Effective Use of Variable Message Signs: Lessons Learned Through Development of Users' Manuals

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In an effort to improve the operations of both portable and permanent (fixed-site) variable message signs (VMSs) in Virginia, a comprehensive research effort to develop operational guidelines was undertaken. These guidelines, presented in the form of users' manuals, were based on information obtained from the literature, VMS operators, and motorists. Issues addressed by the manuals include whether to use a VMS, where to place a portable VMS, and how to design a VMS message. The manuals are not simply a list of predefined messages; instead, they are composed of concise, readable modules designed to guide an operator through the thought process required to use a VMS effectively. An operator follows a logical decision tree as each module is completed, allowing effective use of the VMS as well as training the operator for use of the device. Key lessons learned in developing two such manuals for portable and permanent VMSs are highlighted. On the basis of theoretical calculations and motorists' experiences, it is strongly recommended that a VMS use no more than two message screens. A single message screen is preferred. VMSs should be used only to advise drivers of changed traffic conditions and to convey specific traffic information concisely. Because of limited information capabilities, VMSs should be used in conjunction with other means of communication such as highway advisory radio and static signs. Most importantly, it is crucial that credibility be maintained. Incorrect information can have disastrous consequences on VMS effectiveness.

The need to provide drivers with real-time information has spawned a dramatic increase in the use of variable message signs (VMSs). VMSs are programmable traffic control devices that display messages composed of letters, symbols, or both, and may be either permanently mounted or portable units. The VMS allows transportation officials to quickly inform motorists of abnormal traffic conditions. Although the ability of VMSs to display messages that describe current traffic conditions has made the signs popular, this added flexibility results in increased operational responsibility to ensure that the signs are used to their maximum benefit. Some VMSs are difficult to understand because word choices are confusing, messages contain too much information or are ambiguous, or placement of portable VMSs is poor.

This research sought to develop user's manuals that provide Virginia Department of Transportation (VDOT) field personnel sufficient detail to effectively use VMSs on the basis of the type of situation, predominant travel speed, time of day, goal of message, and type of sign (*1*). These manuals address questions such as

- Under what circumstances should VMSs be utilized?
- Where should a portable VMS be placed?

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- What are the limits of the quantity of information that can be displayed?
- What information should be given to drivers?

Although a significant amount of VMS research has been conducted nationally, most of it has dealt with physical specifications of the signs rather than operational issues. The focal question of this research has been, Given the existing technology, how should VMSs be operated?

METHODOLOGY

Three information-seeking strategies were used for this project: a literature search, surveys of VDOT personnel, and discussions with drivers in the Commonwealth of Virginia. The literature review provided the base of the study, as a significant amount of VMS research had been conducted and needed to be assimilated into a concise format (*2–6*). Additional ideas were gleaned from other states' VMS guidelines (*7–11*). VDOT personnel played an important role because they are the primary users of the manuals, and their participation ensured the development of a product that meets their needs. Finally, motorists' reactions provided recommendations for improvements that make VMSs more useful to the driving population, the ultimate "customer" of traffic information.

RESULTS

The literature addressed the theoretical operation of VMSs, which provided a solid basis from which to construct the manuals. For example, one FHWA publication defined the components of an advisory message to be (a) a problem statement, (b) an effect statement, (c) an attention statement, and (d) an action statement. Such message deconstruction proved useful for understanding how to develop effective VMS messages and for forming the message design modules of the manuals. VMS usage was also addressed. For example, static signs should be used to complement the VMS and should be considered before the decision to use a VMS is made. Working with VDOT VMS operators, it became clear that previous research was not in an easily used form.

The outcome of the literature review, focus groups, and discussions and surveys involving VMS operators yielded six key lessons:

1. VMS operators need a user's manual—not a set of canned messages. Operators need final responsibility for how the VMS is used as well as the ability to respond to unforeseen applications. A list of suggested messages is ineffective, as variations in traffic conditions and available information are numerous. Clearly the operators need a product that is not overly restrictive but is much more substantive than simply authorizing the use of "engineering judgment." The product needs to take the form of a user's manual, which will assist operators but not replace their judgment.
2. VMSs should be used to advise the motorist of changed traffic conditions. Operators' field experience showed that VMSs should be used only to convey information about traffic abnormalities such as lane closures, delays, or sudden stoppages. VMS operators noted that motorists ignored greetings and general safety statements (e.g., "Please drive safely").
3. VMSs must meet motorist information needs. Specifically, the VMS should tell motorists what action is required of them. Messages such as "LANE CLOSED AHEAD" need to indicate which lane is being closed and the distance to that closure. General messages such as "SLOW SLOW SLOW" or "CAUTION" are useless, as they do not inform motorists about traffic conditions. Finally, word choice has a powerful impact. Motorists noted that the word "DETOUR" meant static signs would guide them along the alternate route, whereas the phrase "ALTERNATE ROUTE" means they must find that route on their own.
4. VMSs have limited information capabilities. VMSs can provide effective alternative route guidance for unfamiliar drivers only if used in conjunction with another information medium, such as static signs or highway advisory radio.
5. Credibility is crucial. Failure to confirm the message displayed by a VMS can have disastrous consequences in terms of the public's faith in future VMS messages. Motorists recalled instances in which the information was clearly wrong, such as warnings of construction activity at night when no construction was taking place.
6. VMSs should use no more than two message screens. Even though portable VMSs may display up to six different message screens, it is difficult at high speeds 88.6 kph (55 mph) for motorists to read a message with only two screens.

Motorists cited difficulties reading multiple screen messages because large vehicles blocked the line of sight, visibility conditions were poor, there were other distractions, or the sign was placed on the opposite shoulder. Messages longer than two screens can easily confuse motorists if they encounter such a VMS in midmessage, and VMS operators need to allow for this possibility.

Dudek's technique for determining the amount of time motorists have to read a VMS demonstrates that a portable VMS should employ only one or at most two message screens (*3*). For example, a portable three-line, eight-character-per line, flip-disk VMS will cease to be comfortably readable when the motorist gets very close to it. An equation to account for this distance from the VMS to the point at which it becomes unreadable is given as

$$\text{Unreadable Distance} = [S + (N - 0.33)*L + 0.5*W]*5.67 \quad (1)$$

where

S = distance from the side of the road to the VMS [m (ft)],
N = number of lanes,
L = width of the lanes [m (ft)], and
W = width of the VMS [m (ft)].

This unreadable distance may then be subtracted from the legibility distance, which is the distance at which the VMS becomes legible, to yield the distance for which the VMS may be read by the motorist. This calculation is shown in Equation 2.

$$\text{Readable Distance} = \text{Legibility Distance} - \text{Unreadable Distance} \quad (2)$$

The resultant readable distance may then be divided by the travel speed to compute the time for which the VMS is readable, as shown in Equation 3.

$$\text{Readable Time} = \frac{\text{Readable Distance}}{\text{Travel Speed}} \quad (3)$$

For example, suppose a VMS is mounted such that, as calculated by Equation 1, it has an unreadable distance of 61 m (200 ft). The literature states that in daylight conditions, a flip-disk VMS has a legibility distance of approximately 198 m (650 ft) (*2*; P. Garvey, unpublished data). Therefore, from Equation 2, one may compute the readable distance to be

$$198 \text{ m} - 61 \text{ m} = 137 \text{ m (450 ft)}$$

Substitution of this value and a travel speed of 88.6 kph (55 mph) into Equation 3 yields a readable time of about 6 sec.

Manual on Uniform Traffic Control Devices (MUTCD)-proposed guidelines specify that motorists must be able to read the entire VMS twice while traveling at the posted speed (*12*). Using Dudek's approximation that motorists need 1 sec to read each eight-character line, it will take 3 sec to read a screen once or 6 sec to read a screen twice. Thus for this particular example, an operator should ideally use a message with only one screen. (Even if one decides to display each screen for only 1.5 sec these computations show that no more than two message screens should be used.)

DISCUSSION

The most challenging task of this project was synthesizing the results into easy-to-read operator's manuals. The features of these manuals are discussed.

Use of Modules

The manuals were divided into separate modules designed to step an operator through the thought process involved in using a VMS (Figures 1 and 2). A module is a distinct thought process in the overall VMS message development. Each module serves as a checkpoint for ensuring that the correct decisions have been made, such as whether to use or where to place the VMS.

Using a logical flow of decision points, which is accomplished by dividing the manuals into modules, ensures that the VMS is used correctly. For example, one problem that operators often face is how to convey location information to motorists. Depending on the type of route, driver familiarity with the area, and amount of signing, it may be better to tell motorists that there is an accident at a particular exit near a well-known landmark or a certain number of miles away. If an operator is faced with this decision, Module 10, as indicated in Figure 2, quickly guides the operator to the correct usage. Furthermore, a progression of decision points allows an inexperienced operator to become familiar with the choices that should be

1. SHOULD A VMS BE USED?

A VMS is a tool for grabbing the motorist's attention. Therefore it should be used only when there is a specific message that needs to be conveyed to motorists: overuse of a VMS will cause motorists to ignore it and lessen its effectiveness.

All of the following statements should be true if a VMS is to be used.

T F Drivers are required to do something in response to the message such as:

- change travel speed,
- change lanes,
- divert to a different route, or,
- be aware of a change in traffic conditions either now or in the future.

T F *Where applicable,* static signs which can effectively convey this message are not readily available.

VMSs should be used to supplement, *rather than replace,* static signs that are required by law.

T F The VMS does not tell drivers something they already know.

T F Message accuracy can be confirmed from a reliable source such as State Police, a credible commercial traffic reporter, or visual inspection.

T F Traffic conditions may be monitored to detect significant changes such that the VMS may be removed or the message may be changed as soon as necessary.

IF all answers are True then proceed to 2.

IF any answers are False then stop.

FIGURE 1 Module 1.

made when using a VMS, thereby providing a training opportunity parallel with a VMS operation.

It is believed that the use of modules offers distinct advantages. First, modules facilitate the updating of the manuals, which must occur if they are to become and remain a useful tool. Second, modules streamline the VMS decision process: operators need only complete those modules that are necessary. Often, a decision in one module will eliminate the need to go through certain subsequent modules. Finally, modules present the information in a concise, user-friendly manner.

The example modules, shown in Figures 1 and 2, illustrate the diversity of input requirements and purposes for the modules. For example, the first module's purpose is to determine whether a VMS should be used; thus it should always be completed, and if successful then the result is to simply continue with the second module. However, the tenth module should be completed only if the operator needs to convey a distance or a location, and the tenth module's result is a recommended choice of words.

Integration of Modules: An Example Application

The portable VMS manual is divided into 17 modules, as shown in Figure 3, with each module designed to help the operator answer one basic question: "Where should the VMS be located?" Figure 3 outlines the purposes and some considerations of each module as well as how the modules are integrated to guide the operator through the VMS decision process.

An example scenario briefly illustrates how the operator moves through these modules. Suppose an operator receives notification from the supervisor that a truck has crashed on a rural two-lane Interstate highway, resulting in a traffic queue and blockage of the left lane, although traffic can pass in the right lane. The goal of the first module (Figure 1) is to help the operator decide whether to use the VMS. In this case, the operator makes the decision to use the VMS; drivers are required to do something (change lanes); static signs that can inform motorists of an accident are not available; the VMS conveys new information to drivers (to merge right); message accuracy can be confirmed (by the supervisor); and the VMS operator will be on the scene to monitor traffic conditions. In the second module, the operator decides that the purpose of the VMS will be "current incident advisory." The operator then proceeds to the third module to determine the location of the VMS, considering factors such as access to the VMS, major decision points (in this case, Interstate exits), and the effect of future traffic backups. The VMS is thus placed upstream of an Interstate exit before the crash, and the VMS is placed off the shoulder in conjunction with Group II channelization devices (e.g., orange barrels) such that the VMS itself is not a

10. HOW SHOULD DISTANCES AND LOCATIONS BE CONVEYED?

IF	a distance or a location is part of the message, then complete this module.
OTHERWISE	go to 11.

When using a location or distance, the question arises as to whether the operator should give a distance ("ACCIDENT IN 3 MI"), an exit number ("ACCIDENT AFTER EX 100"), or the name of a prominent landmark ("ACCIDENT AT BROAD STREET"). In order to make this decision, complete this module.

T F The message applies **ONLY** to familiar drivers.

IF	True, then consider the use of cross-streets, landmarks, and exit numbers and select the term that is best known by the local population. Go to 11.
IF	False, then continue with this module.

T F The route is an interstate.

IF	True, then continue with this module.
IF	False, then give a distance in miles. Go to 11.

T F The exits are numbered sequentially (i.e. they do **not** correspond to mile markers).

IF	True, then give a distance in miles. Go to 11.
IF	False, then continue with this module.

T F At least one of the following are located within one mile after the VMS:

- an exit, or
- a static sign indicating a distance to an exit

IF	True, then give the location as an exit number. Go to 11.
IF	False, then give a distance in miles. Go to 11.

FIGURE 2 Module 10.

safety hazard. Had this been an urban area, the operator would have considered moving the VMS even further from the crash depending on previous experience with traffic congestion. In the fourth module, with traffic flowing past at 55 mph (88.6 kph), the operator decides to try and keep the message to one screen. Module 5 shows that because this is a "current incident advisory" type of usage, the operator should complete Module 6, which is the design of the current incident advisory message. In Module 6 the message is synthesized on the basis of the three components of a current incident advisory message: the problem component (an accident blocking the left lane), the *location* component [the incident is about 3 mi (4.9 km) away], and the *instruction* component (motorists should move out of the left lane and into the right lane or exit from the Interstate altogether). The operator tentatively envisions a message such as "accident—left lane closed—3 mi ahead—merge right." Note that this module discourages peripheral information, such as a description of the crash (e.g., "truck overturned"); instead, the goal is to establish the essential message elements.

The operator is now sent to Module 10, which is shown in Figure 2. Because the message applies to drivers both familiar and unfamiliar with the route and it is an Interstate, the operator arrives at the third true/false statement shown in that module. If the exit numbers were according to mile marker, then the operator would change the phrase "3 mi ahead" to refer to an exit, such as "after exit 100." In this case, however, suppose exit numbers are sequential. Because there are travelers using the Interstate who might not be familiar with the distances between exits, Module 10 advises the operator to give a distance in miles and then proceed to Module 11. In Module 11, the operator realizes the word "ahead" is not necessary in the phrase "3 mi ahead." Module 12 is not applicable as the word "next" has been avoided in the message, so the operator proceeds to Modules 13 and 14, where the message is divided into multiple screens, abbreviations are considered, and the necessity of each screen is scrutinized. Supposing a three-line, eight-character-per-line VMS, the operator's first attempt might be as follows:

screen 1	*screen 2*
ACCIDENT	3 MILES
LEFT LANE	MERGE
CLOSED	RIGHT

The operator then uses abbreviations and develops the following message:

screen 1	*screen 2*
ACCIDENT	MERGE RIGHT
LEFT LN	3 MI
CLOSED	

Module	What operator accomplishes in this module	Some factors considered in completing the module
1. Should a VMS be used?	If successful, then goes to module 2. If unsuccessful, then stops.	Change in driver response required, ability of operator to confirm and maintain message accuracy, and inability of static signs to accomplish the task.
2. What is the purpose of the VMS?	Selects ONE of these four categories: (a) current incident or work zone advisory (b) diversion to an alternate route (c) guidance for a current special event. (d) advisory for a future event	Expected purpose of message.
3. Where should the VMS be located?	Determines an acceptable location with respect to the roadway and the condition being conveyed.	Roadway geometry, presence of major decision points, access to the VMS, sight distance, and future traffic backups.
4. What is the maximum number of screens that may be used?	Conveys to operator that 1 screen is ideal, two screens are acceptable, and 3 screens should be used only if absolutely necessary.	Driver inattention, MUTCD guidelines, amount of time required to read a VMS, legibility distance of a flip-disk VMS, and calculations detailed in Appendix A.
5. What is the message type?	Selects ONE of the following modules to complete: 6, 7, 8, or 9.	Category identified in module 2.
6. What is the message? (current incident or work zone advisory)	Designs a message considering problem, location, and instruction components.	Example message components, effect of sensationalist messages, and need to convey specific information to the motorist.
7. What is the message? (route diversion)	Designs a message considering audience, time saved, and instruction components.	Example message components, distinction between "alternate route" and "detour", and the need for "time saved" statement to be accurate or avoided.
8. What is the message? (guidance for a special event)	Designs a message considering audience and instruction components.	Example message components and names or events that motorists will recognize.
9. What is the message? (advisory for a future event)	Designs a message considering condition & location, time, and instruction components.	Example message components and time requirements (such as not describing future conditions more than one week in advance).
10. How should distances and locations be conveyed?	If locations or distances are needed, decides whether to use landmarks, exit numbers, or distances in the message.	Type of exit numbering scheme (sequential or by mile marker), familiarity of the driver population, and proximity of static signs.

FIGURE 3 Overview of portable VMS modules. *(continued on next page)*

11. Are the words "TRAFFIC" and "AHEAD" used correctly?	If applicable, then verifies that these words are used correctly. For example, the message "BEACH TRAFFIC USE EXIT 5" may be shortened to "BEACH USE EXIT 5".	Readability of the message and number of screens used.
12. Is the word "NEXT" used only as necessary?	Ensures that use of the word "next" is not confusing when referring to an exit or turn. Considers options such as naming the exit or turn or replacing the word "next" with "first" or "this".	Whether the exit or turn is visible once the message is read, whether the road is an Interstate, and how well the exit or turn is marked with static signs.
13. How should the VMS message be sequenced?	If message is longer than 1 screen, then determines how message should be divided.	Motorists' comprehension of individual screens if read by themselves.
14. Is the message acceptable?	Verifies that message wording is effective.	Abbreviations, local signing, order of message information, and necessity of all screens.
15. How should the message be displayed?	Determines how to display the message with respect to font and amount of time each screen is shown.	Speed of traffic, increased legibility distances associated with single stroke fonts and upper case letters, and avoidance of blank screens.
16. Does the VMS pass the drive-through test?	Drives past the VMS at least once to verify its effectiveness.	Visibility of VMS, readability of message, driver environment, and the necessity of information conveyed.
17. When should the message be updated, modified, or discontinued?	Determines when to change the message or remove the VMS.	Message accuracy, timeliness of the message, current or expected changes in traffic conditions, and motorists' reaction to the VMS.
Appendix A: Why should a VMS use no more than two screens?	Steps through calculations showing how motorists have a very limited amount of time to assimilate VMS messages.	Limited flip-disk VMS legibility distance, concept of VMS being outside of driver's field of vision when the VMS is very close to driver, prevailing traffic speed, and amount of time required to read a message.
Appendix B: How should the VMS be maintained when not in use?	Understands suggestions for cleaning the screen, removing VMS from the road when not in use, and charging the battery if necessary.	Need to reduce glare (by cleaning the Lexan screen), need to remove VMS when there is no message to be displayed, and the need to charge the battery for VMSs which have not been used recently.
Appendix C: What abbreviations are recommended?	Reads a list of recommended abbreviations (such as "ln" for "lane").	Commonly used words and abbreviations obtained from the literature.

FIGURE 3 *(continued)*

The operator then realizes that not all screens are necessary: on the two-lane road, "left lane closed" and "merge right" imply the same message. The operator concludes Modules 14 and 15 with a one-screen message: "ACCIDENT|3 MI|MERGE RT." In Module 16, a drive past the VMS verifies its effectiveness: this drive-through can reveal simple mistakes, such as the view of the VMS being blocked by a pole or roadway curve. Finally, the last module ensures that the operator either changes the message or removes the VMS as soon as traffic conditions have returned to normal to ensure VMS accuracy.

In the previous scenario a variety of approaches could have been considered that were not mentioned in the interests of time. For example, had the major problem not been for motorists to merge but instead for motorists to divert from the Interstate, the operator also would have completed Module 7, which helps design a message for diverting motorists to an alternate route. In that case the operator also would have examined the need to use static signs for motorists unfamiliar with the area. The emphasis of this example, however, is to show how the modules can help the operator design an effective VMS message for a particular situation.

Two Sets of Manuals

A separate operator's manual was developed for permanent VMSs. This manual is similar to the portable VMS manual, and in many cases the modules are the same. However, the two manuals have distinct differences.

The permanent VMS manual has only 16 modules because it does not include a module describing where to place the VMS. In addition, although portable and permanent VMSs both become unreadable when the motorist drives close to them, the methods differ for computing the distance at which the VMS becomes unreadable. As shown in Equation 1, lateral distance is the key factor for portable VMSs, whereas for permanent VMSs the problem is vertical distance (*3,13*). Thus, the appendixes that describe these calculations are different for portable and permanent VMSs. Furthermore, additional message purposes have been included for permanent VMSs, as they have greater display capabilities. Finally, example message components for the two manuals differ because of their variance in display formats. For example, if one wants to convey that the two left lanes are closed, then a permanent VMS with twelve characters per line can display a message such as "2 LFT LANES | CLOSED" whereas a portable VMS with only eight characters per line might use a message such as "2 LEFT | LANES | CLOSED."

Consistency and Readability Built into Manuals

The single most important aspect of the manuals is that they are users' manuals rather than mandates or a laundry list of messages. They are essentially a training tool that encourages the creativity of the operator and allows him or her to have the final decision in the application of the VMS.

The manuals are simple and effective. They are highly readable but substantial enough to help the operator ensure that the VMS is used properly. Decision boxes placed in the same location on each page step an operator through the manuals. The use of a "true-or-false" procedure enables the operator to easily determine whether each guideline has been met. For example, Figure 3 shows the third module as determining the location of a VMS. Several requirements are included within that module, such as placing the VMS before major decision points in the most level area possible and where it is accessible to maintenance vehicles. If any of the requirements are not met, the operator is advised to consider either a different location for the VMS or an alternative form of communication, such as a static sign, a flagger, or highway advisory radio.

Figure 2 demonstrates the power of the manuals' guidelines for assisting an operator with a complex decision: how to relay distance information to the motorist. The operator is presented with each piece of information in a binary decision format. By following this decision tree an operator quickly learns whether a landmark, exit number, or distance in miles should be used.

A few key concepts are emphasized throughout the manuals. For example, the idea of giving the motorists a message that they can read twice is repeated in several modules: first, the maximum number of screens is established on the basis of traffic conditions; second, the message is designed such that only essential components are retained; third, the operator is asked to verify the message if it is longer than one screen. In this manner, operators can be sure that they have met basic VMS usage requirements without being prevented from using the VMS innovatively and effectively.

Mechanisms for Feedback from VMS Operators

The authors realize that these manuals must evolve to accommodate the needs of VMS operators if this work is to be useful. During training courses based on the manuals, therefore, comments will be solicited from VMS operators. One comment that has already been received from VDOT traffic engineers is that these manuals are more useful as a training tool and reference document than as a pamphlet that should be carried to the field each time a VMS is used. To reflect this change in emphasis, the guidelines are now formally known as a user's *manual.* A second comment that has been received is that the computational methods for determining the maximum number of screens could be expressed as some simple rules: one message screen is ideal, two are acceptable, and three should be used only under extreme circumstances. Thus, although the calculations for determining the amount of time a VMS is legible were used in the development of these manuals, it was not necessary for operators to redo those computations each time a VMS is used in the field.

The traffic engineers also recommended the addition of a "drive-through" module, explicitly stating that the operator should drive past the VMS to assess its effectiveness, with attention to such details as traffic or other obstructions that might hamper the view of the VMS, the amount of time each message screen is displayed, and a motorist's reaction if a VMS is not expected. Finally, a fourth comment illustrates the importance of keeping the manuals consistent with VDOT practices in other areas. The engineers noted that the word "next" had the potential to be confusing, as is the case with static signs. Therefore an additional module was developed that followed practices outlined in previous research and the current MUTCD guidelines (*14*). Additional comments of this nature will be sought and used to improve the manuals.

CONCLUSIONS

It is critical to consider the needs of both operators and motorists to maximize the effectiveness of VMSs. In developing VMS operators' manuals designed to help achieve this objective, essential lessons were learned. Operators need a set of guidelines rather than an extensive list of messages to fully use the capabilities of VMSs. The manuals developed through this research are in a format easily followed by an operator and they assist rather than replace the operator's decisions. Because they outline the thought process an operator should employ when using a VMS, the manuals may also serve as a training tool.

Credibility must be maintained to maximize the effectiveness of VMSs. VMSs should be used only to transmit essential information about changed traffic conditions. Information limitations of VMSs, confirmed by the literature and motorists, demonstrate that VMSs should use no more than two screens, and use of only one screen is preferred. Therefore VMSs should be used in conjunction with other communications mediums if it is necessary to convey detailed information to motorists. Finally, these manuals should be updated as additional feedback from VMS operators and motorists becomes available.

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REFERENCES

1. Miller, J. S., B. L. Smith, B. R. Newman, and M. J. Demetsky. *Development of Manuals for the Effective Use of Variable Message Signs.* Virginia Transportation Research Council, Charlottesville, 1995.
2. Upchurch, J., J. D. Armstrong, M. H. Baaj, and G. B. Thomas. Evaluation of Variable Message Signs: Target Value, Legibility, and Viewing Comfort. In *Transportation Research Record 1376,* TRB, National Research Council, Washington, D.C., 1992, pp. 35–44.
3. Dudek, C. L. *Guidelines on the Use of Changeable Message Signs.* Report FHWA-TS-90-043. FHWA, U.S. Department of Transportation, 1991.
4. Dudek, C. L. *Manual on Real-Time Motorist Information Displays.* Report FHWA-IP-86-16. FHWA, U.S. Department of Transportation, 1986.
5. Smith, S. A. *INFORM Evaluation, Volume I: Technical Report.* Report FHWA-RD-91-075. FHWA, U.S. Department of Transportation, 1991.
6. Dudek, C. L. *Guidelines on the Use of Changeable Message Signs-Summary Report.* Report FHWA-TS-91-002. FHWA, U.S. Department of Transportation, 1991.
7. *Guidelines for Use of Portable Changeable Message Signs.* Michigan Department of Transportation, n.d.
8. *Guidelines for the Use of Portable Changeable Message Signs in Work Zones.* Minnesota Department of Transportation Work Zone Safety Committee, St. Paul, 1994.
9. Commonwealth of Pennsylvania Department of Transportation. *S.R. 0095, Section Eye: Basic Message Library for the Variable Message Sign System.* Urban Engineers, Inc. and Ebasco Infrastructure, 1993.
10. Blodgett, F. J. *Changeable Message Sign, I-5, Vancouver Freeway.* (Experimental Feature WA75-02). Washington State Department of Transportation, 1987. Available from National Technical Information Service, Springfield, Va.
11. Voza, A. *Standard Guidelines for Variable Message Sign Operation, Version 1.0.* New Jersey Turnpike Authority, New Brunswick, 1993.
12. *Notice of Proposed Amendments to the Manual on Uniform Traffic Control Devices,* Part 6. FHWA, U.S. Department of Transportation, 1993, pp. 56–59.
13. Armstrong, J. D. *An Evaluation of Human Factors Aspects of Variable Message Signs on Freeways,* pp. 60–62. Arizona State University, Tempe, 1991.
14. Perfater, M. A. *Motorist Understanding of Directional Messages.* Virginia Transportation Research Council, Charlottesville, 1981.

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