California AHMCT Program
University of California at Davis
California Department of Transportation

EVENT DRIVEN VIDEO MONITORING FOR DRIVER TRAINING: EVALUATION OF PILOT PROJECT

Phillip W. Wong[0] &

Bahram Ravani[0], Principal Investigator

AHMCT Research Report
UCD-ARR-08-10-30-01

Final Report of Contract IA 65A0262

October 30, 2008

Affiliations:
0. AHMCT Research Center, Department of Mechanical & Aeronautical Engineering, University of California, Davis, CA 95616

[*] This report has been prepared in cooperation with the State of California, Business Transportation and Housing Agency, Department of Transportation, and is based on work supported by Contract Number IA 65A0262 through the Advanced Highway Maintenance and Construction Technology Research Center at the University of California at Davis.

Technical Documentation Page

1. Report No. CA08-1586	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Event Driven Video Monitoring for Driver Training: Evaluation of Pilot Project		5. Report Date October 30, 2008
		6. Performing Organization Code
7. Author(s): Phillip W. Wong & Bahram Ravani		8. Performing Organization Report No. UCD-ARR-08-10-30-01
9. Performing Organization Name and Address AHMCT Research Center UCD Dept of Mechanical & Aeronautical Engineering Davis, California 95616-5294		10. Work Unit No. (TRAIS)
		11. Contract or Grant IA 65A0262
12. Sponsoring Agency Name and Address California Department of Transportation Sacramento, CA 95819		13. Type of Report and Period Covered Final Report August 2007 – August 2008
		14. Sponsoring Agency Code Caltrans

15. Supplementary Notes

16. Abstract

This report summarizes, analyzes, and reports conclusions from the pilot project implementation of the SmartDrive driver monitoring product. The SmartDrive product is a video based unit that continuously records the driver's environment and when certain shock loads or speeds are exceeded, a 30 second video clip is marked and flagged for further review. Driver performance is then graded based on the sights and sounds within the video clip by SmartDrive company personnel. By closing the loop and providing feedback to the operators, improvements in safety can be made.

17. Key Words	18. Distribution Statement
Human-machine interface, driver performance, operator safety	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

20. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	TBD	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized
(PF V2.1, 6/30/92)

ABSTRACT

This report summarizes, analyzes, and lists conclusions based on the pilot project implementation of the SmartDrive driver monitoring product in Caltrans, District 11 (San Diego). This driver monitoring product continuously records the operator and the forward environment of the vehicle. When forward or lateral shock loads are exceeded, or the vehicle speed exceeds 75 miles per hour, a 30 second video and audio clip (15 seconds before the trigger and 15 seconds after the trigger) is flagged for capture and later analysis. SmartDrive personnel review and grade the videos; the results are then associated with the individual operator and posted on a web site for reporting to Supervisors. The product was deployed from August 2007 to August 2008 across a District-wide fleet of approximately 50 vehicles.

The study was conduct in two phases. Immediately after installation, baseline data collection commenced. It was announced to the operators that data would be collected and reviewed, but that no feedback (unless an immediate and serious safety issue presented itself) would be given to the operators. After baseline data collection was completed, an informal feedback process was adopted. Data collection continued at this point, as well. One of the more striking conclusions is that driver feedback is extremely useful in modifying driver behavior; however, the effects are not permanent and must be refreshed periodically.

EXECUTIVE SUMMARY

The State of California incurs substantial costs in their vehicle fleet due to driver behavior-related issues. Preventable vehicle accident damage, unexpected equipment breakdown, unscheduled equipment repairs, worker injuries, third-party litigation, workers' compensation costs, and related, can sometimes be traced to less than optimal driver behavior.

The Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center at the University of California, Davis (UCD) evaluated an event-triggered video recording device to record the in-situ vehicle environment during a triggering-event. This vehicle video recording device was manufactured by SmartDrive Systems of San Diego, CA. The recorded data is used to augment driver training and to modify driver behavior, with the primary goal of reducing accident frequency and severity, and with a side benefit of minimizing untimely vehicle repairs. As part of this pilot project, the process and techniques of augmenting the driver training curriculum with the feedback data will be discussed.

Although hoped for in the original proposal, due to limitations in the device, AHMCT was unable to quantify the minimization of untimely vehicle repairs.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

DISCLAIMER/DISCLOSURE

The research reported herein was performed as part of the Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center, within the Department of Mechanical and Aeronautical Engineering at the University of California – Davis, and the Division of Research and Innovation at the California Department of Transportation. It is evolutionary and voluntary. It is a cooperative venture of local, State and Federal governments and universities.

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California, the Federal Highway Administration, or the University of California. This report does not constitute a standard, specification, or regulation.

LIST OF ACRONYMS AND ABBREVIATIONS

Acronym	Definition
AHMCT	Advanced Highway Maintenance and Construction Technology
Caltrans	California Department of Transportation
COTS	Commercial-Off-the-Shelf
DRI	Division of Research and Innovation
GB	Gigabyte
GIS	Geographic Information System
GPS	Global Positioning System
GPS-ATD	GPS-Automated Travel Diary
HMI	Human-Machine Interface
HSGPS	High-Sensitivity GPS
MB	Megabyte
MEMS	Micro-Electro-Mechanical Systems
OBD	On-Board Diagnostics
PDA	Personal Digital Assistant
RAM	Random Access Memory
SDRAM	Synchronous Dynamic Random Access Memory
TSI	Transportation System Information
UCD	University of California-Davis
USB	Universal Serial Bus

ACKNOWLEDGMENTS

The authors thank the California Department of Transportation (Caltrans) for their support; in particular, Bob Meline (DRI), Larry Baumeister (DRI), and the entire crew at San Diego District 11. Additionally, we would like to acknowledge the following people: Ty Lasky (AHMCT), and Vic Reveles (AHMCT). The authors gratefully acknowledge the Division of Research and Innovation of Caltrans which has supported this work through the AHMCT Research Center at the University of California-Davis, under contract IA 65A0262. Finally, the authors would like to thank the SmartDrive Company for their cooperation during this pilot project.

SECTION 1: INTRODUCTION AND BACKGROUND

This section provides a brief introduction to in-situ event monitoring of driver performance and operation of a vehicle.

Rationale

Many types of devices exist to monitor the health and conditions of the equipment itself. These types of self-diagnostic devices monitor performance of the machines by means of a feedback type signal. Generally, these feedback type signals include items such as exhaust gas composition (which would identify combustion problems) or performance deviation from nominal (an actuator reacting slower than normal). Sometimes, the monitor device can predict failure or wear of items and flag for scheduled preventative maintenance downtime before the machine completely fails with unscheduled downtime. The “Change Oil” reminder on the typical car is an example of the predictive monitor. Based on heuristics, algorithms, and usage patterns, the engine computer can predict when the engine oil needs to be changed before the oil ceases to be useful in protecting the engine.

In this pilot project, a device to monitor vehicle operator performance was installed in a fleet of vehicles at Caltrans, District 11 (San Diego). By monitoring and feeding back operators’ performance, insight into the operation of the equipment can be gained and optimal equipment operations can be established. Additionally, should the situation warrant it, corrective actions in operator training can be taken before the situations become more serious.

The Device

The device installed for this Pilot Project is the SmartDrive unit from SmartDrive Systems (San Diego, CA). This unit (Figure 1) is mounted below the vehicle’s rear view mirror and consists of two video cameras, a sensor package, a communications module, and an interconnect to the vehicle’s engine computer. One of the cameras is aimed at the operator and the other is aimed out the front windshield for a frontal view. The system continuously records (buffers) video from both cameras and sound from the built-in microphone until a 30-second segment is flagged for saving into memory for later review by a trigger event. Fifteen seconds before the trigger event and fifteen seconds after the event are permanently saved. When the vehicle returns to the maintenance yard, the videos are uploaded to a central server for later review by SmartDrive personnel.

Figure 1: SmartDrive Unit

Trigger events are composed of three main types: shock load, over-speed, and panic event. All three trigger events cause the video unit to save the 15 seconds before and 15 seconds after the event. Shock load events are generally caused by excessive side-to-side or fore-to-aft acceleration loads (in terms of "g" loads). The side-to-side loads generally correspond to the vehicle jumping off curbs, hitting curbs, or running on rough or unimproved roadway shoulders. The threshold for this trigger event is ~0.38 g's. The fore-to-aft gravity loads generally correspond to excessive braking and acceleration or hard turning. The threshold for this trigger event is ~0.40 g's. Over-speed events are obtained from a diagnostic communications interconnect (On-Board Diagnostics, OBD-II) to the vehicle's engine computer. Over-speed limit for this study was set at 75 miles-per-hour (MPH). Finally, the panic event corresponds to the operator depressing the panic button on the unit itself. Table 1 summarizes the trigger events and thresholds. Once a trigger event occurs, a red light on the unit illuminates to indicate that something has been stored to the internal memory. When the vehicle returns to the maintenance yard, the data is downloaded via Wi-Fi wireless network to a SmartDrive server.

Table 1: Trigger Events and Thresholds

Trigger Event Type	Threshold	Causes
Shock load (side-to-side)	0.38	Driving on rough shoulders, hitting curb, driving off curb
Shock load (fore-to-aft)	0.40	Excessive acceleration, deceleration, hard braking, collision
Over-speed	75 mph	Excessive speed
Panic Button	N/A	Operator wants to flag an incident for further review; potential evidence of crime

Once the downloaded videos are received by SmartDrive Systems, the video clips are reviewed and graded by trained reviewers. The operators are identified by comparing their pictures in the clips with their pictures on file. The report is then filed on the website under the operator's name. Supervisors can then review the reports and take appropriate action. Figure 2 illustrates the complete data collection cycle.

Figure 2: SmartDrive Cycle

Administrative Actions

Once the operators' graded reviews are uploaded to the SmartDrive web site, the reports are available for review by the supervisors and managers. Administrative changes are necessary to support the closed-loop enhancement and augmentation of the operator training curriculum.

SECTION 2:
REVIEW OF TECHNICAL LANDSCAPE AND AVAILABLE COMMERCIAL SYSTEMS

Recent technological developments and improvements in the Global Positioning System (GPS), low-cost small Micro-Electro-Mechanical Systems (MEMS) inertial sensors, low-power embedded computers, high-capacity storage devices, wireless communications, and high-speed Internet have converged to make a portable and low-cost data collection system a feasible reality.

Fleet Management Units

Low-cost data collections devices when fused with GPS location sensing and wireless connectivity and deployed into vehicles typically fall under the category of "fleet management" units. Companies such as Federal Express (FedEx) or United Parcel Service (UPS) install these units to allow tracking of their delivery vehicles in real-time. An example of a fleet management unit is the Preco *PreCise IX-802* unit (Figure 3). This unit is currently being deployed on a fleet of vehicles to support another AHMCT project, the Idling Baseline study. The unit combines GPS location sensing, engine condition monitoring, and GSM cell phone data connectivity to allow for near real-time location tracking of the vehicle. Depending on the management configuration, the unit can report the entire route, along with trigger events, at the end of the day or at scheduled times during the day. The data is collected and presented on the Preco website. Conditions such as exceeding a geo-fence or over-speed can be reported via alerts in email or SMS. A major limitation of this type of fleet management unit is the inability to record, via video and audio, the operating environment of the vehicle. Additionally, this device does not monitor or record the g-loads applied to the vehicle.

Figure 3: Preco PreCise (courtesy Preco)

Driver Training and Monitoring

Many times, it is only desired to monitor driver behavior and improve upon the operation of the vehicle. An especially important audience are parents with a newly-licensed teenage driver. These newly-licensed drivers are inexperienced in the sensation of the dynamics of vehicular operation and tend to drive in an erratic fashion. Another company, DriveCam (San Diego, CA), manufactures a product, *DriveCam*, which mounts behind the rear view mirror of a vehicle and combines vehicle force monitoring and video/audio recording (Figure 4). The forces monitored include loads applied from swerving, cornering, hard braking, hard acceleration, collision or the like. Once triggered, the video and audio before the event and after the event are saved. The data is eventually transferred to DriveCam for review by their analysts. The results are reviewed by the parents in an effort to identify bad driving behavior and reinforce good ones. One insurance company (American Family Insurance), in exchange for reduced insurance rates for teenage drivers, has an agreement with parents to deploy the device into their vehicles.

Figure 4: DriveCam (courtesy DriveCam)

Passive GPS Trackers

Passive GPS tracking and recording devices are available from a variety of manufacturers. These devices only record the location versus time. These devices make no attempt to identify trigger events, much less send an alert. An interesting variation of this type of device, the ZoomBak (Figure 5), melds a GSM data unit and a GPS device to create a location device and geo-fence alert device. The main target for this device is to recover lost dogs and to track children.

Figure 5: ZoomBak (courtesy ZoomBak)

SECTION 3:
FEASIBILITY STUDY RESULTS

As part of the startup of the pilot project, a preliminary feasibility study was conducted. The concentration of this pilot study was to find a methodology to improve operator interaction with the vehicle. Ideally, a device would be found that could monitor driver and vehicle performance, and provide evidence of the vehicle's operational environment. By combining all these types of data, improvements to the operator training can be made, leading to more optimal operation of the equipment.

This phase commenced with a preliminary market survey of competing devices. Primarily, the devices were compared on the types of data they were able to provide for this study. Secondarily, the devices were compared on installation requirements, infrastructure requirements, and vendor support. Once a device was selected, the operational lifecycle was defined and its deployment impact on Caltrans operations clarified.

The Devices

As touched on above, the market survey of devices led to three broad categories of devices: vehicle fleet management, driver monitoring, and passive trackers. Each of these categories of devices had their pluses and minuses. No one device had all the capability desired for this study.

Preco PreCise fleet management units concentrated heavily on monitoring vehicle conditions, location, and operations. These units connect to the engine computer to record vehicle operational parameters, such as fuel consumption, engine temperatures, brake conditions, and the like. An external GPS antenna provides location information of the vehicle. Finally, a maximum of 6 digital I/Os can be used to provide a record of the state change of accessories on the vehicles. Accessories include such items as the activation of power-take-off (PTO) hydraulic pumps and generators, or the lowering of sweeper brooms and the like. Other than the recording of vehicle location, no record of the environmental operation condition of vehicle or the operator is provided.

SmartDrive and DriveCam units both attempt to provide the same information. By monitoring the shock loads imposed on the unit by the vehicle's motion, trigger events can be obtained. Once obtained, a video clip of the operating environment is recorded. In both cases, a forward view clip of the front of the vehicle and a rear view clip of the operator is recorded. When the vehicle returns to the home base, this information is uploaded to the company, where specially trained reviewers view the video and critique the driver's performance. A report is generated and placed on the respective company's web site for later review by the responsible parties. An important difference between the two units was that the SmartDrive unit had a communications link (via OBD-II) to the vehicle's engine computer. This link was used to monitor vehicle speed directly from the vehicle. This link was eventually envisioned to record additional engine parameters (e.g., fuel consumption, etc) with a future firmware upgrade. This distinction allowed the SmartDrive unit to trigger on over-speed conditions. One limitation shared by both was that neither unit had GPS capability, so that vehicle tracking was not possible.

Passive trackers only provided a log of vehicle locations. Speeding conditions can be derived from the location data, but operating conditions of the vehicle and driver performance cannot be obtained.

Since the concentration of this study was to monitor operator performance and try to improve the driver training curriculum, devices that had the ability to monitor the environment were selected. The two devices that provided this ability were the SmartDrive and the DriveCam units. Each company also provided similar company infrastructure and support for the post-processing of data received from the field units.

Finally, since the SmartDrive unit had the ability to monitor speed, it was selected for use in this pilot study.

Operational Scenario

Each vehicle selected for inclusion into this pilot study incurred approximately 2-5 hours of downtime for installation of the equipment. The main unit is installed in front of the rear view mirror to the interior roof of the vehicle. Cables are then run from the unit to attach to the OBD-II data connector and the vehicle power supply. Ignition key-switched and continuous power are required by the unit.

At the maintenance yard, Wi-Fi antennas were installed. These antennas form a network for downloading the event information from the vehicle field units to the central on-site data server. The central data server eventually uploads the video information via a dedicated DSL line to the SmartDrive central office. Finally, the SmartDrive reviewers retrieve the video, critique it, create a report, and place it on the company web site. Figure 6 shows this process.

Figure 6: Operational Scenario (courtesy SmartDrive)

Figure 7 illustrates the complete acquisition, review, and coaching session cycle as recommended by SmartDrive Systems. In order to close the feedback loop, management must coach the operators in reducing the undesirable behaviors and reinforcing best practices. By following this cycle, real risk reductions and improvements in operations can result.

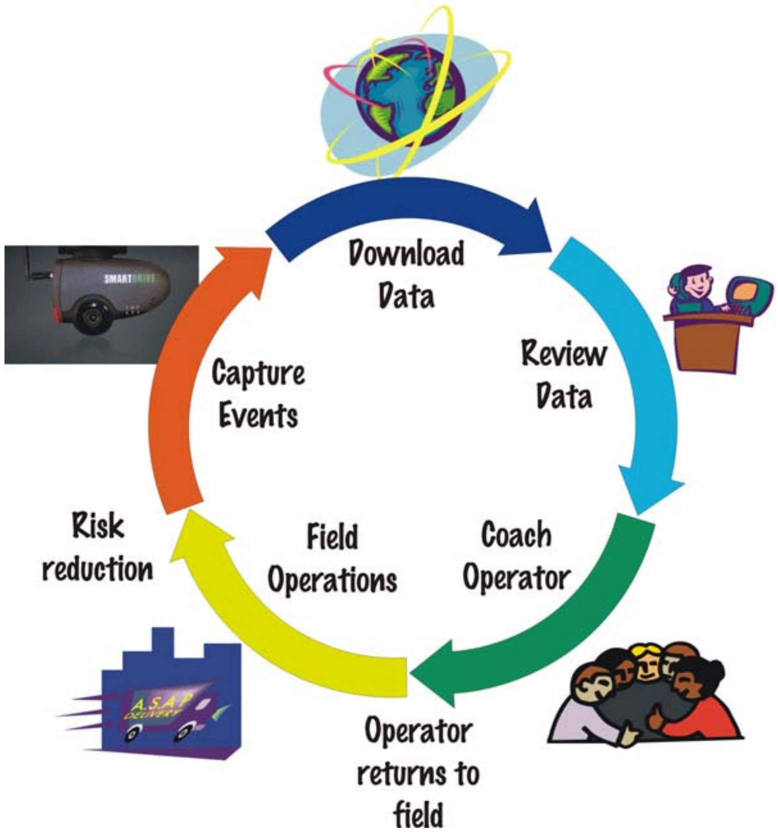

Figure 7: Review Cycle

Operational Impact

Other than the short time necessary for installation, equipment operational impact was non-existent. Administrative impact, however, was a different matter, since no procedures were in place to support closing the loop on the feedback cycle for implementation of these types of devices. Unanswered at the outset were questions such as manager review procedures of the SmartDrive reports and feedback procedures from the managers to the operators. Finally, more serious issues such as implementation of disciplinary action procedures for serious or repeated operational violations were flagged for study later in this pilot project.

SECTION 4:
CALTRANS PILOT EFFORT

The pilot effort began with a kick-off meeting on June 27, 2007 at the headquarters of SmartDrive Systems.[1] In attendance was Michael Dehn (SmartDrive), Walter Gaines (SmartDrive), Larry Baumeister (Caltrans), Victor Reveles (UCD AHMCT), and Phillip W. Wong (UCD AHMCT). The discussion that occurred began with a general introduction of the system, along with a cursory look at the systems components and their connections. The major components touched on were:

- Camera unit with integrated Wi-Fi system
- OBD (On-Board-Diagnostics) unit
- Wiring harnesses
- Key pad (optional)
- Infrastructure requirements
    - Wi-Fi antennas and access points located around parking yard
    - Server to collect data
    - Internet uplink to SmartDrive Systems

A detailed discussion then followed about the utilization scenarios for the Caltrans pilot effort. Items discussed included how the units collected the data, the event triggers, and how to upload the data to SmartDrive for later analysis. Major points from this discussion include:

- Vehicle units feature continuous recording (buffering) of video and audio and when "event" triggered create a snapshot of 15 seconds before and 15 seconds after.
- Vehicle must return to yard to upload captured event records
    - Unit contacts yard access point, local server downloads event records, which are eventually uploaded to SmartDrive central for analysis.
- "Event" trigger can be any of the following:
    - G-Force: Lower limit is "erratic" driving, upper limit is "shock" or "crash"
    - Speed: Speed limit is maximum limit set for the vehicle, regardless of location or road condition
    - Panic button: User triggered event by pressing the red button on the keypad or camera unit.

Finally, a discussion ensued regarding the data analysis procedure employed by SmartDrive for the review of the event data for the vehicular units. Summary points from this period of discussion include:

- "Reviewers" grade the captured events and assign points based on what the video contains. Infractions include eating, cell phone usage, yawning, loud

[1] 10655 Roselle Street, Ste. 100, San Diego, CA. 92121, phone 858.225.5566

music, etc. Totalization of the points leads to classification of severity from 0 through 4, 4 being the most severe event.
- An analysis report is available on the vendor web site for the customer. This report allows feedback loop closure for the driver training curriculum via the managers or supervisors.

The next day, an introductory orientation meeting was held at the District 11 yard to bring the yard managers onto the same page and initiate the Pilot program. The meeting opened with a restatement of the Management objective of this project:

“Caltrans’ objective for this pilot project is to have a measurable reduction in accidents”

SmartDrive also presented their introductory material for the Yard managers and a pilot kick-off scheduled for mid-July 2007.

During the discussions between all the parties at the conclusion of the orientation meeting, an important point concerning the Caltrans operating environment was brought forth. Since the Caltrans usage pattern of off-road and shoulder driving may create more events than necessary due to excessive shock loads, the G-load event threshold must be refined by SmartDrive to reduce unnecessary false alarms.

The Caltrans pilot data collection effort began in late September 2007 with a pilot fleet of approximately 50 vehicles located at the Kearney Mesa Maintenance Yard, San Diego, CA (District 11). As specified in the original proposal, this was the beginning of the year-long data collection period. Attempts would be made at quarterly intervals to visit the Maintenance Yard for interviews and discussions with personnel, managers, and the vendor for updates and comments regarding the use of the SmartDrive system in Caltrans vehicles. It was decided to split this pilot period into two portions. The first portion would be used to record “baseline” data. During this “baseline” period, data would be recorded and reviewed, but no feedback would be given to the individual operators from the manager regarding the analysis of the data from the vehicle units. At the expiration of this first period, manager feedback to the operators would be given in an attempt to modify the driver’s vehicle operating behavior. A comparison of the data from the two halves would then be used as a gauge for the effectiveness of feedback in the modification of driver behavior.

As the pilot progressed, on-going discussions concerning the exact form of the administrative procedural actions for the managers’ feedback to the operators continued. Union issues and excessive or retaliatory actions against operators were a constant concern. Issues of privacy were also brought to the forefront. Issues dealing with administrative actions resulting from equipment tampering also needed to be dealt with. During some routine discussions with Caltrans Headquarters managers, a suggestion was put forth that the minimum adverse action for intentionally tampering with a SmartDrive device should be much more stringent than normal discipline processes. One suggestion was a one pay-step reduction for six months, with a performance re-evaluation at the end of the six month period. The suggested disciplinary actions could escalate all the way to employment termination for repeated violations.

SmartDrive Systems also provided suggestions on providing feedback to the operators (see Appendix A: Generic SmartDrive Policy). In summary, the company suggested that the managers, for first offenses, assign drivers a remedial training class and 30-days probation. For second offenses, the employee would receive a more strident training class and 60-days probation. Finally, for the third offense, employee suspension and perhaps termination were suggested.

Implementing Policy

On April 25, 2008, another meeting was held in District 11, San Diego, to begin the process of implementing the feedback policy. The issues to implementing policy were discussed in the presence of District 11 team managers, SmartDrive company personnel, Caltrans Headquarters staff, and AHMCT researchers. The conclusions reached during the roundtable discussions were:

- For corrective coaching, there would be documented interviews between the managers and the operators.
- There would be progressive discipline starting with coaching, progressing to adverse action, and finally suspension of pay.
- Letters of warning would be filed in the operator’s personnel file for repeated offenses.
- For fairness, everyone’s (including management personnel) vehicles would have the same equipment installed.
- Adverse action would be handled via existing customer complaint processes currently in place. These customer complaint processes deal with resolution actions for complaints and issues called in by the public against Caltrans operators and vehicles.
- Finally, it would be necessary to discuss policy harmonization with the Union.

In reality, based on anecdotal conversations with District 11 managers, in order to not be perceived as “singling out” any particular operator, the managers, during their team “safety briefing”, would mention that during his review of the team’s SmartDrive data, specific issues were noted and that performance must be addressed. i.e., the individual would not be identified in the briefing.

SECTION 5: STUDY ANALYSIS AND RESULTS

Introduction

The data collection phase of this pilot project ran from approximately August 2007 to October 2008. The baseline phase (no feedback phase) ran from approximately August 2007 to May 2008. The feedback phase commenced on May 2008 and ran to project conclusion in October. It should be stressed that although the data was collected by automated instrumentation, the early data should be considered somewhat inaccurate due to the need for fine-tuning of the sensors. Suspected inaccuracies include:

- Excessive speeding triggers due to some vehicle speed limits set at 65 MPH, rather than the desired 75 MPH;

- Excessive shock triggers due to the harsh suspensions of some vehicles (i.e., flatbed trucks) or usage patterns of other vehicles (e.g., sweepers driving on unimproved road shoulders). The g-limits were modified for these vehicles.

- Visibility issues (excessive glare or reflections) with the lens being mistaken for tampering;

- Employee identification issues. Operators can only be identified by face image in the video, and incomplete names and photo files were present at the beginning. It is unknown whether the early incidents were completely and correctly correlated with the operators.

Nevertheless, although specific values of conclusions cannot be drawn, the relative trending of the data will prove to be instructive.

Operator's Review and Comments

As part of the pilot project, an Operator's Review and Comment form (Appendix B: Operator's Review and Comment) was sent to the operators of SmartDrive equipped vehicles. Appendix C contains the completed review forms from the operators. The review form covers roughly four areas: Training, Usage, User Interface, and Effectiveness. The questions on the form are briefly summarized below. Refer to the Appendix for the full text of the questions.

- [Question 1] Hours of operator training.
- [Question 2] Was the SmartDrive theory of operation clearly explained?
- [Question 3] Was the project purpose clearly explained?
- [Question 6] Did SmartDrive change the way you operated the vehicle?
- [Question 7] Was there a possibility of false positives?
- [Question 8] Does the unit create visibility problems while driving?
- [Question 9] Is the user feedback sufficient?
- [Question 10] Would you personally buy this product for your own use?

The survey results from the questions are shown in the Chart below. There are a number of "N/A" (no answer) responses, which might indicate a misunderstanding of the survey question. The "no" answers to questions 2 & 3 indicate a lack of communication between management and the operators. In Question 6, the majority of operators report that having a SmartDrive unit installed in their vehicle is ***not*** a factor in modifying their operation of the vehicles. Some have commented that they are more careful in speaking bluntly since the unit records audio during an incident. Operators were split about the issue of false positives (Question 7). There were repeated comments about the sensitivity of the units to off-road operations, roadway shoulders, Botts dots and stiff truck suspensions. In Question 8, the operators were comfortable with the mounting and size of the unit. One operator commented that the unit created a visibility problem when looking up for overhead or street signs. Once again, on the question of user feedback (Question 9), the operators were split. This survey question had the highest non-answer, perhaps suggesting a misunderstanding of the question. Many had commented that there was no feedback from management to them regarding the data or operation of the device. Finally, when asked whether operators would personally buy the device for their own usage (Question 10), there was a resounding "no." Many felt that there was an "invasion of privacy" to having the units active in their vehicles.

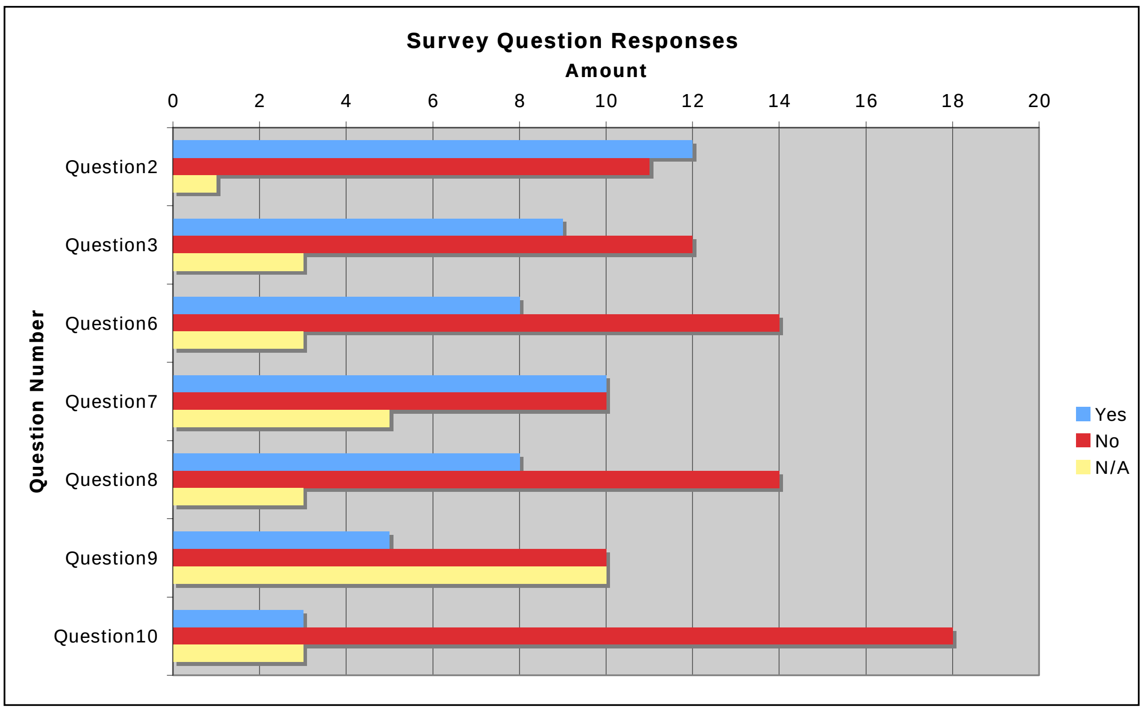

Figure 8: Survey Question Results

As a reinforcement to the answers from survey Questions 2 & 3 and the lack of communications from management to the operators, the chart below reveals that most operator had no training or communications regarding project or its objectives.

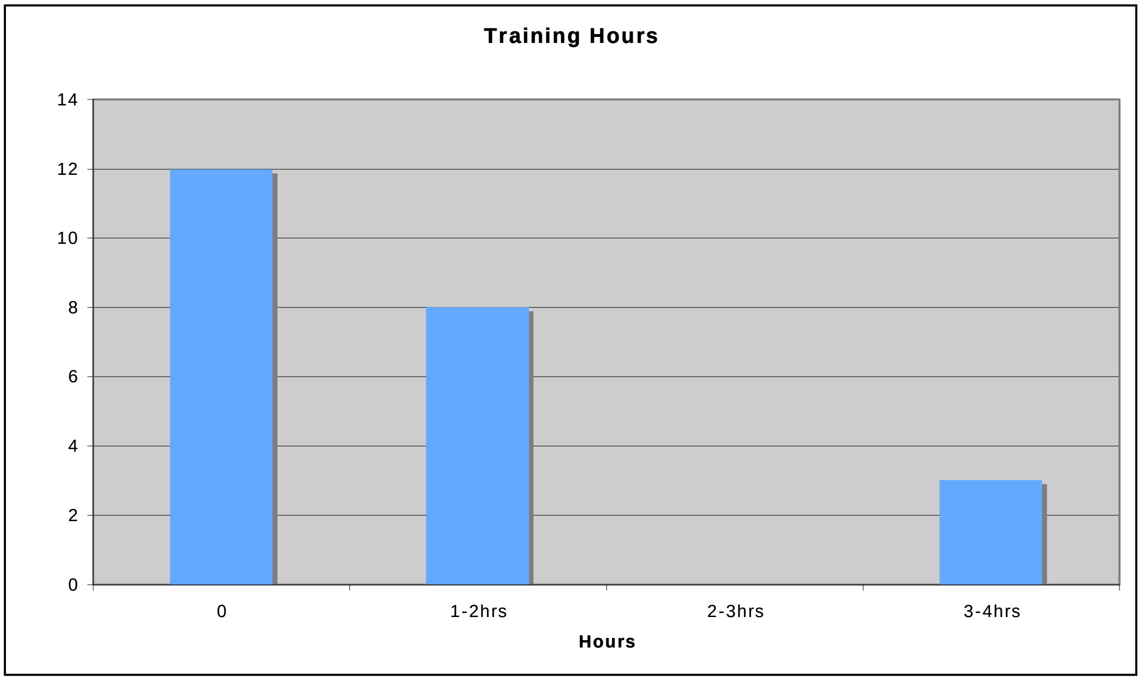

Figure 9: Operator Training Hours

Manager's Review and Comments

Additionally as part of this pilot project, a Manager's Review and Comment form (Appendix D: Manager's Review and Comment) was sent to the manager or team lead of the operators of SmartDrive equipped vehicles. Appendix E contains the completed review forms from the managers. The amount of forms returned was disappointing (only one out of approximately 4 managers). Nevertheless, this manager felt comfortable with the SmartDrive unit in that it reduced incidents without increasing administrative overhead. This review contained an overall positive attitude to the unit and its concepts.

Review of SmartDrive Data

Raw SmartDrive data was captured from the SmartDrive company web site and entered into an Excel spreadsheet workbook for analysis. The spreadsheet data is presented in Appendix F.

Fleet-wide Overview

The overall trends of the Category 1 through 4 incidents are shown in Figure 10, with Category 4 being the most severe and Category 1 being the least severe.

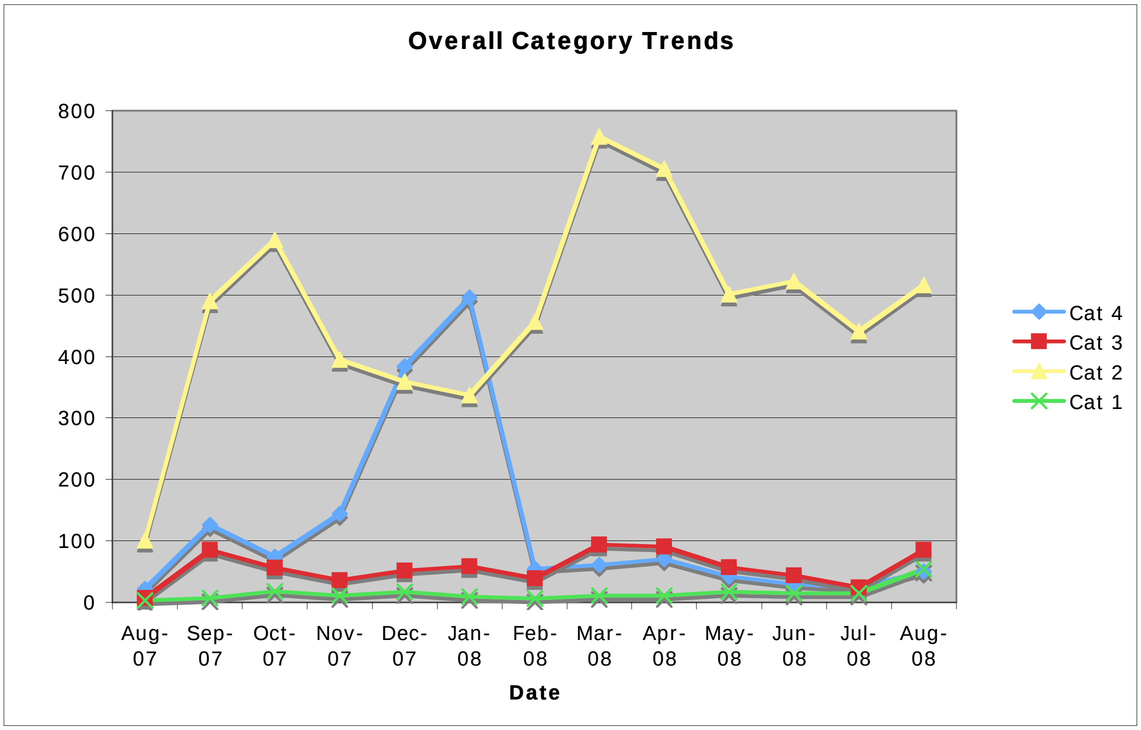

Figure 10: Category Trends

Interesting to note is the large drop off of the Category 4 events around January 2008. There is no known correlation with any of the recorded driving events. Figure 11 graphs the Category 4 events along with two of the suspected most severe infractions. Due the proprietary nature of the SmartDrive algorithms, it is not known what the Category 1 through 4 infraction levels are composed of.

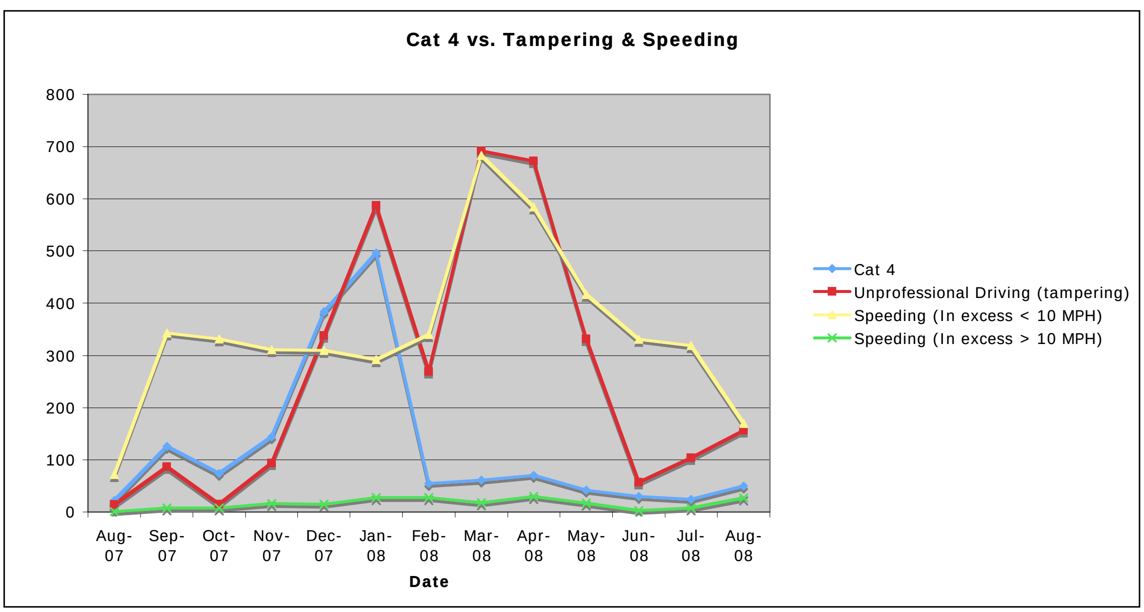

Figure 11: Cat 4 vs. Tampering & Speeding

The most common driver errors are graphed in Figure 12. Interesting to note are the erratic trends from month to month. This is possibly due to different drivers entering and exiting the fleet due to changes in assignments. This contention is supported by a close look at the individual driver performance statistics. Drivers have statistics for some months, but not for other months, indicating that they might not have been operating any vehicle during certain periods of time.

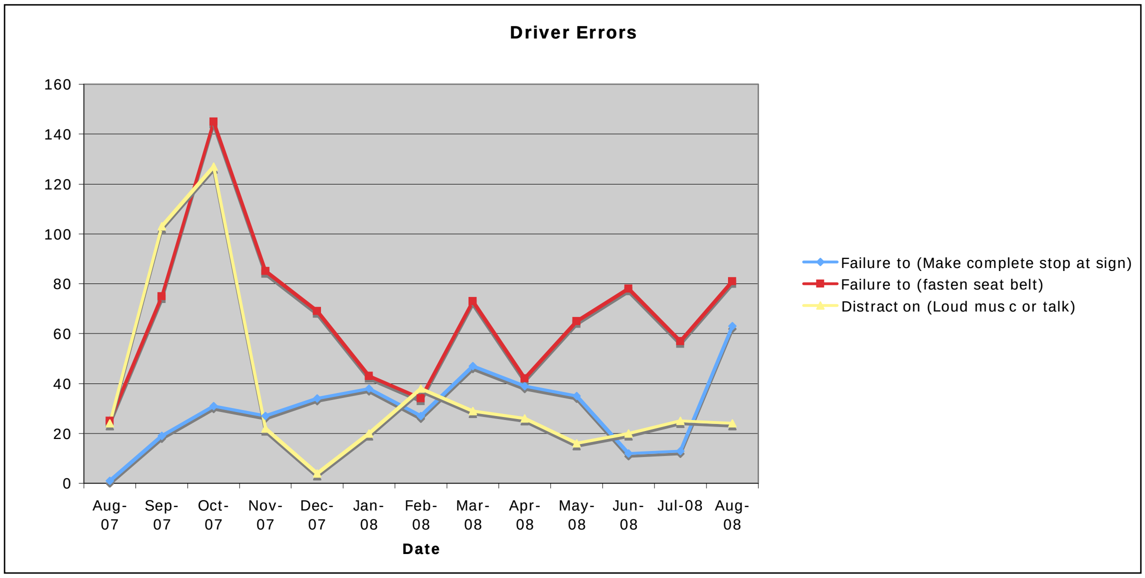

Figure 12: Driver Error Trends

<u>Individual Driver Performance</u>

Although fleet-wide statistics provide a macro-view of how the entire entity is performing, modifying the behavior of the outlying or most "unsafe" operator tends to give the most benefit for the management effort. This is the main goal of this study: ***Modify driver behavior to reduce risky vehicle operations***. To this end, after the "baseline" data collection period of six months expired, driver coaching was implemented around May 2008. General team coaching during the routine safety meetings was implemented as the preferred method of passing manager's feedback to the operators. Figure 13 is a graph of the Category 3 & 4 statistics for two of the most "consistent" operators in the fleet. The operators' "consistent" appearance in the SmartDrive statistics is also a function of the vehicle type that the drivers operate. Stiff suspensions or off-road work will tend to create some "false-positives", unnecessarily adding them to the reviewer's list.

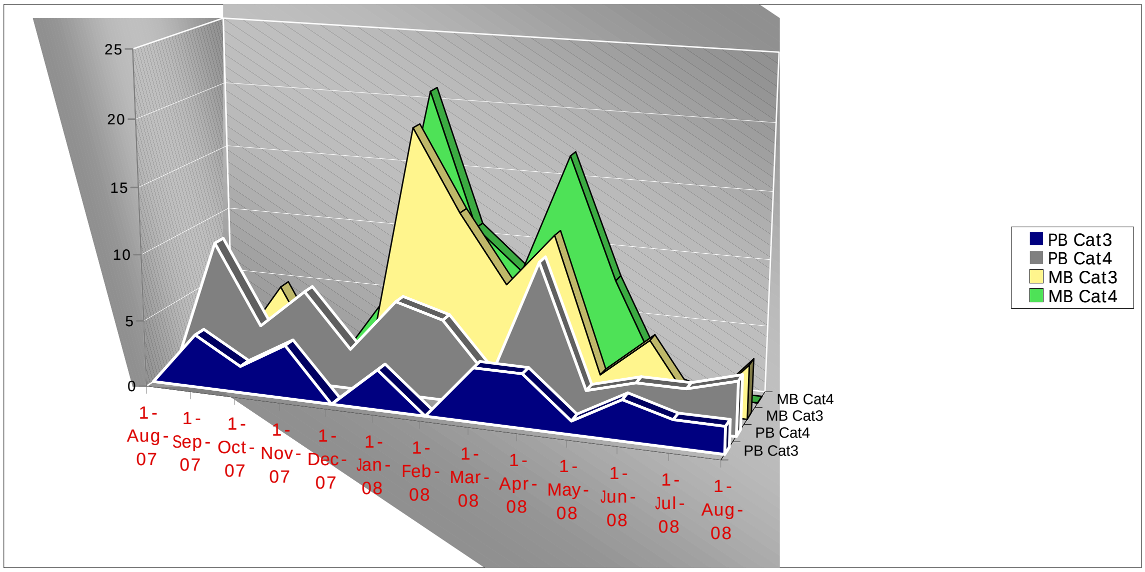

Figure 13: Two Individual Operator's Statistics

As can be seen in Figure 13, qualitatively speaking, before the coaching sessions were initiated in May 2008, the relative amounts of Category 3 & 4 infractions were quite high. After the coaching sessions, the amounts dropped off with an immediate reduction. The effects of coaching on other drivers are inconclusive since other personnel were not consistently captured by the SmartDrive unit. Figure 14 shows this effect for two other drivers' Category 4 infractions. The missing graph sections are where there is absolutely no data on the driver under consideration.

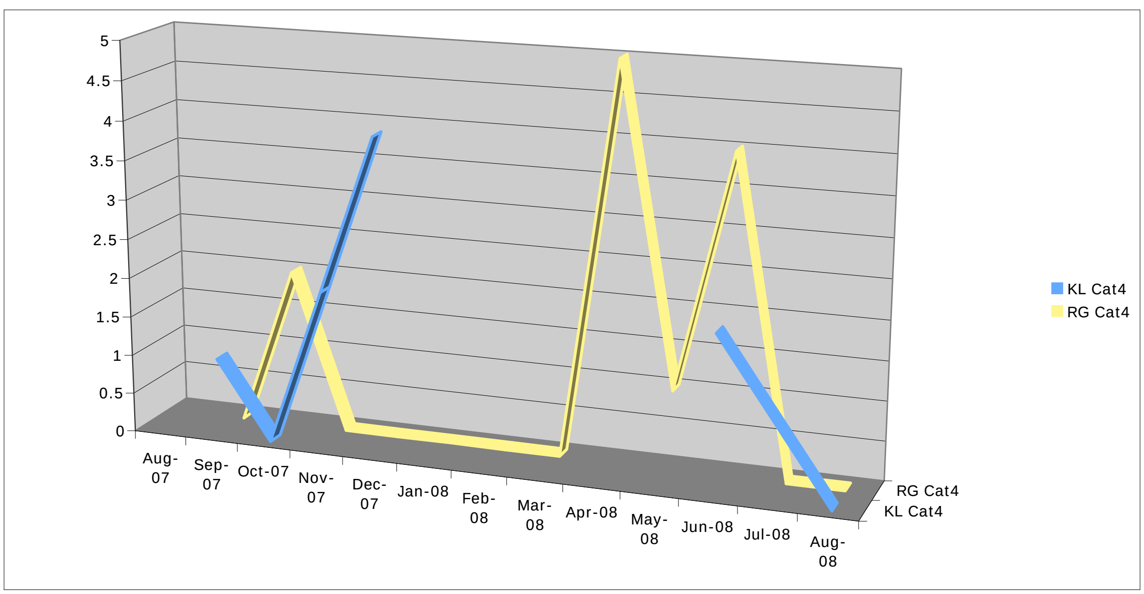

Figure 14: Inconsistent Monitoring

Return on Investment

The installation of the SmartDrive unit into the fleet can have many positive economic results. Since SmartDrive monitors vehicle speeds, one direct savings that results is the decrease in fuel consumption with reduced vehicle speeds. Another is lower accident medical costs since seat belt usage compliance can be monitored. Other issues such as operator distractions and inattention can be monitored and remediated in training and coaching sessions. However, due to inadequate cost accounting and vehicle usage patterns, it is impossible to assign concrete cost dollar amounts to the safety and efficiency trends seen during this pilot program.

A recent fuel economy study[2] by the FHWA of 1997 model year vehicles (composite results of 9 vehicles and light trucks from model year 1997) shows the increase in fuel consumption with speed. The study results are summarized in Figure 15. A speed increase from 65MPH to 75MPH leads to an increased fuel consumption of about 15%. As shown in Figure 16, speeding events from the range of 75 to 85 MPH decreased during this pilot program from about 310 events per month, trending towards 180 events per month. Since the fleet speed profile and distances traveled are not known, exact cost savings cannot be derived. However, for the sake of illustration during this discussion, assume the following scenario: a 40 mile trip at highway speeds, using vehicles with the composite fuel economy shown in Figure 15, gasoline at $2.890 per gallon, and vehicle speeds of 75 MPH (the SmartDrive trigger point, although vehicles can be moving faster than this when triggered due to sampling interval).

At 310 events, the fuel bill would be:

(@75mph) 310 x (40 miles / (24.8 Miles/Gallon)) x 2.890 $/Gallon –or-- $1445.00
(@65mph) 310 x (40 miles / (29.2 Miles/Gallon)) x 2.890 $/Gallon –or-- $1227.26

The excess fuel bill due to speeding would be **$217.74**.

At 180 events, the total fuel bill would be:

(@75MPH) 180 x (40 miles / (24.8 Miles/Gallon)) x 2.890 $/Gallon –or-- $839.03
(@65MPH) 180 x (40 miles / (29.2 Miles/Gallon)) x 2.890 $/Gallon –or-- $712.60

The excess fuel bill due to speeding would be **$126.43**.

The reduction in speeding events translates into a hypothetical ~$91 dollar savings per month for the fleet.

[2] West, B.H., R.N. McGill, J.W. Hodgson, S.S. Sluder, and D.E. Smith, *Development and Verification of Light-Duty Modal Emissions and Fuel Consumption Values for Traffic Models*, FHWA Report (in press), Washington, DC, April 1997, and additional project data, April 1998 (Additional resources: www.fhwa-tsis.com)

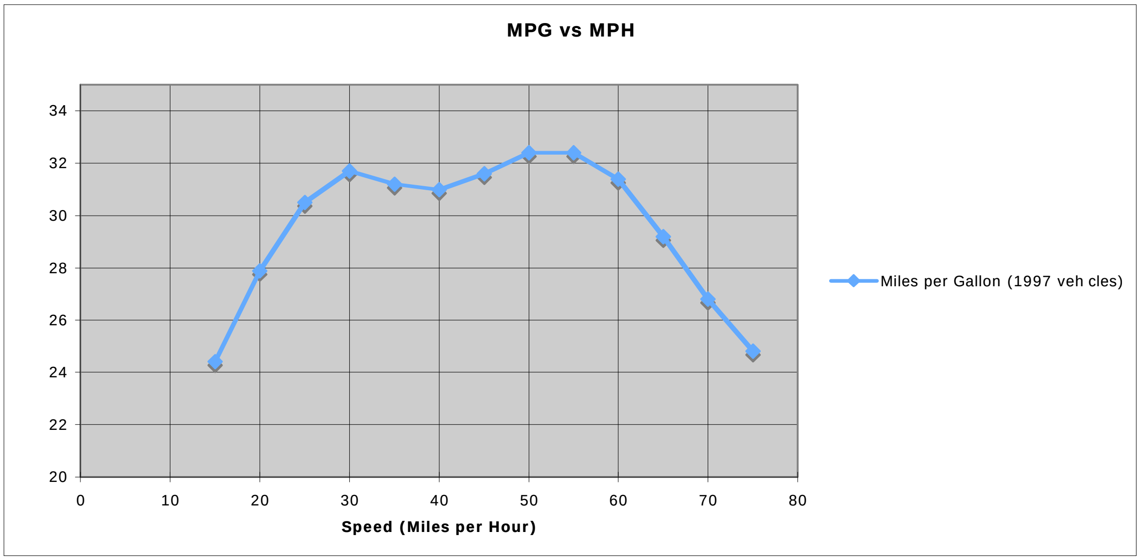

Figure 15: MPG vs. MPH

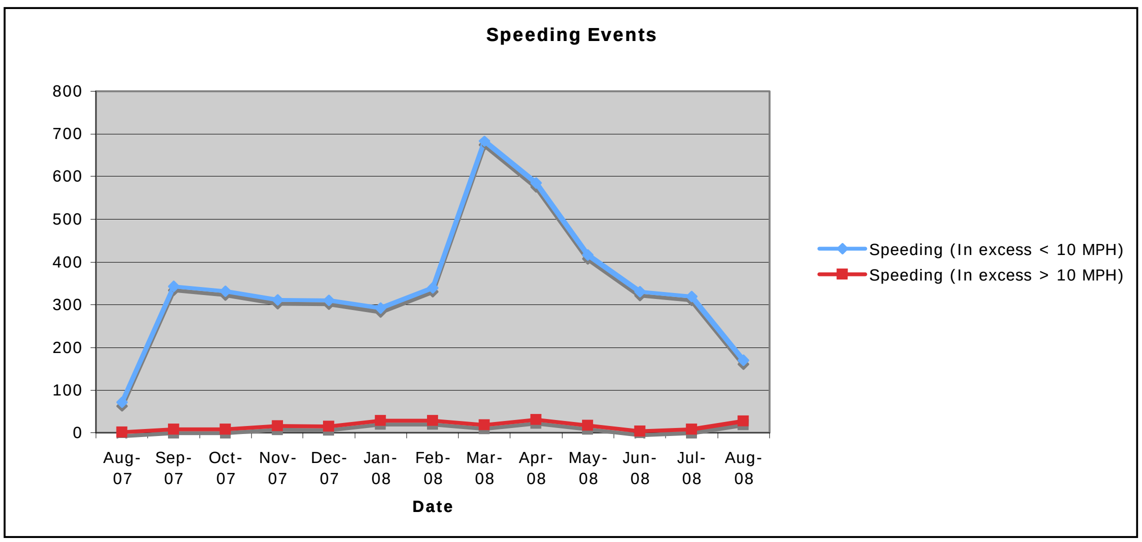

Figure 16: Speeding Events

Another issue captured by the SmartDrive unit during this pilot was the inattention to seat belt usage (Figure 17). After an initial reduction, the non-usage events leveled off, indicating complacency in seat belt utilization. Many studies have shown that enormous economic benefits result from the reduction in bodily injuries from the usage of seat belts. However, due to the lack of accidents or injuries during this study, no economic value can be attributed to seat usage during this pilot study.

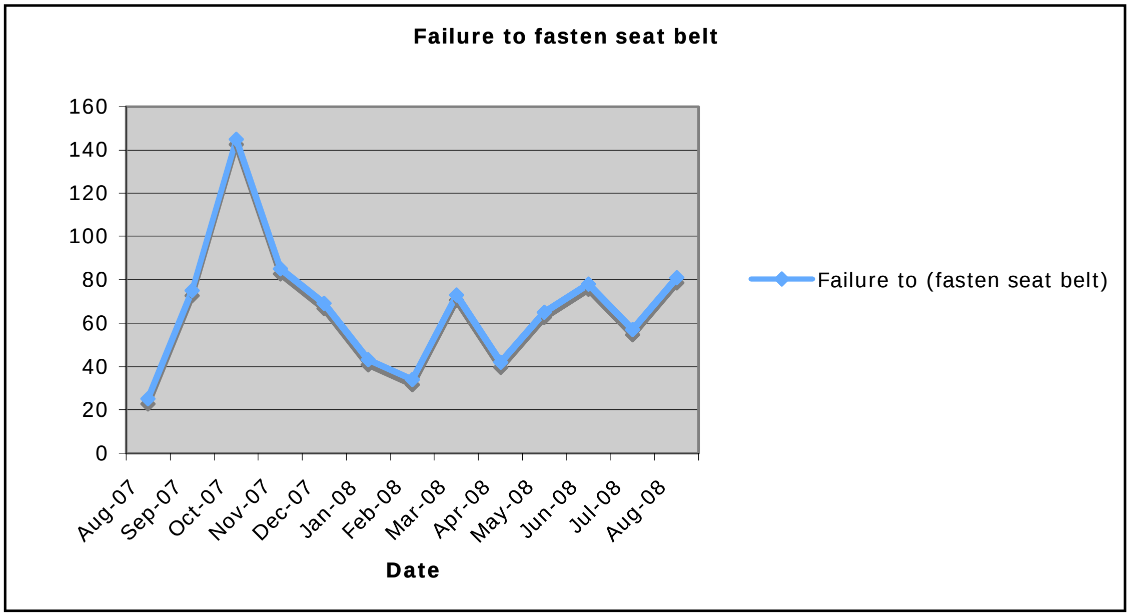

Figure 17: Seat Belt Non-Compliance

Finally, other studies have shown that a reduction in driver distractions should lead to a reduction in accidents. The trends in distractions during this pilot project are shown in Figure 18. The trends appear to have remained stable throughout the pilot project. Once again, no economic benefits can be attributed to the detection of driver distractions during this pilot study. Interestingly, a study[3] (by NHTSA, the Virginia Transportation Research Council and Virginia Tech) that followed 100 cars and 241 drivers over more than one year and 2,000,000 miles, tracking driver distractions and driver performance, shows that their sample fleet was involved in 82 crashes, 761 near crashes, and 8,295 critical incidents. Although the SmartDrive pilot study only involved approximately 50 vehicles and 30 operators, the amount of incidents was considerably less than in the Virginia study. The SmartDrive data only recorded a few collisions (approximately 5) between vehicles and other objects. One conclusion that might be reached is that the Caltrans operators are conscientious about their operating environment since roadway maintenance operations tend to be dangerous.

[3] Klauer, S.G., Dingus, T.A., Neale, V.L., Sudweeks, J.D., and Ramsey, D.J, *The Impact of Driver Inattention on Near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data*, April 2006, Report # DOT HS 810 594 (http://www-nrd.nhtsa.gov/departments/nrd-13/810594/pages/TOC.htm)

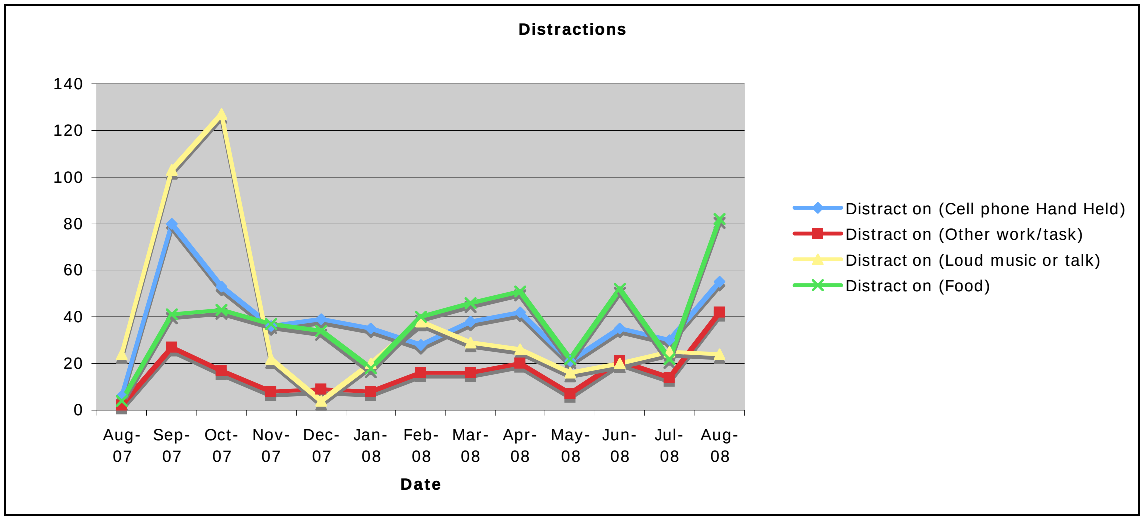

Figure 18: Driver Distractions

SECTION 6:
CONCLUSIONS

Summary

The Video Monitoring Pilot Project ran for approximately one-year duration at the Caltrans District 11 Maintenance Yard. This Pilot Project attempted to quantify and eventually modify driver's performance via the use of a monitoring device within the vehicle. During the first six months, no feedback from management was given to the operators in order to establish a baseline performance standard. At around the six-month mark, management began providing coaching to the operators regarding their performance based on the infractions detected by the monitoring device. An analysis of the year long data stream provides a number of conclusions:

- Coaching is effective in modifying driver behavior. However, coaching must be repeated at regular intervals in order to maintain effectiveness.

- The Caltrans operators' rate of accidents due to distractions is below the rate established by the test pool of the Virginia transportation study. This indicates a conscientious and professional operating organization.

- Lack of seat belt usage is evident. This is unacceptable and a heavy emphasis must be made on consistently using the seat belts.

- Inadequate selection of the test fleet. Trucks and sweepers with harsh suspensions and off-road work create an unnecessarily large amount of false positives.

- Poor return on investment. During the study period, direct savings could only be attributed to increased fuel economy due to enforced reduction in operating speeds. Other cost savings, such as reduced maintenance and accident costs, could not be ascertained due to inadequate vehicular operating histories and utilization data.

- There is evidence of a lack of or inadequate communication between Caltrans management and operating field personnel. The techniques and goals of this pilot project were not effectively disseminated, potentially jeopardizing the study.

Recommendation

Based on the conclusions from this Pilot Project, the following is recommended:

- Due to the expense of a fleetwide deployment, restrict installation of the SmartDrive unit to operating personnel with a history of poor operating practices. This will allow for resources to be concentrated on those that need it most.

- Similarly, only instrument vehicles that can provide consistent and reliable data.
- It might be prudent to install a unit in new-hire or probationary personnel vehicles in order to establish best practices early on.
- Improve seat belt utilization.
- Equip vehicles with a speed governor to eliminate excessive fuel consumption via speeding.
- Investigate a simplified continuous vehicular video recording device in order to provide a video record in the event of an incident; only when there is an incident will the video and audio record be retrieved.
- Recurrent training for vehicular best practices.
- Finally, improve communication methods between Management and operating field personnel. Effective test and implementation of advanced research projects require all of those involved to be "on the same page."

For Further Studies

In addition to the direct cost savings derived from increased fuel economy due to reductions in speed, other indirect cost savings may be gained from areas such as reduced maintenance due to more optimum operation of vehicles. Optimum operation of the vehicles by the operators may result from the continuous improvement in driver training and behavior via the events captured by the SmartDrive unit. In the context of this study, these indirect cost benefits could not be determined due to lack of current and historical utilization and maintenance data of the vehicles. This area of cost reduction shows great promise in creating significant savings to Caltrans. If it is desired to study this area of cost savings, the following is recommended:

- In addition to the SmartDrive unit to capture operating events for use via the driver training curriculum, install an additional device or modify the SmartDrive unit to record vehicle operating history. Ideally, this additional recording device should provide continuous time and speed measurements, a record of brake applications, and estimated throttle input. GPS location tracking may also be useful in providing additional information. Once the vehicles operating histories can be measured, so can the change in maintenance costs via changes in driver training.

APPENDIX A: GENERIC SMARTDRIVE POLICY

APPENDIX B: OPERATOR'S REVIEW AND COMMENT FORM

APPENDIX C: COMPLETED OPERATOR'S REVIEW AND COMMENT FORMS

APPENDIX D: MANAGER'S REVIEW AND COMMENT FORM

APPENDIX E: COMPLETED MANAGER’S REVIEW AND COMMENT FORMS

APPENDIX F: RAW DATA