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16. Abstract

The purpose of this project was to identify, from existing research on warning, regulatory, and symbol signs, where deficiencies in motorists' understanding may pose safety or operational problems and to define acceptable levels of motorists' comprehension. The study developed alternative designs to remedy the identified deficiencies. These proposed alternatives were laboratory tested, and final sign designs were evaluated in a simulated highway environment. The results of the simulator evaluation were verified in closed field tests.

This volume, the first of three, is an executive summary. The second volume is a technical report which documents all the work conducted under this project. The third volume is the appendices to the technical report.

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NOTICE

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INTRODUCTION AND BACKGROUND

Signs used to regulate, warn, and guide traffic have long been one of the standard means of communicating to the driver. However there is evidence that the system of regulatory, warning, and symbol signs currently in use is not well understood by the motoring public. Although there is a wide variation of opinion about the magnitude and severity of this problem, a detailed study of motorists' comprehension of regulatory, warning, and symbol signs is warranted. This report presents the results of that study, which set forth new sign design guidelines and comprehension criteria, and recommends specific changes to the Manual on Uniform Traffic Control Devices (MUTCD).

The purpose of this project is to identify, from existing research on warning, regulatory, and symbol signs, where deficiencies in motorists' understanding may pose safety or operational problems and to define acceptable levels of motorists' comprehension. The study developed alternative designs to remedy the identified deficiencies. These alternatives were laboratory tested, and the final sign designs were tested in a simulated highway environment. The results of the simulator testing were verified in closed field tests.

To achieve the project goals, the following objectives were identified:

- Identify existing regulatory, warning, and symbol signs which may have comprehension problems for motorists.
- Develop criteria for determining acceptable motorist comprehension levels of these signs.
- Develop remedies for those signs identified as poor performers.

- Evaluate the proposed remedies in laboratory and simulator tests.
- Field verify the final designs in closed field tests.
- Recommend new or modified design specifications for replacement signs.

The work done to accomplish the objectives is documented in three volumes. Volume I is an executive summary of the entire project. Volume II is a technical research report which details specific elements of the work done for this project. Volume III contains the supporting appendices.

STATE-OF-THE-ART REVIEW

This study included a comprehensive review of the research literature, as well as other sources of information about the motorist sign comprehension problem. Knowledgeable transportation professionals were contacted to obtain information about this problem. A review of tort liability cases involving highway signing was conducted to see if problem signing showed up in the court records. These activities established an information base which could be used to identify signs with comprehension deficiencies.

The literature search gathered information regarding sign/symbol recognition, understanding, comprehension, and evaluation procedures. The search covered foreign and domestic sources, and included unpublished materials. Over 150 reports, papers, and articles were retrieved, reviewed, and abstracted. The abstracts highlighted the specific signs studied, the methodology used, and the specific results found about comprehension.

Besides identifying research methods and information about comprehension, the literature search attempted to indicate which signs have a comprehension problem. A Problem Sign Identification Form (PSIF) was developed to summarize and incorporate the data derived from the three information sources: literature, experts, and tort liability review. The information on comprehension problems cited in the literature is included on the PSIF, which can be found in volume III, appendix A.

Highhway engineering, safety, and driver education professionals were also contacted to obtain information regarding motorists' sign comprehension problems. The sources contacted represented a cross-section of Federal, State, and local government employees; members of professional organizations and

advisory groups; university and secondary school educators; and private consultants. An effort was made to contact people in different size states in all regions of the country, as well. The responses of each source were recorded on a contact log sheet. The information from the contact logs was summarized by sign and entered on the PSIF.

The tort liability review was an extensive search of all the reported judicial decisions in the United States since 1978 that dealt with highway signing. These cases were examined in detail to determine if sign design or placement in any way contributed to, or was the proximate cause of, the resulting motor vehicle accident. The results of this review are described on the PSIF.

IDENTIFICATION OF PROBLEM SIGNS AND DEVELOPMENT OF COMPREHENSION CRITERIA

All signs included on the Problem Sign Identification Form (PSIF) were initially considered to be possible problem signs. After a review of the PSIF, it was found that many signs were identified by only one information source; shown to have a placement problem primarily; or were word message versions of already identified symbol signs. Because this was considered insufficient reason for their inclusion as actual problem signs these signs were eliminated from further consideration. Each of the remaining signs was evaluated in terms of three factors: consequence of miscomprehension, type of miscomprehension, and degree of miscomprehension.

Consequence of miscomprehension considers the worst case of motorist response when the sign is misunderstood, e.g., the motorist misinterpreting a keep right sign could enter a lane of oncoming traffic and be involved in a head-on collision. Type of miscomprehension assesses the degree to which the sign is misinterpreted, e.g., the advance school crossing sign is interpreted as the school crossing sign. Degree of miscomprehension uses information from sign comprehension studies to determine the magnitude of the misinterpretation problem, e.g., only 7 percent of the drivers tested could correctly identify the added lane sign (Hulbert & Fowler, 1980).

A rating scheme was developed to assess the combined effects of these factors and produce a list of signs with the highest problem severity ratings. This list is shown in table 1. This group of 30 signs became the final choice for redesign.

Table 1. The 30 problem signs selected for redesign.

W6-2	End Divided Highway Sign
R3-9a	Two Way Left Turn Only Sign
R4-7	Keep Right Symbol Sign
W1-2	Curve Sign
W1-5	Winding Road Sign
W2-1	Cross Road Sign
W3-1a	Stop Ahead Sign
W4-1	Merge Sign
W5-2a	Narrow Bridge Symbol Sign
W8-4a	Low Shoulder Sign
W8-4b	Uneven Pavement Sign
W8-5	Slippery When Wet Sign
W20-7a	Advance Flagger Symbol Sign
W21-1a	Worker Symbol Sign
S1-1	School Advance Sign
S2-1	School Crossing Sign
S3-1	School Bus Stop Ahead Sign
W1-1	Turn Sign
W1-3	Reverse Turn Sign
W1-4	Reverse Curve Sign
W3-2a	Yield Ahead Sign
W4-2	Lane Reduction Transition Sign
W4-3	Added Lane Sign
W7-1	Hill Sign
W8-3a	Pavement Ends Symbol Sign
W8-4	Soft Shoulder Sign
W11-2	Advance Pedestrian Crossing Sign
W11A-2	Pedestrian Crossing Sign
W12-2	Low Clearance Sign
W20-4	Advance One Lane Road Sign

Since there are many test techniques used to evaluate traffic signs and many of the articles reviewed contain the word "comprehension," it became clear that comprehension means different things to people. Many of the tests measure similar characteristics of the sign or of the drivers' response to sign stimuli, but they go under different names. These tests include:

- Conspicuity/Detection/Target Value
- Day/Night Legibility
- Glance Legibility/Duration of Exposure/Reaction Time/ Meaning Latency
- Understandability/Accuracy/Comprehension
- Certainty of Meaning
- Learnability/Ability to Remember
- Action Response
- Preference

Many arguments have been advanced as to the validity and importance of each of these techniques. They are all valid to a degree, but their relative importance to the initial design process varies. It can be argued that only two of these measures are of real importance in the initial design process. These would be conspicuity and understandability. Conspicuity is a measure of how well the sign "stands out" from its background or how often it is noticed. Understandability is a measure of how well the meaning or intent of the sign is communicated. Conspicuity can be improved by varying the contrast between the sign legend and sign background or the sign background and visual environment, but meaning and the understanding of a concept are areas where variance of strict physical parameters are not likely to improve performance. Therefore, comprehension as defined in this study is cognitive understanding of a concept represented by a sign.

The search of the literature found that there is very little in the way of actual comprehension criteria levels. The only published standards are those of the Standards Association of Australia (85%) and the International Standards Organization (66%), but both have been criticized as being arbitrary with no empirical data to back up the criteria (Johnson, 1980). Comprehension criteria levels should specify how many people know what a sign means before it can be considered safe enough to be put on the street.

A performance criteria of 100 percent is unrealistic. A performance level of 100 percent is not a frequent occurrence. In previous studies none of the traffic control devices tested had understanding levels of 100 percent. In the Bolt, Beranek, and Newman study (Jones, 1972) there seemed to be expected levels of error for any sign tested. On the other hand, extremely low levels of performance cannot be tolerated. In the Hulbert and Fowler study (1980), the Added Lane Sign (W4-3) was understood by only 7 percent of the subjects tested. This means that this sign has negligible safety benefits since it is understood by so few motorists. Until a minimum percentage value is established by further research, it may be prudent to have a policy of using the Standards Association of Australia or International Standards Organization values.

PROBLEM SIGN REDESIGN

When the final group of problem signs was identified, work began on generating redesigned signs. The designs addressed specific problems associated with each sign; such as aiding the motorist in establishing directional reference, as with the Divided Highway Sign (W6-2), or establishing a concept which may be totally foreign to the driver, such as flagging as a traffic control (Advance Flagger Sign, W20-7a).

Keeping these types of specific problems in mind, the staff of BTI and its subcontractor, the Texas Transportation Institute (TTI) at Texas A&M University, generated new candidates for each problem sign. Any candidate which conveyed the meaning of a sign was considered acceptable in this first phase. This initial step generated a wide variety of new sign candidates.

After this first group of sign remedies was completed, several "brainstorming" sessions were held to see how well the new signs addressed the problems associated with the old signs.

The next step in the process was a final discussion among the principal designers from BTI and TTI regarding the new sign ideas and the common design concepts. The discussion session was structured so that the first part was devoted to general design principles and concepts and the last part to a discussion of specific signs. These discussions were used to generate a revised set of 163 sign candidates that were the subject of the laboratory and simulator testing that followed.

RESEARCH DESIGN, METHODOLOGY, AND EXPERIMENTAL RESULTS

This study employed laboratory, simulator, and field test procedures to evaluate the sign redesign alternatives that were developed. The purpose of the laboratory evaluations was to select the most promising alternatives for simulator testing and field verification. The simulator was used to test for potential problems in viewing the new designs in a dynamic environment. Closed field testing was used to verify the simulator results.

Because of the large number of candidates developed in the redesign phase, two separate laboratory procedures were conducted to select the most promising sign designs for simulator testing. The two laboratory studies involved a screening procedure and a selection procedure. The screening procedure eliminated those sign redesigns that were the least effective. The selection procedure identified the sign design that was the most promising. After each of the most promising design candidates was compared to its existing counterpart, final recommended changes to the MUTCD were made.

SCREENING PROCEDURE

Since the purpose of the first part of the laboratory study was to identify the least promising sign designs, the screening procedure looked for large differences in motorist comprehension. The hypothesis tested was that the driver comprehension level of some of the sign designs is lower than the level of the other signs. The measure of effectiveness was the accuracy of the subjects' meaning/comprehension response to each sign. Test booklets containing about 40 sign redesign options were prepared. Five sets of materials were needed to include all the sign redesigns and the existing signs. Each page included a picture of the sign and the question "What do you think this sign means?"

The role of stimulus context was examined during pilot testing. Two sets of pilot test materials were prepared. One set showed the sign stimuli in the context of a generic highway scene, the other had just the signs. A value of the mean number of correct answers was calculated for each subject group (those shown the signs in a highway context and those who were not). A t-test showed that there was not a significant difference between the means of the subject populations. However, since other research has shown that using a highway context format produces greater levels of comprehension (Wilson & Williams, 1984), it was decided to use the highway context format for testing.

The entire screening procedure was pilot tested at local DMV offices. A total of 240 subjects were tested at Department of Motor Vehicle (DMV) offices in urban, suburban, and rural areas. Subjects were stratified by age and sex.

The test booklets were graded using a numerical coding scheme that was created so that the subjects' responses could be tabulated and analyzed. The coding scheme preserved the gist of the original responses while giving the flexibility to cluster the data in several different categories without losing the ability to expand and contract it into new tabulations. The performance of each of the 163 sign redesigns of the 30 problem signs was analyzed. The results of the first laboratory screening process were used to eliminate the least promising redesigns. When this was done a total of 73 signs (43 redesigns and 30 standard signs) remained for further evaluation.

CANDIDATE SELECTION

The second laboratory procedure selected the best redesign candidate for simulator testing. The procedure was a test of

sign meaning with the emphasis placed on identifying potential sources of confusion between the various candidates for each sign, within sign families, and across all signs. In order to determine the level of detail needed to make this determination, a non-directive laboratory procedure was used.

Subjects were stratified by age/sex categories and, again, drivers from DMV stations were used. The 243 subjects were shown pictures of design candidates superimposed over pictures of an actual street/roadway setting and asked to tell the meaning of each sign. The test instrument was a booklet containing 17 signs. Again, five sets of booklets were needed to include all the signs chosen for testing in this phase.

Since many of the written responses from the screening procedure had meanings which could have been interpreted many ways (e.g., schoolbus - stops ahead or school - bus stops - ahead), it was decided that after the subjects filled out the test booklets they would be debriefed about their replies. Those conducting the debriefing attempted to gather as much additional information as possible with a non-direct approach before beginning any direct questioning.

The same numerical coding scheme used to tabulate the data from the screening procedure was used to analyze the results of the selection procedure. Information gathered from the debriefings was used to clarify subjects' written responses. This allowed the experimenters to assign specific responses to gist response codes with a greater degree of confidence than in the analysis of the screening procedure results. The debriefing also provided additional insight into problems dealing with communication by sign, and the assessment of the effectiveness of that communication which heretofore had not been identified.

The subject responses were analyzed to determine the most effective sign design candidate for each of the problem signs.

SIMULATOR TESTING

Since exhaustive cognitive testing was done in the screening and selection procedures, the FHWA driving simulator (HYSIM) was used to test the most successful (i.e., likely to replace the standard) sign redesign alternatives where information on legibility, conspicuity, and response time was unknown. The HYSIM was also used to examine the curve/turn problem and the ambiguity associated with advance/crossing versions of both pedestrian and school signs. The purpose of the simulator test was to verify that driver performance was not degraded by any of the new signs relative to current signs.

The HYSIM uses a visual scene consisting of computer-generated lines denoting edge and center lines, exit or entrance ramps, and intersections. The roadway configuration follows the distances, curvature, and number of lanes found in the real-world roadways simulated. The basic procedure was a comparison of the relative performance of the redesign candidate and the standard "problem" sign. A total of 33 subjects were tested. The goal was to identify the sign that had the best performance relative to the measures taken by the HYSIM:

- Recognition distance
- Vehicle Speed
- Response Accuracy

In general, there were few speed, recognition, or comprehension differences between the current and redesign signs. The fact that the new signs perform as well as the current standards is a very encouraging experimental result. Although

the screening and selection process had shown that many of the redesign candidates had significantly higher comprehension levels, they frequently did so through the use of increased detail or visual complexity. Apparently this increased detail does not interfere with the performance of these signs in the dynamic visual environment of the driving simulator.

FIELD VERIFICATION

The field verification test was used to verify the recognition distance data and subject responses gathered in the simulator testing. The verification was carried out under controlled field conditions.

Since the field test was undertaken without the use of an instrumented vehicle, the MOEs gathered in the HYSIM to examine the curve/turn and advance/crossing problems could not be verified in the field. Therefore, only the Yield Ahead, Stop Ahead, Slippery When Wet, Clearance, Narrow Bridge, and Lane Reduction Transition signs were field tested.

The field test involved measuring subject recognition distances in a static, simulated highway setting under daylight conditions. The subjects were situated in a passenger vehicle on a field test range. The 13 test signs were displayed on conventional sign posts per MUTCD specifications in terms of height and distance from the roadway. Each of the 34 subjects was shown the signs at static positions of 1,025, 825, 625, and 370 feet from the signs. A movable partition was lowered to allow the subjects to see each sign for five seconds. The subjects were asked to write down what they thought the sign meant.

At the conclusion of the in-vehicle testing each subject was asked to complete a test booklet. This booklet was similar to the ones used in the screening and selection procedures. The data analysis examined the percentage of subjects correctly identifying the test signs at each of the test distances as well as the responses indicated in the test booklets. In general, the standard signs and the redesigned signs performed similarly in the field (the single exception being the new Clearance sign which did poorly even at the closest test distance). Apparently the increased visual complexity of some of the sign redesigns does not adversely affect performance in open field testing.

GUIDELINES, CRITERIA, AND RECOMMENDATIONS

The last section of the report suggests guidelines to be followed in the design of new signs, discusses methods for assessing comprehension levels of new signs, and examines criteria for determining "acceptable" performance. Finally, specific recommendations for changes to the MUTCD and suggestions for further research are presented.

DESIGN GUIDELINES

The design of new signs and the redesign of existing signs should begin with input from several sources:

- Consideration of basic information design principles.
- Determination of the basic cognitive processes involved in the motorists' interpretation of highway signs.
- Identification of motorist comprehension problems associated with existing signs or with signs similar to the new design(s) being generated.

The value of testing and talking to the motoring public cannot be overstated. Signing must be designed to be seen and comprehended by typical motorists. Signs designed by transportation professionals or even professional designers will not be effective <u>unless</u> the characteristics of the user population are considered.

TEST PROCEDURES AND CRITERIA

Candidate sign designs must be developed for the motorist and the cognitive value of the signs must be determined by testing the driving population. Paper-and-pencil testing and in-person follow-up debriefings provide an invaluable tool for determining levels of comprehension associated with design

candidates <u>and</u> identifying ways to modify the candidates to improve motorists' comprehension. State motor vehicle administration offices were found to be a convenient place for testing a wide socio-economic spectrum of licensed drivers.

Although paper-and-pencil testing can identify promising sign designs, field testing should be used to test the most promising signs under conditions which simulate actual driving. The following field testing scenario is suggested. The test sign is placed per MUTCD specifications on a straight section of highway. Test subjects drive by the sign at a speed appropriate for the anticipated sign placement. When the subject has driven past the sign the experimenter asks the subject what the sign means. The experimenter records the subject's response and, if necessary, uses a series of debriefing questions to determine the subject's level of comprehension. This procedure simulates the conditions under which the driver would be gathering information from the sign, i.e., the driver can receive and process information until he is past the sign.

The determination of a required minimum level of comprehension for a new sign or a sign redesign was found to be very difficult. The exisiting minimum percentage criteria for comprehension of signs that were found in the literature do not appear to have any empirical basis. During the course of this project many signs consistently tested at comprehension levels of 90 percent and better. Other signs never did that well. In developing new signs or sign designs typically a number of candidates are identified. Therefore, it is suggested that the candidate that has the best <u>relative</u> performance in the field test be selected as the new sign.

RECOMMENDATIONS

This final section summarizes the recommendations regarding the specific problem signs examined in this project. In some cases the research served to pose more questions, in others additional work is suggested. In still other cases it is recommended that the current MUTCD sign be replaced with a candidate developed and tested in this study. In the discussion that follows, the signs are grouped into sign "families" with similar characteristics. The various signs discussed are keyed to the signs depicted in figure 1. The percentages shown indicate the percent of subjects correctly identifying the sign in the candidate selection phase of the laboratory testing.

The "Curve" Family of Signs (Test Signs 1-16). There was found to be a great deal of confusion in motorists' comprehension of curve and turn signs in terms of the severity of the turn, the direction of the turn, and the number of turns. Additional research is needed.

The "Crossing" Family of Signs (Test Signs 17-23 and 27-31). Motorists generally fail to comprehend the distinction between signs warning of an actual crossing ahead and those located at the actual crossing. Although many of the sign redesigns that were developed and tested were significantly better than the standard it appears that additional study is warranted.

School Bus Stop Ahead Sign (Test Signs 24-26). It is recommended that either Sign #25 or Sign #26 be included in the MUTCD as a symbolic alternative for the existing word sign.

Pavement Ends Sign (Test Signs 32-34). Although Sign #34 did outperform the standard by 10 percent, the results were not considered significant enough to warrant field testing and replacement of the standard.

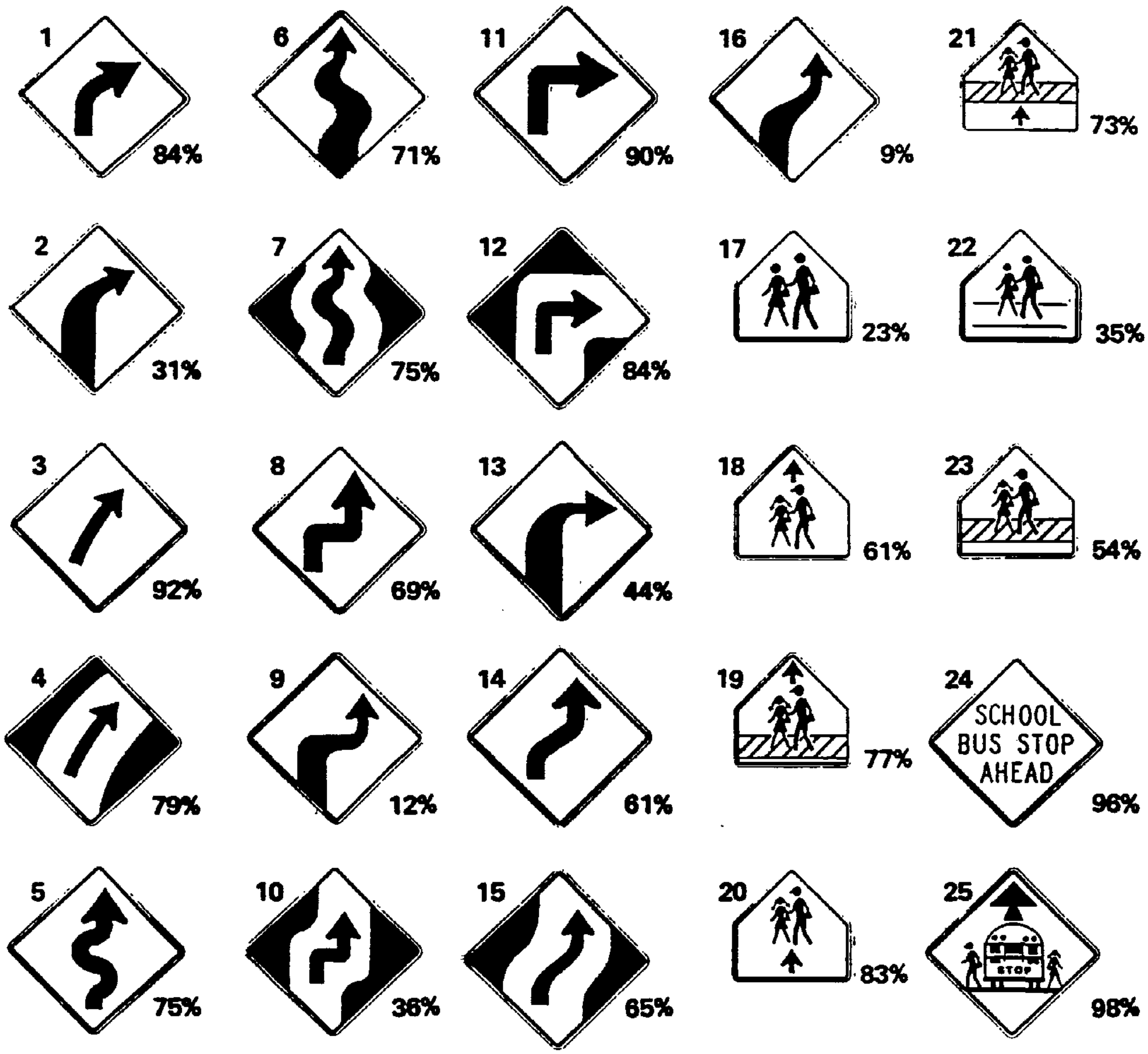

Figure 1. New sign design--step 3.

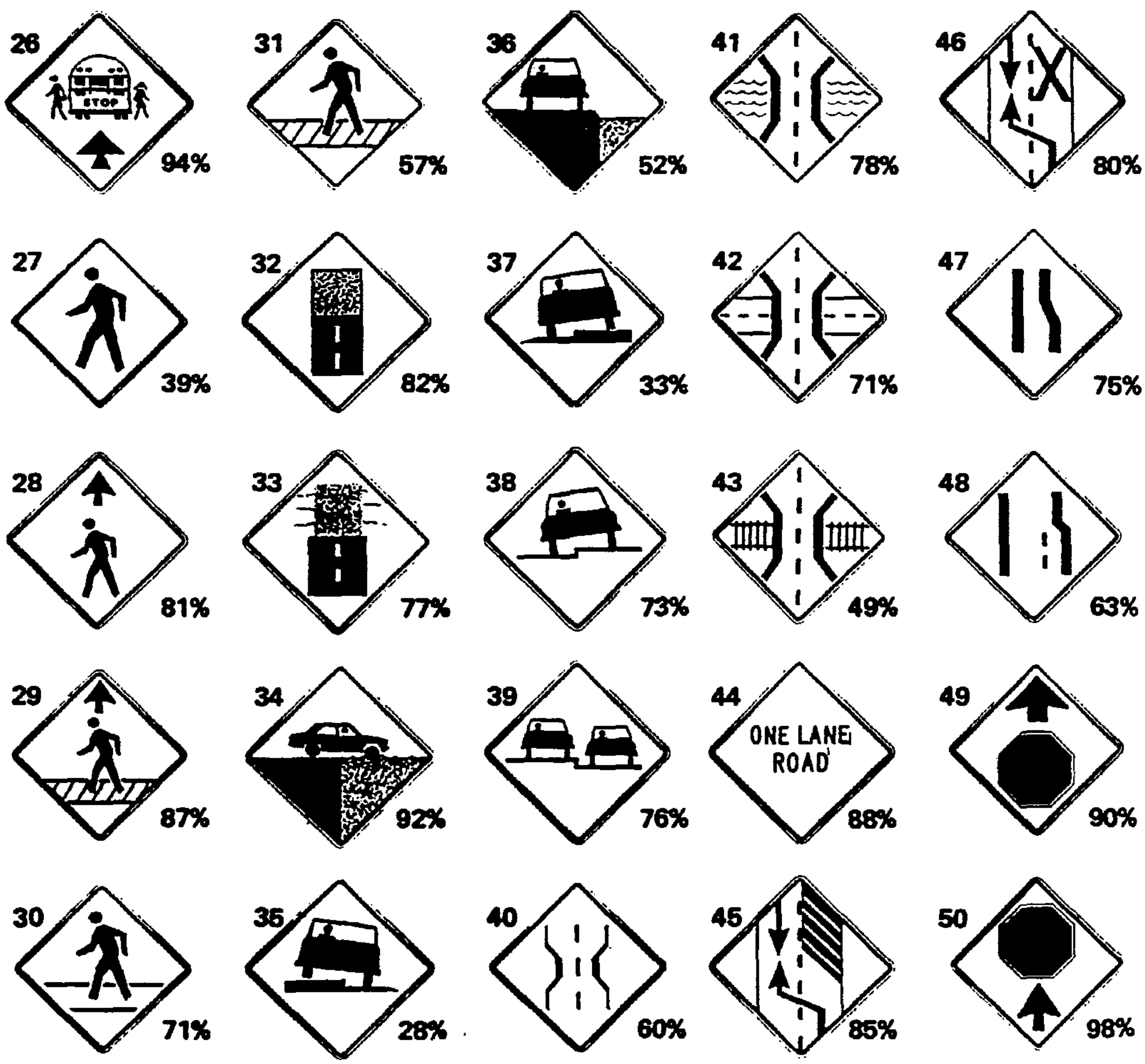

Figure 1. New sign design--step 3 (continued).

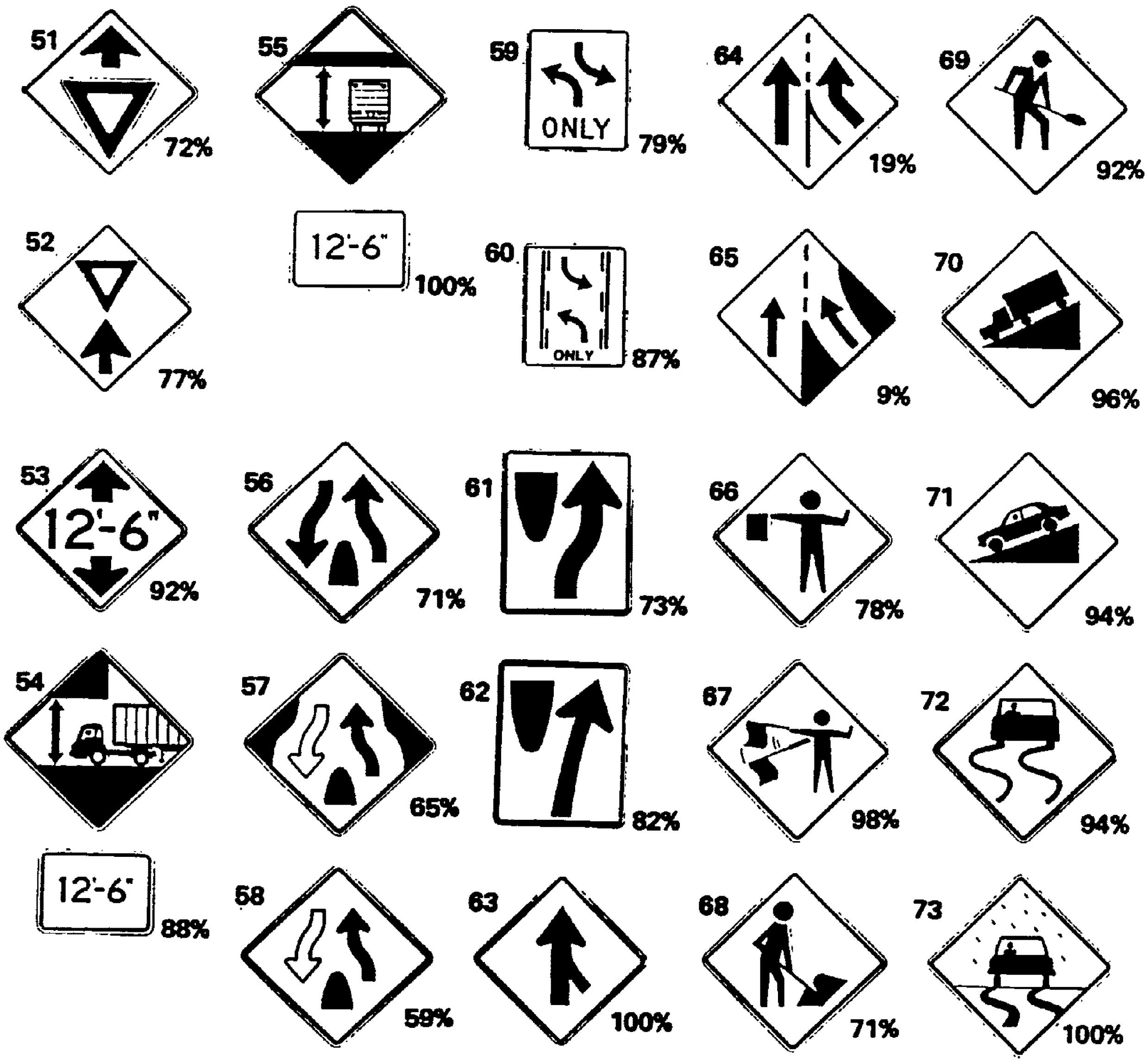

Figure 1. New sign design--step 3 (continued).

The "Low Shoulder/Uneven Pavement" Family of Signs (Test Signs 35-39). The problem associated with this family of signs is that they are often confused with each other. It is recommended that signs #36 and #39 be retained for further study and possible inclusion in the MUTCD.

Narrow Bridge Sign (Test Signs 40-43). It is recommended that Sign #41 be adopted as the symbol version of the narrow bridge sign in the MUTCD.

One Lane Road Ahead Sign (Test Signs 44-46). It is recommended that Sign #45 or Sign #46 undergo field testing for possible inclusion as the symbolic version of this sign in the MUTCD.

Lane Reduction Transition Sign (Test Signs 47-48). Although the standard did not perform badly, the amount and types of confusion associated with the standard suggest additional study.

"Stop Ahead/Yield Ahead" Family of Signs (Test Signs 49-52). It was anticipated that the "ahead" arrow may be interpreted as an indication of roadway alignment. Laboratory testing did not show this miscomprehension to be a significant problem. There is some question, however, whether the arrow should be placed at the top or bottom of the sign. This issue may merit further study.

Clearance Sign (Test Signs 53-55). Although laboratory testing indicated that the redesigns were superior to the standard, the simulator and field test results did not bear this out. It is recommended that the standard be retained although additional development of the more promising redesigns may be warranted.

End Divided Highway Sign (Test Signs 56-58). Although none of the candidate signs did as well as the standard, the standard performed poorly in both laboratory tests. A sign with such important safety implications should be understood by nearly all motorists. Therefore, it is recommended that additional work be done, either through sign design or driver education.

Two-Way Left Turn Only Sign (Test Signs 59-60). Although the new candidates outperformed the standard, apparently this is due to the subjects' lack of familiarity with the two-way, left turn concept. Thus, increased educational efforts about the concept, and not a change in the sign itself, will help this situation the most.

Keep Right Sign (Test Signs 61-62). This sign was most often confused with the end/begin divided highway sign. It is recommended that the standard sign be retained and that an examination of the educational needs of drivers regarding this sign be undertaken.

The "Merge/Added Lane" Family of Signs (Test Signs 63-65). There is no difference between these two types of signs in the minds of most motorists. Therefore, it is recommended that something be done to educate motorists in the two distinct concepts of merging and merging with an added lane, or the added lane sign should be dropped from the MUTCD.

The "Flagger/Worker" Family of Signs (Test Signs 66-69). It is recommended that the new signs be field tested and replace the existing signs in the MUTCD.

Hill Sign (Test Signs 70-71). The MUTCD makes no mention of the fact that this sign is intended only for large vehicles