Identification of Needed Traffic Control Device Research

PHILLIP S. SHAPIRO, JONATHAN E. UPCHURCH, JOHN LOEWEN, AND VIC SIAURUSAITIS

The 50-year evolutionary development of the current *Manual on Uniform Traffic Control Devices* (MUTCD) has resulted in many traffic control device standards that are based on subjective opinion. As vehicle design, the driver population, and society's demand for a safer highway system change, many of these traffic control device standards need reexamination. A research study was conducted to identify those MUTCD standards that (a) lack a research basis, or are in conflict with research findings; and (b) would likely benefit from research and scientific investigation. Nearly all MUTCD standards were evaluated. Identification of those MUTCD standards having the greatest need for additional research was achieved through (a) evaluation of selected MUTCD standards by the project team and a panel of traffic engineering practitioners, and (b) evaluation of relevant previous traffic control device research. Seventeen MUTCD standards were identified as having a significant need for additional research. Eight areas were recommended as having high priority for future traffic control device research. To provide a tool for future research and to serve as an aid to ongoing development of the MUTCD, a computerized data base management system was created. It includes documentation of previous traffic control device research as it relates to each standard within the MUTCD.

The *Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways (1)* provides the basic principles for the design and use of signs, signals, and pavement markings for all public roadways in the United States. The manual sets forth the warrants and standards as adopted by the Federal Highway Administration (FHWA). (It is understood by the authors that the MUTCD contains warrants, standards, description and guidance; however, throughout this paper all material in the MUTCD will be referred to as "standards.")

The requirements for the size, shape, and placement of various traffic control devices have been developed over the years. The American Association of State Highway and Transportation Officials (AASHTO) published a manual for uniform standards for rural highways in 1927. The National Conference on Street and Highway Safety published a manual for urban streets in 1929. FHWA and AASHTO formed a joint committee (NJC) and published the first MUTCD in 1935. Subsequent revisions to, or editions of, the MUTCD were published in 1939, 1942, 1948, 1954, 1961, 1971, and 1978.

As the MUTCD has evolved through the years, changes have often been made on a piecemeal basis. Some portions of the manual have changed very little since the earliest editions. Many of these older standards probably stem from subjective judgments made 40 or more years ago. Of those standards that have changed, some undoubtedly have an objective basis. In many cases, however, the basis for a change in the manual is obscure; documentation is lacking, and it is likely that many changes were made as the result of collective subjective opinion by the groups responsible for the continuing development of the manual.

The foregoing observations suggest that many of the basic elements or standards in today's MUTCD may not adequately serve the needs of the 1980s. Some of the basic standards that have been accepted as gospel may be deficient. For example, the 3.75-ft driver eye-height standard for marking no-passing zones was accepted for more than 20 years. Then, suddenly, the traffic engineering community realized that it was no longer adequate because of changes in vehicle design, and a value of 3.50 ft was adopted. Undoubtedly, other standards embedded in the manual are also obsolete. The basic objective of the research reported herein was to identify those standards so that needed traffic control device research can be programmed and conducted.

Identification of standards that may be obsolete is a difficult task because no single comprehensive source of historical and technical information exists to document the reason changes to the manual were made. To overcome this obstacle and to provide a comprehensive source of information for the MUTCD for future use, a comprehensive computerized filing system, which documents historical changes to the manual and relevant traffic control device research, was developed.

DEVELOPING RESEARCH NEEDS FOR MUTCD STANDARDS

The research review process combined a committee review, expert screening of standards, a computerized search of abstracts, establishment of research priorities, a library search for the high priority articles, an empirical evaluation of research reviewed, and a listing of standards by need for additional research. Figure 1 shows this process in more detail.

In the initial step of the MUTCD evaluation the basic standards included in the document were identified. "Basic standards" exclude very general statements that reflect a broad attitude but do not provide specific guidance. For instance, Sections II-A-8 and II-A-30 contain broad statements on sign standardization and maintenance that really cannot be construed as standards, but as a general philosophy of practice.

Therefore, the study team developed a list of basic standards

P. S. Shapiro, J. Loewen, and V. Siaurusaitis, COMSIS Corporation, 11501 Georgia Ave., Wheaton, Md. 20902. J. E. Upchurch, Department of Civil Engineering, Arizona State University, Tempe, Ariz. 85287.

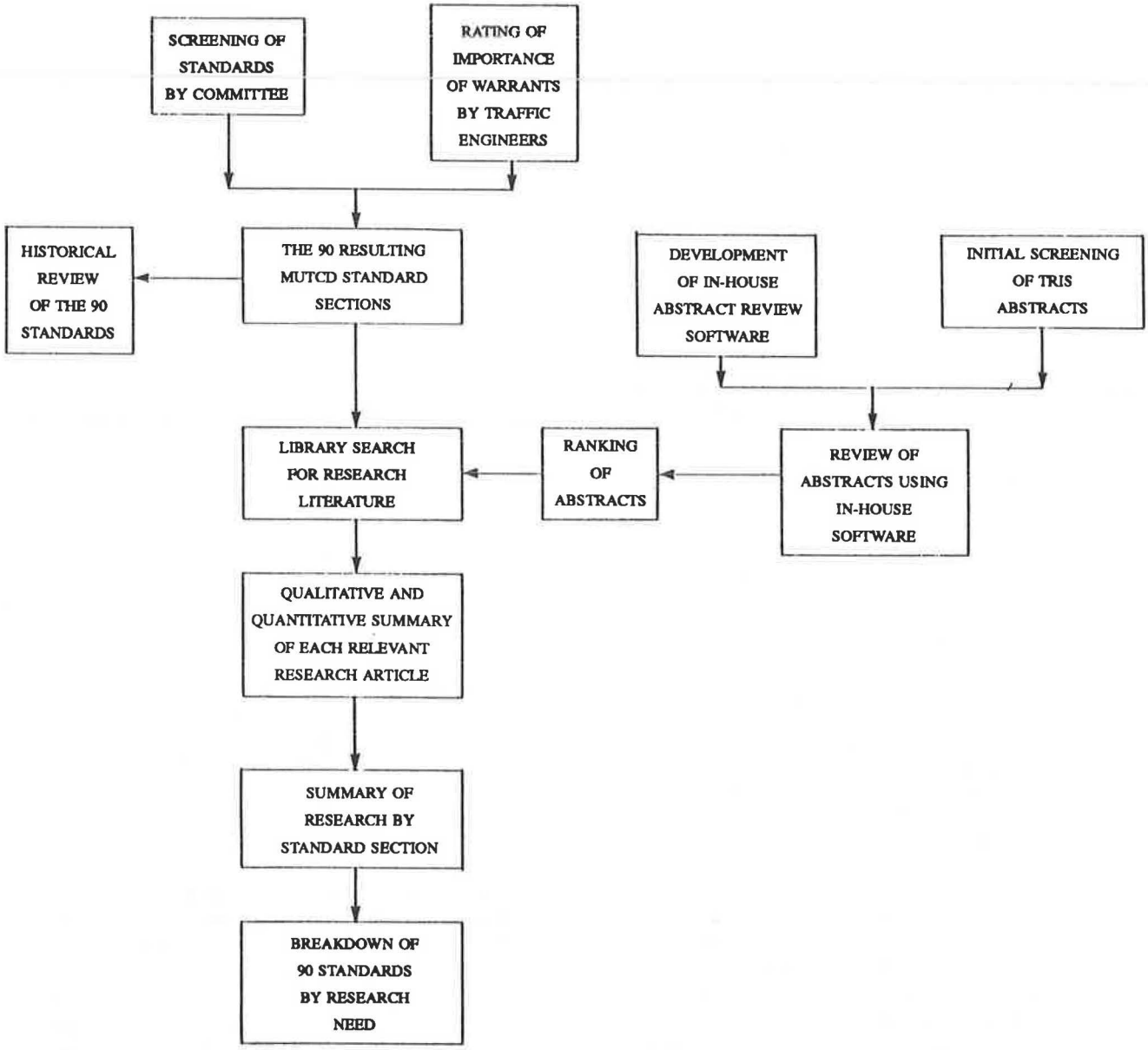

FIGURE 1 Research review process.

derived from review of the manual for each traffic control device, or set of devices. Standards for each device or set of devices were extracted from the manual, and for each device the warrants and standards were reported as follows:

- Physical attributes (size, shape, color, etc.);
- Message/meaning/legend (intended meaning, wording, or image content, lettering, etc.);
- Illumination/reflectorization;
- Warrants;
- Placement; and
- Other [depending on the type of devices, some other aspects may be important (e.g., mounting), or some standards may not readily fit one of the other categories].

The 1978 Manual section number and title was used as the key identifier with the substantive information from each standard placed under its respective heading. By "substantive" information, it is meant that only statements that were general, reflecting broad attitudes or general management approaches, were omitted. Thus the use of every device was fully specified by the list of warrants and standards in a uniform format without superfluous information.

Once the standards and warrants were reformatted as described previously, the research team screened them to determine the standards that would most likely need further research. This subjective screening process was based on the following three factors: importance of the device or standard, lack of a known research basis, and potential of finding research that describes the basis of a device or standard. As a result of this screening process, 517 standards and standard parts were identified as warranting further consideration. These were then compiled into a manual that was distributed to a nine-member panel of traffic engineers for further evaluation. This expert panel consisted of currently active traffic engineers working for operating agencies, FHWA staff from the Office of

Traffic Operations and Office of Research, experts with a long history of activity on the committees responsible for the 1978 Manual and its predecessors, and researchers in traffic operations.

The panel members were asked to independently assign a priority to the standards and standard parts according to a scale between 1 and 3 with 1 indicating low importance and 3 a higher priority for further investigation. The panel was also asked to suggest any additional areas of the manual that should be addressed.

The rating by individual panel members for each of the 517 standards and standard parts was compiled, and a frequency distribution of scores was prepared. All standards or standard parts that received a score of 15 or greater were selected for further review.

Following the ratings, the panel met to discuss the results of the prioritization and the issues involved. Some standards identified by the panel but not included in those selected by the research team were added to those to be reviewed further. The result was a list of 90 standards to be subject to further scrutiny of their research basis. These were then grouped into four traffic control device categories. The categories, followed by the number of standards in each category, were as follows: signs (44), pavement markings (13), signals (10), and construction and school zones (23).

RESEARCH REVIEW PROCESS

Abstract Search

The use of a microcomputer search system to find research for the selected standards expedited the research process. Relevant research for the selected standards was located using the Transportation Research Information Service (TRIS) data file. More than 6,000 TRIS abstracts were identified and transferred to nine-track computer tapes and then downloaded to a PC hard disk. Two microcomputer application programs developed for this project, KEYWORD and XREF, facilitated the abstract search.

Computerized Search Process

The process by which abstracts were located for a selected standard involved three steps. The first step required a review of the wording for the selected standards to extract keywords to be used by the KEYWORD program. Next, the XREF program was run for two or three keywords to generate a more refined listing of abstracts relevant to a selected standard. Finally, abstracts generated by the XREF program were reviewed by the research staff which determined whether or not the reports would provide some research basis for the selected standards.

The KEYWORD program created a file of important words used in each of the manual sections. For example, to find research relating to stop signs the user would enter KEYWORD STOP. A file would then be created of all abstracts, identified by a unique number, which contained the word STOP.

The XREF program allowed for more specific abstract searches. This software cross-referenced two or three words from the keyword file. For example, if the users were interested in finding research related to stop sign location, they would type in XREF STOP LOCATION. This would instigate a two-step interaction. First, all of the abstracts containing the term STOP would be flagged. Of these abstracts, the ones containing the word LOCATION would then be found. Thus a file of abstracts containing both the desired terms would be created.

PRIORITIZATION PROCESS

Before starting the literature review, which was conducted at the U.S. Department of Transportation library and other libraries, abstracts were ranked by their relevance to the question being asked of a particular standard. Ranking by priority was very important because it would be impractical to review all the abstracts identified for each standard.

Prioritization, ranking, and review of relevant research for the selected standards was conducted in a two-tier fashion. Prioritization and ranking processes and forms were developed by the staff. A review of 25 articles by each of 3 members of the staff at the beginning of the review process indicated the consistency of staff rating. Comparing individual staff ratings for the 25 articles, it was found that ratings were consistently uniform for the 3 staff reviewers. Because of the large number of research articles, it was not feasible for each staff member to review each article. Judging from the success of the review of the 25 articles, it was decided that they would be divided among the research staff for review.

Abstract Review Process

Abstracts that were believed to be of greater explanatory power for a standard were reviewed first. The ranking system developed for this step of the research process was as follows:

- A = research based directly on or closely related to the question(s) under examination;
- B = tangential research issues related to the question(s) (but not directly addressing the issue);
- C = discussions related to the question, but not based on research; and
- D = not relevant (delete).

The TRIS search identified 5,893 abstracts related to the 90 standards; 3,288 were referenced as potentially useful. The staff then flagged 1,314 of these abstracts and ranked 371 as A, 250 as B, 308 as C, and 385 to be deleted. Because of the limited amount of time available to locate research related to the abstracts, the researchers concentrated on locating the research described in the 371 abstracts ranked as having the greatest amount of relevance to the selected standards, ranked A. The results of this review are given in Table 1.

Library Search

The next step in the research review process was to develop a way to review A abstracts quickly and efficiently to determine if they contained research that supported the standard wording.

TABLE 1 MUTCD ABSTRACT SEARCH

Section	Standards/ Standard Parts	Total No. of Abstracts Identified Through TRIS Search	Abstracts Identified by XREF Search	Abstracts Initially Reviewed	Detailed Review				
							Rank Order		
					Detailed	Kept	A	B	C
Signs (II)	44	2,394	1,755	695	194	501	166	119	216
Markings (III)	13	1,940	532	171	60	111	46	30	35
Signals (IV)	10	890	565	246	74	172	76	59	37
Construction and school (VI, VII)	23	669	436	202	57	145	83	42	20
Total	90	5,893	3,288	1,314	385	929	371	250	308

Research Form

The research staff developed an MUTCD research form for this review. The form contained items that systematically determined the adequacy of the research. The type of research, geographical location, date, objectives, conclusions, assumptions and biases, methodology, sample size, quality, and significant findings were included in the evaluation of each research effort.

A form was completed for each research report reviewed. A completed form indicated the study team's impression on the quality of the research as well as any significant findings relevant to the standards. At the end of each research form, the staff provided a final ranking on the quality of the research, as follows:

1 = research findings completely address standard wording and fully answer question(s) posed.

2 = research findings partially address standard wording and partially answer question(s) posed.

3 = research findings dispute standard wording and do not answer question(s) posed.

Summary Form

Once all the "A" articles had been reviewed and an MUTCD research form completed for each one, an overview of the research found for each individual standard was conducted. A summary form outlined all the research that had been located for a standard, compared the research to the standard wording, and posed questions on the adequacy of the research and whether or not a research study should be designed. Completed forms and research articles were then reviewed by a member of the team familiar with available research. His familiarity with current research would supplement research not found during the review process.

Quantification Form

The final step in the research process was to determine which standards required additional research. By reviewing the research adequacy forms, the staff could determine the standards that lacked research. Taking the process one step further, a quantification of research adequacy by standard form was developed to rank certain criteria for each standard on a scale from 0 (none) to 5 (very good). This form indicated the type of research performed as well as the quality of the research criteria for each standard. Figure 2 shows the form used in this step.

RESEARCH FINDINGS

The research review process, conducted in a systematic fashion, suggested where further research was particularly needed.

MUTCD standards with little or no apparent scientific research verification as well as standards with significant relevant research were noted. In addition to the literature search, TRB circulars and FHWA documents were consulted to determine current research efforts. Further insight into the status of MUTCD-related research was gained through discussion with transportation professionals in government and the private sector. On the basis of the preceding findings, the research team made judgments about the need for additional research for each standard.

Many traffic control devices and warrants are likely to benefit from further evaluation, improved design, or a better understanding of driver capabilities and behavior. The process was not devised to examine the possible research that might be

TABLE 2 SECTIONS OF THE MUTCD IDENTIFIED TO HAVE A SIGNIFICANT NEED FOR ADDITIONAL RESEARCH

Control Category	Number	Section Title
Signs	II-B-5	Stop sign
	II-B-6	Multiway stop signs
	II-B-8	Warrants for yield sign
	II-B-9	Location of stop sign
	II-B-32	Placement of urban parking signs
	II-C-5	Curved sign
	II-C-21	Narrow bridge sign
	II-D-5	Lettering style
	II-D-6	Size of lettering
	II-E-6	Reflectorization or illumination
	II-E-26	Advance guide signs
	II-F-13	Color, reflectorization, and illumination
Markings	II-B-1	Centerlines
Signals	IV-B-10	Illumination of lenses
	IV-C-2	Warrants for traffic signal installation
Construction and maintenance	VI-C-2	Channelization
	VI-G-3	Signs

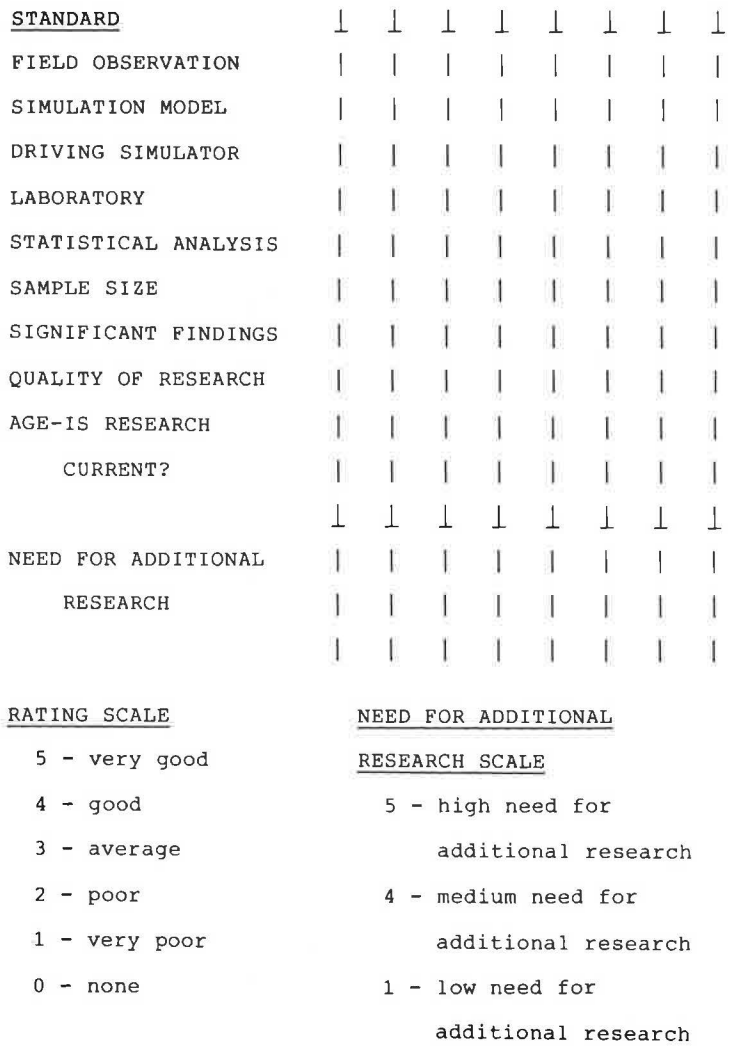

FIGURE 2 Quantification of research adequacy by standards.

directed at each MUTCD standard; rather, it was to identify those standards, or underlying issues, for which no adequate technical basis appears to support the manual requirement.

Signs

Of the four major control categories evaluated, traffic signs proved to be the most prominent. Not only were there more of these standards identified than for other categories, but there were more of these identified that had a significant need for additional research (see Table 2). This may be because signs are the oldest devices. Thus, a large amount of research is outdated. In addition, many of the new sign standards have been added without corresponding research.

Notable among the signs flagged for additional research are the intersection controls. Stop and yield signs—particularly the former—accounted for one-third of the "significant need" sign standards. This is a result of disagreement in the research as well as a lack of research addressing specific questions because a substantial amount of research was conducted for both devices.

Also notable among the various issues related to signs are visibility standards. Two aspects of this issue are notably in need of further research: (a) warrants related to reflectorization and illumination that occur in Sections II-E-6 and II-F-13, and (b) standards related to lettering style and size that occur in Sections II-D-5 and II-D-6. The issues of sign lighting and legibility are also included in another matter needing further research, one that is becoming increasingly important—the needs of the aging driver.

The demographics of the United States are changing; the average age of motorists is increasing. With the growing number of drivers over 50 years of age, visibility and legibility are vital issues. Visual acuity and other visual capabilities of drivers decrease with age. Perception and reaction time also increase. Thus the basic premises of standard design, particularly sight distance and perception reaction time, may need to be readjusted.

Pavement Markings

Among the pavement markings standards, only the issue of centerline markings was believed to be significantly in need of additional research. This issue is related to the need for better

visibility, particularly in relation to wet-night driving. There are also serious concerns about the driving public's understanding of lane markings.

Signals

Signals were, in general, well researched. None of the standards related to this category of device was without research.

Of the two selected standards in the "significant need" category, the warrants for one have changed since 1978. Three new warrants for traffic signal installation (Section IV-C-2) became effective on January 1, 1985. As noted in the December 1985 *ITE Journal*, these warrants could lead to an increase in the number of signalized intersections throughout the country.

The primary research need associated with selected Standard IV-B-10 is daytime versus nighttime visibility. It appears that nighttime visibility is adequate for all three colors. Daytime visibility of traffic signals is often limited, particularly when subject to the direct rays of bright morning or afternoon sun. Green is the least identifiable of the three colors. Thus the visibility of green signals during these critical times is an important research issue.

Construction and Maintenance

One issue that arose throughout the study was the color of construction and maintenance signs. This topic cuts across category classification. It was first mentioned as part of Section II-A-11, the sign color section. Subsequently, it appeared as part of Section VI-B-1, Design of Signs. The question of whether or not orange is the appropriate color also appears in reference to Design and Application (Section VI-B-13), Cone Design (Section VI-C-3), and Drum Design (Section VI-C-6).

RESEARCH RECOMMENDATIONS

Several sections of the MUTCD that have a significant need for additional research were identified in the preceding section of this paper. The following recommendations identify eight high priority areas in which further research on traffic control devices is needed.

A number of important issues surfaced throughout the MUTCD evaluation of various standards. Many standards that are inadequately supported by research were identified in the review process. If there was a specific lack of research in more than one standard, in most cases it proved to be a major issue. The eight major MUTCD research issues are identified as follows:

- Shall, should, may.
- Symbols versus word.
- Yield versus stop.
- Construction and maintenance signs.
- Reflectorization and illumination.
- Compliance.
- Older drivers.
- Design drivers.

These eight issues are recommended to have the highest priority for future MUTCD research, an analysis of each issue is presented next.

Shall, Should, and May

Although the manual defines these terms (Section I-A-5), ambiguity remains and the basis for selection of a particular term for a given application is not apparent. Beyond these issues, two other closely related issues require research. First, how do local traffic authorities actually interpret or respond to each of these terms, and for what reason? It appears that a "should" ("advisory" condition) is often *de facto* a "shall" ("mandatory" condition) if a local jurisdiction is concerned with protection from potential tort liability suits. Second, given the actual response of local authorities to these terms, what is the implication of the use of one term versus another for the safety and operational efficiency of the traffic system?

The effects on overuse of traffic control devices, inappropriate applications, or failure to implement where needed, may be tied to the choice of terms. An appropriate study could examine the operational and safety effects, costs, and tort liability implications of the choice of the terms "shall," "should," or "may." The study may also develop guidelines for the choice of terms and review current MUTCD standards under these guidelines.

Symbols Versus Word Legends

The use of symbol signs versus word legends was an important issue. The question was whether or not word legends can be replaced by symbols and still be clearly and rapidly understood by the motorist. The incorrect interpretation of these symbol signs poses a serious danger to both motorists and pedestrians.

A substantial amount of research has been conducted on this topic. The MUTCD general philosophy has evolved to reflect the strong international trend toward greater use of symbols. In general, symbol signs have been found to be more effective than word messages in terms of their perception time and legibility distance. One study found symbol signs identified at more than five times the distance of signs with word legends. Another research article indicated that symbol legibility can be considerably increased by improving symbol design. Other findings indicated that comprehension of symbols is reduced by the addition of information such as words or prohibitory symbol elements.

Despite the amount of research on symbol versus word signs, the question of superiority remains unresolved. Symbols generally perform better, but this has not been universally true. Many comprehension problems exist for current MUTCD symbol signs.

The authors review suggests that an important general question is, Under what conditions are symbol signs preferable to word signs? To improve symbol sign design, there may be a need for standards that parallel existing standards and guides for word legends. Accepted graphics principles analogous to letter height or stroke width could be useful. There are no criteria for developing, selecting, or evaluating a symbol for comprehension, legibility, and so forth. Research is needed to

determine general criteria for symbol sign use and design: when to use a symbol versus a word legend, how to determine the pictorial content, and what the design and evaluation criteria are. MUTCD symbol signs should be reviewed against these considerations.

Yield Versus Stop Signs

Research indicated that yield signs are underused. In many cases a stop sign could be replaced by a yield sign with no adverse impact on driver safety or the efficiency of road use. Standards affected by this issue include: Section II-B-5: Stop Sign, Section II-B-6: Multiway Stop Signs, and Section II-B-8: Warrants for Yield Signs.

Color of Construction and Maintenance Signs

The color of construction and maintenance signs was a major issue. The major question was whether orange was the best color for use on construction and maintenance signs.

Controversy continues regarding the adequacy of orange signs (with black legend) in terms of both perception and comprehension. The relative visibility and legibility of orange signs has been questioned. Perhaps equally important, but less researched, is the conspicuity of orange signs for unalerted drivers in realistic settings. On the comprehension side, some evidence suggests that the general public does not adequately understand the color coding. Again, an important aspect has not received adequate attention: How well does the orange sign convey the sense of hazard and the need to take some action? If orange were found to be less effective in terms of visibility or meaning, the logic behind independently color coding construction and maintenance signs should be reviewed. The performance of black-on-orange signs (photometrically, perceptually, and in meaning) should be evaluated (a) against objective performance criteria, such as required legibility distance; and (b) relative to the performance of alternative colors.

A recommendation to continue, modify, or drop the construction and maintenance color coding should be made with explicit reference to the data and logic involved.

Reflectorization and Illumination of Traffic Control Devices

The issue of reflectorization and illumination was important with respect to both signs and markings. For signs, reflectorization is a factor in installation of overhead signs, visibility of street name signs, and the importance of sign colors appearing essentially the same by night and day. Illumination was a key issue because with the changing technology for reflective material and the increasing cost of electric power, signs that are illuminated might be replaced by reflectorized signs. For pavement markings, reflectorization is a factor in the visibility of longitudinal pavement markings, object markers, and raised pavement markers.

Most MUTCD standards and recommendations concerning reflectorization, illumination, and options among these are quite vague. A study to develop performance criteria for such standards may lead to greater uniformity and ensure adequacy.

Lack of Compliance with Traffic Control Devices

Many enforcement agencies and highway authorities believe a serious and growing problem is motorist noncompliance with traffic control devices. Although no objective data were encountered to confirm that the problem is increasing, the literature contains a variety of studies that evaluate noncompliance with specific traffic control devices.

A number of compliance-related issues require evaluation. These include the magnitude of the noncompliance problem, its safety implications, and identification of those traffic control devices that constitute the greatest problem. The noncompliance problem may be improved by better MUTCD standards for design or placement of devices or both. Research should analyze why compliance problems occur with particular devices and identify improvements in traffic control device design.

The Needs of the Older Driver

The aging of the driver population as U.S. demographics change has become a concern. Research supporting many MUTCD standards has not incorporated evaluation of the capabilities of older drivers. Many age-related changes in ability and behavior, both visual and nonvisual, may influence the adequacy of warrants and devices. There is a need for a comprehensive review and evaluation of the needs of older drivers and the adequacy of current standards. (This is part of the larger "Design Driver" issue, discussed later.)

The importance of evaluating age-related problems comprehensively has been emphasized in this review. Most attention thus far has focused on visual decrements such as acuity, glare sensitivity, and so forth. This has obvious implications for letter size, reflectivity, and illumination. However, other age-related decrements, in factors such as speed of information processing or ability to time-share simultaneous demands, pose equal demands on MUTCD standards. This affects numerous factors, including device location, information content (particularly guide signs), temporal aspects (e.g., duration of the yellow phase, clearance intervals, advance signing), and symbol comprehension (which has frequently been shown to be poorer for older groups).

Future research must include a comprehensive review of age-related changes, both visual and nonvisual, that affect MUTCD standards. The impact of current inadequacies on the older population should be evaluated in terms of safety, operational efficiency, and the discouragement of mobility.

Improved criteria to address older driver requirements should be developed and current devices evaluated under these guidelines.

The Design Driver

It is suggested that the manual add a section on design driver criteria. This would include factors such as eye height, acuity, and response time for various actions (recognition, braking, etc.). The factors could be broken down by percentile (50th, 85th, 95th), or key driver groups that may be of concern (by age, condition, etc.). Also, it should include the appropriate

formulas for combining the basic characteristics to derive other key quantities, such as legibility distance, decision sight distance, and so forth.

Such a section would achieve several important goals. First, it would provide a clear set of consensus criteria for use in evaluating the adequacy of standards for devices. Second, it would allow the adequacy of devices to be periodically reviewed as changes occur in the vehicle fleet, roadway features, or the knowledge and assumptions about driver performance. Third, it would permit well-defined performance-based standards. It would permit standards such as, "the sign should have a minimum decision sight distance of X," rather than specifying some single size to cover possibly quite different situations.

FILE MANAGEMENT SYSTEM

In addition to identifying areas in which the need for additional research was great, a second goal of this study was to make the MUTCD accessible for review through a computerized comprehensive file management system. To maintain and update the information that was compiled for the MUTCD evaluation, a file management system was developed. The filing system contains (a) all the information obtained during the research of the selected standards, (b) a historical review of the selected standards, and (c) the 1978 MUTCD and requests for changes. The system was developed using a microcomputer that stores all the MUTCD information and allows the user to make changes to the data base.

The MUTCD File Management System (FMS) is a menu-driven search and maintenance program created in dBASE III (registered and copyrighted by Ashton-Tate). The system allows the user to access any of the created files using the standard identification number or a specific keyword. A unique numbering system to find information pertaining to a given standard facilitates searches. The numbering system in the 1978 MUTCD was reformatted to a system that would work in the FMS. For example, MUTCD standards II-B-5, III-A-3, and

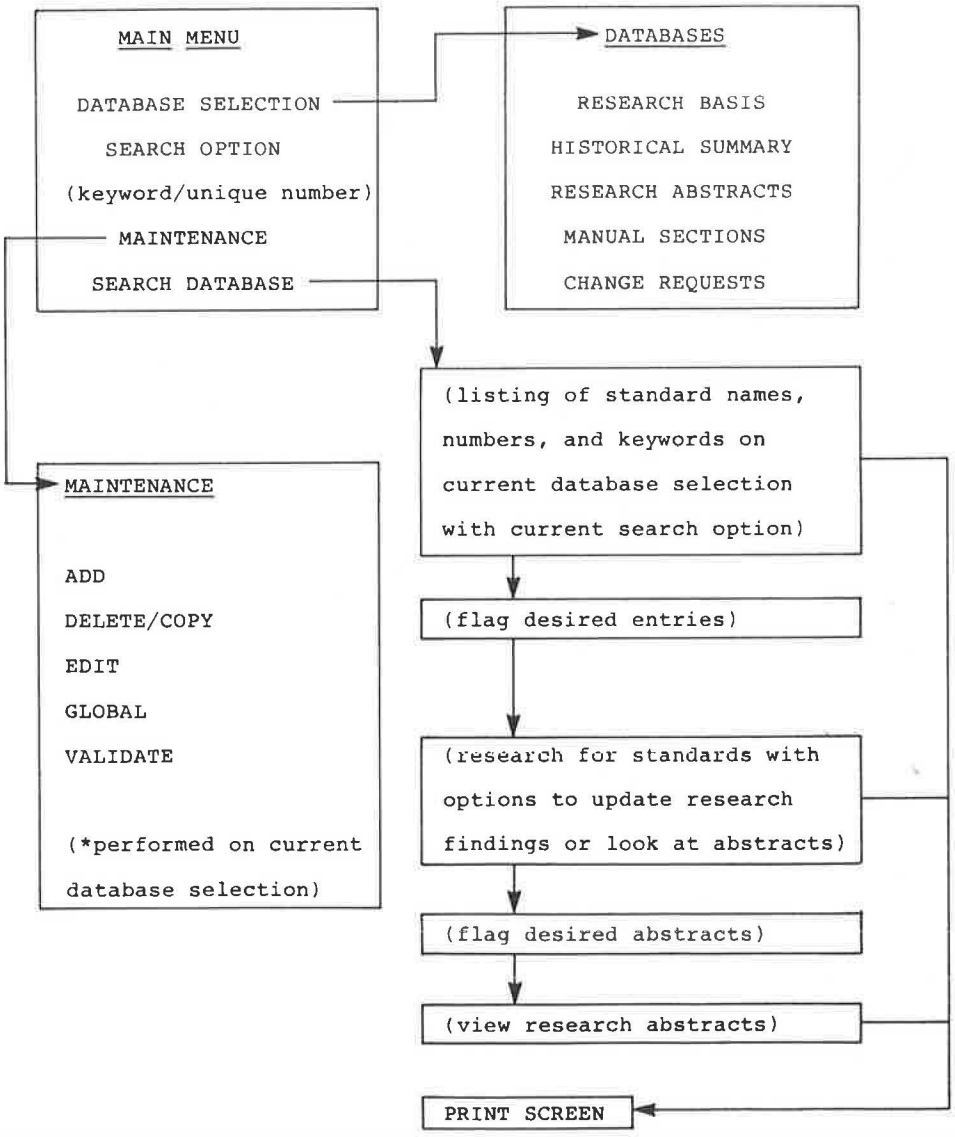

FIGURE 3 File management system flow chart.

VI-D-1 would be 2B#5, 3A#3, and 6D#1, respectively, in the FMS. The system is set up so that the user can locate information for a particular standard, search for information pertaining to a particular topic, update the data base, or add new information to the data base. The following is a description of the functions and screens available in the FMS for MUTCD retrieval or maintenance, or both. Figure 3 is a flow chart of the FMS that helps the reader understand the hierarchy of screen retrieval and access.

When the user logs on to the FMS, the main menu appears and prompts the user for the type of function to perform. The user can specify four options at this point:

- *Data base selection*—prompts the user for the data base to be manipulated (i.e., manual sections, research basis, change requests, historical summary, research abstracts).
- *Search option*—determines if data base manipulation will be performed using the unique numbering system or by keywords related to a given standard.
- *Maintenance*—performs various manipulations on the data base selected.
- *Search data base*—performs a search on the data base selected using the search option selected.

The data base selection and search option set up pointers within the FMS so that the maintenance and search data base options can be performed. In addition to these four options, at this point the user can exit the FMS.

Three of the five data bases available for manipulation only contain information pertaining to the 90 standards addressed during this MUTCD standards evaluation. These data bases are research basis, historical summary, and research abstracts. Research basis is a review of located research that has been completed for the 90 standards. Historical summary is a manual-by-manual history of the 90 standards starting with the 1927 MUTCD where applicable. Research abstracts are the pertinent research reports found for the 90 selected standards. A typical abstract contains the title, author, and location of a research report followed by a brief description of the major points in the research. These three data bases can be added to as research is completed for those standards outside of the 90 already evaluated. This is performed in the maintenance option.

The manual section data base is the 1978 MUTCD. The change requests data base is a summary of all proposed changes to the 1978 MUTCD. Modification to these data bases is also performed in the maintenance option.

The maintenance option provides the user with five functions to manipulate the FMS. The user can change or delete existing information or add new information to the FMS. Specific functions for this option include

- Add. Adds new information to current data base selection.
- Delete/copy. Deletes existing information from the selected data base, or copies that information onto a work file outside of the FMS.
- Edit. Edits the keyword or subject fields for existing standards; these fields are referenced when the keyword search option is specified at the main menu.
- Global. Edits all records with missing keyword or subject fields.
- Validate. Updates the master file with any changes the user may have made during the maintenance option.

The search data base option will display all information in the FMS in the selected data base using the search option specified. For example, if the user performed a keyword search on the word "stop," the FMS will display all standards with the word stop used as a reference in the keyword or subject fields. At this point the user can flag individual standards and view the research that has been completed for that standard as well as the abstracts pertaining to the standard. New or additional research findings can be entered into the search data base option.

The MUTCD File Management System is an easy system to use because of its convenient menu-driven format. Its value is maximized if it continually is used to update changes that occur to the existing 1978 MUTCD. The groundwork has been laid to facilitate the easy access of research and information related to the MUTCD. If the FMS is completed for the entire manual, it would provide a comprehensive reference for information pertaining to uniformity of traffic control devices.

CONCLUSION

Described in this paper is a project whose primary objectives were to locate areas of research need and establish a file management system for the *Manual on Uniform Traffic Control Devices (1).*

Admittedly, the basis for most of the standards was not located. Whether developed through research, in committee meetings, or over lunch, the origin of most of the standards, with several exceptions, is not certain. The research adequacy of selected MUTCD standards nevertheless has been investigated and reviewed. An evaluation of the traffic control device warrants needing further study has been completed and recommendations have been made. In addition, the MUTCD has been systematically placed in a data base management software package to facilitate review.

The review of research has highlighted areas in which future studies are needed. Significant among these is the need for examination of the aging driver and design driver issues.

With its manual, research, historical, change, requests, and abstract components, the PC-based file management software allows the user to easily locate information related to traffic control devices. With the keyword and standard search options, key terms and warrants are found with a few simple keyboard strokes.

Of equal significance, this project has provided a model for future MUTCD studies. The groundwork has been laid to facilitate subsequent investigations related to the manual and to allow for easy access of related research.

Of critical importance is that the process developed to identify research needs regarding the MUTCD and the file management system developed to organize information are both used. It is important that all research related to traffic control devices completed from this time forward be added to the FMS so that, in the future, the bases of individual standards can be established. Furthermore, the basic research needs identified, such as the development of design driver criteria, should be addressed in future research and future modifications to the MUTCD.

Finally, it was impossible to research the basis of all MUTCD standards; therefore, further efforts should be made to determine the basis of standards not addressed by this research.

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REFERENCE

1. *Manual on Uniform Traffic Control Devices for Streets and Highways*, FHWA, U.S. Department of Transportation, 1978.

Publication of this paper sponsored by Committee on Traffic Control Devices.