CALIFORNIA PATH PROGRAM
INSTITUTE OF TRANSPORTATION STUDIES
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Evaluation of Caltrans District 10 Automated Warning System: Year Two Progress Report

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Evaluation of Caltrans District 10 Automated Warning System

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Year Two Progress Report

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Executive Summary

District 10 of the California Department of Transportation (Caltrans) encompasses an area of seasonal fog and dust-related visibility problems that have been the cause of numerous multi-car traffic collisions, many fatal. In 1990, motivated by the expansion of State Route 120 (SR 120) connecting Interstate Highway 5 (I-5) and State Route 99 (SR 99), Caltrans proposed a sophisticated multi-sensor automated warning system as a means for reducing incidents in this high-traffic area. This proposal, and the significant development effort that followed, culminated in the implementation of Phase 1 of the Caltrans Automated Warning System, or "CAWS", which entered service in November 1996. The system includes 36 traffic speed monitoring sites, 9 complete remote meteorological stations including visibility detectors, and nine changeable message signs for warning drivers. The system is controlled by a network of three computers in the District 10 Transportation Management Center (TMC), running specialized software developed by Caltrans Operations. This system is believed to be one of the most advanced of its kind in the world.

An independent evaluation of the CAWS is currently in progress. California PATH, based at the University of California, Berkeley, was asked to set up and monitor the evaluation program, just prior to the activation of the system. The Cal Poly Transportation Electronics Laboratory, one of several PATH University affiliates, was engaged under subcontract to PATH to establish appropriate metrics and modes of evaluation, design the evaluation program, and to analyze and report data collected by Caltrans personnel. Minimum cost was a primary consideration. We proposed an approach comprised of four levels of assessment: long term efficacy in reduction of traffic loss; functional efficacy in terms of effect of warning on driver behavior; operational validation, and technical assessment.

The technical and operational evaluations are nearly complete, lacking a quantitative comparison of actual visibility with reported visibility under fog conditions. However, we are confident from the technical inspections we have performed at selected weather stations and the TMC that the system has all specified capabilities, including but not limited to the capability to warn drivers of hazardous traffic conditions. In addition, the system appears to have operational and research-related capabilities not yet fully utilized. These include predictive driver warning based upon multiple-sensor inputs, high-resolution traffic flow model validation, driver behavior characterization correlated with weather conditions, and very accurate weather monitoring.

The highest evaluation level, directly related to traffic safety, requires analysis of accident statistics over a period of many years prior to and after the activation of the system. To date, we have studied historical data, and done what we can with the very limited data available in the short period since it's activation.

The functional (second) level of evaluation most directly answers questions of cause and effect, ultimately supporting (or not supporting) decisions in other jurisdictions to replicate (or not) the system. We assess driver behavior in terms of average speed, speed distribution, speed gradient, and following distance (average and variance). Our original plan was to delay the activation of the north-most Changeable Message Sign (CMS), and comparing driver behavior and visibility at the first detection site with the same measurements at the next detection site, after drivers have seen a CMS warning, under conditions of visibility suitably poor to activate the warning system. This option was eventually rejected by Caltrans for safety and liability reasons.

This limitation is being overcome by the instrumentation of a site immediately outside the CAWS-monitored area to serve as a baseline comparison point. The chosen site, at the existing French Camp Slough Count Station, must have power and communications routed to it, fog monitoring and communications equipment installed, and an interface to the loop data acquisition system worked out. Identical data collection capability

must also be set up at Weather Station One, located at the north entrance to the study area on Interstate Highway 5 (I-5). The first CMS lies approximately halfway between the French Slough site and Weather Station One.

Due to resource limitations at the District level, support for the evaluation of the system was no longer possible after November 1998. Portable data acquisition equipment, which had been installed temporarily at the French camp test site, has been redirected to other areas of immediate safety need. In view of this situation, PATH cancelled the third year funding for the evaluation. A proposal was submitted in January 1999 to the Caltrans Office of Traffic Safety for support for the continuation and completion of the evaluation program. As of the date of this report, response to this proposal is pending.

In its current state of completion, considerable investment has been made and significant work has been completed on this instrumentation project, but considerable work remains. Qualimetrics meteorological equipment is physically installed at the French Camp Slough site. Conduit to the site has been installed and wire has been pulled, and power is available at the site. Communications to the site will not be available until work and administrative details related to a nearby CMS for the northbound lanes have been completed. The interface between the Qualimetrics Q-net and Phoenix D/A systems remains unresolved. Remote communications and data format issues also remain unresolved, pending the solution of the interface issues. Historical accident data has been studied to establish a baseline “before” loss rate and to establish measurable driver behavior cues to be used later in support of site-to-site comparisons. A technically sound but untested approach for characterization of driver behavior from duplex loop detector data has been developed, awaiting testing on comparative data streams at the two sites.

The role of the evaluators has changed significantly compared with that originally proposed. We have been significantly involved in the specification and coordination of engineering activities. Personnel changes in District 10, and unanticipated highway-safety-related priorities made progress slower than anticipated. Rainy weather delayed the start of trenching activities (for power and communications) by several months. Responsibility for data collection and the ongoing conduct of the evaluation program are unresolved at this time, and it is uncertain if the evaluation project will continue. As an adaptation to this situation, the evaluation team has shifted its emphasis to establishing the infrastructure and protocols needed to support the evaluation, with actual field data collection to occur after the team is no longer involved.

Keywords

California Department of Transportation, PATH, CAWS, IVHS, ITS, fog, monitoring, detection, reduced visibility, accident prevention, automated, driver warning, traffic safety, Caltrans District 10, field operational test, Qualimetrics, ATMS, ATMIS, automated highways, Cal Poly Transportation Electronics Laboratory.

Disclaimer

Acknowledgements

The work was performed as part of the California PATH program of the University of California, in cooperation with the State of California Business, Transportation, and Housing Agency, Department of Transportation. Except where noted, this report was written by the project director, C. Arthur MacCarley, Director of the Cal Poly Transportation Electronics Laboratory.

The District 10 project manager at the start of the evaluation was Frank Weishaar, who provided the original context for the evaluation. He was succeeded as Branch Operations Chief by Laurie Jurgens during the summer of 1997, who is our current contact. Both worked to enlist resources in the district to support this

evaluation project. We have worked with a succession of technical support contacts in District 10, each have contributed information used in this report to various degrees. Among these were Ken Robertson, Jim Eckelstone, Garry Smith, Dave McPeak, and Clint Gregory (our current contact). Joel Retanan of Caltrans Operations in Sacramento provided assistance it setting up our software and modem for direct access to the Traffic Monitoring System interface in the TMC. Floyd Workmon and Celso Izquierdo of Caltrans Operations in Sacramento provided much of the system level details and background information that we report in the background section of this report. Additional background and historical information has been provided by Joe Palen of Caltrans New Technology, Randy Iwasaki, John VanBerkel, and Asif Haq of Caltrans Operations, and Teri Argerbright of Farradyne Systems Inc.

Our PATH contract monitor is Robert Tam, who provided funding and direction for the evaluation. Our Caltrans project monitor is Richard Macaluso of Caltrans New Technology, who has been instrumental in facilitating progress in the setup of the required field instrumentation. Their support, liaison activities, and patience are greatly appreciated.

Several research assistants in the Cal Poly Transportation Electronics Laboratory have supported this project in various ways. Among these are Bryan Gray, Todd Eidson, and Brian Pevear. Prof. Edward Sullivan and Bridget Barrett of Cal Poly's Civil and Environmental Engineering Department provided the traffic accident analysis section (Task 3) and assisted with the driver behavior analysis section (Task 2) of this report.

Background

The San Joaquin Valley lies in the interior of California, extending from Sacramento south to the El Tejon pass, at the north perimeter of Los Angeles County. The valley is known for seasonal ground fog, occurring from approximately October through April. In arid areas of the valley, blowing dust is also a problem during high-wind conditions. Interstate Highway 5 and California Highway 99 are the major north-south traffic arteries that extend the length of this corridor. These and other smaller highways in this valley have historically been prone to multi-car accidents during reduced-visibility conditions due to fog or dust.

The cities of Stockton and Manteca are situated in a low-lying area of San Joaquin County, which is located at the north end of the valley. In this particular area, Highways 5 and 99 almost converge, connected by a seven-mile stretch of California Highway 120, which feeds into State Highway 205, a major artery into the San Franciso bay area. Traffic converges abruptly and is often heavy, comprised of both local and interstate elements. Dense fog occurs regularly and with little warning, especially during morning and evening commuting hours. During fog conditions, driving can become extremely hazardous. This area has previously been used as a test bed for visibility-related traffic safety studies, such as Operation Fogbound[1], a 1973 field test of highway visibility sensors.

In 1991, growth in the greater Stockton area created an urgent need to expand the capacity of Highway 120 from 2-lanes to 4-lanes in the Mossdale area, situated between highways 5 and 99. This project eventually became know as the Manteca Bypass Expansion, and evolved through the normal process of approvals and environmental impact assessments. Just prior to the letting of construction contracts, a resident of Manteca, Mike Barkley, threatened a lawsuit against the State of California citing the failure of the environmental impact study to adequately address the problem of fog-related traffic safety. Mr. Barkley was motivated by his near-involvement in two fatal multi-car accidents on this stretch of highway in 1989. He had become a crusader for some type of solution to this problem. The highway expansion project became the catalyst. Mr. Barkley found support for his concerns in the District 10 office of the California Department of Transportation (Caltrans), which had long been concerned about the problems in the area but lacked resources to implement solutions beyond static warning signs, which had proven to be of little value to drivers. Similar catastrophic events nearby contributed to a sense of urgency. On February 7, 1991, just south of the area on Highway 99, a fog-related accident involved 75 vehicles and killed 4 people. Cooperation prevailed between Caltrans legal council Bruce Behrens and Mr. Barkley. According to Barkley[2] "We sat down and we worked through what the problems were and what the possible solutions were. I think Caltrans truly would like to do what it can to solve this problem of fog-related pile-ups"

The combination of environmental and traffic conditions made it a unique candidate for a high-tech solution. In the assessment of John VanBerkel[3], the deputy district director for system operations, the limited distance, converging traffic pattern, and high incidence of dense ground fog made the area an ideal site for an active fog warning system.

The solution was fleshed out in discussions between VanBerkel and Cliff Rice, chief engineer for District 10 Traffic Operations. Among the primary requirements identified was driver confidence in the warning information provided by the system. It was known from prior studies in this area and in Riverside, California,[4] that lack of driver trust could easily nullify any potential benefits. Another consideration was that fog in this area was highly localized. Visibility can change dramatically between locations separated by as little as 500 feet. These criteria dictated a network of real-time sensors for both visibility and traffic conditions, as well as a display system that could be seen by drivers even under very limited visibility. The system would require automated decision-making capability for 24-hour autonomous operation.

The result was an architecture incorporating three primary elements: a network of remote meteorological stations, a network of traffic speed monitoring stations, and the deployment of self-illuminated changeable message signs (CMSs), all at intervals yet-to-be determined along the highway. The system envisioned would have the capability to warn drivers in advance of potentially lethal combinations of impaired visibility and traffic congestion, and optionally recommend appropriate actions. The system would have direct links to the California Highway Patrol. A network of Closed-Circuit Television (CCTV) cameras would be deployed for incident verification. A Highway Advisory Radio (HAR) system was to be added eventually to supplement the visual driver warnings. Ultimately, the system would be the first fully automated multi-sensor multi-function driver warning system in the United States. The deployment time frame was very limited, precluding extensive development efforts.

Design requirements were written by Caltrans staff, and a request for proposals was issued. In mid-1991, a concept development and feasibility study contract was awarded to Parsons Brinckerhoff's Farradyne Systems Incorporated (PBFSI) and Quade-Douglas (PBQD) divisions, with the intention of awarding the overall project to this team depending on the proposal and cost estimate resulting from this work. Cliff Rice served as the first Caltrans project manager. In mid-1992, when the resulting deployment cost estimate provided by PBFSI/QD was considered excessive, the project was undertaken internally by a joint engineering team from Caltrans District 10 and Caltrans Operations Division in Sacramento. Planning, specifications and estimation was performed by this team. In early 1993, a go-ahead for partial funding from the Caltrans State Highway Operations Protection and Planning (SHOPP) directorate was given, for an estimated capitol cost of $3 million. A first phase would be deployed, covering approximately only half of the intended study area. The Phase 1 deployment would consist of nine meteorological sensor sites and nine CMS's. The coverage area for traffic speed/count monitoring would be more extensive: 36 sites would be installed. The intention at the time was to assess the performance of this first phase prior to deploying a potentially larger second phase.

Randy Iwasaki, deputy director of operations in District 10 became the project manager. Systems engineering responsibilities were undertaken by Floyd Workmon of Caltrans Operations. Software design responsibilities for implementation of the decision-making capability, CMS control, traffic speed monitoring, and data communications would be the responsibility of Joel Retanan and Celso Izquierdo of Operations. Qualimetrics Inc. of Sacramento was selected to provide turnkey installations of nine remote meteorological sensor stations and a central display and communications workstation. Each "weather station" includes a dual-axis forward-scatter visibility sensor, an anemometer, wind direction indicator, barometer, thermometer, relative humidity (dew point) sensor, and precipitation gauge, and a telemetry system for encoding all instrument data and transmitting to a central facility for display and recording on a PC. The traffic speed monitoring system and CMS control system were engineered and constructed by Caltrans Operations. COTS (Commercial of-the-shelf) hardware was utilized whenever possible to minimize cost and reduce deployment time. Standard Caltrans specification 170 controllers were used for both the traffic speed detection sites and the CMS interfaces. Subcontractors were engaged to install loop detectors and CMSs. A map of the Phase 1 study area is shown in Figure 1.

The Phase 1 deployment was completed in the summer of 1996, under budget at a total capital cost of $2.5 million. The system was first activated in November 1996 and has been in continuous service since that time.

The winters of 1997 and 1998 were considered unusual due to the small number of occurrences of dense fog. This was generally attributed to “El Nino” weather patterns, which bought greater than normal rains to the area. There was an incident on Southbound I-5 at I-205 in January 1997 related to highway flooding. The CAWS was detecting and displaying a fog warning, and was overridden by input from the Speed Monitoring Stations to warn of slow and stopped traffic ahead. Warning of congested traffic conditions occurred on a routine basis. Also, in December 1997 a serious fog-related multi-car incident occurred in an area south of and outside the CAWS network on Highway 5.

Lacking an official designation by Caltrans, and following the suggestion of Floyd Workmon of Caltrans Operations, the complete system will be referred to as the Caltrans (District 10) Automated Warning System, or for convenience, the “CAWS”. The three interacting computer systems which implement the meteorological monitoring, traffic speed monitoring, decision-making and CMS display capabilities of the system are located in the Traffic Management Center (TMC), in the basement of Caltrans District 10 headquarters in Stockton. This collective network of IBM-type PC’s will be referred to as the CAWS TMC system.

A system with very similar capabilities was deployed on the A16 near Breda in the Netherlands in 1992, and evaluated over a two year period of observation 1992-94[5]. The configuration of this system and its methods of evaluation are nearly identical to those of the present system, with the exception that three data collection sites and two external reference sites were used. Similar systems have also been deployed in Virginia, Georgia, Arkansas, Oregon, Florida, Tennessee, France, Spain, England and Germany. The bibliography at the end of this report includes summary descriptions of all highway fog warning systems for which published information was available at the time of this report.

One system in the US worth particular mention is a somewhat less ambitious (but much better publicized) system with similar capabilities deployed in 1994 along a 12-mile section of Interstate 75 in South Georgia by the Georgia Department of Transportation (GDOT) and Georgia Tech University[6]. This system, referred to as the GDOT Fog Detection and Warning System, consists of a network of 19 visibility sensors and 5 loop-based speed detection traps. Warning messages are displayed on four incandescent CMSs. Messages can be either manually or automatically selected and actuated. Dial-up access is provided to law enforcement officials. The system is presently in its second year of testing and evaluation. Plans for expansion of the system are in progress.

In October 1996, immediately prior to the activation of the CAWS, the Cal Poly Transportation Electronics Laboratory was engaged through California PATH to assist Caltrans in the design and setup of an appropriate evaluation program, and to process and report data generated by that program over a three year period. This report summarizes the accomplishments and course of events between that time and May 1999, under the support of first and second year evaluation funding provided through PATH by Caltrans.

System Description

The primary function of the CAWS is to detect the presence of reduced visibility and/or congested traffic on the highway, and to warn drivers in advance of such conditions. Particular emphasis is on combinations of these conditions: slow or stopped traffic ahead which drivers might otherwise not be aware of due to reduced visibility. The CAWS is comprised of three primary subsystems:

1. Meteorological Monitoring System (Weather Monitor).

Manufactured and installed by Qualimetrics Inc. of Sacramento, California. Nine remote weather monitoring stations deployed on Highways 5 and 120, each including a dual axis atmospheric visibility sensor, an anemometer, barometer, thermometer, dew point sensor, precipitation gauge, and a telemetry system for encoding all instrument data and transmitting to a central facility for display and recording on a PC. Data is carried over a network of dedicated and leased telephone-type lines to the Traffic Management Center (TMC) located in Caltrans District 10 Headquarters in central Stockton. Information is displayed via a proprietary program running under Windows 95 on a PC in the TMC. Data is retained on disk until disk capacity is exceeded, when it must be manually backed up and erased. PC has RS-232 link in the TMC to another PC running the CMS control system, described below. TMC computer functions can be monitored off-site via modem connection and LapLink 5 (Win95) remote control program.

2. Traffic Monitoring System (TMS).

Duplex loop-pair speed detection traps are installed at 36 sites, spaced at approximately 1/2-mile intervals on Highways 5 and 120 in the Stockton-Manteca area. Some are located at or proximate to weather stations. Six sites are designated as communications hubs, to which all other sites are connected via twisted pair in a “star-type” network. All installations conform generally to Caltrans and US DOT FHWA specifications and practices for field control systems[7]. Field interfaces are implemented via Type 222 dual-channel inductive loop sense (Sarasota) amplifiers, and speed measurement algorithms are run on Caltrans Type 170 controllers, sourced by various venders. Data from each of the five communications hub sites are brought into the District 10 TMC over dedicated and leased telephone lines using Caltrans Type 400 (Bell L202S) 1200 bps modems at each end. Communications is full-duplex and a polling cycle of 30 seconds is used to retrieve data from all sites. Traffic count and speed data are displayed via a Caltrans-developed program under DOS on a PC in the District 10 TMC. The program has display capabilities for up to 36 sites. All speed data are averaged over 15-minute sample intervals. Average speed data is aggregated into fixed-range incremental “buckets” designed for flow classification purposes. Data is retained on disk until disk capacity is exceeded, when it must be manually backed up and erased. The PC communicates with the CMS-control PC described below via an EIA232c cable, at 9600 bps. Working with Caltrans Operations, the evaluation team has installed software (PC-Anywhere, DOS version) and a 33.3 kbps modem in this PC to facilitate remote monitoring of the system. However, lacking a dedicated telephone line, and since the software application must be manually activated by an operator in the TMC, this capability has not yet been realized. Issues of possible interference with the operation of the system during remote access remain unresolved.

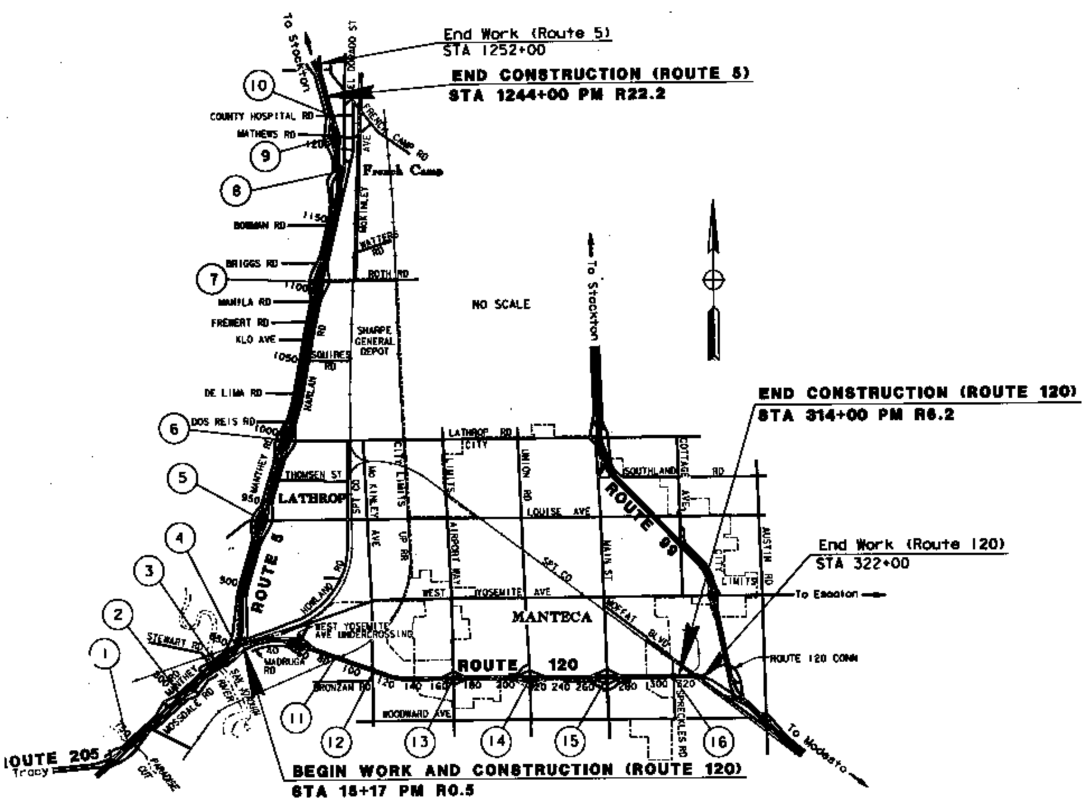


Figure 1. Map of CAWS Study Area, from Caltrans Construction Plans.

3. CMS Network and Control System (SignView System).

Caltrans Model 500[8] incandescent changeable message signs (CMS) are installed at nine locations in the study area. Incandescent-type (self-illuminated) displays have been reported to have the best readability under adverse weather conditions[9]. All display sites are proximate to loop detector sites, and have dedicated Caltrans Type 170 controllers for display and communications. Communications is handled over dedicated and leased phone lines and Caltrans Type 400 (Bell L202S) 1200 bps modems, connecting the signs in star-type clusters to a single central monitoring PC in the District 10 TMC. Proprietary "SignView" software, developed by Caltrans staff, actives the displays, selecting warning messages based upon programmed levels thresholds of traffic speed, visibility and wind speed. The following fixed messages are currently deployed automatically:

- 2 traffic speed warnings: "Slow traffic ahead" and "stopped traffic ahead" based upon thresholds of below 35 mph, and below 11 mph respectively.
- 3 visibility warnings, two of which are currently utilized: Visibility between 200 and 500 feet triggers the display of "FOGGY CONDITION AHEAD"; visibility less than or equal to 200 feet triggers the display of "DENSE FOG AHEAD".
- 1 wind speed warning: "HIGH WIND WARNING" is displayed when local wind speed exceeds 25 mph.

Priority-based preemption is implemented, with traffic speed-related warnings superceding visibility and wind-related warnings. Manually-entered warning messages can be displayed at any time by operator override. The TMC system receives inputs via EIA232c serial links from the adjacent weather monitoring and traffic monitoring PCs in the TMC. The system is only accessible from the TMC. It cannot be remotely accessed via modem. Figure 2 shows the three main computer subsystems of the CAWS, and their respective interactions with field sites and sensors.

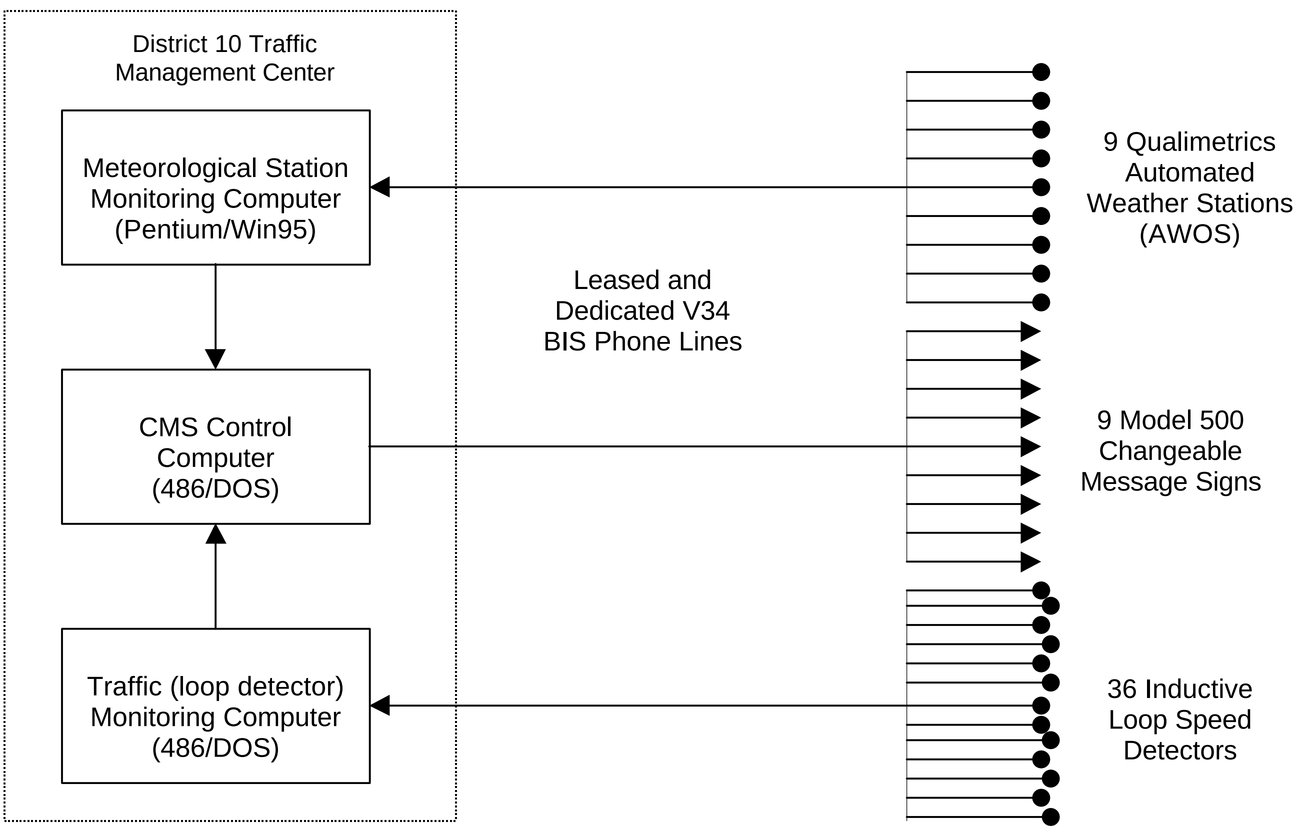


Figure 2. Main components of CAWS as Deployed in District 10 Study Area.

The CAWS has capabilities beyond those currently in use for automated driver warning. Each of the nine weather stations, described in Figure 3, include a full complement of atmospheric monitoring instrumentation. The central weather monitoring PC incorporates comprehensive data collection and interpretation capabilities. Combined with the network of 36 speed detection traps and its associated central traffic monitoring computer, additional reporting, alert generation, and data collection functions are possible. As a test bed for weather-related intelligent traffic management, this system appears to be one of the best equipped in the United States, and possibly the world. Please refer to the Bibliography section of this report for summary information on similar systems in the US and throughout the world.

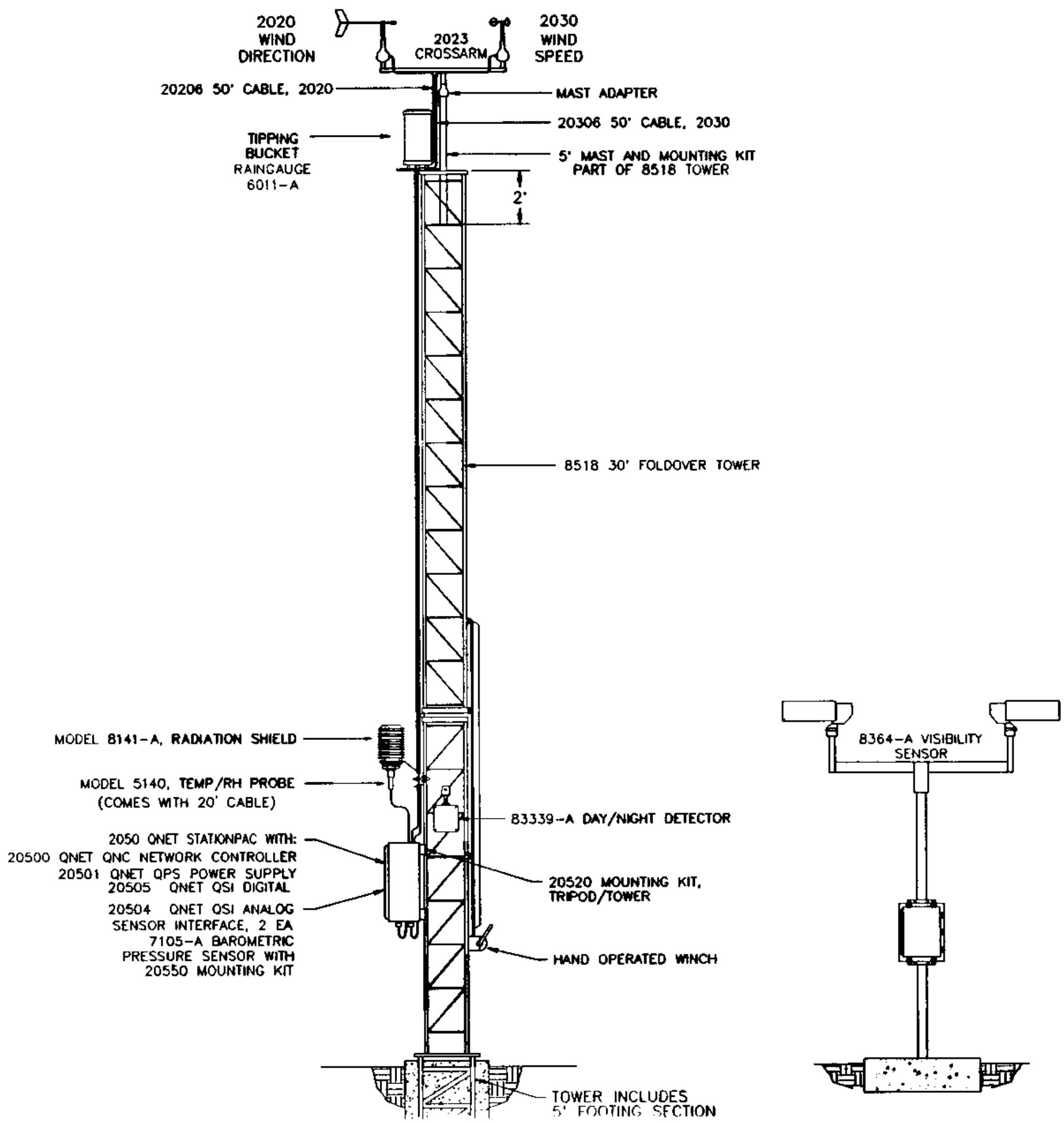


Figure 3. Detail of Qualimetrics Automated Weather Reporting System (AWOS) as Deployed in Caltrans District 10, from Qualimetrics Systems Data Sheets[10].

Figure 4, from a Caltrans internal presentation by Joel Retanan, Floyd Workmon and Celso Izquierdo of Caltrans operations, illustrates the role of each key component of the CAWS.

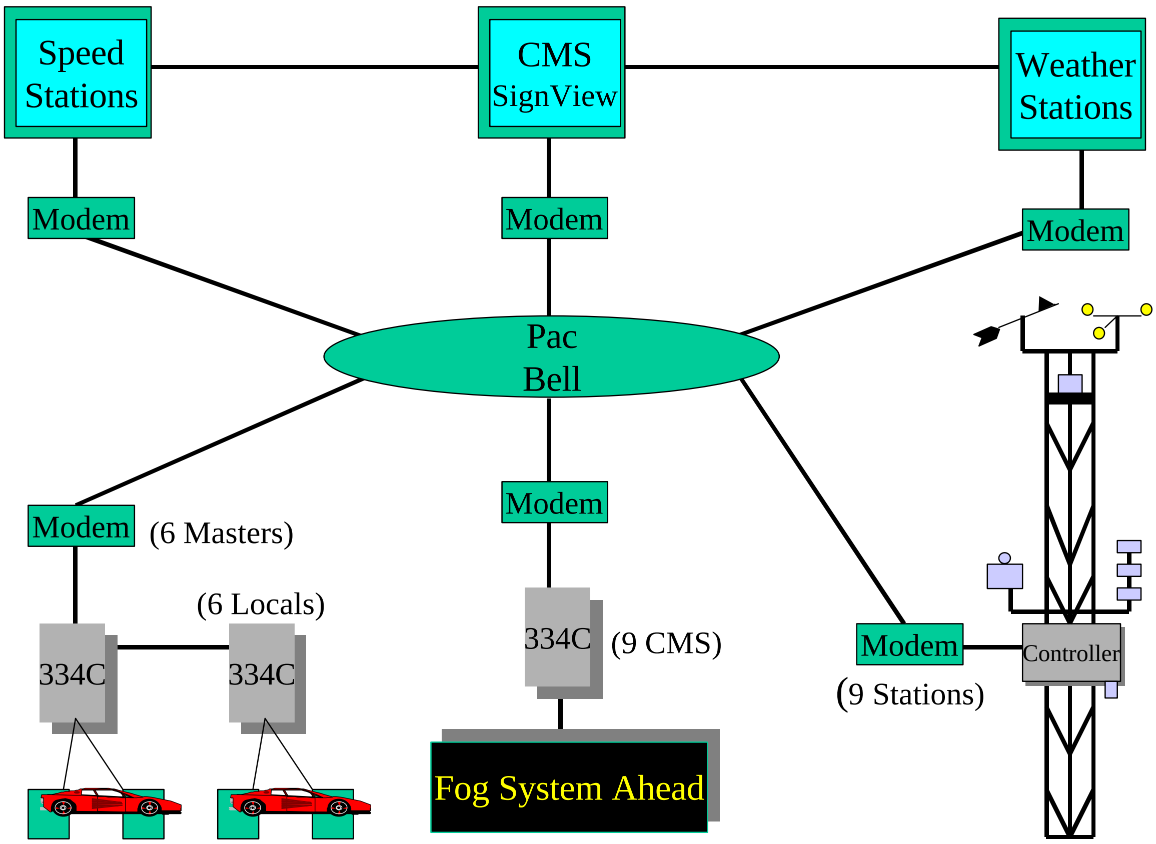


Figure 4. CAWS Key Components and Interconnectivity (provided by Caltrans Operations).

Objectives of Study

The objectives of our evaluation focused on the effectiveness of the CAWS in reducing traffic incidents and loss resulting from limited visibility and congested traffic conditions. This is a multifaceted objective that must be approached at several different levels. At the highest level, we compare accident rates and losses before and after the system's activation. At an intermediate and less direct level, we seek to determine if the warnings provided by the system are having a positive effect on driver behavior. At a lower level, we observe if the system is doing what it is supposed to do: accurately sensing visibility and traffic conditions, and reliably producing appropriate warning messages on CMS's. At the lowest level, we attempt to assess the technical soundness, quality and integration of the system components to assure that the system is capable of performing as specified under all required conditions. We divided the evaluation into four primary areas of study, reflecting increasing levels assessment as articulated above.

1. Technical Assessment.

By study of engineering design and operational documentation, and inspection of facilities, we attempt to assess the soundness of the design and implementation, and effectiveness of the integration of the system and subsystem components. This assessment was originally intended to includes consideration of communications methods, bandwidth and protocols, appropriateness of computational hardware selection, and functional status of field instruments. Lacking reference meteorological instruments more accurate than those installed by Qualimetrics at the nine weather monitoring stations, it was deemed infeasible and unnecessary to attempt to confirm the accuracy of the meteorological sensors. The operation of vehicle detection loops is assessed based upon the reasonableness of data generated for each detectorized lane, and by inspection of selected speed monitoring sites. For practical reasons, it is considered infeasible and unnecessary to comprehensively verify the accuracy of all loop detectors.

2. Operational Assessment.

We assess the operation of the system directly by observing the accuracy and reliability by which the system senses and reports visibility levels and traffic levels, and the consistency and reliability of the system's selection and display of appropriate warning messages. This requires the ability to monitor the operation of each subsystem from a remote site at times in which the system is taking (or not taking) action. We accomplish this by study of operational data acquired by each subsystem during fog incidents, and by real-time remote monitoring of subsystem via modem connection. We have installed software and hardware to make remote access possible, although facilities limitations in the District 10 TMC do not yet allow this capability.

3. Assessment of impact of system on driver behavior during limited visibility conditions.

To test the impact of this warning system on driver behavior, we needed a means for determining if during foggy conditions, drivers alter their behavior immediately after viewing the CMS warning message, compared with immediately before viewing the message. We seek to differentiate between normal changes in driver behavior as a reaction to the fog itself, and driver behavior changes as a reaction to the CMS message. This requires monitoring of visibility and traffic flow at a site prior to the first CMS seen by an approaching driver. Working with District personnel, we have selected a suitable site at French Camp Slough on southbound Interstate 5, and specified instrumentation and telemetry to facilitate this comparison.

4. Assessment of long-term impact of system on accident rates and losses.

By examination of archived accident records over several years prior to and several years after the activation of the system, we can attempt to ascertain if the system is having a positive impact on accident rates and loss. We can also attempt to infer from prior accident reports whether advanced warning of the drivers involved in a particular incident might have possibly eliminated or reduced the severity of the incident.

Due to limited funding and limited time to perform this work, not all areas of study above could be adequately addressed. We therefore sought to design and establish the infrastructure, facilities, procedures and protocols necessary to enable Caltrans personnel to perform these evaluation tasks on an on-going and long-term basis, ultimately providing a body of data from which the effectiveness of the system may be ascertained.

Evaluation Methodology

The methodologies associated with each primary evaluation level are described below.

1. Technical assessment.

A cursory assessment of conformity to nominal specifications was performed for the installation of electronic components at one sample instrumented site. The objective of this task was primarily to verify and document the system under test. Only the installation of the components will be assessed. For reasons described previously, sensor accuracy or calibration were not assessed. Components included in this assessment were the Qualimetrics forward scatter detector, Q-Net Data Acquisition System, day/night detector, anemometer, wind direction sensor, hygrometer, rain gauge, barometer, power supply, relay/telemetry system, network controller, and central processor hardware.

All components were found to be operational and installed competently and in a professional manner. Communications were fully operational, although protocol and bandwidth considerations could not be assessed. PC-based user interfaces of all systems were considered functional and user-friendly, based upon observations of operator interactions.

2. Operational accuracy and reliability.

Continuous data is automatically collected from the output of the Qualimetrics forward diffusion detectors at each of the instrumented roadside sites, accessed via modem through the meteorological monitoring computer in the TMC. Visibility reference targets were installed by Caltrans personnel at one location, however, the anticipated CCTV monitoring system originally planned for observation of these targets was not installed, preventing monitoring at times of critical visibility. It was considered not practical for observations to be recorded by local personnel during all periods of reduced visibility. Observations were intended to correlate visibility readings generated by the sensors with manual observations of visibility as perceived by drivers. District 10 technical staff will maintain log books and service records on the visibility detectors, weather instruments, speed detection system components, telemetry, and the driver warning CMS's. The evaluators will analyze the records to determine obvious or possible areas of unreliability or serviceability problems.

3. Influence on driver behavior during fog conditions.

Identical instrumentation for monitoring visibility and traffic speeds will be installed at two locations: one immediately prior to entry into the study area, and the other at an existing weather station and traffic speed monitoring station located shortly after drivers have viewed the first warning CMS. The site selected for the baseline (prior to viewing the CMS) test point is an existing non-powered temporary count station at French Camp Slough, approximately 0.6 miles north of the first CMS that can be seen by drivers entering the area on south-bound Interstate 5. The second site is the north-most weather and traffic speed detection station, designated Weather Station 1. The locations of these two sites are shown in Figure 5, which also shows the locations of all deployed elements in the study area.

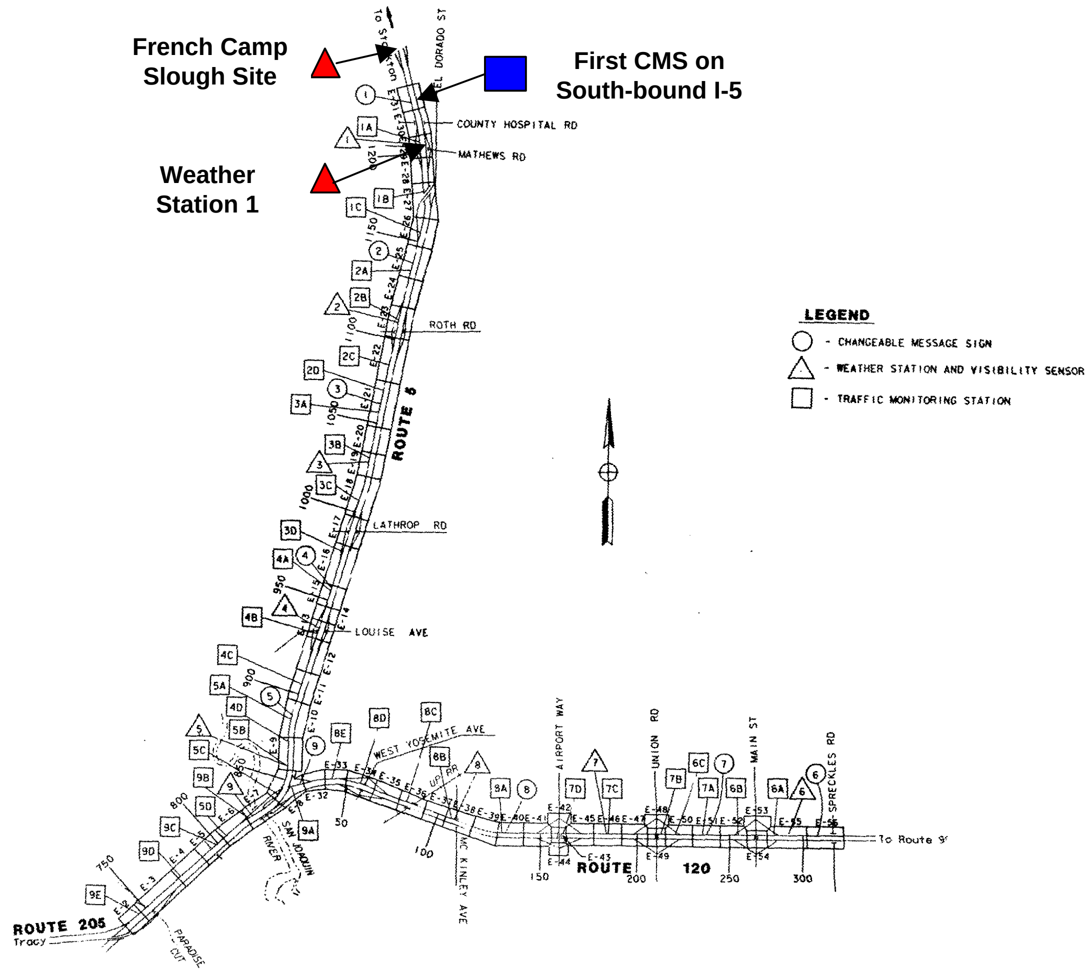


Figure 5. Location of French Camp Slough and Weather Station 1 Comparative Detection Sites, and all Deployed Elements on I 5 and SR 120 (from Caltrans Construction Drawings).

Individual vehicle speed and time-of-arrival records are needed to provide sufficient information for the assessment of comparative driver behavior between the two sites. Individual vehicle speeds and vehicle separation are calculated and recorded. It was not possible to use the existing speed detection program (running on the 170 controller) at Weather Station 1, site, since it automatically aggregates data into speed range “buckets” over 15 minute intervals. Among the options considered, the current plan is to use the same Phoenix portable data acquisition system that is being installed at the French Camp Slough site, programmed to acquire individual vehicle records. The existing Qualimetrics visibility sensor will be used at Weather Station 1. At French Camp Slough, and identical visibility sensor has been installed. Power and communications conduits have been routed to the site, which is approximately 0.3 miles from the nearest accessible power and communications connection at a soon-to-be installed CMS for north-bound traffic on I-5 (not seen by south-bound drivers). It may also be necessary to install an additional dedicated communications line to the Phoenix D/A system to be located at Weather Station 1, since all existing communications lines from the 170 are currently in use.

Vehicle speeds and headways will be recorded during clear conditions (baseline) and during periods of reduced visibility, at the locations before and after drivers view a CMS warning message. Data will be reduced (via methods explained later) and compared to assess the degree to which driver behavior is influenced by the CMS warning message, compared with their normal response to the presence of a reduced visibility conditions alone. This procedure is intended to isolate the effect of the warning system from other factors that drivers would naturally respond to in reduced visibility or congested traffic situations.

4. Long-term impact on traffic safety.

Archived statistics 1971-96 on vehicle accidents, including reported causal factors, traffic and atmospheric conditions, number of vehicles involved, severity and fatality rate, have been and should continue to be obtained (to the extent available) for the study area with the cooperation of Caltrans and the NHTSA. Data before and after the installation of the system will be compared to assess in the most demonstrable sense the efficacy of the system in reducing incidents related to inclement weather. External influences, such as improvements in vehicle and highway technologies, changes in traffic patterns and volumes, or differences in weather patterns are identified, and a qualitative effort is made to explain their possible influences upon the statistical conclusions.

Status of Evaluation Activities

Within budgetary constraints, the evaluation attempted to conform to FHWA guidelines, as articulated by Mitre (1994)[11]. Due to PATH budget limitations, the evaluation team was engaged in a consultative capacity only, relying upon Caltrans D10 staff and supporting facilities to perform all implementation and data collection. The following assumptions were made in the evaluation contract:

1. The project would be active primarily during the winter academic quarter (January-March) of each of the three year years of the study. These months correspond to the mid-late fog season, generally considered to run from November through April, during which time meaningful data can be collected.

2. The evaluation team would perform experimental design tasks and specify the data collection procedures, but all data will be collected and archived to meet the evaluation requirements by Caltrans staff or cooperating agencies.

3. Caltrans District 10 personnel to install at sites to be negotiated several visibility reference targets of the same type deployed in the earlier 1973 "Operation Fogbound" study performed in District 10.

4. The planned network of approximately nine CCTV cameras, to be deployed independent of this project, would be available for visibility reference and traffic incident monitoring for the duration of the study.

5. Electronic access via modem or Internet connection to District 10 would be available to the evaluation team, to obtain archived data and monitor, in real time, all processes related to the automated warning system.

Unfortunately, the project evolved away from some of these assumptions, necessitating changes in the proposed evaluation workplan. Despite the assistance and best efforts of Caltrans personnel, some critical obstacles were encountered that have prevented adequate progress of the evaluation. Some limitations can be traced to the fact that the original CAWS project did not include specific provisions for ongoing operational expenses of the system or the evaluation of system effectiveness. This lead to an unanticipated workload burden on operations personnel in District 10 to operate and maintain the system, not including the even greater workload of supporting evaluation activities. The project did not include a designed-in means for experimental validation of the effect of the warning system on driver behavior. This necessitated the setup and instrumentation of a baseline comparison site after-the-fact. The assumed network of CCTV surveillance cameras planned for the study area was not available, since this depended upon federal funding which ultimately was not secured. The proposed evaluation work plan also assumed the availability of then-anticipated Internet access to the D10 TMC, and provision for remotely monitoring the three computer subsystems that constitute the complete warning system. Internet access is not yet available, although access via modem to one subsystem (the Qualimetrics meteorological monitoring system) has been successfully implemented.

As previously discussed, we proposed an approach comprised of four levels of evaluation: (1) long term efficacy in reduction of traffic loss; (2) functional efficacy in terms of effect of warning on driver behavior; (3) operational validation - "does the installed system and components have the technical capability to do what it is supposed to do?"; and (4) technical evaluation – quality and integration of system components and installation. The last two evaluation levels are reasonably complete, lacking a quantitative means for comparison of actual visibility with reported visibility under fog conditions. Regardless, we are confident from the technical inspections we have performed that the system indeed has not only the capability to do what it is supposed to do (warn drivers), but research and monitoring potential not yet utilized, such as driver behavior characterization in fog, very accurate weather monitoring, and more sophisticated decision trees using additional sensor data including precipitation rate, prediction of ice formation or impending fog based upon dew point and temperature trends.

The first evaluation level requires analysis of accident statistics over a period of many years prior to and after the activation of the system. To date, we have obtained historical data via the TASAS database, and done what we can with the very limited data available in the period since system activation.

The middle level of evaluation most directly answers questions of cause and effect, ultimately supporting (or not supporting) decisions in other jurisdictions to replicate (or not) the system. We assess driver behavior in terms of average speed, speed distribution, speed gradient, and following distance (average and variance). Our original plan was to delay the activation of the north-most CMS, and compare driver behavior and visibility at the first detection site (prior to the CMS) to the same after drivers have seen a CMS warning, under conditions of visibility suitably poor to activate the warning system. This option was eventually rejected by Caltrans for safety and liability reasons.

This limitation has been overcome by the instrumentation of a site outside the monitored area to serve as a baseline comparison point. The chosen site, at the existing French Camp Slough Count station, now has power and communications routed to it, fog monitoring and communications equipment installed, and an interface to the loop data acquisition system worked out. Identical data collection capability must also be set up at the Weather Station 1 site, located after the first CMS. Characterization of driver behavior requires a high degree of resolution, ideally, individual vehicle event records. Since the existing loop monitoring system works with data "buckets" that could not provide the driver behavior data that we need, it was agreed that an identical Phoenix counter would be installed at this site, matching the setup at French Camp Slough, to provide directly comparable data.

As of the date of this report, considerable work has been completed on this instrumentation project, but considerable work remains. Qualimetrics meteorological equipment has been physically installed at the site. Possible interface issues between the Qualimetrics Q-net and Phoenix D/A systems remain unresolved. Remote communications and data format issues also remain unresolved, pending the technical solution of the interface issues. Once individual vehicle record data becomes available, we anticipate some time required to optimize our algorithms for characterization of driver behavior from the anticipated data stream. Some fine-tuning of our methodology may also be required to isolate the most important differential cues to driver safety from the individual vehicle records.

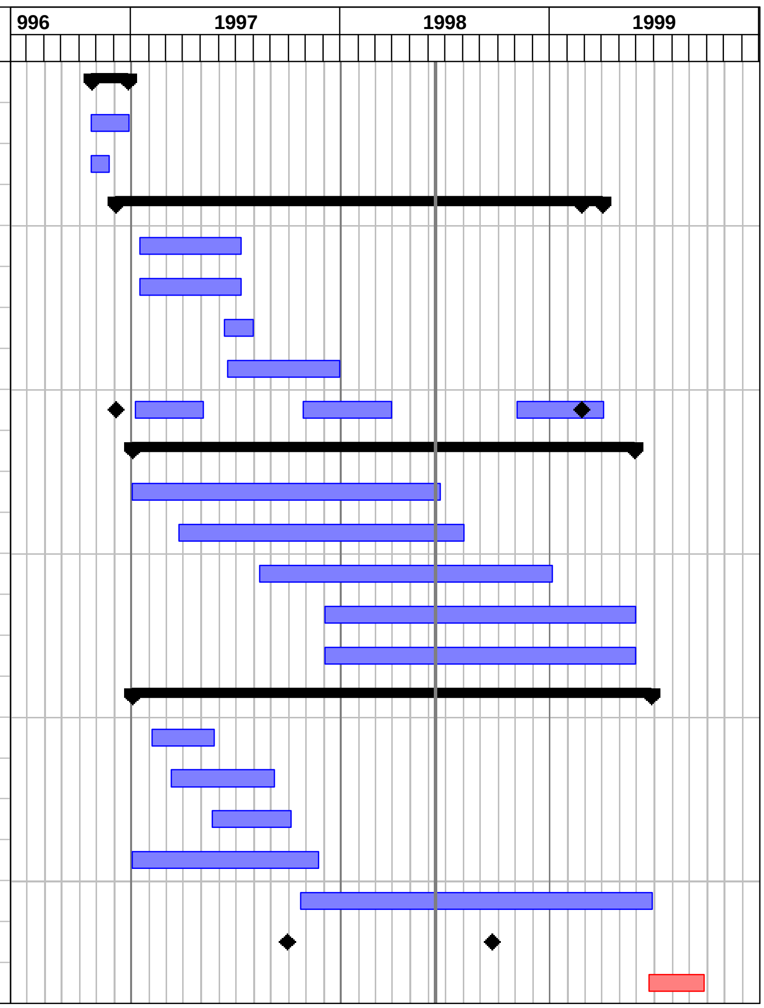
Several personnel changes in District 10 and unexpected highway-safety-related priorities related to El Nino rains have made progress slower than anticipated. The rainy weather delayed the start of trenching activities for power and communications to the site by several months. In perspective, however, we observe that relative to similar field operational tests in California (two of which the evaluators are involved in), the present evaluation project is actually progressing at a better than average rate. We feel that there is potential to learn much, and we are aware of several jurisdictions nation-wide interested in the assessment results of this pioneering system.

The third year of the evaluation, in which most data collection activities would occur, will not be funded due to budget limitations at PATH in fiscal 1998-99 compounded by concern about the slow progress in implementing the evaluation. During the second evaluation year, as an adaptation to the prospect that that little or no field data will be collected during the remaining period of work, the emphasis shifted to ensuring that adequate mechanisms would be in place to support the ongoing evaluation of this system by Caltrans personnel after we are no longer involved.

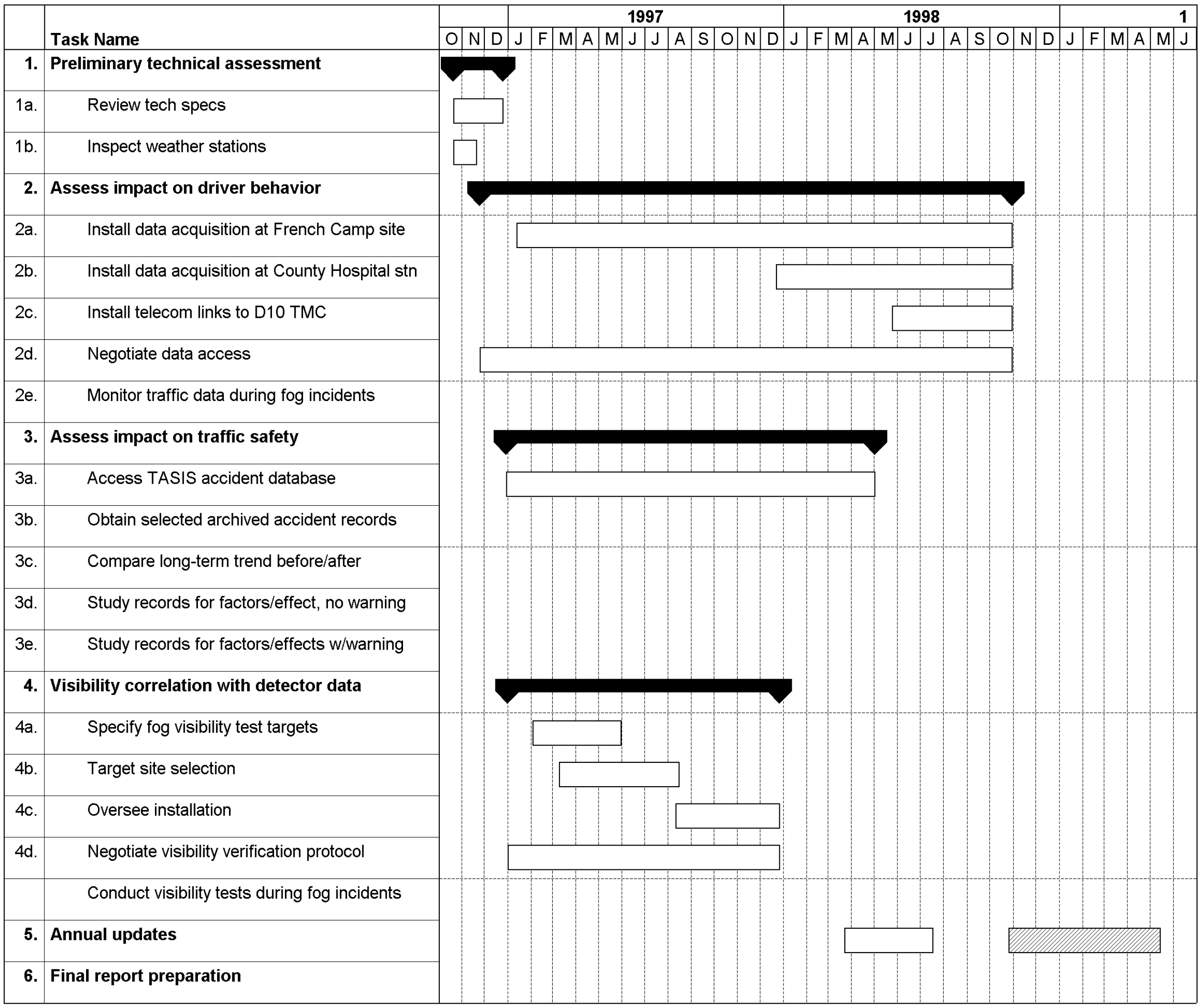
Schedule

The following schedule represented the *originally proposed* evaluation plan, covering a three year period. First year funding has supported the evaluation period from October 1996 through June 1998. Due to delays in implementation of required field instrumentation and cancellation of third year evaluation funding, the schedule has been forward indefinitely, pending approval by PATH/Caltrans to proceed with complete evaluation.

	Task Name
1.	**Preliminary technical assessment**
1a.	Review tech specs
1b.	Inspect weather stations
2.	**Assess impact on driver behavior**
2a.	Install data acquisition at French Camp site
2b.	Install data acquisition at County Hospital stn
2c.	Install telecom links to D10 TMC
2d.	Negotiate data access
2e.	Monitor traffic data during fog incidents
3.	**Assess impact on traffic safety**
3a.	Access TASIS accident database
3b.	Obtain selected archived accident records
3c.	Compare long-term trend before/after
3d.	Study records for factors/effect, no warning
3e.	Study records for factors/effects w/warning
4.	**Visibility correlation with detector data**
4a.	Specify fog visibility test targets
4b.	Target site selection
4c.	Oversee installation
4d.	Negotiate visibility verification protocol
	Conduct visibility tests during fog incidents
5.	**Annual updates**
6.	**Final report preparation**



The following schedule represents the *actual* periods of performance for each originally proposed task. Note that the tasks actually performed were significantly different than those originally proposed, since the original proposal assumed that all system implementation and raw data collection would be performed by Caltrans.



Chronology of Key Events

The following chronology of key events was assembled from the text of quarterly reports submitted to PATH.

July 1996:

The key elements of the system under study and the proposed metrics of evaluation were discussed at a pre-contract meeting in Stockton, July 18, 1996.

October 1996:

First year evaluation contract let by PATH to Cal Poly Transportation Electronics Laboratory.
November 1996:

An evaluation kickoff meeting was held in November 1996 at Caltrans District 10 (D10) Office in Stockton. A preliminary test plan was negotiated with D10 personnel. Fog warning system would be officially activated later this month. A field technical inspection of one detector site was performed after the meeting. All equipment was found to be operational but not yet calibrated. Loop detectors at that site reported traffic speeds that seemed unrealistic. It was preliminarily agreed that the evaluation would consist of four main components, although the implementation of each remained under negotiation with D10:

Archival study - Traffic incidents in the ten years prior to the system implementation will be compared with those occurring during the first three years of operation. TASAS database and individual accident reports in D10 files will serve as basis.

Efficacy – (Driver behavior study). North-most CMS near County Hospital Road OC will be shut down, leaving full monitoring capability at this site, but no driver warning, until following CMS approximately 1 mile later. Effects of warning on traffic flow will be determined by comparison of per lane speed, volume, occupancy and headway at each site (with and without CMS warning).

Real time systems - We will install on D10 TMC PC's remote access software and hardware that will allow us to monitor in real time the instrumentation outputs from each of the nine Qualimetrics stations, the 36 loop detector sites, and 9 CMS sites. Technical details currently under negotiation.

Visibility verification - D10 personnel will install standardized visibility targets at three of the nine fog sensor sites. During dense fog events, D10 personnel will follow specified protocol to visually verify fog condition reported by field detectors. Active period of first year study will commence January 6, the start of the winter academic quarter.

February 1997:

After much continued dialog, in late January / early February our tentative agreement from the kickoff meeting to turn off the north-most CMS for comparison purposes was rejected by Caltrans due to safety considerations. We responded with the best alternative plan we could negotiate: add instrumentation at some site immediately prior to entry into the study area. Several possible locations for such instrumentation were surveyed from detailed maps of the study area and discussions with D10 personnel. The French Camp Slough count site on south-bound I-5 was suggested as a possible candidate site, since it already had duplex loops in the pavement, and an empty 334 cabinet on the median, although it lacked power or communications. Two weeks ago we heard that they cannot connect it to the telecommunications grid, so periodic manual retrieval of data would have to be scheduled. However, they could give us individual vehicle records as we requested, using a battery-powered portable (Phoenix) data recorder. Frank asked evaluators to re-articulate the agreement and our data needs in view of the changes. A letter to this effect was sent to all participants in late February. This went through several revisions with input from Frank, Dave McPeak, Jim Eckelstone, and Joel Retanan. The final form was distributed early March.

We obtained accident event numbers over the past five years in this area from TASAS, directly from Sacramento. We were initially given permission to access hardcopy accident files, but most recently learned that legal department approval would be needed on a record-by-record basis, so it may be more difficult to assess the degree to which visibility may have been a causative factor. Frank is working on this issue. Dave McPeak is still attempting to resolve a liability issue associated with us having direct access to their control PC's. We have the software and modem ready to go, but cannot proceed until this matter is resolved. By using Laplink 7.5, we avoid having to touch the weather station (Qualimetrics) PC, so once we have password access, we should be able to start watching this system work. Joel's direct involvement is needed for the loop/CMS monitoring PC, since the software and binary data storage is all custom programmed by him. We have approval to have PC-Anywhere 7.5 installed on it, but Joel will have to do this and he must implement some access safeguards to prevent us from interfering with the system operation. He will also install the modem that we will give him. Frank committed a phone line for this modem access, but it's not in yet. They are retaining all archival data from both systems at our request.

March 1997:

We received by email from Jim Ecklestone preliminary data acquired by a battery-operated portable Phoenix counter installed in the empty 334 cabinet at French Camp Slough. The data was taken during clear-weather. This sample provided a basis for decisions on format requirements. D10 has no archiving procedure or backup hardware. Fortunately, they still had a few months more of hard disk space before this becomes an issue. We offered to purchase tape backup or zip drive systems for them if necessary, but they will need to have their software people in the loop to integrate these features with the existing proprietary software on each system. This data was in "speed bucket" form, which is of some but not great value to us, since the bucket sizes are too large to access driver response to the activation of a CMS. Still, it's better than nothing, and were able to draw some conclusions from this in our after-the-fact analysis. Our review of this data led to the conclusion that we really had to have individual vehicle records in order to adequately assess possible changes in driver behavior for our evaluation purposes.

We designed and sent to the District 10 sign-shop our visibility test sign specifications (we borrowed and modified the actual Caltrans D6 sign-shop work order for their visibility test signage). Dave McPeak of District 10 said they have been informally verifying (visually) the Qualimetrics fog detector readings, but not keeping formal records. They are not using any type of standardized visibility target - just verbal confirmation, mostly subjective. I asked Dave in December to start keeping some type of records of visibility reports. Frank reported that there has been very little (almost no) fog this season. So he feels that without any significant fog events, the slowness of the set up wouldn't have mattered anyway. I believe that his plan is to have things set up by *next* fog season. We continued to push for getting things on-line ASAP, since some fog incidents could occur out of season. This should be doable, and we need to keep the priority on top.

Noted in quarter report to PATH that one important "institutional issue" following from this experience is that provision for an evaluation must be made as part of the original project rather than after-the-fact. Provisions for experimental verification of efficacy should be built into the project plan., e.g., an upstream reference data collection site, and data collection in a form that is adequate to verify driver reaction and system effectiveness for safety. The cost of accommodating the evaluation should be factored into the original project rather than being left to the district's operation budget at a later time. Another observation is the need for involvement of people with definitive decision-making authority in the evaluation meetings. Thus, for example, our proposal to turn off the north-most CMS could have been vetoed at the time it was suggested, rather than two months later when they go to implement the plan. Also, when we propose direct access to the PC's or access to accident records, legal issues associated with these could be identified and resolved early and the workplan modified accordingly. What this means for us this fog season (Winter 1997):

1. Driver reaction data will probably not be available until next fog season.

2. Direct observation of system operation will be online sooner, as soon as the legal question is resolved by D10.

3. Long-term impact on accident rate/severity should not be a problem, assuming we can eventually get to the accident record files.

4. Technical (installation) evaluation not effected.

5. Visibility verification - informal this season. Standardized next season when the signs are in.

We prepared to extend the period of work on a continuous basis until next fog season, to continue active participation with D10 in the setup of the field instrumentation, PC software and hardware for remote access and archive backup, and resolution of any remaining legal and liability issues. Anticipating this, we were frugal with budget expenditures until the 1997-98 funding cycle. One more trip needed for computer setup, access to accident records, and general logistics.

June 1997:

Continuing work with D10 personnel on getting all telemetry and evaluation-related monitoring provisions in place prior to next fog season. Modem and PC-Anywhere software were installed in D10 TMC computer, but no phone line available yet. Expect to have monitoring access by mid-July. Fog visibility targets not yet in place; expected by late summer. Legal access permission to accident records still unresolved. We were provided an “Information Request” form (included in Appendix) for application to obtain accident reports on an individual basis. We have obtained TASAS (Table B) accident statistics form Sacramento, and are reducing the data base records by converting to Excel format. We hope to identify from these records only a small number of incidents for which we will request the complete accident reports. Meeting held June 19 at D10 with Frank Weishaar, Jim Eckelstone, Joel Retanan, and Jose Huerta. Later met with D10 accident records department to review access procedures. Progress made, but some concerns remain.

Concluded that we need fog monitoring at the French Camp Slough site in order to be able to definitively report driver behavior effects due to CMS warning of fog conditions. Also need telemetry from this site. Site is unpowered with no communications. We installed Phoenix portable data recorders at this site and will need a similar unit at the County Hospital weather station / loop detector site for comparison. French Camp is currently powered by small solar collector charging the battery in the Phoenix unit. We're working this problem and expect to make substantial progress over the summer. We may need PATH support if we have to go to Caltrans Ops to aid D10 in getting funding for the needed telemetry and fog monitoring setup at remote site.

September 1997:

We continued to work with D10 personnel on setting up some form of reference remote instrumentation site immediately outside the study area. The French Camp Slough count station site is apparently the only viable candidate, based upon our prior survey and inspection of the area. D10 was willing to place a solar powered Phoenix count recorder at this site, but, during this period, we did not arrive at a workable solution for remotely monitoring fog at this site, or for getting data back to the TMC or evaluation team. It remains critical that these technical and financial obstacles be overcome and that we have something in place prior to the next fog season, which starts approximately in November. Modem and PC-Anywhere software is still installed in D10 TMC computer, but no phone line available yet.

During the summer, Frank Weishaar was replaced as manager of traffic operations by Laurie Jurgens. Unfortunately, Ms. Jurgens was not appraised of the evaluation project, and is unable to commit staff resources to support it. Discussions remain in progress. We obtain general-public access permission to archived accident record data, requiring filling out a form for each incident, with adequate justification, and wait for approval.

A meeting was held between Macaluso, Tam, and D10 personnel during September 1997 in which D10 agreed to obtain a contractor quote for running power and communications to the French Camp Slough site. Caltrans New Tech offered to support this installation. However, in follow-up phone conversations with D10, no progress on obtaining this quote had been made. It was apparently unclear whose responsibility it was to specify and contract for this work. D10 is very reluctant to support running a power and communication conduit to the site, primary due to the concomitant demands on staff time. As an alternative, they decided that only solar power would be acceptable at the site. At their request, we prepared an analysis and cost quote for an adequate installation for powering a Qualimetrics fog detector, Q-Net interface, and loop counter instrumentation at the site. We obtained a firm quote from Sunnelco, a solar contractor, for approximately $39,000 to power the site, which was cost-prohibitive. Discussions continued.

We obtained a second set of TASAS (Table B) accident statistics form Sacramento, and are continuing to reduce the data base records by converting to Excel format.

October 1997:

Meeting at PATH early October in conjunction with the PATH annual meeting, in which the situation in D10 was discussed. Possible resolution reached, with additional funding to Caltrans D10, possibly through Cal Poly. Negotiations continue between Caltrans New Tech and D10.

December 1997:

Continued progress on preparation of additional required monitoring station at French Camp Slough, to provide reference point out of study area. Caltrans New Technology and District 10 agree to provide funds for purchase of fog detection and communications equipment, and for providing power and communications to the site. Met with Caltrans staff and Qualimetrics at D10 in October to finalize technical plans and scheduling. Successfully accessed Qualimetrics weather station monitoring computer in D10 TMC. Installed software and modem in TMC, but waiting for dedicated phone link into TMC for access to D10 loop monitoring computer. Weekly meetings with Caltrans staff and contractors via conference call. Continued work on historical effects via study of archived accident records.

We report to PATH and Caltrans that we were approximately one year behind original schedule, due to lack of instrumentation at out-of-study-area site (French Camp Slough) and lack of CCTV system in study area that would have provided remote fog detection capability. But major institutional obstacles have been overcome, and we hoped to have monitoring capability in place before end of fog season, in March 1998. This date depended upon rate of progress of contractors.

January 1998:

No-cost extension to PATH evaluation contract, through June 1998.

Jim Ecklestone transferred to another position. New technical designated technical contact is Garry Smith.

Continued coordination of the construction, equipment installation and configuration work at French Camp Slough in Stockton. Continued analysis of archival accident data to establish safety impact over long term. Funds remaining from Year 1 will be expended prior to drawing upon pending Year 2 funds. Due to delays in processing no-cost extension, a stop-work order was issued on December 31, 1997 by the Cal Poly Foundation, which remained in effect until January 25. Evaluation team lost key research assistant (Brian Pevear), partially due to lack of funding during this period.

Continued but slow progress on preparation of additional required monitoring station at French Camp Slough, to provide reference point out of study area. Although unanticipated in our role as evaluators, we are performing the function of site project manager and system integrator. The Qualimetrics system hardware is ready to set up, awaiting completion and powering of site. Weekly meetings with Caltrans staff and contractors via conference call. Continued work on archived accident records. Work started on year one project report.

March 1998:

Reported in quarter report that evaluation was over one year behind original schedule, due to lack of instrumentation at out-of-study-area site (French Camp Slough) and lack of CCTV system in study area that would have provided remote fog detection capability. Field instrumentation for system effectiveness evaluation will not be in place before end of fog season. This date has been delayed by rain constraints on electrical construction contractor, St. Frances Electric.

Qualimetrics instrumentation completed, but can't be delivered until site prep work and power are completed. Continued coordination of the construction, equipment installation and configuration work at French Camp Slough in Stockton. Continued analysis of archival accident data to establish safety impact over long term.

April 1998:

Field construction started by St. Frances Electric, but anticipated date of completion extended to June 1998, due to continued rains. Competing priorities in district and schedule limitations at Qualimetrics continue to prevent getting D10 and Qualimetrics technical personnel together to resolve communications interface issues. Following many phone discussions and email correspondence with D10 and Qualimetrics technical personnel, issue remains unresolved, but hopefully, no insurmountable problems will be encountered.

May 1998:

Gary Smith reassigned. New designated technical contact is Clint Gregory. Following inquiry with Laurie, received email update from Clint on progress at French Camp site. Qualimetrics equipment now physically installed at site, but not yet powered. Communications and interface issues not yet addressed.

Work on first year report accelerated, and scope of report expanded, in preparation for contract closure and possible end of project on June 30, 1998.

June 14, 1998

Presentation on evaluation work completed to date in District 10. Request to attempt to secure additional personnel (0.5 PY) for District 10 to support evaluation-related workload. Tentative agreement for additional 0.5 PY reached, pending Caltrans administrative review and approval. Issues related to construction delays discussed and evaluation tasks rescheduled accordingly.

June 15, 1998

First year report completed; delivered to PATH and Caltrans.

November 30, 1998

Meeting in District 10 to update progress and resolve administrative issues. Issue of supplemental support for District 10 remains open.   District reports that power and communications to French Camp site are now installed, but not yet activated due to delay in completion of related northbound CMS from which communications and power are routed.

December 1998

Budget limitations prevent supplemental personnel support for District 10. Instrumentation in field removed. Evaluation activities ended but option left open to reactivate via anticipated 1999 safety-related funding.

February 1999

Upon request by Caltrans, evaluation team submits proposal to perform complete independent evaluation and set up infrastructure for improved public awareness of advanced safety features of the CAWS in D10.

May 1999

Second year report submitted. Decision on funding of complete evaluation proposal pending.

Project Results and Accomplishments

Results and accomplishments from work completed to date in each area of study are reported:

1. Technical assessment.

We performed a cursory assessment of conformity to nominal specifications for the installation of electronic components at one sample instrumented site. We examined the operator's manual for the Qualimetrics system, and discussed the operation of the loop detector data display system with the author of the program, Joel Retanan of Caltrans operations in Sacramento.

Our objectives were to verify and document the systems under test. Only the installation of the components was assessed. Sensor accuracy and calibration could not be assessed. Components included in this assessment were the Qualimetrics forward scatter detector, Q-Net Data Acquisition System, day/night detector, anemometer, wind direction sensor, hygrometer, rain gauge, barometer, power supply, relay/telemetry system, network controller, and central processor hardware. We also examined the system user interfaces in the TMC for the weather station data display, the loop detector data display, and the CMS control and decision program. All display systems appeared to be fully functional. The graphical user interfaces provided by the meteorological system and the traffic monitoring system appeared to be intuitive and well-designed. The fact that one system ran under Windows 95 and the other two under DOS did not appear to be problem with respect to present needs, but could potentially limit future enhancements.

Based upon field inspections we concluded that the meteorological system was engineered and installed to very high quality standards, and appeared to be fully functional at all except one site (not yet brought on line). We observed that traffic counts reported by the Type 170 controller at the inspected site seemed to run consistently higher than expected, suggesting that the actual loop separation had not yet been calibrated for the speed detection algorithm.

2. Operational accuracy and reliability.

Continuous data will be collected from the output of the Q-Metric forward diffusion detectors at each of the instrumented roadside sites. Visibility reference targets will be placed nearby three (TBD) of the sites, within the field of view of a networked CCTV camera. These video images, displayed and monitored remotely, will be used to manually access visibility at the test locations using the visibility targets. If CCTV cameras are unavailable for any reason, on-site visibility observations will be recorded by local law-enforcement personnel during periods of reduced visibility. Observations will be recorded and compared to correlate visibility readings generated by the sensors with manual observations of visibility as perceived by drivers. District 10 technical staff will maintain log books and service records on the Q-Metric detectors, weather instruments and telemetry at the field sites, and the driver warning changeable message signs. The evaluators will analyze the records to determine obvious or possible areas of unreliability or serviceability problems, and suggest remedial actions if appropriate.

3. Influence on driver behavior during fog conditions.

Progress has been made toward our goal of obtaining representative traffic volume, speed, density, and headway distributions from AM peak period study area traffic and try to determine if, in the presence of reduced visibility or approaching traffic congestion, the activation of the warning system is correlated with a systematic change in these traffic parameters toward what could be interpreted as safer operating conditions. Safer conditions would generally be inferred from reduced speed and increased vehicle spacings and headways.

Work is believed to be approximately 50% complete on the installation and connection of visibility detection and traffic monitoring instrumentation at the French Camp Slough and County Hospital monitoring sites (before and after the north-most CMS on south-bound I-5). In late 1997, funding was provided by Caltrans New Technology to the district, allowing them to subcontract to Baumgartner Construction and St. Frances Electric, both of Sacramento, for the instrumentation and powering of the French Camp Slough site. Costs were minimized by supplementing an existing construction contract for the installation of a new CMS on the north-bound lanes of I-5, located only0.3 miles south of French Camp Slough. The district also purchased from Qualimetrics a visibility sensor and Q-Net interface for this site. The Qualimetrics equipment quote and technical description is included in the Appendix. Rains continue to delay the start of trenching work to route power and communications to the site. Arrangements were made with the local telephone service provider for one additional leased line connection for communications between the TMC and French Camp Slough.

Once installed and fully operational, the data acquisition systems at each of the two comparison sites were to record as individual vehicle records the vehicle speed and time of arrival. From these can be calculated off-line the average speed and speed variance, vehicle separation and/or headway (average and variance) during clear conditions (baseline) and during periods of reduced visibility, before and after drivers have viewed roadside changeable message sign warnings. Data will be reduced and compared to assess the degree to which driver behavior is influenced by the automated fog detection and warning system. Some baseline (non-fog) data has already been acquired at the French Camp Slough site using a portable traffic counter/data recorder. This has allowed us to refine our data requirements and reduction algorithms. No fog-related data has been recorded to date. Development and refinement of algorithms for characterization of driver behavior remains in progress, discussed below. No comparative conclusions have been possible to date.

We have studied various mechanisms to infer driver behavior characteristics from the loop detector-derived data. We have attempted to utilize every possible data source to assess the beneficial effects of the warning system. Comparisons of interest have included:

- Differences in the traffic parameters between periods of clear weather and fog, but without the influence of the fog warning system, other environmental and traffic factors being equal to the extent possible.[1]

- Differences in traffic parameters in the presence of fog, with and without the influence of the warning system, other factors being equal to the extent possible.

In both cases, comparisons of between-group variations would be contrasted to within-group variations, the latter being the differences in the traffic parameters across different observation time periods within each of the three conditions being contrasted. For each condition, we will develop traffic parameters for a number of 15 minute time periods for the AM peak period, within the same days and for different days.

In order to control for the presence and absence of the fog warning system, it is important to obtain both the fog-related and the non-fog-related traffic observations from locations which are close together. For an ideal experiment, it would be best to have Caltrans not activate the fog warning system for all or part of some foggy AM peak periods, so that the effect of having and not having the system could be compared at exactly the same locations. However, this ideal experiment could put travelers at risk, and is therefore not feasible.

As an alternative to the ideal experiment, Caltrans agreed to install supplemental traffic surveillance equipment just upstream of the location of the fog warning system, where environmental and traffic conditions should be very similar to the nearby section protected by the fog warning system. Installation of this equipment is now underway. Therefore the collection and processing of “production” traffic data with which to carry out the comparisons described above must be delayed until the necessary field instrumentation becomes available.

In parallel to the installation of the supplemental traffic surveillance equipment, software decisions are being made which will determine how disaggregate will be the traffic data to be utilized in our analysis. In an ideal experiment,

[1] The principal other factors to be controlled for are total traffic volume, night or daytime condition, and wetness of pavement.

the traffic data set would separately measure traffic parameters for individual vehicles passing over the loops. With entirely disaggregate data, actual measured distributions of speeds, headways, and other parameters could be directly developed for comparison.

Unfortunately, collecting disaggregate, vehicle-by-vehicle data results in huge data sets and, from information received in our conversations with D10 personnel last November, may turn out to be beyond the capability of the available software and/or the equipment installed in the field. If so, we will need to work with comparatively aggregate field data, typical of loop data obtained from Caltrans traffic management systems throughout the state. Typically, these surveillance systems report, at best, 30-second averaged values of the measured traffic parameters.

While waiting for a final answer on whether we will receive disaggregate individual vehicle data or averaged data for 30-second periods or for other periods, we have begun working to develop a procedure for making the best use of averaged data, if that turns out to be necessary. The object of the data analysis would be the same in either case, to develop and compare distributions of the various traffic measurements. In the event we need to work with averaged data, we will need a procedure for estimating the underlying distributions from the available averages. Our current work is aimed at seeing if an acceptable estimation procedure of this type can be developed.

The estimation procedure which we are trying to develop will take advantage of certain statistical regularities which are generally accepted to exist in traffic data. For example, traffic counts within fairly short time periods may be regarded as a random variable which is Poisson distributed. This leads to other well-behaved statistical properties for other parameters, such as the headway distribution. The question is whether or not these assumed regularities can be used to reasonably estimate the needed underlying data distributions for 15 minute periods using the available short period averages.

We have obtained some sample data from D10 traffic surveillance equipment at another location in the study area, and we will use these sample data to develop and test the distribution estimation procedure over the next few months. The timing of this work is not especially critical, since the production data collection cannot be performed until the field installation of traffic surveillance equipment, which is now underway, has been completed. It may turn out that disaggregate vehicle-by-vehicle traffic data can actually be obtained, in which case the distribution estimation procedure using averaged data will not actually be needed.

4. Long-term impact on traffic safety.

Preliminary work was performed to assess the long-term impact of the CAWS on driver safety. Normally, a period of several years is required to amass a statistically significant body of incident data to support valid conclusions. We summarize here the work we have conducted to date, examining District 10 accident data from the study area prior to the activation of the fog warning system, in November 1996. This will eventually serve as baseline data for comparison with future data, permitting valid conclusions and possible recommendations.

The work began by contacting Jesse Bhulllar of Caltrans headquarters staff (jebhulla@trmx3.dot.ca.gov) to request a download of TASAS accident records. We received a text file containing all coded accidents for the period 01-01-93 through 12-31-96 for the following two highway sections:

- San Joaquin County, Interstate 5, postmiles R12.620 through R22.510
- San Joaquin County, State Route 120, postmiles R00.493 through T06.870

These two sections run on I-5 from the junction of Rte. 205 to French Camp Road and on SR 120 from I-5 to Rte. 99. This coincides with the location of the fog warning system, and our study area.

The data set contains a total of 815 accidents, of which 135 occurred during the morning commute period (weekdays, from 5:00 am to 9:15 am). Of the 815 accidents, only 19 were coded as having occurred in the presence of fog. Of these 19 fog-related accidents, 10 occurred during the morning commute period. Of these, 8 occurred in the peak flow direction (toward the S.F. Bay Area).

In addition, of the 815 total accidents, 89 occurred in the presence of rain, but without fog. Of these rain-related accidents, 29 occurred during the morning commute period. It is thought that some insights may be gained by also examining the characteristics of the rain-related accidents, since visibility and ability to operate vehicles optimally is certainly affected by rain, although not in the same way as by fog.

The original detailed accident reports for the 10 AM peak period fog-related accidents were obtained from Caltrans and examined for additional details not present in the TASAS data system. It should be noted that all 10 of these AM peak period, fog-related accidents occurred prior to the activation of the D10 fog warning system.

Investigation of Written Accident Reports. In two of the eight fog-related, peak period, peak direction accidents, the investigating officer cited as the cause of the accidents the presence of "critical" 100-foot visibility fog along with excessive speed for these conditions. These two accidents occurred on I-5 within an hour of each other, with the second accident, a rear-ender two vehicles, occurring in the presence of the traffic backup produced by the first three-vehicle collision. The same CHP officer wrote both of these accident reports.

On another day, two accidents, the first involving four vehicles and the second involving five, occurred within a few minutes of each other on I-5 in the presence of 150-foot visibility fog conditions. One investigating officer (the same officer who wrote the two reports described previously) wrote that the vehicles were going 50-55 mph in foggy conditions. The cited accident factors were "following too close" and an "unsafe lane change" when slow traffic ahead was unexpectedly encountered.

Another 5-vehicle accident occurred on westbound SR 120 in the presence of 150-foot visibility fog. Vehicles were traveling 30-40 mph when they encountered slow moving traffic and couldn't stop on time. The officer concluded that the accident cause was unsafe speed for conditions.

Another accident on westbound SR 120 was a three-vehicle rear-end collision in the presence of reported 500-foot visibility fog. This accident was determined by the CHP investigator to have been caused by unsafe speed for conditions. The driver determined to be at fault was going 55 mph and the driver was looking to the side and didn't realize that traffic ahead was stopping. The at-fault driver said in her statement that "fog was getting bad."

The remaining two fog-related, peak period, peak direction accidents, which occurred on I-5 southbound in the presence of 800-foot and 1000-foot visibility fog conditions, both were caused by drivers changing lanes without seeing other vehicles located in their "blind spots." Fog was apparently not a factor in either of these accidents.

Thus, of the eight accidents coded in the data set as *fog-related*, *peak period*, and *peak direction*, it appears that only six were attributable to reduced atmospheric visibility. These six accidents might have been prevented if drivers had been advised to reduce speed and had heeded that advice.

The remaining two of the ten fog-related, AM peak period accidents for which accident reports were obtained occurred on I-5 in the northbound (off-peak travel) direction. Visibility was characterized in one case as 1000 feet and in the other as 3000 feet. Both accidents were caused by reckless driving where the presence of fog was most likely not of significance. One of these accidents appeared to be a case of "road rage."

Aggregate Comparisons Based on the Full TASAS Data Set.. Obviously, the small number of fog-related accidents in the data set makes rigorous statistical comparisons impossible. However, even though no statistically solid inferences can be drawn, some insights regarding possible aggregate differences between fog-related, rain-related, and non-fog/rain-related accidents were developed using these data.

The review of the accident data set suggests, but does not prove, that there do exist systematic differences between fog-related and non-fog-related accidents. This is not surprising, but it is helpful to see that preconceptions regarding the likely nature of fog-related accidents in heavy traffic appear to be supported by the data. By and large, the findings of this aggregate statistical analysis support the conclusion reached in the analysis of detailed accident reports, that peak period, fog-related accidents are special and might be mitigated by the fog warning system if drivers actually heed the warnings which are posted.

The following table shows the breakdown of accident types for the major categories of interest. It shows that the most prevalent accident type during clear/cloudy weather or during rain, in both the commute and non-commute periods, is the “Hit object” accident. This is also true of non-commute fog-related accidents. In contrast, rear-end accidents account for a full half of the 10 fog-related AM commute period accidents.

Note that in the table, “Commute” means the weekday AM peak period only. “Regular” encompasses all other periods, including the weekday PM peak period and weekends.

		Weather			
Period	Type of Collision	Fog	Rain	Clear/Cloudy	Grand Total
Commute	Broadside	1		6	7
	Head-on			1	1
	Hit Object	1	11	32	44
	Other		1	6	7
	Overturn		2	5	7
	Rear-End	5	6	19	30
	Sideswipe	3	7	29	39
Commute Total		10	27	98	135
Regular	Auto-Pedestrian			2	2
	Broadside	2		24	26
	Head-on		1	3	4
	Hit Object	3	31	214	248
	Other	1	4	52	57
	Overturn	1	5	53	59
	Rear-End		9	139	148
	Sideswipe	2	12	122	136
Regular Total		9	62	609	680
Grand Total		19	89	707	815

The data base seems to show no systematic differences with respect to accident severity. As seen in the table following immediately below, there are generally about twice as many property damage only (PDO) accidents as fatal and injury (F & I) accidents in all weather and time period categories. The presence of fog and heavy AM peak traffic does not seem associated with systematically more severe or less severe accidents.

On the other hand, AM commute period accidents in the presence of fog appear to involve more vehicles per incident than is typical for accidents outside the AM peak, and when fog is not a consideration. The second table below shows the breakdown of accidents by numbers of vehicles involved. Although single and dual-vehicle accidents together dominate in most time periods and without fog, this is not the case for the AM commute period fog-related accident group. In this case, dual-vehicle accidents alone are the most common, and other multiple vehicle accidents appear relatively much more often than in all the other tabulation categories.

		Weather			
Period	Severity	Fog	Rain	Clear/Cloudy	Grand Total
Commute	F			1	1
	I	4	9	35	48
	PDO	6	18	62	86
Commute Total		10	27	98	135
Regular	F	1		11	12
	I	4	21	219	244
	PDO	4	41	379	424
Regular Total		9	62	609	680
Grand Total		19	89	707	815

		Weather			
Period	# Vehicles	Fog	Rain	Clear/Cloudy	Grand Total
Commute	1		10	31	41
	2	4	15	56	75
	3	2		8	10
	4	2	1	1	4
	5	2		2	4
	6		1		1
Commute Total		10	27	98	135
Regular	1	4	36	257	297
	2	5	23	302	330
	3		3	38	41
	4			10	10
	5			2	2
Regular Total		9	62	609	680
Grand Total		19	89	707	815

That accidents in the presence of fog may involve somewhat different driver behavior. This is illustrated in the following table, which tabulates the movements prior to the collisions by the first three vehicles involved in a given incident. (The totals represent vehicles, not accidents, and therefore are greater than the totals of the previous tables. Note that, for convenience of analysis, up to three vehicles per accident are counted, not all vehicles.) These data indicate that, not surprisingly, fog-related accidents in the heavy volume AM commute period involve a disproportionate number of vehicles which were slowing or stopping just prior to the accidents. None of the other periods and weather conditions shows this phenomenon.

		Weather			
Period	Movement Before Collision	Fog	Rain	Clear/Cloudy	Grand Total
Commute	Change Lanes	4	5	30	39
	Going Straight	9	28	86	123
	Not stated	0	0	0	0
	Other	0	2	19	21
	Ran Off Road	0	6	22	28
	Slowing, Stopping	11	1	9	21
	Stopped	2	3	12	17
	Unsafe Turn	0	1	2	3
Commute Total		26	46	180	252
Regular	Change Lanes	2	9	130	141
	Going Straight	7	51	498	556
	Not stated	0	1	10	11
	Other	2	4	94	100
	Ran Off Road	4	23	181	208
	Slowing, Stopping	0	0	65	65
	Stopped	0	4	59	63
	Unsafe Turn	0	1	14	15
Regular Total		15	93	1051	1159
Grand Total		41	139	1231	1411

A number of other comparisons were also made, considering the characteristics Party Type and Primary Collision Factor. Also, cross-tabs utilizing pairs of variables were created. None of these additional tabulations revealed any interesting systematic differences between fog-related and non-fog-related accidents, so the details are not presented here.

The next step of this work will be to obtain TASAS data and selected accident reports for 1997 and winter 1998, for the period after activation of the fog warning system, and analyze these data as above. It is expected, of course, that fog-related accidents would again be rare events during the period. However, replicating the above analysis for the post-warning system period could well reveal that the previously observed differences between fog-related and non-fog-related accidents may have diminished. This would suggest that the fog warning system is having its intended effect. Due to the time lag involved in data collection and processing, the TASAS data for the period January 1, 1997 through March 31, 1998 should be available by early summer.

Tasks Remaining

Based upon lessons learned during the course of the evaluation project and recent discussions with Caltrans personnel, the following remaining tasks were identified for the *complete* evaluation of the CAWS in District 10. Some tasks may be considered optional but advisable, such as Tasks 5 and 11. The completion of these tasks has been addressed in a currently pending proposal to the Caltrans Office of Transportation Safety.

1. Setup of data collection, communications and processing equipment. Initial work must be devoted to developing and implementing appropriate mechanisms for fully automated collection of data at two field sites located on Southbound Interstate 5, at Caltrans-designated sites French Camp Slough and County Hospital. The objective of this preliminary effort will be to have fully autonomous data collection in operation prior to the 1999-2000 fog season, which traditionally extends from October through March.

Several technical alternatives have been identified for achieving this objective. Final details and decisions will be made in cooperation with Caltrans technical personnel, especially with the system designers. The proposed workplan herein follows the mechanization suggested by Caltrans District and technical personnel in meetings conducted during September-October 1999. A separate data collection and communications server will be set up in the District 10 Traffic Management Center for the exclusive purpose of comminuting with and acquiring data from the three existing systems that operationally comprise the CAWS. These systems are designated by Caltrans as the Signview Computer, the Qualimetrics/Caltrans Meteorological System, and the Traffic Monitoring Computer. The server will also provide archiving and preliminary data reduction functions, and provide a mechanism for remote FTP download of data to the evaluation team facilities for processing.

2. Completion of instrumentation, communications, and system integration at the French Camp Slough and County Hospital field sites. Subcontract work by Qualimetrics is required for completion of the French Camp installation, inclusion of this tenth site into the software running on the Meteorological System computer, and communications hardware and software modifications required to permit data access by the server computer.

3. Operation, maintenance and field service. To assure continuous and proper operation of all components installed by the evaluation team, the evaluation team will assume responsibility for the operation and maintenance of all field instrumentation and the server and it's communications interfaces in the District 10 Traffic Management Center (TMC). For correction of network related problems, a service contract will be let to a local Stockton Internet Service Provider (ISP) in conjunction with Task 6, below.

4. Data collection, archiving, processing, and interpretation. The evaluation team will be responsible for collection, archiving, reduction, processing and interpretation of all data generated by the installed instruments, as well as data sets generated by the CAWS itself. A research assistant will be placed on site in the District 10 TMC to handle all manual data collection tasks and assist district personnel with system operation and maintenance. Caltrans technical cooperation will be required for interpretation of the system's several data encoding strategies and protocols. All data reduction, processing and interpretation will be performed by the evaluation team in San Luis Obispo.

5. Remote CCTV monitoring of visibility and traffic conditions. The evaluation team will install a remote CCTV camera and compressed video telecommunications system at one site, to be selected with approval of District 10. Pending Caltrans approval, site installation work will be performed by Javelin Electronics Traffic Management Systems Division. Within the field of view of this camera will be at least one weather monitoring station (preferably the County Hospital station), and a set of five visibility test targets at selected distances from the camera. The video feed from this camera will be accessible to the District TMC as well as the evaluators from their San Luis Obispo Laboratory. Since the video feed will be carried (securely) over the Internet, it will also be accessible, with password access, to any other Caltrans office or any authorized research institution. The visibility reference targets will be approximately the same as those deployed in the earlier 1973 "Operation Fogbound" study performed in District 10. If desired by Caltrans, the video feed may also be made accessible to the public via the District 10 / CAWS web site, to be implemented under Tasks 6 and 10.

6. Remote system access. The evaluation team will set up dedicated full-time internet connectivity in the District 10 TMC to facilitate remote access to the evaluation server for data access and remote control. This capability will also permit public access to a District 10 CAWS Web site, to be described in Task 10.

7. Accident data statistical analysis. The evaluation team will resume previous efforts to acquire and analyze long-term traffic accident data via the TASIS data base and District ten accident records. Archived statistics 1971-96 on vehicle accidents, including reported causal factors, traffic and atmospheric conditions, number of vehicles involved, severity and fatality rate, will be obtained (to the extent available) for the study area with the cooperation of Caltrans and the NHTSA. External influences, such as improvements in vehicle and highway technologies, changes in traffic patterns and volumes, or differences in weather patterns will be identified, and efforts will be made to study their possible influences upon the statistical conclusions.

The objectives of this task are not only to establish before-and-after statistical loss trends, but to better relate driver behavior to the measurable data obtained from field sensors (e.g., speed distribution and headway distribution). This also affords an opportunity to identify potentially correlated phenomena via Multivariate Analysis of Variance (MANOVA), which has been used previously in the 1991-94 evaluation of a similar Fog Warning system in the Netherlands.

8. Permanent automated data collection capability in D10. It is important to leave in place in the District an autonomous system for continued data collection, archiving and processing. This will facilitate the eventual generation of conclusions based upon long-term data and observations, for future analysis and study.

9. Review and assessment of operational issues. While no further study of operational issues is planned, the evaluators will observe the operation of the CAWS system over the evaluation period, and inspect maintenance and service records to identify any obvious or potential areas of unreliability or serviceability problems. In cooperation with Caltrans technical personnel, remedial actions may be suggested.

10. Final and interim reports. The evaluation team will produce a comprehensive final project report at the completion of the study, to include conclusions and recommendation based upon the collected data, subject to the review and guidance of Caltrans Operations and New Technology partners. Progress reports will be generated on a quarterly basis consistent with normal PATH requirements.

11. District 10 / CAWS Web site. The evaluation team will also assist Caltrans in making the public and transportation community aware of the CAWS by creating and maintaining an Internet Web site for the District, with hyperlinked information access for all aspects of the system, its performance and history. If technically feasible, a real-time mechanism for display on the Web site of immediate traffic, visibility and hazard information will be implemented. This may serve as a public aid for trip planning and routing, with some potential benefit in improved safety and reduced traffic congestion. One or more technical papers covering various aspects of the project evaluation should be produced including Caltrans and PATH input, for publication in one or more appropriate technical forums.

Bibliography – Published Information on Similar Highway Warning Systems

During preliminary evaluation work, a comprehensive search of published literature was performed, allowing us to learn as much as possible about similar evaluation efforts, both domestic and foreign. The following selected citations, including abstracts, describe all other automated fog warning systems for which conference, journal or book publications were available. The list is not comprehensive, but is representative. Cited foreign language papers were limited to only those with English abstracts of sufficient detail to provide useful information on a particular project. Publications are categorized by the location of the project, plus a general class for other technology-based papers of direct relevance. In addition to these resources, extensive information is available via the World Wide Web on individual products and traffic warning projects. Excerpts from selected references appear in the Appendix.

Projects in USA

Arkansas

Highway Accident Report: Multiple Vehicle Collision With Fire During Fog Near Milepost 118 On Interstate 40, Menifee, Arkansas, January 9, 1995 And Special Investigation Of Collision Warning Technology

Source: National Transportation Safety Board, 800 Independence Avenue, SW, Federal Office Building 10A, Washington, DC, 20594
Report Number: NTSB/HAR-95/03,;Notation 6530A 105p
Publication Year: 1995
Language: English
Abstract: On January 9, 1995, a multiple-vehicle rear-end collision occurred during localized fog on Interstate 40 near Menifee, Arkansas. The accident about 1:50 a.m. near milepost 118 eventually involved eight loaded truck tractor semitrailer combinations and one light-duty van. Four drivers and a co-driver were killed, one driver sustained a minor injury, and four drivers were uninjured. The safety issues discussed in this report include collision warning technology use during low visibility driving conditions, the emergency channel 9 override feature for citizens band radios, and the nonuniformity in State laws governing four-way emergency hazard flasher operation. As a result of its investigation, the Safety Board issued safety recommendations to the Secretary of Transportation; the National Highway Traffic Safety Administration; the Federal Communications Commission; the 50 States, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, and the Territories; the Telecommunications Industry Association; the Intelligent Transportation Society of America; and the American Association of Motor Vehicle Administrators.

California

“Changeable Message" Warning Signs In Dense Fog

Source: California Highway Patrol, P.O. Box 898, Analysis Section, Sacramento, CA, 95804
Via: National Safety Council, Safety Research Info Service, Intrm Report.
Publication Year: 1977
Language: English
Abstract: The California Highway patrol (CHP) and the Department of Transportation (Caltrans) cooperated in the Fog Sign Study to determine the usefulness of "changeable message" warning signs in dense fog. The study was conducted in Stockton Area on SR 99 south of Stockton and in Riverside Area on SR 91 near Corona. The time period for the study was December 1, 1976, through March 31, 1977. Five warning signs (48" x 48") with telescoping stand and strobe light were assigned to each Area. Two cloth changeable messages were used: "DENSE FOG AHEAD" and "WRECK AHEAD". These messages were attached to a basic sign by means of velcro fasterners and could be easily changed to meet operational needs. The signs were collapsible so they could fit in the trunk of the patrol car. When there was an accident in light to heavy fog, the CHP patrol unit put up the warning

sign with the message, "WRECK AHEAD". To prevent potential chain reaction accidents, the other warning sign with the message "DENSE FOG AHEAD" was put up whenever there was a fog bank ahead of 200 feet or less visibility. The intent of the study was to determine what effect the warning signs ("DENSE FOG AHEAD" and "WRECK AHEAD") hand on vehicle speed. Also, the practicality and the usefulness of the signs were to be determined through comments made by CHP Officers. Objective analysis could not be made because of lack of data. Speed surveys were not conducted, and only eight "Warning Sign Evaluation Forms" were completed. It is recommended that the usefulness and effectiveness of these fog signs be restudied during the 1977 fog season with improvements.

Changeable Message Warning Signs In Dense Fog: Interim Report December 1, 1976 - March 31, 1977

Source: California Highway Patrol, Sacramento, CA,
Supplemental notes: California Highway Patrol, analysis section other phys.
Publication Year: 1977
Language: English
Data Source: UC, Berkeley, Institute for Transportation Studies
Abstract: No abstract.

Detectors for Automatic Fog-warning Signs

Author: Juergens, W. R.
Source: California. Division of highways. Sacramento.
Final report sponsored by the California Dept. of Transportation.
Research report No. CA-dDOT-tr-1115-1-73-02.
Publication year: 1973
Language: English
Data source: UC, Berkeley, Institute for Transportation Studies
Abstract: no abstract provided.

<u>Florida</u>

Evaluation Of Motorist Warning Systems For Fog-Related Incidents In The Tampa Bay Area

Author: Pietrzyk, MC; Turner, PA; Geahr, SL; Apparaju, R
Source: Center for Urban Transportation Research, University of South Florida, 4202 East Fowler Avenue, Tampa, FL, 33620, and Florida Department of Transportation, 605 Suwannee Street, Tallahassee, FL, 32399-0450
Report Number: ESC-DOT-96/97-7007-TO
Publication Year: 1997
Language: English
Abstract: A four-month investigation was conducted to determine (1) the extent of unique and recurring patterns of fog and fog-related incidents in the Tampa Bay area (defined as Hillsborough and Pinellas counties) and (2) suitable countermeasures to detect and warn motorists of fog conditions. The results of this investigation are summarized as follows: The Tampa Bay area typically has about 22 "heavy fog" days annually when visibility is 1/4 mi (0.4 km) or less. Comparatively, the foggiest location in the U.S. is located at Cape Disappointment, Washington, with 106 heavy fog days per year. Fog tends to form on clear, cool nights when moist air accumulates just above the ground or water. Light winds mix this shallow air to form condensation, which dissipates as the sun rises. This condition generally tends to occur between December and February in the Tampa Bay area. However, fog prediction is difficult because of the variability in density, location, development and dissipation rates, and area of coverage at a given point in time. Only the typical "fog season" can be identified. Between 1987 and 1995, 829 fog-related crashes were reported in the Tampa Bay area and 6,323 statewide. This represents 0.30% and 0.32% of the total reported crashes in Tampa Bay and the state, respectively. Crash report sites have been scattered throughout the Tampa Bay area, and thus, historically, there have been no particular fog-prone crash locations. Over the last decade, Hillsborough County has had a fog crash rate somewhat above the state average, while Pinellas County's fog crash rate has been well below the state's average. Hillsborough County has never been

ranked higher than 16th, and Pinellas County has not ranked higher than 47th among all 67 Florida counties over this same period of time. Those drivers who are most likely to be involved in fog-related crashes in the Tampa Bay area are residents of the county where the crash occurs, driving passenger cars, age 20-29, driving during the a.m. commute hours and traveling on local and county roads in rural locations. About 12 states have been formally engaged in detection and warning system evaluation related to fog, and several have invested $2-$4 million for integrated visibility/weather and motorist warning systems. However, the benefits for deployment of such systems have not been documented. Even though a recurring theme in all fog crash evaluations conducted by the states and National Transportation Safety Board recommends the development of a driver awareness campaign (to assure driver behavior is uniform in times of limited visibility), only California has followed through in this endeavor. This report recommends and describes a focused driver awareness campaign as the most cost-effective measure to reduce fog-related crashes, since the Tampa Bay area exhibits no particular fog-prone or fog-crash-prone areas. This awareness campaign should share information related to the fog season, fog crash history, and driving tips in fog.

Georgia

Fog Detection and Warning System

Published on web site: www.dot.state.ga.us/homeoffs/fpmr.www/admin/research/fog.html
Source: Georgia Dept. of Transportation, Research and Development Division
Publication Year: 1999
Language: English
Abstract: One of Research and Development's most innovative contributions has been the installation of a Fog Detection Warning System on a heavily-traveled portion of Interstate 75 in South Georgia. The system, developed jointly by GDOT and the Georgia Tech Research Institute, could serve as a prototype for automated visibility monitoring programs in other states where fog, snow or dust can pose hazards for motorists. Using a network of 19 sensors, 5 sets of traffic speed monitoring loops, weather instruments and an on-site central computer, the system will continuously monitor visibility and control four variable message signs along a 12 mile section of highway in an area where dense fog is known to develop. When the system detects a visibility problem, it will automatically notify authorities by telephone and post information on the variable message signs. The signs, in turn, will warn drivers of the specific hazard, call
for reduced traffic speeds when appropriate, and provide detour information if necessary. Messages are changed automatically, by the system, or on-site by an official. A dial-up system provides law enforcement and highway officials with remote access to the information gathered by the system. Using computer terminals, these officials will be able to monitor visibility levels, traffic speeds, and weather conditions. The fog warning system uses commercially available optical fog sensors, each of which contains a light source and a receiver which are aligned at a slight angle to each other. Under good conditions, the beam of light produced by the source will miss the receiver; however, the presence of fog particles will scatter the beam and reflect light back into the receiver. The receiver then measures the amount of light it is receiving and calculates the extent of visibility impairment. The study phase of this project is expected to provide such basic information as how often fog occurs, how severe visibility problems can become, and how widespread the problems can be. The study also includes measured traffic speeds during various fog conditions and a comparison of the visibility sensor readings with human observations. This information will be used to design the operational system.

North Carolina

North Carolina Experimental Evaluation Project 170-3(5) Fog Detection and Warning Device

Author: Strong, MP
Source: North Carolina Department of Transportation, Planning and Research Branch,
P.O. Box 25201, Raleigh, NC, 27611
Final Report
Publication Year: 1985
Language: English
Bibliographic/Data Appendices: 1 App.

Abstract: The performance of the experimental fog detection and advisory speed warning system was observed during a ten year period of operation. During this period, limited problems were experienced with the power supply modules in the sign system, with the drive motor and roller mechanisms in the sign scrolls, and with integrated circuit logic systems within the sign units. The highway accident experience decreased when this fog detection and advisory speed warning system was converted to a dual remote control and direct control mode of operation.

Oregon

Variable Message Fog Hazard Warning Signs To Control Vehicle Operating Characteristics

Source: Oregon Department of Transportation, State Highway Division, Salem , OR,
97310
Sponsored by FHWA.
Publication Year: 1972
Language: English
Data Source: National Safety Council, Safety Research Info Serv
Abstract: This project is aimed at determining the effectiveness of variable message signs in controlling traffic on an Interstate highway during periods of hazardous driving conditions such as fog, vehicle accidents or congestion. The effectiveness of the signs is being measured quantitatively by use of accident records, vehicular speeds, and headways. Insufficient data preclude drawing quantitative conclusions; however, based on data available, interviews with the State Police, and visual observation of vehicular operations, it appears that the signs are effective in controlling traffic operations and thereby preventing accidents during periods of reduced visibility due to fog.

Fog Warning Sign System

Author: George, L.E.
Source: ITTE, California University, Berkeley, /Proc, 2nd Ann Symposium, pp 23-24
Publication Date: Dec. 1969
Language: English
Abstract: A six-mile section of interstate 5 in Oregon located in the Willamette River valley, was found to be extremely susceptible to radiation type fog forming conditions during certain periods of the year. The conditions which bring about radiation fog are discussed. in early 1968, an extremely vicious chain reaction accident precipitated a series of investigations and studies involving operating conditions on this portion of the freeway as well as possible corrective measures. The general accident pattern in six years preceding 1966, at which time a warning sign system was installed, consisted of a total of 13 accidents involving 129 vehicles. Seven fatalities and 73 injuries were sustained. Orange, diamond-shape warning signs with battery-operated flashing lights fixed to the top of the post were installed in 1966. These signs were manually operated by state patrol men. Since manual sign activation was too slow, the use was obtained of a remote telemeter control for six signs from the Albany office of the state police. Twenty-four hour radio contact between police mobile units on the freeway and the Albany office is used as an early warning system on which decisions are based to activate the signs if there is indications of a critical fog. A research program is being developed to measure the effect of these signs on the traffic stream operation.

Variable Message Fog Hazard Warning Signs to Control Vehicle Operating Characteristics

Final rept. Nov 68-Jun 79
George, L. E. ; Hofstetter, D. K. ; Wagner, D. R.
Source: Oregon Dept. of Transportation, Salem. Traffic Engineering Section.
Sponsor: Federal Highway Administration, Salem, OR. Oregon Div.
Report Number: 79/3; FHWA/OR-79/3. See also report dated Apr 72, PB-210 205.
Publication Date: June 1979
Language: English
Abstract: The objective of the research project was to determine the effectiveness of a variable message fog warning sign system on a 6.5 mile fog prone section of Interstate 5 in Oregon. Prior to installing this variable message sign system in 1968, an intensive literature search was conducted to

determine the optimum signing system for our needs. It was determined that prior experience with this type of system had not been adequately documented. Therefore, the 'Oregon Design' was developed, and this study conducted to determine the system's effectiveness. The primary finding of this study was that the 'Oregon Design' variable message fog warning sign system has been effective in reducing the number of fog related accidents on this section of highway.

Variable Message Fog Hazard Warning Signs to Control Vehicle Operating Characteristics.

Source: Oregon State Highway Div., Interstate 5 - North Albany
Report Number: 5149-602-08 Contract Number: DOT-FHWA-41L4014; HPR-1(6)
Publication Date: April 1972

Abstract: The project is aimed at determining the effectiveness of variable message signs in controlling traffic on an Interstate highway during periods of hazardous driving conditions such as fog, vehicle accidents, or congestion. The effectiveness of the signs is measured quantitatively by use of accident records, vehicular speeds, and headways. It appears that the signs are promising in preventing accidents during periods of reduced visibility due to fog.

<u>Tennessee</u>

Fog Warning System Provides A Safety Net For Motorists

Author: Dahlinger, D; McCombs, B
Source: Public Works Journal Corporation, 200 South Broad Street, Ridgewood , NJ, 07451
Journal of Public Works Vol: 126 Issue Number: 13, pp 36-37 ISSN: 00333840
Publication Date: December 1995
Language: English

Abstract: Motorists on Interstate 75 in southeastern Tennessee now have the benefit of a fog detection/warning system to keep them apprised of adverse highway conditions. The warning system monitors conditions along a three-mile highway section that has a history of severe fogging events. These conditions have resulted in several severe reduced visibility related crashes. The most recent crash involved a total of 99 vehicles in December 1990, which resulted in 12 fatalities and 42 injuries. The project was developed by a Tennessee Department of Transportation committee of public safety, traffic operations, design, construction, and maintenance, and Federal Highway Administration representatives.

<u>Virginia</u>

Fog Warning System To Be Installed On Virginia's Highway System At Critical Locations

Source: Journal of American Highways Vol 50, No 4, P 15
Publication Date: Oct 1971
Language: English

Abstract: The first fog warning equipment on Virginia's state highway system will be installed at two locations on interstate 64 in 1971. The detector on the sensing device, which was designed in Germany, consists basically of a lamp and a light-sensitive tube with screens between them. Fog particles in the atmosphere scatter toward the photocell some of the light that passes under the screens that prevent a direct light-to-tube route. The Elizabeth river bridge installation involves both fog and ice warnings. Two air and moisture sensors are used for the ice detector. One of the two is heated to retain unfrozen moisture, through which a current is conducted. When the second sensor freezes, the current is cut off, and this activates the message to the ice and speed signs. The speed limit sign can be turned on manually also, and therefore can be used with either the ice or fog warnings, or with both. The Elizabeth River bridge installation will be made at a cost of $68,735

Foreign Projects

England

Assessment Of M25 Automatic Fog-Warning System - Final Report

Author: Cooper, Br; Sawyer, HE
Source: Transport Research Laboratory, Old Wokingham Road, Crowthorne , Berkshire, Rg11 6au, United Kingdom, TRL Project Report, Issue Number: PR 16, IRRD Document Number: 858269
Publication Year: 1993
Language: English
Abstract: An automatic fog warning system, designed by Traffic Control and Communications Division of the Department of Transport, became operational during the summer of 1990 on the M25 London orbital motorway. TRL were asked to assess the effectiveness of the system, primarily in terms of any changes in vehicle speeds which occurred when the signals were switched on as a result of the formation of fog. This report on the assessment describes briefly the automatic warning system, the method of data collection and analysis and also presents detailed results. There is an overall net reduction in mean vehicle speeds, of about 1.8 mph when the signals are switched on based on data from 6 test sites. Rather greater speed reductions occur in lanes 2 and 3 and lesser ones in lane 1. Increases in speed occur when the signals are switched off. Faster vehicles slow down more; i t is estimated that the 85th percentile speed (ie the speed exceeded b y only the fastest 15 percent of vehicles) falls by about 0.5 mph more than the reduction in the mean when the signals are switched on. However, the potential of the automatic fog warning system to reduce drivers' speeds is perhaps illustrated by the greatest average speed reduction at a single test site of approximately 5 mph (recorded in lane 3). These speed reductions indicate that drivers are alerted to the presence of fog ahead which coupled to the greater credibility associated with an automatic system, means that drivers are likely t o respond more quickly to the hazard itself. In addition operational benefits would be expected to accrue to the police. Control office staff are notified of the presence of fog, but are relieved of the difficult task of operating motorway signals in response to fog whos e density and location is likely to be continuously changing. Furthermore, the mimic signal display in the control office will tell the police which signals are showing the 'fog' legend and therefore where the fog is.

Germany

Evaluation of an Automatic Fog-Warning System.

Author: Hogema, Jeroen H. et. al.
Source: Journal of Traffic Engineering & Control, pp. 629-632; Includes bibliographical references, Vol. 37, no. 11 Publication Date: Nov.1996
Language: English
Data source: UC, Berkeley, Institute for Transportation Studies
Abstract: No abstract.

Fog Warning: A Step Towards Automation In Accident Prevention

Author: Michaelis, E.E.
Source: Journal: Roads & Road Construction, London, UK, Vol 49, No 588, pp. 430-431
Publication Date: December 1971
Language: English
Abstract: Fog warning systems so far installed in Britain have proved of limited value because motorists have found the arrangements under which these are switched on to be unreliable. The light obscuration caused by fog at British airports is measured at three points along the runways using special transmissometers. The ambient light is also measured using a background luminance monitor. The transmissometer is not only highly accurate initially by maintains its accuracy over a long period of time without requiring constant cleaning. Special housing insures that the instrument will remain operative under the most severe weather conditions. The transmissometer has been used with dramatic reduction of accidents on the Aachen-Cologne autobahn near a plant producing a severe and localized fog.

Netherlands

The Dutch Fog-Detection And Warning Project

Author: Remeijn, H.
Affiliation: Ministry of Transport, Netherlands
Publisher: IEE , London, UK
Sixth International Conference on Road Traffic Monitoring and Control p. 89-93 ISBN: 0 85296 545 1
Publication Date: 28-30 April 1992.
Language: English

Abstract: Holland has known a number of severe motorway-accidents caused by fog. These accidents have occurred on various places in the motorway network, but some roads have been plagued more than others. The A16-motorway, the link between Rotterdam and Belgium, is more or less famous for its fog accidents. In the beginning of 1991 the Ministry of Transport decided that a fog-detection and warning-system should be installed at the A16 near Breda, and that this system would serve as a pilot project for possible later installations. The system design of this pilot is presented. The control equipment is located at a service site near Breda. All outstations are connected to the control equipment via a set of party-lines; the visibility-sensors use wires in the same cable. A mini-computer is used to collect the visibility-data, to control the outstations along the road and to communicate with a number of PC's via modems. One PC (for system supervision) is situated in the control room of the Drechttunnel, because this location is manned 24 hours a day. Another PC is used by the KNMI to collect meteorological research data. A (hot) standby computer is foreseen but not operational yet.

Dutch Fog-Detection and -Warning Project.

Author: Remeijn, H.
Source: Ministry of Transport, Holland
IEE Conference Publication N 355, Michael Faraday House, Stevenage, Engl. P 89-93.
Publication Year: 1992
Language: English

Abstract: In response to a number of severe highway accidents caused by fog, the Ministry of Transport in Holland installed a fog-detection and warning-system on the A16 near Breda. Drawing on the experience of similar systems around Europe, project managers decided that the system should project a maximum speed limit under bad visibility conditions. In addition, the speed used can vary from 100 km/h to 20 km/h, with speeds lower than 60 km/h not having much effect. This paper describes the system and its integration into the Motorway Control and Signaling System.

Evaluation of an experimental fog detection and warning System on the A16 (Evaluatie Proefistdetectie- En Waarschuwingssysteem Op De A16)

Author: Stoop, J
Source: Technische Universiteit Delft, Vakgroep Veiligheidskunde, Kanaalweg 2b, Delft, 2628 Eb, Netherlands.
Publication Year: 1994
Language: Dutch
IRRD Document Number: 875909
Data Source: Transport Research Laboratory (TRL)

Abstract: An accident analysis has been made after the installation of an fog warning and fog detection system on the A16 motorway. Complicated accidents have not occurred after the installation and the number of other accidents have decreased, in particular the rear-end collisions. Other kinds of accidents during fog can be decreased as far as the lower speed adds to the prevention of skidding due to a slippery road. Besides the installation of the fog warning and fog detection system eventual side effects have been studied such as coupling with the Automatic Incident Detection System and the installation of another street lighting.

Spain

Automatic Fog Warning System

Author: Winstanley, J.V.
Affiliation: Plessey Systems Technol., Chessington, UK
Journal: Mundo Electronico (Spain), No.58 p. 39-44
Publication Date: Dec. 1976
Language: Spanish
Abstract: Fog on high-speed motorways can be a deadly and expensive menace. The article outlines an automatic system of fog detection and gauging to allow appropriate accident preventive action to be taken. Two separate optical sensors gauge the visibility level: a point visibility meter measures the fog density as a light scattering function, and a back-ground light meter simulates the sensitivity of the human eye to prevailing lighting conditions. The combined signals are transmitted to a control room for analysis and display/alarm.

General Fog Warning Systems, Devices, and Driver Behavior Studies

Ice and Fog: Detection and Warning Systems. (Latest citations from the NTIS Database)

Source: National Technical Information Service, Springfield, VA. NERAC, Inc., Tolland, CT.
Publication Date: July 1993
Language: English
Bibliography: Contains citations concerning detection methods and warning systems for sea ice, aircraft ice, bridge ice, and fog formation. Remote aerial sensing and ground based detection systems are among the methods discussed. (Contains 250 citations and includes a subject term index and title list.)

Ice and Fog: Detection and Warning Systems (Citations from the NTIS Data Base)

A series of reports covering 4-year intervals from 1964-Feb 94.
Author/Editor: Habercom, G. E.
Source: National Technical Information Service, Springfield, VA.
Publication Date: March 1980
Language: English
Abstract: Sea ice, aircraft ice, bridge ice, and fog formation detecting methods are reviewed in these Government-sponsored research reports. Remote aerial sensing and ground based detection systems are among the methods investigated. (This updated bibliography contains 177 abstracts, 15 of which are new entries to the previous edition.)

Fog Collision-Avoidance Warning Device

Author: de Bruyne, P.
Proceedings IEEE 31st Annual 1997 International Carnahan Conference on Security Technology, Canberra, ACT, Australia, pp. 168-71 ISBN: 0 7803 3913 4
Publisher: IEEE , New York, NY, USA
Conference Date: 15-17 Oct. 1997
Language: English
Abstract: The introduction of 4-way flasher hazard warning switches in cars has helped a great deal in reducing collision pile-up accidents. However, in dense fog this system is inadequate, despite the use of bright rear light fog lights, recommended when vision is less than 150 ft. Low cost car theft alarm actuators operate in the 430 MHz frequency range and have an action radius of about 300 ft. A 430 MHz transceiver in cars coupled to the 4-way flasher control switch could be used. When this switch is on, that is the flasher is working, the transmitter is active within a radius of about 300 ft. When the switch is off, the normal position, the transceiver is in the receive mode. The first cars to approach a hazard will normally actuate their 4-way flashers, thus transmitting the danger signal to cars behind them. The received signal will cause the indicator switch of the 4-way hazard flashing control to flash, or provide some other warning, thus notifying the following cars of a possible hazard ahead.

Behavioural Effects of Signal Changes in the Fog-Warning Function of Motorway Signalling

Authors: Hogema, JH; Van Nifterick, W
Source: Ertico, Rue de la Regence 61, Brussels, 1000, Belgium
ITS America, 400 Virginia Avenue SW, Washington DC, 20024-2730
Journal: Mobility for Everyone. 4th World Congress on Intelligent Transport Systems, 21-24 October 1997, Berlin, paper no. 2396
Publication Year: 1997
Language: English

Abstract: A driving simulator study was conducted to study the behavioural effects of signal changes of a fog signalling system. Fog signalling is an automatic system which in case of fog shows a speed limit to passing drivers that is adjusted to the visibility conditions. The signals as perceived by drivers may change in space (being confronte d with different messages on subsequent signs) or in time (seeing a message change from one state to another while passing a sign). In the experiment, subjects drove in a simulated motorway environment with several fog scenarios, both with and without a fog warning system. The experiment consisted of two parts, dealing with signal changes in space and in time, respectively. This paper summarises th e effects on free-driving speed found in both parts.

Automatic Fog Warning.

Author: Winstanley, J. V.
Corporate Source: Plessey Radar, Cowes, Engl
Source: Systems Technology No. 22 Oct 1975 p 26-31
Publication Year: 1975
Language: English

Abstract: This article outlines an automatic system of fog detection and gaging to allow appropriate accident prevention steps to be taken. Two separate optical sensors gage the visibility level: a point visibility meter measures the fog density as a light scattering function, and a background light meter simulates the sensitivity of the human eye to prevailing lighting conditions. The combined signals are transmitted to a control room for analysis and display/alarm.

Fog warning. A step towards automation in accident prevention.

Author: Michaelis, E. E.
Source: Roads and Road Construction v 49 n 588 Dec 1971, pp. 430-431
Publication Year: 1971
Language: English

Abstract: Features of a special transmissometer developed by Sick Optik-Elektronik of Munich, West Germany in which the light from a single source is split into two light beams which are made to pass through holes in a rotating disk so that the light is modulated to two different frequencies, and light of the one frequency is made to cross the distance over which the measurement is to be made, while the light from the other beam is used for comparison purposes.

Fog Warning Devices for Highway Traffic. (NEBELWARNGERAETE FUER DEN STRASSENVERKEHR.)

Authors: Fruengel, F.; Gelbke, E.
Source: Impulsphys, Hamburg, Ger., Strassenverkehrstechnik V 18 N 5 p 156-165. ISSN: 0039-2219
Publication Date: Sept-Oct 1974
Language: German

Abstract: The measurement of visibility in fog, with the purpose of switching on warning traffic signals, requires visibility measuring instruments which are clearly different from those used at airports and weather stations. The requirements with regard to fog warning devices for road traffic are set forth. Among them are: the warning threshold distance of from 80 to 150 m visibility, a continuous recording of the measured visibility value, and low electric power requirements. Measurements by means of a transmissometer and a videograph are described. The effects are summed up. Visibility distances of dimmed lights, of the main beam, or rear light in conditions of bright fog, twilight, or at night can be read out from the tables presented.

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[10] Qualimetrics Inc. “Systems Catalog and Product Information”. Qualimetrics Inc. 1165 National Drive, Sacramento, CA 95834, 1997.

[11] U.S. Dept. of Transportation, Office of Traffic Management and IVHS, "Intelligent Vehicle Highway Systems Operational Test Evaluation Guidelines." DOT Document HTV-20, Prepared by the Mitre Corporation under contract to the U.S. DOT IVHS Operational Tests Division, November, 1993.

Appendix

1. Slides from project presentation to Caltrans, July 1998.in District 10.

2. Electrical Detail, Control Diagram, Caltrans engineering plans, sheet E-57.

3. Traffic Monitoring Station, Caltrans engineering plans, sheet E-55.

4. Visibility test sign specifications, adopted from Caltrans deployment along Highway 99 near Fresno.

5. Qualimetrics Meteorological System, Quotation for French Camp Slough equipment, and product information on Forward Scatter Visibility Sensor.

6. Caltrans Claims Office “Information Request” application for information on traffic incident.

7. Preliminary reduction of accident data for period prior to activation of system.

8. Information on Georgia DOT Fog Detection and Warning System, from www.dot.state.ga.us.

9. Information on Sutter County Smart Call Box ITS proposed fog warning project on SR99 and SR70.