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EVALUATION OF DYNAMIC SIGN SYSTEMS FOR NARROW BRIDGES

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16. Abstract

This report describes the results of a before-and-after study to evaluate the effectiveness of dynamic sign systems in alerting motorists to the presence of narrow bridges on two lane rural highways. Vehicle speed and lateral placement (perpendicular distance to roadway centerline) data were gathered for each of the dynamic sign systems tested as well as for the base (before) passive system as drivers approached and crossed the narrow bridge. These data were used as the primary measures of effectiveness for determining the ability of each of the sign systems to increase safety and improve driver awareness of potential hazards. A roadside survey was independently conducted by the State of Maine to determine the public reaction to the dynamic sign systems. The results of the survey were made available to the authors and are discussed in this report.

Four sign systems were examined under both day and night conditions. These included flashing beacons, strobe lights, and two neon message signs. Two additional sign systems involving bridge lights were examined at night only. The sign systems were dynamic in the sense that they were activated by traffic approaching the bridge. The experiment was conducted at the Federal Highway Administration Maine Facility located on U.S. Route 2.

Results showed no substantial and consistent differences between the existing and dynamic sign systems in terms of the speed and lateral placement measures. It may have been that these measures were not sensitive to or good indicators of the possible change in driver behavior to the new signs. The roadside survey provided additional driver awareness measures for determining the safety benefits of the new sign systems but also did not reveal any important improvements.

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PREFACE

This document was prepared by the Office of Ground Systems, Transportation Systems Center, under the sponsorship of the Office of Research, Federal Highway Administration. It describes the results of an experiment to evaluate the application of dynamic (activated) sign systems in alerting motorists to the presence of narrow bridges on two lane rural highways. The experiment was conducted at the Federal Highway Administration Maine Facility located on U.S. Route 2.

The authors wish to acknowledge the valuable contributions of the following people: Maurice Lanman, who managed the data collection and data reduction activities at the Maine Facility; Patricia Brown, who conducted the data reduction and analysis at the Transportation Systems Center; Merton Rosenbaum, who provided the project guidance from the sponsor's office; Gerhart King, Paul Abramson, Reuben Goldblatt, Mark Wilkinson, and Jay Cohen of KLD Associates, who developed the experiment design and analytical methods; Kenneth P. Hayes and Geeta Balakrishnan of the Social Science Research Institute at the University of Maine who conducted the roadside survey and analyzed the data; and Ellen Nestervich, who assisted in the preparation and review of the final report.

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1. INTRODUCTION

Although there is little comprehensive documentation and statistics concerning the magnitude of the narrow bridge problem,[1] narrow bridge accidents are common and quite often involve fatalities. For example in Ohio twice as many deaths resulted from traffic accidents at bridges as from accidents at railroad crossings.[2] On non-Interstate highways narrow bridge accidents accounted for 1.6 percent of all accidents and approximately 3.4 percent of all fatal accidents.[3] In West Virginia, accidents occurred at 166 out of a total of 1,316 narrow bridges on two-lane roads in one year. One accident on a narrow bridge on December 26, 1972, in New Mexico was fatal to 19 persons.

While there is no universally accepted definition of a narrow bridge, it is generally considered to be one where the clear roadway width of a bridge is equal to or less than the width of the approach pavement. By this definition, the authors estimate that there are 87,000 narrow bridges on two-lane rural highways. The geometric condition at narrow bridges causes drivers to track their vehicles farther away from the bridge curb than from the normal edge of pavement and in the case of wide vehicles, into part of the opposing traffic lane. A specific hazard potential develops when two opposing vehicles approach a narrow bridge and both attempt to cross at the same time or attempt to avoid one another.

Many studies[4,5,6,7,8,9], have documentated the existence and nature of the serious safety problem at narrow bridges and the need for research designed to develop effective counter-measures. Since some of these studies indicated that many motorists do not respond to the existing passive warning signs in a manner that would seem to promote safe crossings (i.e., a reasonable speed reduction before the bridge and lane centering when there is opposing traffic), this experiment was undertaken to test the effectiveness of <u>dynamic sign systems</u> in alerting the motorists to the presence of narrow bridges and the potential hazards that

2. TEST SITE DESCRIPTION

All tests were concluded at the Sebasticook River bridge located on the Maine Facility,* a 15-mile instrumented two-line rural road section of U.S. Route 2 west of Bangor between Newport and Canaan. The bridge is an overhead steel truss bridge 200 feet long with a guard-rail and with a 22 foot curb to curb width. The approach pavement was 24 feet in width. A schematic of the test site including plan and profile views is shown in Figure 2-1.

Vehicle speed data were collected using permanently installed loop sensors that detected vehicles and tracked their positions as they approached and crossed the bridge. The locations of the sensors are indicated in Figure 2-1. A total of nine loop sensors were used with tracking capability in both directions. Four loop sensors were located west of the bridge covering a distance of approximately 600 feet while five loop sensors were located east of the bridge covering a distance of approximately 800 feet. All sensors were separated by about 200 feet.

Vehicle lateral placement (perpendicular distance to roadway centerline) data were collected using pressure-sensitive coaxial cables in diagonal and perpendicular arrangements across the road. There were three lateral placement sensor locations for each direction of travel: (1) approximately 200 feet before the bridge, (2) at the beginning of the bridge, and (3) in the center of the bridge. These are also indicated in Figure 2-1.

The vehicle detection and lateral placement data were transmitted by buried cable to a control station and there recorded on magnetic tape for subsequent off-line data reduction. The west approach to the bridge was a long straight moderate down grade with

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*See reference (14) for a detailed description of the Maine Facility test site.

an at-grade railroad crossing located approximately 600 feet from the bridge. There were no sight distance restrictions in either direction.*

*More detailed information on the site and sensing system can be obtained from:

Resident Manager
The Maine Facility
RFD Box 421
Pittsfield, Maine 04967.

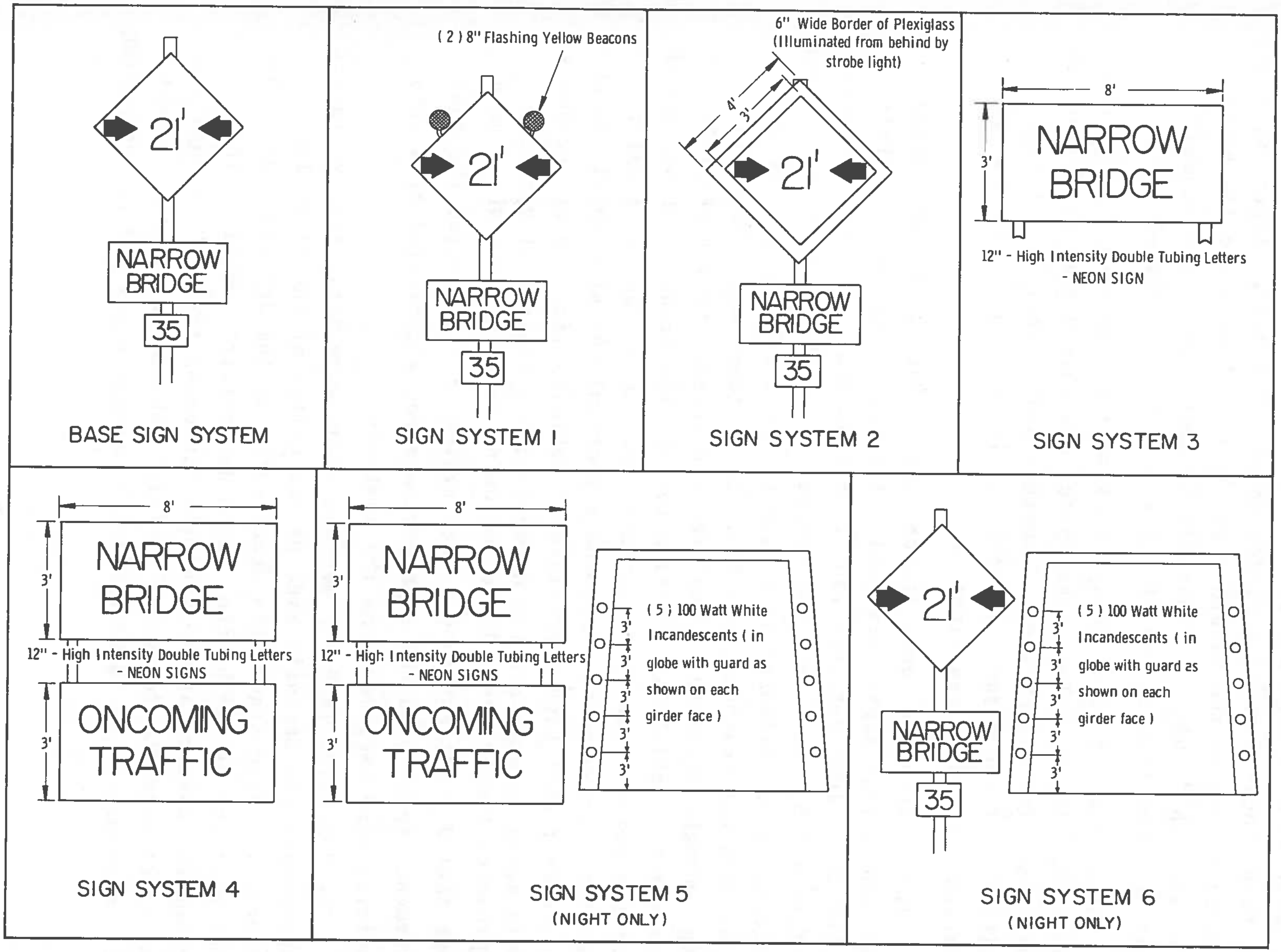


FIGURE 3-1. SIGN SYSTEMS

TRAFFIC" message signs operated independently. Additional software was employed to prevent false activations/deactivations (e.g., by vehicles crossing over the centerline).

The dynamic signs and the base signs shown in Figure 3-1 were located approximately 200 feet from the bridge in each direction. An additional passive, far-advance-warning sign was present for all the sign systems tested. This was a passive diamond shaped narrow bridge sign with yellow background, black border, and black lettering. It was located approximately 500 feet from the bridge in both directions. This sign was initially part of the base (before) condition and remained unchanged throughout the experiment.

with measure b) - speed reduction, provided information on the vehicle's speed profile before the bridge. In general, smaller values of this measure were assumed to imply more effectiveness. However, in the analysis, a bridge speed effect was not considered important unless accompanied by a speed reduction effect. This was because a bridge speed effect alone could have been accounted for by a different-speed driver population rather than a reaction to the sign systems.

b) Speed Reduction. Speed reduction was defined as the speed between the first two loop detectors on the approach to the bridge minus the speed across the bridge. A speed reduction was determined for each vehicle and then averaged over all vehicles for each test condition. This measure indicated whether or not the driver reacted to the sign system by slowing down in the approach to the bridge. This measure together with measure a) - mean speed across the bridge-provided a concise representation of the vehicle's speed profile. In general, large values of speed reduction were assumed to imply more effectiveness.

c) Speed variance across the bridge and immediately prior to the bridge (i.e., between the first two detectors before the bridge). For this measure individual driver speeds were first determined at the two locations. Speed variance was then computed for each location based on the speeds of all drivers for a particular test condition. The speed variance measure was intended to provide information on whether the dynamic sign systems caused confusion to the drivers or led to misinterpretation. Larger values of this measure indicated an increase in vehicle/vehicle accident potential and was considered less desirable.

d) Left wheel lateral placement. This measure was defined as the distance, D1, (see Figure 4-1) between the highway center line and the outside of the vehicle's left tire. Lateral placement was measured at three locations for each direction (see Section 2). This measure was intended to determine if the dynamic sign systems had any impact on the vehicle's lateral position near the bridge. In a no conflict situation (see above), movement of the subject vehicle toward or across the center line was expected and not considered less effective. In a conflict situation movement toward the center line was considered less effective.

e) Lateral placement centering ratio. This measure was defined as the ratio of the distance, D1, from the highway center line to the outside of the left tire, to the distance, D2, from the outside of the right tire to the pavement edge (see Figure 4-1). Centering ratio represented a normalized lateral placement measure eliminating the effect of vehicle size and was essential for auto/other comparisons. This measure provided information on the driver's tendency to center the vehicle in the right lane (i.e., as the centering ratio approached "1"). Centering in the lane was considered more important in a conflict situation than in a no-conflict situation.

4.2 INDEPENDENT VARIABLES

The independent variables included in this study were:

a) vehicle type-two levels: auto (vehicles with lengths under 20 feet but greater than 5 feet) and other (vehicles with lengths greater than 20 feet),

b) vehicle direction - two levels: eastbound and westbound,

c) time of day - two levels: day (sunrise to sunset) and night,

d) conflict situation - two levels: no conflict and conflict.

A conflict was determined when two vehicles passed each other in opposite directions on the bridge or within 200 feet of the bridge.

For the no-conflict situation, only throughput vehicles (vehicles tracked through the nine-detector measurement regions) with headways greater than 6 seconds were included in the analysis. In a conflict situation, this restriction applied only to the subject vehicle (i.e., the vehicle being opposed). Data were collected and analyzed for good weather conditions only (i.e., no rain, snow, fog, or wet roadway conditions).

TABLE 5-1. DATA COLLECTION SCHEDULE

SIGN SYSTEM		DATA COLLECTION PERIOD	
DAY	NIGHT	NUMBER	DATES
BASE	BASE	1	8/9/76 - 8/22/76
1	1	2	8/25/76 - 9/8/76
2	2	3	9/10/76 - 9/27/76
3	3	4	9/29/76 - 10/11/76
4	4	5	10/15/76 - 11/7/76
NO SIGN*	5	6	11/8/76 - 11/16/76
BASE	6	7	11/17/76 - 11/29/76
BASE	BASE	8	11/30/76 - 12/2/76

*Sign system 4 was scheduled but was inoperative during this period.

TABLE 5-2. SAMPLE SIZES - ANALYSIS DATA

DATA COLLECTION PERIOD	WESTBOUND VEHICLES			
	DAY		NIGHT	
	CONFLICT	NO CONFLICT	CONFLICT	NO CONFLICT
1	649/113*	1885/320	51/4	289/27
2	1167/144	3473/490	93/2	605/35
3	754/ 77	2640/320	53/3	457/25
4	985/ 89	3193/306	53/0	576/35
5	724/ 48	2765/203	124/3	1087/51
6	364/ 25	1874/200	119/2	841/48
7	332/ 27	1762/145	101/1	738/48
8	57/ 9	390/49	53/1	285/22

DATA COLLECTION PERIOD	EASTBOUND VEHICLES			
	DAY		NIGHT	
	CONFLICT	NO CONFLICT	CONFLICT	NO CONFLICT
1	657/97	1243/135	50/2	513/25
2	1230/66	2587/191	90/2	639/18
3	743/53	2419/156	59/1	482/13
4	1009/45	2569/138	50/0	562/18
5	738/16	2596/101	121/2	969/21
6	359/13	1657/103	120/0	754/40
7	332/22	1516/ 87	97/3	671/14
8	57/ 6	334/ 40	50/2	259/ 9

*Auto/Other

and speed reduction before the bridge for each sign system and for autos only. Day/night, east/west, and conflict-no-conflict test conditions are also shown in the figures. The effects on lateral placement and the results for other (large) vehicles are discussed in separate sections that follow.

The dominant effect displayed by the figures was due to the presence of opposing vehicles. In a conflict situation, vehicle speeds across the bridge were lower by 2-4 mph and speed reductions before the bridge 1-2 mph compared to no-conflict situations. (Speed reductions in the eastbound direction were negative as the vehicles accelerated from the at-grade railroad crossing to the bridge.) The effect occurred for day and night as well as for eastbound and westbound traffic conditions. Since in practically all cases (the two exceptions were the bridge speed measure for the base sign system, westbound traffic during the day and the speed reduction measure for sign system 3 westbound traffic at night) there was no overlap of the error bars between the conflict and no-conflict situations, this effect was considered significant. It is also interesting to note that relative sign system effects were independent of the conflict/no-conflict situation.

Daytime Conditions

The most effective sign system during the day was strobe lights. This sign achieved the lowest speeds across the bridge (41-42 mph in a conflict situation, 44-45 mph in a no-conflict situation), and the highest speed reduction for westbound traffic (6.5 mph in a conflict situation, 4.5 mph in a non-conflict situation). This was an improvement of about 2 mph over the base sign

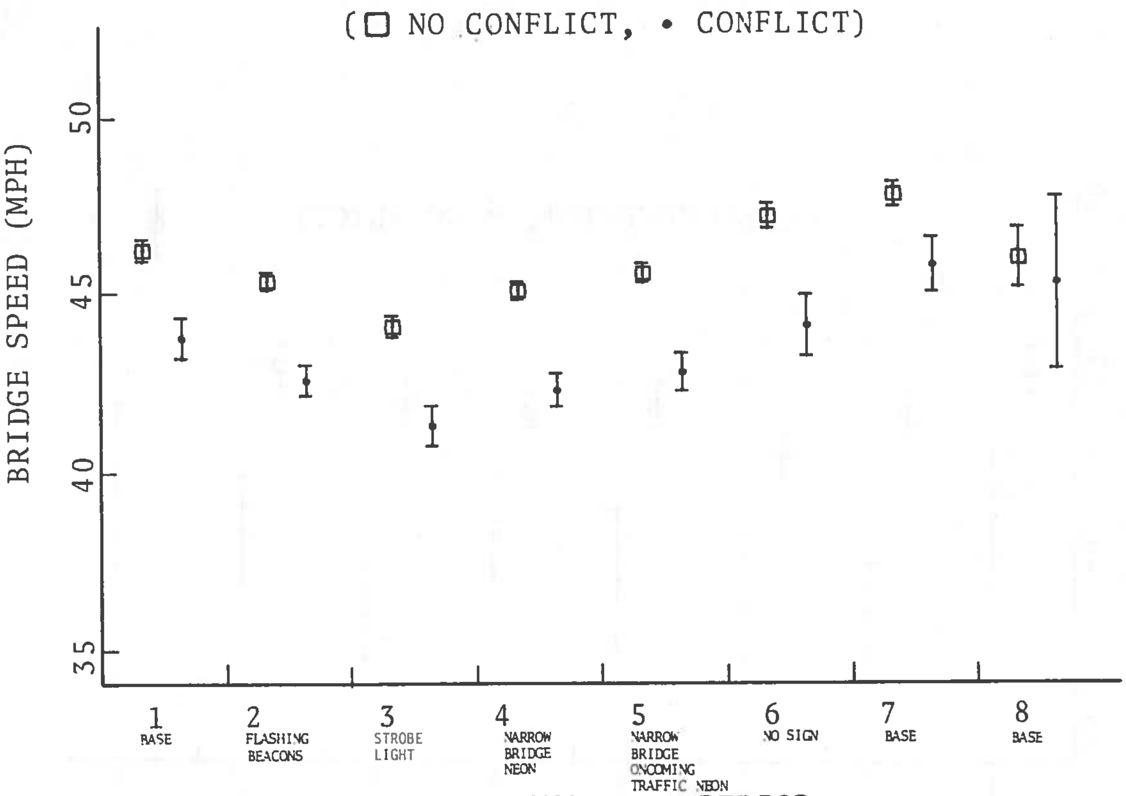


FIGURE 6-3. BRIDGE SPEED VS SIGN SYSTEM: WEST, AUTO, DAY

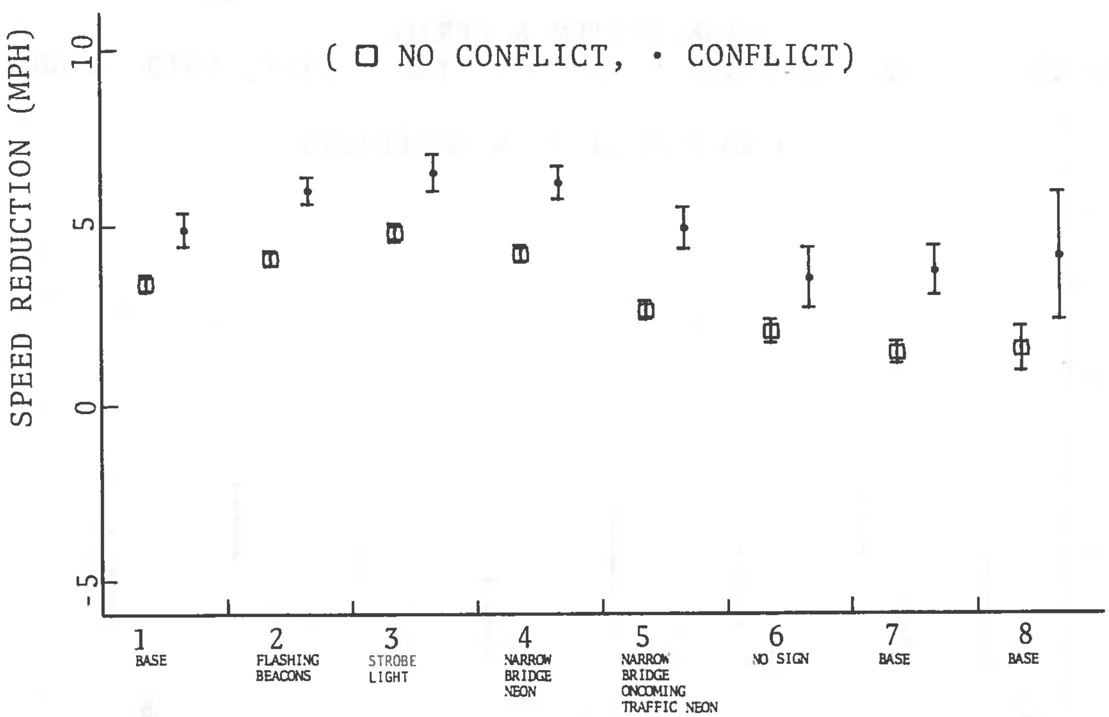
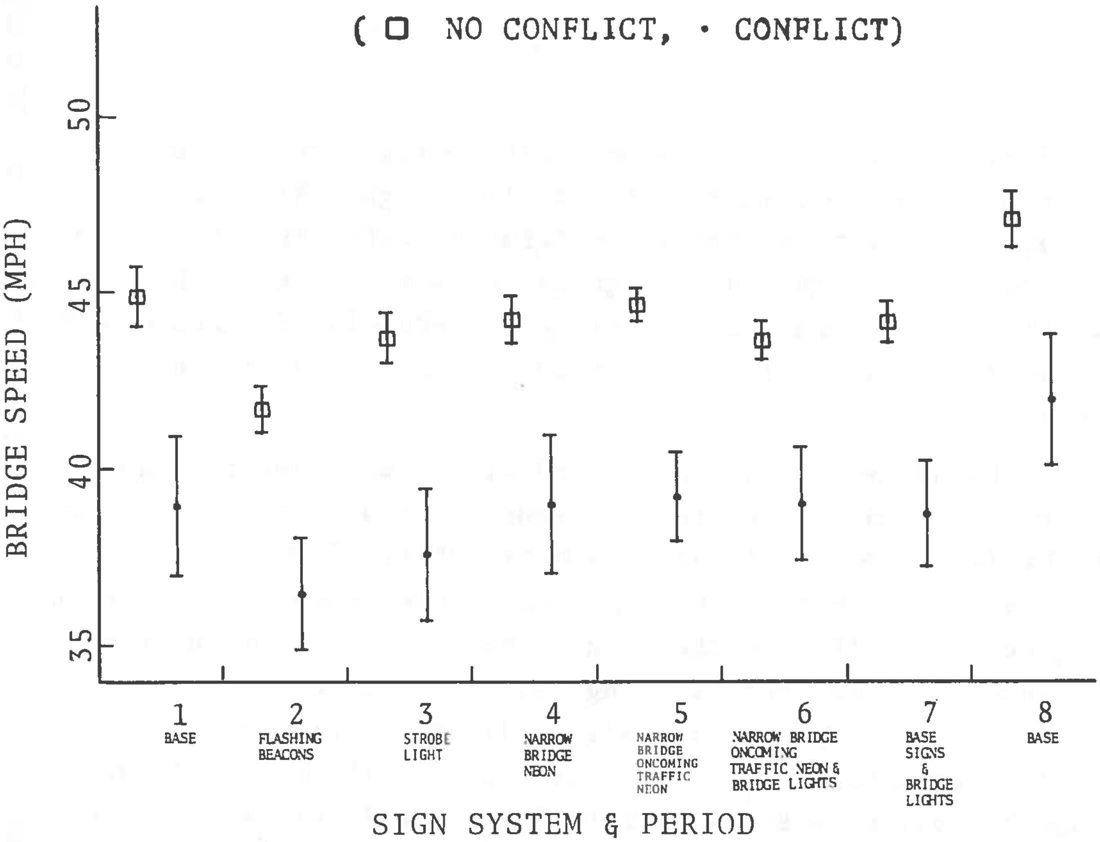


FIGURE 6-4. SPEED REDUCTION VS SIGN SYSTEM: WEST, AUTO, DAY



IGURE 6-7. BRIDGE SPEED VS SIGN SYSTEM: WEST, AUTO, NIGHT

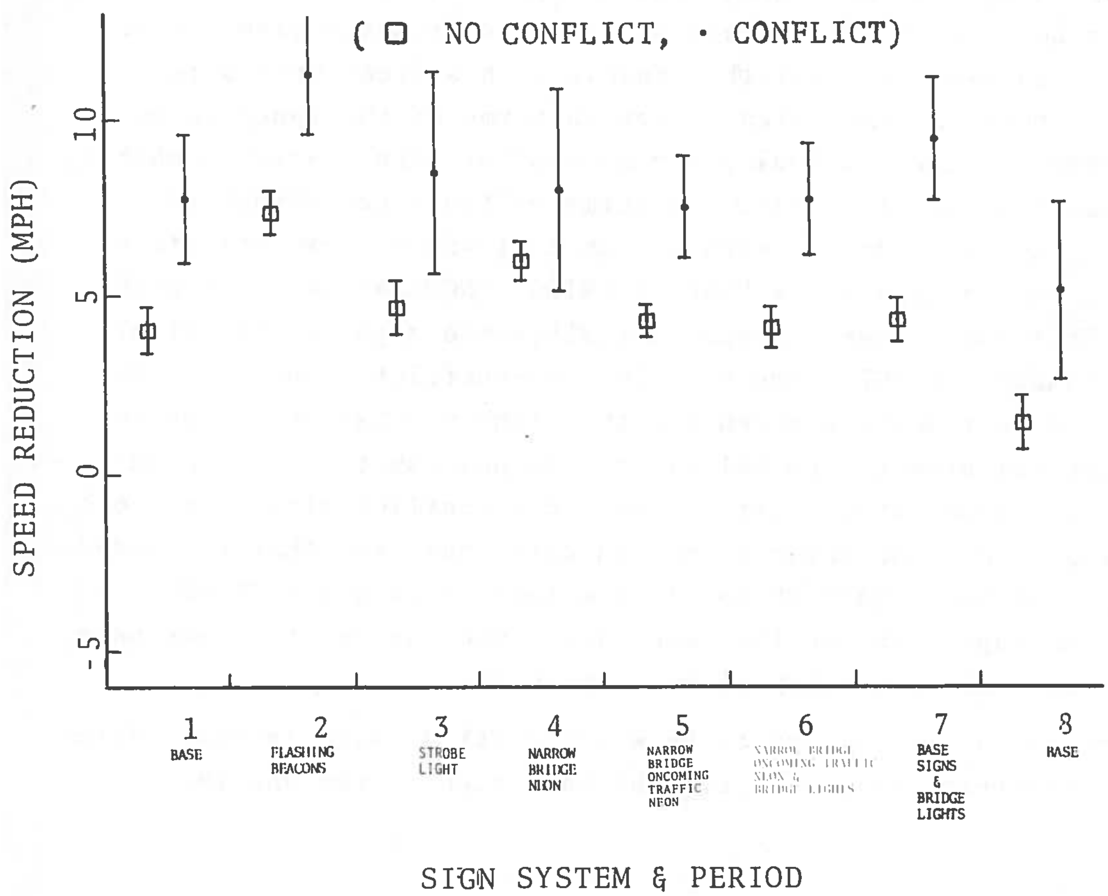


FIGURE 6-8. SPEED REDUCTION VS SIGN SYSTEM: WEST, AUTO, NIGHT

"Narrow Bridge" neon message sign for no-conflict situations) for certain conditions exceeded the sign system effect of the strobe lights. This diminished the impact of the finding for the strobe lights somewhat since part of the effect may have been due to similar variations (seasonal, novelty, or other).

Nighttime Conditions

The most effective sign system at night for westbound traffic was the flashing beacons. This occurred for both conflict and no-conflict situations and in terms of both speed measures, speed across the bridge and speed reduction before the bridge. Furthermore, judging by the single-sample bars the effect was statistically significant and substantial (2-3 mph).

For eastbound traffic the results are less clear. In terms of speed across the bridge, all sign systems (with the exception of the bridge lights with the base sign) were effective. In a conflict situation, these effective sign systems were about equal in their effectiveness while in no-conflict situations, the strobe lights were most effective, and the remaining effective sign systems were about equal in their effectiveness. In terms of speed reduction before the bridge, the flashing beacons were the most effective sign system in a conflict situation. In a no-conflict situation the bridge lights with base signs were slightly more effective (not significantly) than the flashing beacons. Since the flashing beacon effect as measured by speed reduction was more dominant than the strobe light effect as measured by speed across the bridge, the flashing beacon sign system was considered to be the most effective sign system for eastbound traffic at night also.

As was the case during daytime conditions, the added message "Oncoming Traffic" to the "Narrow Bridge" neon message sign resulted in less effectiveness in a conflict situation (see discussion below on novelty effects). Furthermore, the neon message signs together with the bridge lights were no more effective than the bridge lights alone at night.

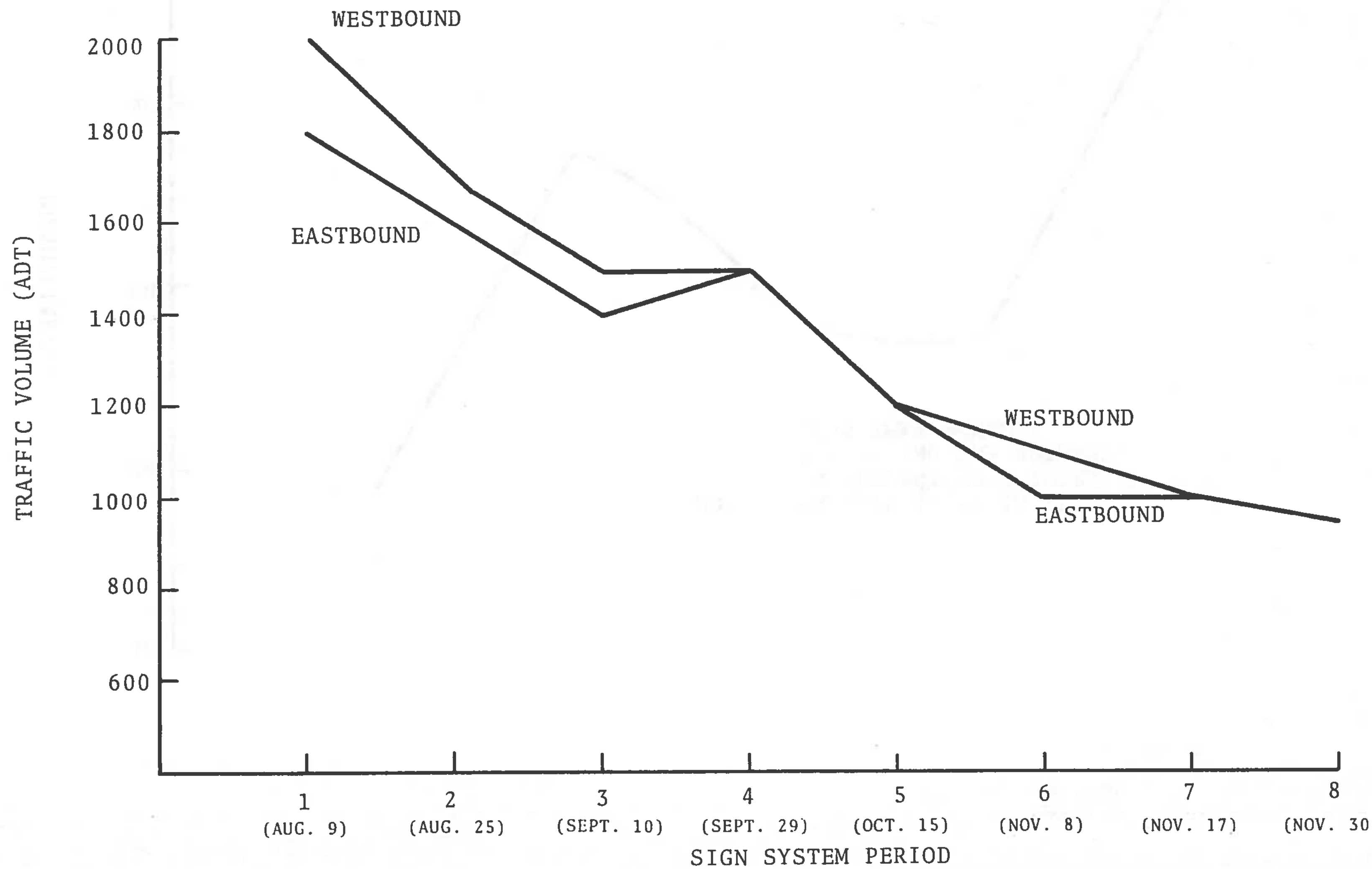


FIGURE 6-9. TRAFFIC VOLUME (ADT) VS SIGN SYSTEM PERIOD

which were unfamiliar with the roadway. As the winter months approached, the traffic volume, percent of recreational vehicles, and hence percent of unfamiliar drivers decreased.

In general, the traffic volume and unfamiliarity curves did not resemble or correlate well with the sign system effect pattern. Portions of the curves resembled each other over similar time periods, but sufficient data points were not available to establish a high degree of correlation during these periods.

Novelty Effect

The sign system effect pattern may have been partially due to a novelty effect by the familiar drivers (over 30% of the total) who travelled the roadway during the course of the experiment. Since these drivers travelled the roadway monthly or more often, they probably experienced most of the sign systems. If all the dynamic sign systems could be presumed to be equally effective *a priori* the novelty effect would mean that for the familiar drivers the dynamic sign systems would "lose" their effectiveness with time. Figures 6-1 through 6-4 show evidence of this: the first few systems tested are most effective while the remaining sign systems "lose" effectiveness with time. Furthermore, the "NARROW BRIDGE" neon message sign in a no-conflict situation appeared to lose some effectiveness from one time period to the next. This latter effect was not significant in itself, but a novelty effect from sign system to sign system cannot be disclaimed without further testing (with a different ordering of the sign systems). The fact that the base sign system tested after the dynamic sign systems was less effective compared to the base sign system tested initially implies some additional or other effect (e.g., seasonal) than novelty.

It is interesting to note that if the sign system results pattern during the day is due to some seasonal or novelty effect, then the bridge lights at night can be judged to have a special effect. The two bridge light sign systems (i.e., with the base sign and with the neon message signs) disrupted the nominal sign system effect pattern showing additional speed reduction and less

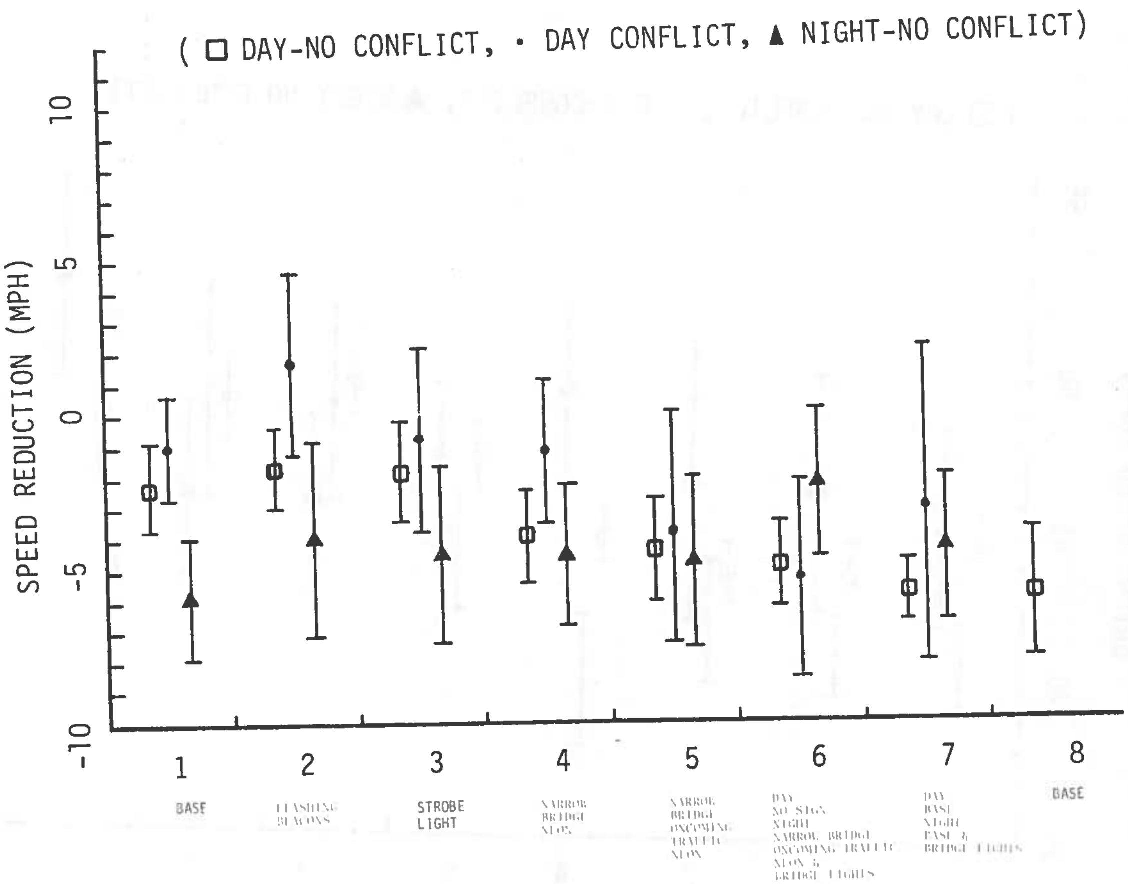
The speed variance measure was intended to provide information on whether the dynamic sign systems caused confusion to the drivers or led to misinterpretation. Speed variance was determined on the bridge and on the approach to the bridge for each sign system and each test condition. The results showed that none of the dynamic sign systems caused a significant increase in speed variance during the day. The largest speed variances occurred when the neon message signs were inoperative (data collection period 6 during the day). In effect, there were no warning signs present during this time period (except for the far advance passive sign). The absence of a warning sign near the bridge apparently led to some confusion on the part of the driver, caused a larger range of driver speeds across the bridge, and created a relatively hazardous situation near the bridge. This information evidently points to the importance of a warning sign near the bridge.

At night the flashing beacons, strobe lights, and neon message signs coupled with bridge lights, caused an increase in speed variance at or near the bridge for other (large) vehicles. The maximum variance occurred for the strobe lights, eastbound traffic and was about equivalent to the variance when no warning signs were present (see above) during the day. This increase in speed variance may have just been a temporary (novelty) effect but is viewed as an important consideration that should be tested further.

In general, speed variance was slightly higher for eastbound traffic (vs. westbound traffic) slightly higher at night (vs. day) and slightly higher for other (large) vehicles (vs. autos). The speed variance was about the same for conflict and no-conflict situations.

Other (Large) Vehicle Effects

Figures 6-11 to 6-14 show the speed results (means and 95 percent single-sample confidence intervals of bridge speed and speed reduction) for "other" vehicles. "Other" vehicles were defined in Section 4 as vehicles with lengths greater than 20 feet and hence were essentially large vehicles, such as trucks and



SIGN SYSTEM AND PERIOD

FIGURE 6-12. SPEED REDUCTION VS SIGN SYSTEM: EAST, OTHER

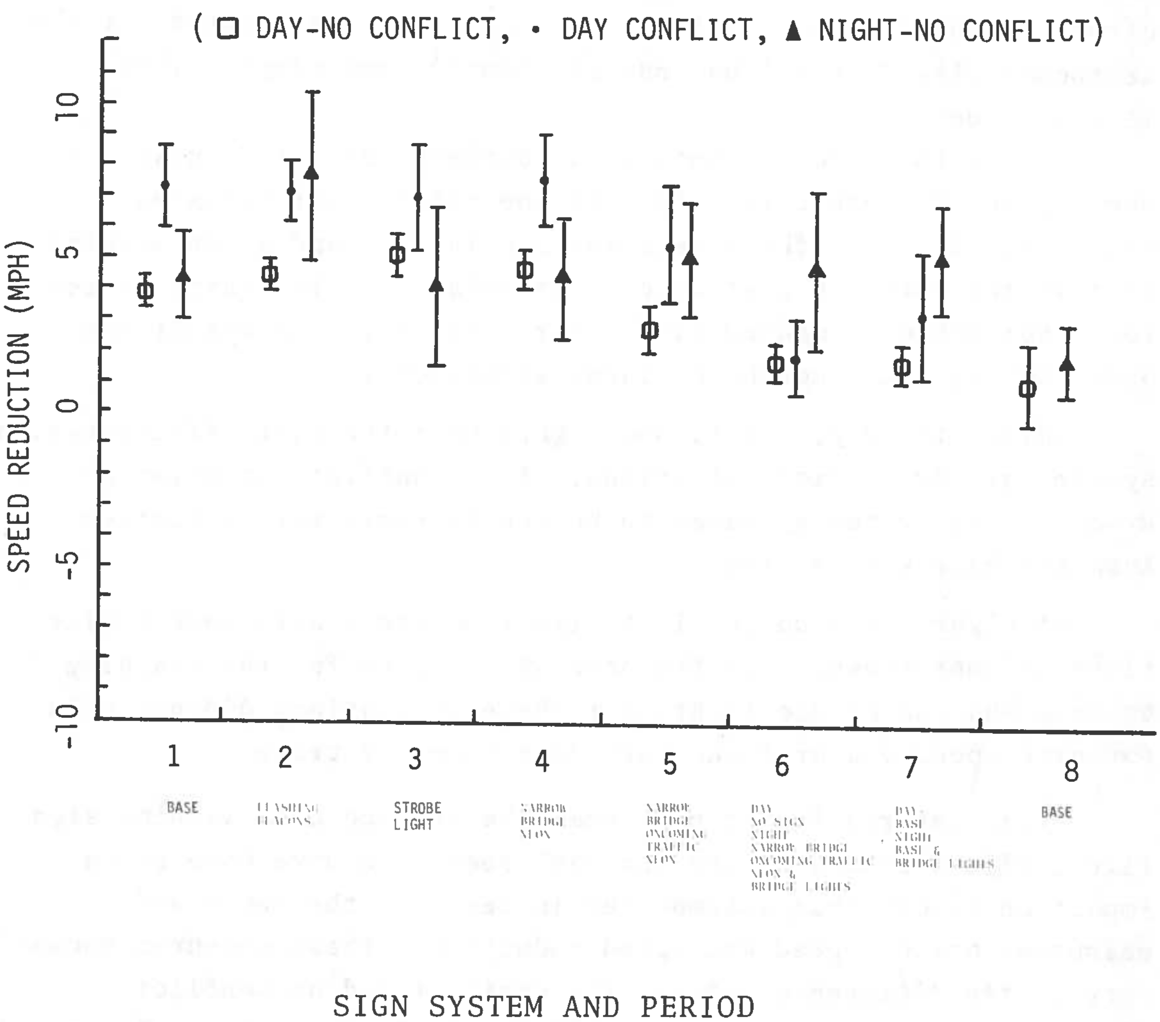


FIGURE 6-14. SPEED REDUCTION VS SIGN SYSTEM: WEST, OTHER

The following additional characteristics that were evident for autos (see above) were also displayed by other "large" vehicles:

1. There was a general tendency for drivers to accelerate to the bridge (from the at-grade railroad crossing) in the eastbound direction;
2. The variation in results between identical sign systems was about the same as the sign system effects in certain cases;
3. The added message "Oncoming Traffic" to the "Narrow Bridge" neon message sign resulted in less effectiveness in a conflict situation;
4. There were indications of seasonal effects for the no-conflict situation during the day.

The results for other vehicles were thus found to be quite similar to those for autos but were somewhat masked by sample size effects (wide error bars).

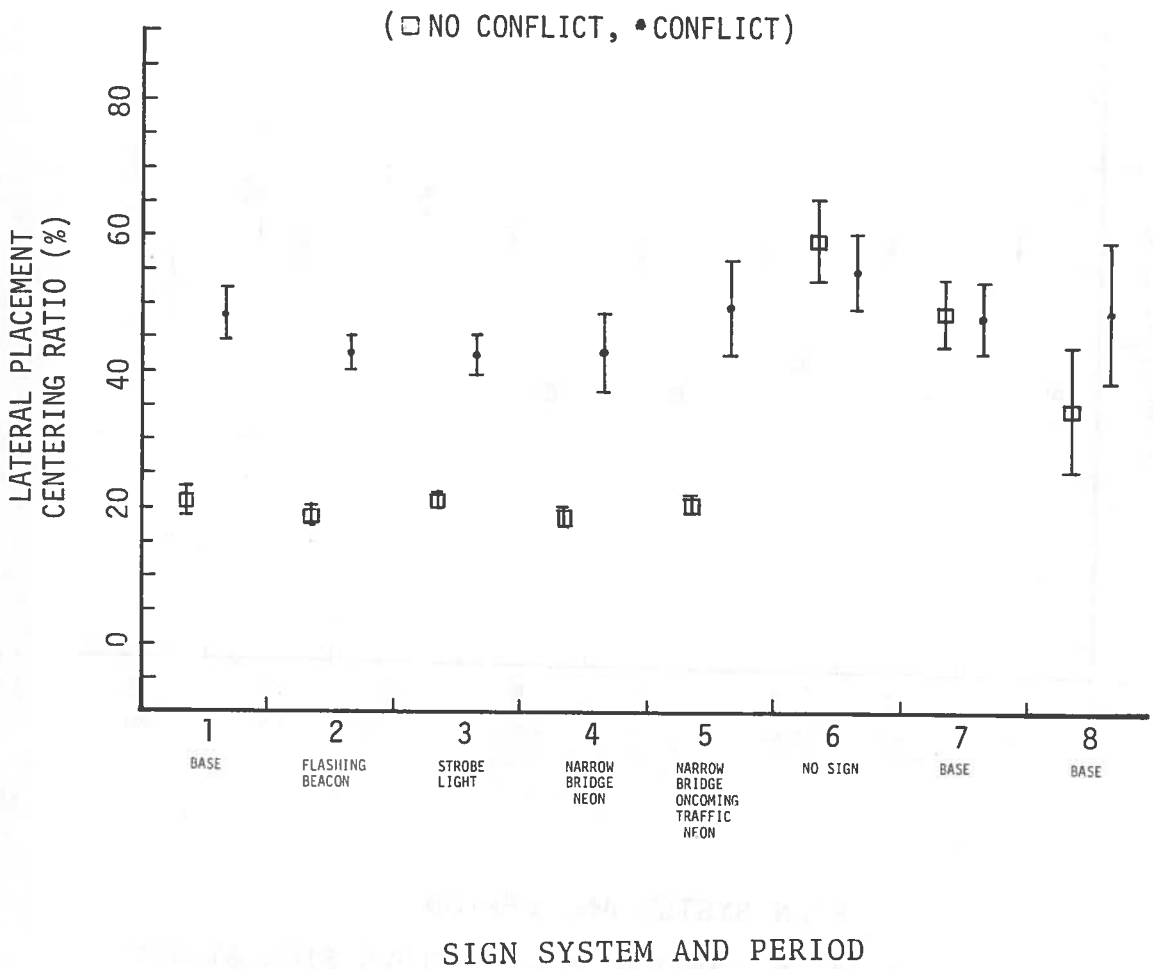


FIGURE 6-15. LATERAL PLACEMENT CENTERING RATIO VS SIGN SYSTEM AND PERIOD, EAST, AUTO, DAY, CENTER OF BRIDGE LOCATION

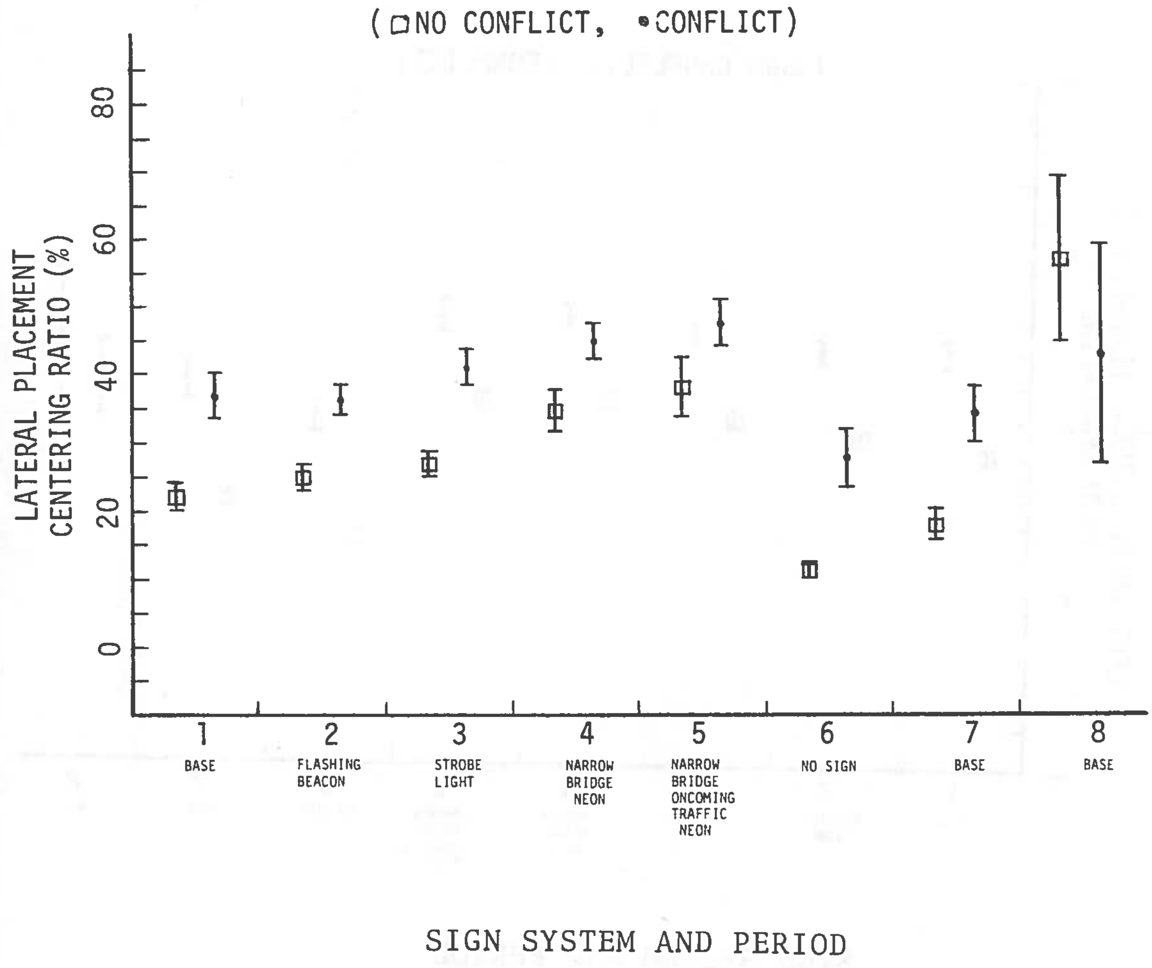


FIGURE 6-17. LATERAL PLACEMENT CENTERING RATIO VS SIGN SYSTEM AND PERIOD, WEST, AUTO, DAY, CENTER OF BRIDGE LOCATION

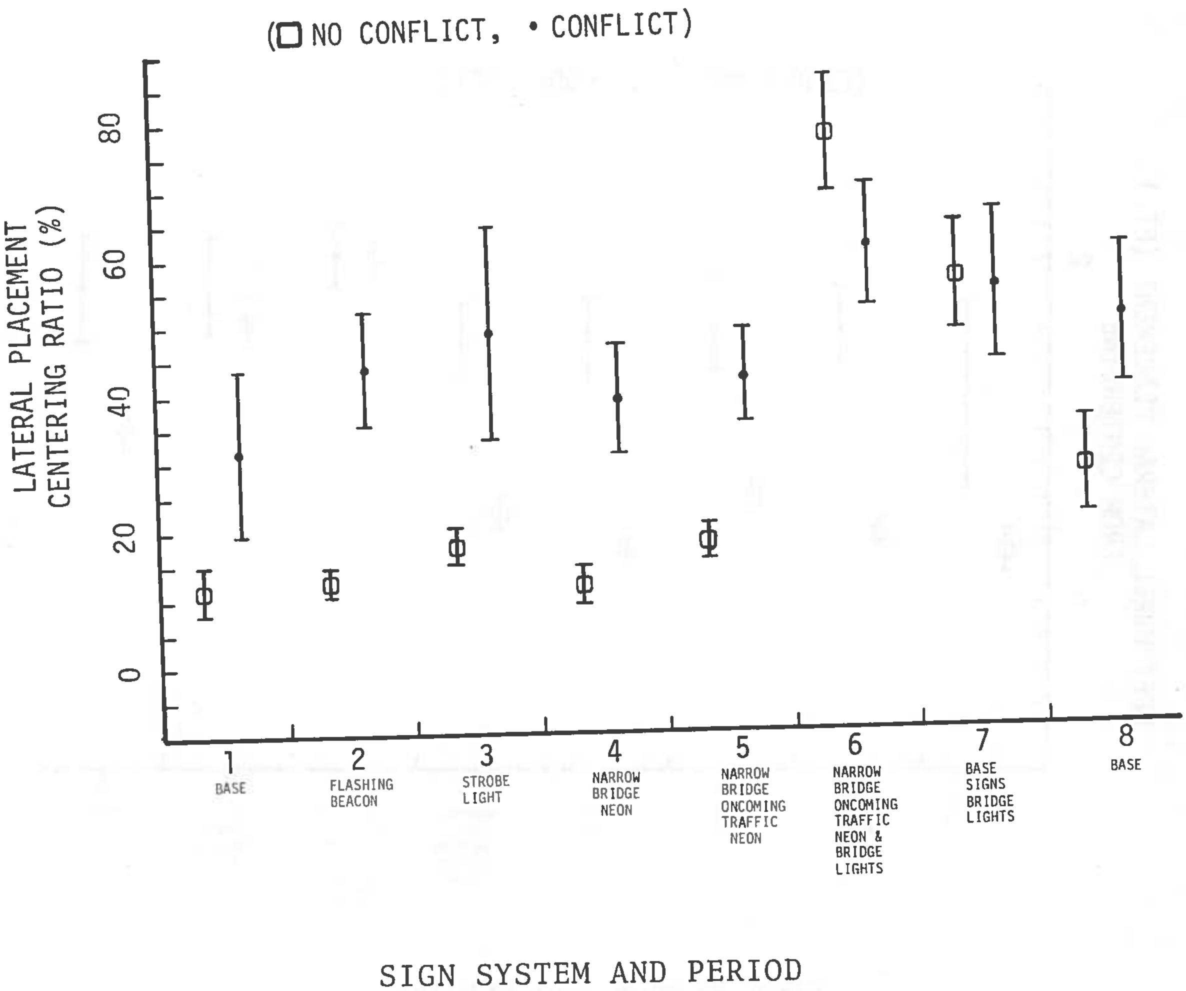


FIGURE 6-19. LATERAL PLACEMENT CENTERING RATIO VS SIGN SYSTEM AND PERIOD, EAST, AUTO, NIGHT, CENTER OF BRIDGE LOCATION

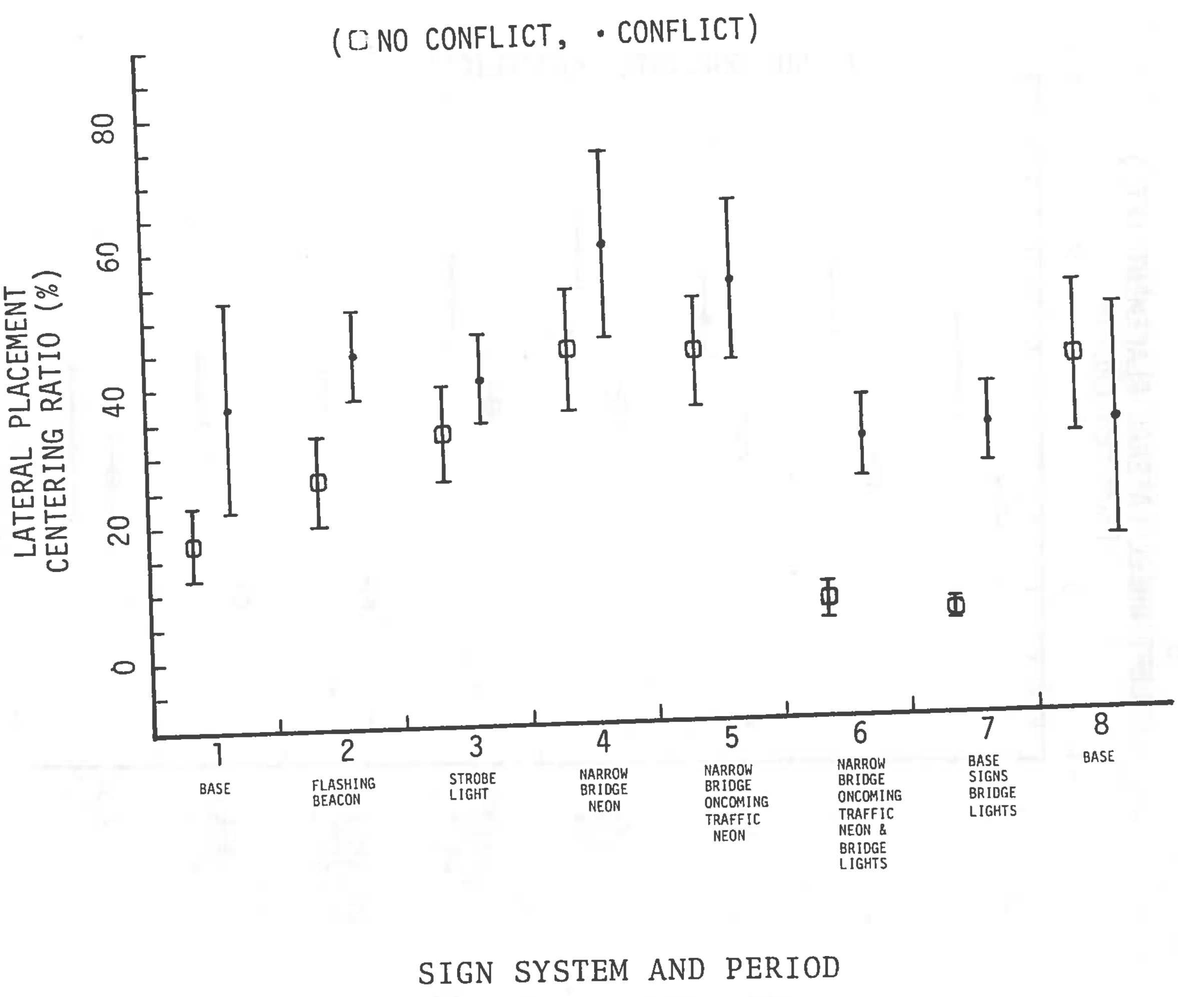


FIGURE 6-21. LATERAL PLACEMENT CENTERING RATIO VS SIGN SYSTEM AND PERIOD, WEST, AUTO, NIGHT, CENTER OF BRIDGE LOCATION

the strobe lights and neon message signs showed some indications of effectiveness but this effect was small (0.1 to 0.2 feet) and occurred in one direction only (westbound). The results for the base sign system were about equal to the results when no signs were present (i.e., data collection period 6). There were some indications that "no signs" were less effective than the base signs, but again the differences were small (0.1 feet) and occurred in one direction only (westbound).

Nighttime Conditions

The results at night (Figures 6-19 through 6-22) also indicated that the sign systems had no strong consistent effect on the vehicles' lateral placement. The bridge lights were effective for eastbound traffic in a conflict situation and for westbound traffic in a no-conflict situation but not vice versa. Futhermore, the bridge lights with the neon message sign were more effective than the bridge lights with the base signs for eastbound traffic in a conflict situation but not for westbound traffic. The "NARROW BRIDGE" neon message was effective for westbound traffic in a conflict situation but not for eastbound traffic. The "NARROW BRIDGE ON-COMING TRAFFIC" neon message sign and strobe lights were effective for westbound traffic in a conflict situation but not for eastbound traffic. These inconsistencies indicated that the dirrerences between sign systems were not due to the signs themselves but rather to unexplained and unaccounted-for effects. Since the differences were small (1.2 to .4 feet or less than one third of the conflict/no-conflict effect) the unaccounted-for effects were considered minor.

Location and Geometric Effects

The above results showed that the sign systems had no strong consistent effect in terms of lateral placement at the center of the bridge locations. Other data (not presented here) showed that the sign systems also did not have a strong consistent effect at the other two locations tested (beginning of the bridge and 200 feet before the bridge). However, at the beginning of the bridge location and to a lesser degree at 200 feet before the bridge, a strong effect occurred after data collection period 5. The results

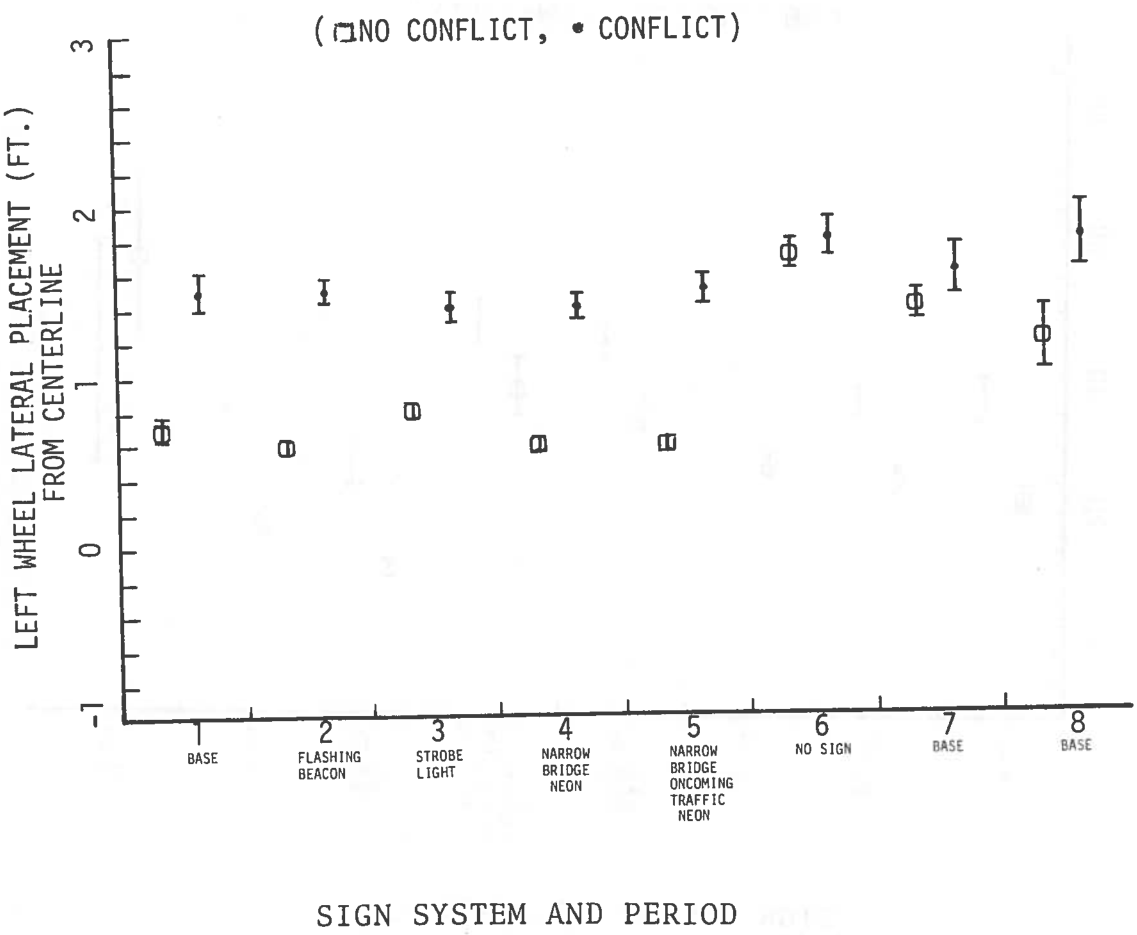


FIGURE 6-24. LEFT WHEEL LATERAL PLACEMENT VS SIGN SYSTEM AND PERIOD, EAST, AUTO, DAY, BEGINNING OF BRIDGE LOCATION

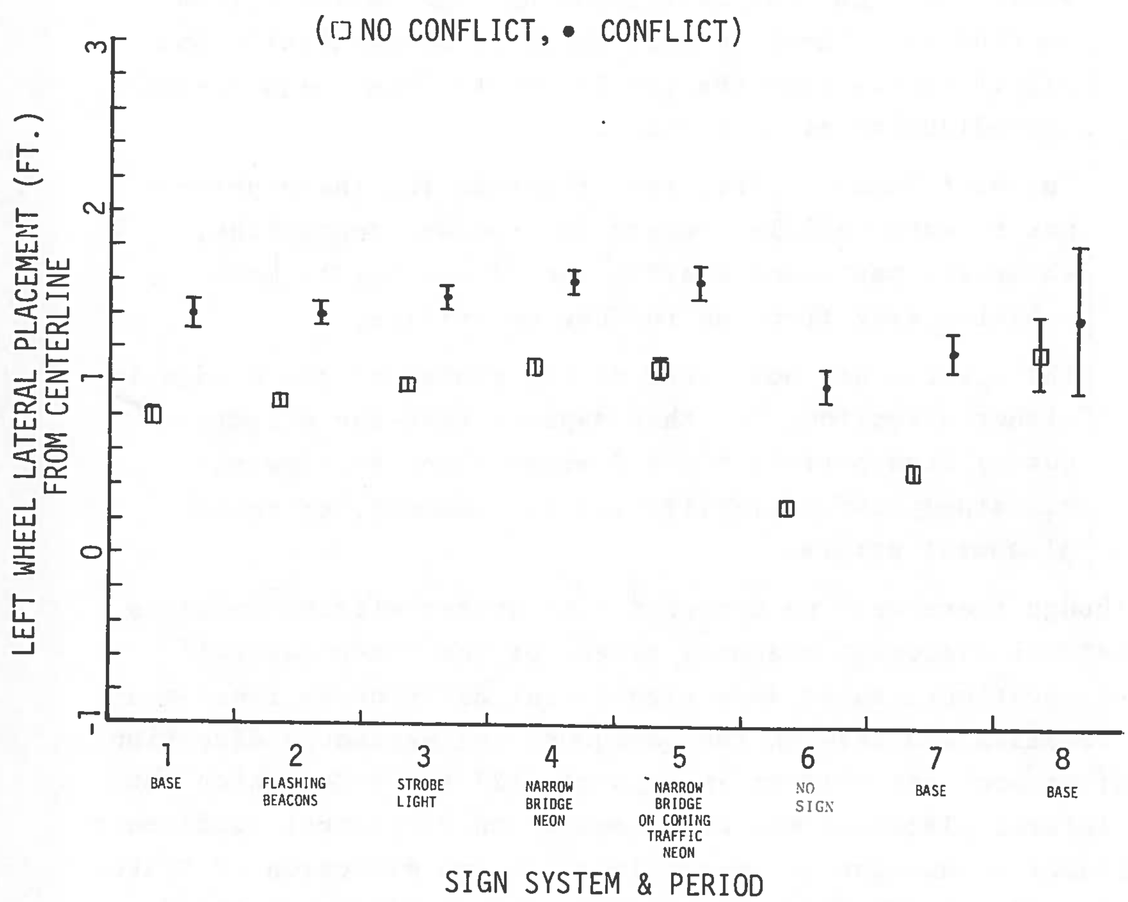


FIGURE 6-26. LEFT WHEEL LATERAL PLACEMENT VS SIGN SYSTEM AND PERIOD, WEST, AUTO, DAY, BEGINNING OF BRIDGE LOCATION

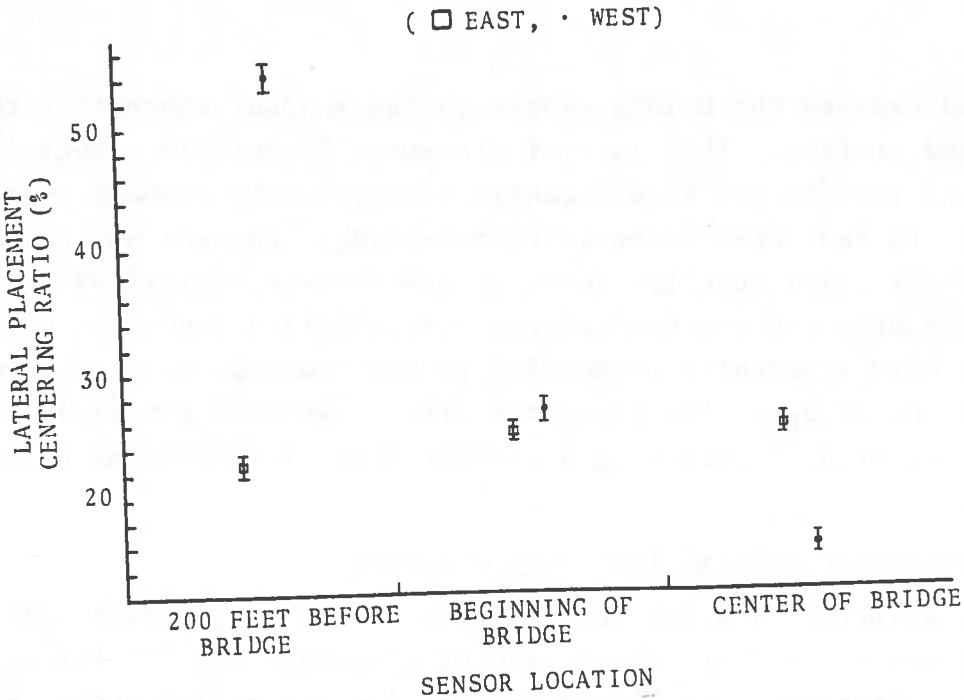


FIGURE 6-27. LATERAL PLACEMENT CENTERING RATIO VS SENSOR LOCATION; AUTO, DAY, NO-CONFLICT

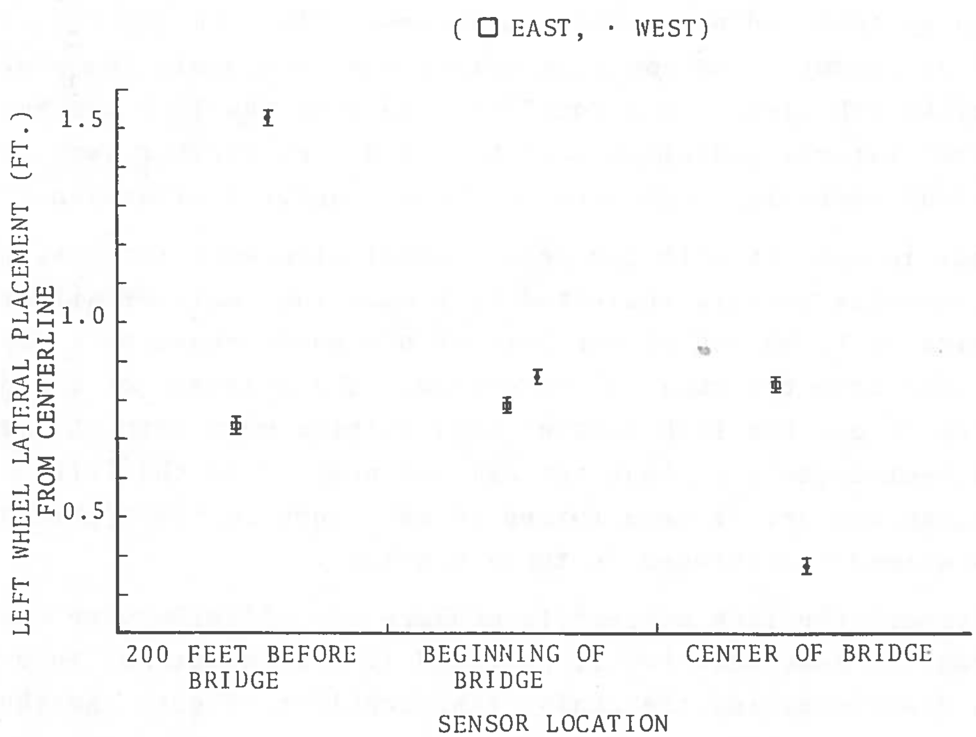


FIGURE 6-28. LEFT WHEEL LATERAL PLACEMENT VS SENSOR LOCATION; AUTO, DAY, NO-CONFLICT

measure was able to detect a sign system effect. Thus in the application to this study, the means and 15th percentiles were equally effective measures.

Other (Large) Vehicle Effects

Figures 6-29 to 6-32 show the lateral placement results (means and 95% single sample confidence intervals of centering ratio and left wheel lateral placement) for "other" vehicles.

Three test conditions are shown for each direction of travel: (1) Day, No-Conflict, (2) Day Conflict and (3) Night, No-Conflict.

The test condition-Night Conflict - was omitted because of low sample sizes. Likewise other test conditions are omitted for certain testing periods due to low sample sizes.

Once again, opposing vehicles had the dominant effect on driver behavior. In a conflict situation drivers tended to center more in their lanes while moving farther away from the roadway centerline. In most cases these effects were significant.

The figures also show that similar to the results for autos; there was no strong consistent sign system effects on the vehicles' lateral placement. The strobe light appeared to be effective in centering vehicles in their lane for the Day No-Conflict East test condition, but for no other test conditions. The flashing beacons, strobe light, and bridge lights with base signs showed some indications of effectiveness for the Night No-Conflict West test conditions, but these were not significant and did not occur for the other test conditions.

It thus was concluded that there were no special effects for other (large) vehicles in terms of lateral placement due to the dynamic sign systems.

6.3 TEST CONDITION EFFECTS

This section examines the test conditions effects (i.e., independent of the sign condition effects) in terms of the means of the two speed measures and the two lateral placement measures. The test conditions were classified by the levels of independent

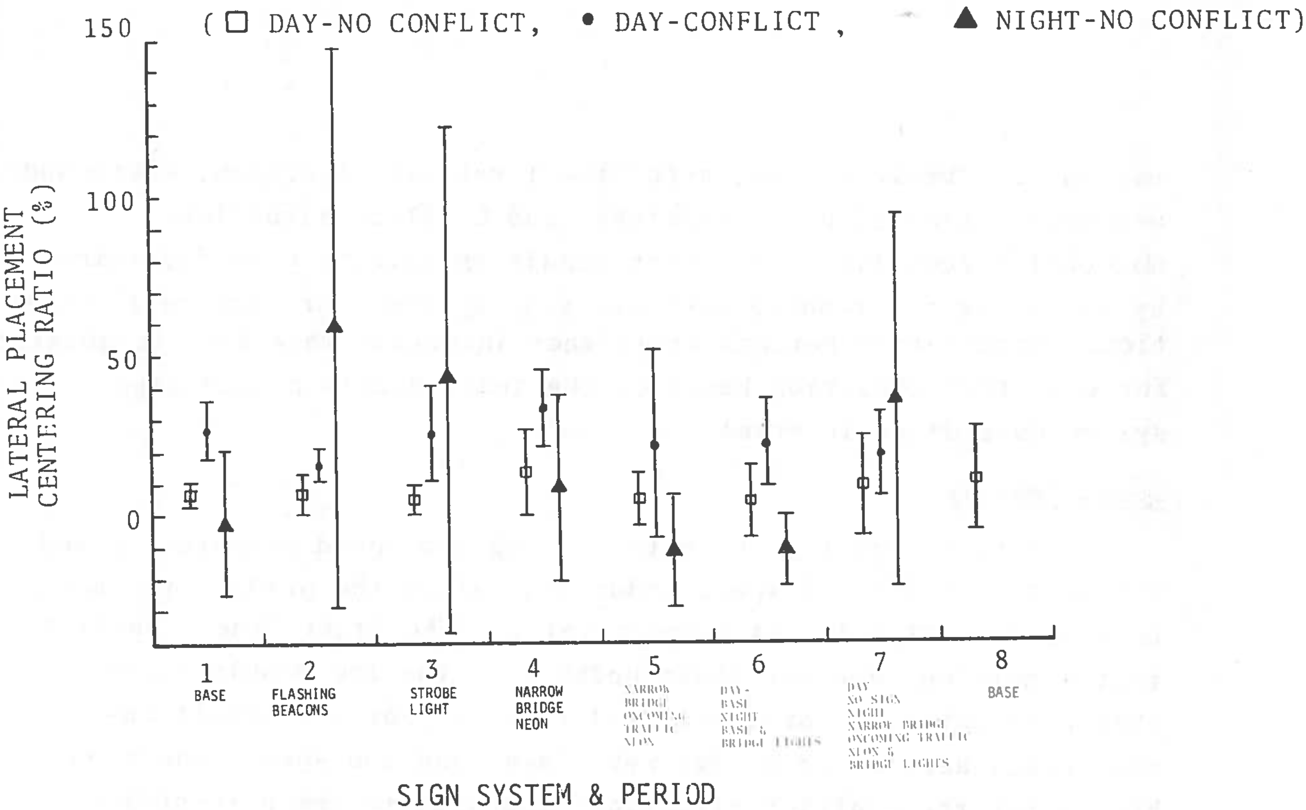


FIGURE 6-31. LATERAL PLACEMENT CENTERING RATIO VS SIGN SYSTEM: WEST, OTHER, CENTER OF BRIDGE LOCATION

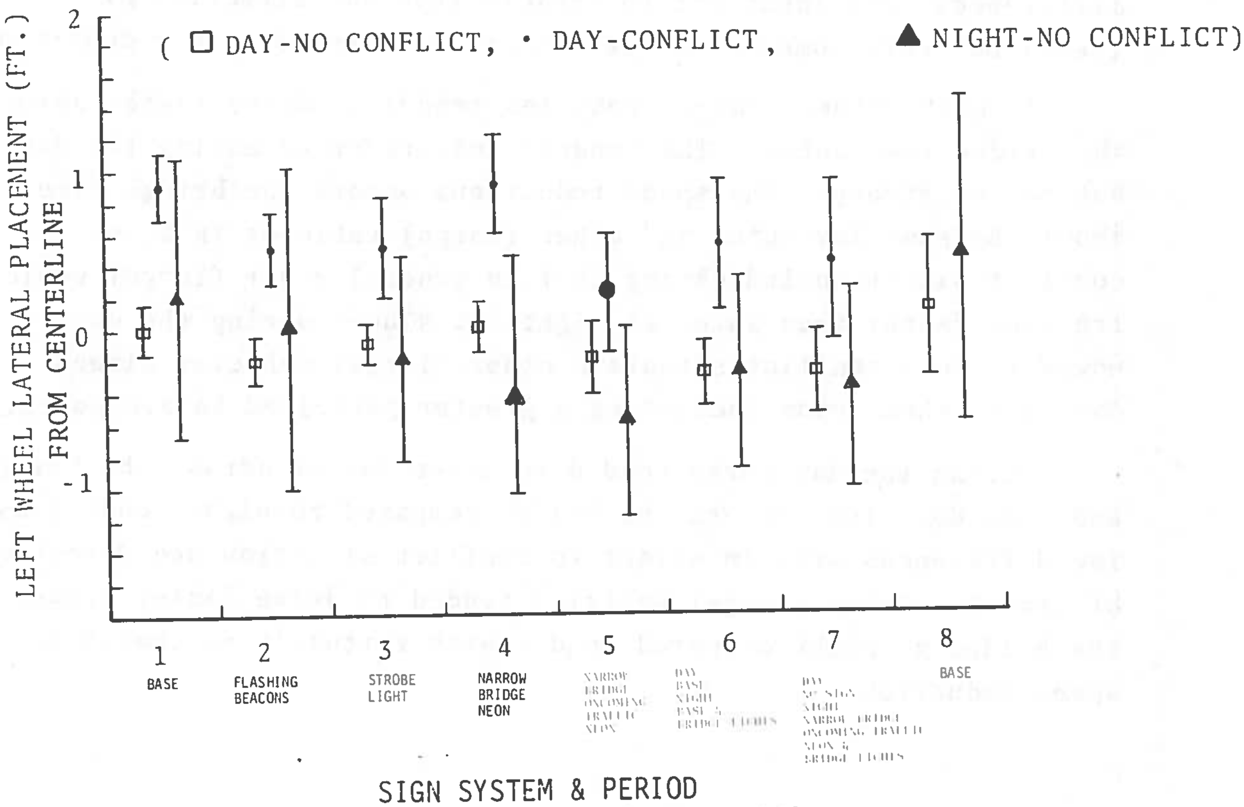


FIGURE 6-32. LEFT WHEEL LATERAL PLACEMENT VS SIGN SYSTEM AND PERIOD, WEST, OTHER, CENTER OF BRIDGE LOCATION

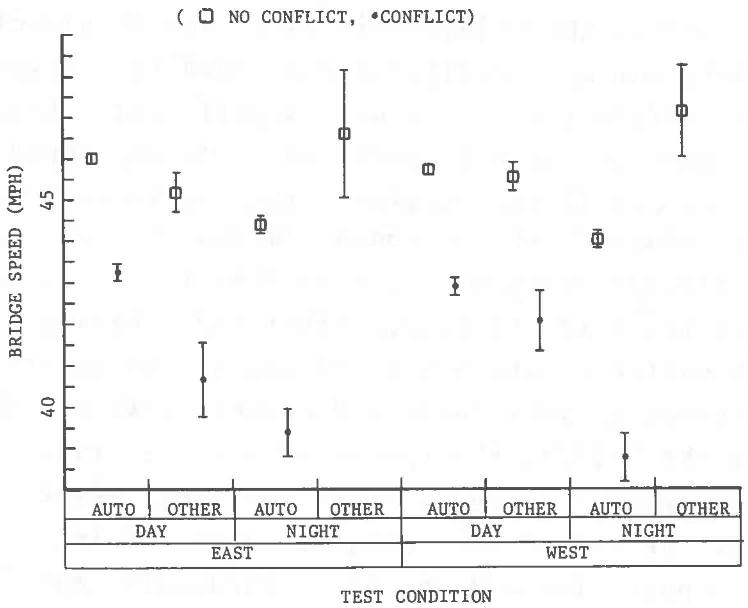


FIGURE 6-33. BRIDGE SPEED VS TEST CONDITION

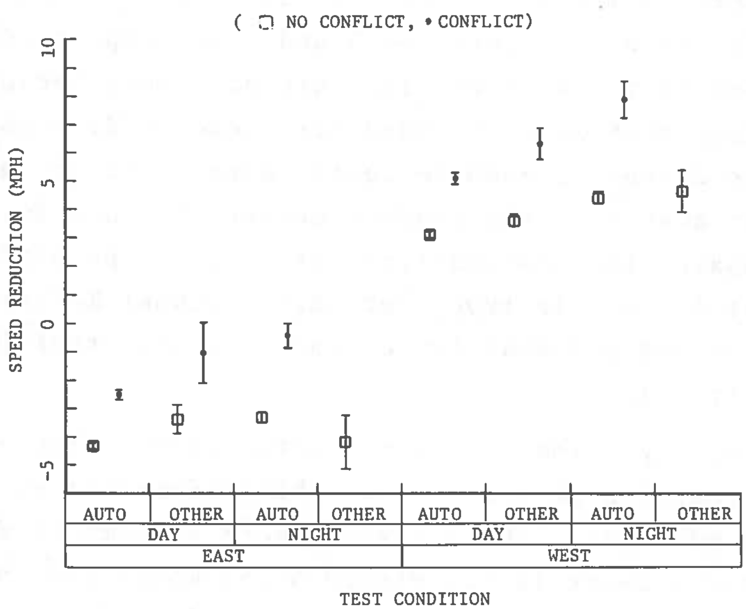


FIGURE 6-34. SPEED REDUCTION VS TEST CONDITION

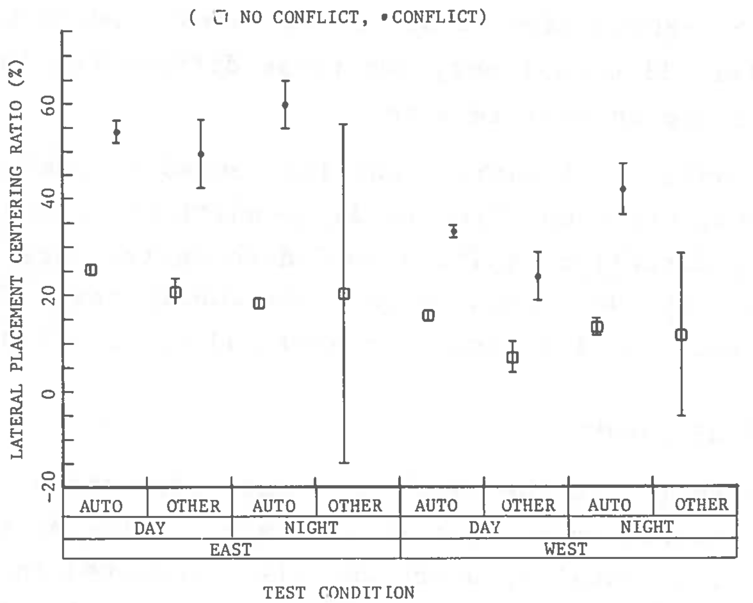


FIGURE 6-35. LATERAL PLACEMENT CENTERING RATIO VS TEST CONDITION

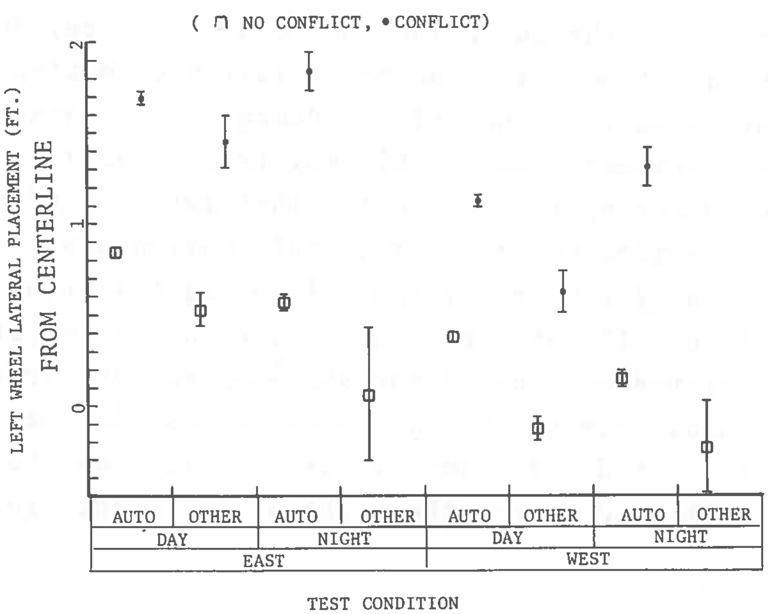


FIGURE 6-36. LEFT WHEEL LATERAL PLACEMENT VS TEST CONDITION

In general respondents to the roadside survey viewed the approaching and/or traversing of a narrow bridge as a traffic situation warranting a great deal of caution. Furthermore, 54% of all respondents chose "traffic on the bridge" (opposing vehicles), while 35.5% chose "width of the bridge" as causing them most concern. This information was supported by additional survey data that showed that whereas 21% of the motorists tended to drive toward the roadway center line when approaching and/or traversing the bridge in the absence of opposing traffic, only 11% did so in the presence of opposing traffic.

The survey data was thus consistent with the electronic data in the sense that opposing vehicles had the greatest impact on driver behavior in terms of the vehicles lateral placement. In terms of speed characteristics the survey data showed practically no distinction between a conflict situation and a no-conflict situation. This was mostly due to the limited speed data available from the survey and the fact that practically all the respondents indicated that they slowed down when approaching the bridge. The more quantitative electronic data showed a distinct difference between conflict and no-conflict situations.

The respondents to the survey indicated no significant and consistent differences in sign system effectiveness by their perceived lateral placement and speed characteristics when approaching and crossing the bridge. However, the neon message signs seemed to be the best attention-getting devices. This was indicated by the data in Table 6-1, which showed the percent of respondents who correctly identified each sign system. The assumption implicit in the data was that the best "attention-getting device" was one which drivers could identify most readily at a later time. It is interesting to note that all the dynamic sign systems were identified correctly more often than the base sign system.

The neon message signs also appeared to be the most effective sign systems in conveying information on the bridge ahead to the motorists. This is indicated by the data in Table 6-2, which shows the factors (in percent) that made the respondents most

TABLE 6-1. PERCENT OF RESPONDENTS CORRECTLY IDENTIFYING SIGN SYSTEMS

Sign System	1 Base	2 Flashing Beacons	3 Strobe Lights	4 "NARROW BRIDGE" Neon Sign	5 "NARROW BRIDGE" "ONCOMING TRAFFIC" Neon Sign
Correct Identifications %	32	47	81	96	93

TABLE 6-2. FACTORS THAT MADE RESPONDENTS AWARE OF NARROW BRIDGE

	Sign System				
What made resp. aware of narrow bridge (%)	1 Base	2 Flashing Beacons	3 Strobe Lights	4 "NARROW BRIDGE" Neon Sign	5 "NARROW BRIDGE" "ONCOMING TRAFFIC" Neon Sign
Bridge	21.0	12.2	17.4	5.0	5.8
Warning Sign	65.4	69.6	68.7	83.1	65.8
Knowledge of Road	10.3	15.7	10.4	11.9	28.4
Other	3.3	2.5	3.5	--	--

TABLE 6-3. BRIDGE VS WARNING SIGN FACTORS THAT MADE RESPONDENTS AWARE OF NARROW BRIDGE.

	Sign System				
What made resp. aware of narrow bridge(%)	1 Base	2 Flashing Beacons	3 Strobe Lights	4 "NARROW BRIDGE" Neon Sign	5 "NARROW BRIDGE" "ONCOMING TRAFFIC" Neon Sign
Bridge	24	15	20	6	8
Warning Sign	76	85	80	94	92

Finally, most drivers drove faster across the bridge than they indicated in the survey by 10 mph. On the approach to the bridge (i.e., near the warning signs) their actual speed was only slightly higher (by 1-4 mph) than their perceived speed. The rather large discrepancy in speeds across the bridge is somewhat alarming and may indicate that the hazard potential at narrow bridges is larger than most drivers perceive. It would seem that a separate experiment to test the differences between actual and perceived speeds under various driving conditions (not limited to narrow bridges) would be a worthwhile endeavor. If major differences persist, an effective countermeasure addressing this more general problem could then be constructed perhaps in the form of an educational campaign.

4. At night the most effective sign system appeared to be the flashing beacons again showing a speed reduction of 2 mph compared to the base sign system under most test conditions. The remaining sign systems were not consistently effective for the various test conditions.

5. The above sign system findings may have been negated somewhat by possible indications of novelty and seasonal effects.

6. There was no strong consistent sign system effect in terms of the lateral placement measures.

7. Survey data indicated that the neon message signs were the "best" signs in terms of attention-getting and information conveying capability. This was determined by the fact that the respondents to the roadside survey were able to identify the neon message signs more often and the neon message signs made more respondents aware of the narrow bridge compared to the other sign systems.

8. Both the survey data and the electronic data showed that the "ONCOMING TRAFFIC" message sign and the strobe lights caused some confusion to the drivers.

9. The added information, ONCOMING TRAFFIC, on the neon message signs appeared to serve no practical purpose. Most drivers were probably made aware of the oncoming vehicle by its presence rather than by the message.

In summary the results of this experiment showed no substantial and consistent differences between the existing and dynamic sign systems in terms of the speed and lateral placement measures. It may have been that these measures were not sensitive to or good indicators of the possible change in driver behavior to the new signs. The roadside survey provided additional driver awareness measures for determining the safety benefits of the new sign systems but also did not reveal any important improvements.

8. REFERENCES

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