


Guidance for the Use of **Portable Changeable Message Signs in Work Zones**

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ATSSA
SAFER ROADS SAVE LIVES
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INTRODUCTION

> In 2010, work zones accounted for almost 600 fatalities and more than 37,000 injuries in the United States. *(FHWA 2003)*

Almost 2 percent of all crashes in the United States occur in work zones. While they don't seem like a major source of roadway crashes, work zones accounted for almost 600 fatalities and more than 37,000 injuries in 2010 *(FHWA 2003)*. Work zones, despite appearing on small portions of roadway temporarily, are associated with higher crash rates as compared to non-work zone locations primarily due to changing roadway conditions and speed limits. Work zone crashes affect drivers, passengers, pedestrians, and construction workers. Additionally, they can lead to follow-on crashes, major traffic delays or congestion, and delays in construction schedules. Some causes of work zone crashes include *(Kansas University Transportation Research Institute, Kansas DOT, and FHWA 2009)*:

- ***High vehicle speeds***. More than 30 percent of work zone crashes are speed-related *(NHTSA 2012);*
- High variance of speeds; between all vehicles;
- High traffic volume through the work zone;
- Driver inattention; and
- ***Driver confusion*** about work zone schedules and changing roadway conditions**.**

Figure 1 – Highway Work Zone [1]

The use of portable changeable message signs (PCMS) in work zones can mitigate some of these issues. According to the Roadway Safety Consortium (2011), "PCMSs [sic] are commonly used in work zones to convey real-time information to drivers, as well as to call additional attention to hazards identified by static warning signs." Though the PCMS devices have been used for many years in work zones, some State DOTs have applied these devices in new ways to improve work zone safety and mobility. State agencies have demonstrated that PCMS can be applied in more cutting-edge ways to specifically manage vehicle speeds and volumes and reduce driver distraction.

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[1] FHWA, Accessed from: http://www.fhwa.dot.gov/publications/focus/10jan/05.cfm

Objectives of the Document

The objectives of this document are:

- To introduce portable changeable message sign (PCMS) exploratory strategies in work zones and convey their benefits and limitations.
  - To discuss when and how to implement the PCMS strategies.
  - To present other key aspects to consider before and during implementation.

GENERAL GUIDANCE

PCMS are made for a variety of scenarios. In order to accommodate numerous work zone applications, PCMS come in a variety of sizes, and with various power sources, mounting options, and methods for controlling or programming. PCMS design factors are described in Section 2.1 below.

Design Factors

PCMS come in numerous types, based on light-emitting technology, size, controls, mounting options, and power options.   Each of these design factors influences the effectiveness of a PCMS in transmitting information to drivers in work zones.

- LIGHT-EMITTING TECHNOLOGY
    - **Light-emitting diodes (LEDs).** Most modern PCMS utilize LEDs to display messages. Typically, these LEDs are arranged in a grid (see Matrix Type, below) in which a cluster of multiple LEDs make up one pixel. *(Wisconsin DOT 2000)*
    - **Flip-disk technology**. This technology utilizes a grid of square, rectangular, or circular "disks", each one reflective on one side and not reflective on the other. When a message is programmed, specific disks flip out to show their reflective side, creating a readable message on the PCMS.[2] *(Wisconsin DOT 2000)*
    - Additional technologies include **fiber-optic and hybrid**, but these models are not as widely used or tested by State agencies. Fiber optic screens utilize fiber optic cables coming from a single light source to each pixel location where there is a small hole on the sign face. Hybrid PCMS utilizes both flip-disk and fiber optic or LED methods. In addition to the tradition flip-disk design, each disk has a hold in the center which allows light to pass through. This light is generated by either a fiber optic bundle or an LED cluster. *(Wisconsin DOT 2000)*

Figure 2 – Flip Disk Technology[2]

The table below, adapted from Wisconsin Department of Transportation's ITS Design Manual (2000), provides advantages and disadvantages of each type of PCMS.

[2] MnDOT, Accessed from: http://www.dot.state.mn.us/trafficeng/workzone/pcms/ADDCO-Flip-Disk/pages/ADDCOFlipD3_JPG.htm

Table 1 – Advantages and Disadvantages of Each PCMS Technology

Technology	Advantages	Disadvantages
Flip Disk	• Proven technology • Low power requirements • Sharp, legible message • Typically a Character Matrix	• More moving parts may lead to additional maintenance • Reflective disk surfaces may become sun-bleached over time • Reduced visibility in low-light conditions at long distances
LED	• Consistent visibility among many light conditions • Fewer moving parts may require less maintenance • LED bulbs are rated for 100,000 hours of service • Typical usage is Full Matrix	• Smaller cone of vision, which can reduce message legibility at close distances • Diodes can be sensitive to heat
Fiber Optic	• Good visibility under normal operating conditions • Sharp, legible message • Typical Usage is Full Matrix	• More moving parts may lead to additional maintenance • Lamps are typically rated for only 8-10,000 hours of service • Illumination intensity cannot be adjusted for various light conditions
Hybrid	• PCMS can still be utilized if light source fails • Sharp, legible message • Typical Usage is Full- or Character Matrix	• More moving parts may lead to additional maintenance • Reflective disk surfaces may become sun-bleached over time

- SIGN SIZE
  - PCMS range in size from small (about 6 feet wide by 4 feet tall) to large (about 10 feet wide by 6-7 feet tall).
  - Consider the speed of traveling vehicles as well as the number of words or characters in the message when choosing the size of the PCMS to use. USSC & Bertucci (2006) provide detailed guidance and calculations for sign size determination.
- MATRIX TYPE (FHWA 2003)
  - **A full-matrix** is comprised of individual lighting elements or pixels arranged in a full-size grid. This matrix type, shown in Figure 3, is the most flexible and allows for a variety of fonts, character heights, and may support symbols or graphics. Full matrix PCMS are

Figure 3 – Full Matrix PCMS [3]

[3] Equipment rental and sales website. Accessed from: http://www.equipmentrentalct.com/rent-safety-equipment-ct.aspx

typically used to support special fonts or font sizes, graphics, or other more complicated messages.

- **A continuous line matrix** is comprised of an individual line matrix for each line of text within which characters can be spaced in any way. A continuous line matrix, shown in Figure 4, allows for proportionally spaced fonts or unique characters.[4] Generally, this results in an easier to read message than a modular or character matrix screen. Continuous line matrix PCMS are used frequently for simple, concise messages with no graphics.
- **A modular / character matrix** is comprised of individual character blocks with one character per block in a pre-arranged grid. Character matrix PCMS, shown in Figure 5, are used for messages with a small number of characters of a single font size and type.

Figure 5 – Continuous Line Matrix PCMS[4]

Figure 5 – Character Matrix PCMS[5]

The figure below shows a comparison of the three types of PCMS displays, where the gray areas represent the areas with pixels that can be used to create the message.

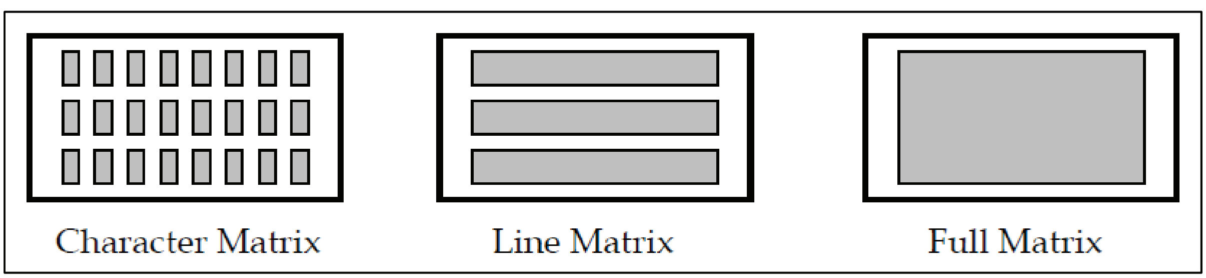

Figure 6 – PCMS Matrix Types *(Wisconsin DOT 2000)*

- CONTROLS/ MESSAGE PROGRAMMING
  - Remote controlling/programming. Some PCMS are programmable using mobile or handheld devices or remote controls. This option provides more flexibility to the programmer since it does not require a physical presence at the PCMS deployment location to program or change a message.

[4] Road Traffic Technology. Accessed from: http://www.roadtraffic-technology.com/projects/big_i/big_i5.html

[5] FEMA Responder Knowledge Base. Accessed from: https://www.rkb.us/contentdetail.cfm?content_id=207105

- On-site controlling/programming. To program the PCMS, a practitioner must connect a laptop computer to the device in the field to program the sign. Some PCMS have built-in computers used for programming.
  - With this control method, there is a risk that a member of the public could easily reprogram the PCMS as illustrated in Figure 7. It is advised that practitioners use safeguards to prevent unwanted reprogramming. Some PCMS require a unique passcode to be entered before re-programming can be initiated on the sign.

Figure 7 – Reprogrammed PCMS [6]

- MOUNTING OPTIONS
  - **Trailer-mounted**. A PCMS can be mounted to a trailer (see Figure 8) so that it can be towed into the field by a truck or vehicle. Traditionally the PCMS remains mounted to the trailer mount, but not the towing vehicle, while deployed.
  - **Truck-mounted**. A PCMS can be mounted to a truck (see Figure 9), typically only if it is smaller in size. Traditionally, the PCMS remains truck mounted during deployment.

Figure 9 – Trailer-mounted PCMS (Source: Matt Myers, SAIC)

Figure 9 – Truck-mounted PCMS[7]

- POWER OPTIONS
  - **Solar-powered.** The PCMS is powered using solar panels installed on the device. This solution may save on costs in the long run, but it requires a relatively sunny environment to power the PCMS for extended periods of time. Typically, solar-powered PCMS boards have built-in batteries to store the solar energy

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[6] FHWA. Accessed from: http://www.ops.fhwa.dot.gov/wz/workersafety/wzfrwebinar/fl/

[7] AmSig. Accessed from: http://www.amsig.com/CMSGP_232.htm

gained during the day and needed at night. These batteries can be engaged in the event that solar power is depleted (e.g., overnight, during cloudy periods). Each agency should carefully review whether solar power is a feasible option in their geographic area.

- **Battery-powered**. The PCMS is powered using batteries only. Typically, a full charge lasts between a couple days and a week. When the battery is discharged fully, a replacement battery must be used, or the PCMS battery needs to be recharged, which may take between a few hours and a day. This solution is feasible in less sunny environments and may present lower costs up-front. Battery power requires more time throughout the project for recharging.
- **Generator**. A PCMS can be hooked up to a generator as a power source. Typically, this solution will not last as long as solar or batter power due to the amount of energy required by a generator. Additionally, the generator requires extra space next to the PCMS which may limit its applicability.

- Additional design factors
  - PCMS with the ability to save or store messages. Some PCMS can be purchased with pre-loaded commonly-used messages.
  - Some PCMS support text animation (text can flash or slide onto the screen).
  - PCMS wind load varies by model (maximum magnitude of wind speed that can be tolerated by PCMS).
  - Some PCMS feature automatic sign-dimming at nighttime.

MESSAGE GUIDELINES

"To be effective, a PCMS must communicate a meaningful message that motorists can read and comprehend within a very short time period." *(Ullman, Dudek, and Ullman 2005)* PCMS messages depend on a variety of factors, including the type of situation the message describes, the number of lanes and speed of traffic, the complexity of the situation, etc. The remainder of the document provides guidance on how to tailor the PCMS message to a specific problem, occurrence, or goal; this section provides general guidelines that apply to all PCMS messages to maximize effectiveness and safety. Guidelines for PCMS messages are described below:

- Message Content
  - The message should describe the problem, its location, and potential actions drivers can take to avoid or reduce the problem.
  - In total, the message should include a maximum of four units of information.

Units of Information

A unit of information is “a single answer to a single question that a driver can use to make a decision,” as explained in Section 2L.05 of the MUTCD. The following example from the MUTCD shows a PCMS message with four units of information. See Chapter 2L in the MUTCD for additional information.

Table 2L-1. Example of Units of Information

Question	Answer	Number of Information Units
What happened?	MAJOR CRASH	1
Where?	AT EXIT 12	1
Who is the advisory for?	Drivers Heading TO NEW YORK	1
What is advised?	USE ROUTE 46	1

Note: The following is an example of a two-phase message that could be developed from the four information units shown in this table:

MAJOR CRASH AT EXIT 12	USE ROUTE 46 TO NEW YORK
Phase 1	Phase 2

Figure 10 – Example of PCMS Message with Four Units of Information *(FHWA 2012)*

- Message Length
    - The message should be as short as possible without becoming confusing, incomplete, or using improper abbreviations. For a list of acceptable and unacceptable abbreviations, refer to Section 1A.15 in the Manual on Uniform Traffic Control Devices (MUTCD). Section 1A.15 is included in Appendix B of this guide.
        - One or two phases is acceptable. *(FHWA 2003)*
        - A third phase may be used, but it is not preferable. Consider using an additional sign when the message requires three phases or more.
    - Avoid generic messages. A generic message is not necessarily the same thing as a short message; generic messages are considered less informative and may be applied across many different scenarios, which often means they do not provide much value to drivers. As a result, “generic messages can cause PCMS to lose effectiveness with the motorists” since they lack specificity that the driver needs to make important decisions. *(Ullman, Dudek, and Ullman 2005)*
- Message Phasing
    - The message should be designed across multiple phases so a driver can understand it starting from either phase.
    - Each phase should be understood by itself.

- Each phase should appear for at least 2 seconds.
- Guidance from the MUTCD states that if the message can be displayed using one phase, the first line should state the problem, the center line should describe the location or distance ahead, and the final line should give recommended driver actions. *(FHWA 2012; Section 6F.55)*

- Required reading time
  - "The minimum distance at which a sign must become legible is a function of the time it takes to read the sign and the decisions and maneuvers required to comply with the sign." *(USSC and Bertucci 2006)* The more times a driver must look away from the road to read the sign, the more safety is compromised. A straightforward, simple message is vital for minimizing the amount of time a driver is looking at the PCMS and not at the roadway.
  - FHWA provides guidance regarding the relationship between character height and average legibility distance, which is the distance from the PCMS where the message can be read accurately. The table below *(FHWA 2003)* provides an estimate of which character height aligns with each vehicle speed – as vehicles travel faster, characters should be larger to allow more time to read the message overall. The speeds provided align with the assumption that drivers can read the entire message, of no more than three phases, twice. The table, originally from the PCMS Handbook *(FHWA 2003)*, is reproduced below:

Table 2 – Relationship between Character Height, Legibility Distance, and Vehicle Speeds

Character Height (inches)	Legibility Distance (feet)	Associated Vehicle Speed (mph)
18	720	40
24	960	50
54	2160	Any

- Considerations:
  - Poor message planning, such as a message too long for drivers on high-traffic (including trucks) high-speed roadways to read or a message with unclear description of which lane ahead is affected, may cause driver confusion or an unwillingness to follow PCMS guidance. *(Ullman, Dudek, and Ullman 2005)*
  - The PCMS should not be programmed to include flashing, animation, fading, dissolving, moving messages, or other dynamic elements that aren't necessary for information transfer. *(FHWA 2012)*

Table 3 on the following page, adapted from the Roadway Safety Consortium (2011) and supplemented with guidance from the MUTCD, provides a summary of the key message guidelines for PCMS:

Table 3 – Key PCMS Message Guidelines

Factor	Description	Guidance
Message Content	Type of information displayed	• Include three essential pieces of information: • What are the conditions or hazards ahead? • Location of conditions/hazards • What action should be taken?
Amount of Information	Number of phrases (or units of information) in a message	• Maximum of four units of information
Length	Number of words and phases	• Maximum of two phases • Maximum of three lines (8 characters each) per phase
Character Size	Height, width, and stroke width of characters	• Speed > 45 mph = 18 inch height minimum • Speed ≤ 45 mph = 12 inch height minimum
Format	Order and arrangement of phrases	• One unit of information per line • Each phase must be understood alone • Entire message should be understood beginning from any phase

PLACEMENT

A portable changeable message sign should never replace or cover up traditional work zone signage required by the MUTCD. PCMS placement within the work zone should follow these basic guidelines when possible:

- Closest to the lane for which the message applies.
- On the shoulder or in the median, preferably behind guardrails or concrete barriers. (Roadway Safety Consortium 2011) In cases where guardrails or barriers do not exist, PCMS should be delineated with cones or barrels to increase visibility.
- Not in the buffer space.
- Rotated 3 degrees towards the roadway to reduce glare. (FHWA 2003)
- After initial work zone warning signs, but in advance of the work zone.
- Not blocking/obstructing other warning signs.
- Be legible:

Figure 11 – PCMS with Cone and Barrel Delineation
(Source: Matt Myers, 2013)

- Each PCMS has specifications for anticipated/tested legibility and readability distances. These distances are influenced by the display brightness and character contrast against the background, the brightness of the environment (especially daytime versus nighttime conditions), a driver's vision, and how the PCMS is placed along the roadway (specifically, how far off the roadway and the angle at which the PCMS is aimed, both vertically and horizontally).
- Place the PCMS close to the roadway to improve readability. A driver's "cone of vision," illustrated in Figure 12 below, extends 10 degrees in both directions *(USSC and Bertucci 2006)*; as a result a driver must divert their line of sight more as they approach the sign. "Signs falling within this cone can usually be viewed comfortably without excessive eye or head movement, and generally can be kept in the motorist's line-of-sight from the time they are first detected until they are passed." *(USSC and Bertucci 2006)* This increases the importance of easy readability and understanding of the message, as explained in Section 2.2.

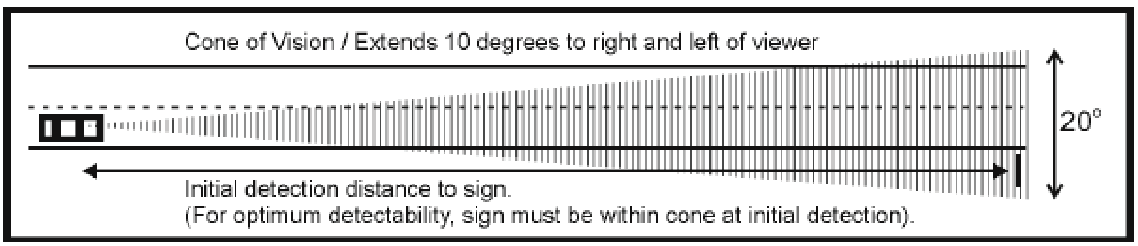

Figure 12 – Cone of Vision Diagram *(Source: USSC & Bertucci 2006)*

- Equipment quality and maintenance considerations
  - Place PCMS in a location near the roadway where it minimizes the possibility for collisions or other damage.
  - When deployed, every PCMS must meet or exceed the quality standards stated within ATSSA's *Quality Guidelines for Temporary Traffic Control Devices and Features* (2008-09 edition), including at least 90 percent of all pixels per character operating properly and dimming appropriately. Figure 13 shows a PCMS with many LEDs either too dim or not working at all. The PCMS message, which is supposed to read "LANE CHANGES AHEAD," is difficult to read since it has not been maintained appropriately. This PCMS should be evaluated to determine if it meets the quality guidelines provided by ATSSA; in the event that it does not meet the guidelines, it should not be used. Figure 14, which is directly from the *Quality Guidelines for Temporary Traffic Control Devices and Features* document, provides examples of the scenarios in which a PCMS of specific quality meets ATSSA's quality guidelines.

Figure 13 – PCMS with non-working LEDs. *(Source: Matt Myers, SAIC)*

- General Considerations:
  - Improper PCMS placement, such as at a location too close or too far from the feature of interest, may cause driver confusion or an unwillingness to follow PCMS guidance.

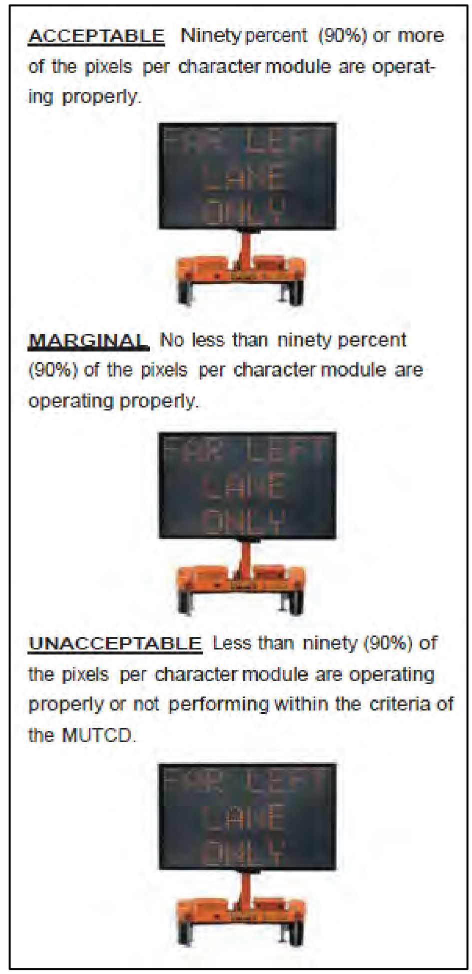

Figure 14 – ATSSA's Quality Guidelines Evaluation Guide for PCMS (ATSSA 2009)

Cost

According to a study by Garber and Srinivasan, when compared to the high costs of other work zone safety measures such as law enforcement, "the CMS … is, indeed, a very effective device for controlling speeds and speed variances both in short-term and long-term work zones." PCMS are highly valuable to a State DOT since the devices can be used year-round at a variety of sites and situations, including incident management and weather-related events. If PCMS are handled carefully and properly, the devices typically last 10 years. (Redel 2013, personal communication)

Generally, a PCMS costs between $12,000 and $20,000. Table 4 below provides examples of costs and specifications of various PCMS that can be purchased by State DOTs.

Initial costs will vary based on size, matrix type, power options, ability for remote controlling, and any additional features. A PCMS with solar panels costs more up front, but over time, it may result in savings as energy requirements are lower.

Table 4 – Sampling of PCMS Specs and Prices

Cost to purchase (range)	Typical Specifications of PCMS
Around $10K	• Smaller size, typically starting at 2.5 ft. (w) * 5 ft. (h) • Portable • Typically truck-mounted • May have longer battery life due to lower power consumption • May include the following features: solar power source, wide viewing angle
$12,000-$14,000	• Character- or line-matrix • Medium sized sign, typically about 8 ft. (w) x 5 ft. (h) • May include the following features: wireless controlling through cellular, modem, or antenna;
$14,000-$16,000+	• Line- or full-matrix • Larger size, typically about 10 ft. (w) x 6 ft. (h) • Typically trailer-mounted

	• May be solar powered, includes battery power • Better visibility and legibility • May include the following features: trailer brakes, wide viewing angle, ability to store messages, radar component for calculating vehicle speeds, wireless controlling through cellular, modem, or antenna;

Typically, PCMS are purchased by State DOTs. Some manufacturers allow rentals over shorter time periods, or by the year or longer. Many State DOTs or agencies have published lists of approved products for construction projects. The lists include specific products from specific manufacturers that have been tested and/or inspected and then approved for use within the State. One example is Oregon DOT's Qualified Products list, which includes more than 30 approved PCMS models of various specifications. (Oregon DOT 2013)

Missouri DOT (MoDOT) reports that their agency has purchased a large number of PCMS such that each is used about 9 months of each year. In this case, when a large number of PCMS are needed at the same time, MoDOT has additional PCMS ready to support those needs. Additionally, MoDOT allows Missouri local agencies to borrow the PCMS temporarily for their use. (Redel 2013, personal communication.)

Periodic maintenance and repairs may contribute to additional annual costs. Typically, a PCMS can be maintained and repaired for about 10 years, at which point it becomes difficult to find parts or perform cost-effective repairs.

APPLICATION: SPEED MANAGEMENT

NHTSA estimates that speed contributes to more than 30% of all fatal crashes. *(NHTSA 2012)* The speeding problem is exacerbated in work zones due to a higher speed variance among all vehicles. This section explores PCMS implementations that may target speeding drivers.

> Speed contributes to more than 30% of all fatal crashes in the US *(NHTSA 2012)*

CONDITIONS, TYPES, AND CHARACTERISTICS

Applying PCMS for speed management is most applicable in work zones with the following characteristics (either observed or predicted):

- High incidence of speeding drivers (Kenjale 2006)
- High speed variance between vehicles (Garber and Srinivasa 1998)
- High incidence of rear-end crashes
- Work zone design that includes a pattern change, lane closure, or flagging operation, as these would tend to increase the speed variance within the work zone.

STRATEGIES

The PCMS applications or strategies listed below can effectively manage speeds of vehicles in work zones.

PCMS Showing Messages Based on Speeds of Vehicles Passing By

Description: This PCMS strategy for controlling speeds in work zones involves a sign with radar or other speed monitoring technology. The radar/speed sensor calculates the speed of passing vehicles in real-time and the PCMS displays a message based on whether the driver is speeding or not speeding. The image on the following page shows a generic message "YOUR SPEED XX MPH" (Figure 15), but other messages may be used such as:

- "YOU ARE SPEEDING / SLOW DOWN"
- "OBEY SPEED LIMIT XX MPH"
- "EXCESSIVE SPEED SLOW DOWN"
- "REDUCE SPEED IN WORK ZONE"

This strategy differs from a traditional speed trailer because the PCMS displays varying messages instead of just vehicle speeds. It is better able to target speeding drivers through unique

Figure 15 – PCMS Displaying Speed of Passing Vehicles in a Work Zone[8]

[8] MSHA, Use of Portable Changeable Message Signs with Speed Display in Work Zones, August 2005, Available at: http://www.marylandroads.com/OOTS/02PCMR.pdf

messages based on whether they are driving at a reasonable speed.

Innovation – PCMS Targeting Large Trucks for Speed Managements

The strategy discussed above, PCMS combined with radar or another speed sensor, can be supplemented with an *over-height vehicle detector* to enable identification of large trucks. The PCMS could display speed-related messages only to speeding vehicles identified as trucks. This targeted speed management strategy would be useful for certain work zones, such as low-height bridge repairs or ramp work, in which speeding trucks would be exceedingly dangerous.

Benefits:

- Reduced average vehicle speeds (due to speeding vehicles slowing down) by 4 to 9 mph (Bai, Huang, Shrock, and Li 2011; Garber and Srinivasa 1998; Kenjale 2006; Mattox et al 2006; McAvoy 2011; Sorel et al 2006)
- Proportion of vehicles speeding excessively is reduced *(Sorel et al 2006)*

Limitations and Challenges:

- PCMS may lose effectiveness in terms of speed management in work zones over time. (Garber and Srinivasa 1998)
- Reduction in speed is not always maintained throughout entire work zone. (Sorel et al 2006)
- Cost of PCMS solution is increased if adding radar, cameras, etc.

Implementation Details:

- "While PCMS with speed display may be used on all types of highways and work zones, either in rural or urban environments, PCMS deployment is particularly recommended for rural and urban multi-lane divided high-speed roadways." *(Maryland State Highway Association 2005)* As an exception, the Maryland State Highway Administration (SHA) reports that on high-speed roadways practitioners must be cautious because drivers may test the limits of the device. For example, on high speed roadways where the speed of passing vehicles is more than 25 mph above the speed limit, SHA recommends not displaying the speed on the PCMS.
- For each deployment of the PCMS, the radar/laser/video camera component should be checked for accuracy.

PCMS Monitoring and Displaying Real-time Conditions Downstream

Description: This PCMS strategy helps to manage speeds within work zones by warning drivers of the conditions ahead. Such conditions may include current speed of vehicles ahead in the work zone, locations or lengths of any queues, etc. This strategy requires implementation of a technology to monitor conditions downstream, such as video cameras, radar or other speed sensor, or a system such as the iCone *(Minnesota DOT 2010)* or a person (highway safety engineer, work zone specialist, etc.) who monitors conditions continuously. Refer to Figure 16 for an example of a speed management PCMS implementation.

Benefits:

- Drivers are warned ahead of time when queues have formed downstream in the work zone.
- Potentially reduces driver frustration or aggressive driving if drivers are aware of slow or stopped traffic ahead.

Limitations and Challenges:

- This solution, when not automated, may require more effort by highway agencies or work zone crews to periodically assess work zone conditions and update the PCMS display. PCMS can lose effectiveness with drivers if they display inaccurate or out-of-date information.

Figure 16 – PCMS in Work Zones Displaying Information about Conditions Downstream [9]

Implementation Details:

- Automate the system by implementing a technology such as the iCone *(Minnesota DOT 2010)* to monitor traffic volumes downstream in the work zone. Traffic volume information gathered within the work zone can be used to program the PCMS, located upstream, to display useful real-time messages to drivers.

PCMS Showing Current Information about Work Zone Speed Limits, Delays, or Construction

Description: This PCMS strategy helps to manage speeds within work zones by providing current information about the work zone characteristics, speed limits, or roadway features. The information displayed will keep drivers informed and allow them to prepare for driving safely through the work zone. The input for this strategy would likely be visual confirmation by a practitioner, highway engineer, or specialist, who would reprogram the device as conditions change.

[9] FHWA, Comparative Analysis Report: The Benefits of Using Intelligent Transportation Systems in Work Zones, October 2008, Available at: http://www.ops.fhwa.dot.gov/wz/its/wz_comp_analysis/index.htm

Benefits:

- Increases driver awareness of upcoming conditions, which may reduce frustration or confusion
- Allows drivers time to reduce their speed before the work zone speed is enforced

Limitations and Challenges:

- Drivers will become frustrated and may not follow PCMS guidance in the future if information presented is inaccurate or out of date.

Implementation Details:

- Limit distraction to drivers – only implement this strategy when the work zone is active or changes to roadway characteristics are in place which may cause speed variations.

Case Studies

Case Study #1: Sorel, Sarasua, Davis, Ogle & Dunning, 2006.

This research studies the use of PCMS equipped with radar for reducing work zone speeds in South Carolina. The study involved placing radar-equipped PCMS along four highway work zones in South Carolina and comparing the effect of four different messages on vehicle speeds. The four messages studied are included in Figure 17. A default message ("STAY ALERT / WORK ZONE") was displayed on the PCMS at all times until the radar detected a speeding vehicle, at which point one of the speed-related messages was displayed. Note that the third message has two possible messages for the second phase depending on whether measured vehicle speed was over or within the speed limit. "Data collection and analysis [were] focused on singling out individual speeding vehicles and providing the driver specific messages." Vehicle speeds before and after PCMS deployment were compared for this study. Overall, the third and fourth messages produced the greatest speed reduction, but "all messages were found to reduce driver speeds" by between 3 and 10 mph. All messages produced significant reductions in the number of vehicles speeding excessively. Researchers noted that even when significant speed reductions occurred in the first half of the work zone test site, "nearly half of the reduced speed was regained" by the end of the test site.

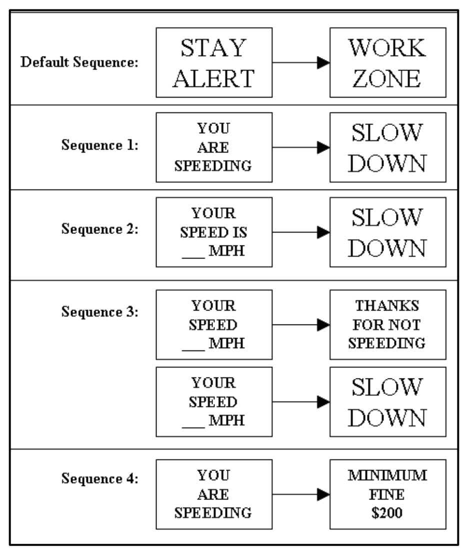

Figure 17 – Four Targeted PCMS Message Sequences Studied in SC Work Zones *(Source: Sorel et al 2006)*

Case Study #2: MnDOT, 2010 – iCone Final Report. *(Minnesota DOT 2010)*

Minnesota Department of Transportation (MnDOT) has used a device called the iCone, in combination with PCMS, in work zones to accurately calculate and display vehicle speeds to drivers upstream. The iCone was developed as a tool for monitoring traffic volumes on a roadway and innovatively hides sensors and communication devices inside what appears to be a typical traffic barrel. The setup transmits information using a cellular modem, though a satellite modem works as well. The device is relatively accurate for measuring both traffic volumes and speeds. Data is uploaded to a web server and can be used to program a PCMS to display certain messages to drivers upstream (such as warnings about low vehicle speeds ahead). “iCone data could be used to actively manage traffic, by integrating iCone data with a PCMS to warn drivers of queued traffic ahead. These signs could communicate directly with the iCones, allowing for the displayed information to be real-time and accurate.”

Major benefits:

- Accurate near-real-time information is feeding the PCMS
- If set up properly using cellular or satellite communication, the system can be autonomous and require little to no human intervention, decisions, or programming
- The iCone, as a supplement to PCMS, can be used in a wide-range of work zone situations such as bridges, city streets, or high-speed arterials

Limitations and Challenges:

- Agencies incur added expenses associated with purchasing and setting up a supplementary device.
- The system is most effective when applied to shorter duration work zones, since discharging of the iCone device happens over 14 to 17 days. “Recharging takes between 12 to 20 hours.”

APPLICATION: INATTENTIVE DRIVING

Inattentive driving can have dangerous consequences both in work zones and on regular roadways, including causing rear-end crashes (which may occur as a driver approaches a queue at too high of a speed) and sideswipe crashes (occurring when a driver drifts off the roadway or into another lane). PCMS can be an essential tool for mitigating inattentive driving in work zones. According to Ullman, Dudek, & Ullman (2005), "when used properly, these signs command more attention than regular static work zone signing." This section describes an effective PCMS implementation strategy for reducing inattentive driving through work zones.

Conditions, Types, and Characteristics

Applying PCMS for mitigation of inattentive driving is most applicable in work zones with the following characteristics (either observed or predicted):

- Long work zones (1 mile or longer) (Maryland State Highway Association 2005)
- Work zones within/around which unexpected queues form
- Work zones with anticipated or observed turns, lane changes, and travel choices that are confusing or easy to miss

Strategy

The PCMS application or strategy listed below can effectively mitigate driver inattention in work zones.

Multiple PCMS throughout the Work Zone Displaying General Reminder of Work Zone Area or Reduced Speeds to Drivers

Description: This strategy involves placement of PCMS in multiple locations throughout the work zone to remind drivers of the modified roadway conditions and keep them focused on navigating the conditions. The PCMS message should state general information, such as a work zone speed limit, reminding drivers that they are in a road work area. Practitioners may locate PCMS based on expected end-of-queue locations or choose to disperse the PCMS based on other factors. Refer to the images in Figure 18 on the following page for an example of this implementation.

Benefits:

- Using multiple PCMS boards allows highway engineers or safety specialists to transfer more than two phases of information to drivers.
- Drivers will be reminded to drive safely repeatedly throughout the work zone.
- If locations of expected queues are known, using a PCMS immediately in advance of this location may alert drivers and reduce crash frequency.

Limitations and Challenges:

- It is important not to use PCMS excessively to the point that it increases distraction to drivers or causes them to ignore all the signs. A study by G. Ullman, B. Ullman, C. Dudek, and A. Williams (2005) concludes that sequential PCMS should not display more than four total units of information; a theory which may translate to more widely dispersed PCMS throughout a work zone.

Implementation Details:

- "Multiple PCMS must be spaced at least 800 feet apart, and should not be placed where they compete with static signs or other features that demand immediate driver attention." *(Roadway Safety Consortium 2011)* [Note: The MUTCD (Section 6F.60) suggests PCMS shall be placed 1,000 feet apart on freeways and interstates, and at least 500 feet on other routes.]
- Work zones one mile or longer can benefit from the deployment of two or more PCMS. *(Maryland State Highway Association 2005)*

Figure 18 – PCMS Alerting Drivers to Work Zone Activity and Reduced Speed Limit[10]

[10] FDOT, FDOT's Work Zone Fatality Reduction Strategies, June 2012, Available at: http://www.ops.fhwa.dot.gov/wz/workersafety/wzfrwebinar/fl/images/fl_s5.png

APPLICATION: DEMAND MANAGEMENT

CONDITIONS, TYPES, AND CHARACTERISTICS

Applying PCMS for demand management in work zones is most applicable in work zones with the following characteristics (either observed or predicted):

- Heavily traveled work zones (in which the traffic volume exceeds the roadway capacity considering construction).
- Work zones within which queues form often and/or cause major delays to traffic or construction schedules.

STRATEGY

The PCMS application or strategy listed below can effectively manage traffic demand in work zones.

PCMS Showing Delay Times through Work Zone Compared to Suggested Alternate Routes

Description: This strategy involves a PCMS providing information about alternate routes which vehicles can take to avoid a major delay downstream in the roadway caused by a work zone. The PCMS should be located upstream of the major delays within the work zone so that drivers have time to react to the information on the sign and decide whether to take an alternate route. *(Athey Creek Consultants 2013)* Additionally, the PCMS should be located before exits to the alternate route. See the image in Figure 19 for an example of this PCMS implementation.

Benefits:

- According to the Roadway Safety Consortium, three benefits of this type of PCMS implementation in work zones are:
  - Reducing vehicle exposure by encouraging travelers to use alternative routes and travel modes.
  - Reducing traffic congestion (which leads to a reduction of rear-end and sideswipe crashes) by diverting motorists to alternate routes, to times when traffic demands are lower, or to alternative travel modes.
  - Increasing driver awareness and expectations of overall delays (e.g., 10 Min Delay Ahead) or hazardous conditions (e.g., Uneven Pavement), which reduces driver frustration and road rage-type aggression and may also lead to safer driving behaviors. *(Roadway Safety Consortium 2011)* This benefit was also noted in *(Athey Creek Consultants 2013)*, which studied the use of travel time displays and alternate route suggestions along a major interstate with construction near Duluth, MN.

Figure 19 – PCMS Warning Drivers to Find Alternate Routes around the Work Zone[11]

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[11] ODOT, Work Zone Awareness Pictures website, Accessed from: http://www.okladot.state.ok.us/newsmedia/workzone/pictures/

Additional benefits include:

- The before and after analysis supports the notion that the message signs are influencing drivers to change their routes.
- This study suggests that a 10 percent alternative route selection rate during peak periods is achievable when accurate, up-to-the-minute, information about delay through a work zone is provided and there is an attractive set of alternative routes. *(Horowitz, Weisser, and Notbohm 2003)*
- Between 21 and 50% of survey respondents for the MnDOT I-35 Travel Times project *(Athey Creek Consultants 2013)* changed their route (at varying frequencies) as a result of the travel time displays.

Limitations and Challenges:

- According to driver surveys conducted by Pesti, McCoy, Meisinger, and Kannan (2002), drivers may question PCMS credibility about delays or suggested alternate routes if the PCMS is placed so far upstream that the work zone is not visible. *(Pesti, McCoy, Meisinger, and Kannan 2002)*
- Similarly, drivers may question PCMS credibility or usefulness if they witness inaccuracies in displayed travel times. A majority of MnDOT I-35 Travel Times Project participants who answered the questionnaire were comfortable with up to 10 minutes of discrepancy between displayed times and actual travel times, but very few would accept larger discrepancies. *(Athey Creek Consultants 2013)*
- "The reasons [drivers fail to take an alternate route when PCMS suggests they do] probably relate to inadequate knowledge of route options or skepticism about the reported amount of delay – issues that should be taken into consideration in future designs of work zone information systems." *(Horowitz, Weisser, and Notbohm 2003)*
- In some incidents, re-routing of vehicles around a work zone may cause congestion or delays on the alternate routes as well.

Implementation Details:

- It is possible for the system to be automated, causing the alternate route guidance to be activated by high traffic flow or extremely low vehicle speed, as illustrated in the case study below.
- As with speed-management PCMS implementations described earlier in the document, traffic volume and speed can be measured using a variety of sensors (e.g., video cameras, radar or LIDAR)
- When the traffic volume through the work zone is lower than the design volume of the roadway (considering work zone conditions) or when the traffic speed through the work zone is above some threshold, the alternate route messaging should be disabled. Drivers may question PCMS credibility if alternate routes are always being suggested, even when work zone traffic conditions are relatively normal.
- Practitioners should be sure that the suggested alternate route(s) have the capacity to handle re-routed traffic from the work zone area.

Case Studies

Case Study: Pesti, McCoy, Meisinger, and Kannan, 2002.

This case study focuses on implementation of a work zone speed advisory system (WZSAS) in a work zone on Interstate-680 in Nebraska. The purpose of the WZSAS is to monitor traffic conditions in the work zone and, when congestion exists, warn drivers to find alternate routes to their destinations. The setup involves a video detection system, a control system, and two PCMS. “The video detection system was used to measure the speeds of traffic at two selected points in advance of the work zone. Average speeds measured at the two points were displayed on the two portable CMSs which were placed upstream of diversion points in advance of the work zone… NDOR personnel were alerted when speeds dropped below the selected threshold of 15 miles per hour, which enabled them to display incident-related messages when necessary. A web page was also provided that displayed real-time traffic condition information for the work zone to the public. The system was designed to inform drivers of traffic conditions at the work zone prior to entering the northbound I-680 corridor. This allowed drivers to decide if I-680 congestion at the work zone was severe enough to warrant a route change.”

CONCLUSION

Portable changeable message signs are extremely effective tools for use in work zones when applied in more cutting-edge ways. They are both versatile, in their design and possible implementation, and they are consistent, in terms of presenting useful information in a well-known format to drivers. The table below summarizes PCMS strategies in work zones based on the intended outcome: speed management, reduced driver distraction, and demand management.

Table 5 – PCMS Applications for Speed Management, Reduced Driver Distraction, and Demand Management in Work Zones

Application Area	Work Zone Characteristics that may Indicate Strategy	Description of PCMS Strategy(ies)	Possible Message Content	Benefits & Limitations
Speed Management	• High incidence of speeding drivers • High speed variance between vehicles • High incidence of rear-end crashes • Work zone design including a pattern change, lane closure, or flagging operation; these would tend to increase the speed variance within the work zone	1. PCMS equipped with speed sensor to deliver targeted messages to speeding drivers 2. PCMS showing current information about work zone conditions, volumes, or queues 3. PCMS showing general information about the work zone or its reduced speed limit	1. SLOW DOWN / YOUR SPEED IS 63 MPH 2. SPEED AHEAD 20 MPH 3. WORK ZONE AHEAD/ SPEED LIMIT 35 MPH	**Benefits**: 1. Reduction in average vehicle speeds 2. Reduction in proportion of vehicles speeding excessively 3. Increased driver awareness of upcoming conditions (including slow or stopped traffic); may reduce frustration or confusion 4. Gives drivers time to reduce speed before work zone speed is enforced **Limitations**: 1. Reductions in speed are not always maintained throughout entire work zone 2. Information and warnings must be up-to-date; longstanding warnings may lose effectiveness with drivers. 3. Implementation of radar, lidar, or another speed sensor may require additional time and money

Application Area	Work Zone Characteristics that may Indicate Strategy	Description of PCMS Strategy(ies)	Possible Message Content	Benefits & Limitations
Reduction in Driver Distraction	Long work zones (1 mile+) Work zones within/around which unexpected queues form Work zones with turns, lane changes, and travel choices that are confusing or easy to miss	Multiple PCMS throughout duration of work zone to remind drivers of work zone conditions	WORKERS PRESENT AHEAD / SPEED REDUCED NEXT 3 MI.	**Benefits**: 1. Allows for more than 2 phases across multiple PCMS 2. Proper PCMS placement could reduce crashes caused by inattention **Limitations**: 1. Practitioners shall not overuse PCMS or they can lose effectiveness

Application Area	Work Zone Characteristics that may Indicate Strategy	Description of PCMS Strategy(ies)	Possible Message Content	Benefits & Limitations
Demand Management through the Work Zone	• Heavily traveled work zones (in which the traffic volume exceeds the roadway capacity during construction) • Work zones within which queues form often and/or cause major delays to traffic or construction schedules	PCMS showing travel times and possible alternate routes, allowing drivers to decide whether to divert	DELAYS AHEAD / USE RTE. 450 -- BRIDGE WORK / 2 MILES AHEAD / USE ALT ROUTE /	**Benefits**: 1. Reduced vehicle exposure through work zone 2. Reduced traffic congestion and associated crashes 3. Increased driver awareness and expectations of delays 4. A portion of drivers do change routes in response to PCMS **Limitations**: 1. Drivers may question PCMS if located too far upstream; they may miss alternate routes if too close to work zone 2. Drivers will not trust PCMS if displayed travel times are inaccurate 3. Effectiveness is limited by driver knowledge of alternate routes 4. Congestion may occur on alternate route as a result of re-routing

A method for agencies to improve the effectiveness of PCMS in work zones is to “incorporate basic PCMS message” and placement guidelines “into work zone traffic control standards” within your State, agency, or even a specific construction project *(Roadway Safety Consortium 2011)*. The article cites that Texas Department of Transportation has used this method in their work zones and State guidelines and policies. “The incorporation of the guidelines into the agency’s standard drawings ensures that it becomes a part of the contract documents that are readily available to field personnel who typically make decisions about what messages to put on the signs and how those messages should be formatted.” It is equally important to have a well-trained workforce with the appropriate and up-to-date knowledge of general principles of PCMS messaging and content. The workforce is able to assess work zones in the moment, realize changing conditions, and best take advantage of the flexibility and other capabilities of PCMS devices for safety in work zones. PCMS principles can be incorporated into agency specifications, manuals, guidance, and/or practices to ensure the most utility is gained from use of PCMS in work zones.

Refer to Appendix A for a summary table of product specifications for select PCMS models. Refer to Appendix B to reference section 1A.15 from the Manual on Uniform Traffic Control Devices (MUTCD) regarding valid and invalid abbreviations to use on PCMS messages.

APPENDIX A: MODEL SPECIFICATIONS

The following table includes specifications for various models of portable changeable message signs. The table was created and modified from *(MnDOT 2005)*.

Table A-1– PCMS Model Specifications

Type C Portable Changeable Message Signs								
Manufacturer	**ADDCO**	**American Signal**	**Daktronics**	**Precision Solar Controls, Inc.**	**Solar Technology Inc.**	**Ver-Mac**	**Ver-Mac**	**Wanco**
Model	DH 1000 ALS	T333	Vanguard VP 1400	SMC 1000 HE	Silent Messenger MB-4048	1210	1500	WTLMB-SLL
Matrix Type (Full, Continuous Line, or Character)	Character Matrix	Full Matrix	Full Matrix	Character Matrix	Full Matrix	Character Matrix	Full Matrix	Character Matrix
Character Height and Width *(max)*	18" x 13"	18.25" x 13"	16.5" x 12"	16.5" x 12"	18" x 12.5"	18" x 13"	17.5" x 12"	18" x 13"
Pixel Aspect Ratio of "H" *(H x W)*	7 x 5	7 x 5	7 x 5	7 x 5	7 x 5	7 x 5	7 x 5	7 x 5
Pixel Dimensions *(H x W)*	2.25" x 2.5"	1.5" x 2"	1" x 1.5"	2.5" x 2.5"	2.6" x 2.6"	2" x 2"	2" x 2"	2" x 2"
Minimum Character to Character Space	3.75"	3.25" Varied spacing according to number and type of characters on a line	3.5"	3"	3.75"	2.5"	3" Varied spacing according to number and type of characters on a line	2.5"
Space Between Lines	6.5"	9.75	6.5"	5"	7.8" (3 pixels)	3.5"	8" (4 pixels)	5"
LEDs per Pixels	4	4	4	4	3	4	4	4
LED Description	Amber	Amber 590nm AllnGaP 17" Wide	Amber. InGaAip 30° view angle	Amber. 590nm 21° view angle	Amber. 592nm 30° view angle	Amber. 17° view angle	Amber. 22° view angle	Amber. 24° view angle

Type C Portable Changeable Message Signs

Manufacturer	ADDCO	American Signal	Daktronics	Precision Solar Controls, Inc.	Solar Technology Inc.	Ver-Mac	Ver-Mac	Wanco
Panel Dimensions	134" x69"	137.5" x 79"	133" x 77"	127.25" x 76"	126" x 76"	133" x 71"	133" x 83"	130" x 72"
Type of Programming Device	Handheld with LCD Readout	Handheld with LDC Readout	Standard keyboard with LCD Readout	Specialized Computer	Specialized Computer	Standard keyboard with LCD readout. Handheld optional.	Standard keyboard with LCD readout. Handheld optional.	Standard keyboard with LCD readout
Lighted Programming Console	LCD Readout is lit	Lit LCD readout	LDC Display is lit	Backlit keyboard and LCD Window	Backlit keyboard and LCD window. Waterproof	LCD Readout is lit.	LCD readout is lit	Yes
Ease of Programming[12]	Easy to use quick programming	Difficult. Too many steps to do a quick message. Must create message and then sequence.	Difficult. We lacked access to all but the basic functions.	Very Easy. Just follow the prompts on the screen.	Easy once you understand the quick programming feature.	Somewhat difficult to get rid of additional phases in a sequenced message.	Somewhat difficult to get rid of additional phases in a sequenced message.	Very Easy. All instructions for a quick sign are printed alongside the readout.

[12] The values in these rows are subjective opinions of the MnDOT PCMS Evaluation team. These opinions are neither factually checked nor endorsed by the authors of the paper. The opinion values are included to increase the reader's understanding of features of each PCMS model.

Type C Portable Changeable Message Signs

Manufacturer	ADDCO	American Signal	Daktronics	Precision Solar Controls, Inc.	Solar Technology Inc.	Ver-Mac	Ver-Mac	Wanco
Ease of Setup Including Sighting[12]	Good - May be aimed from the ground	Different. Requires the use of a wrench to lock and unlock the rotation feature. Must fully raise display before locking rotation. Requires climbing on unit.	Easy. Can stay on ground throughout process. Rotation and solar panel deployment are electrically actuated. Solar panels deployed very slowly.	Good. Sighting tube was misaligned. Can be aligned from the ground.	Good. Can be aimed from the ground.	Good. Used a compression ring to lock rotation. May be aimed from the ground.	Good. Uses a compression ring to lock rotation. May be aimed from the ground.	Good. Nice disk brake rotation lock. Can be sighted from ground.
Angularity Distance (ft)	125'	100'	75'	100'	50'	150'	100'	75'

Trailer Information								
Tire Size	**F78-15 ST**	**205/75 D15**	**205/75-15**	**P235 - R15**	**225/75 R15**	**F78 - 15**	**205/75-15**	**205/75-15**
Radial?	No	No	Yes	Yes	Yes	Yes	Yes	No
Welded Construction?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Advertised Windload	80 MPH	104 MPH Wind gusts	80 MPH	N/A	N/A	N/A	N/A	98 MPH with outriggers
Battery Description	12 volt system. 8-6 Colt Trojan T-105	12 volt system. 12-6 volt deka promaster	12 volt system. 8-6 volt.	12 volt system. 4-12 volt continental	12 volt system. 8-6 volt crown model CR-225	12volt system. 12-6 volt pow R Surge	12 Volt System. 12 - 6 Volt Interstate U2200	12 Volt system. 8-6 volt Exide GC 135
Solar Array Wattage	320 Watt. 4-8W. Shell	369 Watt. 3-123W Sharp	220 Watts. 2 - 110W. GE	225 Watt. 3-75W. Shell	450W - 80Watt	165 Watt. 3-53W. Mitsubishi	220 Watt. 2 - 110W Mitsubishi	240 Watt. 2-120W Kyocera
Steppable Fenders?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Weight	2830 lb.	3000 lb.	2950 lb.	3540 lb.	2690 lb.	3600 lb.	3800 lb.	2640 lb.

Comments:[12]	Surge brakes. Electric brake option. Cable to display held up with spring. Solar array is tiltable and can be rotated independent from display. Gull-wing design plastic covers for batteries and controls. Snow was able to get inside	Surge brakes. Have to make sure there is a wrench of the proper size before venturing out to deploy device	Surge brakes. Solar panels may be tilted. Programming unit was dead on arrival, which required replacing a circuit board. I don't know if the display was on auto-brightness or not. It seemed dim.	Surge brakes, all metal construction. Computer is at a good height for working on. Raised and lowered slowly. Too thick hydraulic fluid?	Surge brakes. Pintle or 2" ball hitch available. Plastic battery and controller boxes. Not easy to open clips. Locking pins for storing computer can catch fingers or gloves. Computer is at a good height for working on. Display glare screen seemed to diminish LED intensity.	Surge brakes. Electric brakes are an option. Old style trailer. No hold down latch for battery box lids. Bungee cord attached to display cable. Cable can drag.	Surge brakes. Electric brakes are an option. Plastic boxes for batteries. Trailer was well balanced. Tongue could be lifted by hand.	No brakes needed with light weight. Outriggers offered as an option. Needed because of light weight? Cable to display good. Only unit to have tongue wheel with screw jack. Raised edge around each character module prevents light bleeding in to next character. Trailer is well balanced.



APPENDIX B: MUTCD SECTION 1A.15

The following pages were extracted from the Manual on Uniform Traffic Control Devices (MUTCD) (FHWA 2012). Refer to this section to determine acceptable and unacceptable abbreviations for use in PCMS messages.



Section 1A.15 Abbreviations Used on Traffic Control Devices

Standard:

01 **When the word messages shown in Table 1A-1 need to be abbreviated in connection with traffic control devices, the abbreviations shown in Table 1A-1 shall be used.**

02 **When the word messages shown in Table 1A-2 need to be abbreviated on a portable changeable message sign, the abbreviations shown in Table 1A-2 shall be used. Unless indicated by an asterisk, these abbreviations shall only be used on portable changeable message signs.**

Guidance:

03 *The abbreviations for the words listed in Table 1A-2 that also show a prompt word should not be used on a portable changeable message sign unless the prompt word shown in Table 1A-2 either precedes or follows the abbreviation, as applicable.*

Standard:

04 **The abbreviations shown in Table 1A-3 shall not be used in connection with traffic control devices because of their potential to be misinterpreted by road users.**

Guidance:

05 *If multiple abbreviations are permitted in Table 1A-1 or 1A-2, the same abbreviation should be used throughout a single jurisdiction.*

06 *Except as otherwise provided in Table 1A-1 or 1A-2 or unless necessary to avoid confusion, periods, commas, apostrophes, question marks, ampersands, and other punctuation marks or characters that are not letters or numerals should not be used in any abbreviation.*

Table 1A-1. Acceptable Abbreviations

Word Message	Standard Abbreviation
Afternoon / Evening	PM
Alternate	ALT
AM Radio	AM
Avenue	AVE, AV
Bicycle	BIKE
Boulevard	BLVD*
Bridge	(See Table 1A-2)
CB Radio	CB
Center (as part of a place name)	CTR
Circle	CIR*
Civil Defense	CD
Compressed Natural Gas	CNG
Court	CT*
Crossing (other than highway-rail)	X-ING
Drive	DR*
East	E
Electric Vehicle	EV
Expressway	EXPWY*
Feet	FT
FM Radio	FM
Freeway	FRWY, FWY*
Friday	FRI
Hazardous Material	HAZMAT
High Occupancy Vehicle	HOV
Highway	HWY*
Hospital	HOSP
Hour(s)	HR, HRS
Information	INFO
Inherently Low Emission Vehicle	ILEV
International	INTL
Interstate	(See Table 1A-2)
Junction / Intersection	JCT
Lane	(See Table 1A-2)
Liquid Propane Gas	LP-GAS
Maximum	MAX
Mile(s)	MI
Miles Per Hour	MPH
Minimum	MIN
Minute(s)	MIN
Monday	MON
Morning / Late Night	AM
Mount	MT
Mountain	MTN
National	NATL
North	N
Parkway	PKWY*
Pedestrian	PED
Place	PL*
Pounds	LBS
Road	RD*
Saint	ST
Saturday	SAT
South	S
State, county, or other non-US or non-Interstate numbered route	(See Table 1A-2)
Street	ST*
Sunday	SUN
Telephone	PHONE
Temporary	TEMP
Terrace	TER*
Thursday	THURS
Thruway	THWY*
Tons of Weight	T
Trail	TR*
Tuesday	TUES
Turnpike	TPK*
Two-Way Intersection	2-WAY
US Numbered Route	US
Wednesday	WED
West	W

*This abbreviation shall not be used for any application other than the name of a roadway.



Table 1A-2. Abbreviations That Shall be Used Only on Portable Changeable Message Signs

Word Message	Standard Abbreviation	Prompt Word That Should Precede the Abbreviation	Prompt Word That Should Follow the Abbreviation
Access	ACCS	—	Road
Ahead	AHD	Fog	—
Blocked	BLKD	Lane	—
Bridge	BR*	[Name]	—
Cannot	CANT	—	—
Center	CNTR	—	Lane
Chemical	CHEM	—	Spill
Condition	COND	Traffic	—
Congested	CONG	Traffic	—
Construction	CONST	—	Ahead
Crossing	XING	—	—
Do Not	DONT	—	—
Downtown	DWNTN	—	Traffic
Eastbound	E-BND	—	—
Emergency	EMER	—	—
Entrance, Enter	ENT	—	—
Exit	EX	Next	—
Express	EXP	—	Lane
Frontage	FRNTG	—	Road
Hazardous	HAZ	—	Driving
Highway-Rail Grade Crossing	RR XING	—	—
Interstate	I-*	—	[Number]
It Is	ITS	—	—
Lane	LN	[Roadway Name]*,Right, Left, Center	—
Left	LFT	—	—
Local	LOC	—	Traffic
Lower	LWR	—	Level
Maintenance	MAINT	—	—
Major	MAJ	—	Accident
Minor	MNR	—	Accident
Normal	NORM	—	—
Northbound	N-BND	—	—
Oversized	OVRSZ	—	Load
Parking	PKING	—	—
Pavement	PVMT	Wet	—
Prepare	PREP	—	To Stop
Quality	QLTY	Air	—
Right	RT	Keep, Next	—
Right	RT	—	Lane
Roadwork	RDWK	—	Ahead, [Distance]
Route	RT, RTE	Best	—
Service	SERV	—	—
Shoulder	SHLDR	—	—
Slippery	SLIP	—	—
Southbound	S-BND	—	—
Speed	SPD	—	—
State, county, or other non-US or non-Interstate numbered route	[Route Abbreviation determined by highway agency]**	—	[Number]
Tires With Lugs	LUGS	—	—
Traffic	TRAF	—	—
Travelers	TRVLRS	—	—
Two-Wheeled Vehicles	CYCLES	—	—
Upper	UPR	—	Level
Vehicle(s)	VEH, VEHS	—	—
Warning	WARN	—	—
Westbound	W-BND	—	—
Will Not	WONT	—	—

* This abbreviation, when accompanied by the prompt word, may be used on traffic control devices other than portable changeable message signs.

** A space and no dash shall be placed between the abbreviation and the number of the route.

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Table 1A-3. Unacceptable Abbreviations

Abbreviation	Intended Word	Common Misinterpretation
ACC	Accident	Access (Road)
CLRS	Clears	Colors
DLY	Delay	Daily
FDR	Feeder	Federal
L	Left	Lane (Merge)
LT	Light (Traffic)	Left
PARK	Parking	Park
POLL	Pollution (Index)	Poll
RED	Reduce	Red
STAD	Stadium	Standard
WRNG	Warning	Wrong

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