CAWS Study Area
Interstate 5 and State Route 120, Near Stockton, California

Study in progress through June 30, 2005
Caltrans Automated Warning System (CAWS)

WEATHER STATION COMPONENTS

A
1 Wind Vane
2 Anemometer (Wind Speed)
3 Rain Gauge

B
4 Visibility Sensor
5 Network Controller

C
6 Radiation Shield (Temperature)
CAWS Changeable Message Sign (CMS) No. 1

(Total of 9)
Components of the CAWS

1. District 10 Traffic Management Center
   - Meteorological Station Monitoring Computer
     (Pentium/Win95)
   - CMS Control Computer
     (486/DOS)
   - Traffic (loop detector) Monitoring Computer
     (486/DOS)

2. Leased and Dedicated V34 BIS Phone Lines
3. 9 Automated Weather Stations
4. 9 Model 500 Changeable Message Signs
5. 36 Inductive Loop Speed Detectors
CAWS Control Computers in District 10 TMC
Evaluation Objectives

1. Technical Assessment.
Assess quality, 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 and assess response of drivers to CAWS warning messages.

4. Assessment of long-term impact of system on accident rates and losses.
Compile long-term accident statistics before and after system activation.
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
Fog Accidents on I5 South and 120 West
Fog accidents in study direction
4 year period after CAWS

Key
- 11-12 Accidents
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Per Quarter-Mile Section
Accidents in Fog, Before and After CAWS

Accident Rate (MVMT)

Year


Study

Control

CAWS Activation
Cross-Peak-Period Accident Rates Before and After CAWS

Accident Rate (MVMT)


Years

CAWS Activation


AM Study
PM Control
Secondary Accidents, Before and After CAWS

Secondary Accident Rate (MVMT)

CAWS Activation

Study Secondaries
Control Secondaries
External Factors Affecting Accident Rates

- Variable weather – number of fog days per year
- Change in national speed limit, 1998
- Changes in commute patterns and vehicle mix
- Roadway construction / lane closures
Direct Assessment of Driver Reaction to CAWS Warning Messages
Evaluation System Components

Before CMS

- 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

After CMS

- 6 Loop Detectors (3 lanes)
- Mathews Road (MR) Data Acquisition Station
- El Dorado Undercrossing Data Acquisition Station
- French Camp Slough (FCS) Data Acquisition Station
- Downing Road Data Acquisition Station

CDPD and CDMA to Internet

VPN access through Caltrans D10 Firewall

CAWS Weather Server in D10 TMC

CAWS Meteorological System Computer in TMC

Loragen Evaluation Database and Web Server
Experimental Apparatus for Monitoring Driver Response to CMS Messages
CMS Site: Southbound I-5 at French Camp CMS  
Last CMS Message Displayed On: Jan. 7 2005, 4:07:03 PM BLANK MESSAGE [View]

<table>
<thead>
<tr>
<th>Visibility Verification Image</th>
<th>Visibility Verification Image</th>
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</thead>
</table>

<table>
<thead>
<tr>
<th>CMS Verification Image</th>
<th>Visibility Verification Image</th>
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</thead>
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**1 Downing Road : Before CMS**

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<tr>
<th>Lane</th>
<th>Speed (mph)</th>
<th>Volume (veh/hr)</th>
<th>Cars/Light</th>
<th>Class5-6</th>
<th>Class7-8</th>
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**2 French Camp Slough : Before CMS**

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<th>Volume (veh/hr)</th>
<th>Cars/Light</th>
<th>Class5-6</th>
<th>Class7-8</th>
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<td>16</td>
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<tr>
<td>Total</td>
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<td>56</td>
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<td>5</td>
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</table>

**Visibility:** 26,400 ft. Jan. 8 2005, 11:32:24 PM [N]
Metrics for Risk or Severity of Collision
Aggregated Metrics

- Mean traffic speed
- Variance or Sample Standard Deviation (from the mean) of vehicle speeds
  - Measured for individual vehicles over a given period
  - Calculated over a period from aggregated contents of speed categories or “buckets”
Metrics for Risk or Severity of Collision

Aggregated Metrics

\[ \tau_{gap,i} = \tau_{headway} - \tau_{presence} \approx \frac{x_{i-1} - x_{i,i}}{v_{0,i}} \text{ for individual vehicles} \]

\[ = \tau_{off\ time,avg} = \tau_{period}(1 - occupancy) \text{ period average} \]

where \( occupancy \) is ratio of time that
loop detector is "on" in presence mode
Metrics for Risk or Severity of Collision
Individual Vehicle Metrics

Time To Collision (TTC) [Hayward 1971, Van der Horst, 1990]

\[ TTC_i = \frac{x_{i-1} - x_i - l_{i-1}}{v_i - v_{i-1}}, \quad v_i > v_{i-1} \]

Defined at moment that vehicle i initiates braking, holding constant the velocities of both vehicles
**Metrics for Risk or Severity of Collision**

**Individual Vehicle Metrics**


Fraction of time that a vehicle travels with TTC below a critical value, typically 4.0 seconds

TIT = Time Integrated Time-to-Collision [Minderhoud and Bovy 2001]

DTS = Deceleration-to-Safety Time [Topp et.al. 1996]
Metrics for Risk of Collision
Enhanced metric for visibility-limited collisions

Derived from velocity of impact with an immobile object in roadway as might be encountered in multi-car pile-up

\[
v_{impact,i} = \begin{cases} 
  v_{0,i} \sqrt{1 - \frac{\min\{x_{vis}, x_{gap,i}\} - x_{react,i}}{x_{brake,i}}} , & \min\{x_{vis}, x_{gap,i}\} \geq x_{react,i} \\
  v_{0,i} , & \min\{x_{vis}, x_{gap,i}\} < x_{react,i}
\end{cases}
\]

\[
x_{gap,i} = (t_{0,i} - t_{0,i-1}) v_{0,i-1} = \text{separation between vehicle } i \text{ and } i - 1
\]

\[
x_{react,i} = t_{react} v_{0,i} = \text{reaction distance of vehicle } i
\]

\[
x_{brake,i} = \frac{v_{0,i}^2}{2 g k_{friction}} = \text{braking distance of vehicle } i
\]
Metrics for Risk of Collision

Velocity as a function of distance during aggressive braking event

\[ v = \text{vehicle speed (ft/sec or m/s)} \]
\[ v_0 = \text{vehicle speed prior to braking} \]

\[ x = \text{distance traveled (ft. or meters)} \]

\[ v_{\text{impact}} \]

\[ x_{\text{react}} \]

\[ x_{\text{brake}} \]

\[ \min\{x_{\text{vis}}, x_{\text{following}}\} \]
Metrics for Risk of Collision

Normalized Risk of Collision $R_i$ for vehicle $i$

$$R_i = \left( \frac{v_{impact,i}}{v_{0,i}} \right) \times 100\%$$

$v_{0,i}$ = measured velocity of vehicle $i$ at point of detection

$v_{impact,i}$ = velocity of impact, stationary object
Period of similar poor visibility
Lane-by-lane analysis:

Animation of traffic speed distributions by lane during a fog event…
Conclusions Related to Evaluation Methods

• Assessment of driver reaction requires the design of an experiment to isolate safety intervention from other factors to maximum extent possible.

• Accident rates are significantly dependent on external factors: speed limit, construction, annual weather, commute patterns. Difficult to isolate effect of a particular safety intervention.

• Statistical analysis of traffic accidents is problematic:
  • Long terms (many years) required to amass a statistically significant body of accident data.
  • But long terms introduce dominant changes in experimental conditions and external factors.
  • Data analysis and statistical modeling is sensitive to model design and selection of control areas.
Conclusions Related to Evaluation Methods

- Short period variance observations focus on interactions between proximate vehicles: improved relevance for risk of collision.

- Aggregated data or long-period averages may conceal useful information in driver reaction patterns.

- Establishing a reasonable trend line through data based on individual vehicle records involves tradeoffs between visual interpretation and data scatter.

- Risk of collision metrics based on individual vehicles better reveal response of traffic to transient events or safety interventions.

- Practical sight distance is an important factor in risk of collision metric for fog accidents.
In cases examined to date:

• Drivers respond primarily to their perceptions of their immediate situation.

• Weak or nil influence of dynamic warnings on vehicle speed or separation.

• Following distances of drivers indicates they consistently underestimate collision risk, especially in fog.
Preliminary Conclusions and Observations Regarding the CAWS

• A complex fully-automated wide-area system – one of the first.
• Visibility is a localized and transient phenomena requiring closely-spaced sensors for accurate effect prediction and warning.
• CAWS partially limited by operational problems including control strategy design issues and software errors.
• Improved testing and validation of software recommended prior to system activation, including a formal alpha and beta testing process.
• Improved documentation of system operation and control strategy needed. Some misconceptions about what the system was doing.
• Study still in progress. To date, safety enhancement effects not established.
### All-Weather Accidents, Before and After CAWS

<table>
<thead>
<tr>
<th>Year</th>
<th>Total ‘All Weather’ Accidents</th>
<th>Total Travel (MVMT) Study</th>
<th>‘All Weather’ Accident Rate (Accidents/MVMT)</th>
<th>Total ‘All Weather’ Accidents</th>
<th>Total Travel (MVMT) Control</th>
<th>‘All Weather’ Accident Rate (Accidents/MVMT)</th>
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Accidents on I5 South and 120 West

All accidents in study direction
4 year period before CAWS
Accidents on I5 South and 120 West

All accidents in study direction
4 year period after CAWS