Evaluation Methods and Metrics

Caltrans
Automated Warning System
Caltrans District 10
Stockton, California

For the National Highway Visibility Conference, May 2004
CAWS Components

Electronic and Communications Components of CAWS
CAWS and Evaluation Sites

- French Camp Slough traffic and visibility monitoring site
- Mathews Road traffic and visibility monitoring site
- Downing Road traffic monitoring site.
- French Camp CMS monitoring and video camera verification site.
- El Dorado Overcrossing traffic monitoring site.
Evaluation Objectives

1. Technical Assessment.
   Assess quality, completeness, innovation, and reliability of deployed system.

2. Operational Assessment.
   Does the system do what it is supposed to do?

3. Assessment of impact of system on driver behavior during limited visibility conditions.
   Observe changes in driver behavior before and after viewing warning message.

4. Assessment of long-term impact of system on accident rates and losses.
   Compile accident statistics before and after system activation.

5. Study of the relationship between measurable traffic flow metrics and relative traffic safety.
   Correlate accidents and near-accident situations with detailed traffic data.
CAWS Evaluation Field Instrumentation: What it does and why it’s there

Site 1. Downing Road - 1.0 miles before first CMS
Site 2. French Camp Slough - 0.9 miles before first CMS
Site 4. Mathews Road - 0.6 miles after the CMS
Site 5. El Dorado Undercrossing - 0.8 miles after CMS
• Record the exact time of arrival, speed, and length of every vehicle, using duplex loops in all lanes
• Record visibility and illumination level
• Relay all data to database server at Loragen

Site 3. French Camp CMS - mid-way, at the CMS
• Monitor all message commands sent to CMS
• Real-time video images of actual CMS display
• Real-time video images of traffic
• Verify visibility via distance markers in video scene
• Relay all data to database server at Loragen

CAWS Evaluation Database and Dynamic Web server
• Located at Loragen Corp., San Luis Obispo
• Records all numeric and image data in SQL database
• Periodically backed up and archived
• Hosts CAWS Evaluation web site, which displays real time data and images, and provides on-line data analysis tools
Evaluation System Components

- 6 Loop Detectors (3 lanes)
- Visibility & Illumination Sensors
- CMS monitor Subsystem
- Traffic and CMS Video Monitoring Subsystem
- 6 Loop Detectors (3 lanes)
- Visibility & Illumination Sensors
- 6 Loop Detectors (3 lanes)

Evaluation System Components:

- Downing Road Data Acquisition Station
- French Camp Slough (FCS) Data Acquisition Station
- Mathews Road (MR) Data Acquisition Station
- El Dorado Undercrossing Data Acquisition Station

Network Components:

- Loragen Evaluation Database and Web Server
- VPN access through Caltrans D10 Firewall
- CAWS Weather Server in D10 TMC
- CAWS Meteorological System Computer in TMC

CDPD connections to Internet
Evaluation of Caltrans Automated Warning System

CAWS Evaluation Web Site
caws-evaluation.loragen.com

District 10, Stockton California, USA
Caltrans Automated Warning System Evaluation

CMS Site: Southbound I-5 at French Camp CMS

Visibility Verification Image
French Camp Traffic Camera Wed Apr 14 17:47:37 2004

CMS Verification Image
French Camp CMS Camera Wed Apr 14 17:44:39 2004

1 Downing Road : Before CMS
5 minute totals as of Apr. 14 2004, 5:48:10 PM
<table>
<thead>
<tr>
<th>Lane</th>
<th>Speed (mph)</th>
<th>Volume (veh/hr)</th>
<th>Cars/Light Trucks</th>
<th>Class5-6 Trucks</th>
<th>Class7-8 Trucks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>74.19</td>
<td>1584</td>
<td>132</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>70.55</td>
<td>1272</td>
<td>99</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>61.88</td>
<td>876</td>
<td>55</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>Total</td>
<td>58.98</td>
<td>3732</td>
<td>280</td>
<td>8</td>
<td>17</td>
</tr>
</tbody>
</table>

2 French Camp Slough : Before CMS
5 minute totals as of Apr. 14 2004, 5:48:58 PM
<table>
<thead>
<tr>
<th>Lane</th>
<th>Speed (mph)</th>
<th>Volume (veh/hr)</th>
<th>Cars/Light Trucks</th>
<th>Class5-6 Trucks</th>
<th>Class7-8 Trucks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>74.44</td>
<td>1452</td>
<td>121</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>70.76</td>
<td>1236</td>
<td>96</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>63.22</td>
<td>924</td>
<td>58</td>
<td>6</td>
<td>13</td>
</tr>
<tr>
<td>Total</td>
<td>66.48</td>
<td>3012</td>
<td>273</td>
<td>11</td>
<td>15</td>
</tr>
</tbody>
</table>


3 Mathews Road : After CMS
5 minute totals as of Apr. 14 2004, 5:47:40 PM
<table>
<thead>
<tr>
<th>Lane</th>
<th>Speed (mph)</th>
<th>Volume (veh/hr)</th>
<th>Cars/Light Trucks</th>
<th>Class5-6 Trucks</th>
<th>Class7-8 Trucks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>72.92</td>
<td>1692</td>
<td>140</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>69.90</td>
<td>1272</td>
<td>90</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>61.66</td>
<td>876</td>
<td>36</td>
<td>4</td>
<td>14</td>
</tr>
</tbody>
</table>

4 El Dorado Crossing : After CMS
5 minute totals as of Apr. 14 2004, 5:48:57 PM
<table>
<thead>
<tr>
<th>Lane</th>
<th>Speed (mph)</th>
<th>Volume (veh/hr)</th>
<th>Cars/Light Trucks</th>
<th>Class5-6 Trucks</th>
<th>Class7-8 Trucks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>74.15</td>
<td>1860</td>
<td>155</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>69.20</td>
<td>1260</td>
<td>97</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>67.20</td>
<td>876</td>
<td>30</td>
<td>4</td>
<td>14</td>
</tr>
</tbody>
</table>
Project Chronology


2. First fog season 2001-2002: no data collection due to lack of phone connections at CMS and MR sites, and discovery that existing loops were incorrectly wired in ground, requiring replacement.


3. Fog season 2002-2003: very little data collected due to 4-month power outage, intermittent phone connections, destruction of loop pull boxes by road construction, visibility sensor failures at FCS and MR.

4. Summer 2003: set up redundant before-and-after sites at Downing Road and El Dorado OC, to assure that prior problems wouldn’t interrupt data collection during fog season. No-cost extension received to extend study.

5. Accurate collection of detailed before-and-after data for duration of fog season, except briefly during failure of loop detectors, visibility sensors, and modification of CMS.
Evaluation Methods and Metrics

1. Study of driver response to warning messages.

Answers the question: How effective are the CMS warning messages in modifying driver behavior?

Two sites prior to first CAWS CMS, and two sites after, record the exact speed, time of arrival, and length of each vehicle, as well as monitor local visibility.

Individual vehicles records with speed, separation, classification (based on length), volume, stored in database 24/7.

Messages on CMS monitored directly, and verified with video camera. Traffic condition and visibility also verified with video camera.

Detailed statistical analysis of speeds, separations, lane-specific and overall, reveal patterns of driver reaction to various CMS messages relative to baseline non-message behavior.
Evaluation Methods and Metrics

2. Observation of CMS activations compared with vehicle speeds and visibility throughout CAWS area.

Answers the question: Does the CAWS activate CMS’s in a way that is conducive to improved traffic safety?

Log files from SignView, TMS and QCMS computers studied during each period of CMS actuation. Messages compared with speed and visibility records to determine reaction of CAWS system to trigger events.

When anomalies observed, SignView and TMS program code and system maintenance records analyzed in attempt to explain behavior of system.

Effectiveness of system control strategy studied and critiqued.
Evaluation Methods and Metrics

3. Traffic accident records studied for 6 year period prior to and following activation of the CAWS.

Answers the question: How have the number and type of accidents changed as a result of the CAWS?

Caltrans TASAS database used to identify and classify every accident occurring in the CAWS area before and after system activation. CHP accident reports provide information on traffic and visibility conditions during accidents.

QCMS log files verify visibility and other weather conditions during after period. National Weather Service visibility data used for visibility assumption during the before period.

SignView logs verify system operational status during each event.

TMS log files confirm accident via speed records.

Secondary accidents identified by time, location, proximity or accident reports.

Accident rates normalized to VMT, traffic flow in opposite direction, and reference areas from similar highways, and segregated by visibility, weather conditions, vehicle class, primary/secondary, etc.
Evaluation Methods and Metrics

4. Account for other factors potentially influencing accident rates to isolate just the effect of the CAWS.

Answers the question: How would traffic accident rates have changed over the 12-year period of study if the CAWS were never installed?

Influence of road construction activities. Construction records obtained from Caltrans.

Influence of change in speed limit from 55 to 70 MPH in 1998. Speeds from CHP reports and TMS log files.

Increased road capacity due to lane addition on SR120 during before period.

Changes in traffic volumes and vehicle class distribution with growth of nearly business centers.

Changes in driver demographics and attitudes (increased business commuters in after period).

Changes in vehicle size (larger/faster vehicles).

Changes in CHP enforcement and presence.

MANOVA used to detect influences of external events on accident rates, independent of CAWS.
Accident Statistical Analysis

All-Weather Accident Rate (Study Vs Control)

<table>
<thead>
<tr>
<th>Year</th>
<th>Study</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>0.60</td>
<td>0.40</td>
</tr>
<tr>
<td>1994</td>
<td>0.40</td>
<td>0.80</td>
</tr>
<tr>
<td>Jan – Oct</td>
<td>0.20</td>
<td>0.80</td>
</tr>
<tr>
<td>1996</td>
<td>0.40</td>
<td>0.60</td>
</tr>
<tr>
<td>1998</td>
<td>0.40</td>
<td>0.60</td>
</tr>
<tr>
<td>2000</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Jan - Mar</td>
<td>0.20</td>
<td>0.20</td>
</tr>
</tbody>
</table>

CAWS Activation
Accidents in fog normalized to MVMT on fog days each year
Proportion of Accidents Occurring in Fog

![Bar chart showing the proportion of fog accidents to all accidents before and after the implementation of the Caltrans Automated Warning System for different segments of I-5.]
Evaluation of Caltrans Automated Warning System

Accident Severity

Proportion of PDO Accidents to All Accidents

<table>
<thead>
<tr>
<th>Percent</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control I-5 S of 120</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study I-5 S of 120</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control I-5 N of 120</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study I-5 N of 120</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- Before
- After
Matching peak traffic periods between the study and control directions

Peak Period All-Weather Accident Rate AM Study Vs PM Control

Accident Rate (MVMT)

Years

Fog Accidents on I5 South and 120 West

Fog accidents in study direction
4 year period before CAWS

Key
- 11-12 Accidents
- 9-10 Accidents
- 7-8 Accidents
- 5-6 Accidents
- 3-4 Accidents
- 1-2 Accidents
- 0 Accidents

Per Quarter-Mile Section
Evaluation of Caltrans Automated Warning System

Fog Accidents on I5 North and 120 East

Fog accidents in control direction
4 year period before CAWS

Key

- 11-12 Accidents
- 9-10 Accidents
- 7-8 Accidents
- 5-6 Accidents
- 3-4 Accidents
- 1-2 Accidents
- 0 Accidents

Per Quarter-Mile Section
Fog Accidents on I5 South and 120 West

Fog accidents in study direction
4 year period after CAWS
Fog Accidents on I5 North and 120 East
Fog accidents in control direction
4 year period after CAWS
External Factors Affecting Accident Rates

- Variable weather – number of fog days per year
- Change in speed limit
- Changes in commute patterns and vehicle mix
- Roadway construction / lane closures
Fog Patterns

Visibility over a typical month
(Extinction Coefficient Shown)
### CMS Messages Monitored and Logged

<table>
<thead>
<tr>
<th>Timestamp</th>
<th>Message Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>20040123185450</td>
<td>DENSE FOG/ADVISE 45 MPH</td>
</tr>
<tr>
<td>20040123185140</td>
<td>BLANK MESSAGE</td>
</tr>
<tr>
<td>20040123183950</td>
<td>DENSE FOG/ADVISE 45 MPH</td>
</tr>
<tr>
<td>20040123183641</td>
<td>BLANK MESSAGE</td>
</tr>
<tr>
<td>20040123181851</td>
<td>DENSE FOG/ADVISE 45 MPH</td>
</tr>
<tr>
<td>20040123104555</td>
<td>BLANK MESSAGE</td>
</tr>
<tr>
<td>20040123090109</td>
<td>DENSE FOG/ADVISE 45 MPH</td>
</tr>
<tr>
<td>20040123084310</td>
<td>DENSE FOG/ADVISE 30 MPH</td>
</tr>
<tr>
<td>20040123080504</td>
<td>DENSE FOG/ADVISE 45 MPH</td>
</tr>
<tr>
<td>20040123064659</td>
<td>BLANK MESSAGE</td>
</tr>
<tr>
<td>20040123064406</td>
<td>DENSE FOG/ADVISE 45 MPH</td>
</tr>
<tr>
<td>20040123063209</td>
<td>DENSE FOG/ADVISE 30 MPH</td>
</tr>
<tr>
<td>20040123061957</td>
<td>BLANK MESSAGE</td>
</tr>
<tr>
<td>20040123053725</td>
<td>DENSE FOG/ADVISE 30 MPH</td>
</tr>
<tr>
<td>20040123052715</td>
<td>BLANK MESSAGE</td>
</tr>
<tr>
<td>20040123050026</td>
<td>DENSE FOG/ADVISE 30 MPH</td>
</tr>
</tbody>
</table>
Evaluation of Caltrans Automated Warning System

Analysis of system behavior during CMS activation events

CMS Activation Records
CMS Activation During Fog Event

December 22, 2003 [12:00AM-3:30AM]

Legend:
- **Yellow**: DENSE FOG/ADVISE 45 MPH
- **Pink**: DENSE FOG/ADVISE 30 MPH
- **Light Blue**: Fog coefficient (Mathews Rd)
- **Red**: Fog coefficient (French Camp Slough)
CMS Activation During Fog Event

January 23, 2004 [12:00AM-7:00AM]

- Yellow: DENSE FOG/ADVISE 45 MPH
- Pink: DENSE FOG/ADVISE 30 MPH
- Gray: BLANK
- Light Blue: Fog coefficient (Mathews Rd)
- Red: Fog coefficient (French Camp Slough)
Traffic Image During Fog Event
Driver Reactions to Warning

Evaluation of Caltrans Automated Warning System

January 8, 2004

Diagram showing driver reactions to warning with different visibility conditions and speed advisories.
Driver Reactions to Warning
Technical and Institutional Problems

1. Communications over leased phone lines unreliable. CDPD modems eventually deployed at all sites.

2. Power outages frequent, unexpected and of longer duration than UPS backups.

3. Loop detectors have been persistent problem. Unreliable and down due to road work.

4. Visibility sensors often out of calibration, sometimes down due to communications or component failure.

5. CAWS system data logs not in readable form and incomplete. Access to archived accident and construction records very labor intensive.

6. Unexpected events effecting study have been common - destruction of loop detectors during road construction, loss of power or communications due to accidents or construction, CMS modifications and message type changes.

7. No direct external access to CAWS computers or archives, which are non-networked computers. Can’t monitor CAWS real-time operation except at our evaluation sites.
Addendum: additional data
Accidents on I5 South and 120 West

All accidents in **study direction**

4 year period **before CAWS**
Accidents on I5 North and 120 East

All accidents in control direction

4 year period before CAWS
Evaluation of Caltrans Automated Warning System

Accidents on I5 South and 120 West

All accidents in study direction
4 year period after CAWS

Key

<table>
<thead>
<tr>
<th>Category</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>101-120 Accidents</td>
<td>Red</td>
</tr>
<tr>
<td>81-100 Accidents</td>
<td>Orange</td>
</tr>
<tr>
<td>61-80 Accidents</td>
<td>Yellow</td>
</tr>
<tr>
<td>41-60 Accidents</td>
<td>Green</td>
</tr>
<tr>
<td>21-40 Accidents</td>
<td>Blue</td>
</tr>
<tr>
<td>11-20 Accidents</td>
<td>Purple</td>
</tr>
<tr>
<td>0-10 Accidents</td>
<td>Pink</td>
</tr>
</tbody>
</table>

Per Quarter-Mile Section
Accidents on I5 North and 120 East

All accidents in control direction
4 year period after CAWS