FINAL REPORT

PB99-152134

ASSESSMENT OF ADVANCED WARNING SIGNS FOR FLAGGING OPERATIONS

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16. Abstract

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The study consisted of a literature review and a survey of motorists. More than 4,500 multiple-choice surveys were mailed out to randomly selected Virginia residents. Open-ended questionnaires were also distributed to select groups to provide a comparison with the results of the multiple-choice responses. The survey results indicated that the proposed sign was for the most part understood by Virginia drivers and appeared to be effective at conveying its message.

This study recommends that: (1) VDOT ask the FHWA to allow the use of the proposed sign in work zone operations throughout Virginia, and (2) VDOT, along with others, petition the FHWA to add the proposed sign to the MUTCD.

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(A Cooperative Organization Sponsored by the
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the University of Virginia)

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ABSTRACT

The Virginia Department of Transportation (VDOT) and several other state departments of transportation have expressed interest in modifying the advanced warning sign for work zone flagging operations. The advanced warning sign is intended to alert drivers to the presence of flaggers and to prepare drivers to stop (if necessary) prior to reaching work zone operations. The current or existing flagger sign depicts a symbol of a worker holding a flag; the proposed sign depicts a worker holding a STOP/SLOW paddle. The purpose of this research project was to assess and compare the motoring public's understanding of the existing and proposed advanced warning signs for work zone flagging operations.

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INTRODUCTION AND PROBLEM STATEMENT

The Virginia Department of Transportation (VDOT) and other state departments of transportation have expressed interest in modifying the advanced warning sign for work zone flagging operations. The general purpose of the advanced warning sign is to alert the motoring public to potential traffic flow interruptions caused by flaggers directing traffic in work zones. Specifically, the advanced warning sign is intended to alert drivers to the presence of flaggers who are ahead and to prepare the drivers to stop, if necessary, prior to reaching the flaggers in the work zone operations.

Currently, the advanced warning sign for flagging operations, W20-7a, displays the silhouette of a highway worker holding a flag. In practice, however, traffic in most work zones in Virginia is controlled with STOP/SLOW paddles instead of red flags. The 1983 Part VI of the *Manual on Uniform Traffic Control Devices* (MUTCD) was revised to state that "The STOP/SLOW paddle, which gives drivers more positive guidance than red flags, should be the primary hand-signaling device."[1] Therefore, the STOP/SLOW paddles have been the standard for work zone traffic control since 1987, following a 3-year phasing-in period.

Although the traffic control symbol itself was changed, the applicable warning sign, W20-7a, was never updated to reflect the change in work zone traffic control practices. Therefore, it was proposed that the flagger sign W20-7a should be changed from the current symbol of a worker holding a flag to one depicting a worker holding a STOP/SLOW paddle. Examples of the original sign and the proposed W20-7a sign are presented in Figures 1 and 2, respectively.

The American Traffic Safety Services Association (ATSSA) made an unsuccessful attempt in 1987 to petition the Federal Highway Administration (FHWA) to modify the W20-7a sign to display a worker holding a STOP/SLOW paddle instead of a flag. The FHWA denied the request, citing a 1987 FHWA in-house human factors study indicating that it was difficult for drivers to identify correctly the meaning of the new sign.[2] The study showed, however,

Figure 1. Original W20-7a Sign.

Figure 2. Proposed W20-7a Sign.

that drivers easily identified the meaning of the original W20-7a sign.[3] A subsequent 1989 FHWA study also showed that drivers more readily understood the original W20-7a sign than the proposed sign showing a person holding a STOP/SLOW paddle.[4]

Part of the reason that drivers were unable to correctly interpret the meaning of the W20-7a sign with the STOP/SLOW paddle may have been the fact that the paddle was not widely used at the time of the original FHWA study. The paddle sign has gained acceptance and increased in usage in work zone traffic control since the previous studies. As a result, increasing numbers of motorists have been exposed to this new sign. Therefore, it would be reasonable to assume that this familiarity will most likely result in more correct interpretations of the proposed sign's meaning.

There is concern among VDOT officials over the continuing discrepancy between what the motoring public sees on the existing advanced warning signs and the actual "flagger" they encounter in the work zone. A 1995 human factors study of older drivers reported as one of its key findings that signs should use representational rather than abstract symbols.[5] Currently, the depiction of a worker holding a flag rather than a paddle does not constitute an accurate representation of the traffic situation encountered by the driver. In addition, continued use of the original W20-7a sign has resulted in roadway workers in Virginia erroneously controlling traffic with flags in an attempt to comply with the advanced warning signs placed throughout the work zone.

Concerns regarding the discrepancy between actual conditions and those displayed on the advanced warning signs have been addressed by the Traffic Research Advisory Committee.[6] The Maryland State Highway Administration (MdSHA) is also interested in modifying the existing W20-7a sign and has approached FHWA about the possibility of modifying this sign. FHWA responded to Maryland's request by informing them that any such modification to a sign presently included in the MUTCD would require a human factors study. VDOT State Traffic Engineer, Lynwood Butner, described VDOT's need to modify the sign and suggested waiving this required study in a January 1998 letter to FHWA.[7] The request to waive the human factors study was subsequently denied by FHWA.[8]

PURPOSE AND SCOPE

This study looks at the feasibility of modifying the W20-7a to reflect actual work zone conditions by depicting the STOP/SLOW paddle in lieu of the flag. The Virginia Transportation Research Council (VTRC) was asked by VDOT's Traffic Engineering Division to conduct a research project to assess and compare the motoring public's understanding of the existing and proposed flagger signs.

METHODOLOGY

Literature Review

A review of pertinent traffic engineering and human factors literature was conducted. The literature review was performed for two primary purposes. The first was to identify previous work in the area of sign comprehension with specific attention directed toward advanced warning signs for flagging operations. The second purpose was to identify possible approaches and methodologies for potential use in the present study. Overall research designs as well as details of survey and analysis techniques were examined and evaluated for their potential applicability.

Questionnaire Development

Two survey questionnaires were developed to ascertain motorists' understanding of both the existing and proposed flagger signs. Each questionnaire contained a color image of the study sign and four study questions. In addition, the questionnaire included several questions to elicit demographic information from the respondents. Two versions of the questionnaire were developed for each of the signs. The questionnaires were administered directly to participants—these face-to-face assemblies were called sample groups. The majority of questionnaires were part of a large mail-out survey. Both versions of the questionnaires contained identical questions, but differed in that those for the mail-out survey contained multiple-choice answers, while those administered to the study groups were open-ended to allow respondents to "write in" their answers. A sample of the multiple choice format questionnaire for the proposed sign is presented in Figure 3. The multiple-choice format was chosen for the mail-out survey to enhance ease and convenience for respondents with the intent of increasing the response rate. An open-ended format was used for the sample groups to provide the researchers valuable information as to what extent the multiple choice format influenced the responses to the mail-out survey. Prior to conducting the surveys, the questionnaires were pretested with VTRC employees to determine their effectiveness. The survey was then tested at a local adult driver's education class.

The questions used in the current study are close variations on three of the six questions used in the original FHWA study of the existing and proposed flagger signs. In fact, the entire questionnaire, including the possible responses and the coding criteria, was based on the 1987 FHWA study that was cited as being the basis for retaining the existing sign as the standard.[2]

The first question to determine how many of the respondents had encountered the existing sign in a work zone also estimates how familiar motorists are with sign details. Question 2 measures how well motorists interpreted the meaning of the signs. The original FHWA study indicated that the preferred interpretation of the sign was "Flagger Ahead." "Flagger Ahead" was the text displayed on the original W20-7 sign prior to adopting the current symbolic sign, W20-7a.[1] Question 3 was a test of what connotations motorists associated with the orange and black work zone warning sign. Question 4 was administered to determine how motorists would respond to each sign in the questionnaire. This question was deemed by the researchers as being the most important. Previous studies have addressed the relative importance of the driving response to warning signs as being more significant than their understanding of these signs.[3,9] This is a very important point in the context of possibly introducing a new sign. The motoring public may not fully understand the meaning of a new sign, certainly without the use of an educational plaque as suggested in the MUTCD.[1] The same motorists, however, may be inclined to react correctly to the warning sign based on their driving experience and the context in which the sign is encountered (i.e., the work zone).

Sample Groups

Particular attention was directed toward assessing the understandability of the proposed sign among younger and older drivers. The needs and responses of older drivers to traffic control are receiving much attention. Older drivers probably would have encountered many flagging operations over the years, whereas younger drivers most likely would have encountered few of these while driving. The open-ended questionnaire with the proposed sign image was administered to 116 students in driver education classes at three Charlottesville-area high schools, 43 undergraduate students in an engineering class at the University of Virginia, and 50 older drivers at the Charlottesville Senior Center.

Mail-out Survey

Self-administered survey questionnaires were distributed to a randomly selected population of Virginia residents. Statistical analysis was performed to identify the sample size necessary to provide an appropriate level of confidence in the survey results. Since there was considerable subjectivity inherit to the survey questions, it was decided that a ± 4 percent error in the survey accuracy at the 95 percent confidence level would be acceptable. This condition resulted in a desired sample size of 600 survey responses. The researchers assumed a 25 percent survey return rate. The assumption was based on conventional wisdom among VTRC staff of a 10 to 20 percent return rates for mail-out surveys and the relative ease of the questionnaire used in the current study. Questionnaires were developed for both the existing and proposed signs. Therefore, the total number of responses desired was 1,200 (600 for each sign), requiring a target mail-out distribution of approximately 4,800 questionnaires.

The Virginia Department of Transportation (VDOT) is investigating how well the public understands some of its roadway signs. By answering the questions below, you are playing an important role in helping VDOT make Virginia's roads safer for everyone. Please take a minute and look at the roadway sign shown below; then answer the questions and return the survey. A self-addressed, stamped envelope has been provided for your convenience. Alternatively, feel free to complete the survey online at our website address, http://www.vdot.state.va.us/vtrc/survey/sign2.htm. Please return the completed survey by Friday, November 13th. Thank you for your participation and your concern for safer roads in Virginia.

1) Have you ever seen this sign in Virginia? (check one)
   - ☐ Yes
   - ☐ No

2) What do you think the sign means? (check one)
   - ☐ Children present
   - ☐ Stop ahead
   - ☐ Workers ahead
   - ☐ Slow down
   - ☐ Flagger ahead

3) Where would you expect to see this sign? (check one)
   - ☐ Near a school crossing
   - ☐ Near road work
   - ☐ Near a pedestrian crosswalk
   - ☐ Near an accident
   - ☐ Near a hospital

4) What would you do if you saw the sign while driving? (check one)
   - ☐ Stop
   - ☐ Slow down
   - ☐ Proceed with caution
   - ☐ Be prepared to stop

The information below is optional. By completing this information, you are helping VDOT ensure that we have surveyed a broad range of Virginia motorists. Please help us make sure that people like yourself are adequately represented in our study. Thank you.

Personal Information: (check one) Male ☐ Female ☐

Age: _____ Years driving: _____

Highest Level of Education: (check one)

☐ did not complete high school ☐ completed high school ☐ completed college ☐ post-graduate education

Figure 3. Sample Survey Questionnaire.

Address List Development

An Internet-based telephone book was used to obtain addresses for 4,800 Virginia residents. This Internet database contains telephone and address listings from phonebooks throughout Virginia. The website provides a searchable interface to the listings in the database by last name, first name, and state. The listings in the database can be searched by the first letter of the first and last names.

A methodology to randomly select names and addresses from the database was developed. The method involved the development of a list of random number pairs. Each of the pairs contained two random numbers between 1 and 26, corresponding to the letters of the alphabet. For example, a number pair containing 1 and 2 would correspond to the letters A and B. For this example pair, A would be entered as the first letter of the last name and the B would be entered as the first letter of the first name. The database would then be searched for names and addresses of Virginia residents with last names beginning with A and first names beginning with the letter B. For each search, 10 name and address listings were reported by the Internet search engine. These listings were then recorded and stored for use in the mail-out survey. A list of 10 names and addresses were obtained for each random number pairs until 4,800 listings had been recorded. The listings were checked for format, screened for repetition, and printed on mailing labels for distribution of the survey questionnaires. Screening of the initial addresses resulted in approximately 300 names and addresses being discarded due to incompleteness.

Survey Website Development

In addition to the business reply envelope included in the mail-out survey, potential respondents were also given the option of responding electronically. A survey website was developed for each of the sign questionnaires and "housed" on the VTRC Internet server. The website surveys were identical to the mail-out survey. The website survey was not intended to solicit responses from any specific demographic group. Rather, it was intended to add an extra level of convenience in responding to the survey questionnaires. In addition, it was included in the current study to allow the researchers to examine the potential use of e-mail as a survey tool for future research projects.

Response Analyses

A detailed analysis was performed after the sample group surveys were conducted and a sufficient number of responses to the mail-out surveys were received. The results of question 1 were tabulated (YES/NO) and analyzed along with demographic information reported with the surveys. The responses to the substantive survey questions (2, 3, and 4) were coded as correct, substantially correct, or incorrect where:

- correct—implies a clear understanding of sign meaning
- substantially correct—implies a substantive understanding of sign meaning

- incorrect—implies a total lack of understanding of sign meaning.

The demographic information was also taken into account during the tabulation and classification of the various levels of correctness for each of the three substantive questions.

RESULTS AND DISCUSSION

Summary of Literature Review

The literature review revealed several studies relevant to the present research. Two previous studies conducted by the FHWA in 1987 and 1989 comparing existing and proposed W20-7a signs were reviewed. Both of these studies concluded that the existing sign was more reliably understood and effective at conveying the intended message.

Comparison of Flagger Symbols

The first of FHWA studies was conducted "in-house" as part of a larger driving simulator study. Forty participants were shown either the existing or proposed flagger sign during a forty-five minute driving simulator session. Either the existing or the proposed sign was encountered by each subject one time during the simulation at a segment that consisted of a two-lane roadway with a 55 mph posted speed limit. It is not clear from the report whether or not the signs were encountered in the context of a work zone operation. The report stated that the subjects were exposed to several different roadway signs during the driving simulator. After completing the simulation, each participant was asked six questions.

The responses to these six questions were coded as being correct or incorrect. The results of the first question, "Did you encounter one of the flagger signs?," indicated that there was no statistically significant difference between the frequency of correct responses for each sign. In other words, neither sign made a larger impact than the other did on the participants.

In the case of the second question, "Which one did you encounter?," 45 percent of the participants viewing the paddle sign remembered the sign they had encountered. On the other hand, 95 percent of those viewing the original flagger sign recalled having seen it.

The results of the question regarding each sign's meaning, question 3, indicated no significant difference between the number of responses referring to construction or a work zone. A correct answer was defined as one including such statements as "slow down," "caution," "prepare to stop," "flagger ahead," etc. Answers were interpreted as incorrect if they included items such as "school crossing" or "stop ahead." The paddle sign garnered 45 percent correct responses and the original flagger sign was correctly interpreted by 100 percent of the participants encountering it during the driving simulation.

In response to question 4, "Where would you expect to see these signs?," more than 50 percent of the responses associated the paddle sign with driving situations other than roadway work zones or construction activity. The percentage of subjects that associated the paddle sign or the flagger sign with a school crossing was 30 percent and 8 percent, respectively.

In response to question 5, "If you saw one of these signs, what action would you take?," the proposed paddle sign received a larger percentage (36 percent) of correct responses than the original flagger sign (11 percent). Finally, question 6, if you were told both signs meant "flagger ahead," i.e., which sign would you prefer, indicated that 75 percent of the study participants preferred the original sign and 11 percent favored the proposed sign. The researchers were careful to point out, however, that people are generally more likely to prefer a familiar sign.

In addition, the driving speed was measured with regard to each of the signs (speed before the sign, speed at the sign, speed after the sign). An analysis of variance (ANOVA) was performed on the speed data and indicated that there was no significant difference in the number of drivers slowing down for either sign.

Based on these results, particularly the fact that study participants interpreted the proposed sign as an indication to "stop ahead," the researchers concluded that the proposed sign would be a less effective advanced warning sign for flagging operations than the sign currently used. [3]

Redesign and Evaluation of Selected Work Zone Sign Symbols

A subsequent 1989 FHWA study also compared the original flagger sign with three proposed alternatives and concluded that the existing sign was more effective.[4] One alternative sign depicted a worker waving a flag. The other two signs were variations on the proposed sign, showing a worker holding a paddle. One of the paddle signs showed a circular paddle and the other showed a silhouette of an octagonal paddle. The study involved 32 test subjects, ranging in age from 20 to 68, with an average age of 47. The understandability of all four signs was evaluated. In addition, participants were also asked to identify which sign they preferred. The preference data indicated that the study participants preferred the original flagger sign to any of the three proposed alternatives.

The understandability of a sign was determined by presenting sample signs to the test subjects and recording their interpretation of the sign viewed. There was no description provided in the report, however, of the methodology used to evaluate sign comprehension. In other words, no sample questions or survey techniques were presented. The results of the comprehension tests indicated that 84 percent of the subjects correctly interpreted the original flagger sign, while only 47 percent correctly interpreted the proposed octagonal paddle sign. Conversely, the proposed sign received 31 percent incorrect responses and the original sign was incorrectly interpreted by only 9 percent of the subjects. Incidentally, the sign with the circular paddle performed worse than the octagonal paddle sign, gleaning correct responses by only 31 percent of the subjects.[4]

The legibility distance of a sign refers to the furthest distance from which the sign becomes recognizable to an approaching driver. Legibility distance was defined in this study as the point at which the subject could correctly identify the unique features of the sign. For instance, when viewing a flagger sign, a response indicating that the subject was able to discern that the silhouette was holding a flag would have been interpreted as correct. Whereas, an answer simply implying that the silhouette of a man or worker was identified would be considered incorrect and the sign would be brought gradually closer to the subject until the actual flag was recognized. The legibility distance of the four alternative flagger ahead signs was evaluated using a sophisticated test apparatus in the Human Factors Laboratory at FHWA's Turner-Fairbank Highway Research Center. The results of the legibility distance study indicated that the original sign was recognizable at a greater distance than any of the three proposed alternatives. The mean legibility distance for the original sign was 162 m. The proposed sign depicting the octagonal STOP/SLOW paddle was shown to have a mean legibility distance of 137 m. The remaining legibility distances were 112 m and 140 m, respectively.[4]

Symbol Signing for Older Drivers

Among other signs, this 1997 study evaluated the effectiveness of the flagger sign in relation to a proposed alternative. The alternative flagger sign was very similar to the original sign with the exception that the silhouette holding the flag was depicted wearing a hard hat to indicate to motorists that the figure was a construction worker and not a school crossing guard. The percentages of study participants correctly interpreting the existing and alternative signs were 69.5 and 81.5, respectively.[5]

Motorist Understanding of Traffic Control Devices in Kansas

A fourth study addressed only the understandability of the original flagger sign, along with 24 other selected warning signs. This study, conducted at Kansas State University, involved the surveying of 500 subjects selected to provide a representative sample population of licensed drivers in Kansas. The study used self-administered printed questionnaires containing color images of the study signs and several questions designed to elucidate the subject's comprehension of the meanings of the selected signs. The questionnaires, some multiple choice and others containing open-ended questions, were administered in person at various survey stations (courthouses, places of employment, etc.) The study did not seek to identify the reason behind a motorist's comprehension or lack of comprehension of the sign. The study also did not focus on identifying what action on the driver's part each sign might elicit. Conversely, this FHWA study focused on the understanding of the "literal" meaning of each sign.

The existing flagger ahead sign was shown to be understood by 94 percent of the survey respondents and incorrectly interpreted by less than 5 percent. The study also compared the rate of correct responses for the multiple choice survey responses and those collected using the open-ended questionnaires. Although no specific data were reported for this comparison for the flagger sign, the trend clearly indicated a higher rate of correct responses for the multiple-choice

questionnaires. It was inferred from these results that respondents to the multiple-choice surveys might have deduced the correct response from the available choices.[9]

Motorist Comprehension of Signing Applied in Urban Arterial Work Zones

A 1990 Texas A&M study indicated that 77.5 percent of Texas motorists correctly interpreted the meaning of the original flagger ahead sign when shown a graphical representation. When shown a photograph of the sign in a work zone, 85.1 percent of the respondents provided correct interpretations. It can be inferred from these results that the context in which a particular roadway sign is encountered tends to increase motorist understanding. Therefore, lower comprehension rates may be expected for survey questionnaires that do not explicitly depict the driving situation in which the sign would normally be encountered by the driver. The surveys were administered in multiple choice format and respondents had the choice of interpreting the sign as indicating road construction ahead, a flagger ahead, or a school crossing guard ahead. Participants were also allowed to respond as "Not sure." The majority of the incorrect responses were reported as misinterpretations of the sign as meaning construction ahead.[10]

Other Studies

The other research identified in the literature did not explicitly address the effectiveness of flagger signs. These reports did, however, provide excellent examples of methodologies and techniques used to assess the effectiveness of roadway signs. One report suggested that a comprehensive evaluation of roadway sign effectiveness should include measurements of the legibility distance, conspicuity, and learnability in addition to understandability metrics.[11] The legibility distance of the two signs was not evaluated in the current study. The conspicuity of a sign is reported as "Not to be considered a function of symbol design, but is determined more by symbol size, color, shape, and contrast between the symbol and the background of the sign panel on which it appears."[12] Some studies cite motorists' preference as an important measure of the sign's effectiveness when evaluating alternatives.[9] Other researchers dismiss the idea of preference on the basis of a tendency for motorists to prefer familiar signs.[3]

Mail-out Survey Response Summary

Approximately 4,500 survey questionnaires were mailed to randomly selected Virginia residents. Of the 4,500 total surveys mailed out, 813 were returned from the Post Office as a result of insufficient address, lack of forwarding address, or other problems with locating addressees. Therefore, only about 3,600 questionnaires actually reached their intended destination. A total of 1,383 questionnaire replies were received (759 contained the existing sign and 624 depicted the proposed sign). Only 20 responses were recorded on the survey websites. Using the number of questionnaires actually delivered, 3,600, the overall return rate for the mail-out survey was calculated to be approximately 38 percent.

The demographics of the survey responders are described in Figures 4 through 7. Chi-square analysis was performed on the demographic information to ensure that the distribution of the various characteristics was the same for the populations responding to questionnaires pertaining to either the existing or the proposed sign. The null hypothesis, H_0, for these analyses was that the distribution of the characteristics (gender, age, number of years driving, and education) was the same for both populations. The results of the Chi-squared analyses are summarized in Table 1. It can be concluded from these results that there is no statistical difference in the distribution of demographic characteristics between the two populations (i.e., those viewing the existing sign and those viewing the proposed sign).

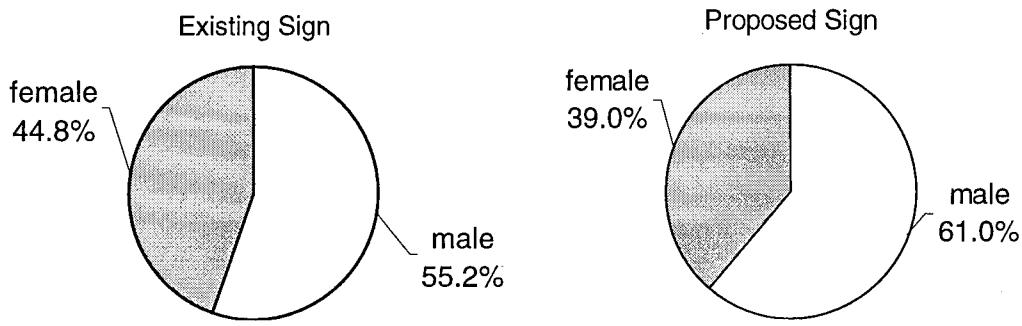

Figure 4. Gender Distribution of Responses for the Existing and Proposed Signs Surveys.

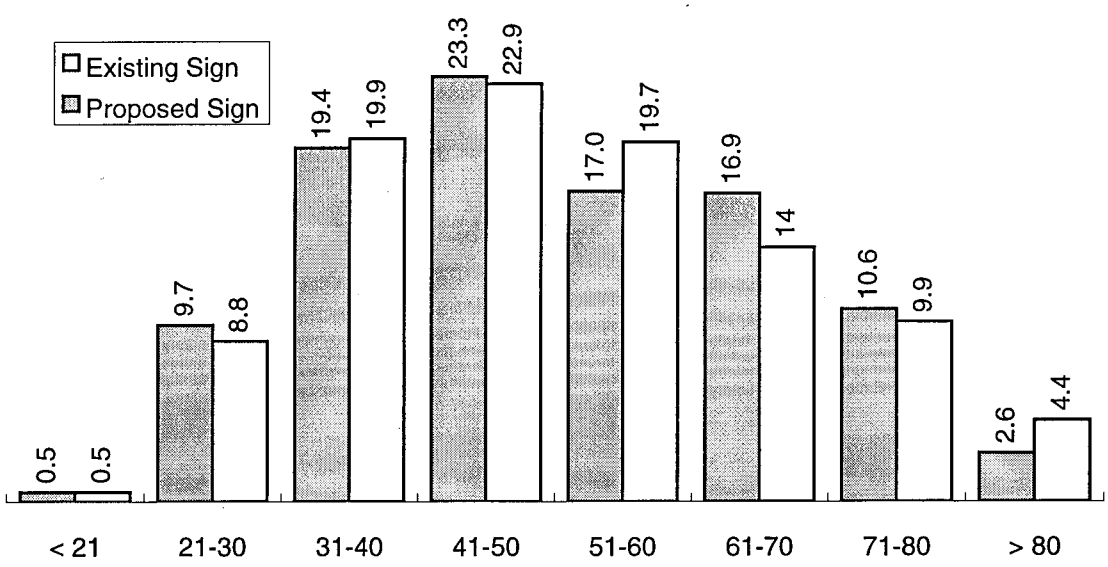

Figure 5. Age Distribution of Responses for Existing and Proposed Sign Surveys.

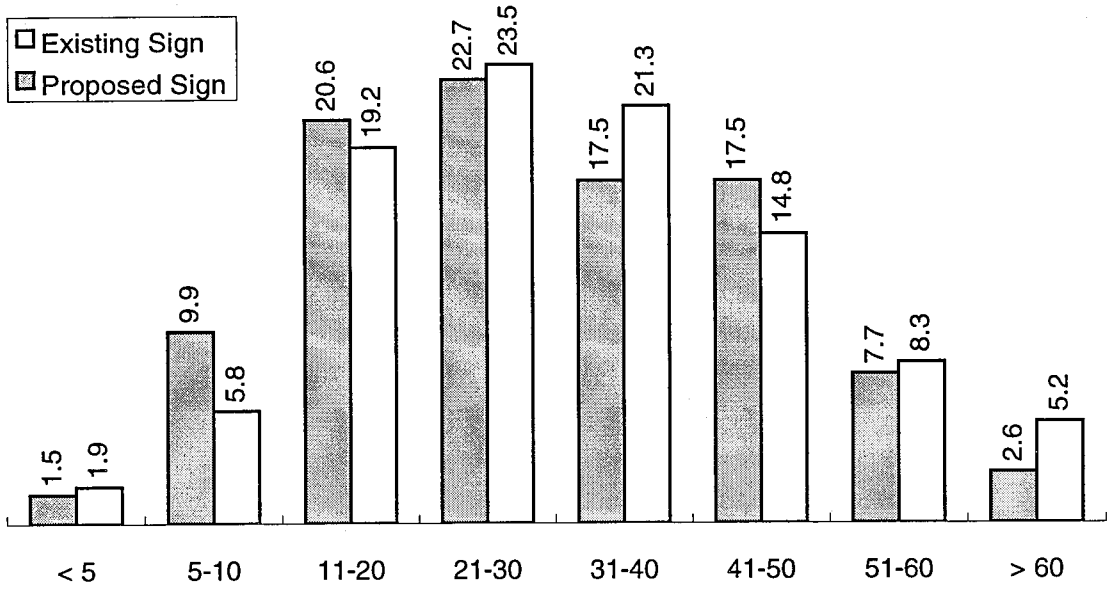

Figure 6. Number of Years Driving Distribution of Responses for Existing and Proposed Sign Surveys.

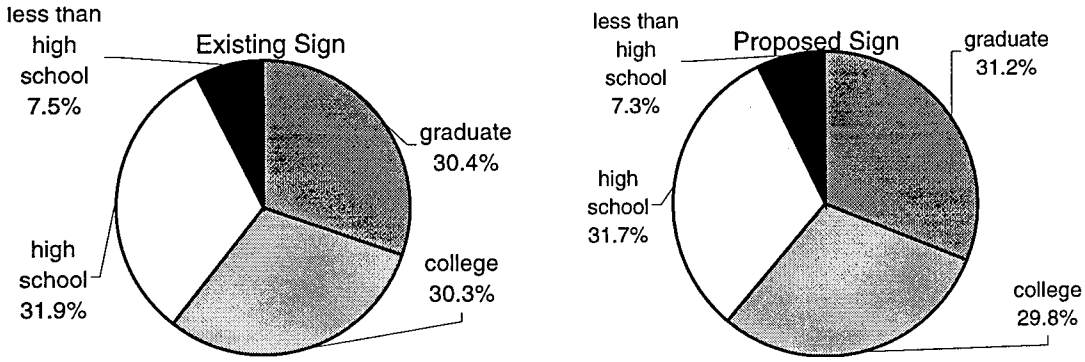

Figure 7. Educational Distribution of Responses for Existing and Proposed Sign Surveys.

Table 1. Summary of Population Demographics Chi-square Analyses.

Characteristic	Calculated X^2	Degrees of Freedom	$X^2_{0.99}$	H_0 status
Gender	4.54	1	6.64	Accept
Age	6.55	7	18.48	Accept
Years Driving	17.29	7	18.48	Accept
Education	0.26	3	11.34	Accept

Comparative Analyses

Survey Question 1: "Have you ever seen this sign in Virginia?"

This question was presented in a multiple choice format allowing respondents to choose either a "YES" or "NO" response. The percentages of each response are summarized in Figure 8 for both signs. Almost a quarter of the respondents viewing the existing sign indicated that they had never seen it. These responses may indicate that the respondents have not encountered the sign or simply do not recall having done so. Slightly more than one third of the respondents who viewed the proposed sign indicated that they had never seen the sign. Approximately 65 percent claimed that they had encountered the proposed sign (although it has not yet been used in Virginia). A possible interpretation of these results is that the motorists' responses indicated that there was a the similarity between the existing and proposed signs. Also, respondents may have perceived the proposed sign as being representative of the use of STOP/SLOW paddles that they have encountered while driving through flagging operations throughout Virginia. It is also possible that the 65 percent response may be, in part, a result of the respondents wanting to give the correct answer or to avoid providing the wrong answer.

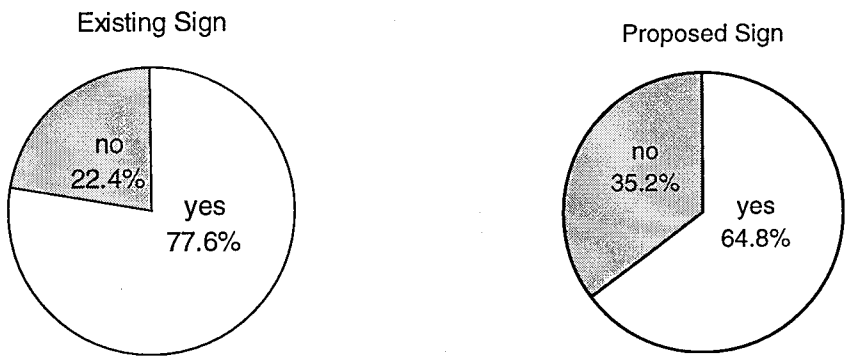

Figure 8. Distribution of Responses to "Have You Seen This Sign in Virginia for the Existing and Proposed Signs?"

Survey Question 2: "What do you think the sign means?"

Question 2 was intended to elicit how well respondents understood the meaning of each sign. Responses indicating "flagger ahead" were coded as correct, while responses of "workers ahead" or "slow down" were coded to be substantially correct. The substantially correct responses were interpreted as indicating that the respondent understood that the sign meant the driver is approaching a work zone and should exercise caution. The remaining responses, "children present" and "stop ahead," were coded as incorrect. The "children present" response indicated that the respondent did not understand the meaning of the sign or the context in which the sign was used. In conjunction with the original FHWA study, the "stop ahead" response was coded as incorrect because it was interpreted to be a potential safety problem if drivers were influenced to make an unwarranted stop upon encountering the sign. The percent distribution of correct, substantially correct, and incorrect responses to question 2 for the existing and proposed

signs are shown in Figure 9. These percentages seem to indicate that the meaning of "flagger ahead" may possibly be more successfully conveyed by the existing sign depicting the worker holding the flag than the proposed sign. However, it should also be mentioned that the presence of the word "flagger" in the list of possible choices may have biased the survey responses to question 2 for the existing sign, since it clearly showed a picture of a worker holding a flag. In other words, respondents may have simply deduced the correct answer by "matching" the symbol with the term flagger. The rate of substantially correct responses was similar for both signs. The rate of incorrect responses, however, was substantially higher for the proposed sign.

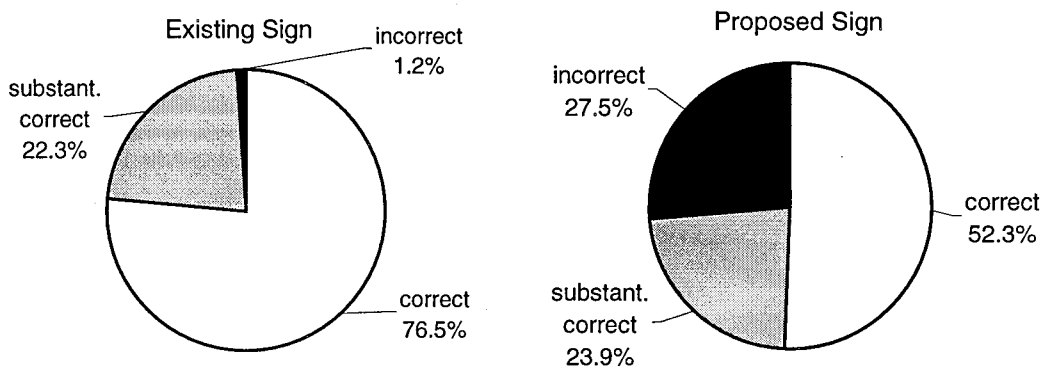

Figure 9. Distribution of Answers to "What Do You Think This Sign Means For the Existing and Proposed Signs?"

Survey Question 3: "Where would you expect to see this sign?"

Survey question 3 was administered to ascertain whether or not motorists correctly anticipated the driving context in which the sign would be encountered. The percentage distribution of correct responses to this question for the existing and proposed signs is shown in Figure 10. The correct response was "near roadwork." There were no specific choices on the questionnaire that were to be coded as substantially correct. Although the questionnaire instructed respondents to check only one answer, some checked more than one in certain instances. Responses that included the correct answer in addition to an incorrect answer were coded as substantially correct, with the assumption that the respondent knew to expect the sign in a work zone, but thought it might also be used in other applications. Any response not containing "near roadwork" was coded as incorrect. It is clear from both survey questionnaires that most motorists correctly associated the signs with roadway work zones.

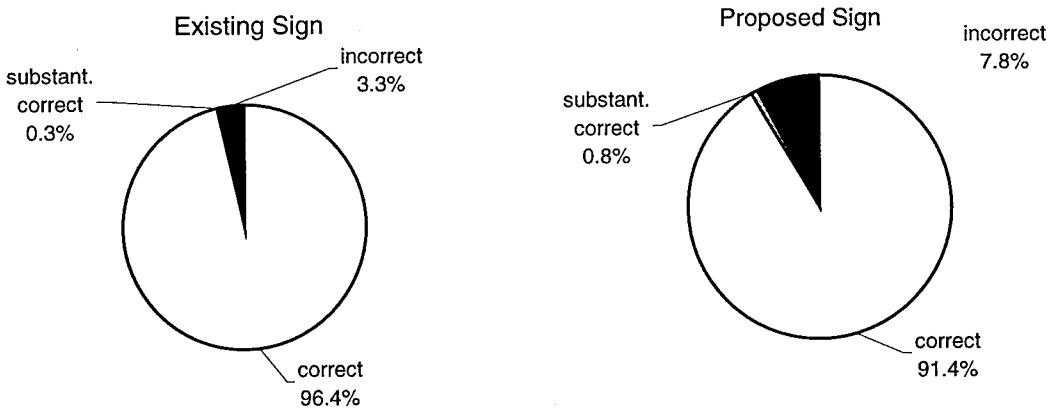

Figure 10. Distribution of Answers to "Where Would You Expect to See This Sign for the Existing and Proposed Signs?"

Survey Question 4: "What would you do if you saw the sign while driving?"

This was considered the most important question in the survey. The previous two questions were intended to determine the level of knowledge motorists possessed about the signs. This allowed respondents to identify the probable driving action they would take after encountering each sign. The response choices included one correct answer (be prepared to stop), two substantially correct answers (slow down and proceed with caution), and one incorrect answer (stop). The percent distribution of correct, substantially correct, and incorrect responses are shown in Figure 11 for both signs. Interestingly, the proposed sign garnered a larger percentage of responses in both the correct and incorrect categories.

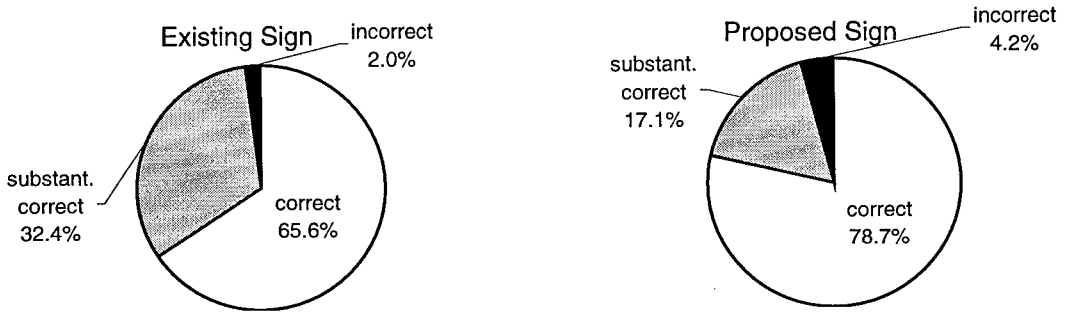

Figure 11. Percent Distribution of Answers to "What Would You Do If You Saw This Sign While Driving?"

Statistical Analysis

Statistical analyses were performed on the response data for questions 2 through 4. Chi-square analysis was employed to test the null hypothesis, H_0, that the distribution of correct, substantially correct, and incorrect responses was the same for both signs. The analyses are summarized in Table 2. The null hypothesis was rejected in the case of all four questions, confirming the differences apparent in the data.

Table 2. Summary of Analyses of Survey Responses.

Characteristic	Calculated X^2	Degrees of Freedom	$X^2_{0.99}$	H_0 status
Question 1	26.95	1	6.64	Reject
Question 2	168.10	2	9.21	Reject
Question 3	15.92	2	9.21	Reject
Question 4	43.69	2	9.21	Reject

Note: see Figure 3 for the questions.

For question 4 ("What would you do if you saw the sign while driving?") the data and results suggested that the rate of correct responses for the proposed sign was statistically higher than the rate for the existing sign. A statistical comparison between the rate of correct responses was then performed. The standard normal z test was used to test whether a statistically significant difference in the rate of correct and not correct responses existed between the existing and proposed sign. Use of the z test requires the assumption that the sample population approximates the actual population and is characterized by a normal distribution. These conditions are generally satisfied with large sample sizes.[12]

The z test was then used to test the null hypothesis, H_0: $\pi_1 = \pi_2$, where:

π_1 = rate of correct responses for the existing sign
π_2 = rate of correct responses for the proposed sign

The difference, π_1 minus π_2, was calculated to be 0.13, indicating a 13 percent higher rate of correct responses for the proposed sign than the existing sign. The z statistic was calculated to be 5.46, which is greater than the critical value of z at the 95 percent confidence level ($z = 1.96$). Therefore, the null hypothesis was rejected, and it was concluded that the rate of correct responses for the proposed sign was indeed significantly higher than the rate for the existing sign.

Study Limitations

Effects of Survey Questionnaire Format

In order to examine the extent to which the possible responses on the multiple-choice questionnaires may have influenced the survey results, the results from the open-ended sample group questionnaires were compared to the results of the mail-out survey. The two sample groups surveyed consisted of younger drivers in high school driver education classes and older drivers from a local senior center. The younger drivers were generally under 20 years of age and had less than 5 years of driving experience. Respondents with similar characteristics accounted for only 0.4 percent of the mail-out survey respondents. Because of the small percentage, the younger drivers were omitted from this analysis.

The drivers surveyed at the senior center were all above the age of 50 with more than 90 percent above 60. These participants generally reported more than 30 years of driving experience. Respondents with characteristics similar to the older driver sample group participants constituted approximately 45 percent of the mail-out survey responses. For this reason, comparisons between the sample group and mail-out survey results were restricted to the responses given by participants over 50 with more than 30 years of driving experience. This constraint allowed the comparison of questionnaire formats over similar demographic populations.

Tables 3 through 5 show the results for questions 2 (sign meaning), 3 (sign location), and 4 (driver action), respectively, for the older driver sample group surveys as well as the corresponding results from the older drivers responding to the mail-out surveys. Tables 3 through 5 also reveal that there is little agreement between the distribution of correct responses among the sample group and mail-out surveys for questions 2 and 4. There is considerable agreement, however, for the responses to question 3. This would imply that the choices provided on the multiple-choice questionnaires influenced the responses.

Table 3. Distributions of Sample Group and Mail-Out Survey Responses to Question 2 on Sign Meaning.

Survey	Percent Distribution of Responses		
	Correct	Substantially Correct	Incorrect
Older drivers sample group	30.0	46.0	24.0
Older drivers from mail-out	46.9	24.0	29.1

Table 4. Distribution of Sample Group and Mail-Out Survey Responses to Question 3 on "Where the Sign is Expected?"

Survey	Percent Distribution of Responses		
	Correct	Substantially Correct	Incorrect
Older drivers sample group	93.8	2.1	4.2
Older drivers from mail-out	88.0	1.1	10.9

Table 5. Distribution of Sample Group and Mail-Out Survey Responses to Question 4 on "What One Would Do Upon Seeing the Sign?"

Survey	Percent Distribution of Responses		
	Correct	Substantially Correct	Incorrect
Older drivers sample group	37.5	45.8	16.7
Older drivers from mail-out	78.5	13.9	7.7

The distribution of the sample group responses to question 2 was somewhat similar to that of the mail-out survey. As previously mentioned, there were subtle differences between responses that were coded as correct or substantially correct. This was particularly the case for question 4 where the correct response was not a specific interpretation of the sign, but rather a description of what driving response the sign would elicit from an individual. The write-in survey responses to question 4 suggest that the answer preferred by FHWA (be prepared to stop) is not necessarily the most probable unprompted manner for how a driver would describe his or her driving response. These results only represent the manner in which drivers describe their probable driving response. A response of "slow down" does not necessarily indicate a disregard for the possibility of stopping in the work zone when and if directed to by a flagger. It simply represents the respondent's interpretation and description of the correct driving action.

Survey Language

The Relationship between Sign Meaning and Expected Driving Behavior

Having established that the multiple-choice format may have contributed to more correct responses, a more detailed examination of the survey language was conducted. Nearly 30 percent of the responses to question 2 were coded as incorrect, indicating that a large percentage of respondents failed to correctly interpret the sign's meaning. "Stop ahead" and "children present" were initially coded as incorrect in order to provide a direct comparison with the original FHWA study.[3] An interpretation of the sign as connoting a school zone, crosswalk, or any other pedestrian activity is obviously incorrect. On the other hand, it was not entirely clear that a multiple-choice response of "stop ahead" necessarily indicated a lack of understanding of the sign's purpose. It is unlikely that a driver would actually stop upon encountering an orange and black advanced warning sign. Rather, a "stop ahead" response to question 2 may indicate a greater likelihood that the driver may be more sensitive to, and therefore react accordingly, to the flagger's directions.

The incorrect responses to question 2 on the signs' meaning were reexamined in more detail. Of the 160 incorrect responses to the question, 145 (91 percent) were "stop ahead" and 15 (9 percent) were "children present." Table 6 summarizes the distribution of responses to question 4 among those individuals providing "stop ahead" responses to question 2. A clear majority of the incorrect "stop ahead" responses to question 2 were accompanied by correct "be prepared to stop" responses to question 4. Therefore, even though approximately 30 percent of the survey respondents indicated "stop ahead" as their choice for question 2, the majority of them indicated in the survey that they would have engaged in the preferred driving response to the

proposed advance warning sign and thus would have prepared themselves to stop. The combination of these two answers suggest that what the respondents say they would do is correct, although what they say the sign means is incorrect.

Table 6. Responses for Driver Action (Question 4) Given an Incorrect Response to the Sign's Meaning (Question 2).

Percent Distribution of Responses		
Be Prepared to Stop	Slow Down/ Proceed with Caution	Stop
79.3	7.6	13.1

Flagger versus Traffic Control Personnel

If one sees an image of a person holding a flag, there is built-in bias in favor of a response of flagger ahead when asked about the sign's meaning. This response may not be provided as readily when an image of a person holding a paddle is shown. In other words, the existing sign may have a better chance of being correct because the word flagger is in one of the multiple-choice answers.

The effect of word choice on the interpretation of the meaning (question 2) was further revealed through a supplemental mail-out survey. Approximately 200 additional proposed sign questionnaires were mailed out in the Charlottesville area and 71 completed surveys were returned. The questionnaires were identical with those used in the original mail-out survey, with the exception that the possible choice "flagger ahead" was replaced with the term "traffic control personnel ahead." More than two thirds of the respondents correctly answered to the revised questionnaire, where it stated, "traffic control personnel ahead," whereas only half responded "flagger ahead" to the original survey. These results indicate that the motorists were more likely to identify the symbol as connoting manual traffic control ahead rather than with the specific term flagger.

The Influence of the Shape of a Stop Sign

Regardless of the term used to identify work zone traffic control personnel or the meaning of the sign, a larger percentage of the respondents indicated that they would be prepared to stop in response to the proposed sign rather than the existing sign (question 4). Although the proposed sign received fewer correct responses regarding its meaning (question 2), it garnered a higher percentage of correct responses to the expected driving response to the sign (question 4) than the existing sign. A possible reason that the proposed sign received more "be prepared to stop" responses than the existing sign is tied to the very reason that spurred the initial resistance to its usage. The FHWA study indicated that drivers interpret the octagonal shaped sign that the worker is holding as a "STOP" sign.[3] In actual practice, the paddle contains a conventional (red and white) "STOP" sign and an orange and black "SLOW" sign on the reverse side. The fact

that drivers may associate the silhouette as a "STOP" sign suggests that drivers may be more prepared to stop than if they had encountered a sign depicting a worker with a flag.

Similarity in Response between the Possible Choices for the Expected Driving Response

With respect to the language used in the survey questionnaire, there is a subtle difference between the possible choices for the expected driving response (question 4). "Slow down," "proceed with caution," and "be prepared to stop" are all very similar responses. A few survey respondents actually checked all three answers and wrote a comment on the questionnaire form indicating that they considered the three choices to be redundant. It is plausible that a driver would slow down and proceed with caution in preparing themselves to stop. It is not absolutely clear that the "be prepared to stop" response is the only correct response but was designated as such only in order to provide a direct comparison to the FHWA study conducted in 1987.[3] A 1998 informational pamphlet on work zone safety published by the FHWA also indicated that "be prepared to stop" was not the only correct interpretation of what a driver should do in response to the flagger sign. In fact, the pamphlet did not even mention this term when describing the existing flagger sign's meaning, stating that: "The symbol means that a flagger is ahead directing traffic in the work zone. When you see this sign, it's time to be cautious, be alert to conditions around you, slow down and watch for other directions or information."[13]

If the scope of appropriate driving responses to the advanced warning for flagging operations were expanded to include logical responses such as "slow down" or "proceed with caution" (as implied in the FHWA pamphlet), the proposed paddle sign would have received appropriate responses by more than 95 percent of the survey respondents in the current study.

Comparing a Single Sign and a Series of Signs in a Work Zone

In this study, survey data were obtained on a single sign, either the existing or the proposed advanced flagger warning sign. This approach was simple and made the mail-out survey easy. It was also used to allow a comparison with the 1987 FHWA study.

In work zones, a series of signs are used to inform and direct motorists. Figure 12 shows the traffic control layout for a typical flagging operation on a two-lane road in Virginia.[15] The third sign, "Be Prepared to Stop," informs motorists of what they expected to do. The advanced flagger warning sign warns of a flagger ahead and identifies the traffic control that will inform the motorists whether or not to stop ahead. The survey asked for responses to a single sign and not the entire context of traffic control in which the sign would be encountered. It is likely that the answers to the survey would have been influenced by the series of signs. The "Road Work Ahead" sign identifies the location or condition that is ahead. The "Be Prepared to Stop" sign is likely to affect the response regarding what the driver would do when he sees the study sign. (This sign is not included in the typical layout for flagging operations in the MUTCD.)

Questionnaire Survey Approach

Most of the limitations of this study were the result of modeling the questionnaire survey after the 1987 FHWA study. Because the study objectives were the same, it seemed appropriate to use the same approach. Moreover, FHWA made a decision based on the findings of the study. This action gave the study credibility. However, during the data analysis, the limitations of this approach as described above became evident. Although these shortcomings are acknowledged, some useful information was obtained.

Comparison with Previous Study

Table 7 displays selected results of both the 1987 FHWA study and this study for comparison. The results of the survey indicate that the meaning of the existing flagger sign, as specified by FHWA, was more readily identified for the existing sign than the proposed sign that depicted the worker holding a STOP/SLOW paddle. Based on an interpretation of the sign as meaning "flagger ahead," the existing sign garnered 76.5 percent correct responses. Conversely, the proposed sign was correctly interpreted by 52.3 percent of the survey respondents. These results are in general agreement with those reported in the original FHWA study of alternative advanced warning signs for flagging operations.[3] When presented with a possible choice of "traffic control personnel ahead" in lieu of "flagger ahead," 67 percent of the respondents in an additional survey correctly chose that answer.

Both signs were correctly identified as being associated with road work operations in the current study. In the 1987 FHWA study, 50 percent of the responses associated the paddle sign with driving situations other than roadway work zones or construction activity. More than 30 percent of the study subjects associated the paddle sign with a school crossing.[3] Less than 8 percent of the survey respondents in the current study incorrectly identified the driving context in which the proposed paddle sign would be encountered. This suggests that the increased usage of the STOP/SLOW paddle over the decade since the original study has made drivers more aware of the paddle and its traffic control function.

With regard to what the drivers would do when they saw each sign, the original FHWA study reported that the paddle sign received 36 percent correct responses and the original flagger sign received 11 percent.[3] The current study indicates that the correct driving response was identified for the proposed paddle sign by 79 percent of the respondents. On the other hand, the correct driving response was identified for the original flagger sign by 66 percent of the respondents.

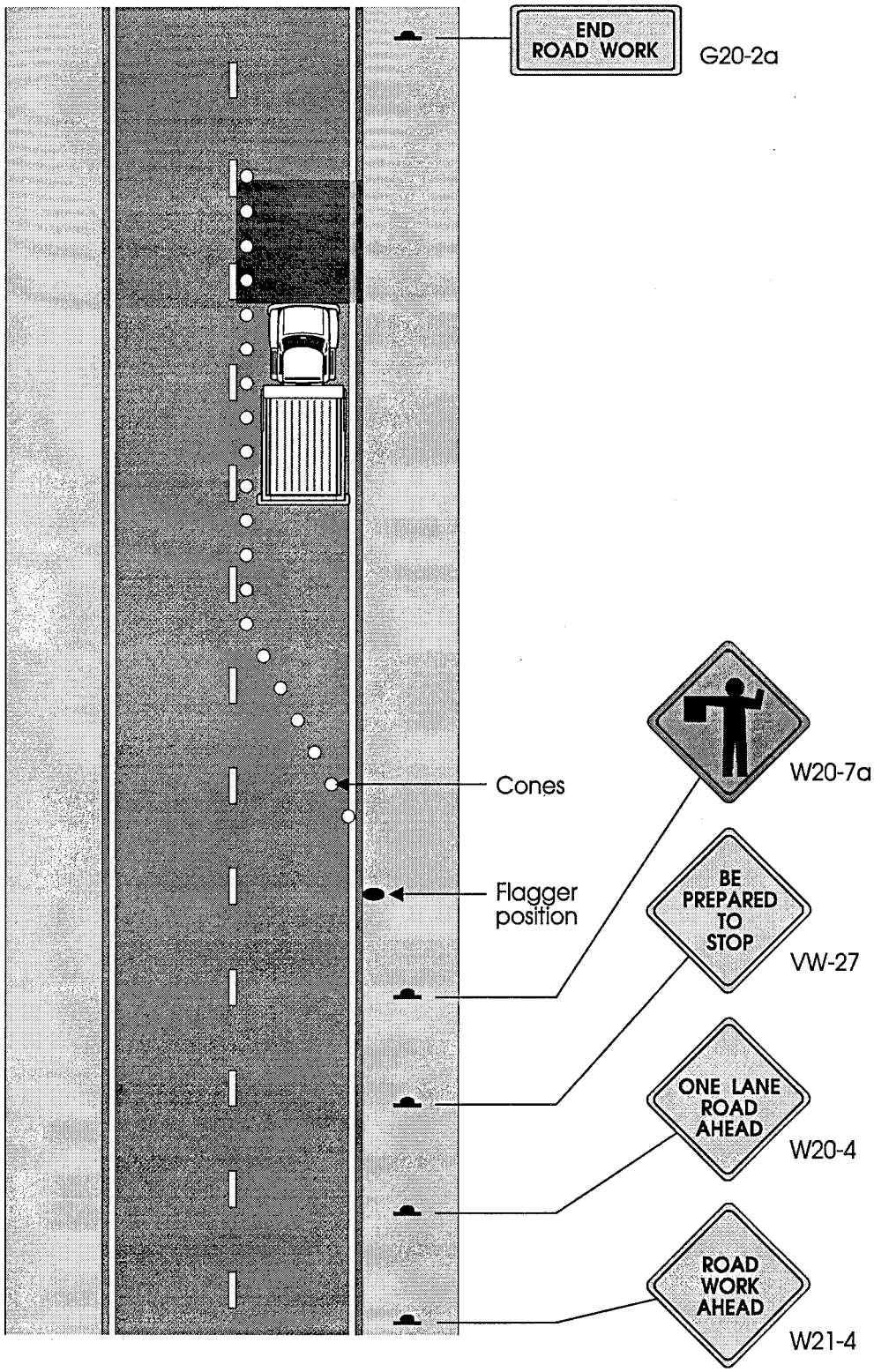

Figure 12. Flagging Operation on Two-Lane Road in Virginia

Table 7. Results of the 1987 FHWA Study and This Study

		Percent of Responses	
		Existing Sign	Proposed Sign
Correct Sign Meaning	1987 FHWA	100	45
	This study	76.5	52.3
Incorrect Sign Location	1987 FHWA		50
	This study		17.8
School Crossing	1987 FHWA		30
	This study		8
Correct Driver Behavior	1987 FHWA	11	36
	This study	66	79

Alternative Points of View

It is acknowledged that an argument in support of the existing sign could be made based on the survey data. For example, if emphasis were placed on the results of question 2 on sign meaning, the results would favor the existing sign. Given that the data may be interpreted in this manner, the survey results, at a minimum, imply that on balance, the proposed sign performs as well as the existing sign.

The logical argument about accuracy of the symbol depicted in the sign; that is, having the advance warning sign display the device that the flagger will be holding–would favor the proposed sign. Having the warning sign accurately depict the conditions ahead is desirable. Given the similarity between the existing and proposed advanced flagger warning signs, the influence of the series of signs that are encountered, the issues regarding survey language, and the accuracy of sign symbols—all of these may be viewed as key reasons for deciding in favor of the proposed sign.

CONCLUSIONS

- The proposed sign accurately symbolizes what the motorist will see based on previous research.

- The correct meaning of the existing sign was clearer to more respondents than the proposed sign. Designation of the word "flagger" as the only correct interpretation of the sign appeared to be biased in favor of the existing sign. Recognizing that the stop sign symbol is an important component of the symbol on the proposed sign, defining "stop ahead" as an incorrect response was considered debatable.

- More respondents associated the desired driving behavior with the proposed sign than the existing sign. Asking what drivers would do when they see a sign is a better measure than asking what the sign means.

- The proposed sign performs as well as, if not better than, the existing sign.

- The concept of only one "correct" driving response was questioned and the argument was made that the actual number of respondents providing suitable descriptions of their probable reactions to the proposed sign was greater than 95 percent.

RECOMMENDATIONS

1. VDOT's Traffic Engineering Division should seek FHWA approval to modify the *Virginia Work Area Protection Manual* to allow the use of the proposed advanced flagger warning sign throughout work zones in Virginia.

2. VDOT, in cooperation with other state DOTs and national organizations, should request that the FHWA modify the MUTCD to allow the use of the proposed advanced flagger warning sign.

IMPLEMENTATION

VDOT's Traffic Engineering Division is currently planning to replace its metal work zone signs with the more portable roll-up signs. As the existing advanced flagger warning signs are retired, they should be replaced with roll-up signs with the proposed symbol. The proposed flagger sign would then be phased-in over a 2-year period along with the roll-up signs. Phasing in the proposed flagger sign will serve to gradually introduce and further educate the Virginia motorists to its usage. Also, such an implementation strategy would incur no additional costs to VDOT as the existing metal flagger signs are already scheduled to be replaced with new roll-up signs.

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