this question, each respondent was told the true meaning of any sign he did not know.

Finally, the respondent was asked if he had any suggestions for improving signing. These suggestions, if any, were recorded, the respondent was thanked and the interview terminated.

WEST SACRAMENTO STUDY

The pilot study was made in an attempt to evaluate the efficacy of using a self-completion questionnaire to gather information from motorists about trip experiences. During December 1957, several hundred questionnaires of this type (shown in Fig. 9) were distributed to motels in West Sacramento. (The fact that this is a slack period for tourist travel was not of consequence, since the primary purpose of the study was to evaluate the technique, rather than the obtained data.) These motels, located along West Capitol Ave., provided an excellent locale for the study. Over 40 motels plus numerous cafes, bars and service stations are located in an area which was by-passed by a freeway route for US 40.

In each motel, the management agreed to place a questionnaire in each room and to replace completed questionnaires with new ones when the room was to be reoccupied. Cooperation was extended freely, an important consideration in the study. The manager

QUESTIONNAIRE FOR CALIFORNIA STATE FAIR STUDY

The purpose of the following questions is to determine how motorists, such as yourself, plan their trip, how they locate their destination, and the guides they use to orient themselves. Your answers to the questions will be of value to the California Division of Highways in determining the need for highway signing improvements.

* * *

Occupation______________________________

Age Group:

☐ 20 to 30

☐ 30 to 40

☐ 40 to 50

☐ over 50

Sex:

☐ Male

☐ Female

Estimated Annual Travel:

☐ less than 10,000

☐ 10,000 to 20,000

☐ 20,000 to 30,000

☐ over 30,000

- 2 -

1. Where did this trip begin and where did it end?

   Origin____________________________

   Destination____________________________

2. Where did you last stop?____________________________

   ____

3. Have you ever made this trip before?

   ☐ Yes

   ☐ No

   (If yes,) when was the last time?

   ____ months ago

   ____ years ago

The first few questions deal with the plans you made for the trip you are now making.

4. When people take off on a trip they usually have some information about such things as roads and places to stop. There are several ways to find out about these things beforehand. Did you use any of the following methods to get most of this information for this trip? (Check only one)

   ☐ a. I used the trip planning service of an auto club.

   ☐ b. I used trip planning services, (gasoline companies, hotels, etc.)

   ☐ c. I did my own planning.

   ☐ d. I talked it over with a friend.

   ☐ e. In other ways. ____________________

-3-

5. On long automobile trips requiring overnight stops travelers have to decide where they will pull up for the night. Some people make reservations for overnight accommodations before they start out on a trip. Others might have less definite plans. Which of the following describes how you chose overnight stopping places on this trip. (Check one)

   ☐ a. I made no definite plans and let the trip take care of itself.

   ☐ b. I knew about where I wanted to stop but I made no reservations.

   ☐ d. I made reservations for some of the stops on the trip.

   ☐ d. I made reservations for every or nearly every stop along the way.

6. Are you consulting a road map on this trip?

   ☐ Yes

   ☐ No

7. Did you have to ask directions along the way?

   ☐ No

   ☐ Incidental

   ☐ Necessary

Figure 8. California State Fair Study.

-4-

The next few questions deal with the signs you used on this trip.

8. Some motorists think of their route in terms of the cities and towns they will pass along the way and pace themselves by estimating when they will pass certain places. Did you set a definite time for reaching various places along the way?

☐ Yes

☐ No

(If yes,) do you remember making use of signs to pace yourself in this way?

☐ Yes

☐ No

(If yes,) what type of signs were they?

☐ a. Signs with city names.

☐ b. Signs with city names and distance

☐ c. Advertising signs.

☐ d. Other. ____________

9. Was your trip altered as a result of something you saw on a sign?

☐ Yes

☐ No

(If yes,) get details. ____________

____

-5-

10. While on this trip how did you know, or what guides did you use to confirm the fact that you were on the right road?

☐ a. Route numbers.

☐ b. Signs with city names.

☐ c. Signs with city names and distances.

☐ d. Advertising signs.

☐ e. Other. ____________

11. Can you recall any time when you were looking for a sign which you could not find?

☐ Yes

☐ No

(If yes,) what were the details? ____________

12. Can you recall any specific sign which was of value to you on this trip?

☐ Yes

☐ No

(If yes,) what type of sign was it and what were the conditions at the time? ____________

____

____

13. At any time while on this trip did you feel that you were on the wrong road?

☐ Yes

☐ No

-6-

(If yes,) were you actually on the wrong road?

☐ Yes

☐ No.

14. Describe as briefly as possible the conditions surrounding that occasion. ____________

____

____

____

____

____

The next few questions relate to the place you are staying while in (Sacramento).

15. To begin with, have you ever stayed there before?

☐ Yes

☐ No

16. Did you have to turn off the freeway to reach it?

☐ Yes

☐ No

(If yes,) how did you decide to use that particular turnoff? ____________

____

____

Figure 8 (continued)

-7-

On conventional highways it is a relatively simple matter to locate businesses which offer goods or services needed by motorists. For example, service stations, restaurants and hotels or motels. On freeways it is not so easy to locate such businesses because they are not always visible from the road.

17. On this trip have you had to turn off a freeway to locate a service station or restaurant?

☐ Yes

☐ No

18. If yes, how did you know that you would find the service or product you were seeking by turning off at that point?

☐ a. City size.

☐ b. Roadside business sign.

☐ c. Advertising sign.

☐ d. Other.________________

☐ e. Visible from highway.

19. If no, which of the following statements best describes the reason you did not have to turn off a freeway for such services?

☐ a. Did not travel far enough to need such services.

☐ b. Put off such services until a stop was made for some other purpose and obtained gas and/or food at that time.

-8-

☐ c. Was not on a freeway when the need arose.

☐ d. Other.________________

____

____

The next series of questions is designed to determine how well certain sign messages are understood by motorists.

20. Please state as briefly as possible what each message means to you. This should not be regarded as a test of your knowledge. It is more a test of the signs.

ROADSIDE BUSINESS________________

____

Have you ever turned off a highway where this sign was located to obtain

☐ a. Gas

☐ b. Food

☐ c. Lodging

☐ d. Never

FRONTAGE ROAD________________

____

YIELD THE RIGHT OF WAY________________

____

ISLANDS________________

____

-9-

U. S. Route number with,

BUSINESS________________

____

ALTERNATE________________

____

NORTH________________

____

SOUTH________________

____

EAST________________

____

WEST________________

____

BYPASS________________

____

ROUTE ARROWS________________

____

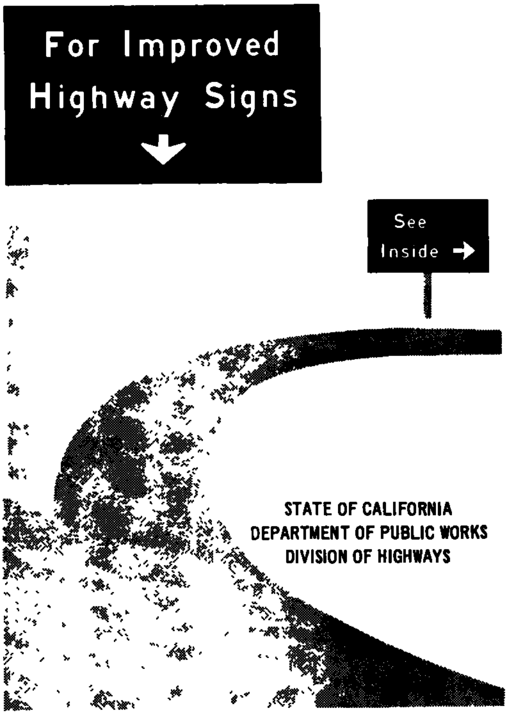
PED XING________________

____

MERGING TRAFFIC________________

____

Figure 8 (continued)



As a motorist you probably have some pretty strong opinions about highway signs

The California Division of Highways wants to provide signs which will suit your needs You, the motorist, are the best source of ideas for better ways to do the job

The attached questionnaire asks a series of questions only you can answer Take a few minutes to fill it out and give us your additional comments on the last page Constructive ideas for improvement based on your experience are what we're looking for

You'll find all the questions are related to the trip you are now making If you don't understand a question, answer it to the best of your ability

There isn't any prize for getting all the answers, but there may be a reward--better signs for your assistance on future trips

QUESTIONNAIRE FOR MOTEL-HOTEL GUESTS

1 I started today from ______________________
(city or place)

2 At any time while on this trip, have you had the feeling that you were on the wrong road?

☐ Yes About how many times? ______

☐ No (If you checked "no", please disregard the following and turn to question 3)

(If yes) were you actually on the wrong road?

☐ Yes About how many times? ______

☐ No

If you were on the wrong road, describe as best you can one of those occasions by filling in the blanks below

(a) At the time I got on the wrong road I was in or near ______________________
(city)

(1) On the road from ______________________
to ______________________

(2) On Route No ______________________

(3) On the ______________________ freeway

(4) Other ______________________
(If possible, give exact location)

(b) I wanted to

(1) Continue on the route I was on ☐

(2) Change to Route No ________ or to the road ________
to ______________________

(3) Find a street The name of the street was ______________________

(4) Find a place The name of the place was ______________________

(5) Get back on the highway after making a stop for meals, auto service, etc ☐

(6) Other ______________________

(c) I was watching for a sign which showed

☐ a route number

☐ a city name

☐ a place name

☐ a street name

☐ other (Please explain) ______________________

(d) Did you see a sign that misled you?

☐ Yes

☐ No

(If yes) what did it say? ______________________

(e) I found out that I was on the wrong road because ______________________

At that time I was at or near ______________________

Figure 9. Questionnaire left in motels for completion by motorist without interviewing.

(f) Do you think that better signs could have prevented this occurrence?

☐ Yes

☐ No

☐ Maybe

If you answered yes, what improvement to the signing would you recommend

☐ Larger signs at the turnoff

☐ More signs at the turnoff

☐ Larger signs in advance of the turnoff

☐ More signs in advance of the turnoff

☐ Any other (please explain) ____________

____

____

____

(g) If these questions have not covered the details of the time when you got on the wrong road, use this space to give any additional information

____

____

____

____

____

____

____

____

____

____

-3-

3 Can you recall any time when you were looking for a sign which you could not find? (Do not repeat a situation which was explained in answers to previous question)

☐ Yes

☐ No

(If yes) what were the details? ____________

____

____

____

____

____

4 How many times today did you stop?

At service stations ____________ times

For meals or snacks <u>Only</u> ____________ times

For all other purposes ____________ times

5 Have you ever made this trip before?

☐ Yes

☐ No

(If yes,) when was the last time?

______ months ago

______ year ago

6 Is this trip for business?

☐ Yes

☐ No

7 Did you consult a road map on this trip?

☐ Yes

☐ No

-4-

8 Have you had to ask directions along the way?

☐ Yes

☐ No

9 While on this trip how did you know (or what guides did you use to confirm the fact) that you were on the right road?

☐ a Route numbers

☐ b Signs with city names

☐ c Signs with city names & distances

☐ d Advertising signs

☐ e Other ____________

The next questions relate to the place you are staying

10 To begin with, what is the name of this motel? ____________

____

Have you ever stayed here before?

☐ Yes

☐ No

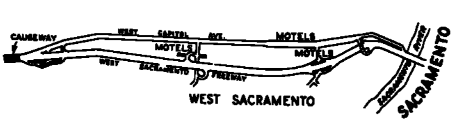
11 How did you decide which turn-off to use to get off the freeway? (Please mention any signs which figured in your decision and trace on the map below the route you took here)

____

____

____

____



-5-

SUGGESTIONS:

____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

Thank you very much! Now place the questionnaire in the envelope and leave it in the room It will be forwarded to the Division of Highways tomorrow morning

Figure 9 (continued)

agreed to refrain from discussions of the questionnaire with his guests, particularly as regards coaching in the completion of answers. All managers agreed to limit their discussions, if any, to a plea to answer the questions honestly and completely.

Discussion

Experience gained in West Sacramento indicated that the self-completed questionnaire may be useful in a study of this kind, but the questions must be carefully tested beforehand. Instructions for completing the questionnaire must be clear. The number of questions should be held to a minimum. In any event, it is likely that face-to-face interviews would be required to check the data obtained by self-interview.

Also, it would probably be more fruitful to rely on data obtained from a smaller number of conducted interviews than on a large number of self-completion interviews.

The questions used in the form apparently were generally satisfactory with the exception of Question 11. This type of question would have to be broken into several subquestions, with alternates dependent on the answers to each successive question (a concept difficult to explain in a questionnaire).

FRESNO STUDY

Exploratory use of the roadside interview technique in San Luis Obispo showed that information of considerable value could be so obtained. One outstanding advantage of this method is that the motorists can be questioned while actually engaged in finding their way to a destination. The city selected for further use of the roadside interview technique was Fresno. Located on US 99 in central California and with a population of 111,000, Fresno has many of the characteristics needed for such a study. It is a popular overnight stopping place and a major highway junction with considerable interchange traffic between US 99 and state routes 180 and 41. In addition, Fresno is a trading center for a large, populous area of the rich San Joaquin Valley. A new freeway route for US 99 through the city was completed and opened to traffic early in the fall of 1957. This 6-mi section of freeway was the site selected for study. Figure 10 shows the Fresno Freeway and the network of city streets in the Fresno area.

Selection of the Interview Sample

Interview stations were established at all of the 32 freeway ramps. Motorists using the ramps were stopped and interviewed in the same manner as in Origin-Destination studies. When all of the interviewers were occupied, traffic was by-passed. There was no systematic selection of motorists for interview; unlike the San Luis Obispo study, no attempt was made to select only those motorists who were unfamiliar with the area because it was desired that the sample be representative of all users.

Interviewing was conducted at each ramp for a full day (8:00 a.m. to 5:00 p.m.). The limited number of personnel available prevented interviewing at all 32 ramps simultaneously. Fourteen days were required to complete the interviewing.

Selection and Training of Interviewers

The interviewers were regular employees of the Division of Highways who were familiar with the Fresno area. They were given sufficient experience in the use of the questionnaire so that they could skip questions when necessary and recognize acceptable answers.

They were also instructed to record any additional comments made by the motorist regardless of their own opinion of its relevance. (For example, some motorists commented about a previous experience with the freeway ramps.)

The Interview Form

Separate questionnaires (shown in Figs. 11 and 12) were prepared for on-ramps and off-ramps. From 45 to 90 sec were required to conduct an interview.

At freeway exits, the driver was asked the origin of his trip and his ultimate destination. If this destination was not Fresno, the motorist was then asked his reason for leaving the freeway. Next, he was asked whether or not he had used that particular off-ramp before and what he had seen that had prompted him to use that particular exit. The intent of the last question was to determine the visual cues which motorists used in selecting an exit. The replies to this question were not always limited to visual cues, as such; for example, a motorist might say "I'm familiar with it" or, "I use it a lot." Experience in San Luis Obispo had shown that in such cases a better description was virtually impossible to obtain. Many motorists, when pressed for more details, would begin long, detailed descriptions of the history of their use of the ramp. Others were affronted, or simply did not comprehend the question. The final question ("What kind of sign were you looking for?") was only asked in those rare cases when the an swers to the preceding questions indicated that the motorist was seeking a particular message or sign which he had not specifically named.

At freeway entrances the driver was asked his trip origin, destination, and, if appropriate, the location of his stop in Fresno. If the motorist was making a trip which began and ended outside the Fresno area he was asked why he had left the freeway. Next, he was asked if he had used the entrance before and how he had located that

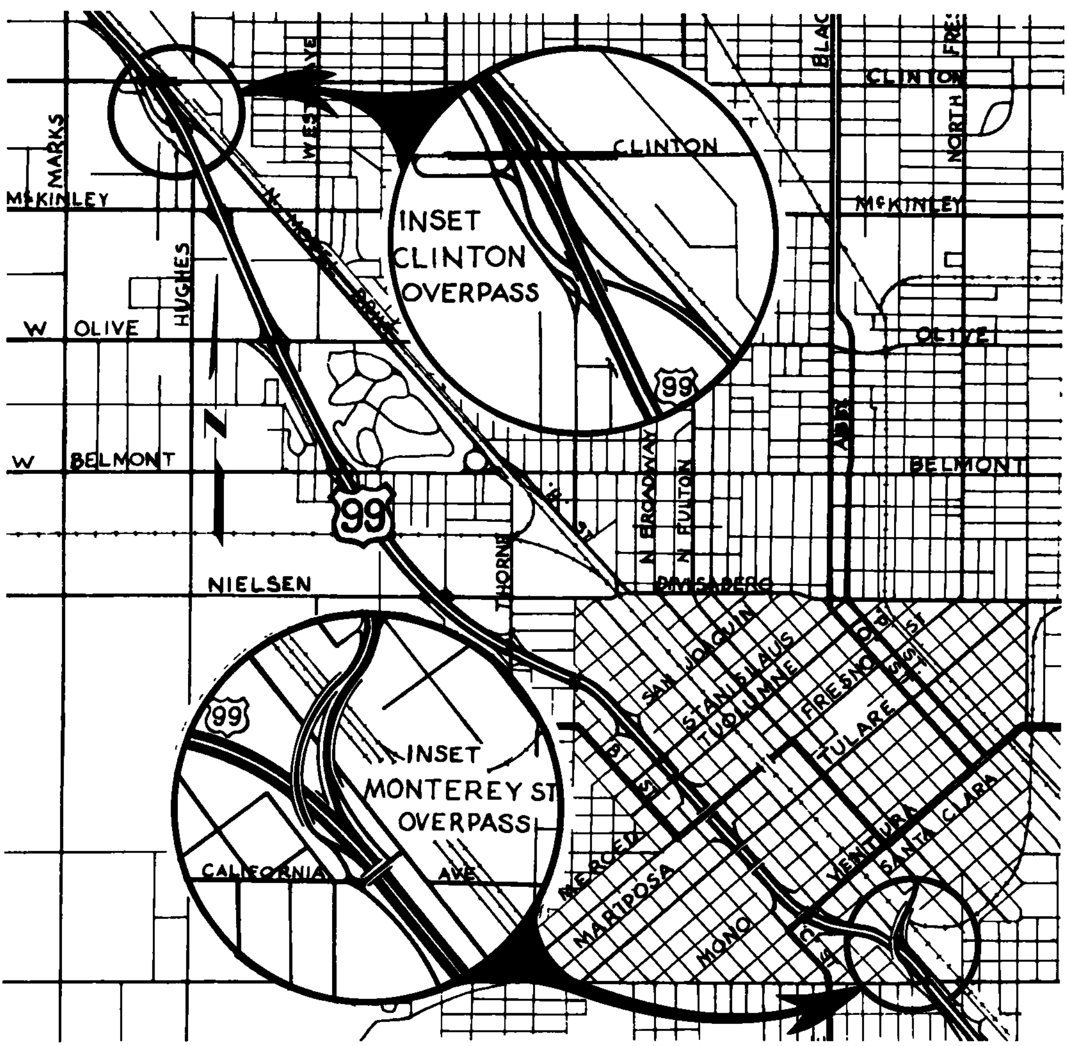


Figure 10. Map of Fresno with insets.

particular entrance. If he said he saw a sign pointing to it, he was asked what the sign said. Finally, if his responses indicated that he had been seeking a sign which he had been unable to locate he was asked what kind of a sign he had been looking for.

The data obtained in the interviews were coded and punched on cards for sorting and analysis. Each entrance and exit was given an identifying number so that the analysis could be made for individual locations. The origins and destinations were grouped into zones served by the ramps so that the number of trips from any zone via each ramp or the number of trips via each ramp to or from any zone could be determined. Volume counts were obtained at all ramps so that the portion of total users interviewed could be determined.

Finally, complete inventories of the directional signs in place on the freeway and city streets were made during the study so that the messages which motorists saw could be related to their answers to the several questions.

LOS ANGELES STUDY

Selection of the Interview Sample

The task of obtaining a large sample representative of the population using the Los Angeles freeway system presented several unique problems not encountered in the previous studies.

At Fresno, for example, the relatively low freeway traffic volume and the small number of ramps made it possible to conduct the interviews at the ramps thereby guaranteeing a reasonably representative sample. In contrast, however, the heavy volume

ROADSIDE INTERVIEW FORM-CALIFORNIA SIGN STUDY

Fresno
Off Ramp No_____ Hour Beginning 1 2 3 4 5 6 7 8 9 10 11 12
AM ☐ PM ☐

1. Registration: California ☐ Other ☐

Trip Origin	Trip Destination	Fresno Destination

2. Why are you leaving the freeway? (Destination not Fresno.)
Food ☐ Vehicle Service ☐ Sightseeing ☐ Other_______
Lodging ☐ Business ☐ Unintentional ☐ _______

3. Have you used this turnoff before? Yes ☐ No ☐

4. There are several turnoffs on this freeway. What did you see that caused you to turn off here?
Route No. ☐ City Name ☐ Business Route Sign ☐
Street Name ☐ Familiar ☐ Roadside Business Sign ☐
Other(describe)_______________

5. What kind of sign were you looking for?_______________

1. Registration: California ☐ Other ☐

Trip Origin	Trip Destination	Fresno Destination

2. Why are you leaving the freeway? (Destination not Fresno.)
Food ☐ Vehicle Service ☐ Sightseeing ☐ Other_______
Lodging ☐ Business ☐ Unintentional ☐ _______

3. Have you used this turnoff before? Yes ☐ No ☐

4. There are several turnoffs on this freeway. What did you see that caused you to turn off here?
Route No. ☐ City Name ☐ Business Route Sign ☐
Street Name ☐ Familiar ☐ Roadside Business Sign ☐
Other (describe)_______________

5. What kind of a sign were you looking for?_______________

Figure 11. Fresno off-ramp interview form.

of traffic and the complexity of the freeway network prohibited a similar approach in Los Angeles.

In addition, it was desired that the interview form used in Los Angeles be considerably longer and more detailed than that used at Fresno. As a consequence, far too much time would be required to permit its use as a "roadside" questionnaire.

After careful consideration it was decided to sample the licensed drivers in the Los Angeles area, and to base conclusions on the data obtained from that segment of the sample which uses the freeways. Toward this end, the California Department of Motor Vehicles was contacted and arrangements were made to conduct interviews at each of 15 DMV branch offices situated throughout the Los Angeles area (Fig. 13).

The interview procedure involved obtaining a random selection of driver license applicants. A clerk at the license application window referred respondents to the interviewer. After concluding each interview, the interviewer would signal the clerk that he was ready for another interviewee. The clerk, thereupon, would ask whomever was next in line if he wished to be interviewed concerning freeway driving. Those who expressed a willingness to do so were escorted by the interviewer to a table set up in the lobby as far removed from the flow of foot-traffic and curious passers-by as possible.

The only applicants systematically excluded from the sample were those obtaining a driver license for the first time, and those who could not speak English.

At the conclusion of the interview the interviewee was given an excellent map of the Los Angeles freeway network provided for this purpose by the Automobile Club of Southern California. These maps were very well received by the respondents.

Selection and Training of the Interviewers

A total of seven individuals (male) were chosen to be interviewers, all of whom were

ROADSIDE INTERVIEW FORM-CALIFORNIA SIGN STUDY

Fresno
On Ramp No._____ Hour Beginning 1 2 3 4 5 6 7 8 9 10 11 12
AM ☐ PM ☐

1. Registration· California ☐ Other ☐

Trip Origin	Origin or Stop in Fresno	Trip Destination

2. If a through trip, what was purpose of leaving freeway.
   Food ☐ Vehicle Service ☐ Sightseeing ☐ Other______
   Lodging ☐ Business ☐ Unintentional ☐
3. Have you used this entrance before? Yes ☐ No ☐
4. How did you locate this entrance?
   Followed old highway ☐ Familiar ☐ What did sign say
   Asked Directions ☐ Hunted for it. ☐
   Could see freeway ☐ Saw sign ☐
5. What kind of a sign were you looking for'______

1. Registration: California ☐ Other ☐

Trip Origin	Origin or Stop in Fresno	Trip Destination

2. If a through trip, what was purpose of leaving freeway?
   Food ☐ Vehicle Service ☐ Sightseeing ☐ Other______
   Lodging ☐ Business ☐ Unintentional ☐
3. Have you used this entrance before? Yes ☐ No ☐
4. How did you locate this entrance?
   Followed old highway ☐ Familiar ☐ What did sign say
   Asked Directions ☐ Hunted for it ☐
   Could see freeway ☐ Saw sign ☐
5. What kind of a sign were you looking for?______

Figure 12. Fresno on-ramp interview form.

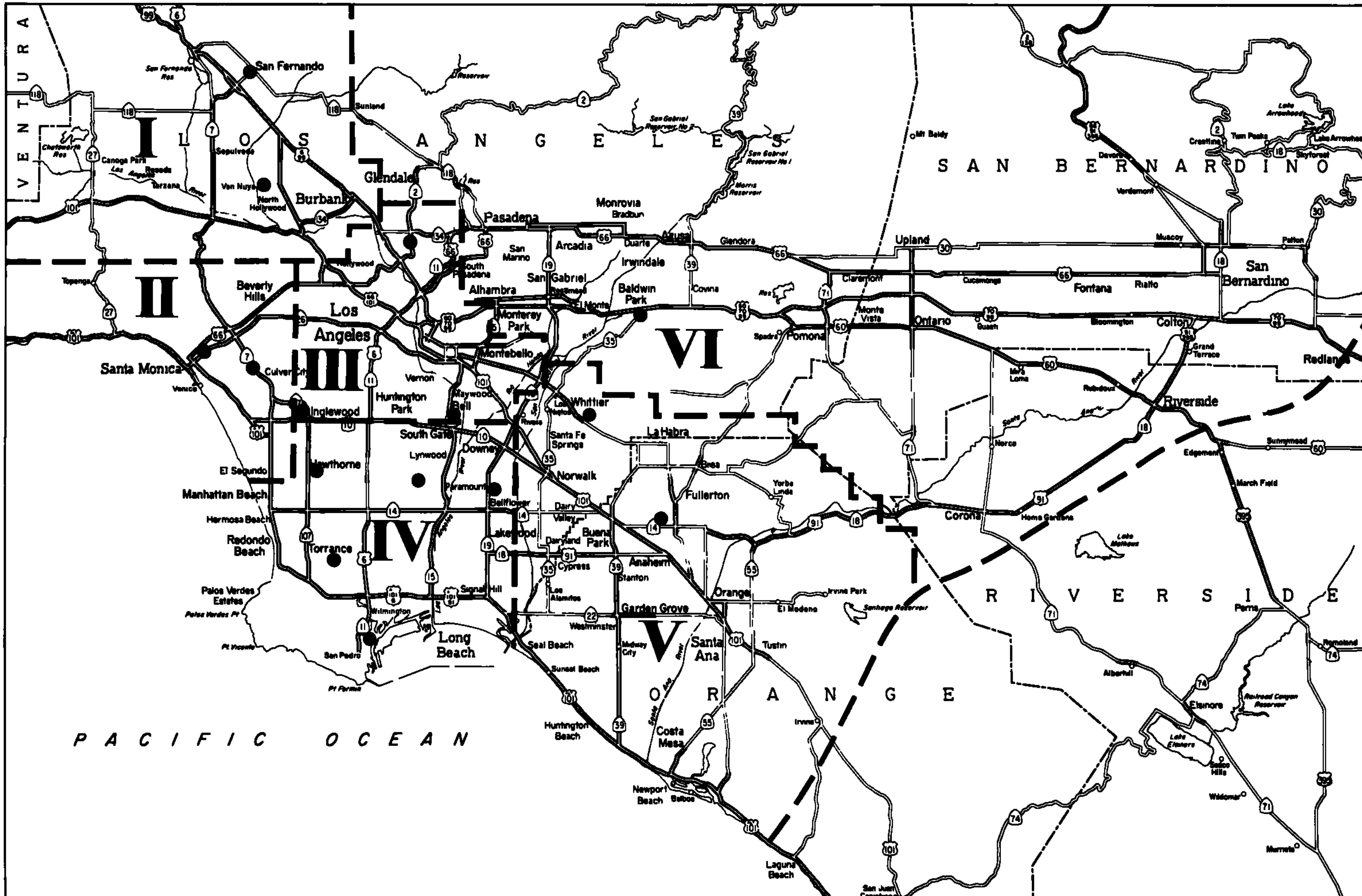


Figure 13. In Los Angeles, interviews were conducted in 15 district offices of the Department of Motor Vehicles throughout the city. The survey area was divided into zones so that answers from residents could be analyzed by zone in some cases.

either senior or graduate students at the University of California, Los Angeles. The interviewers were chosen on the basis of their appearance, their expressed interest in gaining interview experience, and their subsequent performance in training sessions.

An intensified training program was carried out in which the interviewers were made thoroughly familiar with the meaning and purpose of every question on the interview form. Also, each interviewer performed a number of practice interviews until it was felt that his technique conformed to a standard requiring consistency combined with the degree of flexibility necessary to elicit the maximum information possible from each respondent.

Furthermore, once each interviewer became established in his first DMV office, his interviews were checked carefully for the first few days to insure adherence to the prescribed procedure.

The Interview Form

Figure 14 shows the interview form used in the Los Angeles study. The motorist was first asked his places of residence and employment (to the nearest major intersection). Following this he was asked how often he used a freeway (Question V). When the answer indicated rare use, the motorist was then asked why he did not use them more often.

Next, the respondent was asked if he would recall a trip during which he used a freeway entrance or exit for the first time (Question VIII). If so, he was then asked questions designed to reconstruct that trip. These questions elicited information on how he expected to recognize the ramps he used, and the way he actually recognized them. In addition, he was asked whether he experienced any difficulty entering or leaving the freeway and, if so, the location, nature and cause of the difficulties. Finally, he was asked if he had returned over the same route. If he replied affirmatively and if he had trouble entering or leaving, he was asked the location, nature and cause of the trouble.

Then followed questions regarding a trip the motorist repeated regularly such as home-to-work (Question IX). Again, the questions reconstructed the trip from start to finish. In addition, the motorist was asked how he recognized the ramps he used, the freeway route number, and his direction of travel. Further, he was asked to name the two ramps preceding the exit he used, at what points a stranger should start watching for the exit, points at which a stranger could get lost, and any special problem to be watched for by another person making the same trip.

In Question X, the motorist was asked if he could tell how to get from a selected location, usually his home, to 20 places in the Los Angeles area. Half were public buildings or other well-known destinations; the rest, cities or communities in the metropolitan complex. When the motorist stated that he could give directions to a place, he was asked if he would use a freeway to get there. After going through the list, he was asked to give detailed directions to one of the places. Then he was asked what he would do if he had to go to one of the places he said he could not give directions to (for example, "look it up on a map," "ask directions," etc.).

Finally (Question XII) he was requested to give his opinion regarding three phases of signing—directions to freeways, directions to cities or areas, and directions to freeway turnoffs. This question, which served to conclude the interview, was the only one in which the respondent's opinion was solicited.

Rating Sheet

After the interviewee had departed, the interviewer proceeded to fill in the information on the rating sheet. It was decided not to ask the age and occupation of the respondent directly as it was felt that this information tends to be too personal, and out-of-place in the general context of this type of interview situation. However, the interviewer usually was able to make an estimate of the subject's occupation from his answers, appearance, and so on, as well as to estimate his age. (The respondents often volunteered this information in the course of the interviews.)

The purpose of the ratings was to permit the interviewer to make a general appraisal of the subject while the interview was still fresh in his mind.

CALIFORNIA SIGN STUDY

LOS ANGELES QUESTIONNAIRE

DATE ______________________

LOCATION OF INTERVIEW ______________________

INTERVIEWER ______________________

NUMBER ______________________

I. Whereabouts in the Los Angeles area do you live? ______________________

II. About how long have you lived there?
1 Less than one year
2 1-5 years
3 over 5 years

III. Where do you work? ______________________
1 Presently unemployed
2 Housewife
3 Works in various areas (e.g. Salesman, Painter)

IV. About how long at that address?
1 Less than one year
2 1-5 years
3 over 5 years

V. About how often do you use one of the freeways to make a trip in the Los Angeles area?

1___per day

2___per week

3___per month

4___less than once per month

5___never

____

____

____

LOS ANGELES QUESTIONNAIRE

VI. (If once a month or less)

Why do you not use the freeways more often?

1 They don't go to the right places, or doesn't travel much.

2 Don't like to drive on freeways.

3 Have trouble finding the way.

Other: ______________________

VII. (If answer to question VI indicates dislike for freeways, such as answers 2 and 3, try to determine reason for dislike - ask sufficient questions to tell whether difficulty in finding the way is a factor. It might be in order to ask for an example which would illustrate the reason for this dislike.)

____

____

____

____

VIII. We would like to learn how people find their way on and off freeways, particularly those who make a trip for the first time. Do you remember a time when you got on or off a freeway at a place you hadn't used before?

☐ Can't recall such a trip.

If trip recalled:

a) Place where trip started ______________________

b) Place where trip ended ______________________

c) Freeway(s) used ______________________

d) On-Ramp used ______________________ First time? ______

e) Off-Ramp used ______________________ First time? ______

____

____

____

____

Figure 14. Los Angeles questionnaire.

LOS ANGELES QUESTIONNAIRE Page 3

VIII. (cont'd)

f) Did you have any trouble getting on the freeway? 1 Yes 2 No

If yes, specify: ______________________

____

____

g) Did you have any trouble getting off the freeway? 1 Yes 2 No

If yes, specify: ______________________

____

____

h) Did you come to the place you wanted to turn off from the freeway

1 Sooner, or 2 later, or 3 about when you expected?

i) How were you expecting to recognize the turn off? ______________________

____

____

j) How did you recognize the turn off? ______________________

____

____

k) Had you consulted a road map 1 or asked directions 2

before making the trip, or neither one 3

l) Did you make the return trip over the same route? 1 Yes 2 No

If yes, did you have any trouble coming back? 1 Yes 2 No

If yes, specify: ______________________

____

____

____

____

LOS ANGELES QUESTIONNAIRE Page 4

IX. In contrast to trips which you make only occasionally, we would like to know about those which you repeat regularly. Is there a trip using the freeway which you make fairly often? 1 Yes 2 No

If yes:

a) Place where trip starts ______________________

b) Place where trip ends ______________________

c) Freeway(s) used ______________________

d) What route number is it? __________ 1 Knows 2 Doesn't know

e) Where do you get on the freeway? ______________________

f) How do you recognize the place where you get on the freeway? __________

____

____

If no response: (How would I recognize it?) ☐

g) Which direction do you go on the freeway? ______________________

h) Where do you get off the freeway? ______________________

i) How do you recognize the place where you leave the freeway? __________

____

____

If no response: (How would I recognize it?) ☐

j) If I were to make the trip, when should I start watching for the turn-off?

____

____

k) What is the name of the turn-off just before the one where you turn?

____

l) The one just before that? ______________________

m) Is there a particular place where I might become lost? 1 Yes 2 No

If yes, specify: ______________________

____

n) Are there any other special problems I should look out for when taking this trip? 1 Yes 2 No

If yes, specify: ______________________

____

Figure 14 (continued)

X. I have a list of trips. I want you to tell me if you could give me the same information for them that you just gave me for your trip from ________ to ________. (If "repeat" trip was not filled out, say: - "if you could tell me how to get to these places.") As I read them to you, just answer "yes" or "no", then after we have completed the list I will select one of the trips you answered "yes" to and ask you to give me the information. (Select a location from the four places listed on the left column as a point of beginning for all trips.)

FROM (Circle one)	TO	YES	NO	Would you use a freeway? YES	NO
a. Your home	1. Disneyland				
b. Where you work	2. L.A. Int. Airport				
c. Here	3. Forest Lawn				
d. Down town	4. The Rose Bowl				
	5. The Coliseum				
	6. Hollywood Park				
	7. City Hall				
	8. Lockheed Air Terminal				
	9. Union Station				
	10. L.A. County Hospital				
	11. Pacific Palisades				
	12. Pacoima				
	13. La Canada				
	14. El Monte				
	15. Whittier				
	16. El Segundo				
	17. San Pedro				
	18. Bellflower				
	19. Monterey Park				
	20. Monrovia				
	Totals				

X. (Cont'd)

For one "Double Yes" trip: From ________ To ________

a) What freeway(s) would you take? ________

b) What route number is it? ________ 1 Knows 2 Doesn't Know

c) Where would you get on the freeway? ________

d) How would you get to this on-ramp? ________

____

____

________ 1 O.K. 2 N.G.

e) Which direction would you go on the freeway? ________

f) Where would you get off the freeway? ________

g) If I were to make the trip, when should I start watching for the turn-off?

____

____

h) How would you get from the off-ramp to your destination ________

____

____

________ 1 O.K. 2 N.G.

XI. For one "no" trip: From ________ To ________

What would you do if you had to make this trip?

1 Look it up on a map

2 Ask directions

3 Just start driving in the general direction and take a chance.

Other: ________

Figure 14 (continued)

LOS ANGELES QUESTIONNAIRE Page 7

XII. a) In your opinion, are the directions as to how to get on the freeways from the regular streets good or bad? 1 Good 2 Bad

If bad, specify: ______________________

b) When you are on the freeways, are the directions to different cities or areas good or bad? 1 Good 2 Bad

If bad, specify: ______________________

c) When you are on the freeways, are the directions to turn-offs good or bad? 1 Good 2 Bad

If bad, specify: ______________________

LOS ANGELES QUESTIONNAIRE Page 8

RATING

Sex: 1 - M 2 - F

Estimated Age: ______

Occupation
(If determinable) ______

Other: ______

I. Sureness of Answers (circle one)

1 Seemed confident of answers

2 Often answered with "I think", "isn't it?", etc.

3 Frequently didn't know answers.

II. Orientation on Freeways (Circle one)

1 Seemed quite familiar with freeway system - e.g. could name landmarks and advance turn-offs.

2 Seemed unfamiliar with freeway system as a whole, but was familiar with a certain portion of the system which he uses often.

3 Seemed unfamiliar with most aspects of the freeway system.

III. Orientation in City (Circle one)

1 Seemed quite familiar with layout of city, e.g. knew directions of travel, distances, other places nearby destination, etc.

2 Seemed sure of his orientation with regard to only a few places, or in his immediate vicinity only.

3 Generally unfamiliar with layout of city.

IV. In general did the individual seem: (Circle one)

1 distance oriented (used distance estimates)

2 time oriented (used ~~distance~~ time estimates)

V. In your opinion, was this person. (Circle one)

1 well oriented?

2 fairly well oriented?

3 poorly oriented?

Figure 14 (continued)

Follow-Up Field Inspections

As mentioned earlier, inspection of various sections of the freeway system was carried out following termination of the interviewing.

To prepare for these field trips, tabulations were made of those locations at which trouble was often encountered by the respondents. In addition to these "bad" locations, a listing was also made of the locations specifically mentioned by the respondents as being "good." In both cases, only those locations were chosen in which signing was specified or estimated to have played a part in causing the difficulty or in eliciting the favorable comment.

Each of these locations was visited with the pertinent interview forms in hand so that the respondents' trips could be reconstructed.

The purpose of these field trips was to develop basic signing principles by determining the differences in the existing signing between the "good" and "bad" locations. By reading the interviews and examining the location from the standpoint of its relation to the respondent's trip, it was possible to gain insight into the respondent's point of view, and thereby ascertain those aspects of the signing responsible for making certain locations "bad" and other locations "good."

As a result of these investigations, there gradually evolved the set of basic signing principles enumerated in the "Conclusions and Applications" section of the report.

FINDINGS

San Luis Obispo Study

The purpose of the San Luis Obispo study was to evaluate the utility of the roadside interview for data collection purposes. In this regard it proved to be highly successful. A roadside interview has certain fundamental advantages; motorists are actually in the process of completing a trip, and the quantitative data so obtained help to define the scope of the problem.

The study resulted in 246 usable interviews with those motorists who have the greatest dependence on signing (unfamiliar drivers). They were selected from the traffic stream without intentional bias, and thus are probably representative of such drivers for this and similar situations.

Motorists who make a trip through unfamiliar territory rely heavily on road maps for information about their route. In San Luis Obispo, 71 percent of all motorists interviewed were using a road map, while 97 percent of the motorists from states other than California were using road maps (Table 2). In addition to using road maps, 50 percent of the out-of-state motorists had obtained directions either on the road, or before starting, or both. Only 18 percent of California drivers had obtained directions (Table 3), probably because of their greater familiarity with the area and the signing system.

The reason for stopping in a city gives a substantial clue to the type of information which might be of value to the traveler. A tabulation of "Reasons for Stopping" is shown in Table 4.

Those who stop for food, lodging, vehicle service or sightseeing rarely have a specific destination in mind. (About four out of five people seeking lodging have not selected a specific hotel of motel beforehand.) These people could use good directions to the Central Business District from the freeway, such as a business route, but probably would benefit most from directions to the freeway and other major routes when they are ready to continue their trip.

Those stopping to transact business or to visit would derive some benefit from street names and would also benefit from the directions cited above. Those changing their route would, of course, benefit from "further destination" signs and route markings.

In reply to the question about preference for route numbers or place names, 53 percent of the motorists indicated they preferred route numbers, while 18 percent said they preferred place names. Twenty-nine percent replied that they had no preference; apparently they use both with equal, or near equal, facility (Table 5). Motorists from states other than California showed a greater preference for route numbers than did

California motorists, undoubtedly because they were less familiar with the cities in California.

The freeway ramps taken by the motorists were evaluated with regard to trip origin and destination, as shown in Table 6. At off-ramps, 17 percent of the motorists interviewed were taking an indirect route to their destination, while 5 percent actually were taking a route which would have put them in such a position that it is unlikely they would have reached their destination without considerable difficulty. At on-ramps 17 percent of the motorists interviewed were taking an indirect route from their origin in San Luis Obispo to their destination, and 15 percent were using a ramp which would have put them on the freeway in such a way that they could not have reached their destination.

TABLE 2

USE OF ROAD MAPS

Unfamiliar Drivers—San Luis Obispo Study			
Vehicle Registration	Used Map %	Did Not Use Map %	Total %
California (N=188)	63	47	100
Other states (N=58)	97	3	100
Total—all respondents	71	29	100

TABLE 3

USE OF DIRECTIONS

Unfamiliar Drivers—San Luis Obispo Study					
	Obtained Directions				
Vehicle Registration	Before Starting %	On the Road %	Both %	Did Not Obtain Directions %	Total %
California (N=188)	11	6	1	82	100
Other states (N=58)	22	14	14	50	100
Total all respondents	13	8	4	75	100

TABLE 4

REASON FOR STOPPING

Unfamiliar Drivers—San Luis Obispo Study		
Stop Purpose	Number	%
Food, lodging, and vehicle service	99	40
Change route	68	28
Business and visits	38	16
Sightseeing	6	2
Other purposes	12	5
Unintentional	23	9
Total	246	100

When asked for suggestions or comments about signing, 29 percent of the motorists declined comment while 26 percent registered approval of California signing without specific comments. Only three comments, or suggestions, were repeated with sizeable frequency. These were, in order: "more advance notice" (15 percent), "more or larger route shields" (5 percent) and "larger signs" (4 percent). The remaining comments are shown in Table 7.

The findings at two of the off-ramps are of particular significance. At the first off-ramp, 16 percent of the motorists interviewed should not have been leaving the freeway at all, since they were destined for points beyond San Luis Obispo along either US 101 or State Sign Route 1.

The signing in advance of this off-ramp (Fig. 4) was responsible for a large share of the difficulties encountered by these motorists. This type of signing is no longer used by the Division but it illustrates certain violations of good sign practice. The advance signing did not mention either US 101 or State Sign Route 1. It presented a choice between two places, Salinas and San Luis Obispo. At the actual point where the decision had to be made, the signing mentioned only San Luis Obispo. Some of the motorists seeking State Sign Route 1 knew that this route turns at San Luis Obispo, and in the absence of any information that their route continued on the freeway, took the first off-ramp. Others, whose destinations lay along US 101 or, in some cases beyond San Francisco, were unable to relate Salinas to their route or destination. Given their choice between two destinations they did not want to go to, they chose San Luis Obispo.

By contrast, the motorists interviewed at the off-ramp to State Sign Route 1 fared much better. The signing in advance of this off-ramp (see Fig. 4) gave information about the routes as well as a place name.

An interesting finding was the volunteered comment by 10 percent of the motorists interviewed in San Luis Obispo that they had trouble finding their way in Los Angeles. Since only northbound motorists were interviewed it can be assumed that many of them had passed through Los Angeles only a short time before being interviewed. The

TABLE 5

SIGN PREFERENCE

Unfamiliar Drivers—San Luis Obispo Study

Sign Preference	Vehicle Registration		
	California (N=188) %	Other States (N=58) %	Total (N=246) %
Route numbers			
Strong preference	38	57	43
Weak preference	11	7	10
Subtotal	49	64	53
Place names			
Strong preference	14	9	12
Weak preference	6	5	6
Subtotal	20	14	18
Both	31	22	29
Total	100	100	100

TABLE 6

ROUTE EVALUATION

Unfamiliar Drivers—San Luis Obispo Study

Route Taken	Vehicle Registration		
	California (N=188) %	Other States (N=58) %	Total (N=246) %
Off-ramps			
Took most direct route	50	56	52
Had no specific destination	28	22	26
Took indirect route	16	19	17
Took wrong route	6	3	5
Off-ramp total	100	100	100
On-ramps			
Took most direct route	72	57	68
Took indirect route, but was not lost	16	19	17
Could not have reached destination via route taken	12	24	15
On-ramp total	100	100	100

importance of this finding is that it re-emphasized the necessity for study of the freeway network in the Los Angeles area.

California State Fair Study

The motorists interviewed at the California State Fair were reasonably representative of the total licensed driver population in California. In general their estimated annual travel tended to be higher than for the total population. The average age of the males interviewed in the study was lower than that for the total population. However, none of these differences was of such magnitude that the representativeness of the sample could be seriously questioned. A total of 224 usable interviews was obtained.

Of the persons interviewed, 81.5 percent planned their own trips, 13.5 percent used trip planning services, and the remainder either did no planning or used some other method.

Only 10.9 percent of those who stayed overnight made reservations at all the places where they stayed. An additional 7.9 percent made reservations at some of the places.

The remainder, 81.2 percent, made no reservations at all, although 22.8 percent knew approximately where they wanted to stop.

The use of road maps varied according to the length of the trip (Table 8); 86.0 percent of the motorists who made trips over 500 mi in length reported that they had used a road map.

TABLE 7

MOTORIST COMMENTS AND SUGGESTIONS

Unfamiliar Drivers—San Luis Obispo Study

Comment	Vehicle Registration					
	California		Other States		Total	
	No.	%	No.	%	No.	%
No suggestion—no comment	54	29	17	29	71	29
No suggestion—approval	50	26	15	26	65	26
No suggestion—disapproval	3	2	1	2	4	2
More advance notice	26	14	11	19	37	15
More or larger route shields	9	5	3	5	12	5
Larger signs	7	4	3	5	10	4
Better direction to freeways	5	3	0	[1]	5	2
Better warning—detours, etc.	4	2	1	2	5	2
More signs w/dist. to cities	4	2	0	[1]	4	2
More place names	1	[1]	2	3	3	1
Clearer/ larger arrows	3	2	0	[1]	3	1
All others	22	11	5	9	26	11
Total	188	100	58	100	246	100

[1] Less than 1.

Over half (51.5 percent) of the motorists said they paced themselves by estimating their time of arrival at certain places along their route. Of those who paced themselves, 80.0 percent used signs giving place names and distances to help them estimate their time of arrival.

A substantial portion of the persons interviewed (37.9 percent) altered their trip as a result of something they saw on a sign. These were sightseeing trips to points of interest signed to along the road.

TABLE 8

PERCENT OF MOTORISTS USING ROAD MAPS AS RELATED TO LENGTH OF TRIP

California State Fair Study

Map Usage	Trip Length (mi)			
	Under 100 %	100 to 200 %	200 to 500 %	Over 500 %
Used a road map	39	69	70	86
Did not use a map	61	31	30	14
Total	100	100	100	100

Slightly less than half (48.5 percent) of the persons interviewed said they could recall looking for a sign they could not find. Four types of signs, all of which had to do with route confirmation, reassurance or directions, accounted for 70 percent of these cases.

The majority of motorists used route numbers to confirm the fact that they were on the right route; 67.7 percent said they used route numbers only and an additional 18.4 percent used them in conjunction with place names. Only 13.9 percent of the motorists interviewed used place names exclusively (Tables 9 and 10).

Among persons who had not repeated their trip within the past three years, the number who thought they were on the wrong road varied appreciably with the length of their trip (Table 11). Of those making trips over 500 mi in length for the first time, 51 percent reported thinking they were on the wrong road at least once and 34 percent of them actually were.

Table 12 shows the number of persons who were shown the ten pictures of signs used in question 20, and the percentage of the total who knew what each sign meant. Best known were certain warning signs; least known were two signs: "Frontage Road," and the arrows used with a route shield as shown in Figure 15.

It should, and doubtless will, shock the average traffic engineer to know that the L-shaped arrows he so logically devised to indicate that the route is about to turn were misinterpreted by more drivers than were messages like "Merging Traffic" or "Ped Xing," which have been considered esoteric and cryptic. One reason may be that the arrow is diagrammatic instead of representative; another may be the shield is normally used as a reassurance sign, and some other device should be developed for an "action required" sign. Table 13 shows the ten most frequently recorded comments on signing. Unlike the San Luis Obispo roadside interviews, these interviews elicited comments from nearly all respondents. A grand total of 246 comments were recorded. Some were general and others referred to specific locations. Frequently as many

TABLE 9

METHODS OF CONFIRMING ROUTE

California State Fair Study, N=217	
Method of Confirming Route	% of Total
1. Route numbers	67.7
2. City names	7.4
3. Signs with names and distances	6.0
Combinations of	
1 and 2	12.9
1 and 3	4.6
1, 2 and 3	0.9
2 and 3	0.5
Total	100.0

TABLE 10

PERCENT OF MOTORISTS USING ROUTE NUMBERS FOR ROUTE CONFIRMATION CLASSIFIED BY TRIP LENGTH

California State Fair Study				
	Trip Length (mi)			
Method of Confirming Route	Under 100 %	100 to 200 %	200 to 500 %	Over 500 %
Route numbers only	48	62	65	74
Route numbers and names	18	19	17	17
Total	66	81	82	91

TABLE 11

PERCENT OF MOTORISTS WHO BECAME LOST ON TRIPS THEY MADE FOR THE FIRST TIME OR WHICH THEY HAD NOT MADE WITHIN PAST THREE YEARS

California State Fair Study			
Trip Length	Never Lost Or In Doubt %	Felt They Were On The Wrong Road %	
		were not	were
Under 200 mi	67	20	13
200 to 500 mi	47	24	29
Over 500 mi	49	17	34

were opposed to one thing as were for it. Two people even suggested a thorough study to find what motorists want. The ten comments appearing in the table represent only 32 percent of all the comments and suggestions received.

Fresno Study

The motorists in these roadside interviews are believed to be representative of all drivers using the Fresno freeway ramps during the hours of the study. These drivers were selected for interviews without any intentional bias. The number of interviews assured a sample of sufficient size to minimize the variability inherent in very small samples. The findings have general application to all similar situations but can best be described by reference to the specific locations.

The first of these specific locations is at the south end of the city (the Monterey Street Overpass illustrated near the bottom of Fig. 16). At this location, 4.3 percent of all northbound motorists interviewed had destinations beyond Fresno. This amounts to approximately 160 for an average day between the hours of 8:00 a.m. and 5:00 p.m. These motorists should have continued on the freeway but they did not for various reasons. The signing at this location presented two choices: first, between Fresno on the right hand and Madera on the left (Madera is a small city about 20 mi north of Fresno), and second, between "US 99 Business" on the right and "99" in a shield on the left. Because of the amount of space used by the words "US 99 Business," this legend was much more emphatic than the simple "99" in a shield outline, although the letter size of the latter was ample—18-in. high. In addition to the two choices just described, many motorists tried to make a choice between Madera on the left and US 99 Business on the right, or Fresno on the right and "99" in a shield on the left. Furthermore, the exit is a 2-lane concrete ramp which looks very similar to the main line at this location. The motorists who turned off at this location when they should have continued on the freeway did so for the following reasons:

1. Did not know the other choice was

TABLE 13

COMMENTS AND SUGGESTIONS ABOUT DIRECTIONAL SIGNS

California State Fair Study

Comment or Suggestion	Number of Times Cited
More advance notice of turning points	16
More green signs	14
Larger signs or larger letters	8
More signs with city names and distance	8
More route shields	7
California signing is good	7
Use cardinal directions more	6
Use more overhead signs	5
Illuminate more signs	4
Give more directions to freeways	4

TABLE 12

KNOWLEDGE OF SELECTED SIGNS

California State Fair Study

Sign	Number of Responses	% Correct
"Merging Traffic"	189	98.5
"Red X-ing"	62	98.5
"Island"	186	98.0
"North" (shown w/route shield)	207	92.5
"Business" (shown w/route shield)	199	83.0
"Alternate" (shown w/route shield)	189	80.0
Arrows (shown w/route shield)	176	60.2
"Yield right-of-way"	199	91.5
"Roadside Business"	221	90.5
"Frontage Road"	200	64.0

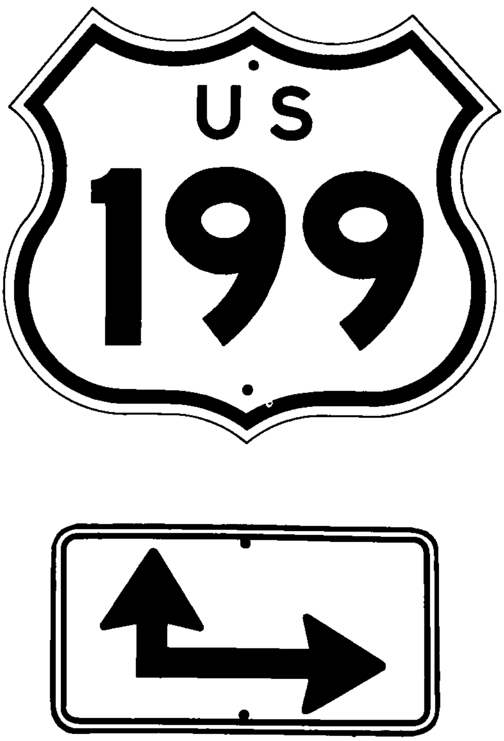


Figure 15.

a freeway route bypassing the city (35.4 percent).

2. Did not know where Madera was (23.8 percent).
3. Confused by business route signs (17.0 percent).
4. Did not see signs (8.5 percent).
5. Various miscellaneous reasons (15.3 percent).

Most of the motorists who mistakenly turned off at this point (the Monterey Street overpass) continued on through the city on the old highway and re-entered the freeway at the north connection, and the percentages quoted above are based upon interviews with motorists at either the off-ramp or at this north connection of the business route and the freeway.

At the north end of the city, the connection between the freeway and the business route is as shown in Figure 10. At this location, 14.7 percent of all southbound motorists interviewed as they were leaving the freeway had destinations beyond Fresno (about 150 motorists for the hours 8:00 a.m. to 5:00 p.m.). They would have benefited materially by remaining on the freeway. An additional 47.5 percent had a destination in the downtown area and would have received some benefits by continuing on the freeway.

When interviewed, these motorists gave the following reasons for their choice:

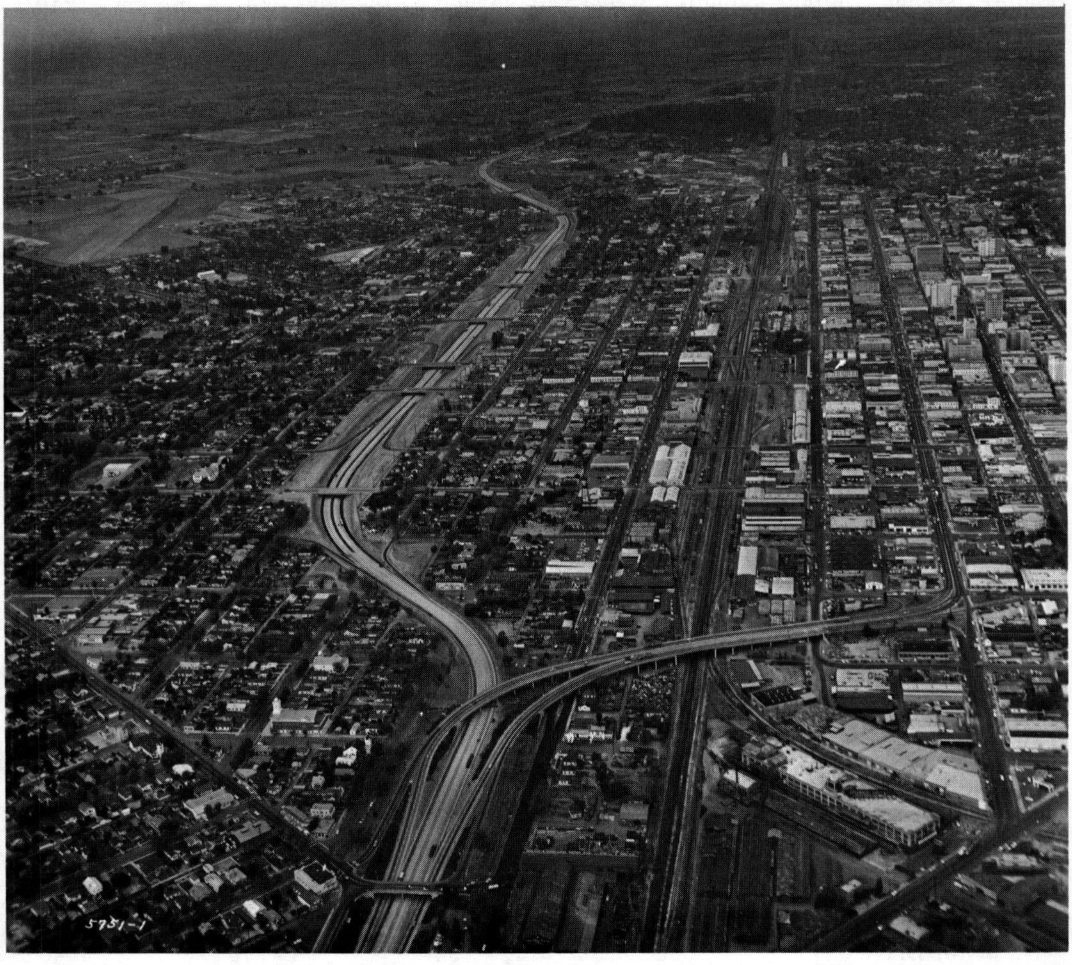


Figure 16. Interviews were conducted at all ramps serving the freeway in Fresno. In this photo, the central business district is to the right.

1. Confused by signs, particularly the "US 99 Business" route—65.4 percent.
2. Saw no indication that the freeway was a bypass or freeway route—9.7 percent.
3. Did not realize that there were other exits ahead—9.6 percent.
4. All others—15.3 percent.

In addition to the people who mistakenly left the freeway when they should have stayed on, there were many who stayed on when they should have left at the business route turnoff. This information was obtained from interviews at the next off-ramp available to southbound traffic.

At this location, the motorists who realized they had passed the business route turnoff left the freeway to seek the business route. These motorists accounted for 11.1 percent of the motorists using this off-ramp. An additional 10.0 percent of the motorists using the ramp were destined for downtown Fresno. The motorists turned off the freeway for two reasons: they did not know there were other exits ahead (46.3 percent), or they felt the freeway was turning away from the city and would not take them to the downtown area (43.6 percent).

The other location which merits emphasis is the southbound off-ramp at Merced Street. At this location the signing messages listed Kings Canyon, Central Fresno and State Sign Route 180; no street name was given. Some motorists, who had known from past experience that Ventura Street led to Kings Canyon, concluded that this ramp led to Ventura Street. In fact, Ventura Street was served by the next exit, some seven city blocks south of the Merced Street (Central Fresno) exit. The interpretation that they made would have been valid prior to the freeway opening, but no longer held true because of changes in the routing of State Sign Route 180.

Table 14 shows how many drivers used certain ramps for both inbound and outbound trips between Central Fresno and points north of the city. The Merced Street ramps are the best choice for such trips. Signs at the Merced Street exit directed to "Central Fresno" but both Mono and San Joaquin Streets could be considered suitable alternates. The others are listed in order of their distance from Merced Street. Although a certain number of the motorists who used less desirable routes did so because of personal preference, the interviews revealed that the majority did so because the sign messages they had seen had led them to make a poor choice.

The motorists interviewed at freeway on-ramps frequently had experienced difficulty in locating a freeway entrance. Table 15 shows the ways in which unfamiliar motorists located freeway entrances. Those who saw signs directing to the freeway did so in the Central Fresno area. Over 20 percent of the motorists either asked directions or just kept driving around until they located the entrance.

TABLE 14

NUMBER OF MOTORISTS USING SPECIFIC RAMPS FOR TRIPS BETWEEN THE DOWNTOWN AREA AND POINTS NORTH OF FRESNO EXPANDED TO 24-HR COUNT

Street	No. of Trips Originated Downtown	%	No. of Trips Terminated Downtown	%
Using Ramps at:				
Mono Street	50	3	111	5
Merced Street	678	41	660	31
San Joaquin Street	163	10	83	4
Thorne Ave.	82	5	50	2
Belmont Ave.	68	4	130	6
Olive Ave.	51	3	100	5
N. Motel Drive	568	34	970	46
Total	1,660		2,104	

In total, 254 unsolicited comments were recorded. The ten most frequent comments are shown in Table 16. The most frequent single comment was that the motorist had left the freeway because he did not know there were other exits ahead. New signing standards in California provide this information. Combining the two comments concerning signing to the freeway would make this item the one most frequently mentioned. It is important to note that 46 motorists mentioned that they could not find signs for which they were looking.

Los Angeles Study

A total of 1,086 interviews were taken (at various Department of Motor Vehicles offices) of which 45 had to be rejected because the respondents were not able to stay long enough to complete a reasonable part of the interview. Of the 1,041 interviews which were usable, two separate but overlapping populations were analyzed. The first consisted of 991 interviews which were considered complete enough to be coded on IBM punch cards for subsequent analysis. This group will hereafter be referred to as the "coded" population, and is the basis for the analyses of all the interview data with the exception of Question X, which was analyzed separately, based on a population of 949 respondents who answered this question.

Because of the diverse nature and large quantity of the data provided by the interviews, no attempt is made in this report to evaluate the information gathered from each and every item on the questionnaire. However, all of those items whose major implications are related to freeway signing are included.

In order to promote ease in reading and understanding the study findings, they are discussed in terms of the specific interview questions to which they relate, and in the order of their appearance on the interview form. With the exception of Question X, the population referred to is the "coded" population.

Biographical Data

Comparison with statistics describing the total licensed driver population in the Los Angeles area[2] (including Los Angeles and Orange Counties) demonstrated a close correspondence with the sample group as regards age, sex and occupation.

Of the 1,041 respondents whose interviews were usable, 68 percent were male and 32 percent were female, which compares favorably with the total licensed driver population in the Los Angeles area (60 percent male and 40 percent female).

The age of each respondent was estimated by the interviewer, and the age-breakdown of the sample is shown in Table 17. When compared with the total licensed driver population, those in the 16 to 20 age group were eliminated because it was known that due to licensing laws the sample of this age group would not be representative (of "Study Procedures"). The comparison is shown in Table 18 and despite the differences in age categories used in the two populations, the distributions are markedly similar.

Comparison of the sample with the total licensed driver population in the Los An-

TABLE 15

WAYS IN WHICH MOTORISTS WHO HAD NOT USED ENTRANCE BEFORE LOCATED FREEWAY ENTRANCES

Fresno Study	
Ways Located	% of Total
Followed old highway	10.7
Asked directions	7.6
Familiar with area	14.4
Saw signs	46.0
Hunted for it	14.3
Could see the freeway	7.0

TABLE 16

TEN MOST FREQUENT COMMENTS FROM MOTORISTS

Fresno Study	
Comment	Number of Times Cited
Did not know there were other ramps ahead	57
Confused by US 99 business route signs	50
Wanted signs to the freeway—did not specify a location	47
Did not see signs for which they were looking	46
Were confused by signs but could not be more specific	45
Did not know freeway was open	35
Did not know where Madera was	33
Signing is good	29
Could not locate business route	28
Felt signs were needed to freeway from downtown	21

[2] Motor Vehicle Use Study of 1953 (latest figures available).

geles area as regards occupation is shown in Table 19. Considering the fact that the interviewers estimated the respondents' occupations and that the classification schemes used in the sample and in the Motor Vehicle Use Study were not exactly comparable, there remains a surprisingly high degree of correspondence between the two populations.

TABLE 17

AGE-BREAKDOWN OF SAMPLE
(N=991)

Los Angeles Study	
Age Group	% of Sample
16 - 20	1.95[1]
21 - 30	24.53
31 - 40	37.78
41 - 50	20.06
51 - 59	8.96
60 - 69	5.65
70 and over	1.07

[1] This small percentage is explained by the fact that first-time license applicants were systematically excluded from the sample.

The fact that the sample included a high percentage of males and of persons in the 21 to 40 age group has special significance. These persons were the most frequent users of the system (see Question V), and because of their relatively greater experience with the system it is reasonable to make the following assumptions:

1. The frequency of occurrence of trouble for these individuals is relatively lower than for the driving population as a whole, and therefore the information gained from them has the effect of biasing the results in a conservative direction.
2. Information obtained from questions relating to knowledge of the system should by the same token indicate a higher average level of knowledge than is possessed by the total driving population.

Question V - Frequency of Freeway Usage

Tables 20 and 21 show the frequency of freeway usage as related to age, for males and females, respectively. An examination of the data reveals the expected fact that males are far more frequent users of the freeway system than females. Considering only regular freeway usage of at least once per week, 61.4 percent of the males fell into this category as opposed to only 38.8 percent of the females. At the other extreme, only 26.3 percent of the males used the freeway once a month or less as compared to 45.4 percent of the females interviewed. It is interesting to note that while only 0.3 percent of the males said they never use the freeway, 2.8 percent of the females made the same claim. (Because of the disproportionately small number of individuals in the 16-20 yr age group interviewed, this age group was eliminated from consideration in these tables.) Combining the data reveals that for both males and females, the 26-40 age group accounts for the majority of freeway usage (53.9 percent of the males, and 58.8 percent of the females answering this question fell into this age group).

Questions VI and VII - Reasons for Infrequent Freeway Usage

Questions VI and VII were designed to elicit reasons why the respondent did not use the freeway often, if he had so indicated in the previous question. Table 22 shows the

TABLE 18

COMPARISON OF AGE-BREAKDOWNS OF SAMPLE AND LICENSED DRIVER POPULATION

Los Angeles Study			
Sample (N=991)		Total Licensed Driver Population	
Age Group	%	Age Group	%
21 - 30	25.02	21 - 29	20.14
31 - 40	38.53	30 - 39	29.94
41 - 50	20.46	40 - 49	22.91
51 - 59	9.14	50 - 59	15.68
60 - 69	5.76	60 - 69	8.45
70 and over	1.09	70 and over	2.87

answers given by those individuals who responded to the question with a specific reason.

The majority of people who used the freeway system infrequently (or not at all) did so because either they did not travel much or their travel habits (or place of residence) made it relatively inconvenient or unnecessary for them to use the freeways.

TABLE 19

COMPARISON OF OCCUPATIONAL BREAKDOWN FOR SAMPLE AND LICENSED DRIVER POPULATION

Los Angeles Study			
Sample (N=991)		Licensed Driver Population	
Occupation	% of Sample	% of Sample	Occupation
Professional and Managerial	16.58	21.96	Professional and Semi-Professional, Proprietors, Managers, Officials.
Agricultural, Fishery, Forestry	0.38	0.45	Farmers
Clerical and Sales	19.85	14.16	Clerks, Salesmen, Agents.
Skilled Workers	11.06	14.08	Craftsmen, Foremen, Skilled Laborers.
Unskilled and Semi-Skilled	25.88	15.16	Operators, Unskilled Labor
Service Occupations	5.65	5.15	Protective and Personal Service Workers
Retired	3.39	4.45	Retired
Housewives	17.21	24.58	Housewives
	100.0	100.0	

TABLE 20

FREQUENCY OF FREEWAY USAGE BY AGE GROUP (MEN)

Los Angeles Study					
	Frequency of Freeway Usage % of Each Age Group				
Age Groups	Once Per Day Or Oftener	One To Four Times Per Week	Two To Four Times Per Month	Once Per Month Or Less	% of Male Sample in each Age Group
21 - 25	19.35	53.23	11.30	16.13	9.28
26 - 30	32.98	36.17	12.76	18.08	14.07
31 - 35	31.30	31.31	10.44	26.95	17.22
36 - 40	32.45	35.10	9.27	23.18	22.60
41 - 45	22.08	36.36	11.69	29.87	11.53
46 - 50	18.84	33.34	18.84	28.98	10.33
51 - 59	22.81	28.07	15.78	33.32	8.53
60 - 69	24.32	16.22	16.21	43.24	5.54
70 and over	0.00	16.67	0.00	83.33	0.90
All Ages	26.95	34.43	12.27	26.34	100.0

A total of 23.0 percent of the drivers who use the freeways infrequently said they do not use the freeways more often (or at all) because traffic is too fast, too heavy or too dangerous. These drivers constituted only 7.1 percent of the total (coded) population.

Only 2.6 percent of the "infrequent" freeway users said they did not use the freeways more often because they had "trouble finding their way." They represented less than one percent of the total sample. It is entirely possible that these persons have difficulty finding their way on any class of highway, and it is improbable (although possible) that changes in signing would materially benefit them. On the other hand, the difficulties experienced by the persons replying to the next question (Question VIII) illustrate a need for better signing.

TABLE 21

FREQUENCY OF FREEWAY USAGE BY AGE GROUP (WOMEN)

Los Angeles Study

	Frequency of Freeway Usage % of Each Age Group				
Age Groups	Once Per Day Or Oftener	One To Four Times Per Week	Two To Four Times Per Month	Once Per Month Or Less	% of Female Sample In Each Age Group
21 - 25	15.38	34.62	15.39	34.62	8.93
26 - 30	18.18	25.45	16.37	40.00	18.90
31 - 35	9.84	26.23	21.31	42.62	20.96
36 - 40	5.45	30.91	12.73	50.91	18.90
41 - 45	7.14	25.00	10.71	57.14	9.62
46 - 50	10.53	26.32	21.05	42.10	6.53
51 - 59	13.79	27.59	6.90	51.73	9.97
60 - 69	6.67	26.67	20.00	46.67	5.15
70 and over	0.00	33.33	33.33	33.33	1.03
All Ages	11.00	27.83	15.81	45.37	100.0

TABLE 22

REASONS FOR INFREQUENT FREEWAY USAGE

Los Angeles Study

Reasons	Number Answering	%
Freeways do not go to right places, or does not travel much	204	66.89
"Don't like to drive on freeways" (no additional comment)	19	6.23
Traffic too fast on freeway	34	11.15
Traffic too heavy on freeway	21	6.89
Driving on freeway too dangerous	11	3.61
Has trouble finding way on freeway	8	2.62
Lighting too poor for night driving	1	0.33
Too high speed and heavy volume	4	1.31
Can make better time on surface streets	2	0.66
Gets "pushed around" on freeway	1	0.33
Total	305	100.0

Question VIII

Over 700 respondents recalled "first-time trips"—trips during which they had used either a freeway entrance or an exit for the first time or both—and were subsequently asked subquestions "a" through "d" of Question VIII. Although these 720 responses to Question VIII were "first time" trips, in many cases either the entrance or exit had been previously used. Therefore, Tables 23 and 24 are divided into two columns, q.v.

For those who used freeway entrances for the first time, 19.5 percent encountered trouble of one kind or another. Some of the troubles were occasioned by congestion or heavy traffic; others were attributed to signing deficiencies. Troubles attributed to signing were experienced by 11.5 percent of those who used freeway entrances new to them, but by only 4.9 percent of those who had used the entrance before, a difference which is significant at the one percent level of confidence (that is, such a difference would occur by chance only one time in a hundred). These data are shown in Table 23.

For those respondents who used freeway exits for the first time, 21.4 percent encountered trouble of one kind or another. Troubles attributed to signing were experienced by 10.4 percent of those using exits for the first time and by only 2.8 percent of those who had used the exit before. This difference is significant at the four percent level of confidence (such a difference would occur by chance not more than four times in a hundred). These data are presented in Table 24.

The number of motorists who had troubles attributed to signing at entrances or exits they had used before, while significantly less than for first-time users, is still surprisingly high. Apparently these troubles are not exclusive to first-time users. In fact, finding that motorists who have used a ramp before have difficulty attributable to signing may indicate a greater deficiency than the fact that first-time users have such troubles.

TABLE 23

TYPES OF TROUBLES ENCOUNTERED AT FREEWAY ENTRANCES

	Los Angeles Study					
Type of Trouble	Were Using Ramp For First Time N=569 (%)		Had Used Ramp Before N=160 (%)		Total N=729 (%)	
No trouble	80.5		92.0		83.0	
Miscellaneous	4.4		1.2		3.7	
Delayed or diverted due to congestion	1.7		0.6		1.5	
Difficulty merging with freeway traffic	1.9		1.3		1.8	
Troubles attributable to signing:	11.5		4.9		10.0	
Insufficient advance notice		2.1		1.2		1.9
Insufficient directions to freeways		5.6		2.5		4.9
Confused by cardinal directions (choice)		0.4		0.0		0.3
Expected a left but found a right (vice-versa)		1.4		0.6		1.2
Misinterpreted sign message		0.9		0.0		0.7
Looking for non-existent ramp		0.9		0.0		0.7
Signs too small		0.2		0.6		0.3
Total	100.0		100.0		100.0	

TABLE 24

TYPES OF TROUBLES ENCOUNTERED AT FREEWAY EXITS

Los Angeles Study			
Type of Trouble	Were Using Ramp For First Time N=648 (%)	Had Used Ramp Before N=72 (%)	Total N=720 (%)
No trouble	78.6	87.5	79.5
Miscellaneous	7.6	4.2	7.2
Could not get into proper lane—heavy traffic	2.8	2.7	2.8
Merging traffic made it difficult to stay in lane	0.3	2.8	0.6
Rain, fog, etc., reduced visibility	0.3	0.0	0.3
Troubles attributed to signing:	10.4	2.8	9.6
Insufficient advance signing	4.8	1.4	4.5
Expected a left, found a right (vice-versa)	0.6	0.0	0.6
Seeking a non-existent exit	2.9	0.0	2.6
Misinterpreted a sign message	1.6	1.4	1.5
Confused by cardinal directions (choice)	0.5	0.0	0.4
Total	100.0	100.0	100.0

Table 25 shows the way it which first-time users expected to recognize their exit when they reached it. Seventy percent were expecting to recognize their exit by signs alone. It is interesting to note (Table 26) that only 43 percent found the particular message they were looking for. The others found some other cue or never found

TABLE 25

HOW MOTORISTS EXPECTED TO RECOGNIZE FREEWAY EXITS USED FOR FIRST TIME

Los Angeles Study	
Method of Anticipated Recognition	% Using
Street name	42.0
City name	1.8
Place name	3.5
Route number	0.6
Landmarks	
Bldgs., Tunnels, etc.	3.9
Streets, Roads, etc.	1.8
Configuration	3.6
Signs—no details	35.6
Signs plus landmarks	2.0
Did not know	5.2
Total	100.0

TABLE 26

METHOD OF ACTUAL RECOGNITION OF FREEWAY EXITS FOR A TRIP USING THE EXIT FOR THE FIRST TIME

Los Angeles Study	
Method of Recognition	% Using
By expected method	42.7
By other methods	
A sign—no detail	15.4
Street name sign	17.3
City name sign	0.8
Place name sign	2.5
Route number sign	0.3
Specific landmarks	
Bldgs., Tunnels, etc.	1.9
Streets, Roads, etc.	0.8
General configuration	1.6
Miscellaneous	10.8
Never reached or recognized	5.7
Total	100.0

their exit at all; in fact, about three percent were looking for exits which did not exist.

Slightly less than a third of the respondents (30.7 percent) arrived at their exit before they expected to, while 9.2 percent arrived later. The 40 percent who arrived at their exit either sooner or later than they expected represent 65.0 percent of all those who had troubles at freeway exits, and 76.5 percent of those who had troubles they attributed to signing. Those who arrived at their exit before they expected represented less than one-third of the total number of respondents but recorded nearly 52 percent of all troubles and two-thirds of troubles attributed to signing (Table 27).

At the end of the series of questions the respondents were asked if they had returned by the same route and, if so, whether they had encountered any trouble on the return trip. Sixty-five percent of the total respondents indicated that they had returned by the same route. Ten percent of these had difficulty entering the freeway and three percent had difficulty at the freeway exits (Table 28).

Question IX

A total of 538 motorists said they repeated a freeway trip regularly and were then asked sub-questions "a" through "m" of Question IX. One of the first questions asked was "What freeway do you use?" This was invariably answered by freeway name, not necessarily the name in current use. For example, the Pasadena Freeway occasionally was called the Arroyo Seco, and the San Bernardino Freeway was referred to as the Ramona.

The next question was "What route number is it?," to which 60.4 percent replied "I don't know," and 4.5 percent gave a wrong answer. These answers are shown in Table 29. The fact that only a third of the motorists knew the route numbers of the freeways they used regularly is probably attributable to the more frequent use of names over route numbers in urban driving. In any event, the acceptance of identifying freeways by name is clearly established in Los Angeles.

The ways in which motorists recognized freeway entrances are shown in Table 30, while Table 31 shows how they recognized freeway exits. A comparison of major groupings is shown in Table 32. Signs were used for exit recognition by 80 percent of the respondents, but for entrance recognition by only 49 percent. This difference is probably attributable in part to the fact that surface streets have more prominent landmarks and individuality than freeways, and in part to the superiority of the freeway exit signing.

Table 33 shows the results of the question, "Which direction do you go?". The interviewers recorded the statement of the respondent exactly as it was given. Cardinal

TABLE 27

TIME OF ARRIVAL AT EXIT AS RELATED TO TROUBLE EXPERIENCED
FIRST TIME MOTORISTS

Los Angeles Study

Trouble Experienced	Sooner (%)	Later (%)	When Expected (%)	Total
No trouble	25.7	8.1	66.2	100.0
Miscellaneous	35.9	20.6	43.5	100.0
Heavy traffic, etc.	53.3	6.7	40.0	100.0
Troubles associated with signing:	30.7	9.2	60.1	100.0
Insufficient advance notice	72.7	4.5	22.8	100.0
Look for non-existent exit	53.0	23.5	23.5	100.0
Misinterpreted a sign	66.7	11.1	22.2	100.0
Total—all troubles	51.8	13.6	34.6	100.0

directions were given correctly in 87.6 percent of the cases, and incorrectly in 9.1 percent. It is entirely possible that some portion of the latter erred in saying the direction; that is, they knew but simply said it wrong. In any event, 11.8 percent of the answers were wrong or improperly stated. A notable thing was that only one percent of the respondents used "inbound" - "outbound" and none used "right" or "left."

Each respondent was asked the names of the two exits preceding the one he had used. Exactly one-half of the respondents did not know either one, 23 percent knew both, while an additional 19.1 percent knew only the one immediately preceding the exit used. These replies are shown in Table 34.

Only 4.5 percent of the respondents knew all three items, namely, the direction of travel, both preceding exits and the

TABLE 28

NUMBER OF RETURN TRIPS OVER SAME ROUTE FOR TRIP USING FREEWAY EXIT OR ENTRANCE FOR FIRST TIME

Los Angeles Study		
Return Trip Description	% of Total	
The trip described was a return trip	3.5	
Did not return by same route	31.9	
Returned by same route:		
Had no trouble	52.7	
Had trouble:		
On-ramps		6.5
Off-ramps		1.4
Four-level interchange		2.3
All others		1.7
Total	100.0	

TABLE 29

KNOWLEDGE OF FREEWAY ROUTE NUMBERS FOR TRIP REPEATED REGULARLY

Los Angeles Study	
Knowledge of Route Numbers	% of Total
Said "Don't Know"	60.4
Gave a wrong answer	4.5
Gave partly correct answer	13.1
Gave correct answer	22.0
Total	100.0

TABLE 30

HOW FREEWAY ENTRANCES ARE RECOGNIZED BY MOTORISTS MAKING A TRIP REPEATED REGULARLY

Los Angeles Study	
Method of Recognition	% of Total
A sign—no details	12.7
City name sign	2.4
Signs directing to entrance	34.0
Specific landmarks	
Bldgs., Tunnels, etc.	5.1
Streets, Roads, etc.	4.2
Freeways—O'Pass, etc.	20.4
Landmarks and signs	5.5
General configuration	13.5
Could not describe	2.2
Total	100.0

TABLE 31

HOW FREEWAY EXITS ARE RECOGNIZED BY MOTORISTS MAKING A TRIP REPEATED REGULARLY

Los Angeles Study	
Method of Recognition	% of Total
A sign—no details	22.9
Street name sign	50.9
City name sign	1.9
Place name sign	4.2
Specific landmarks	
Bldgs., Tunnels, etc.	7.0
Streets, Roads, etc.	2.3
Signs and landmarks	4.0
General configuration	5.4
Could not describe	1.4
Total	100.0

TABLE 32

COMPARISON OF RECOGNITION METHODS FOR TRIPS REPEATED REGULARLY

Los Angeles Study		
	% of Total	
Recognition Method	Entrances	Exits
Signs	49	80
Landmarks	30	9
General configuration	14	5
All others	6	6
Total	100	100

TABLE 33

KNOWLEDGE OF DIRECTION OF TRAVEL AND METHOD OF DESCRIBING FOR TRIP REPEATED REGULARLY

Los Angeles Study	
Direction Description	% of Total
Cardinal directions	
Correct	87.6
Wrong	9.1
Inbound—Outbound	
Correct	0.6
Wrong	0.4
Said "Don't Know"	2.3
Total	100.0

TABLE 34

KNOWLEDGE OF TWO FREEWAY EXITS PRECEDING ONE USED FOR TRIP REPEATED REGULARLY

Los Angeles Study	
Preceding Exit Knowledge	% of Total
Knew both	23.0
Knew only the one immediately preceding	19.1
Knew second preceding exit only	6.7
Knew both preceding exits but in wrong sequence	1.2
Did not know either one	50.0
Total	100.0

route number for their repeated trip. About one-fifth (20.5 percent) knew both of the preceding exits and the direction of travel.

During Question IX the interviewer shifted the orientation of the questioning to: "if I were to make the trip," and asked "when should I start watching for the turnoff?" The replies to this question are shown in Table 35. Answers were commonly phrased in terms of time or distance to the turnoff. Considering that these were regular trips, the distances and times given were surprisingly inaccurate in many cases, showing a disappointing lack of knowledge of the elapsed distance or time between freeway entrances and exits. Landmarks were cited in only 10.8 percent of the cases, while 15.4 percent said "when you see the sign," or, "keep watching the signs."

Finally each respondent was asked: "Is there a particular place where I might become lost?" Because of the tendency for respondents to mention other problems in reply to this question, and in order to keep them from recognizing signing as a primary concern of the interview, they were also asked: "Are there any other special problems I should look out for...?"

In the event of a "Yes" answer, the location and nature of the problems were recorded. There were 167 affirmative replies to the first question. For 55.7 percent the location mentioned was the 4-level interchange, and in another 9.0 percent the interchange of the Santa Ana and San Bernardino Freeways. There were 149 affirmative replies to the second question, dealing mostly with congestion and lane-changing problems. For 27.0 percent the location was the 4-level interchange, and for 10.0 percent the Santa Ana-San Bernardino Interchange. In addition, these two locations were frequently mentioned in the part of Question VIII dealing with a return trip. Congestion and heavy traffic were regarded by the respondents as the principal cause of their difficulties at the interchange, although signing deficiencies were repeatedly mentioned. The essence of the problem mentioned by motorists was the need to be in the proper lane at the proper time.

Question X

The purpose of this question was to determine the respondents' familiarity with the Los Angeles metropolitan area. Twenty locations (ten places of interest and ten cities or communities) had been selected to represent all regions of the Los Angeles area. The locations of these places are shown in Figure 17.

The driver was asked if he could tell how to reach each place, assuming that he had to start at one of several places. Usually the respondent's home was selected, although the interviewer could select as a starting point the respondent's place of work, the DMV office where the interview was being held, or downtown Los Angeles. When the respondent indicated that he could give directions to a place he was further asked if he would use a freeway to get there. On the next part of Question X one of these trips utilizing a freeway was selected by the interviewer for more detailed questioning.

The metropolitan area was divided into six zones to permit analysis of the respondent's knowledge of the total area as a function of the zone in which he lived. Figure 13 shows the zones into which the area was divided.

Table 36 shows the percent of the total number of persons living in each zone who could give directions from their home to each of the 20 places, and the rank order of familiarity is given for each of these places. In general, the farther away a place is, the smaller the number of persons who know how to reach it, for either cities as a group or places of interest as a group. Both the prominence and accessibility of the place also appear to be related to familiarity. There is an indication that length of residence is also a factor,

TABLE 35

HOW MOTORISTS DESCRIBED WHEN TO START WATCHING FOR FREEWAY EXITS ON A TRIP THEY REPEATED REGULARLY

Los Angeles Study	
Description	% of Total
After a stated distance	30.4
After a stated time	18.7
After passing a certain exit	24.7
"When you see the sign"	9.9
"Keep watching the signs"	5.5
After passing a landmark:	
Buildings	3.8
Other landmarks	4.4
Combinations of signs and landmarks	2.6
Total	100.0

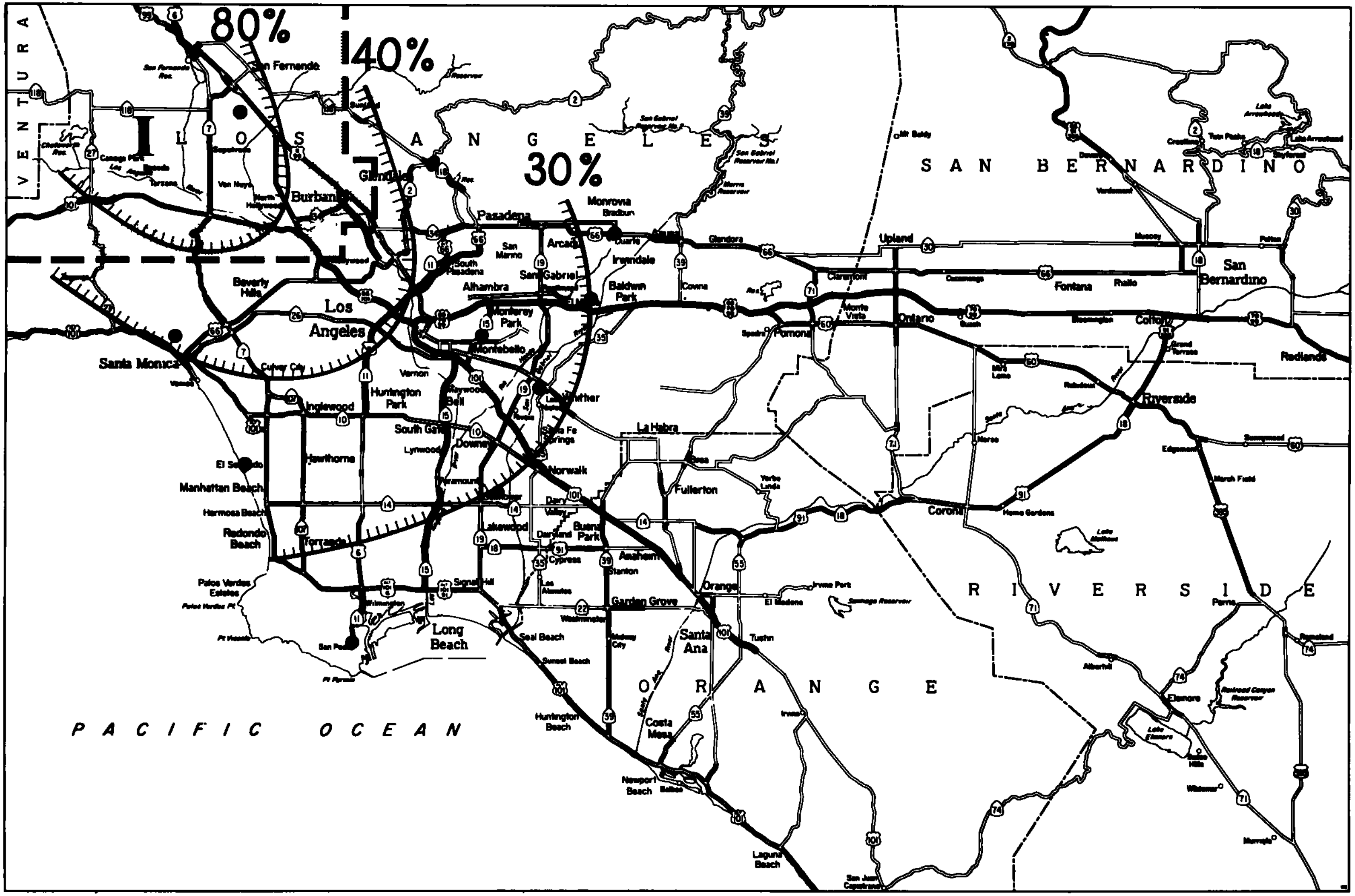


Figure 17. Map of Los Angeles— zone 1.

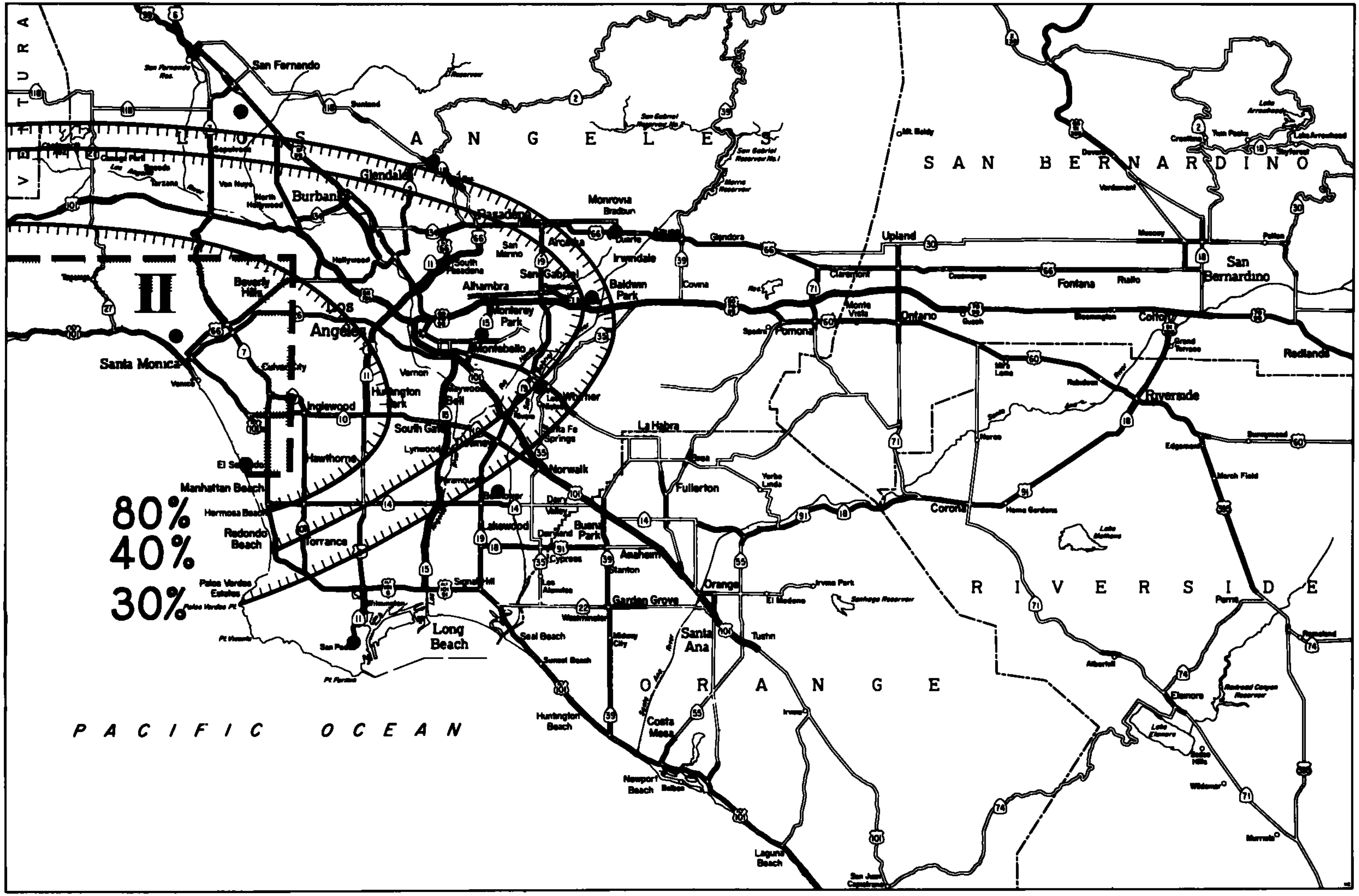


Figure 17a. Los Angeles— zone 2.

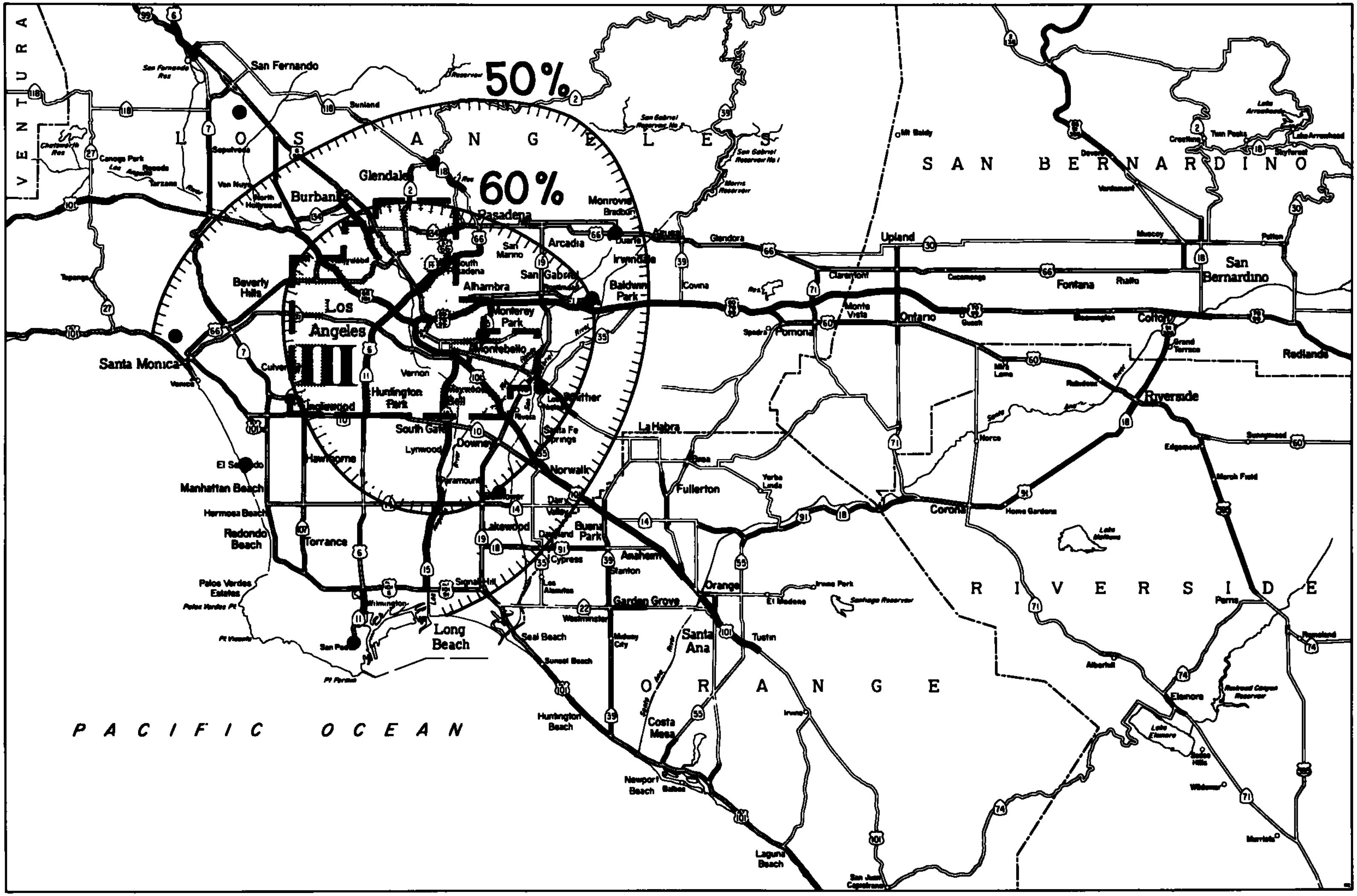


Figure 17b. Los Angeles—zone 3.

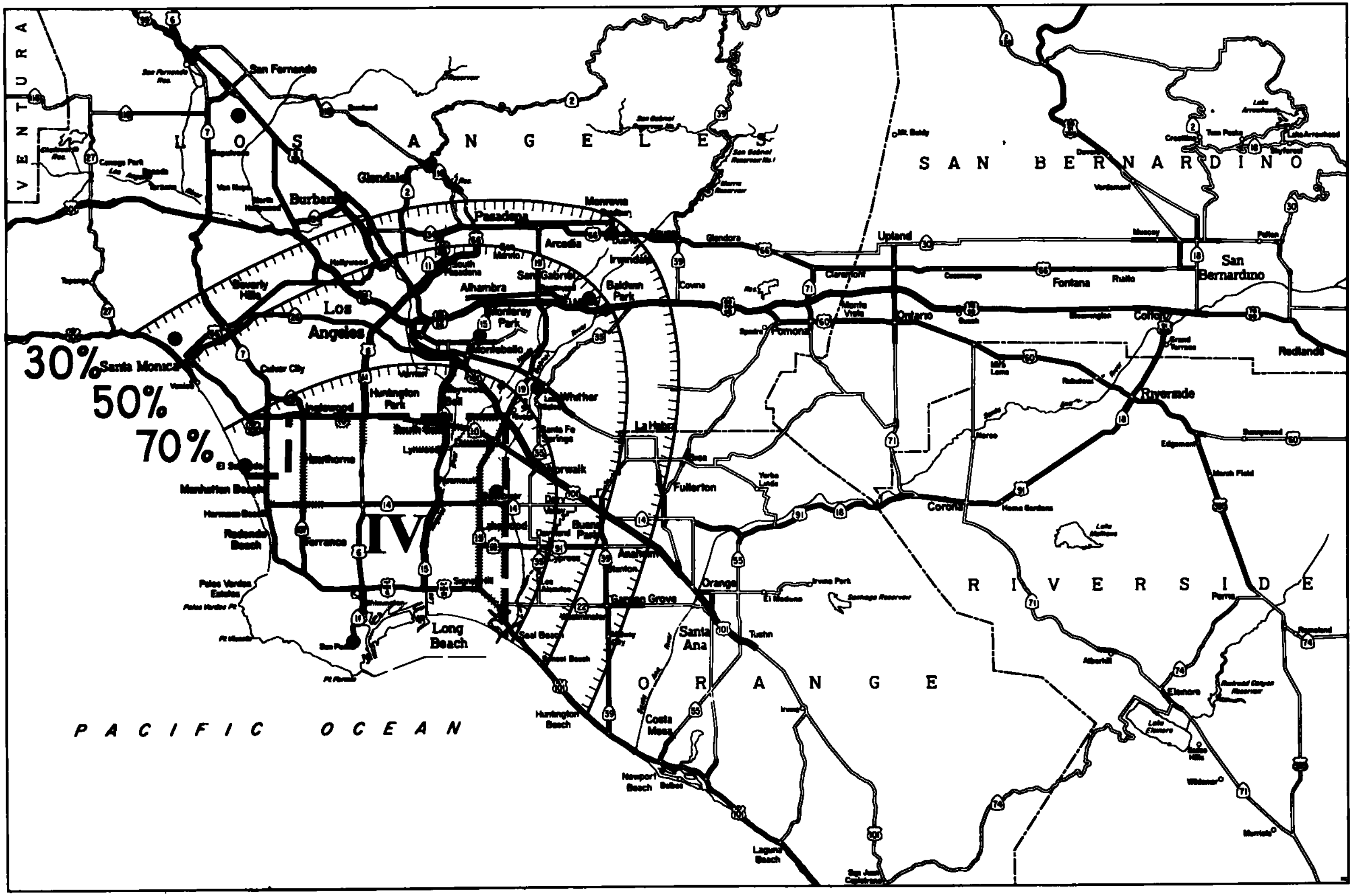


Figure 17c. Los Angeles— zone 4.

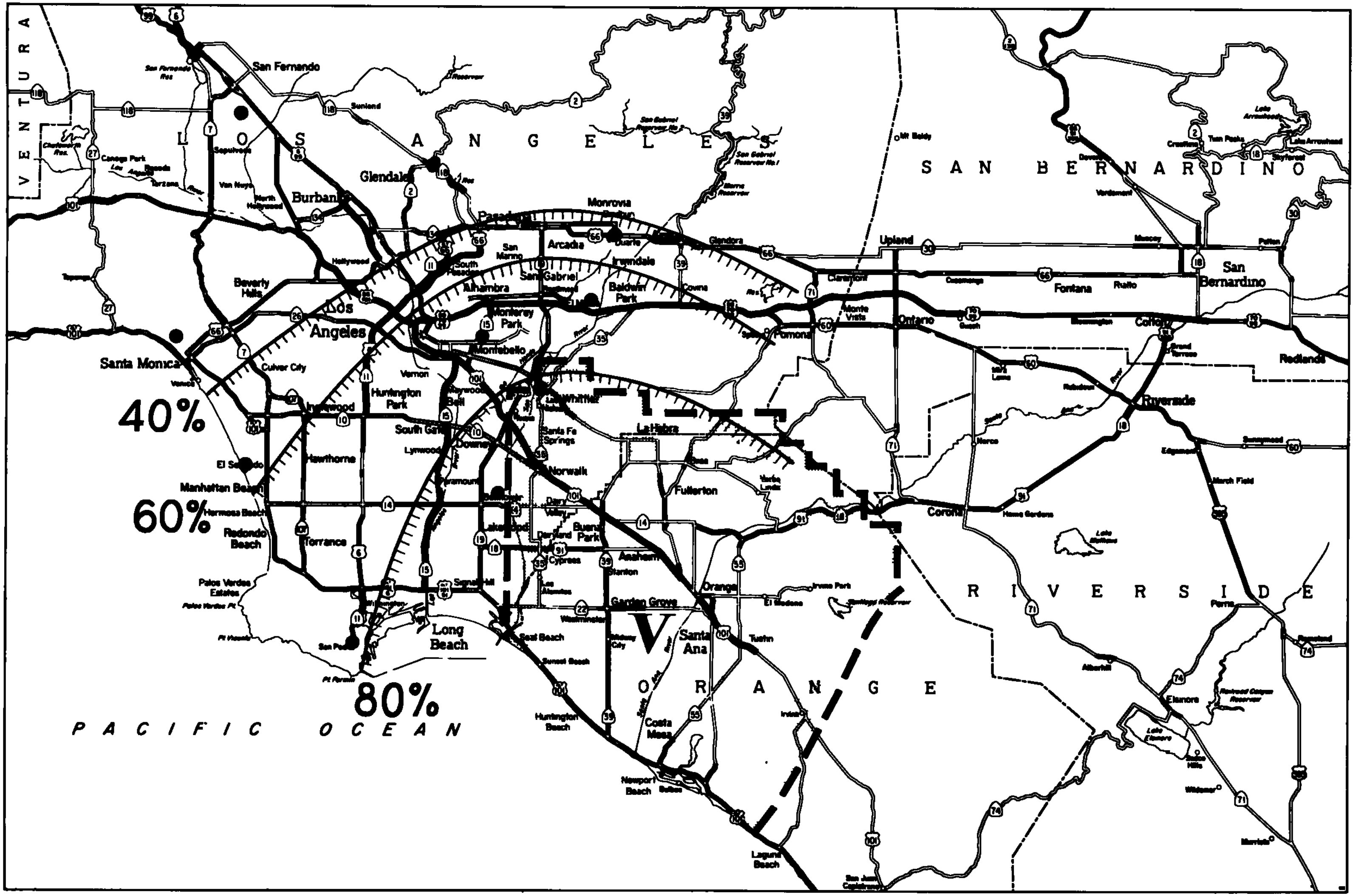


Figure 17d. Los Angeles— zone 5.

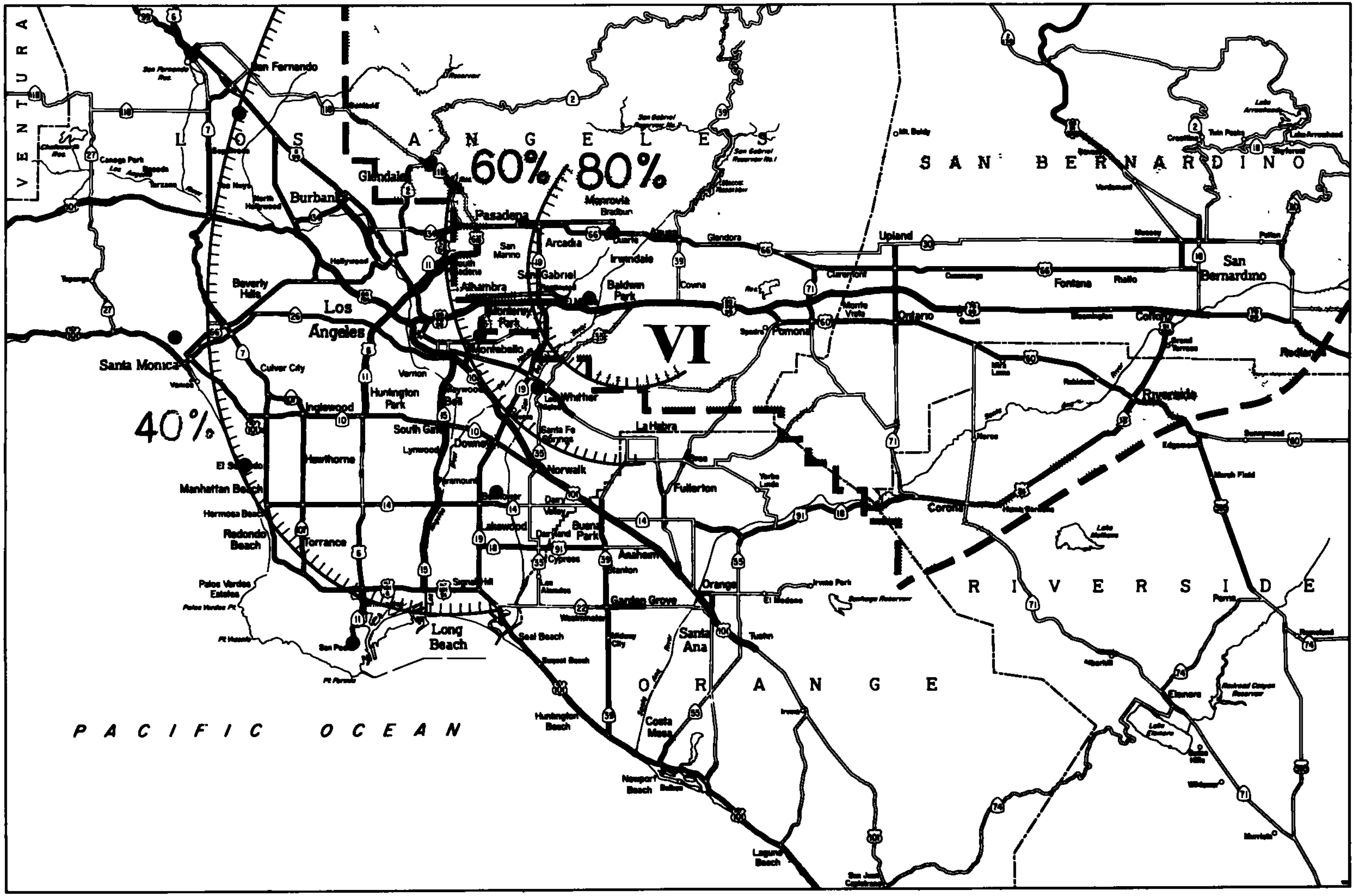


Figure 17e. Los Angeles— zone 6.

although the type of data collected does not permit a full analysis of this point.

These general findings were not unexpected. However, the rapid rate at which knowledge decreased as a function of distance is not only unexpected but is of considerable importance in signing practice. Figure 17 gives an example of this. These contour lines of knowledge are based on only eight of the ten cities or communities, because two of them (San Pedro and Monterey Park) were consistently "out of line" with the others. San Pedro always was better known than places equally far away because it is "Los Angeles Harbor" as well as a community; whereas Monterey Park was consistently less well known than places equally far away, probably because of its relative inaccessibility. Places of interest usually fell into at least the next higher contour than did those communities which are the same distance from the zone in question. Accessibility seems to be an important factor in some cases. For example, Los Angeles County Hospital, centrally located near (and clearly visible from) a freeway, is, however, difficult to reach, and thus was not nearly so well known as might have been expected.

It should be noted that nearly one-fourth of those who were asked to give directions to one of the places they had said they could give directions to were unable to do so. It is therefore probable that the contour levels imply a greater knowledge of the area than is actually posessed by the respondents. It is also important that these levels not be misconstrued as representative of those people who know how to get to these places. Many motorists said they thought they knew how to get there, but doubted if they could tell another person how. Oddly enough, 15.5 percent of the respondents said they would strike out for one of the places without first obtaining directions or consulting a road map (see Question XI).

In any event, the results clearly show that local residents of the metropolitan area can be expected to need and use directional signs for trips beyond the immediate area of their residence. Directional signing is therefore not used exclusively by tourists or non-residents. In fact, in large metropolitan areas the most frequent users of directional signing may well be those people who reside in the area itself.

Question XI

"Hypothetical Trip Preparation" was obtained from Question XI. The term refers to the preparation (consulting a road map, asking directions, just starting to drive in the general direction...) which the respondents said they would make, in reply to the question, "What would you do if you had to go to (a specific one of the 20 destinations)?"

TABLE 36

FAMILIARITY WITH COMMUNITIES AND PLACES OF INTEREST IN THE LOS ANGELES AREA AS RELATED TO PLACE OF RESIDENCE

		Percent of subjects living in each zone able to give directions from their home to each destination													
		Zone I		Zone II		Zone III		Zone IV		Zone V		Zone VI		Total	
Destination	Zone	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank
Disneyland	V	51.5	6.5	58.7	8	57.9	11.5	54.9	10.5	83.5	5	57.1	10.5	61.0	10
L.A. Int'l Airport	II	60.6	5	92.1	1	73.8	3	80.5	4	69.7	7.5	67.9	6	76.9	3
Forest Lawn Cem.	III	51.5	6.5	41.3	10.5	70.1	6	28.4	18	33.0	18	60.7	9	40.9	17
Rose Bowl	VI	45.4	8	36.5	14	60.7	8.5	35.0	14	52.3	11.5	75.0	4.5	45.4	14
Coliseum	III	39.4	10.5	57.1	9	72.9	4.5	72.0	8	69.7	7.5	53.6	13.5	67.5	5
Hollywood Park	IV	27.3	16.5	68.3	7	60.7	8.5	72.8	7	49.5	14	53.6	13.5	62.5	9
City Hall	III	78.8	2.5	73.0	6	91.6	1.5	85.2	1	84.4	4	75.0	4.5	84.1	2
Lockheed Air Term.	I	75.8	4	38.1	12.5	53.3	17	31.9	16	42.2	16	53.6	13.5	41.7	15
Union Station	III	78.8	2.5	76.2	4	91.6	1.5	84.8	2	89.0	1	78.6	3	85.3	1
L.A. County Hosp.	III	24.2	18.5	33.3	15	56.1	13	44.0	13	52.3	11.5	53.6	13.5	45.9	13
Pacific Palisades	II	39.4	10.5	85.7	2	53.3	17	45.1	12	39.4	17	39.3	19.5	49.2	12
Pacoima	I	81.8	1	25.4	17.5	35.5	20	19.8	19	23.9	20	39.3	19.5	28.3	20
La Canada	VI	36.4	12.5	27.0	16	53.3	17	17.5	20	30.3	19	57.1	10.5	30.2	19
El Monte	VI	30.3	15	38.1	12.5	57.9	11.5	54.9	10.5	74.3	6	82.1	2	57.1	11
Whittier	V	33.3	14	41.3	10.5	66.3	7	65.0	9	88.1	2	64.3	7.5	65.2	6
El Segundo	II	36.4	12.5	82.5	3	54.2	14.5	73.2	6	51.4	13	42.9	17.5	63.3	8
San Pedro	IV	42.4	9	74.6	5	72.9	4.5	84.0	3	67.9	9	42.9	17.5	73.9	4
Bellflower	IV	24.2	18.5	23.8	19	59.8	10	73.5	5	86.2	3	50.0	16	64.3	7
Monterey Park	VI	18.2	20	20.6	20	54.2	14.5	32.7	15	62.4	10	64.3	7.5	41.4	16
Monrovia	VI	27.3	16.5	25.4	17.5	52 3	19	31.5	17	47.7	15	89.3	1	40.0	18
Number of subjects		33		63		107		257		109		28		597	

This destination was one of those the respondent had said he could not give directions to in Question X.

This information is of questionable value. When compared with the actual preparation made in a somewhat similar situation by the same respondents (Table 37), the disparity between what they said they would do and what they actually did is so great as to cast considerable doubt on the validity of the data from Question XI. The replies were so heavily influenced by each respondent's desire to give answers which are "proper" or "logical" that the information so obtained is subject to question. One purpose of Question XI was to determine the sources of information which the respondents might use. No new sources appeared in the answers. Less than two percent gave answers other than those anticipated. These "answers" were not classifiable, such as: "I would never go to that place."

TABLE 37

A COMPARISON OF HYPOTHETICAL TRIP PREPARATION WITH ACTUAL TRIP PREPARATION FOR A NEW TRIP

Los Angeles Study		Hypothetical Trip Preparation					Totals	
Actual Trip Preparation		Look It up on Map	Ask Directions	Both Map and Directions	Just Start Driving	Other	No.	%
Used road map		93	3	4	13	-	113	16.4
Asked directions		101	34	12	12	3	162	23.5
Both map and directions		3	-	-	-	-	3	0.4
Neither map nor directions		232	47	31	81	9	400	58.1
Misc. answers		7	2	1	1	-	11	1.6
Totals	Number	436	86	48	107	12	689	
	%	63.3	12.5	7.0	15.5	1.7		100.0

TABLE 38

TABULATION OF SIGNING COMMENTS—SUMMARY

Los Angeles Study	Signing to Freeway from Regular Streets		Signing on Freeways to Cities or Areas		Signing on Freeways to Turnoffs	
Comments	No.	%	No.	%	No.	%
"Good"—no additional comment	485	50.6	649	69.2	754	78.3
"Bad"—no additional comment	28	2.9	27	2.9	23	2.4
"Good and Bad"—no additional comment	18	1.9	12	1.3	14	1.5
"Specific" favorable comments	-	-	-	-	7	0.7
"Specific" unfavorable comments	428	44.6	237	25.3	165	17.1
Misc. neutral comments	-	-	13	1.4	-	-
Total people answering	959		938		963	

Neither the Los Angeles study nor the other studies provided data which showed any correlation between "trip preparation" and "trip success." This does not necessarily mean that there is no correlation; a great deal more would have to be known about each respondent's degree of familiarity with his route and the other assistance he might have had (such as that from passengers) before any such conclusion could be reached.

Question XII - Opinion on Signing

Table 38 shows the comments made by respondents regarding signing to freeways, signing on freeways to cities or areas, and signing to turnoffs. Tables 39, 40 and 41 show the ten most frequently made comments concerning each of these three types of signing, respectively.

Of the three types of signing, signing to freeways came in for the major share of criticism. Of all respondents answering this question, nearly half (47.5 percent) made adverse comments while only 50.6 percent gave "Good" as an unqualified answer. Of all the adverse comments made, "Not enough advance notice" was most frequently mentioned (by 159 respondents, or 16.6 percent of all those answering the question). Close behind was "Not enough signs," mentioned by 154 respondents (16.1 percent).

Signing on freeways to cities and areas came under less criticism, although 28.2 percent of the respondents indicated disfavor. By far the most frequent comment (as is to be expected) was that there were not any (or not enough) such signs. Also noteworthy is the fact that seven respondents felt that there were too many signs on the freeway system already, and that addition of others would only serve to create more difficulty for the driver. Apparently, recognition of the possible deleterious effects of over-signing is not restricted to highway officials.

The respondents indicated less criticism of freeway turnoff signing than of any other type. Field investigations showed that freeway turnoff signing is more consistent and up-to-date than the other types which were observed to be much less adequate from the standpoint of either number or location.

Only 19.5 percent of the respondents

TABLE 39

TEN MOST FREQUENT COMMENTS REGARDING SIGNING TO FREEWAY ENTRANCES

Comment	Number of Times Recorded
Not enough advance notice	80
Not enough signs	57
Not enough signs and not enough advance notice	52
Not enough signs and poorly located	34
Signs are too small and not enough advance notice	27
Signs are too small and poorly located	21
Not enough signs and too small	21
Not enough or unclear information	18
Not enough indication of proper lane to be in	17
Signs are too small	15
Total	342[1]

[1] This represents 80 percent of all adverse comments made.

TABLE 40

TEN MOST FREQUENT COMMENTS REGARDING SIGNING TO CITIES OR AREAS

Comment	Number of Times Recorded
There are no such signs, or I've never seen any	72
There are not enough signs of this kind	60
Not enough advance notice	35
Should be signs showing names of cities approached	9
Signs are too small and not enough advance notice	9
Should be more signs giving distance to cities or places	8
Signs are too small	7
Have enough (too many) signs (of all types) already without adding others	7
Signs should show intermediate or nearby destinations	7
Signs should show cities being passed through	5
Total	219[1]

[1] This represents 88 percent of all adverse or neutral comments.

TABLE 41

TEN MOST FREQUENT COMMENTS REGARDING SIGNING TO FREEWAY TURNOFFS

Comment	Number of Times Recorded
Signs do not give enough advance notice	84
The information given is confusing	10
Signs listing next three turnoffs with distances to them are good	7
Not enough information given after leaving the freeway	7
Signs are too small	5
Should indicate lane to use rather than distance to turnoff	5
Signs are too small and not enough advance notice	4
Signs are too far in advance	4
There should be signs which tell what city you are in	4
Signs do not attract attention	4
Total	134[1]

[1] This represents 77 percent of the adverse comments and all of the good comments.

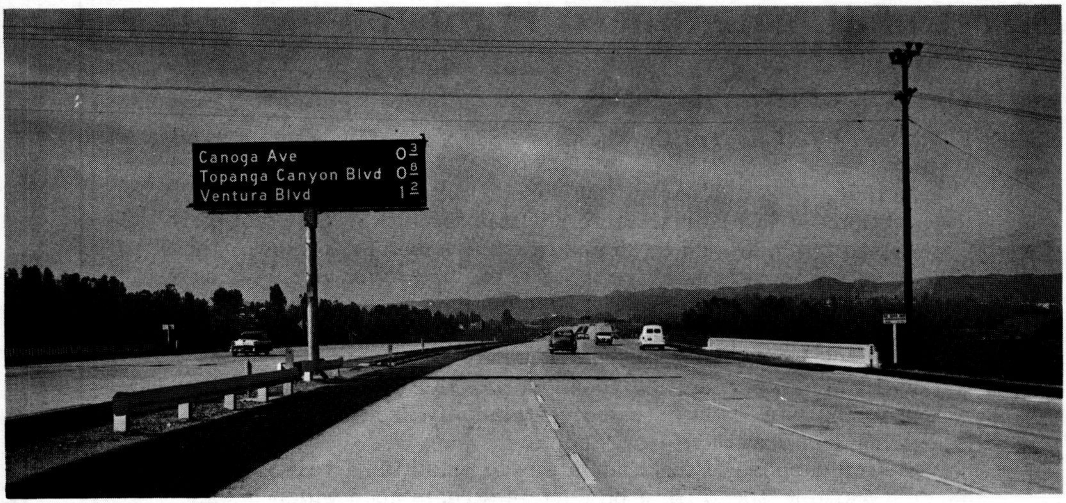


Figure 18.

found fault with freeway turnoff signing. Nearly half of these complained of the lack of advance warning, a criticism which consistently appeared in the other sub-studies.

A relatively new sign (illustrated in Figure 18) which gives the names and distances to the next three exits was specifically praised by seven respondents, a surprisingly large number considering the few such signs in use in the Los Angeles area at that time. This sign probably was singled out for favorable comment because it fulfills the need most commonly expressed in the various studies—more advance warning.

ACKNOWLEDGMENT

Invaluable assistance in the conduct of this study was given by the Automobile Club of Southern California; the California Highway Patrol; the Department of Motor Vehicles, and personnel of the Traffic Engineering Department and Districts V, VI and VII of the Division of Highways. Particular thanks is due George M. Webb for his assistance and counsel during all phases of the study.

Effect of Raising Speed Limits on Urban Arterial Streets

EUGENE V. AVERY, City Traffic Engineer, St. Paul, Minnesota

In 1956, 1957 and early 1958 speed limits on about 22 mi on portions of 11 arterial streets within the City of St. Paul were raised from 30 mph to 35 and in some cases to 40 mph. The streets affected carry from 4,000 to 26,000 veh per day, have no special access control, and are adjacent to a variety of land uses. Most of the spot speeds involved are from 25 to 40 mph. The new limits were set substantially in accordance with the "85 percentile" speed, a practice widely used on rural roads but not, it is believed, extensively used within municipalities on local arterial streets.

The purpose of the change was to establish a reasonable and enforceable speed limit on certain streets upon which it was obvious that the 30 mph limit was unreasonably low. Extensive "before" and "after" studies of the speed characteristics were conducted; the results are reported hereinafter. It is hoped that these findings will be of assistance to those contemplating a speed rezoning program on major streets within municipalities.

CONDUCT OF STUDY

Selection of Streets

● ON THE BASIS of spot speed sampling studies, 11 streets were selected upon which most drivers exceeded substantially the blanket 30 mph speed limit generally in effect throughout the city. On these streets, speeds of 5 to 10 mph higher than the limit were judged to be safe, this judgment being based on trial runs and such considerations as cross traffic characteristics, sight distance, pedestrian movements, street widths and conditions, parking and land use. Prior to the speed limit change, signs indicating the 30 mph limit were in place, but there appeared to be a tacit understanding by all concerned that speeds of 35 or 40 mph were permissible and safe. Shown in Table 1 are the percentages of violation of the 30 mph speed limit.

The streets selected all had pavements in fair to good condition but represented a variety of other conditions as is illustrated in Table 2.

Study Location and Conditions

Sites for conduct of "before" and "after" studies along the streets were selected insofar as possible where traffic was free-flowing and well removed from turning movements, traffic signals, stop signs, congestion, excessive parking, etc. All studies were conducted in fair weather, with dry pavement and during the off-peak traffic hours. In short, every effort was made to conduct the studies at such a time and place that drivers could select freely their travel speed. "Before" and "after" studies were conducted at approximately the same hours of the day, and on the same day of the week. Although speed limit signs were posted within 1,000 ft of most of the study sites, there were several locations where the distances were greater (Table 3). However, the locations were such that nearly all approaching traffic passed at least one sign prior to passing the study site. Enforcement efforts were moderate and about the same both before and after the speed limit change. The studies were scheduled as much as possible to avoid any unusual circumstances such as street repair, special events, etc.

Shepard Road, although substantial traffic volume increases were expected and occurred, was included in the study since speed zoning studies were necessary in any event because of the impending opening of a newly constructed roadway.

No major effort was made as a part of this study to influence or evaluate the publicity attending the speed limit changes. The proposed changes and the reasons for them were reported in a routine way by newspaper, radio, and television media prior to and at the time of the change.

TABLE 1

OBSERVANCE OF 30 MPH LIMIT

Street	% of Vehicles Exceeding Limit
Como Ave.	71.9
Concord St.	78.5
Dayton Ave.	33.2
Jefferson Ave.	94.5
Marshall Ave.	68.6
McKnight Road	92.7
Pleasant Ave.	76.3
Robert St.	52.0
Seventh St.	54.4
Shepard Road	72.2
Summit Ave.	62.6
Avg	68.8

Speed Measurement Method

Three separate series of speed studies were undertaken, a "before" study, an "after" study two to four months after the speed limit raise, and an "after" study six months or longer after the speed limit raise.

The surveys consisted of spot speed determination by means of stop watch measurements over an 88 or 176 ft measured course. Enoscopes were used for most of the surveys. The stop watches used had 10-sec sweeps and could be read accurately to the nearest 0.1 sec.

Before the field speed checks were started, an estimate of the required sample size was made. The probable standard deviation was estimated, on the basis of several pilot studies, at 5 mph. The maximum desired difference in the mean was designated as 0.5 mph. The desired level of significance assumed was 5 percent. The required sample size was then computed for a normal distribution curve as follows:

TABLE 2

CHARACTER OF STREETS[1]

Street	Approx. Length (mi)	Typical Width (ft)	Typical Parking Use	Typical Daily Volume	Number Signals or Stops	Typical Land Use
Como	2	58-40	Varies[9]	15,000 9,000	2[4]	Commercial - residential
Concord	1	56	Minor	12,000	0[5]	Residential
Dayton[7]	1½	36	One side	9,000	2[4]	Residential
Jefferson	½	44	Negligible	9,000	0[4]	Vacant
Marshall[8]	4½	32-48-52	Varies[9]	9,000 20,000	9[3]	Residential
McKnight	1	(2) 32[2]	Negligible	4,000	0[3]	Residential - vacant
Pleasant	1½	50-56	Negligible	7,000	1[4]	Residential - vacant
Robert	2	56-30-46[6]	Varies[9]	20,000 11,000	2[4]	Commercial - residential
East Seventh	1	56	Varies[9]	26,000 16,000	4[4]	Commercial
East Seventh	1½	40	Minor[9]	11,000 5,000	0[4]	Residential
Shepard Road	1	40	None	8,000	2[4]	Industrial
Summit	4½	48 (2) 28[2]	Varies	8,000 15,000	6[3]	Residential

[1] Figures do not include those frequently existing at one or both ends of project.
[2] Divided parkway type of street.
[3] Stopped or signalized at both ends of project.
[4] Stopped or signalized at one end of project.
[5] Not stopped or signalized at either end of project.
[6] The 30-ft width is on underpass where parking is banned.
[7] One-way street with parking banned on one side.
[8] The narrower portion is one-way with parking banned on one side.
[9] Parking banned in certain areas either rush hours or permanently.

$$N = \left(\frac{C\ \ S}{D}\right)^2$$

$$N = \left(\frac{1.96\ \ (5)}{0.5}\right)^2$$

N = 384 (use 400)

Where N = required number of samples.

C = Z value for 5 percent of significance.

S = estimated standard deviation.

D = assigned difference in the means.

TABLE 3

DISTANCE TO NEAREST SPEED LIMIT SIGN

Street	Location	Study Reference Number	Direction	Distance to Sign
Como	Elfelt to Galtier	1	WB	600
			EB	200
	E. of Topping	2	WB	700
			EB	200
Concord	Near Brown	3	SB	800
			NB	1,000
Dayton	Avon to Grotto	4	EB	500
Jefferson	E. of Lexington	5	WB	200
			EB	100
Marshall	Avon to Grotto	6	WB	800
			EB	1,500
	W. of Syndicate	7	WB	1,200
			EB	300
	Aldine to Herschel	8	WB	600
			EB	1,000
McKnight	Fourth	9	NB	3,000
			SB	2,000
Pleasant	E. of St. Albans	10	EB	400
			WB	200
Robert	Chicago to Plato	11	SB	200
			NB	200
	N. of Winona	12	SB	200
			NB	200
Seventh	W. of Eichenwald	13	WB	1,100
			EB	800
	W. of Birmingham	14	WB	1,600
			EB	1,000
Shepard Road	W. of Jackson to Elm	15	EB	1,000
Summit	Victoria to Avon	16	EB	1,200
			WB	2,000
	W. of Hamline	17	EB	200
			WB	200
	Pierce to Aldine	18	EB	1,200
			WB	1,000

It was assumed, therefore, that a sample size at each location of about 400 was required for the desired results, and this number was obtained in nearly all cases. Subsequent analysis of the data obtained confirmed the validity of assuming that with this sample size, any change in the "before" and "after" mean of more than 0.5 mph would be 95 percent certain to be due to a factor other than chance.

Speed Limit Revision

On the basis of analysis of the "before" data, determination of the 85 percentile speeds, and a judgment of conditions present, the former speed limits and signs of 30 mph were replaced with 35 or 40 mph (Table 4). Results of the "before" study are shown in Tables 5 through 11.

ANALYSIS OF DATA

Speed Changes

In evaluating the results of the speed limit changes, the effect on driving speeds was considered to be of fundamental importance. A number of comments were received at the time of the speed limit change to the effect that raising the speed limit 5 or 10 mph would mean that all drivers would automatically speed up by that amount. In order to evaluate this characteristic, "before" and "after" comparisons were made of the mean, median, modal and 85 percentile speeds.

In the analysis of the "before" and "after" mean speeds, a test of statistical significance was performed using the standard error of the difference of the means as follows:

$$D = \sqrt{\frac{S_1^2}{N_1} + \frac{S_2^2}{N_2}}$$

TABLE 4

SPEED LIMIT CHANGES

Street	Location	Study Reference Number	Date of Limit Change	New Limit (mph)
Como Ave.	Elfelt to Galtier	1	2-4-58	35
	E. of Topping	2	2-4-58	35
Concord St.	Near Brown	3	6-24-57	35
Dayton	Avon to Grotto (1-way)	4	1-31-58	35
Jefferson	E. of Lexington	5	11-21-57	40
Marshall	Avon to Grotto	6	1-31-58	35
	W. of Snydicate	7	1-31-58	35
	Aldine to Herschel	8	1-31-58	35
McKnight	Near Fourth	9	6-15-56	40
Pleasant	E. on St. Albans	10	6-27-57	40
Robert St.	Chicago to Plato	11	2-3-58	35
	N. of Winona	12	2-3-58	35
Seventh St.	W. of Eichenwald	13	2-5-58	35
	W. of Birmingham	14	2-5-58	35
Shepard Rd.	W. of Wabasha	15	7-11-56	40
Summit Ave.	Victoria to Avon	16	6-25-57	35
	W. of Hamline	17	6-25-57	35
	Pierce to Aldine	18	6-25-57	35

Where D = significant difference in means.
S_1 = standard deviation "before."
S_2 = standard deviation 6 to 24 months "after."
N_1 = number of measurements in "before" sample.
N_2 = number of measurements in "after" sample.

The D value was computed in each case and multiplied by 1.96 to arrive at the numerical difference in means which would be significant for a 5 percent significance level. It may be assumed, therefore, that where a greater numerical difference occurred, there exists a 95 percent certainty that the difference is due to a factor other than chance. The results are shown in Table 5. It will be noted that at the 18 study locations, six had a significantly higher mean, eight had a significantly lower mean, three had a lower but not significant mean, and one an increased but not significant mean.

The median, modal, and 85 percentile comparisons are shown in Tables 6, 7 and 8. Two sets of "after" studies are reported, one within 2 to 4 months and one within 6 to 24 months. This was done to check whether there would be continuing or reversing changes after a longer time period. It will be noted that some "after" values are slightly increased, some slightly decreased, and some unchanged from the "before" values. Changes in the longer time period do not appear appreciably different from those of the shorter period.

TABLE 5

CHANGES IN MEAN SPEED

Street[1]		Reference Number	"Before" mph	"After" (6-24 mo.) mph	Significance[2]
Como	(35)	1	32.5	32.3	No
	(35)	2	35.3	34.2	Yes
Concord	(35)	3	33.9	34.0	No
Dayton	(35)	4	29.8	31.9	Yes
Jefferson	(40)	5	34.6	36.2	Yes
Marshall	(35)	6	32.2	31.4	Yes
	(35)	7	34.0	32.0	Yes
	(35)	8	33.5	32.8	Yes
McKnight	(40)	9	40.9	37.1	Yes
Pleasant	(40)	10	33.3	34.4	Yes
Robert	(35)	11	31.6	31.2	No
	(35)	12	34.5	30.5	Yes
Seventh	(35)	13	30.0	33.3	Yes
	(35)	14	32.3	31.3	Yes
Shepard	(40)	15	33.5	37.4	Yes
Summit	(35)	16	31.0	33.1	Yes
	(35)	17	34.5	33.9	Yes
	(35)	18	32.9	32.6	No
Avg	(35)		32.7	32.5	
	(40)		35.6	36.3	

[1] Values shown in parenthesis are the new limits in each case. The former limits were a blanket 30 mph.
[2] Whether the difference in "before" and "after" means was greater than 1.96 x standard error. This assumes a 95 percent confidence level.

Uniformity of Speeds

Another important speed characteristic is the tendency toward more uniform speeds. In evaluating this trait, two approaches were used. The first, a determination of the percent of vehicles in the 10 mph pace, involved a computation of the percent of vehicles within the 10 mph range having the greatest number of speeds. The second method involved computing the speed range containing a given percentage of drivers. In the latter method, computations were made of the speed range representing one standard deviation from the mean. The results of these two analyses are shown in Tables 9 and 10. Computations are presented for the time period of 6 to 24 months after the speed limit change. It will be noted that in 11 cases the percent of vehicles within the pace increased, and in seven cases there was a decrease.

In the pace analysis, of course, a tendency toward more uniformity of speeds would be shown by increases in the percent of vehicles within the pace. With respect to the standard deviation, a tendency toward more uniformity of speeds would be shown by decreasing values. It will be noted in Table 10 that there were eight increases and ten decreases in the standard deviation.

The absence of any apparent tendency toward more uniformity of speeds is, of course, contrary to some previous findings with respect to speed zoning on rural highways. For example, Matson, Smith, and Hurd (4) report on rural highways a tendency toward greater uniformity after zoning. There are several factors which may explain the discrepancy. The streets reported on herein rather than being rural are urban arteries in built-up areas with a variety of adjacent land use. The average running speeds on the urban streets are much lower than on rural highways. The study reported herein involved raising the limit slightly at locations already zoned but where the former speed limit was lower than most drivers desired to travel. Traffic volumes on the urban

TABLE 6

CHANGES IN MEDIAN SPEED

Street[1]		Reference Number	"Before" mph	"After" (2-4 mo.) mph	"After" (6-24 mo.) mph
Como	(35)	1	31.7	32.6	31.9
	(35)	2	32.8	32.9	33.5
Concord	(35)	3	32.5	31.2	33.1
Dayton	(35)	4	29.0	31.3	31.4
Jefferson	(40)	5	33.0	33.1	35.3
Marshall	(35)	6	31.0	31.4	31.1
	(35)	7	32.9	31.8	31.6
	(35)	8	32.0	32.3	31.9
McKnight	(40)	9	39.4	36.0	36.4
Pleasant	(40)	10	32.2	32.4	34.0
Robert	(35)	11	30.7	32.0	30.7
	(35)	12	29.7	31.4	29.9
Seventh	(35)	13	29.6	30.6	32.8
	(35)	14	31.7	31.4	30.6
Shepard	(40)	15	32.8	-	37.0
Summit	(35)	16	29.3	29.8	32.4
	(35)	17	32.7	31.1	33.3
	(35)	18	31.9	31.4	31.8
Avg	(35)		31.2	31.5	31.9
	(40)		34.5	33.8	35.7

[1] Values shown in parenthesis are the new limits in each cast. The former limits were a blanket 30 mph.

arteries involved in this study were, in general, greater than those typically found on rural highways.

Speeds and Posted Limit

One of the primary aims of speed zoning is to set a limit at the maximum safe speed and to achieve substantial voluntary compliance with the limit set. In order to evaluate these factors and also to further measure any tendency for all drivers automatically to speed up 5 or 10 mph when the limits are raised by these amounts, "before" and "after" determinations were made of the percent of drivers at or below the posted limit. The results are shown in Table 11. It will be noted that substantial increases in compliance were obtained with the higher speed limits, a definite indication that drivers do not tend to speed up by the limit change. The new limits are obviously more enforceable.

Need For Further Study

This report has been concerned only with the change in off-peak speed characteristics resulting from a 5 or 10 mph raise in the speed limit on several urban arterial streets. The typical speed range involved is 25 to 40 mph, and the speed zoning procedure was the so-called 85 percentile method. The conduct of the study and the report thereon have suggested several related areas in which additional study might be fruitful. These include the following:

1. A detailed study of "before" and "after" accident characteristics. In view of the minor nature of the speed changes in this particular study, little or no change was

TABLE 7

CHANGES IN MODAL SPEED

Street[1]		Reference Number	"Before" mph	"After" (2-4 mo.) mph	"After" (6-24 mo.) mph
Como	(35)	1	33.3	33.3	32.4
	(35)	2	33.3	33.3	34.4
Concord	(35)	3	33.3	30.0	35.2
Dayton	(35)	4	30.0	35.3	31.6
Jefferson	(40)	5	33.3	35.3	40.0
Marshall	(35)	6	31.6	35.3	31.6
	(35)	7	35.3	35.3	32.4
	(35)	8	31.6	35.3	31.6
McKnight	(40)	9	42.8	35.3	36.4
Pleasant	(40)	10	33.3	33.3	35.2
Robert	(35)	11	30.0	33.3	30.0
	(35)	12	30.0	33.3	30.0
Seventh	(35)	13	31.6	30.0	34.4
	(35)	14	33.3	33.3	30.0
Shepard	(40)	15	32.4	-	40.0
Summit	(35)	16	30.0	30.0	32.4
	(35)	17	33.3	33.3	34.4
	(35)	18	33.3	31.6	30.8
Avg	(35)		32.1	33.0	32.2
	(40)		35.5	34.6	37.9

[1] Values shown in parenthesis are the new limits in each case. The former limits were a blanket 30 mph.

anticipated in the number or type of accidents traceable to the speed limit revisions. An approximate check on yearly totals of accidents reported to the Police Department did not reveal any apparent change in the accident frequency trends on the streets involved. However, an analysis of the time of day, type, and severity of "before" and "after" accidents could conceivably show some change.

2. "Before" and "after" studies of rush hour speed characteristics. Observation indicates that rush hour speeds on these outlying arterials may tend to be higher than off-peak speeds, both before and after the speed limit changes.

3. A study of the effect of lowering limits where warranted. There are many streets where a blanket 30 mph limit, for example, is too high. A speed zoning program would normally involve reducing limits as well as raising them. It appears reasonable to assume that reducing a limit in accordance with the 85 percentile method would not result in a tendency toward a significant increase in speed.

4. Studies of the relation between speeds and varying but carefully controlled intensities of signing and enforcement on these types of urban arterial streets.

CONCLUSIONS

For urban speed zoning activities on the types of streets involved in this study and with typical spot speeds of 25 to 40 mph, the following conclusions appear warranted:

1. The generally accepted 85 percentile method of speed zoning, which includes trial runs, evaluation of adjacent land use, and related studies is satisfactory for use on urban arterial streets insofar as its effect on actual travel speeds is concerned.

2. Where justifiably higher limits of 5 or 10 mph are set in accordance with item 1 above, there is a definite tendency for the mean, median, modal, and 85 percential

TABLE 8

CHANGES IN 85 PERCENTILE SPEED

Street[1]		Reference Number	"Before" mph	"After" (2-4 mo.) mph	"After" (6-24 mo.) mph
Como	(35)	1	35.4	37.4	35.8
	(35)	2	36.6	37.6	37.3
Concord	(35)	3	36.8	33.7	36.8
Dayton	(35)	4	32.2	35.3	35.1
Jefferson	(40)	5	37.2	37.4	40.6
Marshall	(35)	6	35.4	36.1	34.9
	(35)	7	36.1	36.5	34.9
	(35)	8	37.1	36.5	36.3
McKnight	(40)	9	46.4	43.4	42.0
Pleasant	(40)	10	35.7	36.4	38.3
Robert	(35)	11	34.7	36.9	34.7
	(35)	12	37.3	35.4	33.9
Seventh	(35)	13	33.5	35.0	37.0
	(35)	14	36.8	35.9	34.9
Shepard	(40)	15	38.4	-	42.2
Summit	(35)	16	32.6	33.2	36.4
	(35)	17	36.9	34.7	37.2
	(35)	18	35.3	35.3	36.3
Avg	(35)		35.5	35.7	35.8
	(40)		39.4	39.1	40.8

[1] Values shown in parenthesis are the new limits in each case. The former limits were a blanket 30 mph.

TABLE 9

CHANGES IN PACE

Street[1]		Reference Number	"Before" Pace mph	"Before" Vehicles in Pace %	"After" Pace mph	"After" Vehicles in Pace %
Como	(35)	1	28.2-38.2	76.1	28.2-38.2	78.4
	(35)	2	29.5-39.5	73.5	29.7-39.7	76.8
Concord	(35)	3	29.3-39.3	81.6	29.0-39.0	83.3
Dayton	(35)	4	25.5-35.5	85.0	27.4-37.4	85.5
Jefferson	(40)	5	29.8-39.8	80.3	32.0-42.0	65.7
Marshall	(35)	6	28.0-38.0	73.5	27.0-37.0	80.0
	(35)	7	29.7-39.7	75.8	27.6-37.6	81.4
	(35)	8	28.5-38.5	74.1	28.0-38.0	80.3
McKnight	(40)	9	37.6-47.6	51.2	31.0-41.0	62.0
Pleasant	(40)	10	28.9-38.9	83.2	29.8-39.8	75.3
Robert	(35)	11	27.5-37.5	80.4	26.8-36.8	77.0
	(35)	12	32.1-42.1	63.2	26.7-36.7	77.9
Seventh	(35)	13	26.3-36.3	73.6	29.2-39.2	81.4
	(35)	14	28.7-38.7	68.2	27.2-37.2	77.1
Shepard	(40)	15	27.0-37.0	65.5	33.9-43.9	64.8
Summit	(35)	16	26.0-36.0	82.4	28.3-38.3	80.3
	(35)	17	29.2-39.2	79.3	29.2-39.2	78.5
	(35)	18	28.7-38.7	81.1	28.2-38.2	75.4
Avg	(35)		28.4-38.4	76.3	28.0-38.0	79.5
	(40)		30.8-40.8	70.1	31.7-41.7	67.0

[1] Values shown in parenthesis are the new limits in each case. The former limits were a blanket 30 mph.

TABLE 10

CHANGES IN STANDARD DEVIATION

Street[1]		Reference Number	"Before" Std. Dev. mph	"After Std. Dev. mph
Como	(35)	1	4.27	4.07
	(35)	2	4.65	4.13
Concord	(35)	3	3.77	5.07
Dayton	(35)	4	3.54	3.56
Jefferson	(40)	5	4.08	5.19
Marshall	(35)	6	4.26	4.13
	(35)	7	3.22	3.79
	(35)	8	5.04	4.46
McKnight	(40)	9	7.21	3.74
Pleasant	(40)	10	3.68	4.17
Robert	(35)	11	4.14	4.04
	(35)	12	6.70	4.13
Seventh	(35)	13	4.73	4.44
	(35)	14	4.91	4.89
Shepard	(40)	15	6.38	5.61
Summit	(35)	16	3.64	3.95
	(35)	17	4.05	4.17
	(35)	18	3.88	4.51
Avg	(35)		4.34	4.24
	(40)		5.34	4.68

[1] Values shown in parenthesis are the new limits in each case. The former limits were a blanket 30 mph.

TABLE 11

PERCENT OF SPEEDS UNDER POSTED LIMITS

Street[1]		Reference Number	"Before"	"After" (2-4 mo.)	"After" (6-24 mo.)
Como	(35)	1	35.4	69.4	79.9
	(35)	2	20.7	67.9	66.6
Concord	(35)	3	21.5	89.6	71.6
Dayton	(35)	4	66.8	82.9	84.3
Jefferson	(40)	5	15.5	94.1	82.0
Marshall	(35)	6	37.8	79.3	86.0
	(35)	7	22.9	76.5	86.1
	(35)	8	33.5	75.2	78.5
McKnight	(40)	9	6.8	91.7	77.2
Pleasant	(40)	10	23.7	97.6	94.3
Robert	(35)	11	43.7	76.2	86.9
	(35)	12	16.4	74.4	90.5
Seventh	(35)	13	54.5	85.3	75.2
	(35)	14	36.6	79.3	85.6
Shepard	(40)	15	27.8	-	73.6
Summit	(35)	16	62.6	92.9	76.4
	(35)	17	20.7	87.3	69.4
	(35)	18	28.9	82.9	77.8
Avg	(35)		35.9	79.9	79.6
	(40)		18.5	94.5	81.8

[1] Values shown in parenthesis are the new limits in each case. The former limits were a blanket 30 mph.

speeds after the change to remain very close to those occurring before the change. "After" speeds may frequently be slightly less than the "before" speeds. The tendency is for any speed changes to be small and to bear no relationship to the change in the limit. There appears to be little or no relation between the amount of the limit raise and any changes in actual speeds.

3. On the types of streets and in the speed ranges involved, a tendency toward more uniform speeds will not always occur. Where an urban arterial street speed limit is raised 5 or 10 mph to conform with a "before" 85 percentile speed, some cases of less uniformity, some of more uniformity, and some of no change may be expected. The tendency is for any change to be relatively small.

REFERENCES

1. Henberger, J.C., Matyas, C.A. and Wiley, C.C., "Effect of Speed Limit Signs on Vehicular Speeds." A Research Study, Department of Civil Engineering, University of Illinois (1949).
2. Dixon, Wilfred J. and Massey, Frank J., "Introduction to Statistical Analysis." McGraw-Hill (1957).
3. Manual of Traffic Engineering Studies. Accident Prevention Department of the Association of Casualty and Surety Companies (1953).
4. Matson, Theodore M., Smith, Wilbur S., and Hurd, Frederick W., "Traffic Engineering," McGraw-Hill (1955).
5. Traffic Engineering Handbook, Institute of Traffic Engineers (1950).

THE NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL is a private, nonprofit organization of scientists, dedicated to the furtherance of science and to its use for the general welfare. The ACADEMY itself was established in 1863 under a congressional charter signed by President Lincoln. Empowered to provide for all activities appropriate to academies of science, it was also required by its charter to act as an adviser to the federal government in scientific matters. This provision accounts for the close ties that have always existed between the ACADEMY and the government, although the ACADEMY is not a governmental agency.

The NATIONAL RESEARCH COUNCIL was established by the ACADEMY in 1916, at the request of President Wilson, to enable scientists generally to associate their efforts with those of the limited membership of the ACADEMY in service to the nation, to society, and to science at home and abroad. Members of the NATIONAL RESEARCH COUNCIL receive their appointments from the president of the ACADEMY. They include representatives nominated by the major scientific and technical societies, representatives of the federal government, and a number of members at large. In addition, several thousand scientists and engineers take part in the activities of the research council through membership on its various boards and committees.

Receiving funds from both public and private sources, by contribution, grant, or contract, the ACADEMY and its RESEARCH COUNCIL thus work to stimulate research and its applications, to survey the broad possibilities of science, to promote effective utilization of the scientific and technical resources of the country, to serve the government, and to further the general interests of science.

The HIGHWAY RESEARCH BOARD was organized November 11, 1920, as an agency of the Division of Engineering and Industrial Research, one of the eight functional divisions of the NATIONAL RESEARCH COUNCIL. The BOARD is a cooperative organization of the highway technologists of America operating under the auspices of the ACADEMY–COUNCIL and with the support of the several highway departments, the Bureau of Public Roads, and many other organizations interested in the development of highway transportation. The purposes of the BOARD are to encourage research and to provide a national clearinghouse and correlation service for research activities and information on highway administration and technology.