Advanced Highway Maintenance and Construction Technology Research Center

Department of Mechanical and Aerospace Engineering
University of California at Davis

Identifying Excessive Vehicle Idling and Opportunities for Off-Road Fuel Tax Credits for Stationary Operations in the Caltrans Fleet - Phase 1

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16. Abstract

This report documents the research project "Identifying Excessive Vehicle Idling and Opportunities for Off-Road Fuel Tax Credits for Stationary Operations in the Caltrans Fleet - Phase 1," performed in response to a California Department of Transportation (Caltrans) Request for Proposals (RFP). The primary goals of this project were to identify baseline idling statistics for a selected set of test vehicles, identify excessive idling situations, identify stationary idling during work activities, and approximate fuel use for Caltrans vehicles under the various usage categories. A commercial-off-the-shelf (COTS) Automated Vehicle Location (AVL) system was used in each vehicle for GPS-based location, data sensing, and communications. AHMCT developed vehicle- and task-dependent criteria to define conditions for active work, and the needed trigger inputs to the commercial system to identify periods of active work. AHMCT instrumented a diverse fleet of 30 Caltrans vehicles, and supported extensive field data collection over at least a year for each instrumented vehicle. In addition, AHMCT developed the necessary back-end database (DB) and front-end user interface (UI) to support researcher and Caltrans visualization and analysis of the resulting data set. This report includes analysis of the data set, summary reports, and a discussion of the visualization and analysis tools. Based on the quantitative data and analysis, the report provides recommendations for improvement in equipment and procedures. For example, there are cases where it may be reasonable to install idle shutdown systems in Caltrans vehicles in order to reduce idle time and fuel consumption without impacting task execution.

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This report documents the research project "Identifying Excessive Vehicle Idling and Opportunities for Off-Road Fuel Tax Credits for Stationary Operations in the Caltrans Fleet - Phase 1," performed in response to a California Department of Transportation (Caltrans) Request for Proposals (RFP). The primary goals of this project were to identify baseline idling statistics for a selected set of test vehicles, identify excessive idling situations, identify stationary idling during work activities, and approximate fuel use for Caltrans vehicles under the various usage categories. A commercial-off-the-shelf (COTS) Automated Vehicle Location (AVL) system was used in each vehicle for GPS-based location, data sensing, and communications. AHMCT developed vehicle- and task-dependent criteria to define conditions for active work, and the needed trigger inputs to the commercial system to identify periods of active work. AHMCT instrumented a diverse fleet of 30 Caltrans vehicles, and supported extensive field data collection over at least a year for each instrumented vehicle. In addition, AHMCT developed the necessary back-end database (DB) and front-end user interface (UI) to support researcher and Caltrans visualization and analysis of the resulting data set. This report includes analysis of the data set, summary reports, and a discussion of the visualization and analysis tools. Based on the quantitative data and analysis, the report provides recommendations for improvement in equipment and procedures. For example, there are cases where it may be reasonable to install idle shutdown systems in Caltrans vehicles in order to reduce idle time and fuel consumption without impacting task execution.

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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 Aerospace 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

AHMCT	Advanced Highway Maintenance and Construction Technology Research Center
API	Application Programming Interface
AVL	Automatic Vehicle Location
Caltrans	California Department of Transportation
CAN	Controller Area Network
COTS	Commercial Off–The-Shelf
DB	Database
DOE	Caltrans Division of Equipment
DOT	Department of Transportation
DRI	Caltrans Division of Research and Innovation
ECU	Engine Control Unit
ESC	Caltrans Equipment Service Center
GPRS	General Packet Radio Service
GSM	Global System for Mobile communications
LED	Light Emitting Diode
MRM	Mobile Resource Management
OEM	Original Equipment Manufacturer
PTO	Power Take-Off
R&D	Research & Development
RFP	Request for Proposals
RPM	Revolutions Per Minute
SAE	Society of Automotive Engineers
TAG	Technical Advisory Group
UI	User Interface
WT	Work Trigger(s)

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CHAPTER 1: INTRODUCTION

Background and Motivation

Problem

The amount of idling of vehicle engines and the amount of fuel used during periods of a vehicle's stationary operation are currently unknown. Caltrans can benefit by quantifying baseline idling, excessive idling, and fuel used by vehicles during stationary operation. Additionally, highway fuel tax is currently applied to all fuel consumed by on-road licensed vehicles, whether or not it is used on or off the road. If fuel used by these vehicles during periods of stationary work-related use can be identified, then a tax savings may be realized for Caltrans. Such quantitative data can identify areas for improvement in equipment and/or procedures and may lead to fuel and CO_2 emission savings for the Caltrans fleet.

Background

As noted in the Caltrans problem statement which this research addressed, Caltrans owns and operates about 14,000 vehicles Statewide, consisting of approximately 580 different vehicle types. Many of these vehicles' engines may be idled excessively, which may vary by vehicle type and application. Also, many of these vehicles operate a power take-off (PTO) system while stationary to perform work on the roadway. Reducing excessive idling time will save in fuel costs and air pollution.

Research Approach

AHMCT instrumented 30 Caltrans vehicles with commercial-off-the-shelf (COTS) fleet tracking, sensing, and communications components. These systems provide vehicle location, vehicle sensor data (depending on engine type and data bus), and communications to a central data repository. With the available information, along with AHMCT-developed customized input triggers to identify periods of active work, Caltrans can quantify idling and fuel use, and identify periods of stationary idling when work is being actively performed. Work triggers (WTs) are specific for a given vehicle type or a particular work activity (e.g. for a sweeper). Identification of these custom triggers and development of appropriate trigger inputs to the COTS system were an important part of the proposed research.

Once the Caltrans research fleet was instrumented, AHMCT performed field data collection and subsequent analysis. The equipped vehicles were used in normal Caltrans operations. No additional operator training was required to support the data collection. Field data was transmitted to the vendor's central data repository by the on-board commercial communications system, and archived for subsequent analysis and reporting. AHMCT worked with the vendor to arrange access to the data, which was hosted by the vendor for the duration of their business contract. To support long-term storage, visualization, and analysis, AHMCT developed means to store and access the data from its own server. In this way, AHMCT was able to perform a variety of statistical analyses to achieve the stated research objectives, and can provide continuing access for future analysis by AHMCT and Caltrans. Standard reports are available from the vendor web site, along with any custom reports developed for AHMCT's analysis. As a key aspect of the project, AHMCT developed a visualization and data analysis tool, which is now available for Caltrans use.

The on-board system is based on commercial-off-the-shelf (COTS) equipment. The unit selected, the InfoX IX-302, referred to herein as a Preco, is made by PreCise MRM (Mobile Resource Management), a subsidiary of Force America, Incorporated. Use of COTS hardware facilitates any future deployment and use by Caltrans. The commercial system provides geo-stamping via GPS (location, heading, speed, date, and time), access to vehicle data (via in-vehicle data networks, including SAE J1708 CAN bus and SAE J1939), and communications to a data center via cellular General Packet Radio Service (GPRS). The system also supports up to six digital input/output (I/O) ports that can be used to input a digital trigger signal to the device. AHMCT worked with the project's Technical Advisory Group (TAG) and other Caltrans personnel to identify Work Triggers (WTs) that indicate active work periods, and then developed the necessary systems to provide WT inputs to the commercial system. Thus, recorded data also indicate whether or not active work is occurring. With this, analysis can provide fuel use (rate, gal/hr) during both working and non-working (while, perhaps, stationary, i.e. idling) periods. This information may support application for fuel tax rebates, help quantify Caltrans activities and fuel use, and identify areas for improvement and fuel reductions, with corresponding economic and environmental benefits to the State.

The research methodology, as discussed in detail in this report, included:

- Formation of a technical advisory group (TAG),
- Clarification and determination of activities that qualify for fuel tax rebate, and identification of associated Work Triggers (WTs),
- Definition of test vehicle candidate selection criteria, and subsequent test vehicle selection,
- Acquisition and installation of commercial off-the-shelf (COTS) data collection and communication systems,
- Extensive field data collection,
- Development of visualization and analysis tools for researcher and Caltrans use, and
- Analysis of collected field data.

Overview of Research Results and Benefits

The quantitative data provided by the proposed research will identify areas for improvement in equipment and/or procedures, and substantiate fuel tax credits for the Caltrans fleet. For example, it may be possible to identify situations where idle shutdown systems could be installed and used in existing Caltrans vehicles in order to reduce idle time and fuel consumption without impacting task execution. If fuel used by these vehicles during periods of stationary use can be identified then a tax savings should be realized Environmental benefits should be realized as well, for the DOT and the State.

As the bulk of the hardware and software used in this the proposed research will be commercial-off-the-shelf available from the vendor selected in the research project, continued use by Caltrans in further deployment and testing will be relatively easy. Caltrans can immediately continue further data collection, testing, and analysis, for the vehicles instrumented in the proposed research. Caltrans can also procure similar systems for additional vehicles, should they opt to expand the study or implementation. For vehicles and tasks equivalent to those in the study, additional instrumentation and analysis would be a simple procedure. For other vehicle types or tasks, the methodologies developed in the proposed research would illustrate a viable approach to apply similar instrumentation and analysis. Thus, the proposed research (instrumentation and analysis methods) would be immediately applicable to practice, and could provide Caltrans operational improvements, fuel reductions, and corresponding environmental benefits.

Reducing fuel consumption through reduced engine idle time can help California reduce its petroleum dependency as well as contribute to cleaner air and lower greenhouse gas emissions. Also, this research may provide a means for achieving a fuel tax savings [1] which could be translated to replacing older, dirty vehicles and engines with newer, cleaner vehicles and engines.

The remainder of the report provides more detail regarding the research problem, information about the COTS system, the research vehicle fleet, work triggers, system installation, and field data collection. In addition, the report presents the visualization and analysis tool developed by AHMCT for this research, and a summary of the data analysis. Finally, the report provides summary conclusions and recommendations for future deployment or research.

The key deliverables of this project include:

- COTS GPS location, sensing, and communications systems installed in Caltrans vehicles,
- Field collection data and summary information,
- Visualization and analysis tools for researcher and Caltrans use, and
- Test results, analysis, and documentation

CHAPTER 2: PROBLEM DETAILS AND COTS SYSTEM INFORMATION

Problem Details

As noted in the Caltrans problem statement that led to this research, Caltrans owns and operates approximately 14,000 vehicles statewide consisting of approximately 580 different vehicle types. Many of these vehicles' engines may be idled excessively, and this may vary by vehicle type and application. Also, many vehicles operate a power take-off (PTO) system while stationary to perform work on the roadway. Reducing excessive idling time will save in fuel costs and air pollution.

Caltrans initiated this research to determine if excessive vehicle engine idling time is occurring in the Caltrans fleet, how much engine idle time can be reduced with idle shutdown systems installed on fleet vehicles, and some estimation of how much fuel and emissions can be reduced by applying idle shutdown systems. In addition, per Caltrans RFP, stationary operation of vehicle engines operating a PTO system may be considered an off-road application and, therefore, the fuel consumed during this use may not be subject to the State fuel tax [1]. The research intent is to identify the applicable fleet, and a commercially-available, vehicle-mounted system or systems capable of capturing data needed to identify a vehicle's total fuel consumption while stationary with its engine operating a PTO system. The research includes the purchase and installation of identified technologies, and a pilot demonstration.

This research contributes to the departmental goals of Stewardship and Mobility by reducing petroleum use and/or exhaust emissions on the state highway system without impacting Caltrans ability to deliver projects or operate the state highway system. Also, the research contributes to the California Transportation Plan goals of enhancing the environment, supporting the state's economy, and promoting community values.

Caltrans currently maintains a list of diesel-powered equipment and the percentage of fuel used while operating in a work zone (off-highway). The data collected and tools developed in the current research project may be helpful in calibrating and/or justifying the percentages in this Caltrans table. The table may be used to apply for diesel fuel tax reimbursement for this off-highway vehicle fuel use while working.

The goals of the research project are to identify an applicable research fleet; identify, procure, and install a COTS system for data collection, develop the needed tools for data visualization and analysis, and perform the data analysis to establish idling and fuel use characteristics for the research fleet, leading to subsequent recommendations for equipment modifications and/or operational changes to reduce idling and fuel use.

Data Requirements and Data Collection Equipment Selection

To support the research objectives, an onboard vehicle system is needed to collect the following vehicle operational data: vehicle speed, location, time, power-take-off status, other onboard vehicle system status, fuel consumption rate, and engine status. Examining the data requirements specification, the researchers developed the system requirements for the onboard vehicle data collection system as follows:

- Include onboard GPS and record time and location
- Have at least 3 digital input ports to detect and record vehicle auxiliary system status such as power take-off (PTO) or vehicle rotating beacon light
- Have vehicle CAN (Controller Area Network) buses (SAE J1708 and J1939) interface and communication software to poll engine rotational rate (RPM) and fuel consumption rate (gal/hr) data from the Engine Control Unit (ECU)
- Have sufficient onboard data storage for a few days of data
- Have onboard wireless data communication link(s) (WiFi and/or Cell phone) to offload data
- Server on the internet to receive and store data from all vehicles
- Ability to download the final data set for analysis
- Prefer COTS system, and within the project budget and time constraints

An extensive COTS products review was conducted to find the best commercially available system that would fit the above requirements for data collection. While there are a lot of Automatic Vehicle Location (AVL) systems available to choose from, only a few systems support external digital inputs. There are even fewer systems that communicate with the ECU to obtain the instantaneous fuel consumption rate. Qualcomm's SensorTRACS system has been used by others to study idling fuel use. The system was effective in indentifying idling duration. However, the system was not able to obtain the instantaneous fuel consumption during the idling time. Qualcomm personnel has presented to AHMCT researcher on their system in tracking idling fuel use. In their presentation, Qualcomm assumed an average of 1 gallon per hour fuel consumption rate for idling diesel engine to estimate fuel use during idling. Obtaining the instantaneous fuel consumption rate from the ECU is not just a simple matter of having the proper communication buses; each manufacturer's ECU may use a different and often proprietary protocol to communicate. Thus, extensive testing and sometimes reverse engineering with various vehicle model and system are required to correctly poll the ECU for the engine data and fuel consumption rate. While AHMCT researchers have the ability to develop such a system, the budget and time constraints of the project dictated use of COTS equipment. After the extensive product review, the Preco system was selected to be the data collection system. During the research project, AHMCT researchers worked closely with Preco system engineers to enhance the Preco system's ability to obtain the instantaneous fuel consumption rate from Caltrans vehicles' ECUs. Preco's systems engineer's willingness to work with our researchers was critical in the project's success in obtaining the fuel consumption rate for most of the instrumented vehicles.

COTS Preco System Information

The Preco PreCise system provides a few common machine CAN interfaces along with six generic switch / digital input ports and two discrete digital output ports. It has a built-in GPS receiver to provide location, vehicle speed, and time information. The PreCise system has the ability to be customized both in communication hardware and software (firmware). Preco engineers were quite willing to work with AHMCT to maximize our project success potential. The commercial vehicle data is transmitted via one of the onboard wireless communication links (GPRS, GSM, Wi-Fi, etc.). The data can be accessed through easy-to-use internet-based web services or Preco's fully-hosted reporting software. The Wi-Fi (802.11 b/g) enables download of large data transmissions with no cellular airtime charges when the vehicle returns to its home base. The PreCise system has been designed to receive CAN-based inputs from On-Board Diagnostics of heavy equipment. This feature is critical in obtaining the vehicle instantaneous fuel consumption rate and engine rotational speed.

The PreCise systems used in the project use the GSM wireless (cellular) data link to upload the vehicle data to the Preco web server. While the WiFi option is free of monthly data service charges, it would require setting up a WiFi station at each test site maintenance yard building. Since the project data collection duration is short, the GSM wireless data upload option results in less total cost. The data is uploaded whenever a GSM data link is available. However, the wireless GSM service is not available in some rural areas. Vehicles selected for the project had to be located in areas with GSM wireless services. The collected vehicle data were uploaded to the Preco web server periodically. The Preco web server provides viewing of a subset of the entire data set. The entire data set was then downloaded to an AHMCT server for final visualization and analysis using AHMCT custom-developed software.

The overall system architecture is provided in Figure 2.1. The Preco system, including integrated GPS/WiFi/GSM antenna is shown in Figure 2.2. Finally, the detailed technical specifications are provided in Table 2.1.

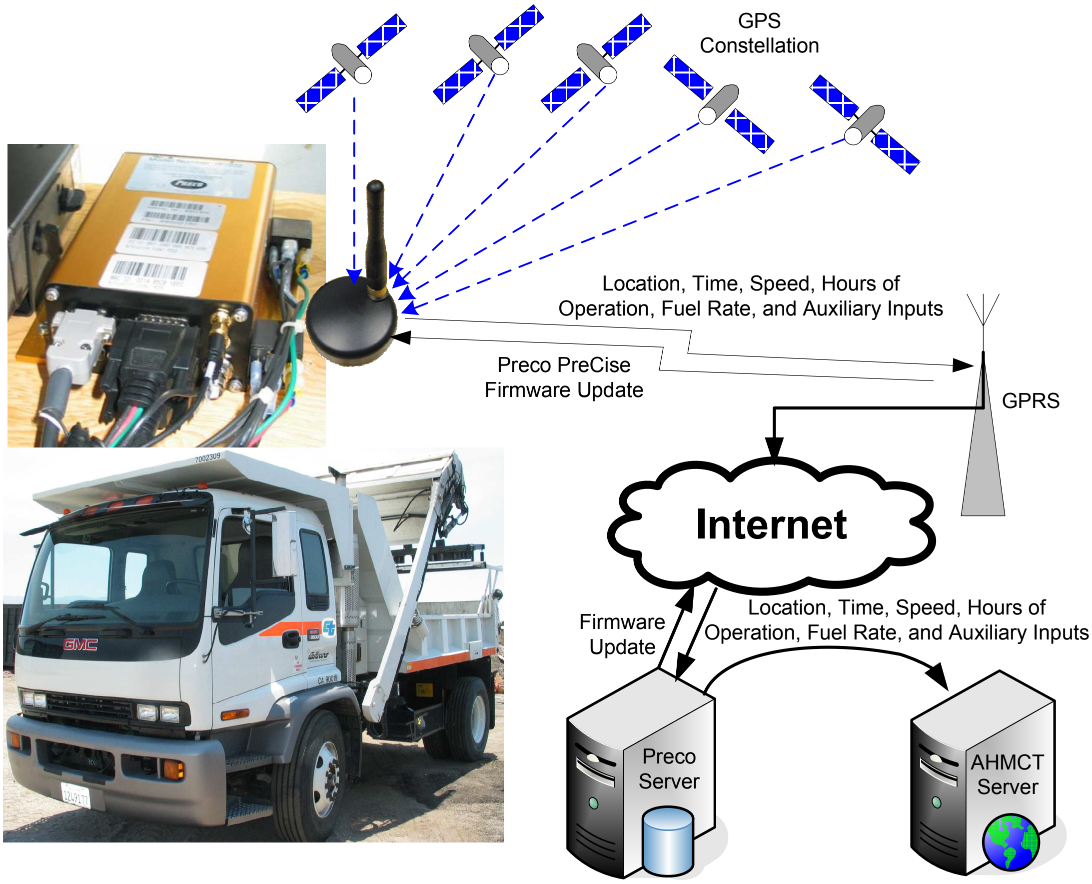

Figure 2.1: Overall system architecture (courtesy PreCise MRM)

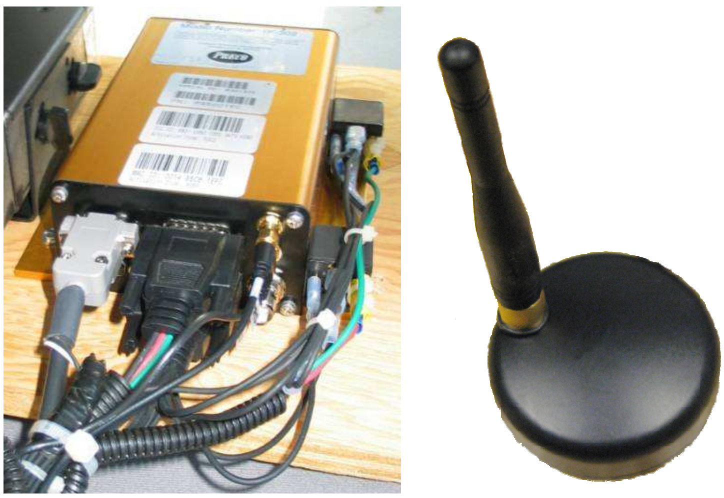

Figure 2.2: COTS Preco PreCise system with integrated GPS/WiFi/GSM antenna (courtesy PreCise MRM)

Table 2.1 Preco system technical specifications

Input Voltage:	10-32 VDC
Operating Temperature:	-30ºC to +60ºC
Operating Humidity:	95% (RH)
Storage Temperature:	-40ºC to +100ºC
Sensor Dimensions:	(in) 2.3 (H) x 5.9 (W) x 7 (D)
Weight:	2.2 lbs / 1.0 kg
Shock:	+/- 25g
Vibration:	SAE J1455
Wired Communication	RS-232, SAE J1708, SAE J1850, SAE J1939, SAE J2284
Wireless Communications	GSM/GPRS and 802.11 B/G
Input	Six discrete digital inputs with internal pull-ups (pull to ground to activate)
Output	Two discrete digital outputs, open drain, short-circuit protected 350mA
Memory	16 MB Flash Memory
CAN	SAE J1939-15 SAE J2284
Mounting	Flexible options for in-vehicle mounting
Firmware Update	Supports over-the-air updates

CHAPTER 3: TEST VEHICLE SELECTION, SYSTEM INSTALLATION, AND FIELD DATA COLLECTION

Test Vehicle Selection

Early project work developed test criteria for the research vehicle fleet selection. These criteria included relevance to the research problem (i.e. a vehicle type that spends a large enough percentage of its time "working while idling"), suitability for data collection (e.g. the vehicle include a modern engine databus such as SAE J1939 or J1708), geographic location (both diversity and reliable access to wireless data services), district location and distribution. The selection criteria are meant to lead to a fleet that corresponds to the broad range of Caltrans vehicles (types, regions, districts) that would benefit from determining idling characteristics and possible means to reduce unnecessary idling.

The selection criteria were discussed with the project Technical Advisory Group (TAG), including members from the Caltrans Division of Equipment (DOE) and Division of Research and Innovation (DRI). A candidate set of vehicles was provided by DOE based on the criteria. This list was further evaluated for suitability, and a final set of vehicle was selected. The vehicle list is maintained internally by Caltrans. Table 3.1 provides the general vehicle information for the research fleet sorted by maintenance class and district. Here, the description, and the current off-highway work zone fuel exemption percentage are taken from [2], when available. Where no entry is found in [2] for a particular maintenance class, the description is from information provided by Caltrans Division of Equipment, and off-highway exemption is assumed to be 0%. Photos are included for 28 of the 30 research vehicles. Figure 3.1 shows the geographic location for the vehicle installations. The numbers in the icons indicate the number of vehicles installed at that particular location. In total, 30 vehicles were instrumented under this research effort. The data collection systems remained in the target vehicles at the conclusion of the research to support future applications and/or research.

Table 3.1: Research fleet sorted by maintenance class and district

	Eq. ID	**Maint. Class**	**Description**	**District**	**Off-Hwy Exempt**
	0131202	01382	Personnel hoist	3	0%
	7000251	02350	Cargo body w/Hoist 12' diesel	3	80%
	7000293	02350	Cargo body w/Hoist 12' diesel	10	80%
	0257596	02552	Cargo truck, 15 ft, w/Scissor lift	4	80%
	0257342	02593	Tilt cab 1000 GL	3	0%
	7000038	02920	Dump body	4	80%
	7000034	02920	Dump body	4	80%
	7000035	02920	Dump body	4	80%
	7002305	03317	Dump body w/Loader, Tilt cab	7	50%
	7002309	03317	Dump body w/Loader, Tilt cab	8	50%

	Eq. ID	Maint. Class	Description	District	Off-Hwy Exempt
	7000055	03321	Dump body w/Plow	3	50%
	7000059	03321	Dump body w/Plow	3	50%
	7002218	03325	Dump body w/2 plows & spreader	2	50%
	7002210	03325	Dump body w/2 plows & spreader	2	50%
	7002217	03325	Dump body w/2 plows & spreader	2	50%
	7000020	03379	Personnel hoist ART 45 ft UB elec	3	80%
	7000081	03384	Trash compactor, 16 cy rear load	10	50%
	7000273	03398	Fence dump body	4	0%
	0470500	04700	Truck tractor	6	50%
	7001934	05300	Truck Tractor	3	0%
	7002323	05325	Dump body w/2 plows & spreader	8	50%

	Eq. ID	Maint. Class	Description	District	Off-Hwy Exempt
	0530509	05325	Dump body w/2 plows & spreader	8	50%
	0537343	05349	Cargo body w/o hoist	9	80%
	0531829	05349	Cargo body w/o hoist	10	80%
	7000098	05360	Striper, low entry cab hot paint	9	80%
	0539905	05380	Tank, spray rig, 3,000 gal	10	80%
	0539906	05380	Tank, spray rig, 3,000 gal	10	80%
	7001200	05383	Catch basin and sewer line cleaner	10	80%
	7002283	17103	Rotary snowplow, conv mt, 3500 T/Hr	3	100%
	7000347	56808	Sweeper, conv. 3-4 cy, diesel	10	100%

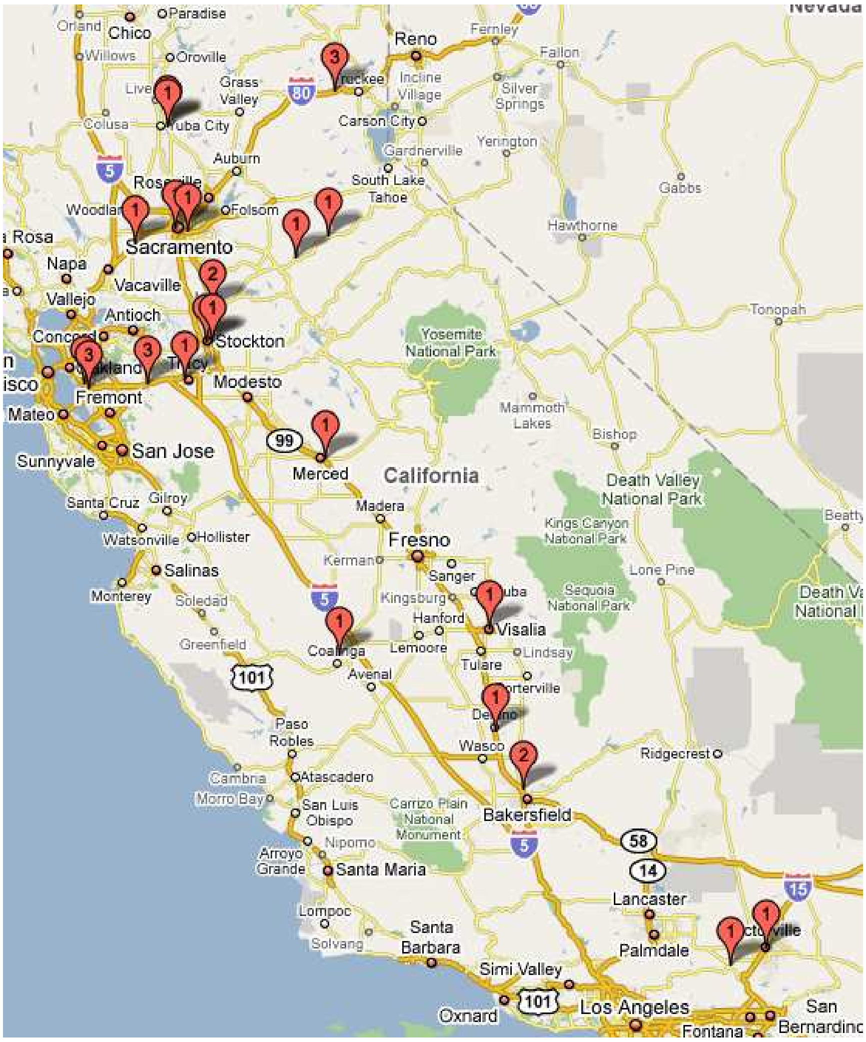

Figure 3.1: Vehicle installation locations in Google Maps

<u>Work Triggers</u>

For each vehicle class, a set of one or more work triggers (WTs) were identified based on the type of work typically performed for that vehicle class. Based on discussions with the TAG, a primary indicator of work being performed for any Caltrans vehicle is when the strobe, amber strobe, or rotating work light (herein all referred to as rotator light) is turned on. Thus, this was a standard WT for all vehicles except for the truck tractor, equipment ID 7001934. The WTs for each vehicle are shown in Table 3.2.

Table 3.2: Work triggers sorted by vehicle maintenance class and district

	Eq. ID	Description	Work Trigger 1	Work Trigger 2
	0131202	Personnel hoist	Rotator light	Hoist PTO
	7000251	Cargo body w/Hoist 12' diesel	Rotator light	
	7000293	Cargo body w/Hoist 12' diesel	Rotator light	
	0257596	Cargo truck, 15 ft, w/Scissor lift	Rotator light	
	0257342	Tilt cab 1000 GL	Rotator light	PTO
	7000038	Dump body	Rotator light	PTO
	7000034	Dump body	Rotator light	
	7000035	Dump body	Rotator light	PTO
	7002305	Dump body w/Loader, Tilt cab	Rotator light	
	7002309	Dump body w/Loader, Tilt cab	Rotator light	

	Eq. ID	Description	Work Trigger 1	Work Trigger 2
	7000055	Dump body w/Plow	Unable to collect work trigger data for this vehicle	Unable to collect work trigger data for this vehicle
	7000059	Dump body w/Plow	Unable to collect work trigger data for this vehicle	Unable to collect work trigger data for this vehicle
	7002218	Dump body w/2 plows & spreader	Rotator light	
	7002210	Dump body w/2 plows & spreader	Rotator light	
	7002217	Dump body w/2 plows & spreader	Rotator light	
	7000020	Personnel hoist ART 45 ft UB elec	PTO	Rotator light
	7000081	Trash compactor, 16 cy rear load	Rotator light	PTO
	7000273	Fence dump body	Unable to collect work trigger data for this vehicle	Unable to collect work trigger data for this vehicle
	0470500	Truck tractor	Rotator light	
	7001934	Truck Tractor	None	None
	7002323	Dump body w/2 plows & spreader	Rotator light	

	Eq. ID	Description	Work Trigger 1	Work Trigger 2
	0530509	Dump body w/2 plows & spreader	Rotator light	
	0537343	Cargo body w/o hoist	Rotator light	
	0531829	Cargo body w/o hoist	Rotator light	
	7000098	Striper, low entry cab hot paint	Rotator light	
	0539905	Tank, spray rig, 3,000 gal	Rotator light	
	0539906	Tank, spray rig, 3,000 gal	Rotator light	
	7001200	Catch basin and sewer line cleaner	Rotator light	
	7002283	Rotary snowplow, conv mt, 3500 T/Hr	Unable to collect work trigger data for this vehicle	Unable to collect work trigger data for this vehicle
	7000347	Sweeper, conv. 3-4 cy, diesel	Rotator light	

For the identified WTs, the research team designed and installed any necessary hardware to interface the associated vehicle hardware (e.g. switches, analog or digital outputs, etc.) to the digital inputs of the Preco system. The Preco system logged each of its active digital inputs to keep track of when the WTs were active ("on"). This information, combined with location and fuel use data, allows detailed classification of whether work is being performed for a given vehicle, during travel, idling, or pausing (see Chapter 4 for definition of these terms).

System Installation

Based on the selected research fleet summarized in Table 3.1, an AHMCT technician worked with each maintenance yard to schedule access, traveled to the maintenance yards, and installed the Preco system and associated work trigger hardware. Each system was validated for functionality, activated, and tested to confirm that data was being collected and transmitted to the central Preco server. Detailed installation logs were maintained for each vehicle. An overview of the general approach for system installation is provided in Appendix A. Of course, specifics varied for individual vehicles, and the variances are noted in the detailed installation log for each vehicle.

Field Data Collection

Field data collection was performed on each of the research vehicles for at least one full year of normal Caltrans vehicle operations. At the time of installation, AHMCT provided a brief orientation regarding the purpose of the research study, and the type of data collected and logged by the system. Any questions or concerns of the operators or supervisors were addressed at that time.

No special operator training was required to support the data collection. The systems were designed and installed to be minimally obtrusive, and in general had zero impact on vehicle operation and usage. The work triggers were instrumented so that no operator input was required to indicate work, other than their normal work operations, e.g. turning on the rotator light, engaging the PTO, turning on a sand spreader, or similar.

Data was collected and logged to the on-board COTS AVL unit (the Preco PreCise system), and periodically uploaded to the vendor’s server when a cellular signal was available. This data was then available for researchers and Caltrans to visualize using the vendor’s web interface.

The complete data set was downloaded by AHMCT so that it will be available for long-term AHMCT and Caltrans use. Visualization and analysis of the data is best performed using AHMCT’s custom-developed tool, described in Chapter 4.

CHAPTER 4: VISUALIZATION AND ANALYSIS TOOL, AND SUMMARY OF DATA ANALYSIS

Visualization and Data Analysis Tool

A visualization and data analysis tool was developed to support the current project's data analysis task. This tool has also been provided to Caltrans for its internal use in examining the data collected in the course of the project, for their independent evaluation and validation. This tool could be used for future analysis on additional collected data.

The COTS vendor has a useful web-based fleet management and visualization tool for the collected data. However, the vendor's tool was not well-suited for the specific goals of this research project. Their tool provides text and map-based visualization for vehicle location and usage, but does not provide a means for visualizing the additional data collected in this research, e.g. work trigger status, engine idling status, and similar critical information.

In addition, the web access to, and data storage on, the vendor's site are limited to the term of the business contract, and maintaining these services after that would incur further cost to Caltrans. Web access requires on-going subscription for each vehicle. Also, the vendor hosts the collected data on its server for a number of years (three years was indicated at one point), then moves the data into archive. Caltrans has the option to maintain the data on the vendor's server, but again at additional cost. Finally, the vendor noted the possibility of moving the data back from archive to the server, also at some cost.

Based on the data visualization and analysis needs, as well as the importance of Caltrans maintaining control over its own data, AHMCT developed a means to transfer the data from the vendor's server to a database server at AHMCT. A database schema was developed, and implemented using PostgreSQL.

The vendor provides a useful web Application Programming Interface (API) to programmatically access the data, and also provided technical support to our software team to assist in using this API. Via this API, we were able to download all of the collected data into the PostgreSQL database, which is maintained on an AHMCT server that is accessible to the research team and Caltrans.

The key tool that the user interacts with is the visualization and analysis program, referred to as IDLEVIEW. This tool was designed and developed specifically for this task, and leverages the PostgreSQL database on the backend. An IDLEVIEW screenshot is shown in Figure 4.1. This figure shows the asset details tab. Other available tabs provide overview information and overall fleet details. The asset details tab provides:

- a picture of the vehicle,
- general information about the vehicle (ID, Preco serial number, vehicle type, odometer, etc.),

- a calendar widget for selecting date ranges for the visualization and analysis,
- a map of vehicle location for the selected date range,
- and graphical (fuel rate vs. time) and tabular information on fuel usage by idling regime, including percentage and total hours for each regime. The instantaneous fuel consumption rate is obtained from the vehicle engine controller via the CAN bus.

The fuel use regimes for the data analysis are:

1. Travel (e.g. moving from a maintenance yard to a work site, no active WT). Not idle or paused.
2. Travel+Work (e.g. moving while doing work, such as with a snowplow or a sweeper, at least one active WT). Not idle or paused.
3. Idle (vehicle stopped with engine running longer than a set threshold of $Idle_{min}$, and no active WT)
4. Idle+Work (vehicle stopped with engine running for time longer than a set threshold of $Idle_{min}$, and at least one active WT)
5. Pause (vehicle stopped with engine running for time longer than a set threshold of $Pause_{min}$ but less than $Idle_{min}$, and no active WT)
6. Pause+Work (vehicle stopped with engine running for time longer than a set threshold of $Pause_{min}$ but less than $Idle_{min}$, and at least one active WT).

A "stationary" state is defined as the vehicle's speed being at most *v_stationary* MPH. An "idling" state is defined as the vehicle being in a stationary state for at least *t_idle* minutes with the ignition on. To calculate the results presented in this report, the following values were used:

v_stationary = 0.1 MPH

t_idle = 5 min.

Any idle duration over 90 min is considered as outliers. Outliers are rejected from the final overall statistics.

The threshold settings, $Idle_{min}$ and $Pause_{min}$, can be modified in the IdleView UI. Default values based on discussions with the TAG are $Idle_{min}$ = 5 minutes and $Pause_{min}$ = 2 minutes. Clearly, $Pause_{min} \leq Idle_{min}$.

The fuel consumption rate plot allows for zooming in or out, panning, and similar advanced charting options.

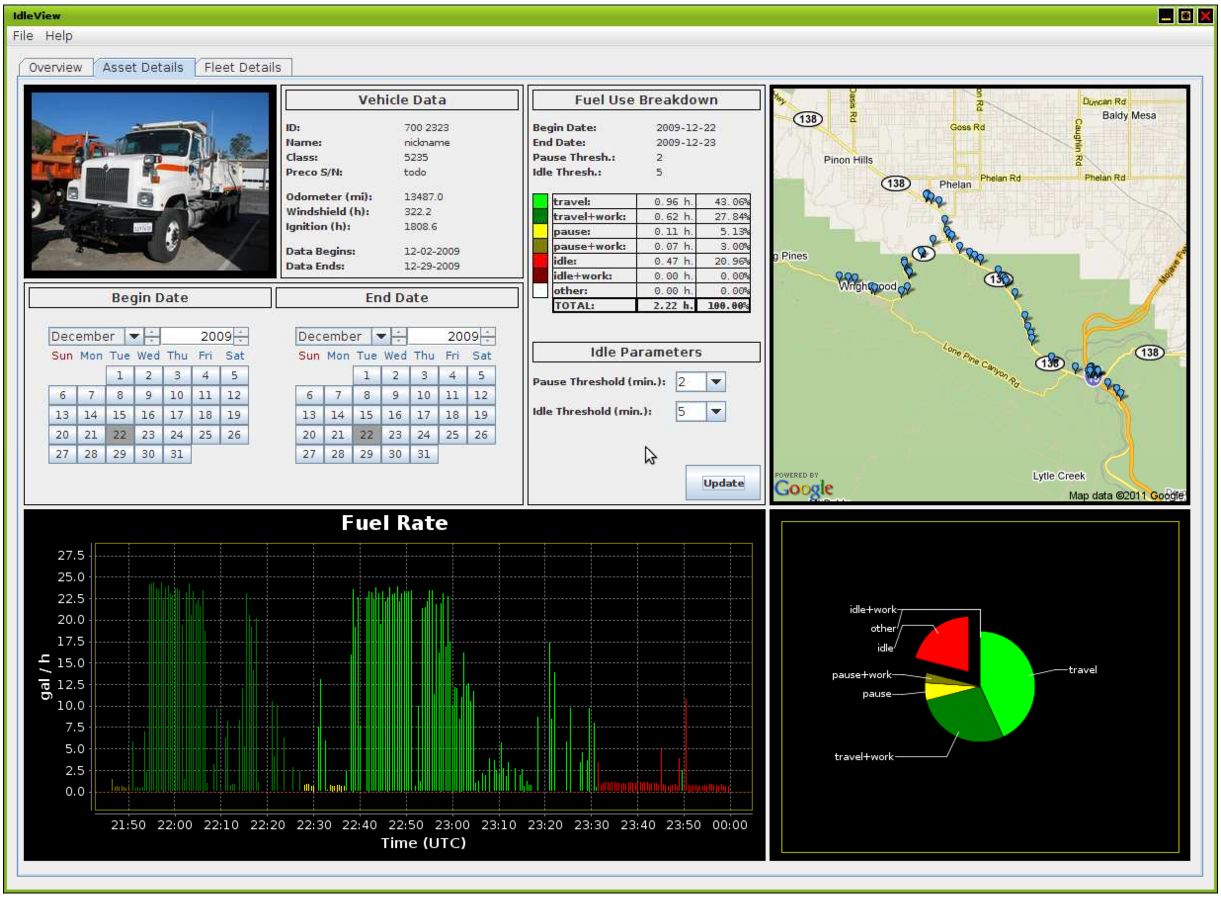

Figure 4.1: Screenshot of user interface for visualization and analysis: Asset details tab

Summary of Data Analysis

Herein we provide a variety of statistical analyses on the data including identifying baseline idling statistics, identifying excessive idling situations, identifying stationary idling during work activities, estimating fuel use during idling, and deriving approximate emissions during idling.

Fuel use during idling is calculated from the vehicle average idle fuel rate multiply by total idle duration. The idling fuel rate is relatively constant for each vehicle. This approach is sufficient to estimate fuel usage during idling, due to the low-frequency nature of the signal. However, based on the Preco sampling period of 30 seconds, estimation of fuel use during normal driving would not be sufficiently accurate using this approach.

Emissions during idling are estimated based on fuel use during idling. For this estimation, we use information available from the US Environmental Protection Agency (EPA) to translate approximate fuel usage into approximate carbon emissions. According to the EPA, the CO_2 emissions from a gallon of diesel = 2,778 grams x 0.99 x (44/12) = 10,084 grams = 10.1 kg/gallon = 22.2 pounds/gallon. More accurate emissions estimation would require instrumentation, sensing, and calibration on a per vehicle or at least per vehicle class basis; this was beyond the scope of the current study.

Summary of Data Analysis Results

Table 4.1 summarizes the findings of our data analysis. For each vehicle, we provided its survey duration, number of days that the vehicle is being used, total accumulated idle duration during the survey, average idle fuel consumption rate, and estimated total idle fuel used. The survey period for each vehicle varies from 8 to 20 months with an average of 14 months. This is caused by the different installation dates of the instrumentation for each vehicle.

The Preco system was able to log the vehicle instantaneous fuel rate from 25 vehicles out of the 30 vehicles instrumented. The average idling fuel consumption rate ranges from 0.5 gallons/hr to 2.2 gallons/hr. The idle fuel consumption rate depends on engine size. The average idle fuel consumption rate for all twenty-five vehicles is 0.96 gallons/hr. This is close to the 1 gallon/hr idle fuel rate that is being used in some idling studies in which the idle fuel rate is not being measured or logged. Thus, a 1 gallon/hr idle fuel consumption rate is a good figure to use as an estimate for a large fleet study. On the other hand, the variation of the idling fuel rate is quite large. The idling fuel rate should be measured and recorded if possible.

The fuel used while idling ranges from 0.65 to 9.6 gallons per month. The average for the entire fleet of 25 vehicles is 4.2 gallons/month. The average idle duration per instance for each vehicle ranges from 10 to 20 minutes, and the average fleet idling duration per instance is 15 minutes. In addition, the average number of idling events is 1.5 per day per vehicle. While these numbers seem small, the total fuel used while idling for the entire fleet during the survey period added up to 1584 gallons (17 tons of CO_2); and the total idling duration for the entire fleet is 1720 hours. Based on these numbers, the savings from minimizing idling duration for the entire Caltrans fleet would be significant.

The frequency distribution of each vehicle's idling duration for each idling event is plotted in Figure 4.2. Each curve represents a single vehicle. Some vehicles have more idling events than others because of their longer survey duration and higher frequency of use. Figure 4.2 shows that the majority of the idle events lasted less than 25 minutes for all vehicles. The distribution resembles a Poisson distribution as opposed to a normal Gaussian distribution. In addition, most idling events lasted between 5 to 15 minutes. Since the distribution for each vehicle is very similar, we could use the statistics of this small fleet (25 vehicles) to estimate the idle fuel use of the entire Caltrans fleet.

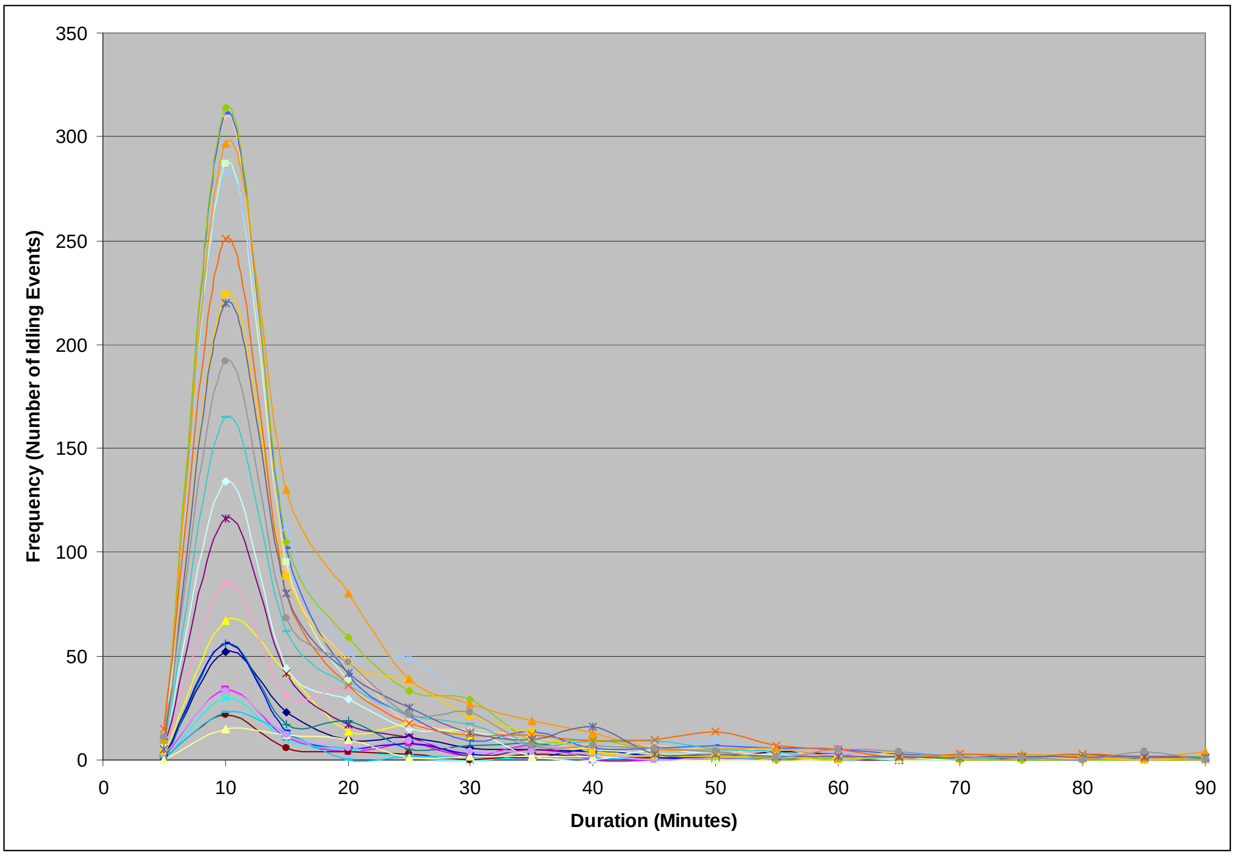

Figure 4.2: Example of Idling Event Duration Distribution.

However, the reader should be cautions when applying this preliminary result. These data have not taken into account the function of the vehicles and their modes of operation. Some of the idle events may be necessary for the operation of the vehicle. In addition, the locations of the idle events have not been examined. Some of the idle events may be necessary for repair and maintenance of the vehicle. In addition, due to the unforeseen failure of the data logging systems in recording the ignition events, there may be some small error introduced when identifying idling events. Interviews with vehicle operators should be carried out to identify the reason for leaving the vehicle idling. The mode of operation of these vehicles should also be examined. Some idling events could be associated with maintenance and administration of the vehicle.

Table 4.1 Summaries of Test Fleet Idling Statistics.

Vehicle ID	Survey Start Date	Survey End Date	Survey Duration (months)	Number of Days Vehicle In Use	Total Idle Duration (hrs)	Total Engine-on Duration (hrs)	Percentage of Time Spent Idling	Avg. Idle Fuel Rate (gph)	Idle Fuel Used/month (gal)	Est. Total Fuel Used Idling (gal)	Est. Total CO2 Emissions (lbs)	Avg. Idle Duration (min)	Number of Distinct Idling Events	Idle Event/Day Used
700 0020	6/20/2008	3/6/2009	8	83	44.2	185.4	27.4	0.88	4.87	39.0	865.4	20.3	131	1.6
025 7342	7/18/2008	8/19/2009	13	117	16.4	267.4	6.1	0.51	0.65	8.4	186.2	14.2	69	0.6
700 1934	8/29/2008	8/13/2009	11	72	47.4	225.9	21.0	0.54	2.32	25.5	566.2	16.2	176	2.4
700 0035	11/6/2008	8/18/2009	9	78	11.5	147.8	8.8	0.86	1.10	9.9	219.8	13.2	52	0.7
700 0273	11/8/2008	8/19/2009	9	144	44.3	373.7	13.0	1.07	5.24	47.2	1047.9	12.9	206	1.4
700 0038	11/14/2008	8/13/2009	8	159	11.2	469.5	2.4	0.82	1.15	9.2	205.1	15.6	43	0.3
700 0293	12/4/2008	8/13/2009	8	89	40.7	191.4	23.3	0.68	3.48	27.8	617.4	18.8	130	1.5
700 0081	12/6/2008	8/14/2009	8	142	23.7	438.1	6.6	0.99	2.93	23.4	519.6	14.4	99	0.7
053 9905	12/18/2008	8/14/2009	7	52	10.2	128.9	9.7	2.26	3.30	23.1	512.3	13.6	45	0.9
053 9906	3/14/2009	11/30/2010	20	287	62.2	949.6	8.2	0.87	2.70	53.9	1197.6	14.2	263	0.9
053 1829	4/4/2009	11/30/2010	19	360	93.7	1176.4	8.1	1.11	5.46	103.7	2301.4	11.7	480	1.3
700 0347	4/15/2009	11/30/2010	19	29	11.7	65.7	17.8	1.05	0.65	12.3	273.0	15.6	45	1.6
700 0034	4/17/2009	11/22/2010	19	305	142.1	1000.9	16.4	0.84	6.30	119.7	2656.4	14.6	585	1.9
700 1200	5/2/2009	11/20/2010	18	212	75.8	761.0	10.6	2.07	8.73	157.2	3489.3	19.7	231	1.1
025 7596	5/15/2009	11/25/2010	18	64	27.7	89.7	42.5	0.64	0.98	17.7	393.2	19.8	84	1.3
700 2210	5/20/2009	11/30/2010	18	284	112.3	1456.2	9.4	0.60	3.75	67.5	1498.9	12.7	532	1.9
700 2218	5/21/2009	11/30/2010	18	326	121.9	1906.9	8.7	0.56	3.78	68.0	1509.4	13.4	546	1.7
700 2217	5/21/2009	11/30/2010	18	240	94.8	835.4	18.3	0.83	4.36	78.6	1744.1	16.2	351	1.5
053 7343	6/25/2009	11/30/2010	17	257	123.3	732.3	17.7	1.05	7.61	129.3	2871.4	12.8	580	2.3
047 0500	6/30/2009	11/30/2010	17	244	108.1	605.2	20.9	1.51	9.62	163.5	3629.2	14.3	455	1.9
700 0251	6/23/2009	11/30/2010	17	207	163.3	501.9	36.6	0.72	6.94	117.9	2618.1	15.2	647	3.1
700 0098	6/26/2009	11/30/2010	17	304	123.4	919.5	13.6	0.90	6.53	110.9	2463.0	15.5	479	1.6
700 2323	8/12/2009	11/30/2010	15	241	105.7	647.4	17.9	0.88	6.21	93.1	2066.7	14.7	430	1.8
053 0509	8/13/2009	11/28/2010	15	254	104.2	841.3	16.3	0.74	5.15	77.2	1714.6	15.5	404	1.6

CHAPTER 5: CONCLUSIONS

Key contributions of this research project included:

- Development of requirements for a research fleet based on the indicated Caltrans problem and research questions. Identification of a research fleet based on requirements.
- Development of requirements for a COTS system, and identification of a COTS system that meets these needs.
- Identification of work triggers for the research fleet.
- Instrumentation of a research fleet of 30 Caltrans vehicles with the COTS system and associated work trigger inputs.
- Extensive field data collection for the research fleet.
- Design and development of a visualization and analysis tool, including front-end user interface and supporting back-end. This tool is available for Caltrans use.
- Download and conversion of field collection data from vendor site and format to AHMCT site and format. This data set is available for Caltrans use.
- Analysis of the field data to identify baseline idling statistics, identify excessive idling situations, identify stationary idling during work activities, estimate fuel use during idling, and derive approximate emissions during idling.

Benefits from the research and the continuing availability of the tools and data include:

- Ability to identify areas for improvement in equipment and/or procedures, and substantiate fuel tax credits for the Caltrans fleet.
- Potential for additional data collection for all or a portion of the research fleet, as the Preco systems remain with the vehicles for possible Caltrans use.
- Potential for reduced petroleum dependency in the Caltrans fleet, with corresponding benefits of cleaner air and lower greenhouse gas emissions.

The data set and visualization/analysis tool are both available for Caltrans use. AHMCT encourages direct interaction with the data by knowledgeable Caltrans personnel, and welcomes any discussion of findings.

The average survey period length was 14 months. The majority of idling events lasted less than 20 minutes, and the average duration of an idling event was 15 minutes. The average idling fuel consumption rate for all 25 vehicles was 0.96 gallons per hour. However, the total fuel consumption in idling during the survey period added up to 1584 gallons and would cost more than six thousand dollars. Given the large size of the Caltrans vehicle fleet, the fuel and cost savings realized by idling reduction could be quite large. On the other hand, it would be a small percentage of the total fuel cost of the entire fleet. Nevertheless, idling duration should be reduced to save fuel, money, and CO_2 emission. The research also found that an average of 1 gallon per hour can be used to estimate the idling fuel consumption rate for the entire fleet, given the idling time.

In addition, without knowing the true function of the vehicle and their mode of operation, we may have misidentified idle conditions. Some idling events may be necessary due to repair, maintenance, or vehicle mode of operation. Vehicle operators and managers were not interviewed to determine if some of the idling events are necessary.

There are several ways to minimize idling. Automatic engine shutoff systems are available as an add-on to existing vehicles or are built in by the vehicle manufacturers. During the installation of the idling monitoring systems, some operators voiced their concern about automatic idling shutoff systems. They suggested that automatic shutoff systems hinder their work. Operator and manager training is another alternative to reduce idling and its associated fuel use and cost. Based on the results of this research, huge potential cost and fuel savings from idling reduction can be shown. Operators and managers could potentially be convinced that it is a worthy pursuit. To further reduce idling, some policy and operational procedures may have to change after thorough and careful review by stakeholders.

The Preco system did not work as well as we had hoped. It frequently failed to log the state of the ignition. This problem led to uncertainty in determining the idling duration. Idling durations between 5 and 90 minutes are considered in our analysis. Any idling events lasting longer than 90 minutes are considered outlier errors caused by the idling identification algorithm. Any idling events lasting less than 5 minutes are assumed to be caused by waiting in traffic or at a traffic signal. In the future, a custom-developed idling monitoring system based on Android devices may be cost-effective and more reliable in producing error-free data. Leveraging Android smart-phones and commercially-available CAN bus interfaces, custom-developed idling monitoring systems could be developed at low-cost in a short time.

REFERENCES

1. California Board of Equalization, "Diesel Fuel Tax Regulations: Regulation 1432 - Other Nontaxable Uses of Diesel Fuel in a Motor Vehicle," California Board of Equalization, Editor, pp, 1999.
2. California Department of Transportation (Caltrans) Division of Maintenance, "Off-Road Fleet Exemptions," 2003.

APPENDIX A: IMPLEMENTATION PLAN

This document describes the baseline instrumentation implementation plan for the Idling Baseline Project. The information contained herein is derived from research data obtained during test installation of the proposed instrumentation equipment into two UC Davis test vehicles.

Equipment List

This list is not all-inclusive; other consumables may be needed as well. (A/R = as required, EA = each).

Table A.1: Equipment list

QTY	Unit of Measure	P/N	Description
1	EA	IX-302	IX-302 Preco Kore
1	EA	BOC-1	IX-201 I/O Breakout
1	EA	J1939 CAN	J1939/J1708 Y Cable
1	EA	J1939 Harness	J1939 Interface Cable
A/R	Feet		Hookup wire
A/R	Feet		Split loom
A/R	EA		Crimp lugs
A/R	EA		Wire tap connector
A/R			RTV adhesive
A/R	EA		Wire ties
A/R	EA		Adhesive mounting feet
A/R			Metal self-tapping screws
A/R	EA		Relay

Installation

System installations were performed by AHMCT personnel and, where possible, witnessed by Caltrans equipment and maintenance personnel. Observation by Caltrans personnel is an important part of the project training and knowledge transfer, which is essential if broader deployment of the technology for this and related applications is to occur.

The full installation for the candidate vehicles began once the first test vehicle results were evaluated by DOE and DRI, and the required instrumentation was subsequently procured. Installation time varied by vehicle type and work trigger suite. Install time is estimated to be between 2 to 6 hours per vehicle. The test fleet vehicle list and geographic locations (Caltrans yards) are shown in the main report body. The large number of widespread locations represented a logistical challenge, covering most of California, including several fairly remote rural locations.

The following instructions and details are meant as general guidelines. Some vehicle and site-specific modifications may be needed and should be noted on the log form so that future instructions can be modified to keep current.

NOTE: The installation information provided here is general in nature due to the diversity of the vehicle fleet. Use good judgment when installing the equipment. Provide for adequate ventilation and make sure that the installed equipment does not interfere with safe operation of the vehicle.

1. Unpack all items and inventory to ensure there is no shipping damage.
2. Unpack the GSM/GPRS antenna and cable unit. The GSM antenna needs to be screwed into the base of the antenna. Untangle and extend the cables.
3. Apply split wire loom to the entire length of the two cables. Position the patch antenna on top of the vehicle cab. The antenna must have complete unobstructed view of the sky. Route the cable from the top of the cab to the interior of the vehicle cab. This procedure may involve reusing existing holes through the firewall, routing through a dome marker light fixture, or drilling a new access hole. Interior chassis panels may also need to be removed to route the cable.
4. (if applicable: see discussion in Section 5) Locate the J1939/J1708 engine diagnostics connector. It is typically located near the driver's-side foot well, below the dashboard. Unscrew the vehicle's diagnostics bulkhead connector and replace it with the bulkhead connector on the J1939/J1708 Y cable. Attach the other Y-end of the Y-cable to the vehicle's diagnostics connector. Route the cable to a convenient location and secure the cables.
5. Locate a convenient place for mounting the Preco IX-302 base unit and secure it with self-tapping machine screws. Locations include areas behind the seats, interior cab walls, overhead compartment bins, and similar areas. Prime consideration should be made for easy access to the main power fuse box, routing of the antenna cables from the exterior of the cab, connection to the J1939/J1708 Y cable connections and visibility of the exterior LED status indicators. Additionally, since self-tapping machine screws are used to secure the unit, ensure that there is nothing directly on the other side of the installation location that can be damaged by being punctured by drilling holes or by the machine screws.
6. Wrap the power cable (three wires – red, green and black) in protective wire loom. Route the cable (plug end to Preco unit) from the unit to the main fuse box. Identify a constant power source wire, an ignition-switched power source wire, and a ground location. Using wire tap connectors, attach the red wire to the constant power source wire, and the green wire to the ignition switched power source. Use a round lug to attach the black ground wire to chassis frame ground. Secure the routing of the wire using cable ties and adhesive mounting feet.
7. Attach the antenna cables. Hand-tighten only. Secure the exterior patch antenna with RTV sealant. Secure the exterior antenna cable with cable ties and adhesive wire tie wrap mounting feet. Apply RTV sealant at regular intervals. Secure the cable on the interior of the cab. If removed, replace interior chassis panels.
8. Identify the work trigger inputs (See discussion Section 4). Attach a sense wire with the wire tap connector to the switch output and route the wire to the Preco unit location. Attach a lug connector compatible with the spade on the relay. Attach this wire to the

positive terminal of the relay coil. The negative terminal of the relay coil should be attached to chassis ground. Attach a lug connector to the input wire from the Preco breakout cable. Attach this wire to the contact side of the relay. The other side of the relay contact should be attached to chassis ground. Continue to connect all specified work trigger inputs. Attach a ring lug to the ground wires from the Preco break out cable and connect to chassis ground.

9. Secure all wires appropriately with cable ties and adhesive mounting feet. Plug all the cables into the correct locations.
10. Replace all removed panels, and clean up work area.
11. Verify the correct installation of the unit. Start the vehicle and let it idle for 10 minutes. Confirm during this time that the status LEDs (Light Emitting Diodes) on the Preco unit illuminate. Turn off the vehicle after 10 minutes. Confirm that the Preco unit eventually turns off. This may take up to 10 minutes.
12. Complete the installation log sheet.

Work Trigger Input

Because of the diverse vehicle fleet in this study, work trigger inputs were difficult to decide beforehand. They were decided on a case-by-case situation. However, general guidelines are provided here. The triggers are used to signal to the data logger that the vehicle's operator has commenced work, e.g. established a work zone. Thus, triggers may include:

1. Activation of the vehicle's rotating warning light,
2. Activation or lowering of the vehicle's protective crash attenuator,
3. Activation of the vehicle's power take-off (PTO) clutch,
4. Activation of the vehicle's auxiliary engine, sensed via the position of the auxiliary engine's run switch or power setting switch,
5. Activation or lowering of sweeper brooms,
6. Activation of sand spreaders,
7. Activation of water spray or herbicide spray nozzles.

In all cases, the activation of the work zone accessory must energize the sense relay and change the state of the Preco sense input to detect the establishment of a work zone. Whatever the choice of the work trigger, the installer must note on the installation log what trigger is represented and what input number on the Preco it is connected to. In addition, Preco must be informed of each work trigger to properly configure data collection for each vehicle.

SAE J1939/J1708 Connections

As a result of the proprietary nature of the engine diagnostics communication protocol, it may not be possible for all vehicles to automatically log the real-time fuel consumption of the vehicle during operation. If the electrical interface is compatible (both by connector form factor and communications protocol), the Preco unit will attempt to query the real-time fuel consumption and record it.

However, if no information is available, fuel use during idling of the vehicle can be ascertained by measuring fuel consumption via other methods and then recording the idling time measurement from the Preco unit data analysis. The idling time derived via this method assumes that the combination of the vehicle's main engine running and the absence of motion (indicated via GPS locations) indicates that the vehicle is idling.

More specifically, for the case that direct fuel consumption is not available, the following approach can be used to estimate consumption:

- Obtain baseline idling fuel consumption rates for each vehicle type, where available. Where this information is not available, calibrate an idling fuel consumption rate empirically (one-time operation)
- Monitor approximate idling time
- From approximate idling time and fuel consumption rate, calculate estimated fuel consumption (idling fuel use = idleTime * fuelRate).

Installation Log Sheet

(to be filled out on any Preco installation)

Installer's Name, Phone Number, and E-mail	
Fleet Manager Contact: Name & Phone number	
Vehicle C-number	
Vehicle Functional Description	
Vehicle Engine Manufacturer	
Vehicle Chassis Manufacturer	
Vehicle VIN Number	
J1939/J1708 compatible (Yes/No)?	
Preco Unit Serial Number	
Preco Unit MacID & Activation Code	
Preco Unit ICCID & Activation Code	
Work Trigger #1 Functional Description	
Work Trigger #2 Functional Description	
Work Trigger #3 Functional Description	
Work Trigger #4 Functional Description	
Completed power-on verification (Y/N)?	
Signature & Date:	