Development of an Emergency Zone Sign

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The concept of having a separate category of traffic sign to control traffic in emergency situations is advanced. This category is referred to as an emergency zone sign (EZS). A rationale is provided for having this category of sign and for developing a family of emergency zone signs. Detail is provided on the sign messages, shapes, and colors.

One of the functions of a traffic control device (TCD) is to warn drivers of unexpected hazards in the roadway. Usually these hazards are permanent features of the roadway or environment, but often hazards are temporary, as in the case of construction and maintenance. The construction and maintenance function has become so pervasive and is viewed as so different a hazard that a special class of TCD was developed for use in work zones. Attention should now be focused on another on-street operation area that poses a hazard to the motoring public and the parties involved—the emergency zone (EZ).

The emergency zone can be defined as an area in which, because of some incident, a special hazard exists that necessitates emergency services such as those provided by police, fire, and emergency medical professionals. Traffic accidents, downed power lines, and building and automobile fires are a few examples of incidents in an emergency zone. These incidents can cause serious safety problems for those attending to the emergency situation and for motorists attempting to pass by or through the EZ. Although most emergency vehicles are equipped with some type of special lighting, these lighting devices alone do not give the motorist enough information to pass the EZ without causing additional problems. Therefore, it is proposed that an emergency zone sign (EZS) or family of signs, similar to the work zone signs, be developed for use by emergency personnel to control traffic in and around the EZ. The objective of this paper is to report on the development of such a sign.

LITERATURE REVIEW

The literature contains many reports that deal with traffic control during emergencies. The Maryland Police Training Commission (*1*) has produced a nine-part instructional series on collision management procedures for police trainees. One part deals exclusively with controlling the accident scene. Flares, cones, and emergency vehicle lighting are all recommended as advance warning devices, but the use of signing of any type is not suggested. In a report prepared by Wilbur Smith and Associates (*2*) for the Highway Safety Division of Virginia, flares, cones, lighting, and signing are advocated as aids to secure a traffic accident scene. Guidelines for placement of these devices are given, but there is no mention of what specific signing is to be used.

Although signing is usually mentioned as a traffic control alternative, the use of vehicle lighting in emergency situations is cited most frequently. According to some state vehicle codes, the use of particular colors on certain types of vehicles at specific times constitutes a specific type of warning, but there appears to be no uniformity among these conventions from state to state (*3*). Another problem cited is the often extreme difficulty for a motorist of determining whether an emergency vehicle is moving or stationary when it is using lights or light bars. One study investigated the possibility of removing the roof-mounted lighting devices from police vehicles as a means of saving energy and to improve surveillance capabilities (*4*).

Changeable or variable message signs have long been recognized as an effective part of a freeway incident management system (*5–7*). Often the effectiveness of these systems is compromised by information that does not reflect actual roadway conditions because of the time lag between a change in the status of the incident and a change in the message to the driver.

This problem of time lags in the reporting system was addressed in a project by 3M Company and the Minnesota Highway Patrol (*8*). A vehicle-mounted changeable message sign was developed by 3M Company and field-tested by the Highway Patrol. The sign used a continuous scroll of eight different messages to warn motorists of various hazards. It was mounted flat on the roof of the vehicle and could be raised while the vehicle was still in motion. Use of this device reduced the time needed to attend to an incident and reduced the number of secondary collisions as well.

Since TCDs for emergency zones do not exist, there is no discussion of the placement for such a device. Placement of many standard TCDs is based on prevailing speed and conditions as well as the time necessary for drivers to comprehend and react to the TCD and alter their driving accordingly (*9*). Methods for determining stopping sight distance and decision sight distance take these factors into consideration (*10*), whereas for placement of flares or other warning devices currently used by police or other emergency personnel, distances are based on vehicle braking distances only (*1*).

Since the EZS is a new type of device, not only can the message be novel, but also colors and shapes can be used that are not bound to currently used forms. In the *Manual on Uniform Traffic Control Devices* (MUTCD), several colors have been reserved for future use in addition to the standard colors already in use (*9*). One of the few studies of motorists' understanding of traffic signing shape and color coding was done by the Virginia Highway Research Council (*11*). The

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study showed that singular and combined uses of color and shape did not effectively communicate to drivers what type of message they were to receive from a sign. Although much has been done to study the recognizability and legibility of various sign shapes and colors (*12*), little has been done to study driver knowledge of the MUTCD color and shape coding conventions.

EMERGENCY ZONE SIGN DEVELOPMENT

The first step in developing the EZS was to determine the needs of the groups who would be using the device and the information requirements of motorists. To accomplish this, the aid of several public agencies was sought to provide information about "on the street" conditions. The author rode with county police traffic units (Montgomery County, Maryland), state trooper units (Maryland), and large urban area fire and rescue crews (District of Columbia Fire Department). These experiences provided insight into the potential uses for an EZS, possible means of deployment, and the nature of the traffic such a device would have to control.

This variety of emergency service agencies provided opportunities to observe a wide range of activities and incidents in EZs. Riding with the county police traffic units provided occasions to observe accidents and stopped-vehicle situations in low- to medium-speed conditions on arterial streets, collectors, and rural country roads. While traveling with the state troopers, the researchers had many opportunities to observe emergency situations on higher-speed limited-access facilities. Riding with fire and rescue squads in the District of Columbia, the author experienced many different emergency situations in an urban setting.

The major advantage of riding in the police and fire vehicles was the speed with which the vehicles arrived on the scene. This allowed observations to be made for the full time period in which an EZS would be deployed, used, and picked up. To facilitate the analysis of each incident, a videotaped record of the emergency was made. The records were limited to views of the traffic approaching the emergency zone and verbal descriptions of the actual hazard.

In analyzing the videotapes, it became apparent that although the exact nature of every incident was different, there were several common elements. These elements were given generic names: recovery time, closure type, and control strategy.

Recovery time is the total time period from when the incident first occurs until roadway conditions return to normal. Recovery time has a great bearing on whether an EZS is to be used. If the time to deploy and take up the EZS is equal to or greater than the recovery time, it is impractical to use it. To assess the impact of the recovery time element, it is necessary to find the point at which the added risk of placing and retrieving the device is outweighed by the added protection afforded by the device. The question still to be answered is "At what point does the break between liability and benefit occur?" This subject was beyond the scope of this study.

Closure type is a description of what part of the roadway is no longer available to the motorist because of the incident. On the basis of the field observations, there were six self-descriptive types of closure: shoulder, single-lane undivided roadway, multiple-lane undivided roadway, single-lane divided roadway, multiple-lane divided roadway, and full roadway. Each of these closure types can be treated with specific control strategies.

The control strategy is the means by which the traffic is redirected past the specific closure type. There are three basic control strategies. The first is to direct the traffic around a hazard utilizing the same side of the road as the affected motorists' direction of travel. The second is to direct the traffic around a hazard utilizing the side of the road opposite the affected motorists' direction of travel. The third is to completely close off the area to traffic at the nearest junction and reroute the traffic. These control strategies were the basis for the design of the message on the EZS.

Message Content

When the actual sign messages were developed, several things were kept in mind. One was that symbolic messages appear to offer several advantages over word messages, and the current preference by the National Committee on Uniform Traffic Control Devices and FHWA is symbolic signing. Another is that emergency personnel cannot keep an entire sign shop in the trunks or equipment bays of their vehicles; therefore, a limited number of designs with a wide variety of uses would be desirable. Last, it would be advantageous to use conceptual elements already in use on other TCDs in order to facilitate comprehension and learning of the new signs.

The candidate signs were designed by a team of traffic engineers, human factors specialists, and graphic artists.

The first series of signs, designed to execute the first control strategy, moving the traffic around a hazard using the same side of the road, was designated the E1 series (Figure 1). The

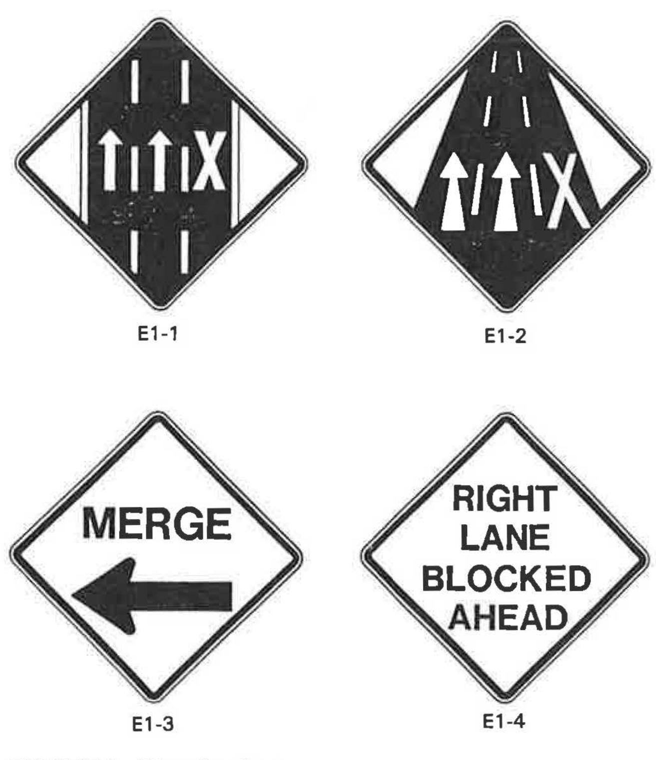


FIGURE 1 E1 series signs.

design incorporates the use of arrows for allowed through movements and X's for closed lanes, following the conventions for many existing signs and lane-use control signals. The signs would be fabricated so the arrows and X's could be moved from lane to lane to provide applicability for all situations. The perspective view used for Sign E1-2 is a variation based on experimental issues raised by Pietrucha and Knoblauch (*13*) in their study of sign comprehension. Signs using only word messages were also tested. These signs were designed to allow the MERGE arrow to point right or left or to have Sign E1-4 read RIGHT/LEFT LANE BLOCKED AHEAD.

The second series of signs, designated the E2 series, would be used to direct moving traffic around a hazard using the opposing flow lanes, the second control strategy (Figure 2). The designs again use the familiar arrows, X's, and merging elements of other TCDs. The signs could be modified to depict any situation. Within this series there are two types of signs. One shows the road condition to a driver who is approaching the hazard and would have to cross over to a contraflow lane (E2-1, 3, 7, and 9). The other type shows the road condition and would restrict the driver approaching the contraflow situation to a certain lane or lanes (E2-2, 4, and 6).

The third series of signs, designated the E3 series, is to be used for roadway closures. The signs use a variety of symbols—some familiar, some new to communicate the meaning of "no entry" (Figure 3). These symbols may be supplemented by a word message as part of a hybrid word-symbol sign (E3-1a).

Laboratory Procedures

The EZS went through a two-phase laboratory test. The first phase of testing was a screening procedure to winnow down the large number of EZS candidates. The second phase was a device-selection procedure to designate the specific device messages.

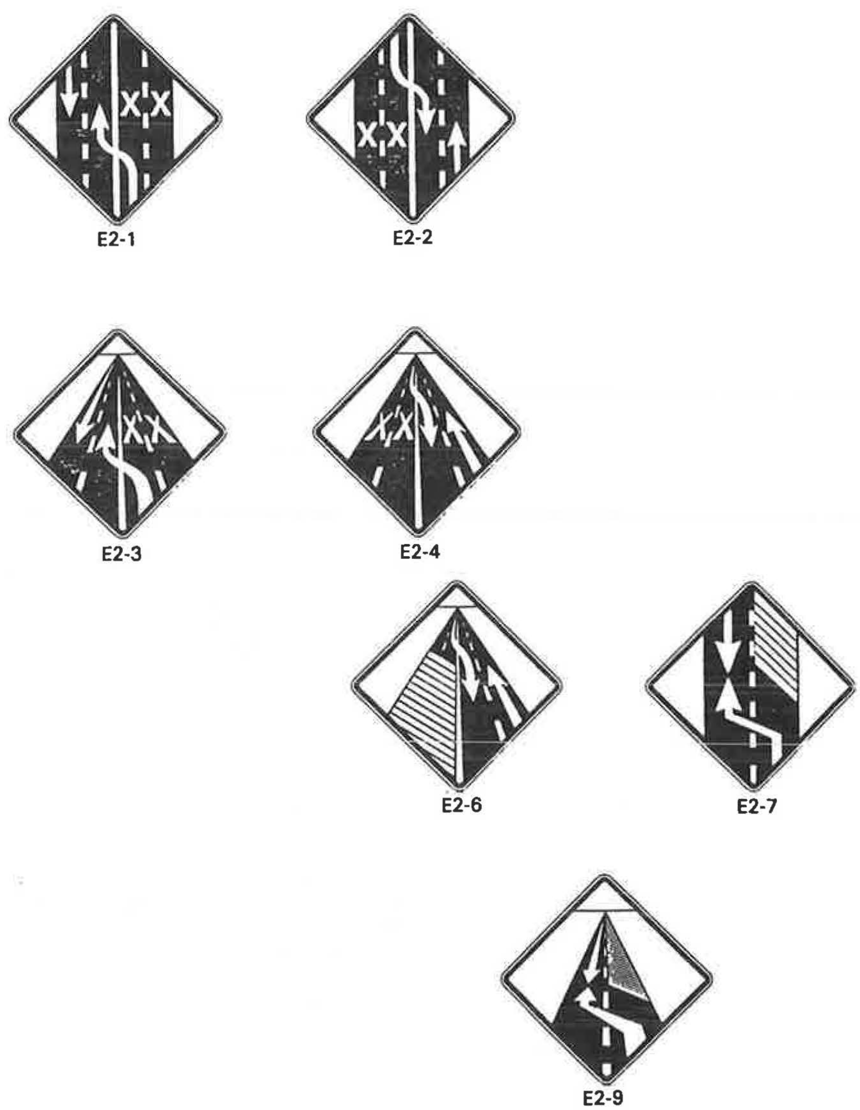


FIGURE 2 E2 series signs.

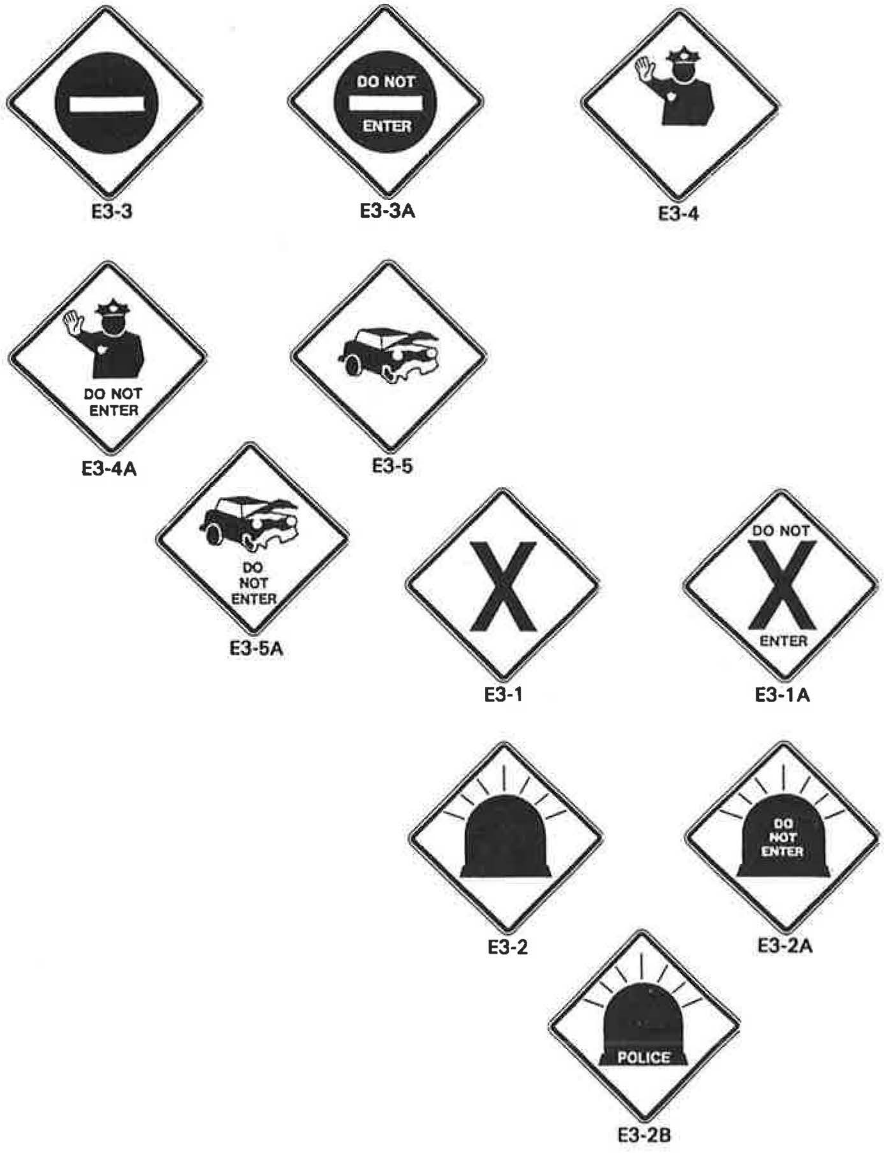


FIGURE 3 E3 series signs.

The primary measure of effectiveness (MOE) was made by administering paper-and-pencil tests to determine the accuracy of the subjects' interpretation of each design. This was done by presenting a stimulus (a picture of a traffic sign) and asking the simple open-ended question "What do you think this sign means?" (Figure 4).

Test booklets containing the EZSs and other traffic signs were prepared. Each page included a picture of the sign and the question "What do you think this sign means?" The subjects were given as much time as they needed to complete the test booklet.

Screening Procedure

Test Subjects The subjects were selected from among individuals who were renewing their driver's license at a local office of the Department of Motor Vehicles (DMV). Test subjects were selected from an urban area (Baltimore, Maryland), a densely populated suburban area (Arlington, Virginia), a less densely populated suburban area (Fairfax, Virginia), and a rural area (Warrenton, Virginia). There were three age categories (<30, 30 to 50, and >50) for both sexes. A target cell total of 10 subjects was set. By testing 10 subjects in each age and sex category from each of the four geographic areas, a total of 240 subjects was tested. This guaranteed that each sign would be interpreted by at least 30 subjects.

Results A numerical coding scheme was created so that the subjects' answers could be tabulated and analyzed. The coding scheme attempted to preserve the essence of the original responses while giving the flexibility to cluster the data in several different categories and not lose the ability to expand and contract the data into new tabulations.

A two-part code was assigned to each response. The first part assigned the response to a general answer category. The second part identified individual responses within each cat-

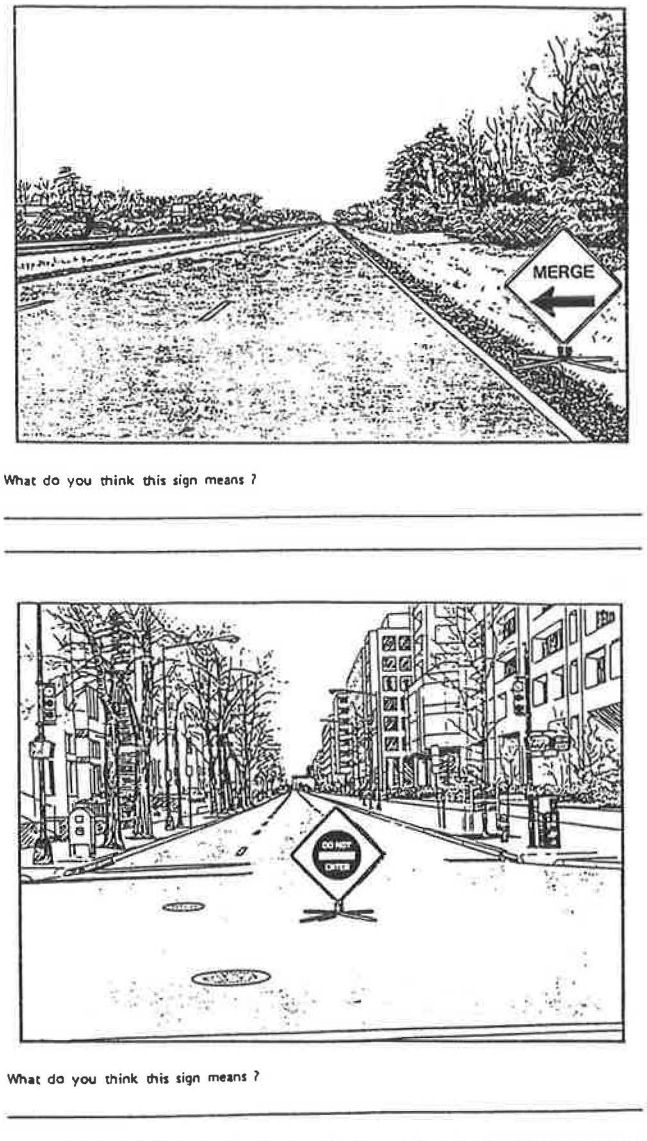


FIGURE 4 Sign presentation in test booklet.

egory. Every distinct response was given its own code, and all similar replies were assigned the same code. The subject response code is as follows:

Code	*Category*
RIGHT	
0X	Correct
1X	Nearly correct
WRONG	
2X	Conceptually close
3X	Incorrect
4X	Bizarre
5X	Dangerously incorrect
6X	Confused with existing sign
7X	Overflow from other categories
8X	Overflow from other categories
9X	Unknown
00	No response/Don't know

In an attempt to facilitate decision making, a superhierarchy was established for the categories. Any answer considered correct or nearly correct was grouped into a "right" supercategory and all other responses (e.g., incorrect, bizarre, unknown) formed the "wrong" supercategory. Although the categories were useful for noting trends in responses and breaking ties among promising sign candidates, the decision to use a sign was based on how many people (expressed as a percentage) could give a functionally correct (right) interpretation of the sign. A chi-square test of independence was used to determine if there was a relationship between the sign candidates and the subject responses.

It was originally intended to use only one test procedure. When conducting the (screening) test and analyzing the results, researchers identified problems with the test method and analysis procedures. These identified problems were used to redesign the test and to modify the method of analysis.

The written responses from the screening procedure yielded answers that could have been interpreted in many ways. After the tests were completed, the subjects were no longer available to explain any ambiguous answers, so it was decided that the laboratory procedure would be repeated. In the new (selection) procedure, after the subjects filled out the test booklets, they were debriefed about their replies. Nondirective questions to clarify vague responses or to elicit additional information provided more information for analysis.

The screening procedure resulted in the elimination of several of the original EZS designs. Signs E1-1 and E1-2 were the only signs from the E1 series tested in the screening phase. It was thought that the word message signs (E1-3 and E1-4) would be fairly well understood, so they were defaulted to the selection procedure. A statistical analysis of the results showed the relationship between the signs and the subject responses to be significant at the 0.05 level. Although Sign E1-2 was interpreted correctly more often by the subjects (94 percent correct), it was decided to use Sign E1-1 (78 percent correct) for further testing because of the problems caused by perspective view signs in another sign comprehension study (*13*). In the previous study, there was no consistency in the performance of perspective view signs. For some types of sign, a perspective view version of the standard sign was very convincing; however, for other types perspective view versions performed poorly. Rather than introduce perspective view signing as part of a new sign category, it was decided to continue with standard plan view representations.

The large black area on Sign E1-1 also caused some concern about potential visibility problems, so a negative version of this sign was designed for subsequent testing along with Signs E1-3 and E1-4.

In the E2 series, the "crossover" signs, there were two subcategories, the four-lane crossover and the two-lane crossover. The two-lane crossover is a situation similar to that of a one-lane road. The pictographs for Signs E2-7 and E2-9 were tested as part of a set of One Lane Road Sign (W20-4) candidates in the previously referenced study by Pietrucha and Knoblauch (*13*). The results of the four-lane crossover signs, which were not statistically significant, were as follows:

Sign No.	*Percent Correct*
E2-1	71
E2-2	58
E2-3	74
E2-4	71
E2-6	69

Since perspective has been shown to cause cognitive problems, Signs E2-3, E2-4, and E2-6 were eliminated from further testing. The potential visibility problems caused by the large black areas on Signs E2-1 and E2-2 necessitated a change to a negative version for these signs.

The E3 series of signs consisted of symbols only and hybrid word-symbol signs. It was decided to test only the symbol signs, since it was believed that the hybrid signs would be more easily understood and the real interest was to see what responses the different symbols would elicit. The results for this group, which were statistically significant, were as follows:

Sign No.	*Percent Correct*
E3-1	14
E3-2	0
E3-3	22
E3-4	51
E3-5	42

Although the "wrecked car" (E3-5) was the second most often correctly identified sign, it was decided to eliminate it from further testing because the E3 series signs are envisioned as being used at all types of street closures (e.g., fires, crime scenes) rather than just for motor vehicle accidents. The police and fire dome light performed poorly and was eliminated from further testing. The remaining signs (E3-1, E3-3, and E3-4) were retained for testing in the next phase together with their hybrid counterparts (E3-1a, E3-3a, and E3-4a).

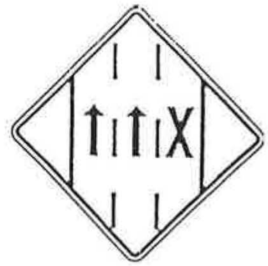
Selection Procedure

Test Subjects Subjects were selected from the age and sex categories previously described. Again, drivers from DMV offices were used. Results of the screening procedure showed that there was no significant variation among the test results at the four testing locations. Therefore, it was decided to test at only one location for this procedure. The Fairfax, Virginia, location was used. To ensure that at least 30 subjects saw each sign, a minimum of 240 subjects had to be tested.

Results The same coding scheme used to tabulate the data from the first procedure was used to analyze the results of the second procedure. Information gathered from the debriefings was used to clarify subjects' written responses. This allowed the subjects' individual responses to be assigned to specific response codes with greater confidence than was the case in the first procedure. Upon probing subjects about some answers that were considered "incorrect" in the first procedure analysis, it was found that these subjects had a functionally correct interpretation of the sign but failed to express it in writing. Therefore, many of the answers previously considered incorrect were counted as correct answers.

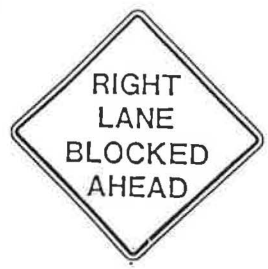
The selection procedure results were used to choose the signs to be recommended for use as actual EZSs. The reformatted signs, which were tested in the selection procedure, are shown in Figures 5, 6, and 7.

For the E-1 series the results were significant at the 0.05 level. Sign E1-4 was correctly identified by all of the test subjects (100 percent correct). Signs E-1 and E-3 performed about the same, scoring 77 percent and 73 percent, respectively. Sign E1-3 caused a problem for some of the test sub-



E1-1

E1-3



E1-4

FIGURE 5 E1 series signs: selection procedure.

E2-1

E2-2

FIGURE 6 E2 series signs: selection procedure.

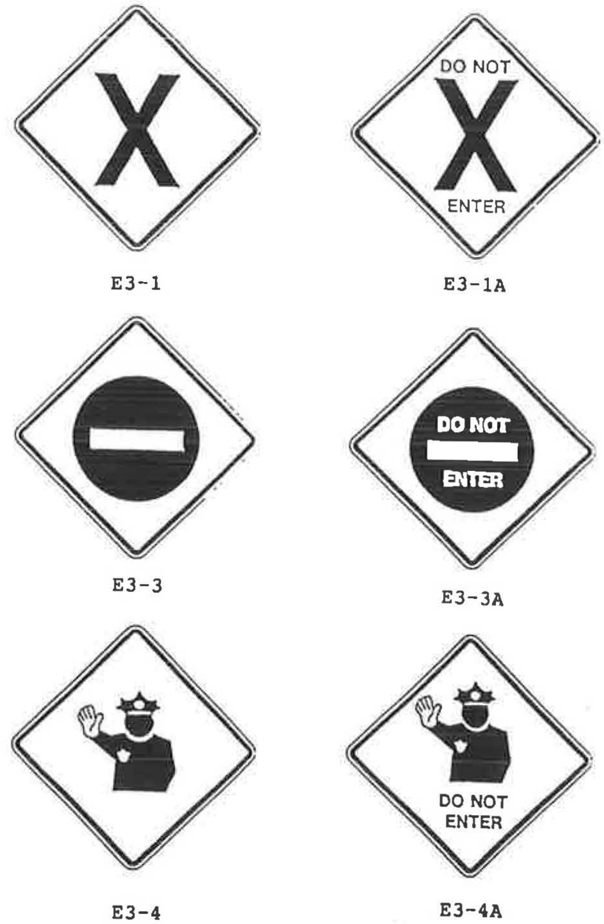


FIGURE 7 E3 series signs: selection procedure.

jects. The message to "merge" was clear, but many subjects did not know how many lanes were closed. That type of confusion did not occur with Signs E1-1 or E1-4. Sign E1-3 does not have the flexibility to warn of a center-lane closure as Signs E1-1 and E1-4 do: the X on Sign E1-1 can be moved from lane to lane to show the closure, and the word RIGHT on Sign E1-4 can be changed to CENTER or LEFT. Detachable arrows, X's, and words would make the use of either of these signs very flexible.

As mentioned previously, the E-2 series of signs, the two-lane crossover subcategory, was tested as part of the One Lane Road Sign (W20-4) candidates in a separate study by Pietrucha and Knoblauch (*13*). The four-lane crossover signs were actually two different signs. One (E2-1) shows the traffic pattern for the driver who is crossing over the centerline, and the other (E2-2) shows the conditions for the driver who is sharing the first driver's side of the road. Sign E2-1 was correctly understood by 94 percent of the subjects, whereas Sign E2-2 was understood by 63 percent of the test group. There seems to be no explanation for the fact that although the signs were similar in concept, there was such a wide disparity in their interpretation.

In the E-3 sign series, all of the hybrid signs (symbol and word messages) performed very well. All three signs were understood by over 96 percent of the test subjects. The symbol-only signs did not perform quite as well. Sign E3-1 was correctly understood by 79 percent of the test group, Sign E3-3 by 77 percent, and Sign E3-4 by 64 percent; however, Sign E3-4 was often misunderstood as involving traffic control by a police officer. The results were considered statistically significant.

Sign Shape and Color

As part of this research project, a specific shape and color for the EZS was considered. On the basis of past research, there were some doubts about motorists' understanding of the shape and color code currently in use (*12*). Since no work has been done to check or update the results of the testing done by Ferguson and Cook (*11*), it was decided to do some limited testing on sign color and shape by repeating their 1967 test to verify their results.

In the Ferguson and Cook technique, blocks of color or a colorless outline of a traffic sign was presented. The test subjects were asked to write down the message or type of information they would expect to see on a sign of the given color or shape. The test subjects were drivers from Virginia DMV offices, high school students, employees of industrial concerns, and members of civic and service organizations. Included in the sample were drivers who had stopped at rest areas along Virginia Interstate highways. There was no apparent effort to control the sample for age or sex. The results showed that, overall, only a few colors and shapes were very well recognized by the population sample.

The testing done as part of this project was an attempt to update the Ferguson and Cook findings, as well as to test other shapes and colors not tested as part of the 1967 study, to determine the comprehension levels associated with these shapes and colors.

In a technique similar to that used by Ferguson and Cook, a group of upper-level engineering undergraduate students at the University of Maryland formed the test sample. Since the Ferguson and Cook results showed relatively low recognition, it was thought that the interpretations of a well-educated, system-oriented audience might yield higher results. Surprisingly, the results were essentially the same. Since the number of subjects tested by Ferguson and Cook was so large, their data were assumed to be the population data or the expected results. The data from the University of Maryland tests were considered the sample or the observed results. A Z-test of statistical significance was performed between the observed and expected results. The Z-test results were considered significant at the 0.05 level.

Table 1 shows the results of the shape test. For the sign shapes tested in both procedures, there are no differences between the results. The octagon was correctly identified most often (89 percent correct). The regulatory rectangle (long axis vertical), the guide rectangle (long axis horizontal), and the pentagon were not tested in the Ferguson and Cook study. In the University of Maryland results, the pentagon was the only shape to have a less than 70 percent recognition level (38 percent correct).

Table 2 shows the results of the color testing. In most cases in which there were comparative data, the results again did not differ significantly. The only exceptions to this were for blue and green. Although orange was tested in the Ferguson and Cook study, it was not considered appropriate to compare

TABLE 1 Subjects Correctly Identifying Sign Shape

Shape	Percent Correct Ferguson and Cook (n = 1163)	University of Maryland (n = 37)	Difference Statistically Significant?
Diamond	71	70	No
Rectangle (long axis horizontal)	n/t	73	—
Octagon	89	89	No
Pentagon	n/t	38	—
Triangle	85	84	No
Rectangle (long axis vertical)	n/t	73	—

NOTE: n/t = not tested.

their results with the University of Maryland results because in 1967 orange was not the standard construction and maintenance colorit was used to denote school areas. In the University of Maryland results, the strong yellow-green (SYG) was the only color currently reserved by the MUTCD that was tested. In the past, it had been proposed to use SYG as the background color for the EZS and to remove it from its "reserved" status. Therefore, "correct" results for this color were those that included references to emergency vehicles (8 percent of the responses), general warning (5 percent of the responses), and special route information (3 percent of the responses).

CONCLUSIONS AND RECOMMENDATIONS

It would appear that an EZS would be a useful TCD for emergency situations. The laboratory procedures show that Signs E1-1, E1-4, and Signs 3-1 and 3-3 and their hybrid counterparts have the greatest potential for near-term use on the basis of the levels of understanding associated with these signs. However, before any field deployment under actual operating conditions is contemplated, it is recommended that these signs undergo further testing regarding visibility under closed field conditions.

All of the testing procedures showed that the shape and color coding scheme is not well understood. Of all the concepts tested, the only strong relationships appear to be between the "stop" concept and the use of an octagon and red. Strong recognition also occurred when the customary shapes and colors used for guide signs and motorist services were tested. Some other relationships exist, but they are much weaker.

TABLE 2 Subjects Correctly Identifying Sign Color

Color	Percent Correct Ferguson and Cook (n = 1163)	University of Maryland (n = 37)	Difference Statistically Significant?
Red	85	84	No
Orange	n/a	32	—
Yellow	86	76	No
White	48	54	No
Blue	26	54	Yes
Brown	n/t	51	—
Strong yellow-green	n/t	16	—
Green	24	49	Yes

NOTE: n/a = not applicable. n/t/ = not tested.

The question to be answered is "What would be the best shape and color for the EZS?" Since there are no reserved sign shapes and there does not appear to be any strong relationship between the emergency concept and any sign shape, it is recommended that a diamond shape be used for drivers who understand the shape codethe diamond indicates a hazard warning.

It was also important to determine the significance of the recognition and visibility of various colors. It is well known that the reserved SYG color is the best color at night, whereas yellow has the best daytime visibility. Since SYG is currently reserved, it should come as no surprise that the test subjects did not associate it with any traffic sign use.

This is not to say that individuals cannot learn to recognize SYG as representing an emergency situation to a degree, just as they moderately recognize other colors, excluding red. The conclusion is that there appears to be no cognitive reason for using or not using SYG as the EZS color. It is recommended that if a more appropriate use of SYG cannot be found, then on the basis of its superior visibility characteristics, it should be considered for use as the EZS color.

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