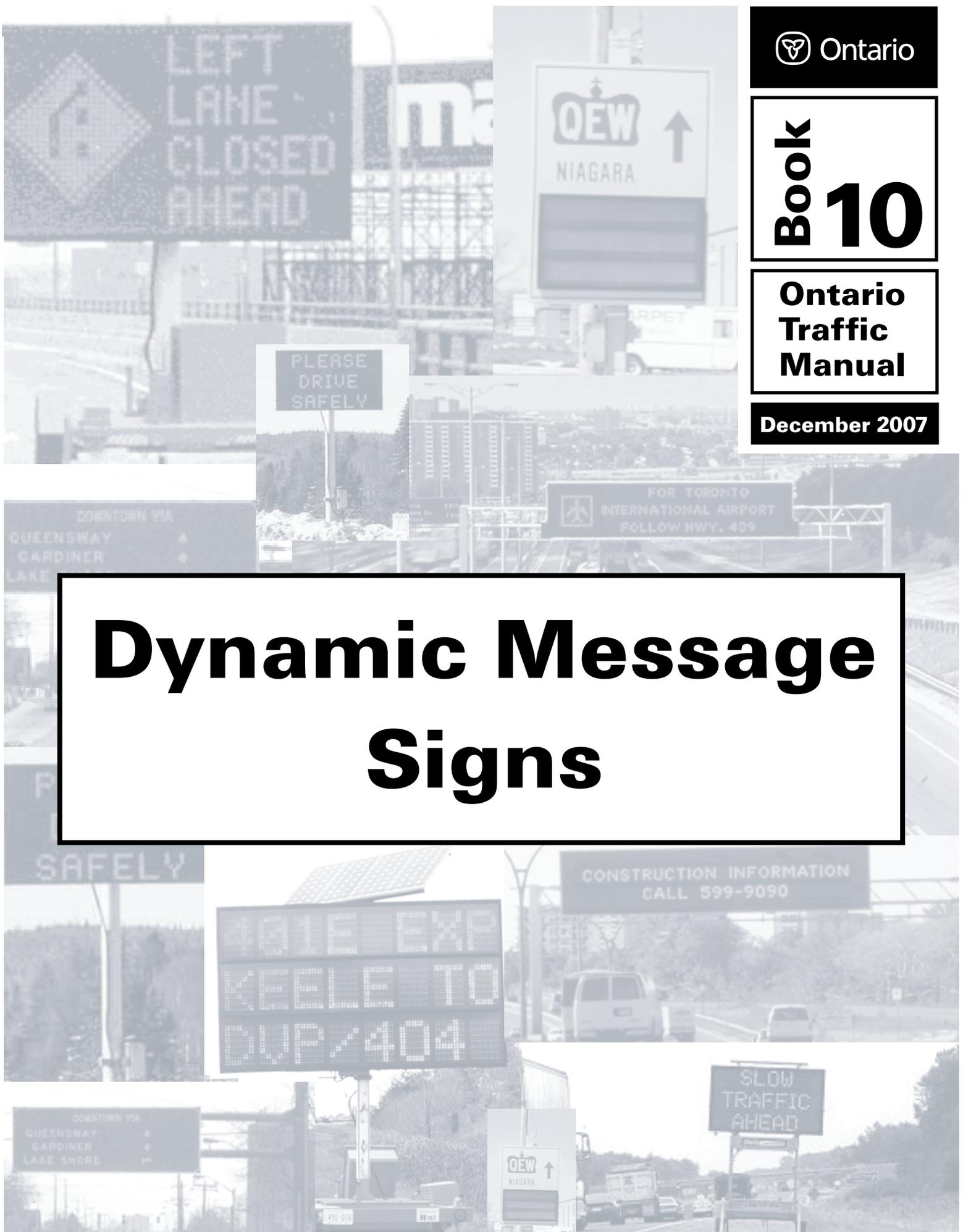


Dynamic Message Signs



Ontario Traffic Manual

Foreword

The purpose of the Ontario Traffic Manual (OTM) is to provide information and guidance for transportation practitioners and to promote uniformity of treatment in the design, application and operation of traffic control devices and systems across Ontario. Further purposes of the OTM are to provide a set of guidelines consistent with the intent of the Highway Traffic Act and to provide a basis for road authorities to generate or update their own guidelines and standards.

The OTM is made up of a number of Books, which are being generated over a period of time, and for which a process of continuous updating is planned. Through the updating process, it is proposed that the OTM will become more comprehensive and representative by including many traffic control devices and applications specific to municipal use. Some of the Books of the OTM are new, while others incorporate updated material from the Ontario Manual of Uniform Traffic Control Devices (MUTCD) and the King's Highway Guide Signing Policy Manual (KHGSPM).

The Ontario Traffic Manual is directed to its primary users, traffic practitioners. The OTM incorporates current best practices in the Province of Ontario. The interpretations, recommendations and guidelines in the Ontario Traffic Manual are intended to provide an understanding of traffic operations and they cover a broad range of traffic situations encountered in practice. They are based on many factors which may determine the specific design and operational effectiveness of traffic control systems. However, no manual can cover all contingencies or all cases encountered in the field. Therefore, field experience and knowledge of application are essential in deciding what to do in the absence of specific direction from the Manual itself and in overriding any recommendations in this Manual.

The traffic practitioner's fundamental responsibility is to exercise engineering judgement and experience on technical matters in the best interests of the public and workers. Guidelines are provided in the OTM to assist in making those judgements, but they should not be used as a substitute for judgement.

Design, application and operational guidelines and procedures should be used with judicious care and proper consideration of the prevailing circumstances. In some designs, applications, or operational features, the traffic practitioner's judgement is to meet or exceed a guideline while in others a guideline might not be met for sound reasons, such as space availability, yet still produce a design or operation which may be judged to be safe. Every effort should be made to stay as close to the guidelines as possible in situations like these, to document reasons for departures from them, and to maintain consistency of design so as not to violate driver expectations.

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A user response form is provided at the end of Book 1. Inquiries regarding the purchase and distribution of the OTM Books and the Master Sign Library (MSL) may be directed to the custodial office identified above, or to the OTM Committee's current publishing agent.

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1. Introduction

1.1 Purpose and Scope

Book 10 (Dynamic Message Signs) is one of a series of volumes that makes up the Ontario Traffic Manual (OTM). Book 10 should be read in conjunction with Book 1 (Introduction to the Ontario Traffic Manual) and its appendices, which contain considerable information about the fundamental principles and policies behind the design and application of traffic control signs, signals, markings and delineation devices. Applicable Ontario experience has also been provided to illustrate current practices within the Province of Ontario.

Other books in the OTM series provide practical guidance on a full range of traffic control devices and their applications. A complete listing of the planned and currently available volumes is found in Book 1, and an illustrated master index is found in Book 1a (Illustrated Sign and Signal Display Index).

This Book provides information about the planning, design, installation and operation of Dynamic Message Signs (DMSs) for use in outdoor, traffic management related applications. The information provided is by no means exhaustive and agencies are encouraged to refer to the research reports listed in the References section at the end of this book. Other applications, such as the use of DMSs in bus or rail passenger information systems or other specialized purposes are beyond the scope of this Book.

Earlier documents used the term “Changeable Message Signs” to encompass all signs that had the capability to display different messages. However, the term “Dynamic Message Signs” is now used to describe an array of sign technologies that have the capability of displaying different messages to suit changing conditions on the roadway. Included within the family of Dynamic Message Signs are full-matrix

displays, single-line or character-matrix displays, multiple pre-set message displays and simple on-off or “blank-out” displays. Although the term “Changeable Message Signs” has in the past been used in Ontario to describe the full family of sign technologies, the term “Dynamic Message Signs” is being adopted in the OTM to conform with standard terminology being adopted by the Joint Committee on the National Transportation Communications for ITS Protocol (NTCIP). The terms “Variable Message Signs” and “Changeable Message Signs” are used in the OTM to describe specific sub-sets of Dynamic Message Signs. The “variable” message sign is a type of sign in which the message to be displayed can be created and downloaded into a temporary memory area of the sign controller and displayed on the sign face. They can display a full array of message combinations. The “changeable” message sign is a type of sign which can display a small number of predefined messages or a blank message. Additional information about the different sign types and technologies is provided in the following sections of this Book.

The intent of Book 10 is to give sufficient information to the reader to ensure that he/she is aware of the key design elements that must be considered in the selection and use of Dynamic Message Signs. Typically, such signs are used within the context of a traffic management system. Information about the control systems for DMSs and how the signs fit within a traffic management system may be found in a companion volume, OTM Book 19 (Advanced Traffic Management Systems).

Portable Variable Message Signs (PVMSs) are often important for traffic control under temporary conditions, particularly in construction zones. For information on the application of PVMSs under temporary conditions, reference must be made to OTM Book 7 (Temporary Conditions).

1.2 Background

The ability to provide real-time or near real-time dynamic messages to motorists facilitates safer and more efficient use of existing roadways. As a result, motorists can experience less delay, reduced frustration and a safer environment, while transportation agencies can maximize the capacity of existing infrastructure and defer costly capital expenditures for infrastructure expansions. Dynamic Message Signs (DMSs) can provide diversion information in the event of partial or full closures, can enable network management by providing travel time and speed information on the different links, and can assist with route planning by notifying motorists of scheduled events that may impact roadway operation.

Considerable research work has been done on the effective design and use of Dynamic Message Signs over the thirty or more years that they have been in common use in North America, Japan and Europe. Sign technologies have changed. Although new technologies will no doubt emerge in the future, research has identified several fundamental factors that influence the effectiveness of all sign displays, independent of the technology in use. These fundamental factors govern the size, location, display characteristics and message content of Dynamic Message Signs, which are listed below. Within these guidelines, the most appropriate technology should be chosen to suit the particular combination of traffic management goals, functional requirements and available budget.

- **Conspicuity** – does the sign attract attention given the background in which it is placed?
- **Legibility** – at what distance can drivers read the sign?
- **Information load** – do drivers have sufficient time to read the entire message without unduly diverting their attention from the driving task?

- **Comprehension** – do drivers understand the meaning of the message, including any symbols and abbreviations used?
- **Driver response** – do drivers make the desired action as a result of reading the sign?

Additional information about these factors and how they affect sign design and the driver's ability to safely navigate within the traffic stream may be found in OTM Book 1b (Sign Design Principles) and in OTM Book 2 (Sign Design, Fabrication and Patterns). It should be noted that although the basic design principles apply to all signs, some of the specific information and comments presented in Book 1b are primarily applicable to fixed signing. Some examples include sign colour, shape and fonts, which are generally different for dynamic signs due to restrictions imposed by the technologies involved. These factors are explored further in Section 4 (Design Considerations).

2. Planning Considerations

Dynamic Message Signs (DMSs) are useful in many situations where traffic operations and safety can benefit from the ability to advise drivers of changing conditions in real-time or near real-time. They can be used in rural and urban settings on any classification of road. DMSs can be used for various purposes and can provide incident management, congestion advisory, queue advisory, route diversion, general speed management, work zone speed management, lane control, parking guidance, travel time advisory, and planned event information.

Dynamic Message Signs are typically implemented as part of an Advanced Traffic Management System (ATMS) and serve as the mechanism for providing information to motorists. The link between the DMSs and the ATMS is crucial as the ATMS is responsible for collecting the information that will be displayed on the DMS. Therefore, the size, location and type of DMS is dictated largely by the particular application, including specific messages to be displayed, or the type of system that it is supporting.

DMS planning is one component of overall planning for Advanced Traffic Management Systems, as described in Section 3 of OTM Book 19 (Advanced Traffic Management Systems). In order to make sound decisions on DMS type, technology and quantity, it is necessary to perform the preliminary planning steps, including establishing the goals and objectives to be fulfilled by the specific ATMS and selecting appropriate strategies to be delivered by the system.

In rural areas, DMSs can play a key safety role in locations that have a history of road closures due to poor road conditions as a result of weather (heavy fog, ice, drifting snow etc.). When placed in key

locations in advance of these hazard areas, the DMSs can be used to advise motorists of weather-related restrictions so that they can modify their travel plans accordingly.

In urban areas, Dynamic Message Signs form an integral part of freeway or urban arterial ATMSs, at varying levels of sophistication. For example, they can be linked to highly automated systems that collect various types of traffic information, such as traffic volume, speed and lane occupancy, in which the DMSs are used to automatically display congestion and travel time advisory messages. The opposite end of the spectrum is a more manual system that requires manual collection of information, selection of appropriate messages and control of the DMS.

Portable Variable Message Signs (PVMSs) can be useful for providing information or warning to drivers when temporary conditions are encountered, for example, where roadway alignment or lane configuration is altered during various stages of road construction, during roadway maintenance activities, or during special events. In all cases, the deployment of these portable devices has to be carefully managed (see Sections 3.3 and 4.4.5).

When the appropriate type of DMS has been selected to meet the functional requirements of a specific ATMS, the latter stages of planning need to consider placement of all DMSs within the physical constraints of the applicable roadways (see Section 4.4), including freeway, arterial and portable applications. Placement issues may impact DMS size and technology. Performance, reliability and maintenance issues (see Sections 3.1.2, 3.2.2, 3.3.2 and 6.5) also need to be considered in DMS planning, as they impact the DMS technology selected for the system.

DMSs can be used to support different types of Intelligent Transportation Systems (ITS) including Commercial Vehicle Operations (CVO) and Advanced Public Transit Systems (APTS). These types of applications for Dynamic Message Signs are considered to be outside the scope of this book. The general guidelines discussed in this book are still appropriate for these different types of applications; however specific details such as mounting and placement will need to be adapted to suit the application.

3. Dynamic Message Signs

There are several categories of Dynamic Message Signs (DMSs) available on the market, which will be referenced in this Book as Variable Message Signs (VMSs), Changeable Message Signs (CMSs) and Portable Variable Message Signs (PVMs). Each sign type provides real-time or near real-time information to motorists. The differences between these types of DMSs are determined by: the capability of the technology, the level of variation in the messages to be displayed, and the different levels of functionality that each type offers.

One of the first steps that an agency must undertake when determining which type of DMS to implement, is to develop a good understanding of the traffic management purposes for which the DMS will be used. This includes understanding the length, number and type of messages that will be displayed, as well as the frequency of use. Using this background information, the required functionality of the sign can be determined and the appropriate type chosen. Other factors, such as maintenance considerations and price, will also influence the selection of the signs.

The following sections describe the functionality of each DMS class, as well as the current technologies that are used for each sign type. Once an agency has decided on functionality requirements, the most appropriate technology may be selected.

3.1 Variable Message Signs

3.1.1 Functionality

Variable Message Signs (VMSs) provide the highest level of functionality of all of the DMSs and are consequently also the most expensive. As suggested by the name, VMSs contain a variable display, made up of a grid or matrix of discrete dots, known as pixels. Using different combinations of these discontinuous pixels, the sign appears to the human eye as if the display is actually a continuous formed character or graphic symbol. VMSs can display a full array of characters and spaces to form virtually any message combination and can also have full graphics capability.

VMSs are particularly effective tools for providing motorist information in an environment that experiences continuous and rapid change. The flexibility in message combinations and graphics ensures that the VMSs are capable of displaying any type of information. The VMSs are fully configurable and can be designed to meet an agency's specific requirements. This includes the number of lines as well as the number of characters per line.

There are three different classes of VMS, listed in ascending levels of functionality: Discrete Character Matrix; Line Matrix; and Full Matrix.

As the functionality increases so does the cost of the sign. However, greater functionality allows more flexibility in displaying content and improves legibility.

These different classes of VMSs can also be combined to form a combination sign. This combination sign can provide the appropriate level of flexibility at a reduced cost. From a functional standpoint, full-matrix or combination signs are preferred.

Discrete Character Matrix

A discrete character matrix sign has a display board containing an individual display module for each character, as illustrated in Figure 1. Characters are separated by a blank space. Each display module can display a full array of characters but only simple graphics, because the size of the graphic is limited to the size of the module. This limitation means that only simple graphics such as arrows can be displayed. The font is also restricted to characters that fit the size of the matrix, resulting in some letters, such as "X" or "W", being compressed. The discrete character matrix is the most economical type of VMS, however, the use of discrete character matrix signs has largely been eliminated in favour of more flexible designs.

Figure 1 – Discrete Character Matrix

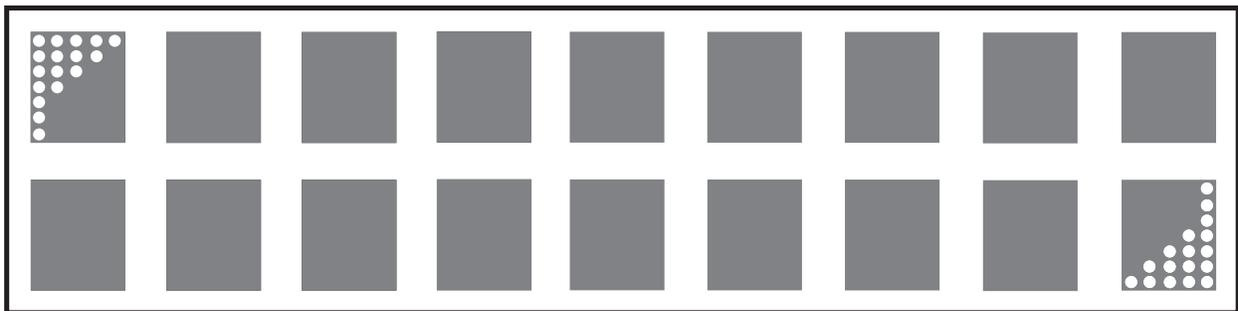


Figure 2 – Line Matrix



Line Matrix

A line-matrix sign has full-matrix capabilities along each line of standard character height and can display a full array of characters along that line, as illustrated in Figure 2. Typically, such a VMS will be made up of two or three lines. The line-matrix sign often has limited graphics capabilities as the height of the graphic is physically restricted by the height of the line. Also, if French language accents are required, a reduced height letter must be used to accommodate the letter and accent within the line height. The legibility of the line-matrix sign is better than the discrete character matrix sign because the characters can be fully formed and the fonts can be configurable, allowing for proportional spacing. Proportional spacing is discussed further in Section 4.2.2.

Full Matrix

A full-matrix sign offers the most flexibility of all of the VMSs. As Figure 3 indicates, the entire area of the sign face can be used for display; and can be divided into lines to display text messages, or used in its entirety to display full graphics, or broken into sections of text and graphics. These signs also allow for variation in the height of characters used for messages, e.g., French language accents over full-height letters are supported. The full-matrix signs are the most expensive type of sign.

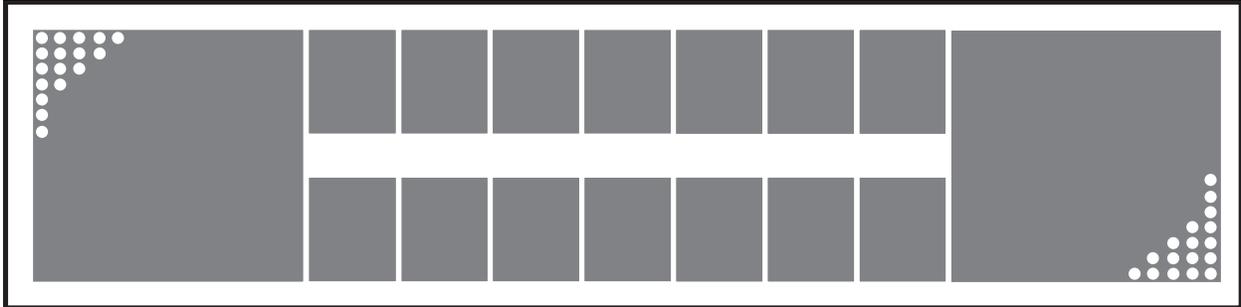
Combination

Combination signs integrate the different types of signs into one sign, depending on the functionality required for the different areas of the sign. For example, a full-matrix area could be provided on either end with line matrices in between, as illustrated in Figure 4. Combination signs can also

Figure 3 – Full Matrix



Figure 4 – Combination



be made up of both static and dynamic components. The advantage of combination signs is that they optimize functionality at a reduced cost. The disadvantage is reduced display flexibility, i.e., a particular sign configuration may not be ideally suited for applications such as French language accents over full-height letters.

3.1.2 Technology

There are various Variable Message Sign technologies available on the market, which have been developed over a period of time for use in different environments, e.g., roadway, advertising, pedestrian, indoor use and sporting arenas. Some of the technologies can be used in all environments, while other technologies, such as neon lighting, are best suited for non-traffic applications. Technologies such as incandescent bulb matrix and fluorescent flip-disc technology have been used in the past for DMSs and may still exist in some jurisdictions, but new installations are not recommended due to high operating and maintenance costs and the superior performance of alternative products.

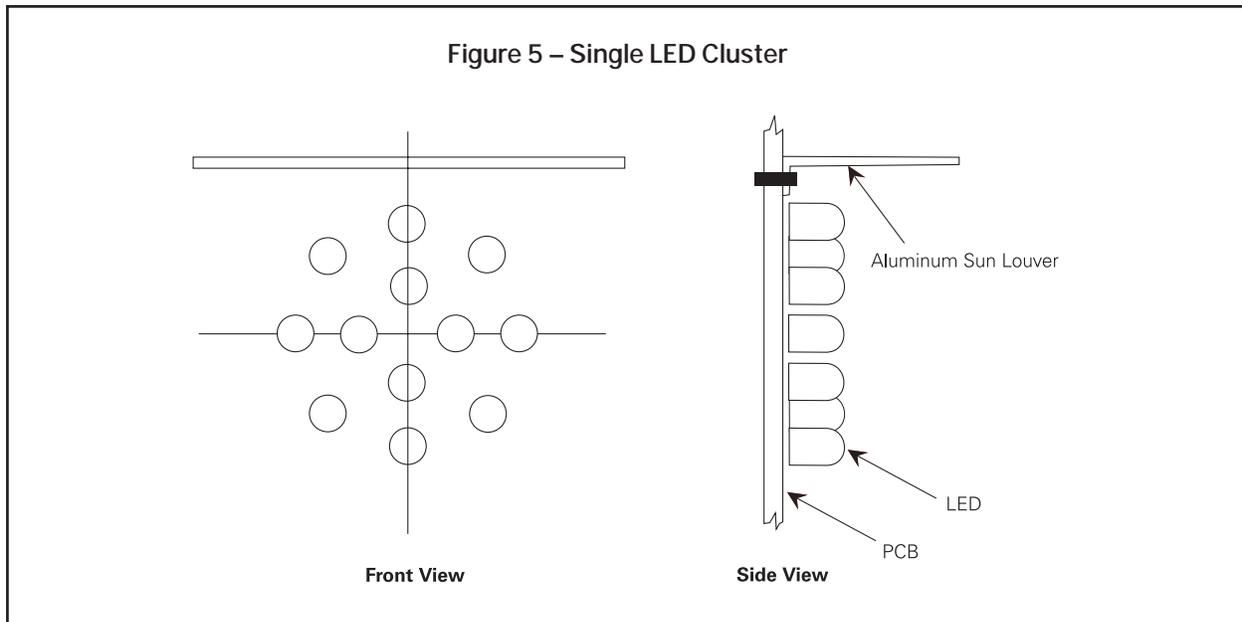
The technologies described below have been tested and used successfully in roadway environments. Alternative technologies to this list could be considered, but the transportation agency must ensure that the visual requirements discussed in

Sections 4.1 and 4.2 have been met and tested and that the technology can deliver the required functionality. Consideration should also be given to on-going operating and maintenance costs.

Light-emitting signs are now considered to be the only acceptable option for VMSs, as they provide the best visibility to motorists under different lighting conditions. There are three basic types of light-emitting signs in common use worldwide, with varying degrees of performance and reliability: light-emitting diode (LED), fibre optic, and hybrid signs. Fibre optic signs are the oldest of the three sign technologies and currently have limited availability in the North American market. Hybrid signs are considered to be obsolete. LED technology is currently the only viable VMS technology. Continuing availability of particular sign models of any technology can be uncertain, due to a particularly volatile supply industry.

Light-Emitting Diode (LED) VMSs

Light-emitting diode or LED VMSs are currently the preferred type of light-emitting sign technology. The pixels for LED signs are comprised of multiple light-emitting diodes, which are solid state electronic devices that glow when a voltage is applied. Various techniques are available to adjust the luminance of the sign to ambient light conditions.



Individual pixels are typically comprised of multiple strings of LEDs connected so that if one string fails the other strings will still emit light, reducing the risk of a total pixel failure. LEDs have a very high reliability with over 150,000 hours of continuous operation expected. The low power requirements coupled with the long life and high reliability have resulted in the LED VMSs becoming the most popular type of light-emitting VMS.

Some earlier examples of LED signs had pixels made up of a combination of red and green LEDs to give an amber colour display. However, the different colour LEDs did not age at the same rate, causing colour shifts and loss of colour uniformity across the sign. In subsequent development, LED manufacturers designed and produced high-intensity yellow/amber LEDs with an emitted light wavelength of 590 nanometres (nm), which has become the *de facto* standard output for VMSs in traffic applications. Signs are now available with as few as four high-intensity LEDs per pixel, focussed through a special lens. Recently, a white LED has been developed, which is now available in signs

from at least one VMS manufacturer; however, there is as yet no long-term experience with these LEDs. Figure 5 illustrates a single pixel from a LED-type VMS.

Full-matrix LED signs sometimes use pixels of red, green and blue LEDs to generate the full spectrum of colours. While these signs have been used mainly as scoreboard displays in stadiums and as billboard advertisements in North America, there are a few examples of their use in transportation applications in South America. These signs are expensive, making them an unlikely technology for widespread transportation applications in North America.

It can be expected that continuous improvements will be made to LED technology, resulting in changing price and performance characteristics. It will therefore be important to monitor how well the VMS manufacturers incorporate these developments into their products.

3.1.3 Ontario Experience

The Ministry of Transportation Ontario has implemented several types of VMSs with varying levels of functionality over the past 25 years, including discrete character matrix signs, line-matrix signs and combination signs. Technologies have included fluorescent flip-disk, fibre optic flip-disk and LED signs. All of the original fluorescent flip-disc signs were replaced a number of years ago. MTO has been very active in the development of LED displays since 1989, and the current MTO approach is to deploy only LED-based VMSs. The few remaining fibre optic flip-disk signs are scheduled for replacement in the near future. Early generation LED displays utilized pixels which combined red and green LEDs to achieve the desired amber colour.

Over time the LEDs tended to degrade at varying rates contributing to non-uniform discolouration and light output. These early generation displays have since been upgraded to current high-output amber LED pixels.

The Ministry's current standard for overhead gantry-mounted VMSs is a combination sign as illustrated in Figure 6. The display contains a full-matrix graphics display element at each end of the sign face, comprised of display modules (each with 35 pixels in a 5 x 7 matrix) arranged in five horizontal rows and seven vertical columns giving a 35 x 35 pixel display. Between these two full graphics panels is a three line matrix, each line comprised of 21 display modules, giving a 105 x 7 pixel display.

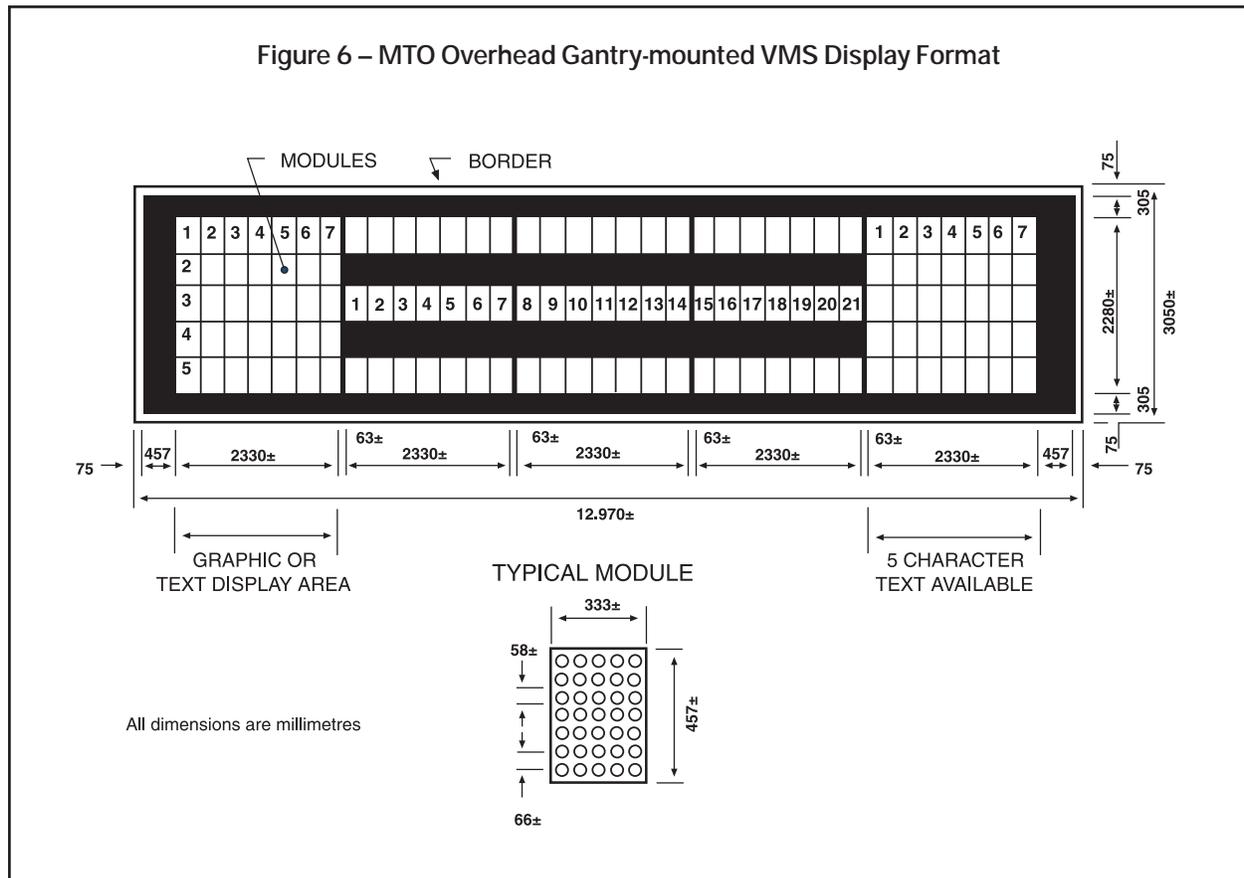


Figure 7 – MTO Overhead Gantry-mounted VMS



MTO originally developed the combination sign for implementation throughout the Highway 401 corridor in order to be able to display full graphics, such as exit arrows and highway identification shields, on either end of the sign. Through the middle section of the sign, text messages are displayed to motorists and therefore the full functionality of a full-matrix sign is not required. Line matrices were specified instead in order to reduce cost. Figure 7 depicts a MTO overhead gantry-mounted VMS on Highway 401, Toronto.

A different VMS configuration is used on undivided highways and freeways where there are two or less lanes per direction. Figure 8 shows an example of a roadside-mounted (cantilever) VMS located on

Highway 69. The VMS is full matrix in its entirety, and is 105 pixels wide by 30 pixels high. Three lines of text can be displayed on the VMS, and the display width is about 60% that of the standard MTO overhead gantry-mounted VMS illustrated in Figure 6.

Different VMS designs have resulted not only from technological advances, but also from variations in the intended function of the display and the location of the sign being installed.

MTO has implemented combination signs for the Queue Warning System on the Queen Elizabeth Way in Fort Erie, on Highway 405 in Niagara Falls, and Highway 402 in Sarnia. The signs consist of a static

Figure 8 – MTO Roadside-mounted (Cantilever) VMS



sign, amber flashers, and a single line-matrix LED VMS. Figure 9 depicts an MTO combination sign for the Queue Warning System.

When procuring VMSs, several months lead time are usually required for delivery, as each order is custom made to suit the needs of the purchaser. VMSs are not generally commercially available as off-the-shelf items.

Figure 9 – MTO Combination Sign for the Queue Warning System



3.2 Changeable Message Signs

3.2.1 Functionality

The class of Dynamic Message Signs known as Changeable Message Signs (CMSs) also provides dynamic information to motorists; however, only a limited number of messages can be displayed. The messages are pre-defined and, unlike on VMSs, cannot be individually configured. One type of CMS is known as a Blank-out Sign.

Blank-out signs have two states, either on or off. When the Blank-out Sign is off, no message is displayed. When the sign is on, a pre-determined message is displayed to motorists. This type of sign is effective in situations where the agency wishes to advise motorists that a particular condition either exists or does not exist. Examples might include a ramp, road or bridge closure or turn restrictions that only apply at certain times of the day. When the Blank-out Sign is in its default state (off), the motorist can assume that the condition is not present.

Pre-set message signs are capable of displaying one of several static messages to motorists. The specific messages available are fixed, but there is flexibility in which message to display. This type of CMS is useful in providing, for example, information on levels of congestion or alternate routes to major attractions.

3.2.2 Technology

There are several different types of CMS technologies on the market. In Ontario, the types that are used include the light-emitting Blank-out Sign, the Fold-out or Flap Sign, the Rotating Drum/Prism Sign, and the Fixed-matrix Sign.

Blank-out Sign

The Blank-out Sign is a light-emitting sign that only has two phases: either on or off. The technology used for these signs includes:

- Formed neon-type clear glass tubing on a painted background;
- Fluorescent lamps behind a cut out legend;
- Fibre optics in a fixed pattern; or
- LEDs in a fixed pattern.

When the CMS is on, the fixed message is illuminated. Otherwise, no message is displayed. Depending on the level of system automation desired, the signs can be operated either manually, whereby an operator is responsible for activating a message, or automatically, whereby if a particular condition is met, the sign message is automatically displayed.

These technologies have a reasonably good maintenance experience because there are few moving parts. The neon and fluorescent types may have some difficulty in start-up during very cold weather.

Fold-out/Flap Sign

The Fold-out/Flap Sign is a non-light-emitting sign. It is a conventional-looking highway sign that has a hinged or louvered viewing face, generally operated by a motor. When the hinged face is open, motorists can view the front of the sign face and see a typical standard static sign. When closed, only the back side of the hinged section is visible. These signs can be used very effectively at intersections where right or left turns are only permitted during certain periods of the day and also to support transit applications where motorists are allowed to enter a transit right of way only during off-peak hours. As the signs are made from the same material as static signs, they

are identical in look and can easily conform to the regulatory requirements. The design of the legend for these signs must be in conformance with the standards for highway signs. See OTM Book 2 (Sign Design, Fabrication and Patterns).

Fold-out/Flap Signs have been known to experience significant maintenance problems due to the exposure of moving parts to the environment.

Rotating Drum/Prism Sign

The Rotating Drum/Prism sign is a non-light-emitting sign. Typically, the viewing face is similar in appearance to that of the conventional highway sign. Designs used to form the message include raised sheet metal letters on a painted aluminum background, spray masked lettering on painted aluminum sheeting, reflective sign sheeting or translucent plastic background. Rotating Drum/Prism Signs typically have two or more active messages and a default or blank state that can be displayed to the motorist. Messages are displayed by rotating the drums to the appropriate viewing position. Each drum typically has three to six faces to display different messages. The overall number and combinations of messages that can be displayed increases with the number of drums used for each sign. As a result, rotating drum signs have the highest functionality of all the CMSs. Rotating drum signs are relatively inexpensive to operate and maintain, however, the moving parts such as motors and drive mechanisms and drum position switches are susceptible to wear and damage. Winter weather conditions can cause snow and ice build-up, which can restrict or prohibit movement of the sign panels. For these reasons, the rotating drum/prism is not recommended as a CMS technology.

Fixed-matrix Sign

With this type of sign a message is created on the sign by arranging LEDs or fibre optics on the sign face to make up the desired message. Additional messages are created on the sign face in the same

way. The desired message is displayed by turning on only the LEDs or fibres for that message. A common example of this type of sign is the pedestrian walk/don't walk signals used at many traffic signal installations where both messages are displayed on the same sign face.

The number of messages is limited by the space on the sign face. Generally only a few messages will fit.

3.2.3 Ontario Experience

The City of Toronto uses lane control signs to operate the reversible lane on Jarvis Street. These lane control signs consist of LED lane control modules. They are primarily installed as pairs of single heads (back to back, facing opposite directions). A typical lane control sign installation on Jarvis Street in the City of Toronto is shown in Figure 10.

The City of Toronto uses mechanical louvered signs to display turn restrictions by time of day, generally controlled through an output from the traffic signal controller. These mechanical signs typically require two to three preventive maintenance visits per year. The signs seize (stop moving) from time to time,

Figure 10 – Jarvis Street Lane Control Signs



Figure 11 – Thorold Tunnel Lane Control Signs



requiring immediate maintenance. Any lack of reliability causes concern over the enforcement of turn restrictions at locations with mechanical signs.

The Thorold Tunnel on Highway 58, which crosses under the Welland Canal, incorporates a lane control system for traffic control during normal operations and during maintenance or emergency situations within the tunnel. The dual tube tunnel has two lanes in each direction. Lane control signs are mounted at the ceiling of the entrance and exit portals and throughout the tunnel, to show that the lane is either open (green arrow), or closed (red "X"). Figure 11 shows the Thorold Tunnel lane control signs.

The Champlain Bridge is a three-lane structure spanning the Ottawa River between Ottawa, Ontario and Gatineau, Quebec. The centre lane is reversible, and functions as an HOV (High Occupancy Vehicle) lane for buses, taxis and vehicles with two or more occupants. The reversible traffic flow is governed by peak-hour traffic volumes. Hours of priority operation are midnight to noon (flow from Gatineau to Ottawa)

and noon to midnight (flow from Ottawa to Gatineau). Overhead, double-sided, lane-control signs displaying either a downward green arrow or red "X" indicate the lanes available for each traffic direction. The overhead signs are supplemented by side-mounted blank-out signs, activated only for the stream including the HOV lane. The Champlain Bridge lane control sign system is shown in Figure 12.

Figure 12 – Champlain Bridge Lane Control Signs



In work zones, the MTO has started to install radar-linked Portable Variable Speed Display Signs that display the speed of an approaching vehicle. The display elements are light-emitting diode (LED) technology, and the sign is capable of displaying speeds from 0 to 140 km/h (i.e., 3 digits). The active sign display is a minimum of 200 mm high and should be clearly legible from any part of the approach lanes from distances between 45 m and 200 m.

3.3 Portable Variable Message Signs

3.3.1 Functionality

Portable Variable Message Signs (PVMSs) typically have the same functionality and basic design as fixed-location Variable Message Signs and are comprised of discrete characters or full-matrix arrangements. They should meet the same optical requirements as the other light-emitting DMSs and are subject to the same character height requirements. Full-matrix PVMSs provide more display flexibility than discrete character matrix signs. The primary difference between PVMSs and regular, fixed VMSs is their smaller size and hence reduced message display capability. It is possible to use CMSs in a portable configuration, however, the limited display capability is not well suited for use in a temporary environment.

Portable Variable Message Signs should only be used for situations where the conditions are changing. In general PVMSs could be used in the following conditions:

- Advanced notification of closures due to construction. The notification period should not exceed 9 days.
- Advanced notification of major special events impacting traffic. The notification period should not exceed 9 days.
- Notification of initiation of long-term changes in road configuration (e.g., lane closures, lane openings, HOV lane openings, etc.).
- Temporary notification of long-term conditions in the interim until static signs can be manufactured. A PVMS may be used for up to one week while a static sign is being manufactured.
- Notification of a construction zone and/or a reduced speed limit.

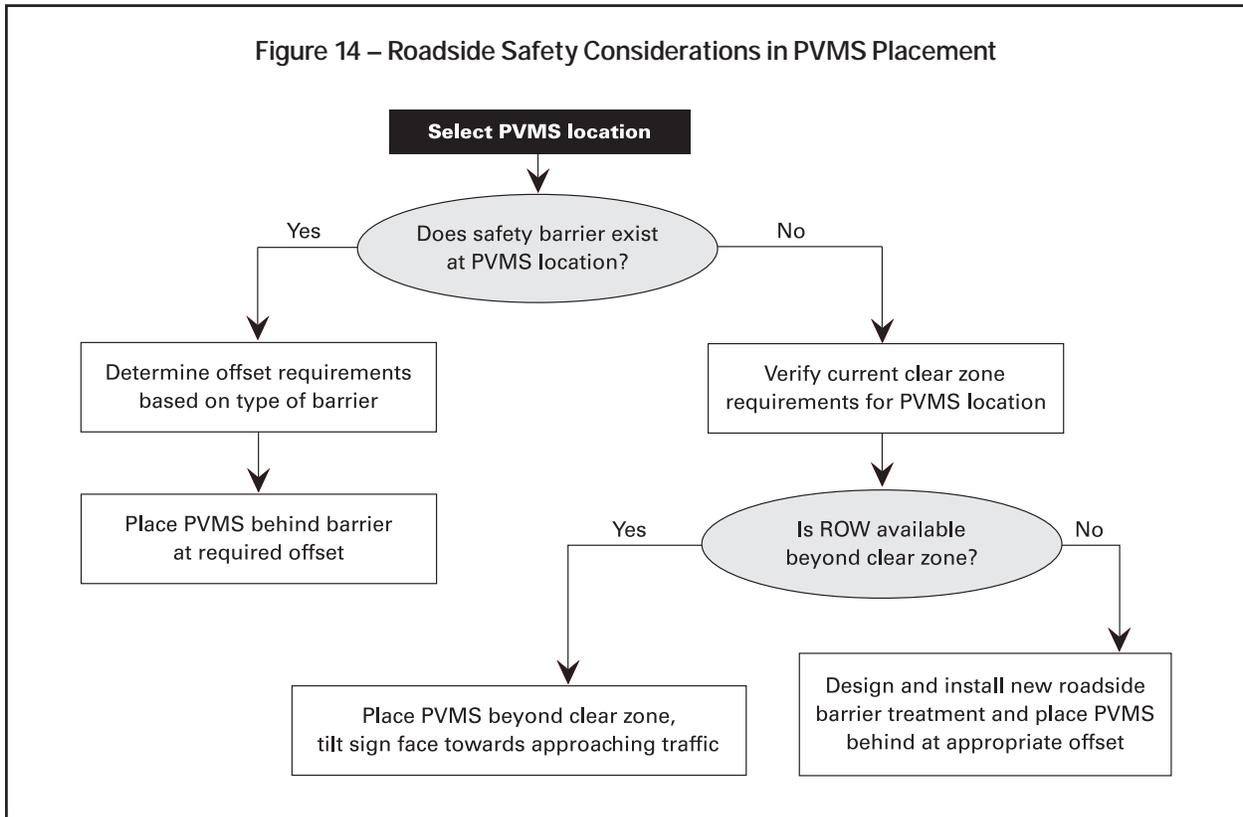
PVMSs help alleviate congestion by providing advance warning of unusual conditions ahead, providing the motorist the opportunity to alter travel plans. Figure 13 depicts a PVMS providing advance warning of a lane closure.

PVMSs should never be used for advertising an event. Their use should be limited to the display of traffic-related information only.

PVMSs have to be easily moveable and placed where they can be readily seen from the roadway without compromising public safety. The signs should, where possible, be placed in an area with existing barrier protection. If this is not possible, they must be located a sufficient distance away from moving traffic so as not to introduce a hazard to motorists. Figure 14 provides the logic to be followed when determining the appropriate location and protection for a PVMS. Substantial additional information about the application of PVMSs in temporary situations may be found in OTM Book 7 (Temporary Conditions). In no case should a PVMS be considered in a roadway work zone without reference to Book 7.

Figure 13 – Portable Variable Message Sign





The relatively small size of PVMSs can severely restrict the length of message that can be displayed. Care must therefore be taken to ensure that the message is simple, clear and readily understood. Two-phase messages can be used to expand the message display capability of the signs.

Where PVMSs are introduced into an area already containing permanent VMSs operated as part of an ATMS, care must be taken to ensure that the two signs are operated in a co-ordinated manner, so that the message on one sign does not conflict with the other, or with the actual traffic conditions on the road. The dynamic nature of the signs leads the public to believe that the information displayed is updated regularly, and considerable loss of credibility can result if two signs display conflicting information.

Other issues to be resolved when using PVMSs include securing reliable power supply and data communications, as well as security against vandalism. Because they are portable and are often operated at remote sites, the majority of signs use batteries that are recharged, either by solar panels or diesel generators. Consequently, some signs may not operate continuously over a 24-hour period without periodic inspection. Additional information relating to power supply can be found in Section 6.2. Communications to temporary sites can also be a challenge if the intent is to change messages without requiring a site visit. Security issues also arise with PVMSs: wheels and towing devices should always be removed to prevent theft, and vandal-proof locks should be installed on all controls.

Useful guidelines and cautions for the deployment of PVMSs include:

- The use of the signs on a 24-hour daily basis requires careful management to prevent draining the batteries;
- Retro-reflective display borders help to improve conspicuity;
- Finding safe mounting locations with good visibility can be a challenge on urban freeways, as the signs will frequently not fit on the available shoulder area;
- Wherever possible, the signs should be controlled centrally by the road authority.

3.3.2 Technology

See Section 3.1.2 for a description of the different types of technology that can be used for PVMSs. Due to power supply limitations and fewer moving parts, PVMSs using LED technology provide a more viable and robust sign than other types of light-emitting technologies. LED is the only technology currently allowed on Provincial Highways.

3.3.3 Ontario Experience

PVMSs are used by the Ministry of Transportation Ontario as well as numerous municipalities across Ontario for a variety of traffic applications, the most popular being to support construction work zones or to help manage scheduled events that draw large crowds.

There are essentially three types of PVMSs approved for use on the provincial highway network: trailer-mounted temporary, trailer-mounted semi-permanent, and pole-mounted PVMSs.

There are several methods of obtaining the required PVMSs:

- (1) MTO regions purchase a fleet of signs through a stand-alone contract,
- (2) Contractor purchases PVMSs as part of a construction contract; PVMSs would be owned by MTO at the completion of the contract, or
- (3) Contractor provides his own or rented PVMSs for the duration of the contract.

The MTO prefers to procure PVMSs through a stand-alone contract which includes a provision for movement of the signs. This provides the MTO flexibility in the location of the signs as well as their operation, with messaging typically controlled through a local COMPASS operations centre. The MTO is moving forward with deployment of fleets of PVMSs, with GPS tracking, and NTCIP communication protocol.

4. Design Considerations

There are five important factors to be considered in the planning, design and selection of DMSs to ensure their successful application. The description of these factors also applies to PVMs, except where noted otherwise. The five factors include:

- (1) **Conspicuity** – does the sign attract attention, given the background in which it is placed? This is a function of both sign technology and design as well as the physical environment.
- (2) **Legibility** – at what distance can drivers read the sign? Legibility depends on character height, font style and spacing, contrast ratio, the spacing of characters, words and lines and the aiming of the sign.
- (3) **Information load** – do drivers have sufficient time to read the entire message?
- (4) **Comprehension** – do drivers understand the meaning of the message, including any symbols and abbreviations used? Consistent message information is required, particularly for geographic descriptions, abbreviations and amount of information presented.
- (5) **Driver response** – do drivers make the desired action as a result of reading the sign? To respond appropriately, drivers must have adequate time (distance) to respond to the message. This will depend on the location of the DMSs relative to routing decision points.

An additional issue, especially for DMSs providing information in real time or near real time, is **credibility of information**, that is, whether drivers can rely on the information displayed. This will depend on how the source information is obtained, the timeliness of information updates and how well the system is managed and operated.

This section addresses the physical design and message composition issues that relate to the conspicuity, legibility and comprehension of Dynamic Message Signs. An agency can help ensure the successful implementation of DMSs by reviewing, understanding and implementing the following design considerations.

In practice, many variables must be considered in DMS application:

- traffic often travels in excess of the posted speed in uncongested conditions;
- sign visibility is frequently impaired by weather conditions or the presence of large trucks;
- a significant segment of the driving population does not have 20/20 vision;
- there continues to be an increasing number of aging drivers, some of whom experience poor night vision.

Whenever there is any doubt, design standards should always be raised rather than lowered.

4.1 Optical Characteristics

It is important to establish minimum optical performance characteristics for DMSs to ensure consistent visibility under various applications and environmental conditions. The objective is to consistently achieve:

- Visibility at 300 m for high-speed arterial road or freeway applications;
- Visibility at 200 m for lower-speed applications (Dudek).

The parameters used to define the optical performance characteristics vary, depending on whether the DMS is light emitting or non-light emitting. Book 1b (Sign Design Principles) and Book 2 (Sign Design, Fabrication and Patterns) apply to all types of non-light-emitting signs, whether they are DMSs or static signs. Therefore, for non-light-emitting signs, the guidelines detailed in Book 1b and Book 2 should be followed.

The parameters used to establish optical characteristics for light-emitting signs are colour, luminance, contrast ratio, and viewing angle. There have been numerous technical reports and specifications prepared around the world that provide significant detail about each of the performance requirements. Detailed technical specifications are beyond the scope of this Book. Any agency that is contemplating installing a light-emitting DMS should refer directly to these documents and specifications for assistance in determining requirements. Examples of current specifications include:

- (1) Ministry of Transportation Ontario Special Provision 685S01 – Changeable Message Signs; and
- (2) Highways Agency UK Specification TR2136 (Issue B) – Optical Performance Functional Specification for Discontinuous Variable Message Signs. This Specification has also been adopted as the European standard,

The optical characteristics described below were developed for permanent overhead VMS applications. It is intended that they also apply to PVMS applications.

4.1.1 Colour

Several colours can be displayed on DMSs, depending on the technology that is utilized: amber, white, red, green and blue. The most visible of these colours, and the most commonly used for text messages, is amber or white. The choice of colour is often limited by the technology chosen. Until recently, LED-based DMSs were unable to display white light, therefore amber became the preferred colour, with a nominal wavelength of 590 ± 5 nanometres. White LEDs have not yet been widely used in transportation applications, so experience to date is limited.

Colours other than white or amber are not commonly used, due to their lower contrast values. One exception is when the DMS must display regulatory information and red is introduced into the DMS, usually on non-light-emitting signs only.

Regardless of which type of technology is used, the colour of all pixels should be uniform across the display.

4.1.2 Luminance

The light output of the sign, or luminance, is measured in candelas per square metre (cd/m^2). Each DMS should be capable of achieving a luminance of $10,000 \text{ cd}/\text{m}^2$. This typically equates to a luminance of not less than 40 candela (cd) per pixel at the brightest level for a full 5×7 matrix of amber or white DMS pixels, with all pixels activated at their maximum design output.

Colours other than amber or white should not be used, as the maximum achievable luminance for other colours is approximately 50% or less lower than white or amber. Consequently, it may not be possible to achieve the desired luminance, making the DMS difficult for motorists to see under certain conditions.

PVMSs using solar power are now capable of meeting the luminance output requirements.

There must be a mechanism for the luminance to be controlled both automatically and manually, depending on the ambient light level, in order to provide the best visibility for motorists. During the brightest period of the day, and particularly with direct sunlight on the sign face, the DMS will be operating at the high end of the luminance range. During the night, the DMS will operate at the low end of the luminance range, otherwise the DMS would cause considerable glare to the motorist. Unless the DMS is operated in manual mode, the controller is responsible for assigning the luminance. It should be capable of assigning a pixel output within a range of 1 cd to 40 cd, depending on the ambient light characteristics, as measured by an appropriately designed photo sensor array on the display.

The readings from the photo sensor array should be averaged over a suitable period of time, approximately 30 to 60 seconds, so that the DMS intensity is unaffected by transitory changes in external illumination, such as passing clouds.

4.1.3 Luminance Ratio

Rather than the pure luminance output of a sign, it is actually the contrast between the legend (i.e., text, symbol, border) and the background of the sign which provides the legibility of the message to the driver. This characteristic is known as the Luminance Ratio. The VMS must provide a suitable level of contrast between activated and non-activated areas of the display in order to provide the necessary legibility. The luminance ratio for light-emitting signs defined in the current MTO specifications is 10 to 1 for permanent VMSs (both overhead gantry- and

roadside-mounted) and 6 to 1 for PVMSs with external illuminance ranging from 400 lux to 40,000 lux. This requirement is consistent with the current European standard.

At the lower ambient light levels, the contrast ratio becomes less critical for light-emitting signs than for reflective signs. (Ref. CEN/TC 226 EN 12966-1.)

The luminance ratio is tested under laboratory conditions utilizing a standard methodology and is calculated as follows:

$$\text{Luminance Ratio} = (L_a - L_b) \div L_b$$

Where:

L_a = The measured luminance (cd/m^2) of the element in the ON-state.

L_b = The measured luminance (cd/m^2) of the element in the OFF-state.

The luminance output of LEDs, and hence the contrast, typically degrades over time. Therefore, VMSs using this type of technology should be developed to compensate for this loss in luminance. VMSs should be specified for the LEDs to be powered at less than 100% of the maximum output when new. Then, as the LEDs age, the power output can be increased, thereby maintaining the required luminance level. Running the sign at less than maximum output will also prolong the life of the LEDs.

Care must be taken to maintain contrast ratio and legibility, which can be adversely affected by direct sunlight. To overcome these problems it has been necessary to screen LEDs with sunvisors, louvers and blinds. For example, a 52 mm diameter pixel has to be set back into a sun visor about 200 mm to protect the LED from sunlight.

4.1.4 Ontario Experience

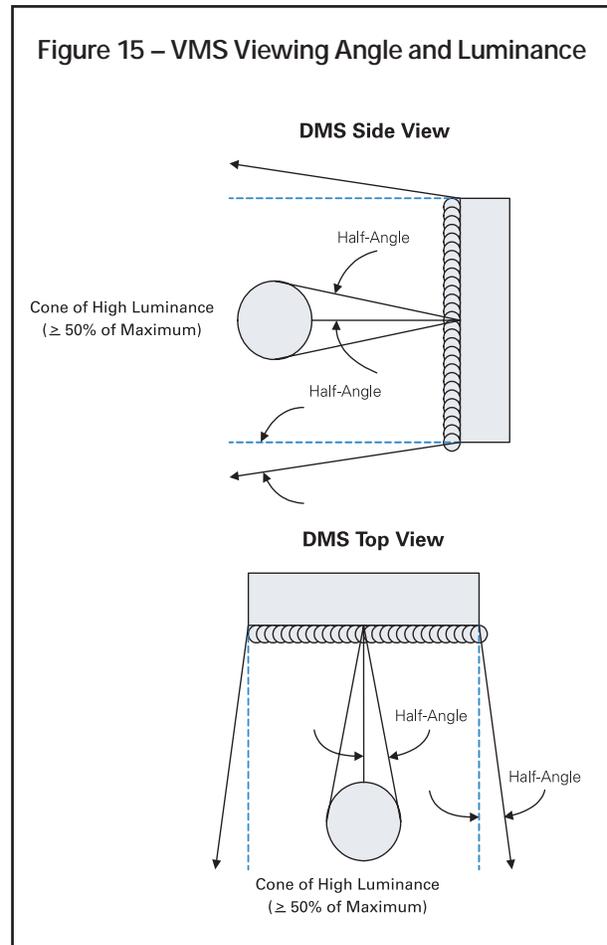
Experience to date in Ontario with both the City of Toronto and the Ministry of Transportation Ontario has been to use a black matte background material behind a non-glare polycarbonate sheet. This combination with the amber/white light provides very good contrast and enhances the legibility of the DMS.

The MTO has also introduced a 75 mm wide strip of fluorescent retro-reflective chartreuse or strong yellow-green sign material as a border around the perimeter of the sign case to enhance the conspicuity of the sign, making it stand out better against an ambient background, particularly at night. This is consistent with accepted practice in static signs.

4.1.5 Viewing Angle

With light-emitting signs, the angle at which the sign is viewed is very important, due to the properties of the light sources. As light travels in a straight line with minimal dispersion, there is a relatively narrow cone of vision where the light can be viewed at full intensity. This is a particularly significant property of LED-based signs. As a result, the alignment of the signs becomes an important issue, to ensure that the message is not truncated for the observer at more extreme viewing angles and motorists can view the message at the highest possible luminance value.

The viewing angle can be influenced by the technology and the designs that are used by different manufacturers. For example, with LED technology there are different designs and patents relating to the “bundling” of pixels into the display element. One manufacturer has developed a patent for a lens that encapsulates the LED, causing internal refraction, thereby increasing the luminance of each LED pixel as there is less light lost to



dispersion. High luminance at larger viewing angles enables increased flexibility for installing DMSs in more challenging environments, e.g., grade changes. When specifying and testing light-emitting VMSs, it is good practice to ensure that the luminous intensity of a VMS pixel does not decrease more than 50% when viewed at a specified angle, measured off centre from the optical axis and perpendicular to the display surface (the half-angle). Figure 15 illustrates the viewing angle and its relationship to luminance. See Appendix B (References) for documents containing additional information about the test specifications and testing methodology for optical output of VMSs.

Due to the importance of viewing angle to legibility, it is critical that PVMSs be carefully aimed when installed to maximize the viewing time for the driver.

4.1.6 Ontario Experience

In Ontario, a standard specification for light-emitting VMSs has been developed whereby the luminance does not decrease by more than 50% when viewed at a minimum half-angle of 7.5 degrees from the optical axis and perpendicular to the surface of the display. This has proven to accommodate the required viewing area in most highway situations.

4.2 Display Characteristics and Requirements

Several key display characteristics, which significantly affect the legibility and hence the effectiveness of a Dynamic Message Sign, must be taken into consideration when preparing specifications for the purchase of DMSs. These characteristics include character and line spacing, fonts, and the use of symbols.

4.2.1 Spacing

Line spacing and character spacing are important factors that increase legibility of characters by providing dark space around each character. This blank area ensures that each character stands out on its own and does not blend together with adjacent characters. Typically, spacing is referenced in terms of pixels.

Line spacing should be a minimum of 3 to 4 pixels and character spacing should be 2 pixels. Spacing between words is typically one character width or 9 pixels (a 5-pixel character plus a 2-pixel space on either side). For line-matrix signs the line spacing is

achieved by having no pixels along the permanent strip between the lines, while for full-matrix signs, the spacing is achieved through rows of unlit pixels. Both methods will meet the required contrast ratios. With more sophisticated sign control capabilities, such as proportional spacing discussed below, some variation to these guidelines is possible.

4.2.2 Fonts

In situations where the sign technology has the capability of displaying standard fixed highway signing fonts, alphabets, symbols, etc., such as through the use of reflective sheeting on rotating prism CMSs, the fixed signing design guidelines outlined in Book 1b (Sign Design Principles) and Book 2 (Sign Design, Fabrication and Patterns) will apply.

In the case of light-emitting matrix signs however, the inherent restrictions imposed by the matrix of individual pixels that make up the display present a significant challenge to achieving good sign legibility. A series of dots simply cannot offer the same clarity in font design as is available on fixed signs. Specific design aspects that are relevant include:

- character height/width aspect ratio;
- character height/stroke width;
- character spacing;
- borders;
- use of serifs to aid distinction between similar characters;
- upper/lower case.

These design parameters are incorporated in various combinations to create different font sets.

In general, the higher the pixel resolution on the display, the more closely the font can resemble an ideal font design. Higher pixel resolution also increases the complexity and hence the cost of the sign. Some trade-offs must therefore be made in the selection of the most appropriate sign for the intended application.

Based on much research and practical experience, the minimum pixel density necessary to display a full alphabet of upper case characters for use in highway applications is a matrix of five pixels wide by seven pixels high (5 x 7). This is a nominal requirement, as the configuration is actually different for each character, and is influenced by whether the display is a continuous matrix or discrete characters. Where a full-matrix or line-matrix sign has the capability to accept varied width characters, the font illustrated in Figure 16 and Table 1 should be used. For a discrete character matrix VMS or where the control software is unable to accept varied width characters, a fixed 5 x 7 matrix font set must be used, although characters such as X and W will be compressed. On PVMs a mixture of 4 x 7 matrix font letters and 5 x 7 matrix font letters, as illustrated in Figure 17, has been used to allow more text on these narrower signs. While this font is more difficult to read, this is a trade-off to achieve more complete messages.

Lower-case characters require additional rows of pixels to accommodate the ascenders and descenders of the characters. The minimum requirement for lower case character display is a nominal 7 x 9 matrix, which adds significantly to the size and cost of the sign to achieve equivalent legibility distance. For this reason, it is generally recommended that messages on VMSs be displayed in upper case characters only.

Table 1 – Character Spacing for MTO COMPASS Signs

Adjacent Text Character Spacing

Preceding Character	Following Character and Spacing		
	0 Pixels	1 Pixel	2 Pixels
A	Y	J, T, V, W	All Others
B			All
C		J, Y	All Others
D			All
E		J	All Others
F		J	All Others
G			All
H			All
I			All
J			All
K		J, Y	All Others
L	Y	A, J, T, V, W	All Others
M			All
N			All
O			All
P		A, J, T, Y	All Others
Q			All
R			All
S			All
T		A, J	All Others
U			All
V		A, J	All Others
W		A, J	All Others
X			All
Y	A, J		All Others
Z			All
0			All
1		4, 7	All Others
2			All
3			All
4			All
5			All
6			All
7		4, 7	All Others
8			All
9			All
punctuation			All
/			9 pixels minimum
&			9 pixels minimum
-			9 pixels minimum

Proportional spacing of characters, in which each character is spaced at a specific distance from the adjacent character (0, 1 or 2 pixels) appropriate to the unique shapes of the two characters, enhances the legibility of the message. Proportional spacing can only be achieved when the sign has a line-matrix or full-matrix display and the sign control software has been developed to specifically take advantage of this feature. The character spacing employed in the MTO COMPASS signs is presented in Table 1.

MTO has developed font sets which employ characters of seven pixels in height and from one to nine pixels in width, depending on the character. Each font set is unique to either the permanent VMS or the PVMS and can only be used in line-matrix or full-matrix signs. These font sets are shown in Figures 16 and 17.

4.2.3 Symbols

The selective use of symbols can increase the level of understanding of a message; however, caution should be exercised in the design and use of unfamiliar symbols and pictograms, particularly when limited by the design parameters of a discrete character matrix sign.

Among the most readily recognized and acceptable symbols in Ontario are arrows and highway number/name identification logos or shields. Certain other pictograms are in widespread use across Europe, although North American drivers may not be familiar with their meaning.

Arrows may be used in a passive mode to advise of exit ramp locations, or in a more active mode in association with an advisory message relating to lane changes or full roadway diversions. The design of the arrow on the DMSs should resemble as

closely as possible the equivalent fixed sign symbol described in Book 1. The specific array of pixels possible will depend on the capability of the sign to display graphics characters.

4.3 Sign Dimensions

Overall sign size is a function of the required character height and the maximum length of the message to be displayed. MTO has adopted an approach wherein overhead gantry-mounted VMSs are capable of 3 lines of text, with 25 characters each. To ensure that signs are legible at an appropriate distance, the minimum height of the letter on a text sign or the symbol size on a symbol sign must be large enough to accommodate the majority of the driving population.

A considerable body of knowledge has been developed over the years about the required message legibility and viewing distances for dynamic message signs on highways. The ability of the driver to read and understand the message is dependent on character height, number of characters and number of lines, which are in turn dependent on operating speeds, minimum required visibility distance, and the messages to be displayed. This section deals with character height. The other operating characteristics are addressed in Section 5.

Based on recent human factors research, the legibility of current LED technology varies with letter height in a non-proportional fashion. Table 2 shows the recommended character height for different message characteristics and operating speeds. For freeway applications, a minimum character height of 450 mm (18 in.) is recommended.

Figure 16 – MTO Font for Permanent Variable Message Signs

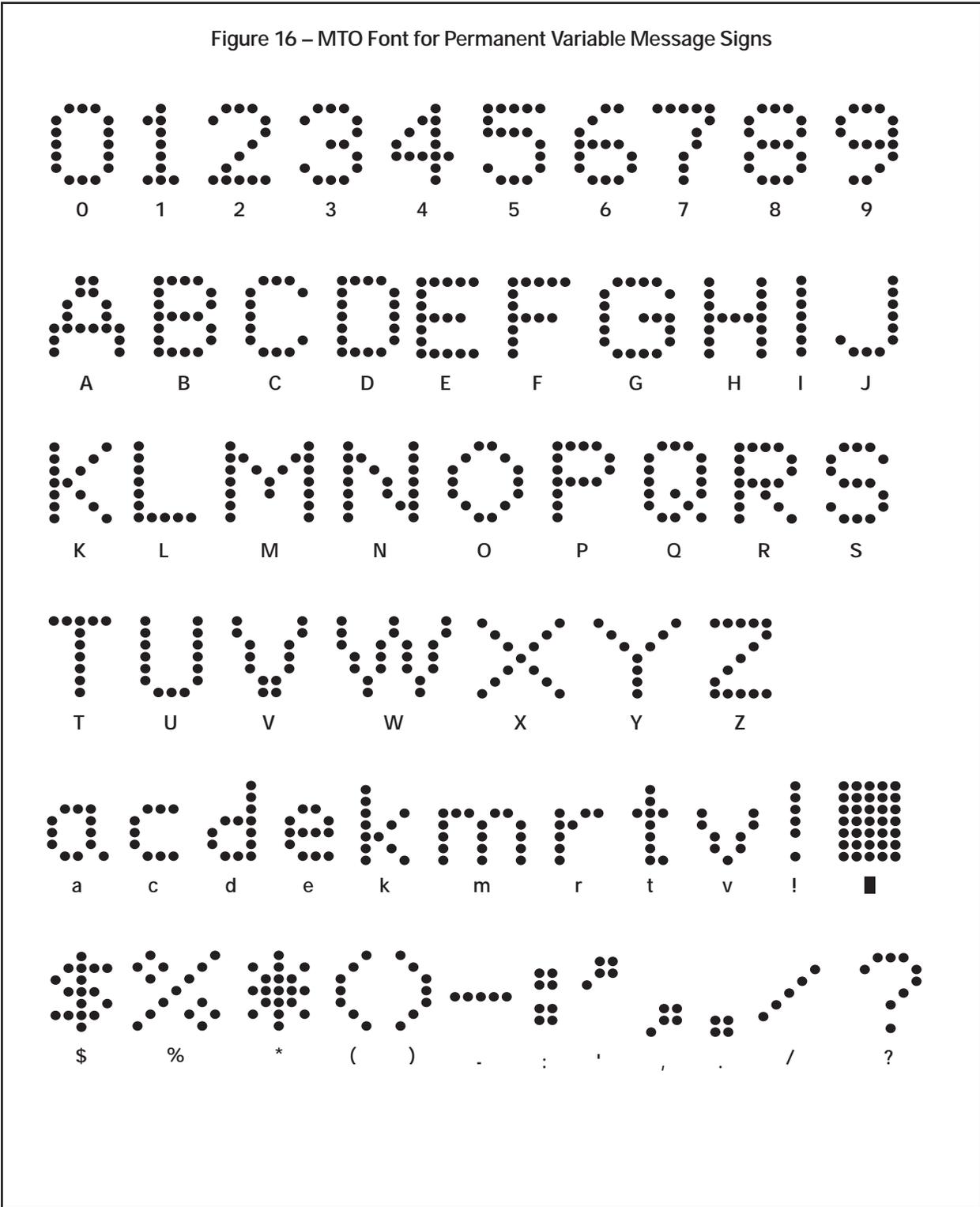


Figure 17 – MTO Font for Portable Variable Message Signs

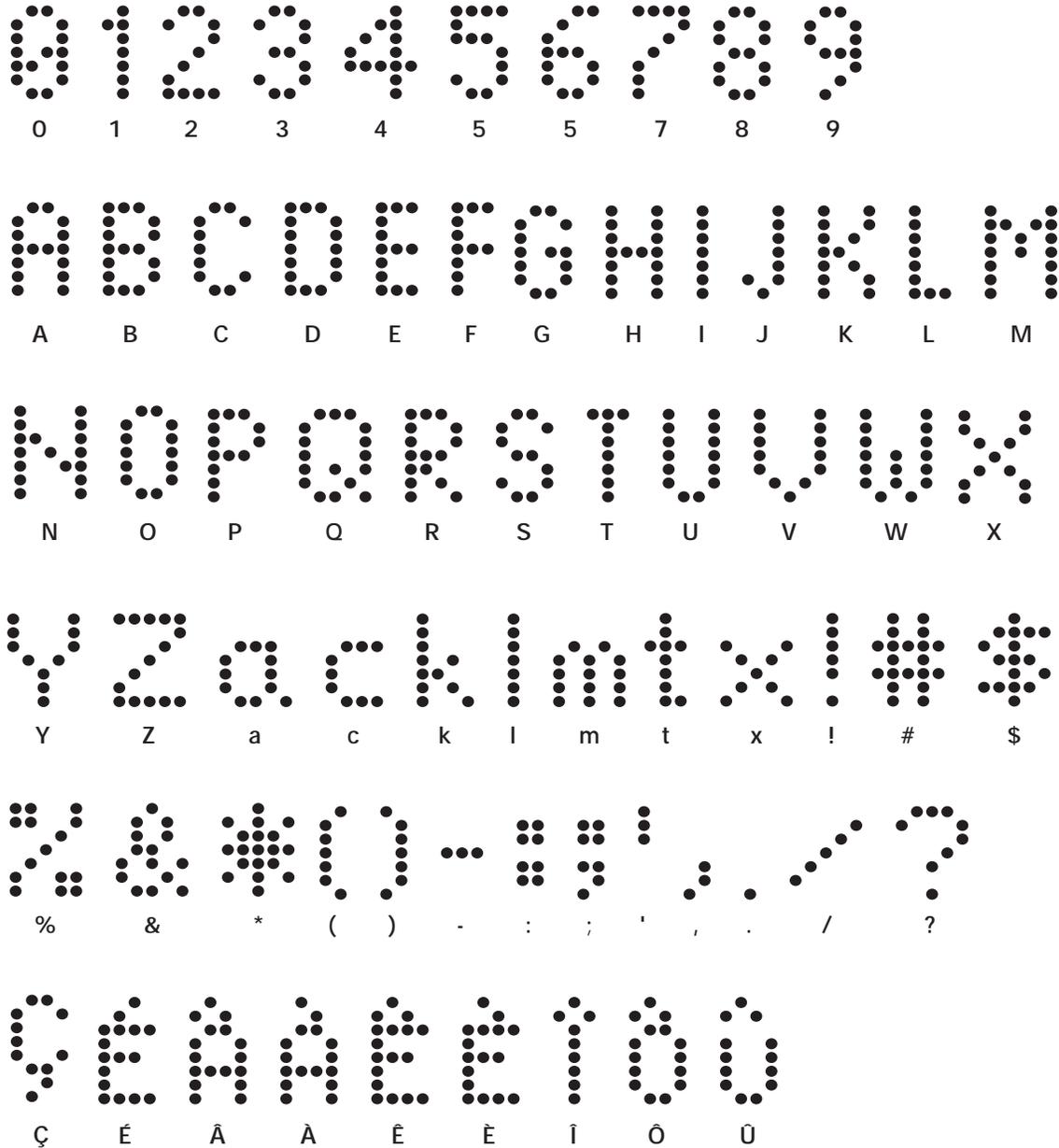


Table 2 – Recommended Character Height Based on Message Content and Posted Speed¹

Character Height	Day/ Night	Height: Distance Ratio ²	Max. Legibility Distance (m)	60 km/h		80 km/h		100 km/h		120 km/h		
				Max. Reading Time ³ (s)	Max. Message Length ⁴		Max. Reading Time ² (s)	Max. Message Length ⁴		Max. Reading Time ² (s)	Max. Message Length ⁴	
					Words	Units		Words	Units		Words	Units
200	Day	1:300	60	4	2	3	1	2	1	2	1	
	Night	1:160	32	2	1	1	<1	1	<1	1	<1	
250	Day	1:300	75	5	2	3	1	3	1	2	1	
	Night	1:160	40	2	1	2	1	1	<1	1	<1	
300	Day	1:360	108	6	3	5	2	4	2	3	1	
	Night	1:240	72	4	2	3	1	3	1	2	1	
350	Day	1:360	126	8	4	6	3	5	2	4	2	
	Night	1:240	84	5	2	4	2	3	1	3	1	
400	Day	1:360	144	9	4	6	3	5	2	4	2	
	Night	1:240	96	6	3	4	2	3	1	3	1	
450	Day	1:530	239	14	7	11	5	9	4	7	3	
	Night	1:360	162	10	5	7	3	6	3	5	2	

- 1 Table derived from the following sources:
 – Ullman, B.R., Ullman, G.L., Dudek, C.L., Ramirez, E.A., Legibility Distances of Smaller Letters in Changeable Message Signs with Light-Emitting Diodes. In Transportation Research Record No. 1918, Transportation Research Board, 2005, pp 56-62.
 – Ontario Traffic Manual, Book 1b (Sign Design Principles). Ministry of Transportation Ontario, Publications Ontario, 2001.
- 2 Based on 15th Percentile Driver.
- 3 Mounting height, mounting location and the optical properties of the technology used will influence the actual reading time that a motorist has to read the DMS. Therefore, the reading times listed here are maximums and should be reduced as appropriate.
- 4 "Words" represents the number of major words in message. Number of words should be limited to avoid driver information overload, and to keep sign size reasonable. "Unit" represents a unit of information or thought that can be up to three words long. e.g., "Use next exit", "Beyond Avenue Road".

4.4 Sign Placement

4.4.1 Freeway Applications

Freeway DMSs are typically placed in advance of freeway-to-freeway interchanges to allow for freeway-to-freeway diversions resulting from incidents or scheduled closures. DMSs may also be installed prior to major arterials to allow for diversion opportunities. For corridors characterized by recurring congestion, DMSs may be regularly spaced along the corridor to provide for queue warning and congestion management. DMSs should be installed in accordance with the following placement criteria:

- DMSs should be located 1,000 m to 1,500 m upstream of freeway interchange decision points;
- DMSs should be located at least 300 m downstream of visual obstructions including overpasses and other signs;
- Overhead DMSs should be located a minimum of 300 m upstream of other overhead static signs.

There are three types of mounting that can potentially be used for freeway applications. The more common and greatly preferred approach is to mount the DMS overhead, centred over the lanes (See Figure 7). This allows for optimal viewing by the motorists.

Roadside (ground-mounted or cantilever) DMS displays may be considered under one or more of the following conditions:

- Rural conditions;
- Two or fewer lanes per direction;
- The intended message content is conducive to a smaller scale display;
- A temporary installation is required.

Depending on the nature of the physical environment and the roadside mounting configuration, the view of the display may be subject to obstruction from passing heavy vehicles. Figure 8 shows an example of a roadside-mounted (cantilever) DMS in Northern Ontario.

DMSs should be installed in accordance with the mounting provisions discussed in Section 6.4.

4.4.2 Arterial Applications

DMSs may be located on major arterial roads in advance of key road network decision points such as freeway entrance ramps and major intersections. DMSs should be installed in accordance with the following placement criteria:

- DMSs should be located a minimum of 100 m upstream of decision points;
- DMSs should be located at least 100 m downstream of visual obstructions including overpasses and other signs;
- Overhead DMSs should be located a minimum of 100 m upstream of other overhead static signs.

DMSs should be installed in accordance with the mounting provisions discussed in Section 6.4.

Roadside ground- or cantilever-mounted VMS displays may be considered under the conditions outlined in Section 4.4.1.

Depending on the nature of the physical environment and the roadside mounting configuration, the view of the display may be subject to obstruction from passing heavy vehicles.

4.4.3 Queue Warning Signs

Placement guidelines for Queue Warning Signs are as follows:

- Locate upstream of areas with recurring congestion;
- Locate in areas with higher than average collision rates;
- Locate upstream of areas with limited sight line distance;
- Desirable minimum spacing is 300 m and desirable maximum spacing is 3,000 m between signs;
- Locate at least 300 m upstream of static signs;
- Locate at least 200 m downstream of all signs and visual obstructions.

Depending on the nature of the physical environment and the roadside mounting configuration, the view of the display may be subject to obstruction from passing heavy vehicles.

4.4.4 Lane Control Signs

Placement guidelines for Lane Control Signs are as follows:

- Locate on roadways operating reversible traffic lanes;
- Locate in areas with specific lane usage designation;
- Locate in areas with limited sight line distance and areas with special safety consideration such as bridges and tunnels;

- Spacing between signs ranges from 100 m to 1,000 m depending on the nature of the application, size of display and physical environment. Ideally, a driver should always have at least two lane-control signs in the lane of travel visible at all times; and
- Locate downstream of every intersection.

4.4.5 Portable Applications

PVMSs can be installed to support freeway or arterial applications and should be placed in accordance with the guidelines stipulated in previous sections of this book. For additional information about the application of PVMSs in temporary situations, reference should be made to OTM Book 7 (Temporary Conditions).

Due to the temporary nature of PVMSs, it is unlikely that an agency will invest in the capital infrastructure to install an overhead PVMS. Therefore, PVMSs are typically placed on the side of the road. For semi-permanent locations, the PVMS may be installed on poles; however, they are typically trailer-mounted. Care must be exercised in order to minimize visual obstructions resulting from barriers, static signs and other structures. The directional sensitivity of light-emitting VMSSs, in particular LED-type signs, suggests that great care should be taken in aligning the optical axes of PVMSs towards the correct point on the upstream roadway.

The criteria that should be considered when locating a PVMS include: visibility, roadside safety, and availability of power and communications.

Visibility

The horizontal and vertical geometry of the highway will have the greatest affect on the visibility of the sign. Whenever possible, the sign should be placed on a tangent section of the highway, if it makes sense to do so while maintaining the intent of the

message content. The signs shall be installed level. The bottom of the sign display shall be at least 1.5 m above the adjacent edge of pavement elevation. The signs shall be set at the proper angle to traffic so that they can be viewed at the highest possible luminance value. The signs shall be placed so that the messages are legible to approaching motorists for at least 300 m on freeways and 200 m on other highways/arterials. PVMSs should not obstruct, and should not be obstructed by, any existing signs or other objects.

Roadside Safety

A PVMS can be a roadside hazard to the travelling public. Therefore, when located on highways, PVMSs should be placed outside the clear zone or placed behind a section of barrier. PVMSs should be far enough behind the barrier to account for the deflection angle of the given barrier style. When choosing a location for PVMSs, it is important to remember that the sign head is significantly wider than the trailer when in display position.

For urban applications, PVMSs should be placed so as not to pose a hazard to pedestrians or passing vehicles. Care should also be taken that they do not obstruct the visibility of adjacent signs or the field of view from intersecting streets.

4.4.6 Site Safety and Maintenance Requirements

All DMS installations should incorporate appropriate barrier protection for the mounting structure in accordance with the requirements set forth in the relevant roadway design safety standards of the implementing authority.

Field sites should be designed to facilitate safe access to the DMS displays and controller cabinets for routine maintenance and emergency repairs. This would include consideration of such features as:

- Safe access/egress for maintenance vehicles at the site;
- Barrier protection for maintenance staff and vehicles on site, including bucket trucks for aerial access to the display;
- Walk-in enclosures for overhead signs;
- Integral gantries and safety harness attachments on the mounting structure to facilitate safe access to the serviceable DMS components;
- Placing components such as controllers and cabinets at readily accessible ground level locations.

5. Operational Considerations

Considerations such as message content, alternate display technologies and message comprehension and credibility are critical to the successful operation of DMSs. In this Section, these operational considerations are discussed as they apply to DMSs with fully variable message content, such as VMSs and PVMSs, as opposed to devices with more limited displays, such as CMSs.

5.1 Message Content

One of the key activities in the development of VMS messages is to reach a clear understanding of the operational objectives of the sign, and to develop an appropriate set of operational strategies. This will govern the structure and content of the messages to be displayed.

For greater information about the planning for Dynamic Message Signs and other aspects of Advanced Traffic Management Systems (ATMS) refer to OTM Book 19 (Advanced Traffic Management Systems). For signing for Temporary Conditions, refer to OTM Book 7 (Temporary Conditions).

One example of an operating strategy decision is whether to implement passive or active signing. *Passive signing* provides factual information relating to traffic conditions on the road ahead, such as lane blockages, closures or special events, enabling the motorist to make a decision as to whether or not to divert. *Active signing*, on the other hand, suggests specific alternative routes or other specific actions to motorists. In the case of active signing, caution should be used when attempting to direct traffic into an area where there is little known information about current operating conditions. A passive strategy may

be more appropriate. On the other hand, if the road ahead is closed, with no choice but to divert, an active strategy may be better. Different message sets can be developed for each condition.

While the choice of passive or active signing depends in part on the quality and coverage of information collected, this decision is often made at a policy level. Often, such a decision is based on liability considerations and an agency's perception that they may be at risk by providing active information to motorists, rather than from their lack of ability to provide that level of information to motorists. A typically sensitive decision is whether to divert traffic from a blocked or congested freeway or expressway onto a local or regional arterial road, and if so, under what conditions. Indecision or disagreement between road authorities on such issues can result in DMSs not being utilized to their full potential.

Another aspect of operating strategy is the set of objectives for which the DMS messages are to be used by a transportation agency. The first question that needs to be asked is what problems are to be addressed? Once that has been determined, the transportation agency can develop DMS messages based on the identified target audience, the type of information to be conveyed, the degree of driver response required, and how the system will be operated.

Typical DMS objectives applied on a general basis include the following:

- **Local Incident Management** – Identification of directional roadways, streams, ramps, lanes and/or shoulders blocked or closed due to an incident; location (including road name if on a connecting road, and both upstream and downstream points if applicable); and in some cases, information or instructions on diversion.

- **Area-Wide Incident Management** – Information on major, severe and lengthy incidents (including weather-related road closures) requiring area-wide re-routing of traffic through a network; and recommendation of major routes for specific area-wide target destinations.
- **Congestion or Queue Management** – Identification of congestion, queues, slow traffic, etc., for recurring and non-recurring congestion; location (including road name if on a connecting road, and both upstream and downstream points if applicable) for drivers upstream of the congestion or queue; and location of downstream point for drivers within the congestion or queue. To be effective, congestion and queue management messages must be operated in a fully automated manner where they can be updated every 20 to 60 seconds.
- **Express/Collector or Corridor Balancing** – Information on relative status of alternate streams or parallel routes, to enable drivers to make “fastest route” decisions. To be effective, express/collector or corridor balancing messages must be operated in a fully-automated manner where they can be updated every 20 to 60 seconds.
- **Route Travel Time** – Information on current travel time(s) to one or two destinations; for locations with HOV lanes, comparison of travel times on the regular route and the HOV route (e.g., number of minutes saved on HOV route). To be effective, route travel time messages must be operated in a fully automated manner where they can be updated every 20 to 60 seconds.
- **Planned Event Management** – Information on road work, special events, etc., similar to that noted above for local incident management; advance information on planned event start and end dates and times; information during the planned event about end date/time; and safe speed for road works displayed during the planned event.
- **AMBER Alerts** – Information provided by police on child abduction (e.g., description of vehicle) and instructions for drivers (e.g., call 911 if described vehicle is seen, tune to local media).
- **General Warnings** – Soft or non-specific messages advising general driver caution, used for pre-confirmed incident or congestion/queue detected by automatic means, or for known incident location where camera viewing is impeded.
- **Default Safety Messages** – General safety reminders for drivers on seat belts, following too closely, etc.; seasonal safety warnings, such as attention to school buses, driving in winter conditions, etc.

Once an agency has determined the operational strategy and objectives of the DMS, it is important to find the right structure to the messages, in terms of the length and content, in order to accurately convey the information. There are several factors to consider when developing the messages. The first and most important relates to message comprehension, and the ability of the motorist to understand the amount of information that should be displayed on the sign. The amount of information that can be displayed is determined by the driver’s exposure time to the message, which is based on the speed at which the vehicle is travelling and the distance (therefore the time) over which the sign is legible.

An explanation of the basic principles behind the interrelationship between sign message length, character height, and the required viewing time/distance may be found in OTM Book 1b (Sign Design Principles) and OTM Book 2 (Sign Design, Fabrication and Patterns). While these fundamental human factors apply to signs in general, recent research conducted on signs displaying LED technology has yielded results which apply specifically to DMSs. (Upchurch et al.) (Ullman et al.)

As discussed in OTM Book 1b and Book 2, good sign design considers the needs of the majority of drivers, rather than the average. A typical target is to design for 85% of the population, allowing the needs of 85% of the population to be met. This represents a reasonable worst case scenario for design.

Based on a 1992 study (Upchurch et al.), which provided mean, not 15th percentile values, LED technology used in variable message signs has a mean legibility of 4.7 m/cm. This means that 4.7 m of legibility distance is available per centimetre of letter height. The same study indicated a lower mean of 4.1 m/cm for older drivers at night. Based on a 2005 study (Ullman et al.), current LED technology legibility varies in a non-proportional fashion with letter height, with 15th percentile legibility values as follows (see also Table 2):

- 230 mm (9 inch):
 - day 3 m/cm
 - night 1.6 m/cm
- 270 mm (10.6 inch):
 - day 3.6 m/cm
 - night 2.4 m/cm
- 460 mm (18 inch):
 - day 5.3 m/cm
 - night 3.6 m/cm.

Based on the 2005 study, current Ontario freeway overhead VMSs with 450 mm letters will be legible for 239 m (8.5 seconds) during the day, and 162 m (5.8 seconds) at night, based on the 15th percentile driver. Therefore, a range of 6 to 9 seconds represents the typical time that a VMS sign with 450 mm high letters is legible for the 15th percentile driver at a posted speed of 100 km/h.

Other research (Dudek) has suggested that the minimum exposure time of one second per short word (excluding prepositions or linking words) or two seconds per unit of information, (e.g., “lane blocked”

or “next exit”), whichever is the largest, should be used to accommodate the needs of unfamiliar drivers. Pictogram reading time is generally calculated to be one second per symbol.

Other factors that affect exposure time are driver workload, message familiarity and display format. For driver workload, it is important that the message be legible over a long enough distance to allow sufficient exposure time for drivers to attend to the complex driving situation and glance at the sign often enough to read and comprehend the message. These factors combine to reduce the effective message exposure time. A maximum of three units of information should be displayed at one time, given that there is adequate legibility to provide six or more seconds of exposure time at the operating speed. When motorists are given four units of information, one-third of the drivers cannot recall all four units. Therefore, a maximum of three units of information should be used.

Message familiarity is another factor that affects the reading time for drivers. Message familiarity relates to the format of the message and what the driver is expecting to see. Commuters, or other motorists who are familiar with the network and reading the signs, will recognize message types based on their format. For instance, if information about an incident is being displayed, the driver will actually, in a sense, not have to read the word “incident” because they understand the format and can focus primarily on the location information. This results in the exposure time required for a frequent road user to read the message being reduced, in comparison with that of a road user who is unfamiliar with the system. A person who is travelling the network for the first time or is unfamiliar with the message format will have to read the sign in its entirety, thereby increasing the required exposure time to the message.

The format of the message is another important criterion. Drivers must receive the information in a consistent manner in order to be able to quickly understand the message, respond to it, and then

have time to implement that response. The format must be developed so that drivers can quickly ascertain if a message does not apply to them. For example, placing the name of the connecting roadway first in the message immediately targets only those drivers who are interested in using the identified road.

Finally, driver comprehension is a requirement for the success of DMS messages. Testing is required to establish comprehension. Even when text messages or pictograms have been in use for many years, they are not always well understood when tested with the general public. A list of well-understood abbreviations is available (Dudek et al.). It is also important to use location terminology that is well understood by the drivers using the roadways referenced in DMS messages, e.g., interchanges, cross-roads, exit numbers, as applicable. If drivers do not understand a message, reading time and incorrect responses increase.

To ensure consistency of application, the ATMS software should provide decision support for creation of messages. In this way, appropriate strategies and messages which meet the transportation agency's objectives and follow the principles of good design can be developed. This decision support function can be applied in two general ways:

- (1) Using a static message library, where a list of messages pertaining to different situations and different signs is developed and stored;
- (2) Using a rule-based or algorithmic approach, where response rules are defined and applied to conditions and locations in a structured manner, similar to the way in which data are processed in an algorithm.

A combination of both approaches is also used. With a static message library, all possible messages are known and viewable at any time. With a rule-based or algorithmic approach, more testing is

required to ensure the rules behave as expected in all situations. The advantages of this approach include flexibility to accommodate a large number of specific conditions, consistency, simplicity, accuracy, comprehensiveness, and facility of building plan sets. Whichever approach is used, the practice of operators creating messages 'on the fly' and dispatching them to the signs should be prohibited.

A particular issue for some areas of Ontario is the necessity to provide bilingual signage. If mandated for DMS applications, it would increase the functional requirements of the sign. Potential solutions include alternating messages (discussed further in Section 5.2), increased sign size, and more signs, while maintaining compliance with the messaging guidelines as defined herein. Additional sign design considerations pertaining to the display of bilingual messages on DMSs include the following:

- Consistency in format, so that drivers can quickly find the language that they understand, e.g., not mixing multi-phase and single phase formats on bilingual signs;
- Delineation of languages, e.g., showing English on the upper lines of an electronic or static sign and French on the lower lines, separated by a horizontal line, where practical;
- Limited use of pivot words consisting of an English and French term separated by a slash, e.g., to / à, to one per line of text;
- Consistency of pictogram treatment, e.g., establishing conventions for depicting express and collector lanes on pictograms, incorporating use of colour to convey information, representation of left, centre and right lanes, etc.;
- Grouping of information units together, with one unit per line of text, if possible;

- Use of pictograms with supporting text (e.g., similar to the function of educational tab text), and not using pictograms that provide new information unsupported by the sign text;
- Simplicity of sign legend and economy of text; and
- Clear communication of the linkage between a traffic event and its location.

In some cases, trade-offs may be required between design considerations. Testing can be used to decide which trade-offs are more effective in terms of driver reading time and comprehension.

5.1.1 Ontario Experience

Typically, the City of Toronto and the Ministry of Transportation Ontario utilize passive signing, allowing the motorist to make a decision based on the information presented on the DMS. The only exception is under total closure, where traffic is required to exit at a pre-determined location.

A common structure to message development has been implemented within Ontario so that drivers receive information in a consistent manner. The format used by the City of Toronto and the Ministry of Transportation Ontario for sign messages is to answer the following questions in sequence:

- What is the situation being noted?
- Where is the situation occurring?
- What should the driver response be? (active signing only)

Not all messages will require all of this information to be displayed to the motorist. The response can be either explicit, as in the case where a road or lane is closed at a particular location and so diversion is essential, or implicit, where by providing the location

and nature of the traffic disturbance, drivers can make their own decisions as to the most appropriate action to take. The guidelines for information loading will also have a bearing on how much information can be relayed in a single message.

Both MTO and the City of Toronto use DMSs for local incident management, area-wide incident management, congestion or queue management, express/collector or corridor balancing, planned event management, AMBER alerts, and safety default messages. In addition, MTO uses DMSs for route travel time and specific driver impacts of weather (e.g., high winds on skyway, snowplowing in collector), but not general weather conditions (e.g., drifting snow, fog). The City of Toronto has the capability of displaying general warnings prior to confirmation of any incident or queue detected by an automatic incident or queue detection algorithm. MTO policy prohibits the display of non-traffic-related messages such as advertising, or time and temperature.

In 2005, MTO conducted a study on how bilingual English and French messages could be accommodated on VMSs and PVMSSs. Approval of the implementation plan is still pending. A long list of alternative approaches was evaluated, and human factors testing was conducted on the most promising alternatives. Preferred alternatives were selected for implementation. Since they involve the use of alternative display technologies, they are discussed in more detail under Section 5.2.

The preferred alternative for accommodating bilingual VMS messages was the use of existing three-line VMS installations throughout the French Designated Area to display bilingual, one-phase messages. The messages would rely on additional abbreviations, bilingual words, pictograms and colour to display existing message content in a consistent bilingual format, as follows:

- Line 1: English text indicating a condition or action, e.g., Use Collector Lanes;

- Line 2: Location or unilingual text, e.g., At/À Keele Street; and
- Line 3: French text indicating the same condition or action.

The study also established consistent guidelines for translation of original English messages into French. The French translations need to be targeted to an audience of French-speaking Ontario drivers who, like English drivers, are generally not knowledgeable about technical traffic terms. The terms used in the messages are similar to current practices used elsewhere in Canada.

The study showed that PVMS and VMS messages need to be adapted to fit under certain space constraints. In certain cases, there is a need to remove articles or interpret, rather than translate, the original English message in a proper linguistic format. Consistency of language terminology is an important criterion in message translation.

Other guidelines for French language messages include the following:

- Do not use abbreviations in French signing. Abbreviations are not recognized by French-speaking drivers except for road classification abbreviations, or days of the week;
- Use the 24-hour clock for French messages. Where applicable, the Ontario format for the 24-hour clock should be used (i.e., 13h30 instead of 13:30). Most times shown on messages however, are expected to be on the hour;
- Do not translate terms such as "road", "avenue", "drive" or "boulevard", which are officially part of place names established by a municipality or region, unless the municipality has passed a by-law supporting official bilingual use of these terms in signage as part of the place name (e.g., Cornwall).

5.2 Alternate Display Techniques

A number of alternate display techniques, usually associated with advertising signs, are technically possible in the control of DMSs for highway use. These include:

- (1) Message flashing, where the message cycles on and off several times a minute to draw the observer's attention to the message. This can occur with all or part of the message. Flashing messages take longer to read than static messages and should be avoided.
- (2) Message alternating, where two physically separate signs, which are close enough to be perceived by drivers as a pair, are used to convey parts of the message. With the exception of bilingual applications, this approach is inconsistent with other types of signing on the roadway. It may be confusing to drivers, and should be avoided.
- (3) Message scrolling, where the message appears to scroll from right to left across the screen or from top to bottom, to accommodate longer messages than would otherwise be possible. Message scrolling requires significantly more attention from the driver, as drivers cannot just glance at the message but must watch it scroll. This constitutes a potentially hazardous distraction and should not be implemented.
- (4) Message phasing, where two or more parts of a message are displayed in sequential time slots, separated by a brief blank period, to accommodate longer messages than would otherwise be possible. No more than two phases should be used in any application as drivers have difficulty in remembering more than two phases. Two unrelated messages generally require more reading time than two parts of the same message.

- (5) Pictogram components, where symbols are used to replace or supplement text displays. Use of colour within pictogram components can add further meaning for the motorist, e.g., use of green for fast speeds, light orange for slow speeds and red for very slow speeds.

In summary, message flashing, alternating or scrolling should be avoided, as these messages are more difficult and require extra time to read. This extra time constitutes a distraction for drivers and is therefore undesirable.

If the sign is not large enough to display the full message required, as is typically the case with PVMSs, and the total message exposure time is adequate, consideration may be given to phasing the display between two related messages to achieve the desired effect.

If phasing is used, a maximum of two phases is recommended. The 2005 study of bilingual signing showed that when three (monolingual) phases were used, only 55% of younger drivers and 19% of older drivers could recall the third phase (see Section 7). Therefore, a design that meets the needs of a majority of drivers should include no more than two phases.

Due to the demands of the driving task, a driver may not be able to read the sign until halfway through a phase. Therefore, the driver should be given more than one opportunity to read the first phase he/she sees. This means that for a two-phase message, at least three phases (the first, the second, and a repeat of the first) must be viewed within the available legibility window (six to nine seconds for current freeway overhead VMSs at 100 km/h) to allow the driver a second chance to see the first phase viewed. The *FHWA Design Handbook for Older Drivers and Pedestrians* is even more

stringent, recommending that the message should be presented so that it can be read completely, twice – i.e., the opportunity to see four phases for a two-phase message.

Based on the above considerations, the maximum time for displaying one message phase on an overhead VMS is less than three seconds, which enables the display of no more than three major words, or well under two units of information. Given that most of MTO's VMS messages require at least six seconds of reading time, the use of message phasing on overhead (gantry-mounted or roadside) VMSs would not meet human factors requirements, and is not recommended.

PVMSs have more limited message content than the overhead VMSs, and consequently require less reading time. Therefore, two-phase messages are a viable option for PVMSs. Each message phase should be limited to a maximum of three units of information. Example messages may be found in OTM Book 7 (Temporary Conditions).

The use of alternating messages on separate signs spaced longitudinally along the roadway is sometimes proposed as a technique to display messages in two languages. While this approach is unwieldy for VMSs due to high capital cost and the difficulty of placing two VMSs within close proximity to each other, it is a feasible consideration for PVMSs, where message capacity per phase is short, and human factors guidelines limit the number of phases per message to two. Providing an advance indication of the language(s) displayed on a given PVMS (e.g., using colour-coded lettered tabs, and/or colour-coded tabs) would assist drivers in language differentiation. This type of advance indication would reduce the driver requirement to read all signs, and only require drivers to read those in their preferred language. Because of the requirement to read only one PVMS of the pair, the inter-sign spacing could be relaxed to as low as 75 m. If multiple PVMSs are located close together but showing one language

only, a minimum longitudinal distance of 150 m should separate the signs because drivers need to read and process the first sign before they see the second. The relationship between sign location and language should be consistent from one location to another (e.g., always put English on the first sign and French on the second).

Where part or all of the DMS is available with full-matrix functionality, the potential exists for displaying pictograms containing symbols. Symbols are typically used alone or in combination with supporting text on VMSs, or alone as a single message phase on PVMSs. Symbols can convey several words, and are therefore significantly larger and more legible than letters, provided that they are well-recognized and easily comprehended. They offer an obvious solution for transcending language barriers without the additional loading associated with two-language text (e.g., more words, impact on longer reading time, more signs and/or larger signs). They are used internationally, for example in Europe, where many languages are spoken in relatively small geographic areas. By installing colour LEDs in the full-matrix portions of DMSs, the opportunity to further enhance symbol meaning and conspicuity through colour-coding exists.

Given the current industry standard of PVMSs capable of supporting three lines of text, two scenarios for PVMS messaging in bilingual designated areas are suggested. The first is to use a single PVMS with two phases, one phase for each language. The second is to use two PVMSs.

5.2.1 Ontario Experience

With the exception of pictogram components, the Ministry of Transportation Ontario does not utilize any of these alternate display functions on the permanent VMSs, although the functionality has

been incorporated into the signs. Phasing, flashing and alternating displays are used in some cases on PVMSs in work zones. The MTO uses a minimum exposure time of 1.5 seconds per message phase.

According to the 2005 study conducted by the MTO on accommodating bilingual messages on DMSs, the preferred VMS alternative for accommodating bilingual signing incorporates the display of pictograms on the full-matrix portions of the overhead gantry-mounted VMSs (see Figure 6). Information regarding express and collector lane specific operating conditions is provided in the existing Central Region Message Library. To maintain this level of information using bilingual messages, the use of pictograms, supplemented by a reduced amount of text, was extensively employed in the study. Further, based on a review of the typical incident and congestion management messages, it was determined that many of the express and collector messages included in the Central Region Message Library would be conducive to a pictogram convention, where the left panel would signify a condition in the express lanes and the right panel would signify a condition in the collector lanes.

For PVMSs, the preferred bilingual alternative is to accommodate bilingual messages in one English and one French phase, if the message can fit, supplementing with pictograms where applicable. If the message cannot fit into this format, two alternating PVMSs would be used in longitudinal succession. The first PVMS would display two phases in English, and the second two phases in French.

The approach using alternating PVMSs has already been applied by the MTO. Longitudinal space constraints in some locations of Central Region have prohibited this approach, which requires 150 m longitudinal spacing between signs. If means such as colour-coded text or language identification tabs are used to assist drivers in identifying, in advance,

which sign is in the driver's language of preference, the longitudinal spacing requirement may be relaxed to a minimum of 75 m, depending on the number of words in each message phase.

The City of Toronto has implemented message phasing in order to provide additional information to motorists. In order to manage the phasing, priority levels for the different messages have been developed to ensure consistency in approach. The VMS located along the Gardiner Expressway provides information on both the Gardiner Expressway and the parallel arterial, Lake Shore Boulevard. Level 1 relates to signing for incidents, level 2 for congestion information and level 3 for other advisory signing. These levels are in place for both the Gardiner Expressway and Lake Shore Boulevard, with the Gardiner taking precedence. In the event of an incident on both roadways, the first phase of the message would sign for the Gardiner incident and the second phase would sign for the incident on the Lake Shore. The City is of the opinion that two phase messages are very effective at disseminating information to motorists. The lower speed of the traffic normally present, due to construction or routine congestion, typically compensates for the additional time required to absorb the two-phase messages.

5.3 Message Comprehension and Credibility

Once the transportation agency has implemented a DMS system, it is very important to provide the correct information on the signs. The operating agency must maintain the credibility of the signs. Therefore, agency staff must develop operating procedures and standard messages that will be used consistently throughout the life of the system. In order to ensure that the credibility of the system is maintained, driver confidence must be achieved and maintained. Driver expectations must be considered when operating real-time displays. Motorists

travelling along the highway and viewing the DMSs want to see reliable, accurate and up-to-date information. The agency must be willing to support the ongoing operation of the system and must ensure that operators are properly trained to provide consistent responses to incidents. If this is not accomplished, the messages will lose credibility, as they may be untimely and inaccurate and consequently, the drivers will ignore them. Drivers will not react positively to any system that:

- displays information that is contrary to existing conditions, or suggests that existing conditions have not been detected;
- displays information that is not understood or cannot be read in ample time to make the appropriate manoeuvres;
- recommends a course of action that is not significantly better than the motorists' intended action; or
- often tells them something they already know.

In many cases it is much better to display less information, or no information on a sign if the operator is unsure of the traffic condition.

A subject of considerable debate is the question of what messages, if any, should be displayed on the DMSs when the roadway is operating under normal flow conditions. There are two schools of thought to this question, both of which have been applied effectively around the world.

The first option is to always display a message on a sign, regardless of whether or not there is anything abnormal. The rationale behind this option is that the motorist knows that the sign is working. During conditions where the freeway or arterial is operating in accordance with normal operating conditions, such as during the off-peak period, a safety message or a directional signing message can be

put on the display. The disadvantage of this approach is that it can reduce the impact value of high-priority messages if drivers become desensitized to the VMS messages through overexposure to low-priority, default messages.

The second option is to leave the sign blank and to display a message only when unusual conditions occur. This way, no unnecessary or irrelevant information is provided to motorists. It also reduces the credibility risk of displaying a safety message or default directional message at a time when abnormal congestion or incident information should be displayed, and the problem is evident to motorists. One of the drawbacks of the second option is that this may mean that drivers, when they approach a sign that is blank, may not be sure whether or not it is working. It can also lead to questions from the public concerning the apparent under-utilization of high-cost infrastructure. Recent evidence from jurisdictions that leave signs blank most of the time shows that posting a message on a normally blank sign can cause traffic to slow down to read the sign.

At the other extreme is the situation where different messages compete for the use of the same DMS device and a decision must be made about which message actually gets displayed. These situations occur fairly frequently, due to factors such as the occurrence of secondary incidents, the vulnerability of work zones, and the link between incidents and congestion. Transportation agencies need strategies for determining which message has priority under which circumstances, particularly since time is at a premium in responding to more than one simultaneous event. Factors such as severity, proximity, advance knowledge and longitudinal extent are typically used in determining message priority. System software that handles this type of occurrence in a consistent fashion saves time by expediting DMS response.

Different types of drivers make up the target audience for the DMSs, and it is important to be able to try to reach as many of those drivers as possible and to provide them with information that is relevant to their needs. Among the different driver types are:

- those who are familiar with the road network, and those who are not;
- local drivers and visitors;
- business and tourist travellers;
- regular commuters and occasional drivers;
- young and old;
- aggressive and timid;
- urban and rural drivers.

Some of these drivers have similar needs and understandings of the transportation network, while others may have completely different requirements. One example of this relates to the location naming strategy utilized on the messages. A local driver or commuter, familiar with the network, will understand the sequence of interchanges coming up, and will understand destinations that the streets are taking them to, as well as the location of any upcoming major freeway. Other drivers, unfamiliar with the network or travelling through using a map or directions that they have received, may be looking for major freeway-to-freeway interchanges or end destinations. For this group, information that relates to a cross-road that they may not be aware of may be irrelevant to them, as they will not understand the implications of the message being displayed. Care must therefore be taken to ensure that the message strategy employed will make sense to the majority of drivers who will encounter the sign during their

travel. On urban freeways with high levels of congestion, commuters usually make up a large percentage of drivers. Messages are usually targeted at commuters for this reason.

It is recommended that operators not be permitted to create and display customized messages. A pre-authorized message set should be created in advance, and operators are responsible for confirming response messaging proposed by the system, as generated using the pre-authorized message set.

5.3.1 Ontario Experience

Agencies in Ontario that operate Freeway Traffic Management Systems have traffic management centres that are staffed with experienced and knowledgeable staff who are able to use the system to automatically determine the correct response to a variety of situations, whether it is incident management, congestion management, safety messages, scheduled closures or another type of message. Typically the operators are responsible for confirming the system-generated messaging, and are not provided with the capability to create messages as part of an event response. The operational strategies employed have been developed and have evolved over many years. It is important, however, to continually review the effectiveness of the overall strategies as well as the specific messages employed, to ensure that they continue to serve their intended purposes.

The City of Toronto has incorporated into its VMS response software a mechanism for response conflict arbitration, which automatically suggests a priority message from more than one message competing for any given VMS. The prioritization is in accordance with City of Toronto policies. The MTO is currently developing software which will enable VMS message composition to address simultaneous situations, e.g., incident together with congestion.

With an increasing number of agencies and contractors using DMSs, it is important to co-ordinate message content among the various parties to ensure a consistent, rational approach to messaging from the perspective of the motorist. The MTO and the City of Toronto have agreed to display variable messages whenever their control rooms are in operation, leaving the signs blank when not attended.

For PVMSs in regions where there is an Operations or Communications centre, the centre should control all PVMS messages. This holds true whether it is a contractor-owned sign, an agency-owned sign, or a sign rented from a third party.

6. Other Considerations

6.1 Communications

Communication with DMSs can be successfully accomplished in a number of ways. Alternatives include private communications links or networks over fibre optic cable, over wireless communications, or a combination of the two, or public telecommunications service providers supplying access to dial-up telephone lines, leased lines, or wireless mobile services. The communication options are listed in descending capital expenditure. DMSs that are installed within or close to an ATMS area are typically connected to the fibre communication backbone or via a wireless link connecting to the fibre backbone. DMSs that are installed away from the fibre communication backbone will usually use dial-up, leased line or wireless services as the capital cost for the infrastructure is significantly lower. Portable applications generally use commercial wireless services.

Under the ongoing U.S. National Transportation Communications for ITS Protocol (NTCIP) standards efforts, standard communications messages (i.e., objects) have been drafted for various ATMS subsystems, including DMSs (www.ntcip.org). The standard addresses both the transmission rules, and the format and meaning of standardized messages transmitted using those rules. The NTCIP DMS standard is currently under review for updates. The latest standard release will include a definition of objects governing display of pictograms.

6.2 Power

DMSs should be, as much as possible, installed to utilize utility power not solar power. DMSs typically use 60 Hz, 115 VAC input voltage. Power consumption depends on the sign size and manufacturer, and should be verified prior to arranging the power supply connection. DMSs installed within areas with full roadway illumination should be designed to utilize existing substation power. A step-down transformer will be required. DMSs installed in areas with no roadway illumination should be connected to a dedicated utility supply point of adequate capacity.

Power requirements for portable applications require special consideration, since these signs typically use power generated by an assembly of solar panels and deep cycle batteries. The capacity of solar array/batteries should be determined on the basis of sign usage. The typical design criteria should assume continuous, year-round use of PVMSs at 30% pixel utilization. Designs should give consideration to the efficiency of solar array during short days of fall and early winter months, as well as the efficiency of the batteries during cold temperatures, and account for possible manual recharging of the batteries during these periods. For maximum flexibility, the PVMS should be designed to also use an input voltage of 115 VAC, 60 Hz, for locations where utility power is easily accessible. The sign shall include power supplies required to convert the input voltage to the voltage required by the sign components.

When installing a solar-powered DMS, the installer should ensure that the solar panel is directed towards the south and tilted according to the manufacturer's recommendation. If this is not done, the power output from the solar array is reduced, which causes premature battery drain.

6.3 Grounding

DMS structures should be installed with appropriate grounding facilities in accordance with local and provincial codes and regulations.

6.4 Mounting

All assemblies within the sign case should be mounted using shock-, vibration- and weather-resistant hardware in accordance with appropriate local and provincial codes and regulations.

When mounted overhead, there should be a minimum vertical clearance of 5.5 m between the lowest point of the DMS/overhead structure and the crown of the road. For roadside mounting, the bottom of the DMS should be at least 1.5 m above the adjacent edge of pavement for visibility reasons. Higher mounting may be required in urban locations to avoid potential hazards or conflicts with pedestrians.

The display should be mounted perpendicular to the direction of travel measured at the mid-point of the upstream legibility distance of the sign, confirmed with a site check prior to final acceptance. It should also have a tilt, typically of 3 degrees from vertical, towards oncoming traffic. Tilting is not a required feature for PVMs.

6.5 Maintenance Access

Either front access or walk-in maintenance access to overhead mounted signs is generally acceptable, subject to compatibility with the design of the sign support structure and the maximum dimensions of the sign. The sign design should permit easy access to the modules, wiring and internal components for maintenance purposes.

Walk-in signs provide a number of advantages. First, maintenance work is conducted inside the sign, and therefore it does not distract motorists. Working inside eliminates concerns about weather conditions, provides a safer environment for workers, and also for motorists, by eliminating the risk of dropped equipment or materials falling onto the roadway.

If access to the sign is to be gained from a catwalk structure rather than an enclosure, care must be taken to ensure that the design is such as to minimize the risk of dropping parts, tools, etc., onto the roadway below. Safety of the workers is of paramount importance, so elements such as non-skid surfaces, adequate handrails and harness points must be considered.

Consideration should also be given to providing a safe off-road vehicle access site for maintenance activities, to minimize the need for lane or shoulder closures.

6.6 Material Specifications

The structural design for the sign casing, including the load on the sign face and mounting hardware, shall comply with the requirements of the current Canadian Highway Bridge Design Code.

The structural design of the sign and the associated mounting assembly must be compatible with the design of the sign support structure, including any trusses, columns and foundations. All structural designs (including weight calculations, wind loads etc.) should be reviewed and attested to by a professional engineer licensed to practice in the Province of Ontario.

The sign case should be constructed of durable materials. The sign case should provide the required protection and mechanical strength for the application. The design must safely accommodate the maintenance activities required, including ease of opening and closing access panels in an outdoor environment.

Sign Face

When the manufacturer's design calls for the installation of weathertight sheeting, (usually polycarbonate or "Lexan") to protect the sign face, the polycarbonate sheets should be uniform from one panel to another across the sign. The polycarbonate sheet system should be designed to allow cleaning of the internal surface of the polycarbonate sheets.

The sign enclosure and the equipment housed within should be protected from moisture, rain, snow, sun radiation, dust, dirt, and salt corrosion found in a highway environment. The environmental system should maintain the internal environment of the sign within the operating range of all internal components, considering the external conditions encountered in Ontario. A heating system and thermal insulation should be provided, if required, to prevent any adverse effects on the equipment due to condensation. A forced ventilation system should be provided, if required, to mitigate the effects of dust ingress and for providing thermal cooling, and thermal equalization. All forced intake air should be filtered.

Control of negative (out-forward) pressure should be carried out as specified by the Canadian Highway Bridge Design Code.

The materials specifications should also address: electronic components, electrical components, cables and wiring, grounding materials and driving circuitry.

6.7 Security

Most DMSs have been installed in a freeway or expressway environment where pedestrian activity is minimal, and therefore vandalism has not been a major issue. If a DMS is installed in an area experiencing pedestrian movement, positive steps must be taken in the design to prevent public access to the sign structure.

Cabinets should have as a minimum a standard traffic signal lock. Consideration should also be given to implementing high-security coded cylindrical locks. With this type of lock, the access code can be changed after a contractor has completed a work assignment. Anti-climb measures for the DMS structure legs should also be considered.

The hardware and software components should be designed to minimize the potential for infiltrating the system. This has become a greater risk, due to the use of wireless communication systems, and IP-addressable equipment.

7. Addendum

Excerpt from Bilingual Sign Design Study

The Ministry of Transportation Ontario commissioned a Bilingual Sign Design Services report that has not been publicly released as of the date of publication of this Ontario Traffic Manual. The Bilingual Sign Design Services report contains valuable information on human factors considerations, some of which has been included in Section 5 of this manual. To assist transportation practitioners, an excerpt of the report is being provided below in its entirety.

Human Factors Design Specifications

This section describes human factors design specifications, which apply to the sign types within the scope of this study. These human factors specifications are used as benchmarks to screen the preliminary options and later assess in detail the short-listed scenarios.

General

The following guidelines briefly summarize human factors requirements for bilingual variable message signs. These requirements are based on studies in which driver visual acuity, reading time, message comprehension and message recall have been measured in relation to VMSs. Good design considers the needs of the majority, rather than simply the "average". A typical target is to design for 85% of the population. In order to design for a wide range of drivers with respect to literacy and cognitive skills, all requirements apply to 15th percentile driver performance, and are based on studies involving a wide range of drivers. With respect to legibility, for example, a 15th percentile driver performance of 4 m legibility/cm of letter height (e.g., a 10 cm character could be read at 40 m distance) would mean that 85% of the population do better than this, and 15% are worse. Thus the 15th percentile value, which allows the needs of 85% of the population to be met, represents a reasonable worst case for design.

Legibility

Based on a 1992 study, which provided mean, not 15th percentile values, LED technology used in variable message signs has a mean legibility of 4.7 m/cm. Therefore, 4.7 m of legibility distance are available per centimetre of letter height. The same study indicated a lower mean of 4.1 m/cm for older drivers at night. Based on a more recent study, current LED technology legibility varies in a non-proportional fashion with letter height, with 15th percentile legibility values as follows:

- 23 cm (9 inch): day 3 m/cm, night 1.6 m/cm;
- 27 cm (10.6 inch): day 3.6 m/cm, night 2.4 m/cm; and
- 46 cm (18 inch): day 5.3 m/cm, night 3.6 m/cm.

Based on the 1992 study, current 400 Series Highway overhead variable message signs with 45 cm letters will be legible for 212 m (7.6 seconds at 100 km/h), based on mean legibility, and 185 m (6.6 seconds) based on average legibility for older drivers at night, which is a reasonable worst case. Based on the more recent study, overhead VMS will be legible for 239 m (8.5 seconds) during the day, and 162 m (5.8 seconds) at night, based on the 15th percentile driver.

Therefore, it was determined that six to nine seconds would represent the typical time that a VMS sign is legible for the 15th percentile driver at the posted speed of 100 km/h. These values were used to establish typical exposure times.

Font

A width-to-height (W:H) ratio of 1:1, with single-stroke character width on a 5 x 7 matrix is recommended to maximize legibility distance. Current VMSs on 400 Series Highways use a maximum W:H ratio of 1:1 (e.g., 7 pixels x 7 pixels for the letters "W" and "X") to produce 25 characters on the 7 x 175 matrix. Increasing the W:H ratio of a PVMS character from 0.7 to 1.0 increases legibility by 0.84 m/cm, equivalent to an additional 1.4 sec of reading time at 100 km/h for 45 cm letter heights. A larger width-to-height ratio reduces the number of characters that can be displayed per line, and therefore, per message, on the already constrained capacity of PVMS.

Exposure Time

Current 400 Series Highway overhead VMSs, based on reasonable worst-case legibility, have nine seconds of available reading time (exposure time) during the day and six seconds of available reading time at night (day), at a driver speed of 100 km/h.

Required time should be tested for specific messages, as the clarity of the message has a major impact. In the absence of testing, based on an on-road study to determine 15th percentile reading times, approximate assumptions can be made as follows:

- One second per major word (e.g., Accident, Congestion, Lawrence Ave.); or
- Two seconds per unit of information (e.g., at Avenue Rd. or left lane blocked), whichever is longer.

One unit of information answers a question such as "What happened?" "Where did it happen?" "What effect did it have on traffic?" "What action should be taken?" "Who should take an action?" etc. Most current 400 Series Highway overhead VMS require five to eight seconds of exposure time.

Comprehension

Testing is required to establish comprehension. Even when text messages or pictograms have been in use for many years, they are not always well understood when tested with the general public. A list of well-understood abbreviations is available (Dudek, Huchingson, Williams, and Koppa, 1981). If drivers do not understand a message, reading time and incorrect responses increase.

Information Load

A maximum of three units of information should be displayed at one time for a given language, as long as there is adequate legibility to provide six or more seconds of exposure time at the operating speed. When motorists are given four units of information, only about two-thirds can recall all four units. Thus a limitation of three units is likely to meet the needs of more than 67% of the population.

Most current overhead VMSs display three units of information. However, several display four or five units of information.

Phasing

A phase refers to a message segment that is individually displayed. For example, the first phase may be "Construction Ahead" and the second phase "Reduce Speed to 60 km/h." If phasing is used, a maximum of two phases is recommended. When three (monolingual) phases were used, 55% of younger drivers and 19% of older drivers could recall the third phase. Therefore, a design that meets the needs of a majority of drivers should include no more than two phases.

Because of the demands of the driving task, a driver may not be able to read the sign until halfway through a phase. Therefore the driver should have more than one opportunity to read the first phase he or she sees. This means that for a two-phase message, at least three messages (the first, the second, and a repeat of the first) must be viewed within the available legibility window (six to nine seconds for current overhead VMSs at 100 km/h) to allow the driver a second chance to see the first phase viewed. It should be noted that, in recommending an opportunity to read three messages, we are assuming that there is some advantage to the monolingual driver, in that some of the words in one language will be repeated in the other. The FHWA Design Guide for older drivers recommends that the message should be presented so that it can be read completely, twice – i.e., the opportunity to see four phases for a two-phase message.

Based on considerations above, phasing of some of the longer messages in both languages will be problematic. It is possible to more effectively display information statically than to do so dynamically.

A minimum time of three seconds per phase is recommended, no matter how short the message. An inter-frame time interval of 0.25 to 0.5 seconds is advisable. Current MTO minimum spacing between overhead signs is 300 m. At 100 km/h this is equivalent to 10 seconds. Even if the current letter height were to be increased, sign spacing sets a limit of 10 sec of legibility.

Other Design Considerations

In addition to the human factors design specifications, the guidelines for good sign and message design need to be followed. The guidelines for static sign design are described in specific Books of the Ontario Traffic Manual (OTM), including Book 1b (Sign Design Principles), Book 2 (Sign Design, Fabrication and Patterns) and Book 7 (Temporary Conditions). The guidelines for VMS and PVMS design are covered in OTM Book 10 (Dynamic Message Signs) and Book 19 (Advanced Traffic Management Systems).

The following sign design considerations pertain in particular to the display of bilingual messages on the signs within the scope of this study:

- Consistency in format, so that drivers can quickly find the language that they understand, e.g., not mixing multi-phase and single phase formats on bilingual signs;
- Delineation of languages, e.g., showing English on the upper lines of an electronic or static sign and French on the lower lines, separated by a horizontal line, where practical;
- Limiting pivot words consisting of an English and French term separated by a slash, e.g., to / à, to one per line of text;
- Consistency of pictogram treatment, e.g., establishing conventions for depicting express and collector lanes on pictograms, incorporating use of colour to convey information, representation of left, centre and right lanes, etc.;
- Keeping information units together, with one unit per line of text, if possible;
- Use of pictograms with supporting text (e.g., similar to the function of educational tab text), and not using pictograms that provide new information unsupported by the sign text;
- Simplicity of sign legend and economy of text; and
- Ensuring that the linkage between a traffic event and its location is clearly conveyed.

In some cases, trade-off may be required between design considerations. Testing can be used to decide which trade-offs are more effective in terms of driver reading time and comprehension.

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Appendix A • Definitions

A

Advanced Public Transit Systems (APTS)

The application of advanced electronic and communications technologies to improve the safety and efficiency of public transit systems.

Advanced Traffic Management Systems (ATMS)

The application of advanced electronic and communications technologies to improve the safety and efficiency of the road network.

APTS

Advanced Public Transit Systems.

ATMS

Advanced Traffic Management Systems.

B

Blank-out Sign

A type of CMS with two states, either on or off. When the blank-out sign is off, there is no message displayed. When the sign is on, a pre-determined message is displayed to motorists.

C

Candela

The basic SI unit of luminous intensity.

CMS

Changeable Message Sign.

Changeable Message Sign (CMS)

A specific subset of Dynamic Message Signs which may display a limited number of fixed messages, any one of which may be displayed at any given time, or display no message at all. It is an electrical, electro-optical, electro-mechanical, or mechanical sign which permits the sign message to be changed, either locally or remotely. The messages that can be displayed to the motorists are pre-defined. Unlike VMSS, CMSs cannot be individually configured.

Commercial Vehicle Operations (CVO)

The application of advanced electronic and communications technologies to improve the safety and efficiency of commercial vehicle/fleet operations.

Comprehension

The ability of drivers to understand the meaning of a sign message, including any symbols or abbreviations.

Conspicuity

The ability of a traffic control device to attract or command attention, given the visual setting in which it is placed.

CVO

Commercial Vehicle Operations.

D

DMS

Dynamic Message Sign.

Dynamic Message Sign (DMS)

An array of sign technologies that have the capability of displaying different messages to suit changing conditions on the roadway. Included within the family of Dynamic Message Signs are full-matrix displays, single line or character-matrix displays, multiple pre-set message displays and simple on-off

or “blank-out” displays. The terms “Changeable” and “Variable” are used in the OTM to describe specific sub-sets of Dynamic Message Signs.

F

Fibre Optic Signs

Fibre optic signs are light-emitting signs that utilize a halogen bulb light source and fibre optic cable to illuminate the pixels, which are lenses coupled with shutters that either let the light through or block the light from being displayed.

I

Intelligent Transportation Systems (ITS)

The application of advanced and emerging technologies (computers, sensors, control, communications and electronic devices) in transportation to save lives, time, money, energy and the environment.

ITS

Intelligent Transportation Systems.

L

LED

Light Emitting Diode.

Legibility

Sign legibility is governed by the distance at which the sign becomes legible and the duration for which it remains legible. Legibility depends on character, word and line spacing, character height, font, contrast ratio and clarity of symbols.

Light-Emitting Diode (LED)

Light-emitting diode or LED VMSs are currently the preferred type of light-emitting sign technology. The pixels for LED signs are comprised of multiple light-emitting diodes, which are solid state electronic devices that glow when a voltage is applied. Adjusting the voltage that is transmitted to each pixel controls the intensity of the light emitted from each LED pixel.

Luminance

The luminous flux in a light ray, emanating from a surface or falling on a surface, in a given direction, per unit of projected area of the surface as viewed from that direction, per unit of solid angle.

Luminance Ratio

The ratio of the difference in luminance between the ON and OFF condition of an illuminated sign element, to the luminance in the OFF condition.

$$\text{Luminance Ratio} = (L_a - L_b) \div L_b$$

Where:

L_a = The measured luminance (cd/m^2) of the element in the ON-state.

L_b = The measured luminance (cd/m^2) of the element in the OFF-state.

M

Matrix

A variable message sign display, made up of a series of dots (pixels) in a matrix format. Parameters or symbols are formed by illuminating different patterns of pixels.

Module

A unit in a character matrix sign, which is comprised of several pixels and can display an individual character.

N

National Transportation Communications for ITS Protocols (NTCIP)

A family of communication protocols developed, or being developed, for the transportation community.

NTCIP

National Transportation Communications for ITS Protocols.

P

Pixel

An individual dot of light that is the basic unit from which the images on a variable message sign are made.

Portable Variable Message Sign (PVMS)

A Variable Message Sign that may be moved from place to place to provide drivers information on conditions, usually work zone conditions, at the time and place where needed.

PVMS

Portable Variable Message Sign.

V

Variable Message Sign (VMS)

A specific subset of Dynamic Message Signs. VMSs provide the highest level of functionality of all of the DMSs. VMSs contain a variable display, made up of a grid or matrix of discrete dots, known as Pixels. Combinations of pixels render the appearance of a continuous formed character or graphic symbol. The VMS can display a full array of alphanumeric characters and symbols to form message combinations and can also have full graphics capability.

VMS

Variable Message Sign.

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