Evaluation of Signs for Hazardous Rural Intersections

RICHARD W. LYLES

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 record-
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
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 (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 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 vari-
ables was then a speed or speed-related characteris-
tic of the vehicle's passage. Each of these vari-
ables was selected so that the interpretation was
directly related to the effectiveness of the partic-
ular 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 cal-
culated 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.

Exit Speed

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.

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
at x. 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.

<table>
<thead>
<tr>
<th>Sign</th>
<th>Presence of Vehicle at Intersection</th>
<th>Site 1 Day</th>
<th>Site 1 Night</th>
<th>Site 2 Day</th>
<th>Site 2 Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Present ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>2</td>
<td>Present NDA</td>
<td>NDA</td>
<td>ND</td>
<td>NDA</td>
<td>ND</td>
</tr>
<tr>
<td>3</td>
<td>Present NRDA</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>4</td>
<td>Present SDA</td>
<td>NDA</td>
<td>NDA</td>
<td>NDA</td>
<td>NDA</td>
</tr>
<tr>
<td>5</td>
<td>Present S</td>
<td>ND</td>
<td>ND</td>
<td>NDA</td>
<td>ND</td>
</tr>
<tr>
<td>6</td>
<td>Present SNDA</td>
<td>S</td>
<td>ND</td>
<td>NRDA</td>
<td>ND</td>
</tr>
<tr>
<td></td>
<td>Not present NDA</td>
<td>ND</td>
<td>NDA</td>
<td>NDA</td>
<td>NDA</td>
</tr>
<tr>
<td></td>
<td>Not present NRDA</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td></td>
<td>Not present S</td>
<td>NDA</td>
<td>ND</td>
<td>NDA</td>
<td>ND</td>
</tr>
</tbody>
</table>

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

Table 2. Motorist recall of signs and situation.

<table>
<thead>
<tr>
<th>Sign</th>
<th>Presence of Vehicle at Intersection</th>
<th>Percentage of Drivers Sampled</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Saw Correct Sign</td>
<td>Saw No Sign</td>
</tr>
<tr>
<td>2</td>
<td>Present 20</td>
<td>29</td>
</tr>
<tr>
<td>3</td>
<td>Present 22</td>
<td>29</td>
</tr>
<tr>
<td>4</td>
<td>Present 41</td>
<td>23</td>
</tr>
<tr>
<td>6</td>
<td>Present 45</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Not present 41</td>
<td>14</td>
</tr>
</tbody>
</table>

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.
The principal component of the analysis was the Analysis of 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 motorist familiarity with the road and the index of familiar effects 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 at sign A (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 is presumably attributable to the greater visibility of some of the signs (i.e., the lighted ones) at night. Generally, 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 3.9 to 7.9 km/h (2.4–4.9 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 estimated speeds given to 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—is, 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 signs 4 or sign 6 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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REFERENCES


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Improving the Accuracy of Information on Direction Signs

H. J. WOOTTON AND R. S. BURTON

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 and Avon (6) suggests that 66 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