Supplemental Interchange Signing and Driver Control Behavior

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A study was conducted to determine the effect on driver behavior of supplemental interchange signing on rural freeways, including various combinations of tourist-oriented attraction and service signs. Thirty-six test subjects "drove" the FHWA driving simulator over a 40-mi freeway course with 14 interchanges. Subjects were requested to scan the signs presented on an interchange approach and to exit the freeway if they saw a sign for the attraction or service they were seeking. Data were collected on the speed, acceleration pattern, and lateral placement pattern of the simulated vehicles on interchange approaches and on the distances from the signs at which the subjects recognized the logo or legend they were seeking. Supplemental signing in addition to that already permitted on a rural freeway interchange approach was generally detrimental to driver control behavior. Field tests should be conducted to confirm the behavior effects. The design of the supplemental attraction signs used in the simulation may have contributed to the changes in driver behavior, so designs that include different color schemes or that have picture logos as well as legends may be worth testing. Driver age, driver sex, and the number of supplemental service signs were other variables controlled in the experiment that were associated with control behavior differences and should be included in any future testing.

Inadequate in-trip directional information on attractions available to motorists along rural freeways has received attention recently from transportation professionals. The problem can be summarized as follows (*1*):

> With the exception of major traffic generators, which qualify as destinations on standard or supplemental guide signs, information needs concerning attractions have normally been satisfied by billboards and hard copy information sources. However, the cost of adequate billboards for small, non-profit or local government owned attractions may be prohibitive, especially in areas with limited legal sign space. Hard copy sources suffer from uncertain and unreliable distribution mechanisms and are often less than optimum in fulfilling needs for direction rather than selection. The satisfaction of this group of information needs thus represents one of the major deficiencies of the current information systems.

A possible solution to the problem has been proposed by several states. These states want to install up to two new signboards on the freeway right-of-way before selected rural freeway interchanges and remove current supplemental guide signing. The proposed new signing concept is shown in Figure 1. Each new signboard, referred to hereafter as "attraction sign," would contain up to four attraction names or logos and a message informing the motorist of the proper exit to use. One attraction sign would contain names or logos of traffic generators such as business districts, medical facilities (other than hospitals), or government installations and would be blue with white lettering. The second attraction sign would contain the names or logos of cultural, recreational, and historical facilities and would be brown with white lettering. Each attraction name or logo would fit into an area 3 ft high and 5 ft wide. The sign, including border but not support, would be 10.5 ft high and 13 ft wide. The proposed attraction signs would be erected in advance of the specific service logo signs permitted under federal regulations (*2*) for camping, lodging, food, and fuel with a minimum spacing between supplemental signs of 800 ft. A maximum of 18 business names or logos are now permitted on the four service logo signs. One possible arrangement of the new attraction and other signs near a typical rural interchange is shown in Figure 2. Smaller versions of these attraction signs, with directional arrows and mileage to the attraction, would be erected near freeway ramp terminals for attractions not visible from the ramp.

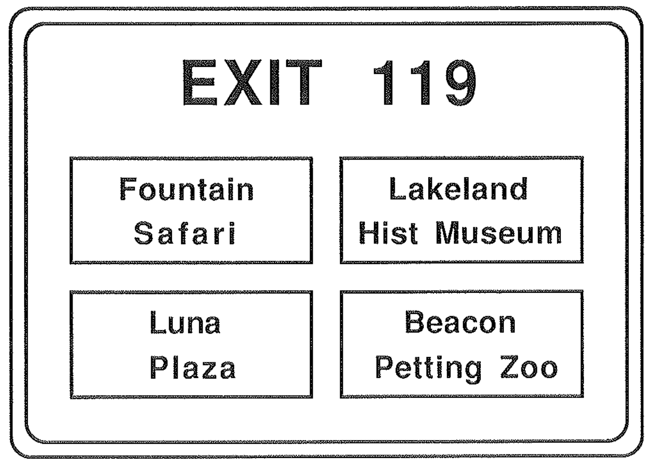

FIGURE 1 Typical proposed "attraction" sign.

The driver safety effects of supplemental attraction signs at rural freeway interchanges were investigated in a study for the FHWA (*3*). The objectives of the research were to assess the need for and to narrow the range of variables to be considered in a future field study of attraction signs. A large number of sign-related variables that may affect driver safety were examined. This paper summarizes the results of that examination.

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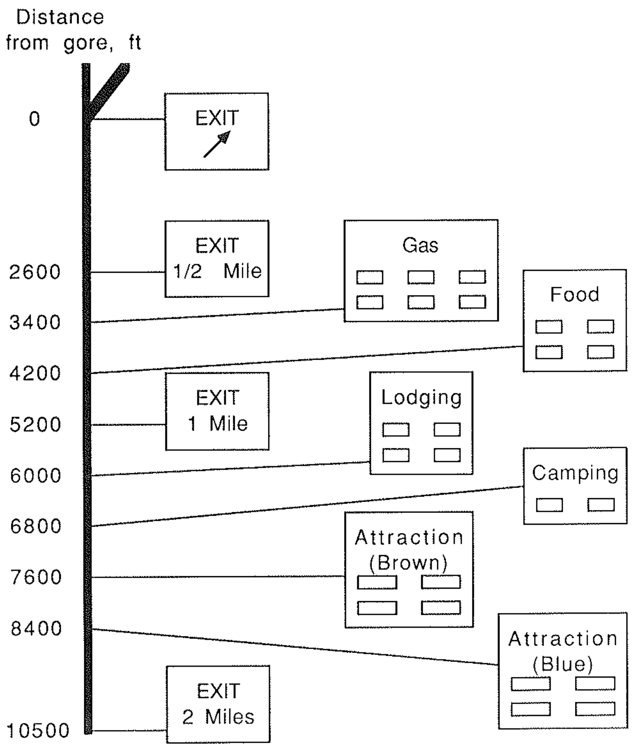

FIGURE 2 Example sign sequence and spacing in advance of rural freeway interchange including supplemental service and proposed attraction signs.

BACKGROUND

The literature was examined for clues on the impact of the propsed attraction signs on driver behavior. From the current regulation on such signs, human factors theory, installations of analogous types of signs, and past installations of attraction signs, it appears that there may be an effect on driver safety from the proposed signs, but the extent of the effect remains unknown.

The Manual on Uniform Traffic Control Devices (MUTCD) contains specific regulations on supplemental guide signs (*4*). The MUTCD first specifies the exact appearance of a supplemental guide sign. Then, the MUTCD warns of a potential driver information overload problem from a profusion of such signs and places limits on their use. The proposed attraction signs violate both the specified appearance and usage guidelines; therefore, the concern expressed regarding an impact on driver performance from such signs may be justified.

The human factors literature does not offer a solution to the problem of determining the safety impact of the proposed signs. Driver information overload is a concern regarding signs placed near freeway interchanges, but information overload is difficult to define and it is not yet possible to calculate the magnitude of information overload from theory.

Past studies have been conducted on the effects on driver safety of freeway guide signs, supplemental service logo signs, and advertising signs. Longer messages on freeway guide signs have been shown to degrade driver performance in laboratory and field studies (*5–9*). However, the optimum message length varies widely with sign function and placement. Research on the number of signs before a freeway exit has been inconclusive. Studies of the installation of service logo signs in Ohio (*10*) and Virginia (*11*) and gasoline logo shields in Vermont (*12*) have found no major impacts on rural freeway operations. Controversy remains over the effects of the number of roadside advertising signs on driver behavior, with most recent research indicating that a greater density of advertising signs leads to more driver operation problems.

Vermont and Nebraska, among other states, have installed supplemental signs for attractions on major roads. Vermont's program involves a system of smaller signs along non-freeway roads (*13*). A typical sign has several attraction panels with a standard category symbol, the attraction name, the distance to the attraction, and a directional arrow. The sign is part of a sequence of such signs placed 200 ft apart before an intersection. Driver information overload was a concern of Vermont officials, and field tests made with signs with five attraction panels showed that those signs were unsatisfactory. A limit of three panels per sign was adopted and the standard category symbol was made optional.

Nebraska's program involves installation of signs on rural freeways (*14*). A large sign containing the logo and a legend for a particular attraction is placed near the interchange to be used, while a similar sign is placed 50 mi from the interchange. No attempt was made to measure the driver safety impact of the signs during the extensive evaluation of the program.

EXPERIMENTAL DESIGN

Since the potential driver safety impact from the proposed attraction signs cannot be identified with the available theory or by analogy to similar sign installations, an experiment was conducted on the FHWA driving simulator (HYSIM). HYSIM models real-world driving conditions in the laboratory with a stationary automobile in which a test subject manipulates vehicle controls in response to a continuously updated roadway view projected on a screen. HYSIM was an advantageous way to conduct the experiment because it offers high degrees of test subject safety and experimental control. Limitations to the accuracy with which HYSIM models real-world driving were mitigated and the results showed that the limitations did not adversely affect the study objectives.

The measures of effectiveness (MOEs) selected for the experiment were measures of driver performance rather than mental load. MOEs were selected because they were related directly to the study objectives, reliable, feasible, and of value in reaching conclusions. Five MOEs were selected:

- Speed differential (the difference between a driver's speed near an experimental sign of interest and the mean speed for all drivers),
- Number of erratic maneuvers (steering far off course or missing an exit),
- Acceleration noise (the standard deviation of acceleration measured at points near an experimental sign),
- Lateral placement (the standard deviation of the center of the vehicle relative to the center of the lane measured at points near an experimental sign), and
- Recognition distance (distance between an experimental

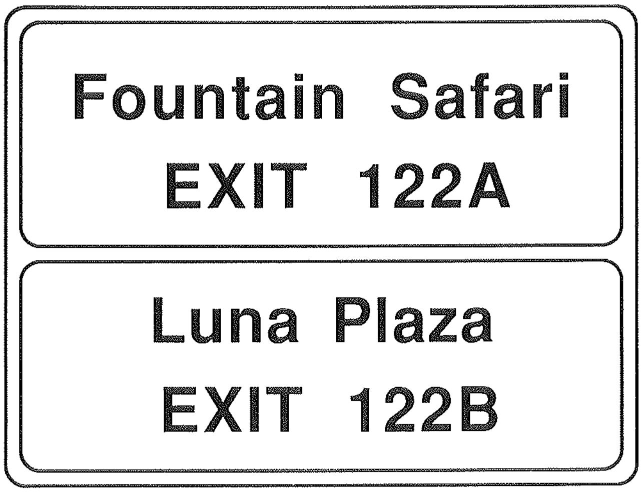

FIGURE 3 Typical current MUTCD supplemental sign.

sign and the point at which drivers signaled their recognition of the message on the sign).

Variables under systematic control of the experimenter included the age and sex of the driver, the presence of a pair of the proposed attraction signs versus a current MUTCD supplemental sign (shown in Figure 3), the number of service logo signs, and the number of logos per attraction sign (i.e., two per sign versus four per sign). Testing was conducted during the summer of 1985. The basic instructions given to the 36 paid test subjects were to scan the guide signing presented before a freeway interchange for a specified destination "cue" and to exit where the signs showed the destination was located. The HYSIM driving course consisted of 40 mi of simulated rural freeway with 14 interchanges, 9 of which a test subject used as the experiment progressed. Standard diamond and cloverleaf interchange designs were used and the results for each design type were analyzed separately. The signs were projected from slides produced on an advanced computerized color graphics system and were similar in appearance to actual highway signs. Fictitious two-syllable attraction names rather than pictures or logos were used on the attraction signs to eliminate bias from particularly famous or vague logos.

Eighteen different signs were used for data collection. However, each combination of MOE, cue type, and interchange type was analyzed as a separate experiment. The design of these "separate experiments" was factorial, that is, several different independent variables were controlled and the effects investigated at each of two or more categories. The basic hypothesis tested statistically through the entire effort was that there was no difference in an MOE between different categories of a particular factor (or several interacting factors). Rejection of this hypothesis for a particular combination of variables, MOE, cue type, and interchange type meant that the sign or driver characteristic(s) may influence performance over the ranges tested.

Analysis of variance (ANOVA) was used to test the hypotheses. ANOVA was chosen because it examines interactions among the variables as well as the separate main effect of each variable. For example, for the speed MOE, the "presence of new attraction signs" and "number of service signs" may have proven insignificant by themselves, but a significant interaction between them may have been the basis for the conclusion that there was a driver performance effect when both variables were at extreme points.

RESULTS

Results from a questionnaire given to the subjects after their simulated drive showed that the subjects thought the experiment was credible. Most test subjects thought the simulation was realistic, the sign legibility was good, the effort required to "drive" 40 mi was about right, and the instructions were easy to understand.

ANOVA was applied to 56 combinations of cue and interchange type, variable main effect, and MOE. A 0.05 level of significance was used, meaning that the hypothesis was rejected only when the chance of a mistaken rejection was equal to or less than 5 percent. The data presented in Table 1 show that the hypothesis was rejected in 16 cases. In many of these cases the hypothesis would have been rejected at very low levels of significance.

Comparisons of the average values of MOE between levels of variables for which the hypothesis was rejected are shown in Figures 4 through 13. Several trends emerged from the comparisons. First, the hypothesis was rejected several times for the driver age variable because of poorer performances by younger and older drivers, for the driver sex variable because of more negative speed differentials for female drivers, for the attraction sign variable because of poorer performances in response to the proposed attraction signs, and for the number of service signs variable because of poorer performance when four signs were presented. Second, rejection of a hypothesis indicated worsened but not necessarily unsafe driver behavior. For example, the basic hypothesis was rejected for the driver age variable and the speed differential MOE when the subject was given an attraction cue and exited at a diamond interchange. The average MOE values for this case showed (Figure 4), however, that the average speed differential for the 50 years and older group was only about 2 mph below that for the other age groups. Third, an anomalous trend was apparent in the case of the attraction sign type variable and the lateral placement MOE with an attraction cue at a diamond interchange. It was expected that the hypothesis was rejected due to greater lateral placement values in response to the proposed attraction sign. However, the plot for the case shown in Figure 9 indicated that the hypothesis was rejected because of greater lateral placement values in response to the current supplemental signs. Analysis of the lateral placement data revealed that the cause of the anomaly was one particular interchange through which almost all test subjects drove with considerably lower lateral placement values than any other. There are several possible explanations for the unexpected lateral placement results at the interchange but no particular explanation was proven.

Interactions between variables were also examined during the statistical analysis. All combinations of two and three variables were analyzed using ANOVA. The hypothesis was rejected for only eight of the several hundred interactions examined. One of those, the type of attraction sign and the

TABLE 1 ANOVA RESULTS FOR MAIN EFFECTS

Experiment Part	Independent Variable	MOE: Speed Differential	Lateral Placement	Acceleration Noise	Recognition Distance
1 (Attraction cue, diamond interchange)	Age	.0001[1]	*[2]	.0035	.0081
	Sex	.0345	*	*	*
	Attractions Signs	.0049	.0024	.0108	.0001
	Service Signs	*	.0085	*	*
	Logos/messages per sign	*	*	*	*
2 (Attraction cue cloverleaf interchange)	Age	*	*	*	*
	Sex	.0384	*	*	*
	Attraction Signs	.0132	*	*	.0001
3 (City and attraction cues)	Age	.0017	*	*	NA[3]
	Sex	*	*	*	NA
	Attraction Signs	*	*	*	NA
	Reinforcement	*	*	*	NA
4 (Service cue, diamond interchange)	Age	.0001	*	.0385	NA
	Sex	*	*	*	NA
	Attraction Signs	*	*	*	NA
	Service Signs	*	*	.0365	NA

1. A decimal value means that the basic hypothesis was not rejected at a .05 level of significance but would be rejected at the indicated level of significance (e.g., age affected speed differential significantly in experiment part 1).

2. The symbol "*" means that the basic hypothesis was rejected at a .05 level of significance (e.g., age did not significantly affect lateral placement in experiment part 1).

3. The symbol "NA" means that the results were not analyzed or that the analysis was not applicable.

number of service signs for the lateral placement MOE, was related to the main effect anomaly discussed above. Six of the remaining seven interactions with rejected hypotheses were related closely to the significant main effects discussed above. For example, the hypothesis was rejected for the driver sex and type of attraction sign interaction for the speed differential MOE because the basic hypothesis was also rejected for both of the component variable main effects. The analysis of interactions between variables revealed little new information from which to draw conclusions.

The erratic maneuver MOE was not statistically analyzed because of the small sample size. Only 13 erratic maneuvers were recorded out of 324 observations near interchanges. A qualitative analysis of the erratic maneuvers failed to uncover a trend.

A number of subjects preferred the blue over the brown attraction signs. Ten of the 36 subjects indicated such a preference on the post-test questionnaire independent of any particular question and unsolicited by the experimenter. The data do not show a correlation between this preference and performance, however. The difference in average recognition distance between blue and brown attraction signs of interest was small. A t-test of these data showed no significant difference and the hypothesis was not rejected.

Data were analyzed which showed a difference in driver performance when drivers viewed signs including "logo" pictures as compared to signs with word messages only. Subjects reported substantially more difficulty recognizing word message attraction signs than logo service signs on the post-test questionnaire. Blue service signs were recognized, on average, at a greater distance than attraction signs. A t-test showed a significant difference and the hypothesis was rejected. This result must be tempered considerably by the fact that the service signs used for comparison were gasoline signs with logos of national distinction. Nonetheless, the target recognition value of the picture logo was clear.

CONCLUSIONS

Conclusions were drawn with the original scope of the study in mind. The study was undertaken to assess the need for and to narrow the range of variables to be considered in a future study.

If serious consideration is given to using attraction signs, a field study to evaluate the proposed attraction signs should be undertaken. The types of supplemental attraction signs viewed made a difference in driver performance for two types

FIGURE 4 Average values of speed differential for cases with statistically significant driver age effects.

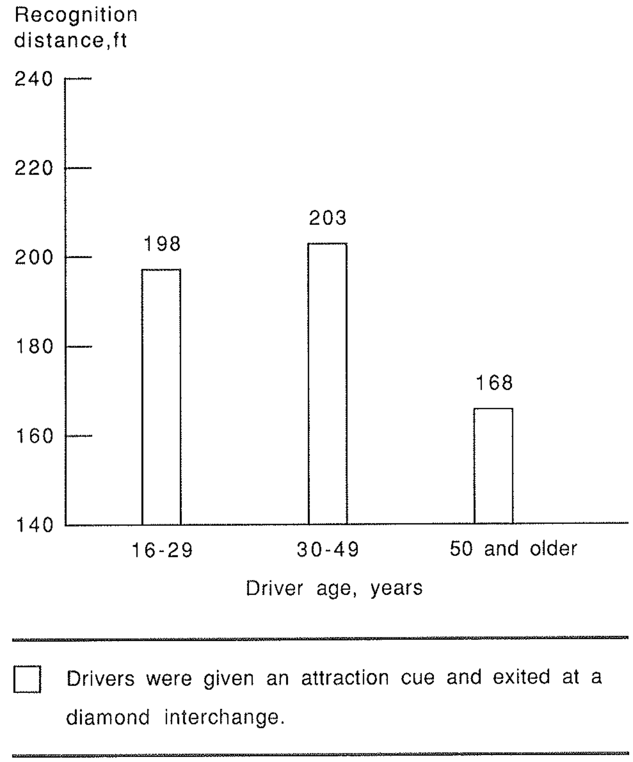

FIGURE 6 Average values of recognition distance for cases with statistically significant driver age effects.

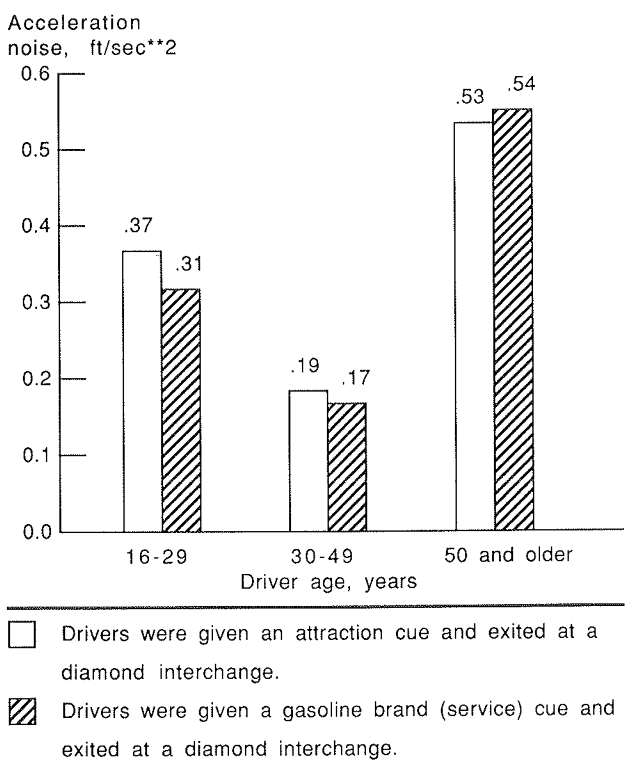

FIGURE 5 Average values of acceleration noise for cases with statistically significant driver age effects.

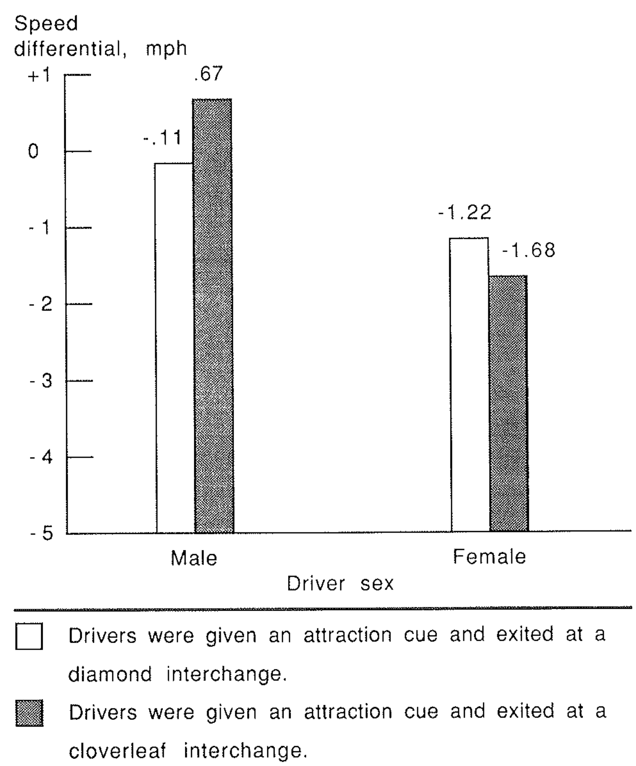

FIGURE 7 Average values of speed differential for cases with statistically significant driver sex effects.

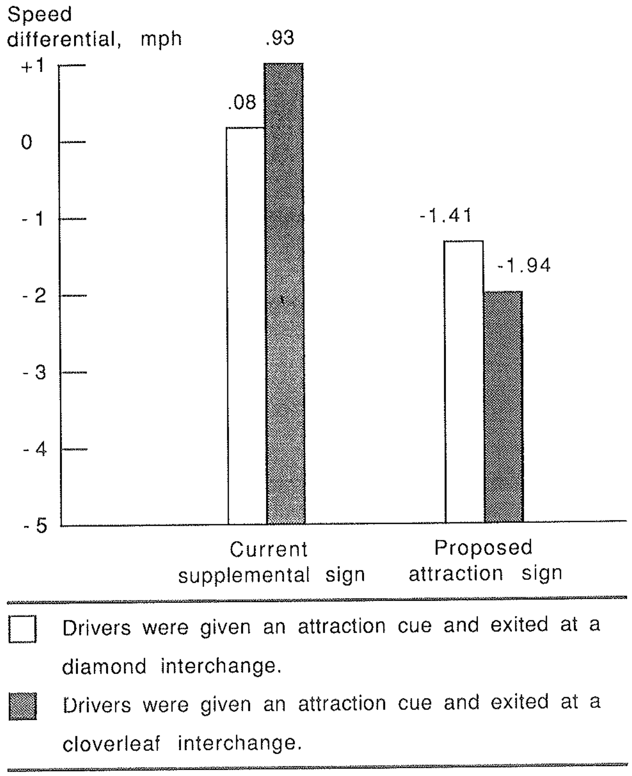

FIGURE 8 Average values of speed differential for cases with statistically significant sign type effects.

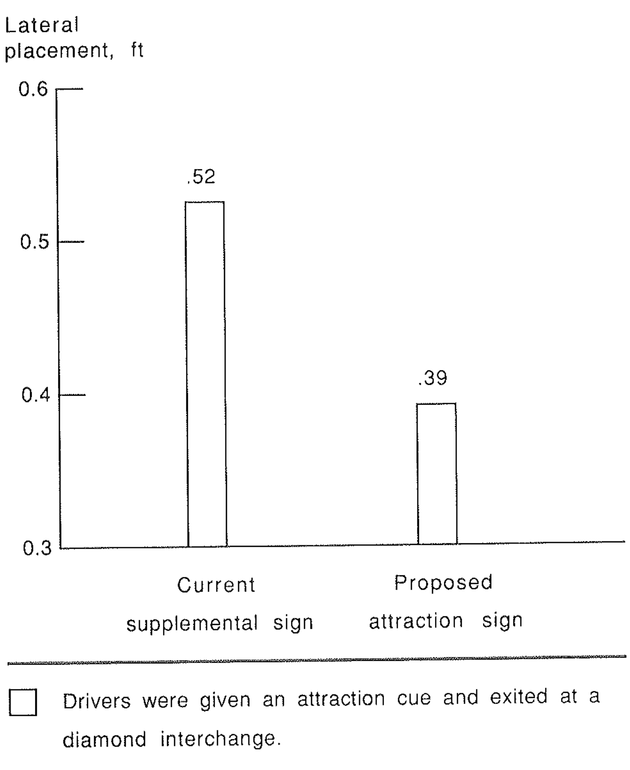

FIGURE 9 Average values of lateral placement for the case with a statistically significant sign type effect.

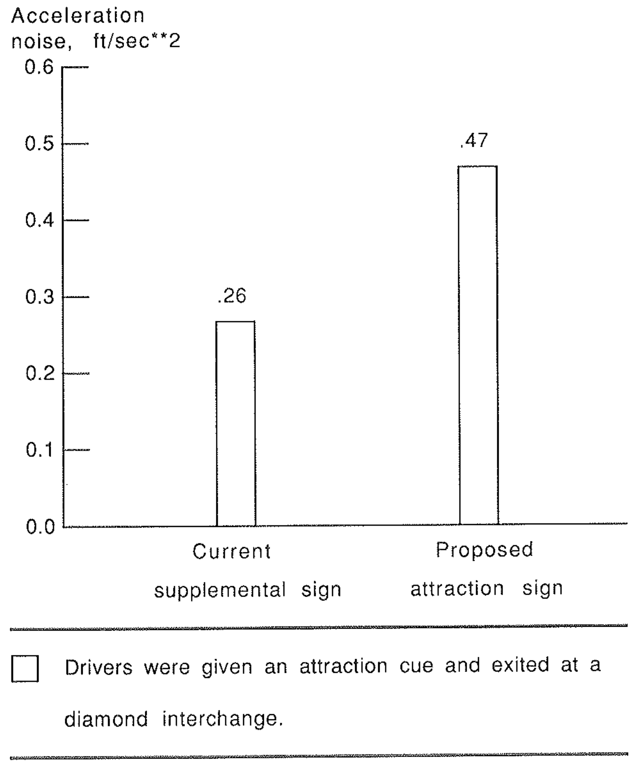

FIGURE 10 Average values of acceleration noise for the case with a statistically significant sign type effect.

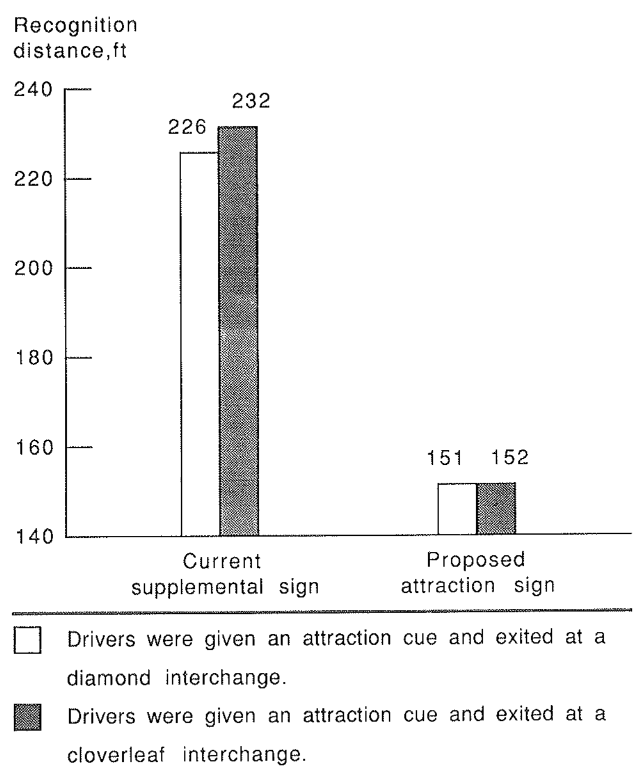

FIGURE 11 Average values of recognition distance for cases with statistically significant sign type effects.

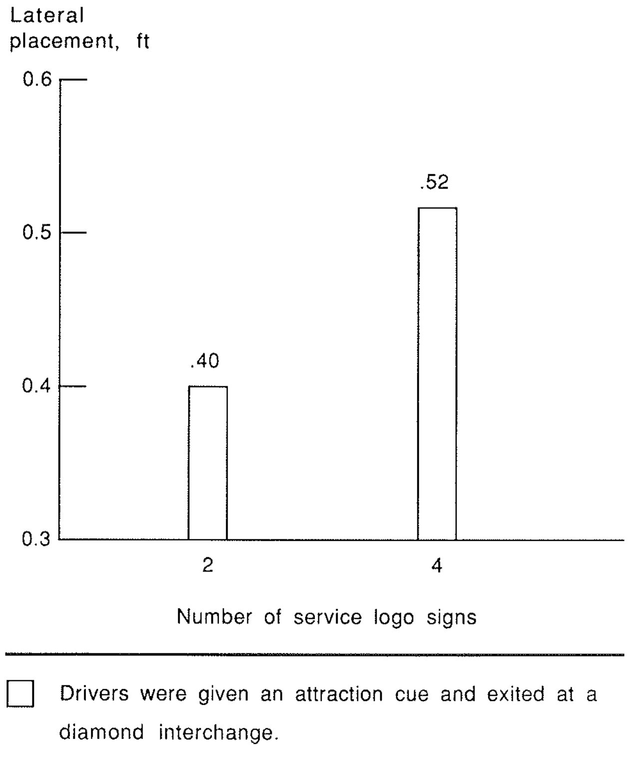

FIGURE 12 Average values of lateral placement for the case with a statistically significant effect due to the number of service signs.

FIGURE 13 Average values of acceleration noise for the case with a statistically significant effect due to the number of service signs.

of interchange geometrics and several MOEs. The proposed attraction signs on an interchange approach led consistently to poorer driver performance on the approach than the current supplemental sign on an identical interchange approach. The difference in terms of average values for MOEs was not great and the MOEs were not necessarily indicative of unsafe driving. The differences in driver performance between the proposed and current sign presentations were large enough and consistent enough, however, to cause concern should the proposed signs be installed without further study.

The design of the proposed attraction sign, rather than the sign concept, may have led to the changes in driver performance. Driver preferences for blue over brown attraction signs and better performance when scanning service logo signs with picture logos as opposed to attraction signs with word messages are indications of the need for more refinement in sign design. If picture logos are used, caution should be exercised that the pictures or symbols for local attractions are recognizable and do not further confuse unfamiliar motorists. A large letter size for the attractions may also be necessary to increase the average recognition distances.

Driver age, driver sex, and the number of service signs should be considered in the design of a future field study. All three variables were found to cause a statistically significant difference in performance under several sets of circumstances. Older drivers, female drivers, and four service signs were the levels of these variables at which the greatest differences were seen.

Several factors and MOEs were included in this study that do not need to be examined in the field. There was no significant difference demonstrated in driver performance between the different levels of the "number of logos per sign" variable for any MOE. The findings of this study should not be generalized for cases of greater than four logos per sign, because four or less messages per panel were tested. The cloverleaf interchange results differed only slightly from the results at diamond interchanges. This slight difference may be due to the smaller sample sizes available for the cloverleaf interchange analyses. Thus there may be justification for omitting this more complex geometry and sign type from a future study. The erratic maneuvers MOE appears warranted only when a very large sample size is available. The lateral placement MOE yielded anomalous data and is not recommended for use in a field test.

Two issues that were covered briefly in this study should be considered in the formulation of a field test. The sign density or sign spacing issue should not be neglected in a field test. Also, the possibility of violated driver expectancies due to inconsistent supplemental signing should be examined.

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