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April 2, 2012

Mr. Jermaine Hannon, Director
Planning and Air Quality
Federal Highway Administration
Region Nine, California Division
650 Capitol Mall, Suite 4-100
Sacramento, CA 95814-2724

Dear Mr. Hannon:

Enclosed for your review is the California Department of Transportation (Caltrans), Division of Research and Innovation's Annual Report on Developed and Deployed Products or Services for 2011. The submittal of this Annual Report highlights the progress of Caltrans' research program for the Federal Highway Administration.

If you have any questions concerning the list, please contact Coco Briseno at (916) 654-8877 or by email at Coco_Briseno@dot.ca.gov.

Sincerely,

Coco Briseno

COCO BRISENO, Acting Division Chief
Division of Research and Innovation

Enclosure

2011

Developed and Deployed Products and Services Report

California Department of Transportation
Division of Research and Innovation

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Message from the Research Division Chief

The Division of Research and Innovation (DRI) is pleased to present the California Department of Transportation (Caltrans) *2011 Developed and Deployed Products and Services Report* highlighting research projects that were completed during the 2011 calendar year. This report fulfills a federal requirement to report on the progress of Caltrans' research program.

DRI's purpose is to manage a comprehensive program to research, develop, test, and evaluate transportation innovations sought by our customers. These innovations in methods, materials, and technologies enable Caltrans to provide continual improvement to the management of public facilities and services, protect public investment in transportation infrastructure, and enhance mobility and safety. We hope this information will enhance DRI's purpose to improve mobility across California by performing applied research, developing innovations, and implementing solutions.

The research efforts highlighted in this year's *Developed and Deployed Products and Services Report* were selected by Caltrans DRI staff to highlight a broad range of products and services from Caltrans strategic research priorities.

Our research program will continue to bring innovation to Caltrans and to the state of California with the support, contributions, and collaboration of Caltrans staff, the Federal Highway Administration, and our many research partners. We welcome your comments, questions, and suggestions. Additional information about our research efforts can be obtained by contacting any of the research staff identified in this report.

COCO BRISENO, Acting Chief
Division of Research and Innovation

Maintenance Research Program

Maintenance research focuses on worker safety, winter operations, and increased productivity. Safety for highway workers and the traveling public is Caltrans' number one priority. The maintenance research program focuses on identifying ways to increase driver awareness of work zones, providing ways to inform workers that vehicles are encroaching on the work zone, providing safety devices to warn or protect workers, and emergency management.

In the winter, Caltrans is responsible for keeping the mountain highways open and safe for the traveling public. Winter operations research focuses on removing snow and ice in a safe, efficient, and environmentally friendly manner. The final component is investigating equipment to increase productivity and decrease costs having the added benefit of removing workers from the roadway thus increasing worker safety.

Project Manager: Larry Baumeister Email address: larry.baumeister@dot.ca.gov

Project Title:

Driver Training Methodology

Project Description:
Caltrans wanted to research the application of using video monitoring to improve employee driving skills. This project was initiated to evaluate an event driven video monitoring system. The monitoring system video camera continuously records saving the data if the car goes over a trigger, such as 70 miles per hour or if the gravitational force sensors are triggered. The video was analyzed by the system vendor as part of the service. The results were summarized and reviewed by Caltrans.

This research was a pilot project in District 11, San Diego and Imperial Counties in California, where the event driven video monitoring devices were installed in a select number of its fleet vehicles. The video cameras were installed next to the rear-view mirror with a view out the front of the windshield and another looking back into the vehicle cab. The information gathered from the monitoring system was then analyzed and used to supplement employee driver training.

Project Outcome:
The project determined the product had a potential use. The product provided driver analysis such as the number of speeding incidents, use of driver safety belt, and erratic driving for vehicles selected for the District 11 pilot. There were improvements in driver behavior related to safety issues when driver training or coaching was completed after the infractions. Another finding was completing the reviews and subsequent coaching of drivers was difficult to complete in a timely manner. If this type of system is used in the future, a plan needs to be adopted so the reviews are completed regularly.

Project Benefit:
This project determined if the monitoring system is viable for use with Caltrans vehicles. If the system was viable, it would be considered for use to assist with driver's training for Caltrans employees.

Project Deployable Product or Service:
The project determined an event driven video monitoring system had a potential use with fleet vehicles. Some factors still need to be reviewed and addressed prior to deployment.

Project Manager: Gloria Gwynne Email address: gloria.gwynne@dot.ca.gov

Project Title:

Identify and Implement Successful, Measurable, Maintenance Friendly, and Safe Roadside Design Practices

Project Description:

This project sought to further the development of safer and more efficient roadside maintenance operations, with a focus on efforts to collect litter and debris and control vegetation on roadsides. Communication methods were evaluated for sharing the solutions to existing roadside maintenance problem-areas with practitioners. This project developed a roadside maintenance online toolbox of best practices. The toolbox was designed as an interactive database presenting the features, pros, and cons of different methods of addressing various roadside maintenance concerns.

A review and assessment of existing equipment and methods was performed followed by the development of mechanical tools that solved identified holes in the existing best practices. Conceptual vegetation cutting tools that allow workers to perform remote operations from within a truck were designed and tested. Vegetation cutting tools intended to be used with a vacuum truck were further refined and tested. The vacuum truck, known as the "Automated Roadway Debris VACuum" or ARDVAC, allows an operator to use a joystick and position the "vacuum cleaner" nozzle while staying in the truck. By adding vegetation cutters, noxious and invasive weeds can be safely cut and removed from the roadside. The next step is to gain input from experienced users of the ARDVAC prior to further tool refinement.

Project Outcome:

A literature search that reviewed and assessed best practices was compiled and distributed in a web based document titled *The Vegetation and Debris Control Toolbox*. The information in the toolbox described present day equipment and methods. It also included concepts of equipment that could be implemented in the future. This toolbox was designed to efficiently provide information to persons working in the field and those seeking to develop solutions. A method of grading the value of existing and potential alternatives was developed with the application of fuzzy logic, a form of logic that does not require statements to be either true or false, but rather statements and inputs can have varying levels of truth. The toolbox uses fuzzy logic to convert the English grades of Bad, Marginal, OK, Better, and Good into numeric values. In addition, two concept tools, a rotary cutter and a reciprocating cutter, were tested on grasses and woody-stemmed weeds. A third tool was assembled and tested for use on tumbleweeds.

Project Benefit:

The goals of addressing roadside maintenance problem areas are many: reduced worker exposure, improved fire safety, improved visibility, and less impact on the

environment. Providing an online resource for practitioners helps to both identify the best tool for the job and to share experiences. Equipment that allows operators to work remotely from within the protected confines of a truck cab is safer and more efficient.

Project Deployable Product or Service:
The deployable product of this project is a web based toolbox to communicate to and seek input from roadside maintenance personnel. The toolbox is a very flexible tool, and because it is based on the internet, it can evolve as technology and trends change. The graphical format demonstrated in this project allows efficient use. This project also delivered three prototype tools designed to address holes identified by the literature search. Testing of the tools has demonstrated the strengths and weaknesses of each concept.

Project Manager: Larry Baumeister Email address: larry.baumeister@dot.ca.gov

Project Title:

Workzone Safety Improvements through Enhanced Warning Signal Devices

Project Description:
This research project was developed to address Caltrans' need to enhance the visibility of maintenance vehicles to reduce the chance of collisions. The main outcome of this research project was to determine the viability of creating emergency warning lights that could be used to increase the visibility of Caltrans vehicles used in certain maintenance activities such as sweeper train operations. The proposed emergency warning signal used light emitting diodes (LEDs) that can be programmed for light intensity and rotating signal speed. The project also intended to develop an arrow display board that can be programmed the same way as the emergency warning signal.

Project Outcome:
The project developed and tested prototype emergency warning signals, a new arrow display board, and a new shadow truck light bar. The prototypes were presented to the Caltrans Warning Light Committee. After viewing the demonstration of the two prototypes, the Warning Light Committee determined the prototype warning light using LEDs was not as bright as the current warning light used by Caltrans. Even though the prototype would be unique to Caltrans, the Warning Light Committee felt it could find a more suitable and effective light through commercial means.

The shadow truck light bar was also demonstrated to the Warning Light Committee. They determined it could be useful, but ultimately decided it would be better to spec out the light to a commercial vendor who could provide a more effective light. The light sequence of the shadow truck light bar seemed to be effective, but the LEDs do not provide enough light to be effective at distances over 50 feet.

Project Benefit:
The benefit of this research project is the development of new warning light systems that could be deployed on Caltrans vehicles. The systems enhance worker safety by increasing the visibility of the vehicles to reduce collisions with the traveling public.

Project Deployable Product or Service:
The project resulted in a programmable (speed and intensity) emergency warning light and shadow truck light bar. Both of these devices accomplished the goals of the research, and both were demonstrated and presented to the Warning Light Committee at the Maintenance Equipment Training Academy (META). The Warning Light Committee determined that the warning lights were very promising.

Modal Research Program

Modal research is focused on solving passenger transportation problems that affect the utility (safety, accessibility, convenience, connectivity, user friendliness, and affordability) of the State's public transportation systems.

DRI has been in the forefront of the research effort to improve the efficiency and attractiveness of modal systems throughout the State. By making public transportation more efficient, comfortable, and dependable, it will grow in importance as a traveler's choice. Benefits such as efficient integration of land use and transportation, congestion relief, and air quality improvements can occur as a result.

Project Manager: Robert Justice Email address: bob.justice@dot.ca.gov

Project Title:

EasyConnect

Project Description:

Like many regions in the United States, the California Bay Area has an extensive transit system with a network of buses, light rail, and heavy rail extending to most major destinations. However, access (walking distance or parking) to transit stations limits the number of patrons that can effectively use the transit system. An effective demand-responsive, easy to use system that links home, work, and other activity destinations with transit stations could encourage greater transit use.

The EasyConnect project objectives were to deploy, test, and evaluate a demand-responsive system that utilized low speed modes (bicycles, Segway Human Transporters). The low speed modes were integrated with smart parking, bike sharing, stationary fuel cell technology, hydrogen fuel cell vehicles, car sharing, community-based social marketing tools, and real-time traveler information. All of these elements were evaluated to determine whether or not commuters were incentivized to mode shift to public transportation, and if their "first and last mile" public transportation access issues were minimized or eliminated.

Project Outcome:

The research determined that seamless connectivity, a demand-responsive, easy to use public transportation system that links home, work, and activity destinations with transit stations incentivizes commuters to mode shift and increases public transportation use. Commuters were willing to utilize integrated, multi-modal transportation services with both traditional and innovative technologies. Commuter participation was excellent, and there was wide acceptance and use of the integrated technologies. Approximately 15 companies and more than 34 employees signed up to participate in the project.

Project Benefit:

The integration and combination of EasyConnect project elements provided a much better understanding upon which to deploy demand-responsive systems that are integrated with smart parking, bike sharing, stationary fuel cell technology, hydrogen fuel cell vehicles, car sharing, community-based social marketing tools, and real-time traveler information. "First and last mile" public transportation problems that commuters experience improve with seamless, demand-responsive transportation systems.

Project Deployable Product or Service:
The EasyConnect field test was introduced at the Pleasant Hill Bay Area Rapid Transit (BART) District stations to evaluate the effectiveness of shared-use low-speed modes vehicles service at bridging the "last mile" from a transit station to the workplace.
The project enabled businesses within a four mile radius of the Pleasant Hill BART station to rent shared-use bicycles, electric bicycles, and Segway Human Transporters (HTs) for their employees to use for commute and day-time travel.

The low-speed modes were integrated with smart parking, bike sharing, stationary fuel cell technology, hydrogen fuel cell vehicles, car sharing, community-based social marketing tools, and real-time traveler information. The project also provided smart growth policymakers with strategies to help mitigate increasing vehicle travel, congestion, and emissions by providing high-quality modal alternatives to single occupant vehicles. The integration of innovative technologies with traditional modal options in transit-oriented developments is the key to providing high-quality transit service that can viably compete with the automobile in suburban transit corridors.

Project Manager: Robert Justice Email address: bob.justice@dot.ca.gov

Project Title:

Smart Parking

Project Description:

Increasingly, public transit authorities are harnessing advances in sensor, payment, and enforcement technologies to operate parking facilities more efficiently. In the short term, these innovations promise to enhance customer parking experiences, increase the effective supply of existing parking with minimal investment, and increase ridership and overall revenue. Over the longer term, these systems could further expand ridership by generating revenue to add parking capacity and improve access.

The research project objectives investigated smart parking technologies and techniques along the Coast Express Rail (COASTER) commuter train route in San Diego County, California. This also included analyzing commuter behavior at transit stations to assist in designing solutions that can increase, and add efficiency to transit ridership. This provided insight into new and innovative parking management strategies. The program was separated into three phases: 1) the implementation of the smart parking pilot program, linked to COASTER stations in San Diego, 2) the evaluation of the program based on behavioral responses, cost-effectiveness, functional and technical performance, and institutional barriers, and 3) a commercial deployment strategy based on the evaluation.

Project Outcome:

A public transit agency, North County Transit District (NCTD) used advanced parking management technologies and strategies that impacted their public transit ridership, especially at the corridor level. Transit agencies have improved decision making tools to analyze parking investments to examine the tradeoffs of expansion, advanced parking management systems, and real estate development. At overcrowded parking facilities, pricing was a strong tool for allocating demand efficiently. Recovering the operational costs of parking is fairer to users who use alternate access modes.

When the research project was originally developed, it was anticipated there would be full deployment of the project at all of the six NCTD Coaster commuter train stations where ridership was constrained by parking. The regional and local economy declined during the research project requiring NCTD to adjust fares and services. This resulted in the train station parking lots not always filling. Therefore, the research project scope was modified to account for the economic downturn. A business model guidance document was developed that draws on the research project results to assist NCTD and other transit agencies with smart parking technology applications, and pricing at transit stations during changing economic conditions.

Project Benefit:
NCTD was provided with advanced sensor, payment, and enforcement technologies to operate their parking facilities more efficiently. These enhanced customer parking experiences increased the effective supply of existing parking with minimal investment, and increasing ridership and overall revenue. Smart parking systems further expand ridership by generating revenue to add parking capacity and improve access. Advanced parking management systems make transactions easier for customers, gather useful data for improving parking management, and improve enforcement efficiency.

Project Deployable Product or Service:
The project developed a public transit business model for the North San Diego County Transit District incorporating smart parking technologies. Smart parking technologies included embedded parking lot sensors that detect vehicles entering and exiting parking facilities at specific "premium" areas. The sensors also detected vehicles in each reserved premium parking space, and the information was transmitted to parking management system servers. Parking availability information was communicated to commuters via the web, cell phone, personal digital assistants, and commuters could make parking reservations using the same technology devices.

This public transit business model which may be implemented in the future on a San Diego County regional basis, reduces commuter time and frustration, encourages transit ridership, reduces pollution, congestion, fuel consumption, land use impacts, optimizes existing parking infrastructure, and increases revenue to communities and transit properties.

Pavement Research Program

Pavement research is designed to meet Caltrans' needs for improved policies, operations, and business practices that preserve and enhance California's pavement resources and investments in the following areas:

- Improved sustainability of Caltrans's pavement network by reducing energy use, emissions, use of new materials through recycling, and minimizing the impact of the road network on surrounding human and ecological communities
- Improved delivery of pavement projects and services through new and improved methods and specifications for design, construction, and pavement preservation
- Optimized pavement performance and lower life cycle costs of pavement through improved capacity to model and calculate life cycle costs
- Reduced congestion from recurring maintenance and rehabilitation by use of improved design methods, construction strategies and better analysis of the interaction between traffic delay and work zone design
- Reduced noise from traffic on pavements, and improved smoothness and safety through development and implementation of better pavement surfacing techniques
- Continue development and support of a Pavement Management System that will allow for optimization of budgets for pavement work

The overall objective of pavement research in these areas is to make the California highway system the safest and most efficient in the nation for travelers, freight movement, and highway workers.

Project Manager: Joe Holland Email address: t.joe.Holland@dot.ca.gov

Project Title:

Quieter Pavement Research

Project Description:
Caltrans and the concrete and asphalt industries have cooperated in a study that measures the tire and pavement noise on existing pavement surfaces and is developing new quieter pavement surfaces. The early work identified the surface characteristics that make pavement noisy or quiet and developed new quieter materials and surface textures based on those results. These results have been incorporated into Design Directives and a Quieter Pavement Policy Bulletin.

Additional research is evaluating how long these materials and textures keep the pavement noise levels low. The most cost-effective solutions for making pavement quieter are identified based on life cycle cost analysis using the performance data developed by this research.

Project Outcome:
This project created the data and knowledge, incorporated into Caltrans processes and specifications, to successfully implement quieter pavement in a cost-effective manner. It leads to new quieter surfaces that also consider safety (friction).

Project Benefit:
The most cost-effective solutions for making pavement quieter is identified based on life cycle cost analysis using the performance data developed by this research. The resulting research data helps identify where quieter pavements can be effective, how effective they can be, and for how long. New quieter surfaces have been developed and tested.

Project Deployable Product or Service:

- Databases of noise performance data for concrete and asphalt surfaces
- Models of noise versus time for use in life cycle cost analysis
- Information for use in planning documents
- New materials and textures, proven in the field (noise and durability) and with accelerated pavement testing (early answers about durability)
- Data and information for use in planning

Project Manager: Joe Holland Email address: t.joe.Holland@dot.ca.gov

Project Title:

Warm-Mix Asphalt

Project Description:
Caltrans and industry have been interested in using a set of technologies collectively called warm-mix asphalt. Warm-mix asphalt can improve construction quality and reduce energy use and emissions from asphalt paving, especially paving using rubberized asphalt binders that contain recycled tires. In the past four years, an increasing number of technologies have come on the market. There is limited data to assess risk for initial deployment of the first set of technologies and no process for assessing new technologies.

This project involved accelerated pavement testing (APT), laboratory testing, analysis and work with a Caltrans/industry task group, as well as interaction with a national task group. The research performed to date has provided the starting point for assessment of risk of early failure. Since new warm-mix technologies are being developed at a rapid pace, an internal Caltrans task group was formed to approve products for Caltrans use. As additional information is developed through this research study, it will be incorporated into the acceptance process.

Current related research and future projects will investigate emissions and energy use reductions, potential increases in durability, and look at the use of high percentages of recycled asphalt pavement (RAP) with warm-mix asphalt.

Project Outcome:
The project has created data and knowledge that has been incorporated into Caltrans processes, to successfully implement warm-mix asphalt for conventional asphalt, rubberized asphalt, and asphalt containing higher percentages of RAP.

Project Benefit:
Pavements are better constructed and last longer. Paving is done with lower energy use and lower emissions that cause air pollution. Additional durability benefits also occur. The emission reductions and improvements in compatibility reduce some of the obstacles to using rubberized asphalt in urban environments.

Project Deployable Product or Service:
The initial database of APT and laboratory performance expands to include higher percentages of RAP. This information is incorporated into Caltrans process for accepting warm-mix technologies. Emissions and energy use reductions is quantified for use by industry and Caltrans in planning. The results are also used as part of another project which is implementing a new mix design method for asphalt mixes, after 50

years of using the previous method. Data regarding emissions is used in determining where rubberized asphalt can be used in the state.

Planning, Policy, and Systems Information Research Program

Planning and policy research provides support for developing key policy decisions, addressing critical transportation issues, environmental needs and opportunities, and better understanding of travel behavior and the relationship between transportation and land use. The research is also geared towards developing more effective transportation planning tools and practices.

Technological advances have created new opportunities for transportation planners - advances that include more powerful computers and software, automated data collection and data generation from advanced communications, remote sensing and global positioning systems (GPS). New opportunities for planning research occur with the use of geographic information systems (GIS), and data derived from Intelligent Transportation Systems (ITS) applications.

Project Manager: Robert Justice Email address: bob.justice@dot.ca.gov

Project Title:

Software Tools for Sharing and Integrating Geographic Information System (GIS) Data

Project Description:
There is a critical need to develop, implement, and distribute a variety of tools and processes for sharing and integrating statewide geo-spatial transportation data. There are various obstacles to the development and maintenance of such a statewide network using data from multiple sources, both organizational and technical. This study looked at both, but focused on research to help develop processes and software utilities to overcome the technical obstacles.

The basic research objectives included:

- Design and implementation of a core database, based on federal standards, within the state as a central repository of multi-jurisdictional location data
- Translation of the data from the provider's schema to a centralized database and from one database to another
- Integration of data from disparate data sources into a seamless whole
- Quality Assurance/Quality Control processes and software to monitor data quality, security, data entry, and retrieval processes
- Change detection and change management to support maintenance of the data over time
- Documentation of a set of processes necessary to support data sharing from a variety of sources, (e.g., data sharing agreements, agreement points)
- Linear referencing integration

Project Outcome:
The software and processes developed enable sharing and integration of local government geo-spatial transportation data for the creation and maintenance of a statewide transportation network. Software packages are available, and have been delivered to each state research partner. These software packages include documentation specific to each state department of transportation (DOT) environment.

Caltrans is implementing a version of the design, processes, and tools developed as part of this study to obtain and process open source road data for the Highway Performance Monitoring System (HPMS) management and federal reporting. Not only is Caltrans replacing the commercial roads layers with an open source roads layer leveraging the tools and methods, but implementation of the model is also being considered for use in other data integration and sharing efforts.

Project Benefit:
State DOTs have computer based software tools that facilitate geo-spatial transportation data sharing and integration for users. This provides economies of scale for retrieving and sharing data among various state DOTs and other entities that require transportation data for various purposes.

Project Deployable Product or Service:
This project developed computer software tools that facilitate local government geo-spatial transportation data sharing and integration, for the creation and maintenance of state transportation networks.

Structures and Geotechnical Research Program

Structures and geotechnical research results in safer and more economical bridges and other highway facilities with an emphasis on mitigating earthquake, landslide, and other geologic hazards. This research accomplishes these objectives through several major areas of study:

- Geotechnical risk management research identifies geologic hazards, such as landslides and liquefaction, and provides a framework for engineers and transportation planners to adapt designs to reduce impacts and costs.
- Geotechnical data management leverages internet and database technologies with the constantly growing collection of geotechnical data generated by the Caltrans to streamline design and construction processes.
- Studies on post-earthquake assessment and service restoration focuses on improved evaluation of bridge integrity through better bridge modeling methods and tools for raising post-earthquake situational awareness. Caltrans maintains over 12,000 bridges and monitors them for safety and traffic capacity. Implementing tools for rapidly assessing and inspecting bridges after earthquakes will keep the transportation system safe and operational.
- Foundations and ground motion research focuses on cost-effective foundation designs of structures, providing safer designs through better understanding of ground motion variability due to earthquake fault type, distance from the fault, and behavior of soils. More cost-effective designs are accomplished through understanding soil-pile interaction and improving pile designs.

Project Manager: Charles Sikorsky Email address: charles.sikorsky@dot.ca.gov

Project Title:

Accelerated Bridge Maintenance to Reduce Time/Traffic Impacts

Project Description:
This project focuses on accelerating bridge maintenance processes. It includes development and testing of materials, methods, and design alternatives that reduce the need for maintenance. When maintenance is required, the rate of delivery is accelerated and worker exposure to traffic hazards is reduced. Tasks under this project include:

- Identification and testing of advanced materials to reduce maintenance time
- Investigation and development of bridge design alternatives (possibly higher initial cost systems) that require lower overall maintenance and repair costs during the life of the structure
- Explore and develop opportunities for greater use of quick-change bridge elements/systems

Project Outcome:
This project provided means to accelerate Caltrans bridge maintenance practices, impose fewer maintenance-related delays on the traveling public, and reduce maintenance worker exposure to safety hazards. Impacts of using accelerated methods on cost and long-term performance are understood.

Project Benefit:
Accelerated bridge maintenance methods reduce worker exposure to safety hazards and result in fewer and shorter road/lane closures thus minimizing construction-related traffic congestion.

Project Deployable Product or Service:
Deployable products include new tools, materials, and practices for conducting bridge maintenance as well as alternative bridge designs, details, and specifications for lower-maintenance bridge systems.

Project Manager: Charles Sikorsky Email address: charles.sikorsky@dot.ca.gov

Project Title:

Battered Piles in Layered Soils and Piles in Sloping Ground

Project Description:

In recent years, the demand for developing effective design tools and procedures for elements of foundations under lateral loads has increased. Many experimental (model-scale) and field (full-scale) lateral load tests on vertical piles into level ground have been performed nationwide and internationally. However, the full and model scale load tests on battered piles or piles into sloping ground are still very limited. As a result, the progress in developing design tools or specific procedures that allow the assessment of response for such particular cases is very slow.

Battered piles and piles in sloping ground share the same features of having characterizations that are different from those of the laterally loaded vertical piles in level ground. Therefore, an appropriate design method for the determination of the lateral load resistance of a battered pile or piles in sloping ground is needed. This procedure should be compiled into a flexible computer program that is used as a design tool.

Caltrans has been one of the leading organizations which sponsored and conducted a large number of research projects, and field and experimental tests on the lateral resistance of piles, drilled shafts, pile caps, and bridge abutments. The basic goal of such a research and testing project is to establish reliable design procedures with high certainty and a flexible design tool for such structural elements, which are susceptible to damage under earthquake loading. At present, several research groups have conducted programs of study in order to provide a better understanding of laterally loaded pile and drilled shaft behavior. However, very few of these research efforts have approached or discussed the design of the battered piles or pile into sloping ground.

Project Outcome:

This project improved bridge foundation design procedures which use battered piles or piles in sloping ground.

Project Benefit:

The design of battered piles and piles in sloping ground requires clear, experimentally verified design procedures. A clearly defined effective design method with a flexible design tool (computer program) provides significant cost savings. Having such a clear design method reduces the level of uncertainty and the large safety factors used by designers, resulting in potential savings of millions of dollars.

Project Deployable Product or Service:
As a result of this research and field testing, new designs and procedures to predict the response of battered piles and piles in sloping ground or piles supporting bridge abutment were developed. It provides cost savings and greater certainty relative to such type of analysis.

Project Manager: Joe Holland Email address: t.joe.holland@dot.ca.gov

Project Title:

Evaluation of a New Bridge Deck Joint for San Francisco – Oakland Bay Bridge

Project Description:

Caltrans is interested in using lane-width and half-lane width bridge deck joints for long bridges, such as the new eastern span of the San Francisco – Oakland Bay Bridge. The new deck joints allow closure of single lanes to replace or maintain the bridge joint rubber absorption pads. Current multi-lane deck joints require closure of multiple lanes to fix just one lane which increases traffic delay, traffic closure cost, and risk to workers and the public.

This project consisted of constructing and testing of a new type of deck joint using a Heavy Vehicle Simulator (HVS) in a yard next to the bridge, which removed the risks associated with testing on the bridge. The use of the HVS also allowed the deck joint to be instrumented to provide better understanding of the joint mechanics. The HVS was able to apply a large number of repetitions with heavy overloads to obtain results more quickly than a pilot installation.

Project Outcome:

The testing concluded the new deck joint will not fail under normal traffic conditions. Overloading the new deck joint indicated the rubber absorption pads, which accommodate normal thermal expansion and contraction, should plan to be replaced on a long term basis.

Project Benefit:

Caltrans was able to get quick and reliable answers regarding the deck joint performance and mode of failure, including assessment of performance under overloads, without putting the public and Caltrans workers at risk. Caltrans was also able to obtain data regarding the failure mode and mechanics of failure for the joint.

Project Deployable Product or Service:

The deck joint was successful and will be implemented with some minor changes, the need for which was identified by the testing.

Project Manager: Saad El-Azazy Email address: saad.el-azazy@dot.ca.gov

Project Title:

Improved Facility Restoration Techniques

Project Description:
This project aimed at developing and refining methods, tools and techniques to quickly and effectively repair or replace structural components damaged by an earthquake or other extreme event. These same techniques may also have broader applicability for more conventional repairs. Project objectives included:

- Synthesize surveys of best practices on bridge emergency repair methods
- Develop new types of structural components and systems that can be quickly and efficiently repaired or removed and replaced with minimal traffic impacts
- Develop new techniques to temporarily repair a structure and restore functionality until final repairs can be made
- Develop guidance/training materials with recommendations on how to optimally manage restoration of damaged bridges

Project Outcome:
The project produced a suite of structure-repair capabilities and associated expertise that allows Caltrans to quickly and effectively restore service after an earthquake or other extreme event.

Project Benefit:
The public depends on the rapid restoration of transportation service after an earthquake or other extreme event to facilitate recovery operations and restoration of regional economic activity. This project helps to assure that Caltrans is well positioned to quickly repair structures vital to the restoration of service.

Project Deployable Product or Service:
This project produced documentation of methods, materials, and techniques for emergency bridge repair. Practical deployment occurs as stand-alone synthesis reports, as new or updated structural systems documented in Caltrans engineering manuals such as Seismic Design Criteria, Load and Resistance Factor Design (LRFD) Bridge Design Specification, and Memos to Designers, and in bridge maintenance documentation.

Project Manager: Peter Lee Email address: peter.s.lee@dot.ca.gov

Project Title:

Improving and Assuring Materials Quality

Project Description:
This project aimed at examining opportunities for Caltrans to improve the tools, methods, or strategies used for quality assurance and quality control (QA/QC) of bridge construction projects. The project also evaluated emerging tools and both technical and administrative procedures to manage the quality of materials placed in bridges.

Project Outcome:
The project aimed to provide improvements to Caltrans QA/QC procedures used for bridge construction.

Project Benefit:
Continuous improvements to the QA/QC procedures used by Caltrans for bridge construction enable reductions in cost and improvements in assessment capability over existing methods, thus increasing the value of construction inspection services in assuring that bridges are built to design standards and deliver anticipated performance.

Project Deployable Product or Service:
Improved tools, methods, or procedures for QA/QC of materials and methods used in bridge construction were developed.

Project Manager: Peter Lee Email address: peter.s.lee@dot.ca.gov

Project Title:

Managing Corrosive Environments

Project Description:
This research project seeks ways to reduce or prevent corrosion from seeping into bridge structures. Project objectives include:

- Development of improved concrete deck design to reduce salt infiltration
- Development of corrosion inhibiting methods, materials, and barriers
- Development of methods to protect steel cable restrainers from corrosion
- Investigate the potential of salt extraction methods to extend bridge service life

Project Outcome:
Improved Caltrans' ability to mitigate corrosive environments that deteriorate bridge structures and reduces their service life.

Project Benefit:
Proactive management to increase service life of bridge structures caused by corrosion leads to cost savings and reduced construction-related traffic congestion by reducing the need for bridge repair and replacement.

Project Deployable Product or Service:
This project yielded improved materials and product specifications, new and revised design aids, and standard design details sheets.

Transportation Safety and Mobility Research Program

The mission of the State Highway System is to enable the movement of people and goods in ways that are safe, efficient, and cause minimal impact to the environment. Research performed under the Transportation Safety and Mobility (TS&M) Program investigates new innovative ways to achieve this mission. Specific projects address traffic safety, driver behavior challenges, bicycle and pedestrian travel safety. On the mobility side, the program explores the use of traveler information to benefit drivers and transit riders. The program also investigates better ways to manage traffic along a corridor and respond more effectively to incidents such as crashes. Commercial Vehicle Operations (truck travel) is another important component of this research program area.

Project Manager: John Slonaker Email address: john.slonaker@dot.ca.gov

Project Title:

Detector Evaluation and Deployment

Project Description:

This project consisted of two tasks that took measurements from conventional inductive loop detectors in unconventional ways. The "Evaluation" task (1726) measures every event (i.e. vehicle passage) output by loop detectors and compares each one to corresponding events output by vehicle detectors using different technology in order to gain an understanding of the relative performance characteristics of each type of detector. The "Deployment" task (1718) measures the relative amount of time loops are occupied by each event in order to determine the percentage of commercial truck traffic relative to overall traffic. The Evaluation task used custom test hardware and software, while the Deployment task used a custom configuration of commercially available hardware and software. Both tasks sought to understand and enhance the capabilities of inductive loop detectors.

Evaluation (Task 1726)

Caltrans needs information about the performance of out-of-pavement and wireless in-pavement detection systems. These systems are easier to install and maintain than conventional inductive loop detectors, but there is evidence from pilot installations, however anecdotal, that they have different detection characteristics and can yield different results. Due to situations including lane-changing, high ground clearance, trailers and occlusion, detectors will occasionally fail to detect, falsely detect or multiple-detect individual vehicles. These errors tend to cancel each other when detection data is aggregated into bins, as is common practice. Non-aggregated (i.e. individual vehicle) data is needed on how these detectors perform in different situations in order to optimally specify equipment for certain detection requirements and environments. There was previously no way to compile individual detection data or quantify detection errors without manually comparing each individual detection event record to video ground truth, which is a labor-intensive process that is practically impossible for large data sets. The Video Vehicle Detector Verification System was developed to address this problem.

Deployment (Task 1718)

Truck transportation impacts every aspect of traffic and infrastructure in the Los Angeles area. That impact is growing as truck traffic continues to grow. The pilot deployment of the intelligent loop detector software module, running intelligent modems, at 20 single-loop sites was designed to track where trucks are going after leaving the California Ports of Los Angeles and Long Beach using accurate, cost-effective technology.

Project Outcome:
Evaluation (Task 1726):
This project resulted in a system that automates the comparison of the accuracy of volume, speed, and occupancy data output from vehicle detection systems that are under consideration for deployment. The system includes a user-friendly computer application that imports and compares data generated by all detectors and provides detailed event-based performance results. The system acquires a digital image of every car in every lane at the moment of detection by any sensor under test by accepting trigger signals from all sensors. This information helps Caltrans or other transportation agencies accurately evaluate new sensing technologies and understand relative advantages and limitations of various detectors.

Deployment (Task 1718):
Twenty intelligent modems were installed in count station cabinets along Route 710, leading to and from the ports of Los Angeles and Long Beach, and Route 60, which carries a significant amount of truck traffic into and out of the Los Angeles basin. The collected data showed that the less costly intelligent modems, connected to existing single loop count stations, performed with about 95% accuracy. As a result of the 20-site installation, Caltrans District 7 (Los Angeles and Ventura counties) personnel are now able to track the movement of trucks after leaving the Ports of Los Angeles and Long Beach and determine where infrastructure maintenance efforts should be focused.

Project Benefit:
Evaluation (Task 1726):
The Video Vehicle Detector Verification System enables Caltrans to identify the accuracy and precision of alternative detection technologies as well as relative advantages, disadvantages, and limitations through accurate ground truth analysis. This allows assessments of different applications to determine which types of detectors are most appropriate and allow for the installation and maintenance of traffic detectors that require less time, expense, and impact on the traveling public.

Deployment (Task 1718):
The benefits of integrating advanced loop detector technologies with existing inductive loop count stations include: no construction costs, rapid deployment potential, relatively low per-unit cost, more available data collection points, and low maintenance cost. It allows for better planning of ramp metering and improved congestion management. It can provide detailed statistics on goods movement in the monitored area. Finally, it supplies information on pavement use for highway maintenance planning.

Project Deployable Product or Service:
Evaluation (Task 1726):
The Video Vehicle Detector Verification System is a one of a kind detector-testing tool currently deployed in the field as a test system. It performs a number of functions that greatly reduce the human workload associated with detector performance assessments, especially for long test periods and large data sets.

Deployment (Task 1718):
The intelligent modems integrate a General Packet Radio Service (GPRS)/ Enhanced Data for Global Evolution (EDGE) wireless modem and a Java programmable microprocessor that collect traffic data from loop detectors. This modem applies an algorithm to the data in real time, distinguishing long and short vehicles and summarizes volume and occupancy. The processed results are relayed to traffic management centers via a cellular network. The software is compatible with several major database systems including Oracle, Microsoft Access, and Microsoft Structured Query Language (SQL) databases.

Project Manager: Christopher Caldwell
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Project Title:

Development of a Self-Restoring Impact Attenuator

Project Description:
This project was initiated to develop and test a nonproprietary end treatment for a guardrail and median barrier. This end treatment was to be self-restoring with little or no maintenance, exhibit little or no vehicle rebound, and meet National Cooperative Highway Research Program Report 350 standards.

Project Outcome:
The intended outcome of this project was to design a new end treatment. This would result in new plans, specifications, and operating instructions. Caltrans designers would then have an additional cost effective crash attenuator option when designing California roadways.

Project Benefit:
By developing a nonproprietary end treatment, Caltrans would reduce project costs by not having to purchase expensive proprietary end treatments. The new end treatment would also reduce life-cycle costs by providing an economical, self-restoring, and low-maintenance crash cushion. The new end treatment would also reduce the amount of time that maintenance crew are exposed to traffic repairing the end treatment after a collision.

Project Deployable Product or Service:
The intent of this project was to deliver a fully designed and tested self-restoring low-maintenance end treatment at a substantially lower installed cost than existing systems. After the project started, several preliminary designs were abandoned due to intellectual property issues. Additionally, several lower maintenance crash attenuators became commercially available that reduced the need for the project. With these changes, it was determined that the project should be summarized and closed. The information gained from the project has been beneficial for Caltrans. The project information has been incorporated into the Caltrans roadside safety program and product development.

Project Manager: Jose Perez Email address: jose.d.perez@dot.ca.gov

Project Title:

Dynamic Control Strategies to Increase High Occupancy Vehicle (HOV) Lane Vehicle Speeds

Project Description:
The project developed an automatic hybrid vehicle recognition system that will be used to obtain hybrid vehicle counts on HOV lanes and determine if there is a direct correlation between the degradation increases in HOV facilities and the number of single occupant hybrid vehicles (SOHV) driving along HOV lanes. Based on acceptable results, the project team initiated identification of required components of the proposed HOV management system. The project looked into the aspects of whether or not it is feasible to regulate HOV lane access at the periods in which hybrids are not allowed to use the facility. The project provided Caltrans with a recommendation to address the feasibility and effectiveness of limiting hybrid access, a system design to provide an efficient solution to the degradation problem, and a deployment plan for the demonstration.

Project Outcome:
This research developed various strategies that can be utilized to manage degraded HOV lanes and maximize HOV lane use. In addition, based on the evaluation results, more elaborate control access scenarios can be developed if needed, such as controlling a subset of vehicles only on the degraded segments of the HOV lanes. Successful implementation of the proof of concept demonstration can be extended to a full-scale deployment, which may be able to satisfy the federal HOV requirements to improve performance of the HOV lanes or discontinue SOHV hybrid access to congested HOV segments. It may lead to obtaining full approval for the use of HOV facilities by hybrid vehicles in California by the Federal Highway Administration (FHWA).

Project Benefit:
The benefits of this project were the identification of the design requirements for a HOV lane management system and development of an efficient HOV lane access control scenario for SOHVs.

Project Deployable Product or Service:
The deployable product of this project was a modeling method to show how managing HOV lanes more efficiently could be done, which includes regulating hybrid vehicle access, restriction to HOV lanes and access, and a restriction control scenario for SOHVs accessing the HOV lanes.

Project Manager: Hassan Aboukhadijeh
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Project Title:

Evaluation of Alternative Construction Plans

Project Description:
In the summer of 2008, the Fix I-5 project offered a great opportunity to investigate and manage how different types of construction closures affect traffic and the environment. The Fix I-5 project was the reconstruction of a one-mile stretch of Interstate 5 (I-5) in downtown Sacramento, California which closed I-5 intermittently for nine weeks. The project affected I-5 between R Street and Richards Boulevard, which connects US Route 50, State Route 99, and Interstate 80. This portion of I-5 is part of a major north-south conduit for interregional traffic (extending from Canada and Mexico), and also a key commute route serving downtown Sacramento and other job locations in the region with over 195,000 vehicles traveling daily.

This research project investigated how different alternative construction plans for the I-5 closure affected highway traffic, transit ridership, emissions, and fuel consumption in the affected areas. The study required extensive modeling work that took into account travel demand changes, mode shifts, departure time shifts (peak spreading), and rerouting. By quantifying the user costs (delays and fuel costs) and environmental impact (emissions and energy usage) of different construction plans for the I-5 closure, researchers were able to pinpoint what plan did and did not work, and developed guidelines for effective construction plans that produce the smallest congestion, emissions, and energy footprints for large construction projects in major urban corridors.

Project Outcome:
The outcome of this project showed how different alternative construction plans for the I-5 closure could affect highway traffic, transit ridership, emissions, and fuel consumption in the affected areas. This research looked at what strategies and policies that do and do not work, by gathering detailed information about the alternative construction plans for the I-5 closure, including geographical scope of the closure, lane closure configurations, and the construction schedule.

Researchers came to the conclusion that using cost plus time bidding for most future projects similar to the Fix I-5 Project results in a significant user cost reduction to the traveling public compared to the traditional 195-day lane-closure plan. They also recommended using directional closures over lane closures, because directional closures can significantly reduce project duration. Therefore, overall user costs are reduced while producing comparable levels of fuel consumption and emissions.

Project Benefit:
This project has three benefits 1) developing strategies for alternative construction plans that improve the efficiency of the existing transportation system by encouraging the use of alternate travel modes, 2) developing a set of guidelines for the development of construction/traffic management plans for future large-scale highway reconstruction projects based on a full range of performance measures: safety, travel delay, energy use, and emissions, and 3) extracting lessons for improving disaster preparedness.

Project Deployable Product or Service:
The deployable outcome of this project was the modeling of alternative construction plans into the NetZone software tool to help plan future large-scale highway reconstruction projects. NetZone is a traffic analysis tool that was developed for Caltrans as part of another study to manage work zone traffic with various traffic control measures such as traveler information and ramp metering.

These models can be used to evaluate the travel delay, fuel consumption, and emissions of alternative construction/traffic management plans in a corridor network, thus facilitating the choice of the most effective plan. By helping the development of more effective construction/traffic management plans, the main benefits of this research are reduced construction and user costs, as well as reduced environmental impact.

Project Manager: Haniel Chung Email address: haniel.chung@dot.ca.gov

Project Title

Integrated Work Zone Traffic Management

Project Description:
Currently, non-recurrent traffic congestion caused by construction work constitutes a large proportion of the traffic congestion on highways. A robust network wide traffic performance measure modeling tool, along with an improved graphical user interface (GUI) that will take advantage of the computer's graphics capability, can help identify the cause of traffic congestion level and recommend mitigation measures. This project developed a comprehensive, state-of-the art dynamic network analysis software tool called "NetZone". NetZone is capable of showing the traffic congestion level in a network model over time to provide traffic performance measures such as vehicle miles of travel and total delay in time. Case studies have shown that practitioners can use NetZone to study a reasonably large network in a fraction of the time that a micro-simulation package takes for the same network.

The objective was to provide a work zone modeling tool that is 1) easy to use, 2) models congestion evolution in an entire network, not just the freeway containing the work zone, 3) captures traffic diversion, and 4) measures effectiveness and provides visualization tools for problem analysis and report generation.

Project Outcome:
The research resulted in a robust and powerful planning model to reproduce congestion patterns and to model queues and traffic diversions throughout California. The NetZone software was successfully applied to the Fix I-5 project in which directional closure of Interstate 5 (I-5) near downtown Sacramento was modeled. The Fix I-5 project was a Caltrans safety improvement project to improve travel safety conditions on I-5 by upgrading drainage systems and pavement. NetZone, compared with other modeling software, has taken significantly less time to develop and calibrate in reproducing congestion patterns due to the ability to quickly and accurately model queues and traffic diversions.

Project Benefit:
The project provided Caltrans with an analysis tool to conduct quick and detailed analysis of work zone traffic impacts to better meet the demands of the state of California on safety and mobility for travelers in response to traffic congestion. With the improved GUI functions and upgrade to include the High Occupancy Vehicle component, NetZone significantly improved traffic performance measures in work zones. The tool helped to reduce delays, improve traffic safety, and minimize environmental impacts.

Project Deployable Product or Service:
Using the algorithms and GUI developed for NetZone, the researcher created an enhanced software tool for Caltrans to analyze congestion patterns and model queues and traffic diversions. Caltrans used the tool to study a reasonably large network in a fraction of the time that a micro-simulation modeling takes for the same network. NetZone meets the demands of safety and mobility for travelers in response to traffic congestion. Training workshops and demonstrations have been provided to Caltrans traffic engineers as part of the implementation strategy.

Project Manager: Roya Hassas Email address: roya.hassas@dot.ca.gov

Project Title:

Measuring Tool for Intelligent Transportation System (ITS) Impacts on Freeway Safety Performance

Project Description:

This project updated and enhanced a tool for measuring freeway safety performance, enabling Caltrans to evaluate the safety impacts of roadway traffic volume changes over time. It provides an easily accessible tool to assess the safety performance of freeway operations and to evaluate and document improvements to safety arising from such ITS deployments such as System-Wide Ramp Metering (SWARM), Freeway Service Patrol (FSP), driver information, and other incident response measures.

The objective of this project was to implement a real-time tool for safety analysis by calibrating and verifying a model that translates traffic flow, as measured by Inductive Loop Detectors (ILD), into an extensive set of statistical parameters that describe traffic flow, and the types of accidents that occur under different types of traffic flow conditions.

Project Outcome:

This project resulted in the development of a website and open web services. The website provides a map-based interface to the safety models and data in a "Performance Measurement System (PeMS)-like" safety performance system based solely on loop detector data, together with real-time Transportation Management Center (TMC) maps displaying the relative likelihood of traffic-related safety hazards. The open web services allow other projects and tools to access everything from raw data, to intermediate results, to the final accident risk predictions so as to incorporate the information into new projects.

Project Benefit:

By using this tool, Caltrans evaluates the safety impacts of roadway changes over time by looking at the aggregate risk of accidents before and after a new roadway improvement is constructed. The tool allows the cumulative accident probabilities to be estimated with real conditions over any given time period. It serves as a monitoring tool as well as planning tool. When used as a monitoring tool, it predicts the odds of different types of accidents for all loop stations providing data. When used as a planning tool, it compares the safety level of changes in traffic flow over time.

Project Deployable Product or Service:
This research developed a real time monitoring tool for assessing the ITS impacts of changes in freeway traffic flow on the level of traffic safety measured in terms of the probability of a reportable accident.