FREEWAY-STYLE DIAGRAMMATIC SIGNS IN NEW JERSEY

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Ninety-four freeway-style diagrammatic signs were installed on I-287 in New Jersey to replace 120 conventional signs at 22 interchanges. Traffic volumes and specific unusual maneuvers were counted and categorized for a 7-day period at each of 10 exit sites before and after guide-sign changes. Evaluation of 5 of the sites included statistical comparisons of correlated, hourly, unusual-maneuver rates. The results of comparisons between conventional and diagrammatic signs showed that (a) conventional signs produced a lower rate of critical maneuvers than did diagrammatic signs at a split for parallel roadways; (b) diagrammatic signs at cloverleaf interchanges effected a lower rate of stopping and backing maneuvers but a higher rate of exit gore weaving maneuvers; and (c) diagrammatic signs at right-hand, T-ramp exits approached by either an auxiliary lane or a regular deceleration lane resulted in a lower rate of stopping and backing maneuvers as well as fewer or the same number of exit gore weaving maneuvers. Seasonal and yearly variations in unusual maneuvers were derived from the results of seven 7-day studies performed at 1 site from 1969 to 1974. The adequacy of the diagram standards was reviewed, and recommendations for further research were made.

•SINCE the trial of diagrammatic guide signs at freeway interchanges has been advocated (1), there have been several major developments in the evaluation of these signs. The Federal Highway Administration sponsored a national program to design and evaluate U.S.-style diagrammatic signs to reduce unusual maneuvers at high-incidence exits. Several research studies worthy of mention came out of this effort. The effects of diagrammatic signs were shown in a field study at a left-hand exit gore by means of a narrowly defined unusual maneuver measure and a matched pairs statistical analysis of unusual maneuver rates (2). Diagrammatic sign concepts were evaluated in a laboratory setting, and recommendations were made for specific applications and graphic design (3). Inclusion of graphic lane lines in signed diagrams was evaluated in another field study (4). Relevance of erratic maneuvers at several zones upstream and downstream of the exit gore and results of driver interviews were shown in a diagrammatic sign evaluation (5). The utility of unusual maneuvers, lane changes, speed changes, and headways in evaluating diagrammatic signs was demonstrated by information gathered by automated tape switches in several zones approaching exits as well as from driver interviews and learning-curve detection (6).

In pilot studies conducted at I-287 and US-22 in New Jersey (4), signs with both diagrams and lane lines were considered to be more effective than conventional signs. However, some doubt remained about whether the improved performance found in unusual maneuvers was due to the effects of novelty or sudden importance given to the signs. Thus a study of diagrammatic signs over a continuous, 22-mile (35.4-km) section of I-287 was conducted that included a variety of geometric, exit-ramp configurations.

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AREA CHARACTERISTICS

I-287 in Somerset and Middlesex Counties was chosen for study because of its varied geometry and its importance as part of a road system that encircles New York City.

The route in the study area is not yet connected to the rest of the encircling system although extending sections of the route in the study area were constructed between the 1971 and 1973 studies. At the southern end, entrances from the Garden State Parkway and US-9 were opened during the 2 main study years, which extended the roadway approaching US-1 from 2 to 3½ miles (3.2 to 5.6 km). Other existing entrances included those from US-1, the New Jersey Turnpike, and county Route 514. At the northern end, 6 miles (9.7 km) of roadway were added, which gave access to NJ-24 and county Route 510. Seven miles (11.3 km) of a connecting Interstate route, I-78, were constructed to the east of I-287 during the 1971 studies. A total of 12 miles (19.3 km) were constructed before the 1973 studies. The study site locations are shown in Figure 1.

A noticeable amount of growth in shopping and industrial areas took place during the study years in the study area, and the section between US-22 and county Route 527 was resurfaced and concrete center barriers were reconstructed immediately before and during the study in 1973. The repaving contract was coordinated with the diagrammatic sign study in such a manner as to keep studies and construction as far apart as possible. Although cooperation was good, studies and repaving work were not a great distance away from each other at a few sites and were bound to affect motorist behavior.

STUDY AND SIGN DESIGN PROCEDURES

Scope

This study includes an evaluation of 30 signs at 10 exit sites within a 22-mile (35.4-km) section of I-287 and I-95 in Somerset and Middlesex Counties. The exit sites had both simple and complex geometric situations among which are left- and right-hand exits; semidirect, indirect, and direct ramps; left- and right-turn connections; and interchanges that have both 1 and 2 ramps exiting from a single direction. Exit sites were selected originally for their potential for unusual maneuvers. All the exit sites in the study route were studied to determine this potential.

A limitation that no new structures for mounting signs could be built was placed on the study. Within that limitation, several signs were modified to upgrade existing sign messages before formal data collection began. Unusual-maneuver and volume data were collected at each site during July and August 1971 and at site 5 during August 1972 after an additional sign had been erected at that location. Figure 2 shows a project activity bar chart.

All structures were analyzed for design wind load to determine maximum panel size for the increased area that is often required for diagrams on ground-mounted signs. Less than standard layouts had to be resorted to on some ground-mounted signs. Less overall area usually was needed when 1 diagrammatic sign replaced 2 or more conventional signs.

Diagrammatic signs with breakaway posts on ground mounts replaced conventional signs in the spring of 1973 and studies at all 10 sites were again made in July and August 1973. One hundred twenty conventional sign panels were replaced on the entire study section of I-287 with 94 diagrammatic sign panels. Twenty-two interchanges were involved in the change.

Letters, numbers, diagrams, and lane lines were reflectorized by using cube-corner reflex buttons; high-intensity, beaded reflex sheeting was used for shield backgrounds. Both cube-corner buttons and beaded sheeting had been tested for diagram visibility and recognizability at night from up to 1,000 ft (305 m). Panel backgrounds were made from extruded aluminum coated with polyvinylidene fluoride paint.

Figure 1. Study site locations.

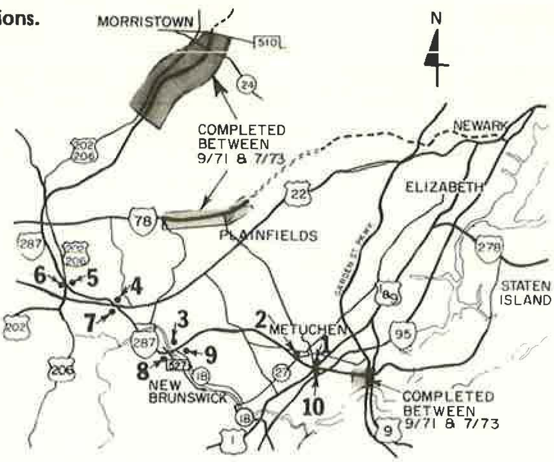


Figure 2. Project activity bar chart.

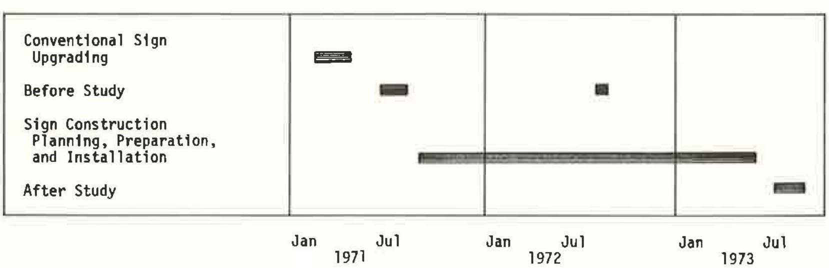
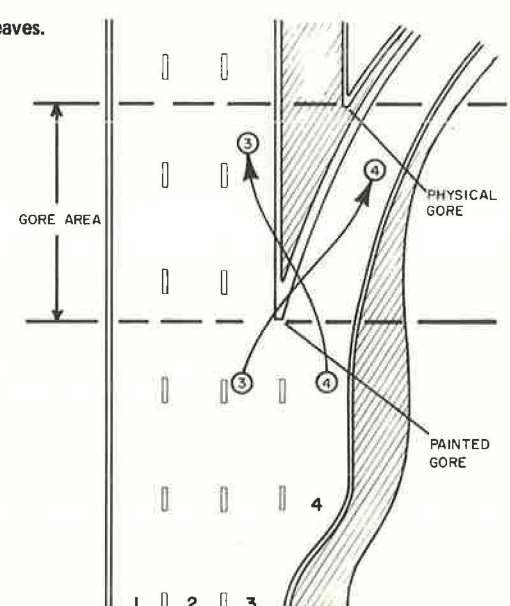


Figure 3. Typical gore weaves.



Sign Design Procedure

The diagram design methodology was aimed at satisfying the following requirements:

1. Greater visibility to compensate for increased information content,
2. Simplicity for ease of interpretation,
3. Road-diagram and diagram-message relatability,
4. Diagram continuity within each interchange,
5. Message redundancy for continued confirmation within exit approaches, and
6. Uniform application among all interchanges for reliable driver recognition.

Diagram designs and sign layouts were developed with the use of a photographic inventory film. Frames of signs on location were projected against a large screen. Alternate diagram and message layouts were superimposed on the scenes to judge their adequacy from a driver's visual point of view. Opinions from engineering and non-engineering persons were solicited on an informal basis.

Both plan view (3) and a more symbolic style of diagram were simulated and reviewed. A practical set of standards that offered a consistent and reliable basis for designing a diagram for any geometric condition was arrived at by using the more symbolic style of plan view. Overhead signs were often easier to design than were ground-mounted signs because less space was needed after messages from several signs were organized onto that with a diagram.

Data Collection

During each site study unusual maneuvers and volumes were counted by hidden observers. Three observers counted all unusual maneuvers while 2 observers counted all volumes. For this study, an unusual maneuver was any stopping or backing up in the exit gore section or any driving on the gore line between the physical gore and a predetermined point upstream of it (Fig. 3). At each site, unusual maneuvers and volumes were collected for both through and exit movements as well as for 2-axle and 3- or more axle vehicles in each hour from 2:00 to 5:00 p.m. on 7 consecutive days. On days when data were collected, before and after conditions were matched to the closest date from year to year.

Analysis

The rates of unusual maneuvers (in maneuvers per thousand vehicles) for conventional and diagrammatic sign conditions were compared at each site. Only the rates for 2-axle vehicles were compared because vehicles with extra axles were considered to be in a different group. Differences between studies were tested statistically by using the conservative, nonparametric, Wilcoxon, matched pairs, signed ranks test (8). The following formula was used:

$$Z = \{T - [N(N + 1)]/4\}/\sqrt{[N(N + 1)(2N + 1)]/24}$$

where

T = sum of positive ranks,
N = number of qualified ranks, and
Z = normal standard deviation.

Rates were paired by hour, day, and movement. Rates paired by movement are referred to in the following abbreviated form:

1. EUR—exiting unusual maneuver rate: a proportion of exiting volume such as a 3 to 4 maneuver (Fig. 3),
2. TUR—through unusual maneuver rates: a proportion of through volume such as a 4 to 3 or a 3 to 3 maneuver,
3. SBR—stopping and backing unusual maneuver rates for both exit and through movements as a proportion of combined volumes, and
4. UR—exiting and through maneuvers for a combined volume.

A change was considered significant when it could be accepted at greater than the 95 percent level of confidence when a 1-tailed test was used. The analysis of data for each site included:

1. Statistical comparisons pairing unusual maneuver rates for each sign condition,
2. Sufficiency or validity of the data, and
3. Possible or probable effects produced by extraneous factors such as construction activity, new access, changed volume, accidents, and rain.

A stopping or backing maneuver was considered to be more critical than a gore weaving maneuver, but SBRs were included with EUR and UR totals as well as separated for before and after comparisons. EUR or UR may be regarded as gore weaving rates because SBRs were quite infrequent.

Nonexperimental Factors Control

Repaving and restriping, independent signing programs, new access, changing traffic volumes, changing travel patterns, and new industrial development can bias comparisons of before and after data.

The method of analysis used minimized effects from factors that were dependent on hour, day, and season. Loss of visibility during heavy rain is rare, but 1 hour of affected data was eliminated by the analysis.

Although control groups could not be used effectively in this kind of study, a great effort was made to reduce bias from outside influences. For a repaving project that was conducted simultaneously with the after study, plans were prepared for repaving and restriping work so that the result on exit striping would be the same in both studies. This was accomplished by documenting the dimensions of original gore stripes and entering them in restriping plans. The contractor also was scheduled to conduct work away from planned study sites. Requests were made to other agencies to refrain from making their own sign changes at locations relating to planned studies. Needed changes in destination names and exit numbering generally were postponed. The only exception was at site 6 where gore-mounted supplemental signs were removed and a standard exit gore sign with a number was installed.

Despite all efforts to minimize bias, the accuracy of the data at sites 2, 4, 6, 7, and 8 was in doubt, and we were left without a reasonable method of adjustment.

Sign changes made in relation to exit geometry at sites 1, 3, 5, 9, and 10 are shown in Figures 4, 5, 6, 7, and 8.

RESULTS

Table 1 summarizes the data collected and the results of statistical analysis. Vehicles with 3 or more axles are not included. The significance of the rate change is shown in a Wilcoxon, nonparametric, matched pairs test. The change in rate from before to after conditions is shown to be significant or not significant at the 95 percent level of confidence in the direction of the change.

Study sites 3 and 5 were the only sites at which both the direction of SBR and UR change agreed and there were no observable sources of bias. Conclusions without qualification are based on the results from these sites.

Figure 4. Study site 1.

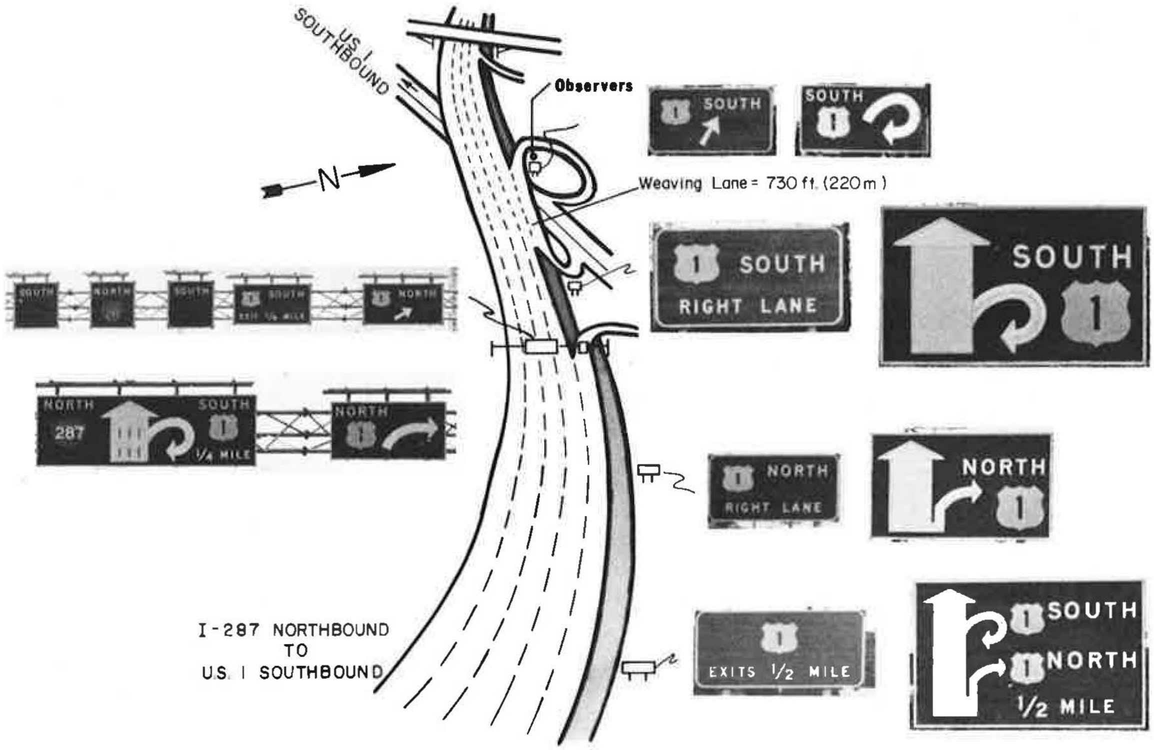


Figure 5. Study site 3.

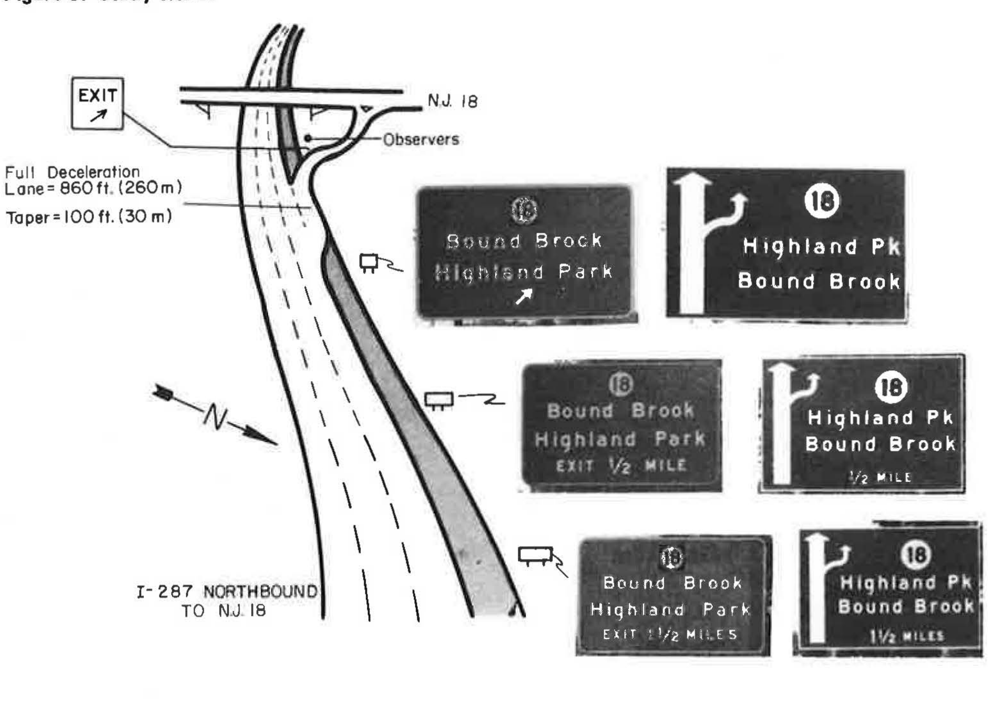


Figure 6. Study site 5.

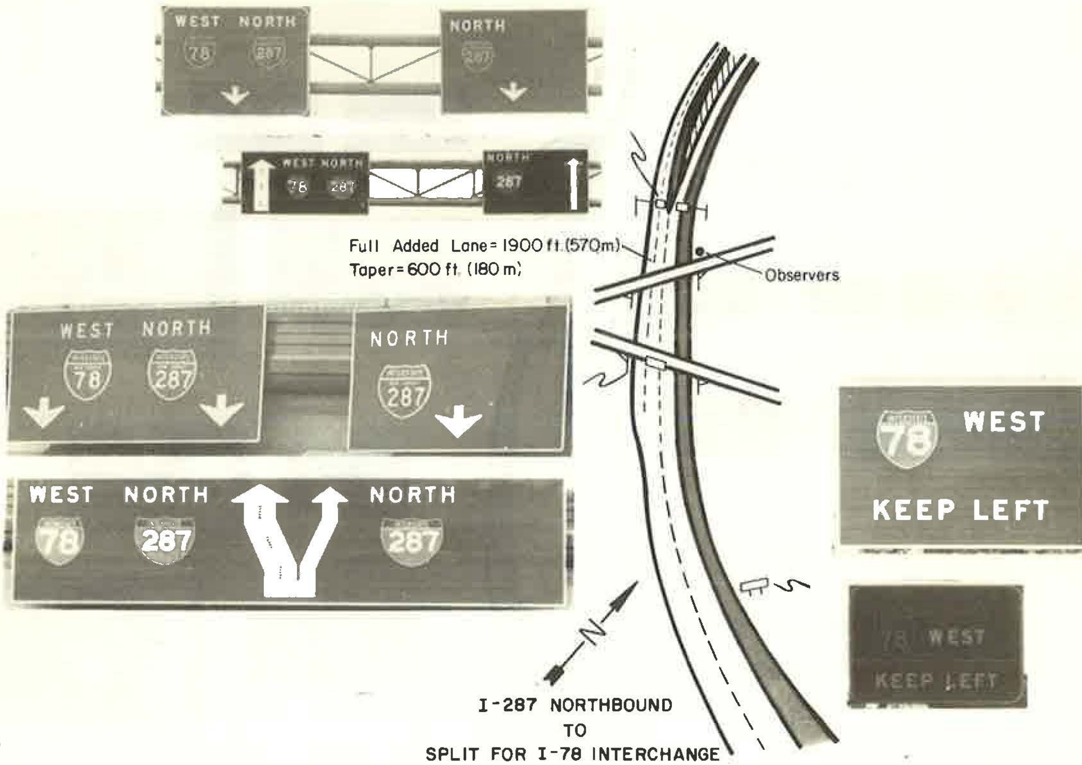


Figure 7. Study site 9.

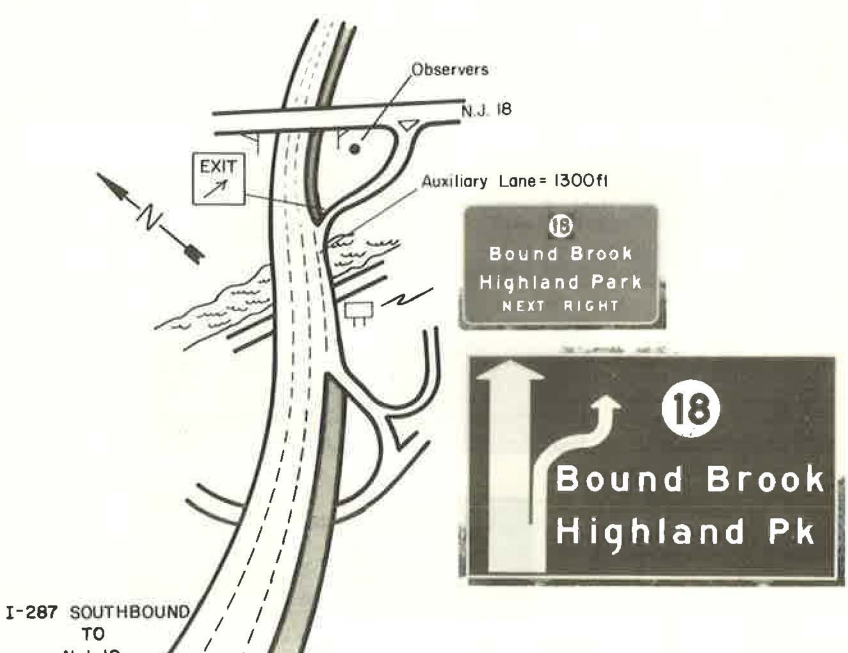


Figure 8. Study site 10.

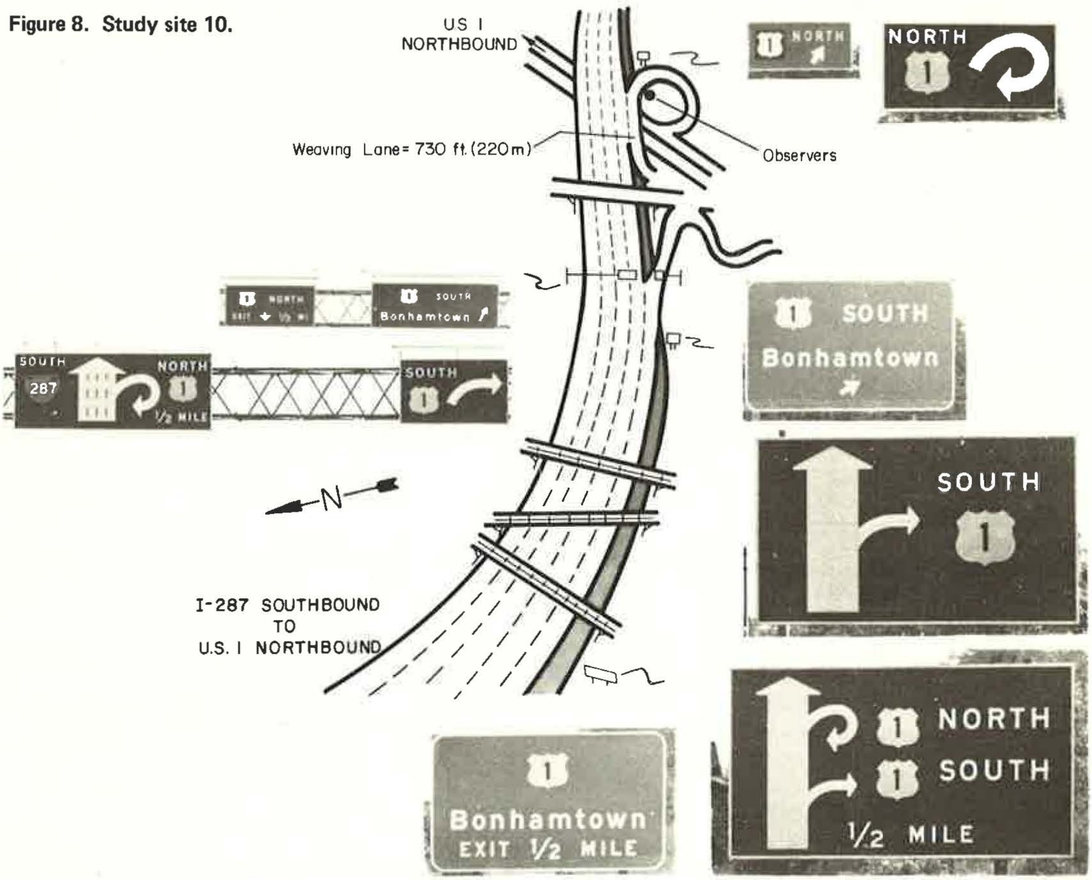
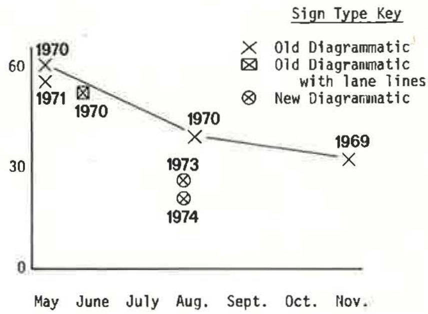


Table 1. Unusual maneuvers and statistical summary by study site.

	Maneuvers									
	SBR (per 100,000 vehicles)		UR (per 1,000 vehicles)		Avg Hourly Volume		Exit Volume (percent)		Z-Value[a] (hourly rates)	
Site	Before	After	Before	After	Before	After	Before	After	SBR	UR
1	19.0	6.4	4.3[b]	30.8[b]	1,002	1,483	7	10	1.21[c]	3.75[d]
3	16.2	3.3	1.0	0.8	1,232	1,528	10	8	1.75[d]	1.04[c]
5	23.0	60.5	38.7	46.1	826	865	50	51	1.78[d]	2.85[d]
9	23.6	3.1	1.1	0.6	1,209	1,550	19	17	2.02[d]	2.50[d]
10	134.6	39.0	23.2[b]	22.7[b]	1,309	1,833	38	24	3.33[d]	0.14[c]

[a]Wilcoxon test. [b]Includes unusual exit gore maneuver rates for exiting vehicles only. [c]Not significant. [d]Significant.

Figure 9. Unusual-maneuver rates for site 4 studies by month of year.



Agreement between the SBR and UR direction of change in rates is shown for study sites 9 and 10, but a bias factor was known to have been operating during the after studies at each of these sites. At site 10, the effect of bias from a lower percentage of approach volume that exited would make the reduction in rates appear to be greater than it would have been without bias because bias would make the after study rates superficially low. The opposite was true at site 1. At site 9, bias from the effects of upstream construction activity would tend to have made the reduction in rates given in Table 1 less than it would have been without bias because the after study rates tend to be superficially high. For this reason the reduction of rates should be regarded as conservative at site 9.

Estimated results of studies at sites 1 and 10 are made on the basis that the data may be combined for analysis because the sites have geometrically similar loop exits and the same type of interchange. The bias effects from a change in percentage exiting are opposite and should cancel when combined. Applying the Wilcoxon test for 1 direction at the 95 percent level of confidence, we found a significant decrease in SBR and a significant increase in EUR after diagrammatic signs were erected at sites 1 and 10.

CONCLUSIONS

Some conclusions can be drawn from the results of comparing the performance between conventional and diagrammatic signs.

1. At a split for parallel roadways, conventional signs were shown to be more effective in reducing critical maneuvers than were diagrammatic signs.
2. At 2 loop exits within a cloverleaf interchange, a conversion to diagrammatic signs effectively reduced stopping and backing maneuver rates but resulted in either no change or an increase in unusual exit gore maneuver rates. Grouping these data for a combined before-and-after analysis resulted in a decrease of stopping and backing maneuver rates and an increase in unusual exit gore maneuver rates.
3. At a right-hand T-ramp, a conversion to diagrammatic signs reduced stopping and backing maneuver rates and resulted in no change in unusual exit gore maneuver rates.
4. At a right-hand T-ramp terminating an auxiliary lane, a diagrammatic sign was more effective than a conventional sign in reducing critical unusual maneuvers.

FINDINGS FROM STUDIES AT SITE 4

In Figure 9, 7 studies performed for 6 years at site 4 are plotted by month according to average unusual maneuvers per 1,000 vehicles for each study. A base curve is drawn among 3 studies performed with the same signs in different seasons within a 12-month period to illustrate seasonal variation. Variation between years is also shown among studies made with the same signs on the closest dates of the same month. Several conclusions can be made from these comparisons.

1. Seasonal variation can be greater than annual variation.
2. Declining gore weaving rates may be found for at least a year after installation of a diagrammatic sign.

Seasonal variation of unusual-maneuver rates may have a marked effect on before and after comparisons with a month between studies. The actual rate reduction found when lane lines were added on the old diagrams in June 1970 may be seen in Figure 9 by directly comparing the point for old diagrammatic signs with lane lines with the point directly above it for old diagrammatic signs without lane lines. A lower rate than the previous year when there was no change in signing was found on 2 occasions as can be seen in Figure 9 by comparing 1970 with 1971 in May and 1973 with 1974 in August. The reduced rates have not been found to be related to volume but may be related to driver familiarization. Comparisons of before and after conditions in future studies should take these possible variations into account.

DISCUSSION AND RECOMMENDATIONS FOR FUTURE RESEARCH

The method developed to design diagrams for I-287 could be improved to benefit the motorist's perception. We recommend the following modifications to the diagrams:

1. Complete separation of graphic movements for exit-lane drops and splits (Fig. 10),
2. Extension of leading ends on gore-located, independent arrows that curve (Fig. 11),
3. Establishment of standard stem lengths for ground-mounted advance-guide exit-direction sign diagrams (Fig. 12),
4. Widening of lane lines to 3 in. (7.6 cm) instead of 2 in. (5 cm) (Fig. 13), and
5. Heavier overhead arrowheads (Fig. 14).

In general, more panel space should be considered for advance-guide, diagrammatic, ground-mounted signs than that that was used on I-287 because the addition of a diagram requires more space for the given letter standards. In addition to needing more space, diagrammatic signs require a greater degree of overall graphic organization than do conventional signs. In future work, design standards should be developed to minimize incorrect message-to-diagram associations, maximize correct associations, and organize diagram-to-message and message-to-message interfaces in predictable locations. With the exception of sign panel space, these goals were accomplished on I-287 by standardization.

There is some uncertainty about the specific design of diagram symbols beyond the long, narrow plan view for I-495 (6) and the short, wide symbolic type for I-287 (4) as shown in Figure 15. The plan view type is a truer reproduction of the gore area approach because main roadway curvature is shown. Although the plan view type shows exiting sides, it does not show exit-ramp turn directions. The symbolic type reproduces the gore area approach, but all approach roadways are shown vertically regardless of approach curvature. In the more symbolic type, exiting sides as well as exit-ramp turn direction are displayed.

Although all drivers should profit from knowing the exiting sides in advance, and, although the information should not be too hard to understand, there is some doubt about the ability of all drivers to perceive the symbolic value of an exit-ramp turn direction when it is semidirect or indirect. Further research is suggested to document the values of these differences in types of signs in terms of exit performance because this area has not yet been adequately documented.

ACKNOWLEDGMENTS

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The cooperation given to us for the timely replacement of signs by the Pennwalt Corporation, Porce-Len Company, PPG Industries, Amerace Corporation, 3M Company, Interstate Highway Sign Company, and Whitmyer Brothers Corporation also is appreciated.

Figure 10. Exit-lane drops and splits.

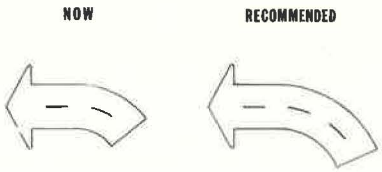

Figure 11. Extension of gore-located arrows.

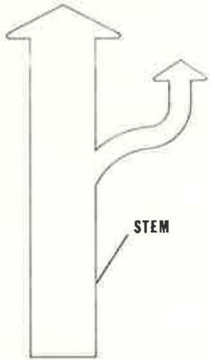

Figure 12. Stem lengths.

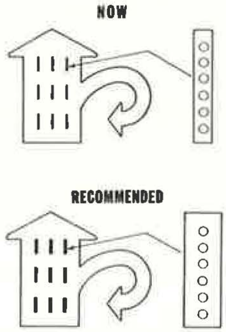

Figure 13. Lane lines.

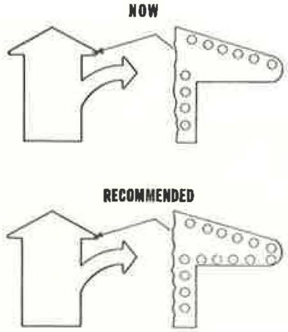

Figure 14. Overhead arrows.

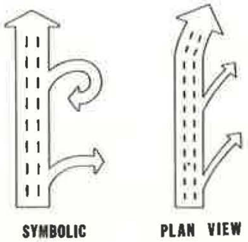

Figure 15. Symbolic and plan view arrows.

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