1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
CA08-0974		

4. Title and Subtitle	5. Report Date
Advanced Changeable Message Sign (CMS) P229/TID0974	12/17/2008 6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Doug Galarus and Gary Schoep	

9. Performing Organization Name And Address	10. Work Unit No. (TRAIS)
Western Transportation Institute College of Engineering Montana State University	11. Contract or Grant No. 65A0238

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Caltrans – Division of Research and Innovation 1227 O st. 5th Floor Sacramento, CA 95814	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

In cooperation with the California Department of Transportation (Caltrans), Montana State University's Western Transportation Institute has begun development of a Changeable Message Sign (CMS) specification, the Model 700, for use by all Caltrans Districts.

In addition to and preceding this final report, four items were produced as project deliverables:

- Survey of State Department of Transportations on use of CMS technology
- Survey of Caltrans districts and departments on use of CMS technology
- Draft Concept of Operations document
- Presentation of the project at the Intelligent Transportation Society's World Congress

This document is presented as a high-level summary, and the documents above should be referenced for further detail.

17. Key Words	18. Distribution Statement

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
none	none	20	N/A

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

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Final Report for the project entitled:

Advanced CMS
(CFS# 2056DRI, Problem Statement No. TS-510)

by

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Caltrans Division of Research & Innovation
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Sacramento, CA 94873-0001

December 17, 2008

ACKNOWLEDGEMENTS

The authors would like to thank the following for assistance or support on this project:

Randy Woolley, Ha Nguyen, and the members of the Caltrans Technical Advisory Group,

Terry Haukom of Traffic Made Simple, LLC,

The many WTI personnel that have worked on this project including Christopher Strong, Nabil El Ferradi, and Larry Hayden,

And lastly the many vendor representatives who may have given tours of their facilities, assisted with technical matters, gave assistance reviewing and commenting on documents, and spent many hours in support of this project.

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EXECUTIVE SUMMARY

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1. INTRODUCTION

Standardization and tight specification of technologies has been a critical component in encouraging the usage of intelligent transportation systems (ITS) across the United States. Early adopters of changeable message signs were challenged with vendors who went out of business or no longer supported their products. They were also challenged when trying to operate similar products manufactured by multiple vendors. Standardization efforts such as NTCIP have gone a long way toward addressing these problems. Nonetheless, there remains a considerable diversity of products with limited if any interchangeability between system components. This introduces training and spare parts inventory challenges for customers, and makes customers more dependent on vendors for ongoing support.

These challenges are especially acute in California which has the greatest number of CMS deployed by any state department of transportation (DOT). The California Department of Transportation has deployed changeable message signs conforming to its Model 500 specification for almost two decades. The specification is tightly defined with respect to geometric dimensions and communications protocols. As such, it supports nearly complete interchangeability between components made by different manufacturers. However, in the years since the Model 500 specification was developed, there have been many improvements in CMS technology including improvements in lighting, communications, control, reporting, and diagnostics. Consequently, Caltrans contracted with a team led by the Western Transportation Institute to develop a new CMS specification.

While many transportation agencies have developed CMS specifications, the Caltrans effort is unique in its scale and scope. In scale, Caltrans is the largest state transportation agency owner of changeable message signs. In scope, the specification is more ambitious than those developed by other states in that it seeks to achieve component-level physical and communications interchangeability between signs provided by different manufacturers.

2. BACKGROUND AND METHODOLOGY

Based on results of this project and corroboration with industry, when state DOTs create a specification for Changeable Message Signs it is exclusively done with functional or performance measures. Caltrans is unique in that it creates a detailed design specification that is complete enough for multiple vendors to create a compatible product with all existing or any future signs. Also, since Caltrans owns the standard and therefore all information needed for production of a sign, dissolution of any specific vendor will not affect future availability of signs based on the specification. However, the success of the detailed design specification and subsequent stability of the Model 500 specification has allowed the industry to surpass the Model 500 specification with new features and technology. The intent of this project in creation of the Model 700 Advanced CMS Specification will move Caltrans to the fore-front of CMS technology and allow the new specification to add new CMS features and functionality to California's highways.

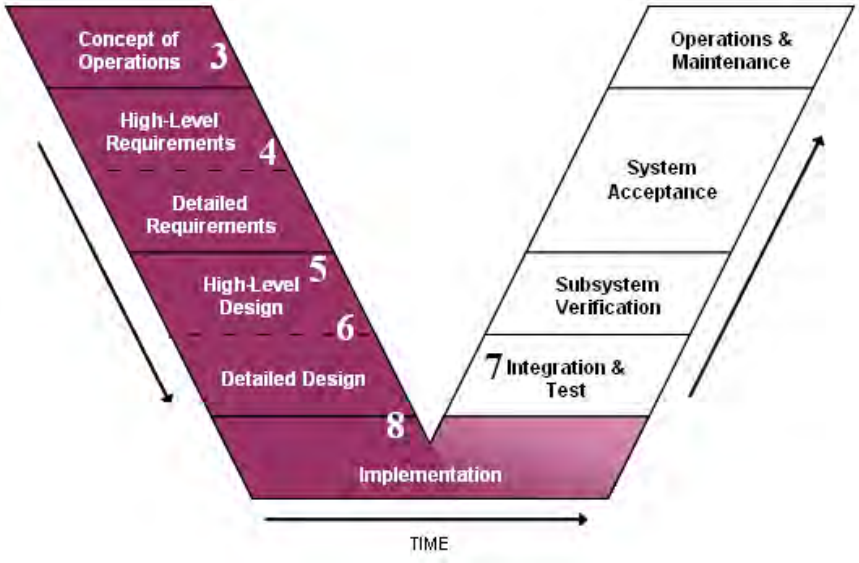

Figure 1: Systems Engineering Process

The research team chose an approach based on the Systems Engineering approach for ITS projects. Each of the projectstasks are based on a specific item in the process. Refer to Figure 1. The team believes that this approach will provide Caltrans with sufficient demonstration of the specification's capabilities and functionality that the department will be able to confidently replace the Model 500 specification with the new one developed through this project.

Major project tasks are defined as follows:

- Task 1: Survey of Departments of Transportation
- Task 2: Caltrans District Survey
- Task 3: Concept of Operations
- Task 4: Develop Requirements Document
- Task 5: Outreach Planning and Activity

- Task 6: Specification Development and Completion of Final Standard
- Task 7: Develop Testing Plan
- Task 8: Support RFP for Prototype
- Task 9: Conduct Training Workshops
- Task 10: Final Project Report and Workshop Presentation

This project has been delayed by revisions of scope, a stop work order and funding shortfalls. At the time this document was written, it was understood that the project was approved for a revised scope of work and a $175,000 extension with preliminary time extension through December 2009, at which time original project funding expired. The project could not continue until additional funding was released, and that funding was ultimately not allocated. This Final Report satisfies the research team's obligation of a final report to the sponsor.

Description of the project's tasks and deliverables, explanation of the completion of the tasks and status of documentation was written in anticipation of subsequent funding , and follows in sections 3, 4, 5, and 6.

3. TASK 1: SURVEY OF DEPARTMENTS OF TRANSPORTATION

3.1. Survey Background

A survey of state DOTs was performed to evaluate current practice in CMS. The survey gathered information on CMS inventory, concept of operations, maintenance practices, potential sign improvements, and procurement.

3.2. Survey Methodology

The survey was sent to 49 states, of which 21 responded. It was composed of 75 qualitative questions, which could have several parts.

Survey responses were compiled into a document that is stored and available for future project use.

3.3. Survey Results

Results for the survey are summarized below.

a. Inventory

Twenty-one states responded to the survey. States varied in their usage of CMS as some had as many as 500 CMS to as few as 15. One state responded that had no deployed CMS but was in the process of developing their own specification within the state.

The states owned a wide variety of CMS from vendors including American Signal, Display Solutions, Addco, Vermac, K&K, Daktronics, DSI, Ledstar, Mark IV, Adaptive, AES/3M, Skyline, Telespot, Voltron, US Traffic/Quixote, FDS, Sylvia, and Precision Solar.

The states also used many types of CMS including character, line, and full matrix with displays using LED, including color, and other types. Most states reported a high level of NTCIP compliance with five states being 100% NTCIP compliant.

In the survey no responders were familiar with the Model 500 specification but one knew of the history of CMS in California.

b. Concept of Operations

Half of the states used CMS infrequently or only when there is a need. Less than a quarter of states used CMS greater than 40% of the time. States displayed all types of messages including Amber Alerts with 6 states currently or pursuing the use of travel time messages.

The location from which messages are posted to the signs was divided between either a statewide TMC or a district office. Most states posted Amber Alerts from a single statewide office.

Only one state reported that it did not use the NTCIP protocol to communicate with any of their signs but a wide variety of protocols are still in use.

Communications with signs in states is represented by all types available including dial-up, fiber, wireless, satellite, cellular, ISDN, DSL, and microwave.

Only 2 states reported that they only had signs built by one vendor.

c. Maintenance

Three quarters of states reported that they performed maintenance in-house with few using vendors and contractors or doing maintenance in-house and by vendors.

States reported a variety of maintenance challenges such as difficulty in procurement and getting spares, vandalism, staff resources, equipment and communication issues, and problems with vendors including companies going out of business. Two states reported no major maintenance problems. States reported that there were some sign specific features that made maintenance easier such as conformal coat of printed circuit boards, using a common controller for signs, driver and pixel check diagnostics, eliminating copper conductors from the sign to the controller, and use of surge protectors. Spares and part non-interchangeability were issues for states with multiple vendors products in the field.

d. Improvements

States reported that their signs have improved by changing to LED displays and using Ethernet and/or NTCIP.

States are looking toward the future with new features in their signs. They desire multiple communications paths to a sign, the ability to download firmware and diagnostics from the TMC, self diagnosing and self-healing signs, and true interoperability and interchangeably.

e. Procurement

Over half of the states would be interested in adopting a specification like the Model 700 in whole or part. All the states use a CMS specification with functional and performance specs based on NTCIP and NEMA TS-4.

The majority of states buy CMS on the lowest bid with some qualifications for vendors with purchases in specific quantities. Life cycle cost is not a factor in bid evaluation but a few states are moving to pre-qualified vendor lists. States may purchase signs as one order for the state or allow districts to purchase their own inventory.

Most states do not take precautions against vendor dissolution by maintaining high inventory of spare parts but some make arrangements for continued software use.

Most states chose to maintain and repair older signs as long as parts are available. Older signs may be replaced or retrofitted when upgrading to newer features such as NTCIP or LEDs.

4. TASK 2: CALTRANS DISTRICT SURVEY

4.1. Survey Background

A survey of Caltrans districts, agencies and personnel was performed to evaluate current and future user needs for CMS. The survey gathered information on CMS inventory, concept of operations, current maintenance practices, structures, operating environment, potential sign improvements, and future inventory.

4.2. Survey Methodology

The survey was sent to all 12 Caltrans districts, of which 10 responded. It was composed of 75 qualitative questions, which could have several parts.

Survey responses were compiled into a document that is stored and available for future project use.

4.3. Survey Results

Results for the survey are summarized below.

a. Responses to Questions on Inventory

The Model 500 CMS is the primary specification used within Caltrans, with little exception. Different vendors' signs are used on special projects within the districts, but Model 500, 510, and 520s are used across the state.

Most of the signs use Xenon bulbs for pixels, with districts moving to Light Emitting Diodes (LEDs). Very few incandescent-bulb signs are still in operation. Signs are used sparingly on arterials, with some additional use planned in the future.

NTCIP is not used within the state, even on other vendors' signs that are thought to be NTCIP compliant.

b. Responses to Questions on Concept of Operations

Because signs primarily display incident messages they are lit less than 40 percent of the time within the districts that responded to the survey. Even signs that display travel times do so only during a three-hour rush period. Not all districts post travel time info, but all districts post incident information, weather information, and Amber Alerts.

Messages are posted by personnel from the district TMC or, in rare circumstances, a neighboring TMC. A message may also be manually posted to a sign on-site. Most cooperative posting of messages is arranged by a phone conversation with that district's operator.

Messages are sent to the sign by ATMS, SOCCS or the Signview 170 protocol. All messages are posted by an operator, with no messages posted from an in-sign library.

Respondents reported that signs are connected to the TMC by dial-up, dedicated phone service, fiber, unspecified wireless, DSL, serial and Ethernet. No district reported current cellular use, although one used cellular in the past but has since moved to dial-up.

Districts desire signs that are natively capable of communication using any method.

Software compatibility or the need for NTCIP has not been tested within districts. also the need for NTCIP which is not compatible with current software of current signs. Currently SOCCs allows rapid posting of messages on signs.

Messages are verified by viewing an image of the sign by a nearby CCTV, by manual verification with personnel driving by the sign, or not verified at all.

The districts did not express a need for battery backup systems but suggested that a sign operate from 1 to 8 hours with one, with an average of three hours.

District had many suggestions for features on a new controller, the most common being better feedback or diagnostics of a sign including automatic pixel check of the display.

District personnel desire an IP based sign with a local display, keypad, and menu-driven interface that allows messages to be posted without a laptop. The display should show what is on the sign in a graphic format.

c. Responses to Questions on Current Maintenance Practices

Maintenance is performed by Caltrans personnel who are trained locally on the job.

Spare parts are stored locally or at Caltrans headquarters. Getting spares for the Model 500 has not been a problem with the exception of LED matrix modules which did not have spares ordered.

There is no error reporting capability on the Model 500 signs and also no automated pixel check. Personnel must verify pixels on site with a sign test.

Maintenance on individual signs requires little time yearly, from four to fifty hours per sign including inspections and cleaning.

There are no special test interfaces required on the sign as testing is usually done with a multimeter.

There are no recurring maintenance challenges reported that were specifically the sign. Vandalism, communications failures, and individual component failures were all reported.

d. Responses to Questions on Structures

Caltrans districts were surveyed on use of cantilever, over-the-road full structure, over-the-road cantilever, and over-the-shoulder butterfly structure designs. The information is beyond the scope of this report.

e. Responses to Questions on Operating Environment

The temperature rating for operation of CMS suggested by the districts was -10 to 120 degrees Fahrenheit.

There are no reported problems with ventilation, condensation, overheating issues on the Model 500 CMS. The need for heating of the signs was not known except to met snow off the sign face.

Districts desire to choose paint color for CMS to be able to support local ordinances.

f. Responses to Questions on Potential Sign Improvements

Districts reported no need to improve weather sealing, structural integrity, or weather resistance of sign construction materials.

Sign vandalism was reported by half the districts.

The districts reported that sign visibility could be improved by allowing signs to be rotated from perpendicular to the roadway and use of screens on the display.

Some improvement in photocell placement, adjustment, and reliability was suggested by the survey.

Respondents did not feel that color was a necessity for reasons of driver distraction and cost but felt that beacons on the sign could help get attention for important messages.

Districts felt that NTCIP should be included in a new sign specification and that IP interface was also important.

Power consumption has not been a problem with Model 500 signs although the ability to power new signs with solar is attractive although they are worried about vandalism and theft of solar panels. While all districts did not think of a battery backup as essential, most would like the option.

Districts prefer front access signs but rear and walk-in type was also requested.

For parts interchangeability districts unanimously requested that as many parts as possible be interchangeable to minimize parts inventory and spare issues. And districts wish that the same interchangeable parts be used in signs smaller than 520/720 such as EMS.

All districts would like to start the new specification with industry standards such as NTCIP and NEMA TS-4.

Districts would like new features in the Advanced CMS including better diagnostics, including pixel check, power supply, temperature, and communications, and tool-less maintenance.

Most districts see no improvement for safety needed besides possible improvements for maintenance vehicles near the sign.

Districts do no desire vendor maintenance or warranty as it is problematic. They wish to rely on Caltrans maintenance for the signs.

Additional features requested are modularity (such as brick type signs), graphic user interfaces and integration with radar units and emulation of Extinguishable Message Sign emulation. The ability to build signs of different sizes with the standard components of the Model 700 specification is also desired.

g. Responses to Questions on Future Inventory

Districts all plan on installing new CMS but have no set plans as to when they will be installed as it depends on funding. Districts wish that the Advanced CMS have an operating life of greater than 10 to 25 years. The Model 500 CMS currently installed will be used until they are required to be replaced or fail completely.

5. TASK 3: CONCEPT OF OPERATIONS

The concept of operations document serves as a foundational document for how the Advanced CMS is operated from the perspectives of operators, maintainers and travelers. This document addresses the environment in which the CMS operates. In it can be found how the Advanced CMS displays messages, interacts with various software packages, and communicates. The document also gives power requirements, temperature ratings and similar characteristics.

5.1. Creation of a Draft Document

For the creation of a draft document the research team made extensive use of the information gained from the Caltrans district survey. Using this approach the research team hoped to develop a specification which thoroughly meets Caltrans needs.

The research team followed the Systems Engineering Guidebook for ITS Projects regarding the contents and organization of this deliverable (1).

5.2. Comment Disposition

The concept of operations was distributed as a deliverable to the TAG for review and comment. Comments were incorporated into the draft document.

The document was also submitted to vendors for review and comments. While some of these comments could be incorporated into the draft document, many must be dealt with after a more detailed design is defined. These comments are stored and available for future project use.

5.3. Document Status

The Concept of Operations Document exists in a final, draft form awaiting detailed design, build and test of the Advanced CMS prototypes. It should be expected that changes will occur to the document after the prototypes are built.

6. REMAINING TASKS AND PROJECT WORK

As the project has been extended and a revised scope approved but remains without funding, many of the tasks described in last approved scope document are incomplete. The following sections briefly describe the state of the remaining tasks and the state of resources available when the project is funded.

6.1. Task 4: Develop Requirements Document

The requirements document builds upon the concept of operations drafted under Task 3 and lists specific functional, performance, and operational requirements. The document reflects backwards traceability to the concept of operations, and also provides backwards traceability for the subsequent specification. It was intended that a draft requirements document would be distributed to CMS vendors to provide feedback. After vendor input was incorporated into the requirements document, the document will then be redistributed to the TAG for finalization.

A draft of the requirements document has been distributed to vendors for review and comment. While some of these comments could be incorporated into the draft document, many must be dealt with after a more detailed design is defined. These comments are stored and available for future project use.

6.2. Task 5: Outreach Planning and Activity

It was originally planned that the research team would gather information from the CMS industry by means of requests for information (RFI) and requests for comments (RFC). However, an interesting new method was purposed by the TAG for Task 5, Outreach Planning and Activity. It was suggested that a group of vendors be brought together to create a working group (vendor consortium) to design the new specification and an internal sign module protocol loosely based on NTCIP.

Vendors were selected from manufacturers that serviced the market and were offered limited compensation for travel and participation in group meetings. It was hoped that by having multiple vendors work together that the new specification could become standard and include the best new features that the industry had to offer. Although some vendors opted out, five accepted the offer to be part of the process. Of the vendors that opted out, some were willing to give comments on documents and offer ideas.

In the end, legal and procedural challenges, mostly in reference to procurement fairness, eliminated the vendor consortium process from going further. The project moved back to the original RFI and RFC approach.

Much of the information that would be presented to the vendor and user community for comment is in a draft state. However, the project team started outreach activity by presentation of the project at ITS World Congress in November of 2008. The team submitted a paper and presented at a technical session.

During the course of the project the research team has had frequent contact with vendors including vendor factory site visits. Documents describing the interaction and documenting technical details are stored and available for future project use.

6.3. Task 6: Specification Development and Completion of Final Standard

The end result of the project is a new CMS standard at a level of detail equal with the existing Model 500 CMS standard. The actual document will be in the form of a specification which is the end result of this task.

The specification document will give detailed description of every element of the Advanced CMS with a mapping to the requirements which in turn maps directly to the concept of operations document.

No documentation has been produced for this task.

6.4. Task 7: Develop Testing Plan

After the specification document is completed, a test plan will be developed. The test plan will use testing capabilities currently available at Department headquarters or readily available off-the-shelf technologies and will be modeled after the testing requirements in the NEMA TS-4 specification.

No documentation has been produced for this task.

6.5. Task 8: Support RFP for Prototype

Validation of the new specification is necessary before actually investing great amounts of resources by purchasing a quantity of Advanced CMS. The research team recommended that Caltrans first purchase prototypes from the vendors following the new specification. The research team will support the purchase of prototypes by assisting in the Request For Proposals (RFP) process by creation of documentation and interaction with vendors.

Work on this task requires that the specification be complete. No documentation has been produced for this task.

6.6. Task 9: Conduct Training Workshops

After completion of the final specification, the research team will conduct workshops throughout the state to communicate that an updated procurement specification exists to ensure that the new procurement specification is understood and used. Along with members of headquarters staff, two members of the research team will conduct workshops which describe the specification in sufficient detail so that attendees understand the relevance of each item in the standard.

Work on this task requires that the specification be complete. No documentation has been produced for this task.

6.7. Task 10: Final Project Report and Workshop Presentation

At the conclusion of the project, the research team will deliver a final project report and presentation of the project results in a workshop forum.

Work on this task requires that the specification be complete. No documentation has been produced for this task.

7. CONCLUSIONS

Although the project is not funded to completion, significant work on five tasks has been performed with 2 tasks completed. Task 1, State DOT Survey, is complete with 21 states responding. Task 2, District Survey, is complete with 10 districts and other important departments responding. These two tasks provided the background for Task 3, Develop Concept of Operations, and Task 4, Develop Requirements Document. These tasks have produced draft documents that have been evaluated by Caltrans (and vendors) and associated feedback that will be used to produce the final specification. It is expected that these two documents will be modified as the specification is tested and in support of the procurement of the first signs. Task 5, Outreach Planning and Activity, has begun by presentation of the project at ITS World Congress.

The project team is developing the specification using a novel process. Rather than engineer the specification in a relatively closed environment, we are developing the specification in an open and collaborative environment while adhering to systems engineering best practices. We anticipate that the result will be successful in meeting the needs of Caltrans and providing an example for others to follow.

Based on results of the survey of state Departments of Transportation and of Caltrans departments and personnel, the Advanced CMS is a worthy and important concept. Caltrans has a unique opportunity to make advances in the CMS industry by producing what is in simple terms a Caltrans branded, open design, Changeable Message Sign product. By publication of a capable finished specification, Caltrans could affect and advance what is done over the entire CMS industry and improve traveler safety and efficiency across the nation.

8. REFERENCES

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