Evaluation of Signs for Hazardous Rural Intersections

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An experiment to evaluate the effectiveness of several different signs (or sign sequences) in informing motorists of an intersection on the road ahead in rural two-lane situations is described. Typically, intersections that would require these treatments would be those where stopping sight distances for prevailing speeds were inadequate. As random motorists approached and passed through two test intersections, they were "tracked" by means of a data-collection system that collected time intercepts of motorists at 60-m (200-ft) intervals in the vicinity of the intersection. These data were supplemented by manually collected vehicle registration and classification data and, in selected instances, survey data collected from motorists who had passed through the intersections. The results essentially showed that a regulatory speed-zone configuration and lighted warning signs were more effective than more traditional unlighted warning signs in reducing motorists' speeds in the vicinity of the intersection and increasing their awareness of both the signs and conditions at the intersection.

Motorist behavior at intersections is among the most important concerns of traffic engineers and safety officials. Literature in the field ranges from capacity- and operations-related issues to driver and pedestrian safety and complex simulations of traffic patterns. Whereas the urban motorist typically deals with intersection problems many times during the course of the average work or shopping trip, the motorist in rural areas faces a somewhat different problem--i.e., other vehicles turning on to, or off of, the primary route at isolated, often sight-restricted, locations, a situation that can be unexpected and hazardous.

In 1975, 16 percent of fatal rural accidents and 24.8 percent of all rural accidents occurred at intersections (1). Considerable research has been undertaken to identify methodologies to be used to assess how hazardous such situations are (2). King and others (3) have provided an extensive review of research dealing with warning devices used at intersections, especially those in rural areas. Their preliminary work provided the basis for the experiment reported in this paper.

The experiment discussed here was undertaken at two sites in central Maine (east of Waterville on ME-137) under the auspices of the Federal Highway Administration (FHWA) research program at the FHWA Maine facility. The general purpose of the experiment was to evaluate several alternative signs or sign sequences that could be used to warn motorists of a hazardous, sight-restricted intersection ahead in a rural two-lane situation. Signing alternatives that were examined ranged from the standard intersection warning symbol (a cross) to vehicle-activated signs with flashing warning lights.

Data that were collected during the course of the experiment included automatically collected speeds of vehicles as they entered the test sites and passed by the intersection, manually collected vehicle classification and registration information, and, for selected sign-site combinations, survey information from some motorists regarding their recollection of the signs and other details about the intersections and their reactions to them.

IMPLEMENTATION OF THE EXPERIMENT

The basic purpose of the experiment was to evaluate several types of signs that could be used to warn motorists of an intersection ahead. Individual motorists were tracked as they approached and passed through the intersections by use of a series of sensors placed on the road surface at 60-m (200-ft) intervals. The sensors were connected to a recording unit in a mobile data-collection vehicle, where the data were recorded on magnetic tape for later processing. The general capabilities of the facility's mobile data-collection system and processing equipment have been described elsewhere (4).

Site Selection

Two sites were used in the experiment, primarily to ensure that effects of various signs were not unique to a specific site. Both sites were on ME-137 between the cities of Waterville and China. ME-137 is a two-lane road with rural characteristics that is frequently used by nonlocal motorists (the nearby China Lakes region is a tourist area in central Maine).

The intersections at both sites were reasonably well hidden. Stopping sight distances were less than 150 m (500 ft), which requires some warning sign to be provided. One site was on a crest vertical curve, and the other was on a horizontal curve and was further obscured by considerable vegetation.

Figure 1 shows the layout of site 1 and the typical positioning of the data-collection equipment. Sign locations A, B, and C are for experimental signs and also for the sign in the base (existing) condition (see Figure 2 and the discussion below of the various sign treatments). Only sign treatment 4 requires three locations. Location B is the position for treatments 2, 3, 5, and 6.

Data Collection

In addition to the electronic data collected as motorists were tracked through the experiment area, some manual data were also collected. Observers were stationed at the mobile system vehicle (van) near the intersection, where they could observe vehicle classification (automobile or recreational vehicle), Maine or non-Maine license-plate classification, and whether or not an entering vehicle was present on the side road at the intersection. These data were observed and recorded for every "lead vehicle" (the first vehicle in a queue, if a queue exists) and were input to the magnetic tape record with the electronic data. The observers were also able to monitor the electronic equipment (e.g., the road sensors). In addition, on selected days a survey was administered to motorists who had passed through the intersection.

Data collection alternated between the two intersection sites and two others (from another experiment), so that data collection was not continuous in one area over the entire summer. In general, all data were collected between June and October of 1978.

VARIABLES AND MEASURES

Independent Variables

The principal variable of interest in the research was the sign condition displayed, but several other factors were also considered. These other factors ensured that the effectiveness of the signs was consistent over a variety of other conditions.

Figure 1. Layout of intersection at site 1 showing sensor and sign locations.

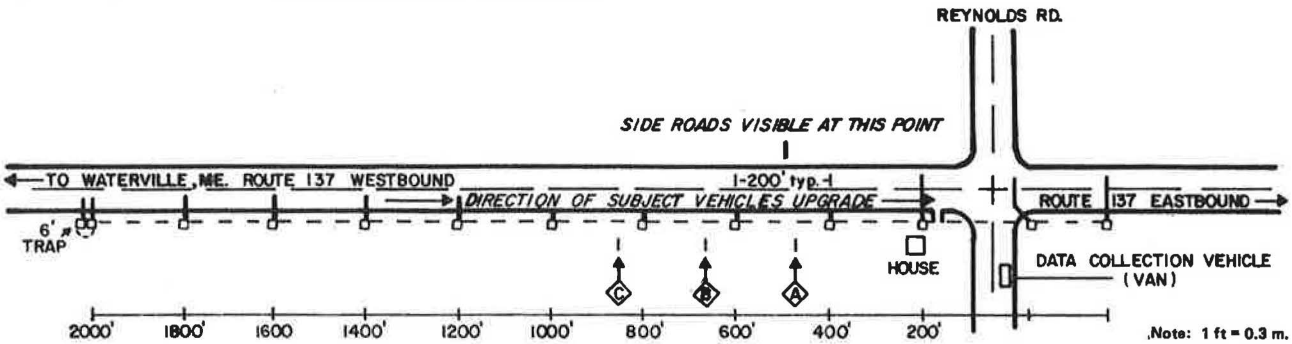
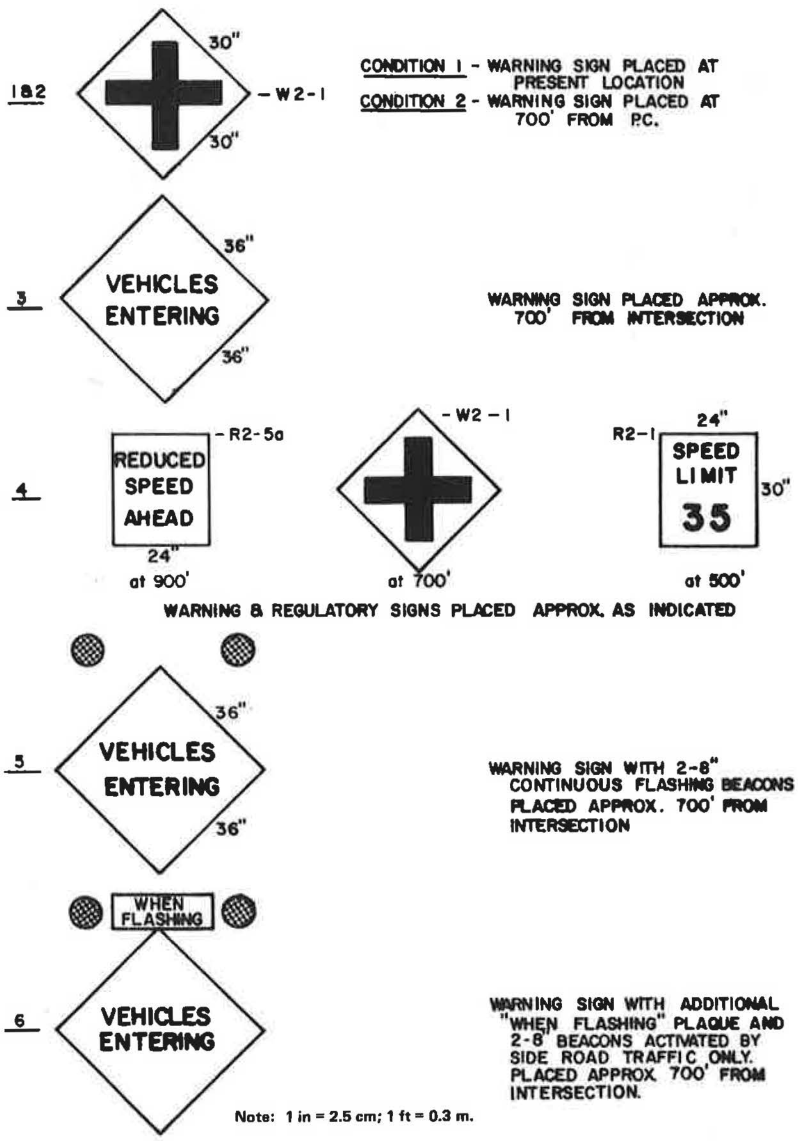


Figure 2. Sign treatments.



Sign Treatments

Five different sign treatments and a base (existing) condition were tested (Figure 2). The treatments covered a variety of approaches to intersection signing.

The first (base) condition was taken as the existing condition at each site. At both sites, the only sign warning of the intersection was the cross symbol (W2-1 in Figure 2). In each case, however, the sign had been placed somewhat closer to the intersection than the Manual on Uniform Traffic Control Devices (MUTCD) (5) suggests. The distance from the intersection to the sign in the existing position was approximately 150 m (500 ft).

The second condition incorporated the same sign

(W2-1), but it was located more in accordance with MUTCD standards [at 213 m (700 ft)] in order to maintain a constant relation between the data-collection equipment and each sign position.

The third sign condition was a warning sign that read VEHICLES ENTERING. A word message was chosen to provide a comparison between symbol and language messages and to provide a consistent message that could be used with activated signs. Although this is not a "standard" sign, the wording is quite common.

The fourth condition was a three-sign sequence that incorporated a regulatory speed zone (R2-1 and R2-5a) with the intersection warning sign. Inclusion of this condition allowed for a comparison between advisory and regulatory sign strategies.

The fifth treatment used the same message as the third but was made more emphatic by the addition of continuously flashing beacons. The lighted signs were included in the sequence primarily because of results from previous facility experiments (6), which indicated that such lights were successful as an attention-getting device (at a minimum).

The final treatment was the most emphatic and conveyed the most positive information to motorists. A WHEN FLASHING message was added to sign condition 5 to indicate that the flashing beacons were on only when a vehicle was present on the side road at the intersection. The flashing lights were activated by two events: (a) when a vehicle was present on the side road at the intersection and (b) when an approaching vehicle struck a particular sensor, turning on the lights. It should be noted that at one of the sites the motorist was always in a position to see the lights come on whereas at the other site the lights would be on (if a vehicle were present) when the motorist first saw the sign.

The sign treatments were randomly ordered at the two sites so that data were not collected sequentially from increasingly emphatic signs.

Sites

The primary differences between the two sites used in the research were as follows: One was on a vertical curve whereas the other was on a horizontal curve, one had an "extra" sign present (i.e., a standard curve warning arrow), and one had a few houses present at the intersection. Comparisons can be made based on the relative effects at both sites. Other geometric characteristics, such as lane and shoulder width, were quite similar at both sites, and the base speed limit was the same--80 km/h (50 miles/h).

Ambient Light

Data were collected during both day and night hours (twilight data were discarded). The day-night stratification provided a reasonable basis for determining whether light conditions caused any change in sign effectiveness.

Presence of a Vehicle at the Intersection

In general, it seemed safe to assume that motorists would behave differently if, when they could see the intersection, they saw a potential conflict--i.e., a vehicle waiting to turn on to or cross the road on which they were traveling. If the signs had any impact at all, the difference in behavior would be especially marked when the sixth sign condition was displayed. Thus, the data were stratified as follows: motorists who traversed the site when no vehicle was at the intersection and motorists who traversed it when there was a vehicle present.

Since side-road volumes were quite low and sporadic, a vehicle (van) was deliberately positioned on the side road for 50 percent of the data collection. The van was pulled up on the side road at the intersection so that it appeared ready to turn on to the main road. One of the observers was always behind the wheel, and at night the headlights were turned on.

Motorist Familiarity with the Road

Another issue of interest was the impact on sign effectiveness of motorists' familiarity with the road. For example, it could be argued that everyday users of the road would certainly be aware of the changing signs and the activity at the intersection and would therefore respond differently to the signs than would a one-time road user.

In order to study the potential difference in behavior between these two groups of motorists, manual data were taken by the observers so that motorists could be classified according to whether or not their vehicles were registered in Maine, a crude proxy for motorist familiarity with the road. It should be noted that it was possible to make this determination only during the day.

Entry Speed

Results from other experiments (6) have indicated a significant correlation between motorist response to road signs and speed; i.e., faster drivers react to signs differently than slower drivers. Motorists were therefore examined according to their entry speed; i.e., speed was used as a covariate in the analysis of the data.

Weather Conditions

Although a full sample of weather conditions was not possible, data were collected on rainy days so that at least a partial analysis was done for "good" versus "bad" weather conditions.

Type of Vehicle

In the past, axle counts have been used to represent the type of vehicle passing through a site. In this experiment, the observers classified vehicles as either automobiles or recreational vehicles. The former class included automobiles and pickup trucks (with or without low caps), and the latter included large motorized mobile homes, pickups with large (over-cab) caps, larger vans, and cars or pickups with trailers.

Other Variables as Restraints

There were several other factors that could be considered as independent variables and provide further levels of stratification. To keep the analysis (and data collection) manageable, the more important of these were used either as restraints in the experiment or as conditions for eliminating some data. These variables included

1. Day of the week--To provide as much homogeneity in the traffic mix as possible, data collection was limited to weekdays only;
2. Turning vehicles--Vehicles that entered the system but then turned off at the intersection were discarded;
3. Queue vehicles--Because vehicles that were in a queue (less than 6-s headway to the preceding vehicle) tended to react more to the vehicle

immediately in front of them than to other conditions, including signs, they were eliminated from consideration and only lead vehicles were considered; and

4. Slow vehicles--Vehicles that had an entry speed of less than 56 km/h (35 miles/h) were discarded as being anomalous.

Dependent Variables and Measures of Effectiveness

A set of 12 dependent variables were measured for each vehicle as it passed through the experiment area. The raw data took the form of time intercepts of the sensors on the road surface. These data were later processed so that a vehicle was "tracked" through the area. Each of the 12 dependent variables was then a speed or speed-related characteristic of the vehicle's passage. Each of these variables was selected so that the interpretation was directly related to the effectiveness of the particular sign treatment and thus to the minimization of the hazard. All speeds were measured over 61-m (200-ft) lengths except entry speed, which was calculated over a 1.8-m (6-ft) trap.

Entry Speed

As indicated, the entry speed of vehicles was used as an independent variable to account for faster and slower drivers. The other principal use for this variable was to establish the similarity among the various samples of drivers that passed through the experiment site. That is, the average entry speeds of motorists experiencing different combinations of experiment conditions--e.g., sign 4, dry pavement, night--were compared and tested for statistical similarity. The similarity of the samples established that speed differentials noted at other locations (at the intersection, for example) could be attributed to various experiment conditions and were not intrinsic to the samples of motorists used.

Initial Speed Change

Soon after each vehicle entered the experiment area, the sign treatment was visible, although not legible. The first variable that reflected any possible reaction to the treatment was the initial speed change, measured over the first 122 m (400 ft) of the experiment area.

Speed Changes at Signs

Three other speed changes were also measured. These changes were in the vicinity of the three test sign locations. Each of the speed changes was measured as the difference between the speeds calculated over the links ending 91 and 30 m (300 and 100 ft) ahead of the sign location. Measuring the speeds at these points illustrated any speed change that resulted from motorists' having read the sign. Measurement of these speed changes also provided a general overview of when speed changes occurred on the approach to the intersection.

Speed at the Intersection

One of the most important measures of the effectiveness of signing was the average speed of vehicles at the hazard itself (in this instance, the intersection). A lower speed indicated a safer situation.

Overall Speed Change

Another measure of the overall effectiveness of a treatment was the overall decrease in speed from entry to speed at the intersection.

Distance to Point of Minimum Speed

It was possible that the minimum speed attained on the approach to the intersection was achieved at some point other than the immediate area of the intersection. For example, motorists who saw no vehicle in the intersection may have speeded up as they went through the intersection itself. Thus, the location at which minimum speed occurs is of interest.

Maximum Speed Change

The maximum speed change was indicative of the abruptness of motorists' reactions to either the signs or the intersection itself. Assuming that speeds at the intersection were within acceptable limits, the more desirable sign treatments would result in a more gradual reduction in speed.

Location of Maximum Speed Change

The location at which the maximum speed change occurred was also observed. For example, if the maximum reduction in speed occurred in the immediate vicinity of the intersection, it could be interpreted to mean that motorists were surprised by the intersection, or by the activity there, which would indicate a relatively ineffective sign treatment.

Speed Change at the Intersection

The last speed change of interest was that which occurred at the intersection (the inclusion of this variable is based on the assumption that the maximum speed change typically did not occur at the intersection). Comparison of this value with the other speed changes provided an indication of the effectiveness of the various sign treatments in relation to the effect on the motorist of actually seeing the intersection and/or the activity in the intersection area.

Exit Speed

The last variable calculated was vehicle speed on leaving the intersection. Comparison of this value with vehicle speed at the intersection provided an indication of how rapidly motorists resumed their normal speed. It also provided the basis for a comparison with information obtained from the motorist survey--i.e., a comparison of actual vehicle speeds versus the speeds perceived by motorists.

MOTORIST SURVEY

An unknown in many experiments similar to the one described here results from the fact that only overt actions on the part of the motorist are detected--e.g., whether the average motorist slowed down at point x. It can be argued that motorists seeing certain signs may not actually slow down but do become more alert to the hazard that is present (6). To address this issue, a survey was designed for, and administered to, random motorists who had just driven through the experiment area.

Several kinds of information were solicited in the survey, including background information (e.g., how often the motorist used the road and the number of adults and children in the car), the driver's recollection of the intersection (e.g., whether

Table 1. Summary of data availability.

Sign	Presence of Vehicle at Intersection	Site 1 Day	Site 1 Night	Site 2 Day	Site 2 Night
1	Present	ND	ND	ND	ND
	Not present	NDA	NDA	NDA	NDA
2	Present	NDA	NDA	S	NDA
	Not present	NDA	NRDA	S	NDA
3	Present	NRDA	NDA	S	NDA
	Not present	NDA	NDA	S	NDA
4	Present	SNDA	NDA	NDA	NDA
	Not present	S	NDA	NDA	NDA
5	Present	NDA	NDA	NDA	NDA
	Not present	NDA	NDA	NDA	NDA
6	Present	S	ND	NDA	NDA
	Not present	SNDA	NRDA	NDA	NDA

Note: ND = no data; NDA = normal data available; S = survey; NRDA = normal and rain data available; SNDA = survey and normal data available.

Table 2. Motorist recall of signs and situation.

Sign	Presence of Vehicle at Intersection	Percentage of Drivers Sampled: Saw Correct Sign	Saw No Sign	Saw "Ringer"[a]	Saw Vehicle
2	Present	17	25	2	67
	Not present	20	29	8	15
3	Present	22	29	4	71
	Not present	21	21	3	15
4	Present	41	23	4	69
	Not present	51	19	3	49
6	Present	45	9	3	89
	Not present	41	14	2	62

[a]Sign not used in Maine.

another vehicle was present), the driver's recall of any signs present and their meaning, the driver's perception of his or her actions at the intersection (e.g, whether he or she became more alert, slowed down, etc.), and any awareness of the experimental situation.

Thus, for selected motorists on nine different days (covering four of the six sign treatments), data were available not only on how the motorists actually responded but also on their perceptions of the situation and their actions.

The survey was administered several hundred meters beyond the intersection, and the crew could not be seen until well after a motorist had exited the instrumented area. The survey was administered late in the summer, between August 10 and September 1, 1978, to minimize the effects that seeing the survey crew would have on local motorists during any subsequent data collection.

DATA ANALYSIS AND RESULTS

The data analysis is separated into two major sections: (a) analysis of the data obtained from personal interviews (including matched electronic data for each respondent) and (b) analysis of electronic data collected for each sign-site combination. Table 1 summarizes the types of data that were available for each basic combination. For the first section of the analysis, the results are primarily qualitative. The second section relies primarily on analysis of variance (ANOVA) techniques.

Analysis of Survey Data

The survey was administered on nine different days and covered the various combinations of sites, signs, and vehicle presence given in Table 1. Not all of the results from the analysis of the survey will be presented here; the more important results will be summarized.

Between 90 and 115 motorists were stopped during each survey period (day), and approximately 75 percent of those stopped on any day resulted in "good" responses; that is, they were willing to participate in the survey, and they had not been stopped previously. Approximately 20 percent of the respondents were nonregular users of the road (motorists who used the road several times per month or less), which was a somewhat lower figure than anticipated. Some of the key issues on which the survey was designed to provide data were whether or not motorists saw signs, understood the message to be conveyed, became more alert, and/or exhibited some other favorable reaction, such as slowing down.

Table 2 summarizes some of the information obtained on motorists' recall of signs and other vehicles. No less than 70 percent of the respondents always claimed to have seen one sign or another (they were given seven choices). The noticeable trend was that motorists were twice as likely to recall the presence of signs when the speed-zone configuration (sign 4) and the vehicle-activated sign (sign 6) were used. As a corollary, fewer respondents recalled no sign when sign 4 or sign 6 was displayed. It should be noted that the percentage of respondents who observed the "ringer" sign remains about the same throughout.

Accompanying the higher recall of signs 4 and 6 was a greater tendency to see the vehicle in the intersection. It should be noted that when the vehicle was "present" it sat on the side road at the intersection as if to make a turn or cross the road. When the vehicle was "not present" it sat between 75-100 m (250-330 ft) back from the intersection and on the side of the minor road. Thus, the van was always noticeable to the observant driver.

It can be concluded from these data that two of the four sign conditions elicited a better retention level than the others and, further, that notice of the signs appears to be related to a greater awareness among drivers of conditions in the intersection itself.

Very few motorists seriously misinterpreted the meaning of the signs. Typical of the responses to the VEHICLES ENTERING sign that might be considered technically "wrong" but were ultimately appropriate were the following: slow down, be cautious, reduce speed, and trucks turning. These responses were incorrect only in the most literal sense.

Motorists exposed to signs 4 and 6 were somewhat more likely to recall the intersection than those exposed to signs 2 and 3, although, in general, the recall of the intersection was high regardless of the sign displayed (the lowest figure was approximately 82 percent). Although the majority of respondents indicated that they slowed down for the intersection, no clear trend was evident from the survey data as to whether those exposed to signs 4 and 6 were more likely to indicate such a reaction. A direct comparison was made between respondents' estimates of how much they slowed down and their real (electronically measured) decrease or increase in speed, but it revealed nothing other than that people do not remember, or estimate, their speeds very well.

When motorists were asked how they responded to whatever sign they saw (many identified a sign that

Table 3. Typical summary of significance of main effects and interactions.

Dependent Variable	Significant Main Effect	Significant Two-Way Interaction
Entry speed	None	Signs/vehicle presence, signs/familiarity with road
Speed change		
Initial	Signs	Signs/vehicle presence
Sign A	Signs, vehicle presence	Signs/vehicle presence
Sign B	Signs	None
Sign C	Signs	Signs/vehicle presence
Speed at intersection	Signs, vehicle presence	None
Overall speed change	Signs, vehicle presence	None
Distance to minimum speed	Signs	None
Maximum speed change	Signs	Signs/vehicle presence, signs/familiarity with road
Distance to maximum speed change	Signs, vehicle presence	None
Speed change at intersection	Signs, vehicle presence	None
Exit speed	Vehicle presence	None

was not present on the day they were interviewed), results were mixed. However, no recognizable trends emerged as to differences in motorists' perceptions of their reactions to the signs.

One of the survey questions asked how often the respondent used the road in order to determine what effect familiarity with the road had on drivers' reactions to the signs. The actual reactions (values of the dependent variables) could then be compared with the survey response. Typically, there were no differences among groups of regular and non-regular users of the road.

In this connection, there was some evidence that respondents who said they slowed down for the intersection actually did although, as noted, their estimates of how much were typically inaccurate.

Also included in the survey was information on the sex of the respondent, the number of children in the car, and so forth. Women in the sample tended, overall, to go slightly faster than their male counterparts, both as they entered the test site (entry speed) and at the intersection (speed at the hazard). Whether or not there were children in the car seemed to have no relation to driver behavior; entry speed and speed at the hazard were almost identical in both situations. Not enough of the respondents were wearing safety belts to indicate whether they reacted differently from those who were not wearing safety belts.

In general, the following points emerged from the review of the survey responses:

1. Motorists exposed to signs 4 and 6 were more likely to recall seeing the correct sign than those exposed to signs 2 and 3;
2. Motorists exposed to signs 4 and 6 were also more likely to be aware of conditions at the intersection, as indicated by their recollection of another vehicle (a controlled situation) in the intersection; and
3. Regardless of what signs were displayed, similar percentages of motorists indicated that they reacted by becoming more alert and/or slowing down.

Analysis of Electronic Data

The principal component of the analysis was the review of the electronic data. The basic technique used was ANOVA based on observational data. The data for each cell in Table 2 were selected at random from all of the data collected under each combination of sign, site, light, and vehicle presence. Each subset of data consisted of 25 observations, which included some out-of-state motorists (motorists not familiar with the road) and some recreational vehicles or cars with trailers. The data selected were analyzed under the multiple-factor design, which allowed for adequate statistical significance testing. A 95 percent confidence level was used throughout.

The following discussion of the results of the analysis deals, on a variable-by-variable basis, with the effects of the signs on the independent and dependent variables.

General Observations

An initial multiple-way ANOVA, in which the factors were signs, site, conflict (whether a vehicle was in the intersection), and weather (wet or dry pavement), showed that the effect of the site was very significant. Thus, in much of the succeeding analysis, each site was considered separately. Overall analyses with and without entry speed as a covariate showed that entry speed was also significant. Thus, all analyses were done with and without entry speed as a covariate.

The site effects were not unexpected, since the two sites were geometrically different in that one site had an upgrade approach all the way to the intersection and the other had a slight downgrade at the intersection. These differences notwithstanding, comparisons of the trends at each site are valid and were made and reported. The overall multiple-factor ANOVAs also showed the general impact of other independent variables--e.g., ambient light and vehicle registration.

Independent Variables

Multiple-factor ANOVAs were used to assess the general effects (as measured on the dependent variables) of signs and other factors, both as individual impacts (main effects) and in various combinations (interaction effects). The overriding conclusions drawn from this part of the analysis were that (a) the effects of the signs were almost always detected (i.e., they were statistically significant) regardless of the situation; (b) absolute effects differed by site, although the trends were similar; (c) neither vehicle type (automobile versus recreational vehicle or car and trailer) nor state of vehicle registration caused significant main effects; and (d) on a few occasions, the presence of the vehicle in the intersection had a significant main effect.

Table 3 gives a typical summary of factor significance from daytime data for site 2. The factors tested were signs, conflict, vehicle type, and motorist familiarity with the road. Since a prior ANOVA had already indicated that the site was a significant factor, separate analyses for site 1 would show similar results.

Because of the recurring evidence of the impact of entry speed, the analysis illustrated in Table 3 was also undertaken with entry speed as a covariate. The outcome of that analysis showed that for most dependent variables the entry-speed covariate was significant. The significance of the main and interaction effects given in the table, however, remains the same except in the following instances: The interaction between signs and motorist familiarity with the road is significant for speed change (sign C), the vehicle-presence main effect is significant for distance to minimum speed, and the signs main effect is significant for exit speed.

Sign Treatment

Sign treatment, as indicated above, was almost always found to be significant, which indicated that there was some difference in motorist reactions to different sign configurations. The effectiveness of various signs is reviewed later in this paper, in the discussion of dependent variables.

Site

Site was also found to make a significant difference, presumably because of the difference in geometric characteristics. Although absolute speed changes might differ by site, the speed-change trend was the same regardless of the site.

Ambient Light

Analysis of day and night data for the same combinations of other factors showed that light did not generally have a statistically significant effect. In a two-way ANOVA that considered both light and sign effects (controlling for site and conflict), the main effects of light were typically not significant. There were several instances when the interaction between signs and light was significant, notably for initial speed change (sites 1 and 2, vehicle not present), speed change at sign A (sites 1 and 2, vehicle not present), distance to maximum speed change (site 2, vehicle present), speed change at intersection (site 2, vehicle present and not present), and speed change at sign B (site 2, vehicle not present). The interaction effect can presumably be attributed to the greater visibility of some of the signs (i.e., the lighted ones) at night. Generally, though, the signs were not much more or less effective at night than during the day.

Vehicle Presence

Vehicle presence at the intersection (conflict) has been mentioned previously as often having a significant effect (more often as an interaction with the signs) on motorists' reactions. Thus, in the analysis undertaken to determine the explicit differences in effect among the signs (i.e., which signs were most effective), careful note was taken of those differences both when a conflict situation was present and when it was not.

Familiarity with the Road and Type of Vehicle

Motorists' familiarity with the road and type of vehicle were two independent factors that had been anticipated to be important. The analyses, however, showed that little difference in motorist behavior could be attributed to either of these factors. For example, as Table 3 indicates, the main effects of these two factors were never significant, and in only two instances was an interactive effect noted. One of the instances in which the interactive effect was noted was when entry speed was considered, an effect that, if at all important, would be allowed for when entry speed was considered a covariate.

Weather

Weather conditions were not fully explored because of a scarcity of rain data. Although a superficial review revealed that weather was a significant factor in several instances, an examination of the trends in speed changes from one condition to another indicated that the effects were quite inconsistent. Thus, no conclusions can be offered on the impact of weather on motorists' reactions.

Entry Speed

All analyses were undertaken with and without entry speed as a covariate. Note, however, that there was a great deal of consistency in the results regardless of whether or not entry speed was a covariate.

Dependent Variables

The primary purpose of the following discussion of each of the dependent variables is to identify the differences in the effectiveness of the various signs. The discussion is based primarily on the results from site 2, although any variations between results at the two sites are noted. Otherwise, it should be assumed that the results were similar at both sites.

Entry Speed

Significant variation occurred in the effectiveness of signs within the sample of motorists in several instances, which indicates that some of the variation in speeds at later points (such as at sign B) might be better explained by the initial speed than by the effect of the signs. Using entry speed as a covariate (and thus implicitly controlling for it) makes the examination of subsequent variables meaningful. Thus, the typical procedure was to examine the variation in a dependent variable that is attributable to sign conditions with and without controlling for entry speed.

Speed Change

No conclusions were noted for initial speed change because, in most instances, the changes measured were quite small and the trend in the results was not consistent between sites or between day and night data. Similar problems were encountered with speed change at both signs A and B. There was overall statistical significance attributable to sign effects but no consistent trend, and actual differences were very small.

The results for speed change at sign C were somewhat more consistent. The overall significance of the sign effects had already been established. The trend in the data was that signs 4-6 (the speed-zone sign and both lighted signs) tended to be more effective than signs 1-3. A statistical comparison (contrast) of these two groups was significant: Signs 4-6 resulted in greater speed reductions than signs 1-3 for site 2, for both day and night, and for site 1, but only at night. The actual physical variations were rather small, although statistically significant. For example, the average decrease for signs 1-3 was about 0.8 km/h (0.5 mile/h) and for signs 4-6 ranged from 1.6 to 3.2 km/h (1-2 miles/h).

Speed at the Intersection

It can be argued that some of the best measures of effectiveness are those that describe motorists' reactions at the hazard itself. In this case, those measures included speed at the intersection, overall decrease in speed (for which speed at the intersection was used as a reference), and speed decrease in the vicinity of the intersection. The results for speed at the intersection appear more clear-cut than those for previous variables. The overall ANOVAs for speed at the intersection showed that the signs had a significant effect, whether or not a vehicle was present and whether or not entry speed was included in the analysis as a covariate. A direct comparison between signs 1-3 and signs 4-6 showed that the latter group of signs did result in a lower speed at the intersection. This result was consistent for both day and night data, whether or not a vehicle was present, and for both sites. Actual speeds averaged about 75 km/h (46 miles/h) for signs 1-3 and about 69 km/h (43 miles/h) for signs 4-6.

Overall Speed Change

Measuring overall speed change served to highlight the effects of the signs on the overall reaction of motorists to the intersection. In all instances, the sign effects were statistically significant. Although overall change in speed was based directly on entry speed, significance was still obtained when entry speed was included as a covariate. Direct comparisons of the signs indicated that signs 4-6 resulted in significantly greater decreases than signs 1-3: For site 2, decreases for signs 1-3 ranged from 0.8 to 3.2 km/h (0.5-2 miles/h), and decreases for signs 4-6 ranged from 6.3 to 7.9 km/h (3.9-4.9 miles/h). The absolute differences between the two groupings were similar for site 1 and for both day and night data at both sites. Additional comparisons showed little difference within the two groupings: For example, there was no significant difference between signs 1 and 2 or between signs 5 and 6.

It had been anticipated that whether or not a vehicle was in the intersection would make a difference in motorists' reactions to signs 5 and 6, since the lights in sign 6 were flashing only when a vehicle was present. Sign 6 typically resulted in a greater decrease in speed--about 0.8-1.6 km/h (0.5-1 mile/h)--but the difference was not statistically significant.

Maximum Speed Change

Signs 4-6 often resulted in slightly higher maximum changes in speed, although the difference--about 0.8-1.2 km/h (0.5-0.75 mile/h)--was generally not significant. Thus, although speed decreases for signs 4-6 were slightly more abrupt than for signs 1-3, the differences were not particularly meaningful, either statistically or practically.

A very general trend was noted in the location of maximum changes in speed. Maximum changes in speed occurred farther back from the intersection for signs 4-6, although some inconsistencies were noted.

Speed Change at the Intersection

Although speed change at the intersection showed a statistical significance attributable to the signs, this variable proved to be inconsistent when it was examined closely. At site 1, motorists exposed to five of the six signs increased speed in the vicinity of the intersection; at site 2, there was a speed decrease for all sign treatments. Presumably, this phenomenon was related more to site geometrics than to sign treatments.

Exit Speed

Exit speed was used (a) to indicate how quickly motorists resumed their speed after passing through the intersection and (b) as the basis for a comparison with the estimated speeds given by motorists who were surveyed. As previously indicated, there was little relation between actual and estimated speeds. In the attempt to measure how quickly motorists resumed speed, it was not possible to conclude anything other than that this effect was apparently overshadowed by the slower speeds attained at the intersection for the most effective signs.

CONCLUSIONS

The experiment reported in this paper was designed to test a series of progressively more informative (and emphatic) signs that could be used to warn motorists of a hazardous intersection (i.e., inadequate stopping sight distance) on the road ahead in rural two-lane situations. Both electronic and survey data were collected as part of a multifactor experiment design at two sites in central Maine. Random motorists were classified by type and whether or not their vehicles were registered in Maine. The survey data were collected for a selected number of sign-site combinations.

Based on the analyses described, the following conclusions can be drawn:

1. Presumed familiarity with the site (measured indirectly for most motorists by whether the vehicle was registered in Maine and explicitly for others by the survey) did not have a significant effect on motorists' reactions to the intersection situation.
2. Type of vehicle had no significant effect on motorists' reactions.
3. All motorists who were surveyed gave similar answers when asked how they responded to the sign(s) and the intersection, but those exposed to the speed-zone sign (sign 4) had a better recall of which sign they had seen, and those exposed to the vehicle-activated VEHICLES ENTERING WHEN FLASHING sign (sign 6) had a better recall of the intersection itself, i.e., of whether or not a vehicle was present.
4. Separate analysis of survey respondents by sex, whether children were in the vehicle, and whether safety belts were in use produced no discernible trends.
5. The effectiveness of the signs--as measured principally by the overall decrease in speed on the approach to the intersection, the speed at the intersection itself, and, to a lesser extent, the decrease in speed near sign C--can be divided into two categories. There were small differences in effectiveness among the standard warning signs (i.e., signs 1-3) and among the more informative (or emphatic) ones (i.e., signs 4-6). There was, however, a significant and consistent difference between the two basic sign groups. Signs 4-6 consistently resulted in more positive effects. The magnitude of the effects was illustrated by speeds at the intersection: Signs 4-6 resulted in speeds typically about 4.8 km/h (3 miles/h) slower.

A major concern in experiments of this type is whether the measurement of actual motorist reactions--e.g., a speed decrease--is an adequate basis for recommending acceptance or rejection of a particular sign. For example, the effect of a sign on a motorist's general alertness to a potentially hazardous situation is also important. In this experiment, an attempt was made to determine whether motorists' awareness was increased by different signs.

The survey indicated that, whereas all motorists tended to claim a positive reaction to the sign they saw (or thought they saw), motorists who saw either sign 4 or sign 6 actually had better recall, not only of the sign but also of the presence of the vehicle in the intersection. Furthermore, the same signs resulted in a positive physical reaction, such as a decrease in speed. Thus, the second group of signs did well on both awareness of the situation and reaction to it (because of other similarities among signs 4, 5, and 6, it is assumed that motorist response to sign 5 would have been similar to the response to signs 4 and 6).

A review of all of the analyses done reveals that differences among signs 4-6 were not always apparent or consistent. In general, however, sign 6 seemed to be the most effective in several instances. In a field application, however, the deployment of equipment for sign 6 would be quite complex. Sensing devices would be required on both side roads at a four-way intersection, and these devices would have to be linked to the sign several hundred meters down the road. In addition, failure of the sign could result in a serious situation at the intersection. A question thus arises as to whether the marginal increase in effectiveness is worth the additional cost of installation, maintenance, and risk associated with sign 6. It is my conclusion, based on effectiveness and anticipated cost, that either sign 4 or sign 5 would be a better choice than sign 6.

The overall conclusion of the experiment can be stated as follows: The regulatory speed-zone configuration (sign 4) and the continuously lighted VEHICLES ENTERING configuration (sign 5) appear to be superior to typical warning signs, such as the standard cross or plain VEHICLES ENTERING sign, in increasing motorist awareness of a hazard and inducing a physical reaction to it. Speed reductions in response to signs 4 and 5 appeared to be about two to three times those normally experienced with the more conventional signs, and awareness (as measured by sign recall and observation of the vehicle in the intersection) was increased by an overall factor of approximately two.

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Improving the Accuracy of Information on Direction Signs

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Recent studies in Great Britain have suggested that more than £700 million/year (£1 = U.S. $1.80) is being "wasted" by drivers traveling longer distances than are strictly necessary. Most drivers state that they are seeking the shortest or quickest route to their destination, yet studies show that only 50 percent achieve their stated objective. Direction signs and maps are the most common and simplest form of route guidance. An analysis of data collected in Gloucestershire suggests that 86 percent of travelers follow a route that is signposted, that less than 50 percent of the signposted routes are minimum-cost routes, and that to change the signs to make them indicate the minimum-cost routes would require 7 place-name changes/junction, 3 distance or route-number changes/junction, and 1 directional change every 6 junctions. The cost of modifying all the signs in Great Britain to provide more accurate information is estimated at £70 million, and the annual savings that are likely to result from this investment are estimated to be in excess of £180 million. It is possible that the annual savings in fuel and accidents alone will cover the total investment.

In the recent past, four independent studies in Great Britain (1-5) have suggested that in 1976 (in 1976 currency, £1 = U.S. $1.80) between £700 million and £960 million was wasted in terms of fuel, operating costs, and time by drivers traveling distances in excess of those that were strictly necessary. Although one of the studies (1) was able to suggest that some of the excess could be attributed to "limitations in maps and road signs", none of the studies were able to identify deficiencies in existing signing or propose improvements.

The purpose of the work reported in this paper was to determine the importance of existing direction signs in driver route choice, to identify deficiencies and propose improvements, and to estimate the costs and benefits to be obtained by improving direction signs. This study used an existing set of travel information from the British counties of Gloucestershire and Avon (4) that was originally collected to determine drivers' route-choice criteria in terms of time or distance. To these data we added information from the existing direction signs and analyzed all the data by using a