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16. ABSTRACT
Workplace motor vehicle incidents at Caltrans are a significant cause of injuries, employee lost time, and property damage. Because backing crashes are major contributors to motor vehicle incidents, identifying and promoting methods of reducing backing accidents is a top priority. According to internal Caltrans' data, 92.3% of workplace backing crashes were preventable by the driver. Backing crashes are the single largest category of preventable crashes, representing 30% of preventable crashes in the Caltrans fleet. From 1998 through 2007, preventable backing crashes cost Caltrans at least $5.45 million in vehicle repairs alone. The Traffic Safety Center (TSC) at the University of California-Berkeley completed this study, which examines Caltrans crash data from the Safety Information Management System (SIMS) and identifies trends in backing-related crashes. The findings describe how these crashes are distributed across Caltrans sites, various work locations, and among vehicle types. This study also presents a summary of a literature review of technological solutions to backing crashes, a summary of results from a Caltrans backing prevention technology pilot, and an outline for a proposed Field Operational Test of promising backing technologies. Based on careful review of Caltrans data and backing incident counter-measures, the study evaluates current Caltrans safety policies relevant to backing crashes and offers recommendations for strengthening them.

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CALIFORNIA PATH PROGRAM
INSTITUTE OF TRANSPORTATION STUDIES
UNIVERSITY OF CALIFORNIA, BERKELEY

Develop Methods to Reduce or Prevent Backing Crashes

**Douglas L. Cooper, Sarah Duffy,
Phyllis Orrick, David R. Ragland**

California PATH Research Report
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This work was performed as part of the California PATH Program of the University of California, in cooperation with the State of California Business, Transportation, and Housing Agency, Department of Transportation, and the United States Department of Transportation, Federal Highway Administration.

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Develop Methods to Reduce or Prevent Backing Crashes

Prepared for: the
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Prepared by: Douglas L. Cooper, Sarah Duffy,
Phyllis Orrick, and David R. Ragland

May 2009

The mission of the UC Berkeley Traffic Safety Center is to reduce traffic fatalities and injuries through multi-disciplinary collaboration in education, research, and outreach and to strengthen the capability of state, county, and local governments, academic institutions, and local community organizations to enhance traffic safety through research, curriculum and material development, outreach, and training for professionals and students.

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Abstract

Workplace motor vehicle incidents at Caltrans are a significant cause of injuries, employee lost time, and property damage. Because backing crashes are major contributors to motor vehicle incidents, identifying and promoting methods of reducing backing accidents is a top priority. According to internal Caltrans' data, 92.3% of workplace backing crashes were preventable by the driver. Backing crashes are the single largest category of preventable crashes, representing 30% of preventable crashes in the Caltrans fleet. From 1998 through 2007, preventable backing crashes cost Caltrans at least $5.45 million in vehicle repairs alone.

The Traffic Safety Center (TSC) at the University of California-Berkeley completed this study, which examines Caltrans crash data from the Safety Information Management System (SIMS) and identifies trends in backing-related crashes. The findings describe how these crashes are distributed across Caltrans sites, various work locations, and among vehicle types. This study also presents a summary of a literature review of technological solutions to backing crashes, a summary of results from a Caltrans backing prevention technology pilot, and an outline for a proposed Field Operational Test of promising backing technologies. Based on careful review of Caltrans data and backing incident counter-measures, the study evaluates current Caltrans safety policies relevant to backing crashes and offers recommendations for strengthening them.

Keywords: Human Factors, Risk Analysis, Vehicles, Work Zone Safety

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Executive Summary

This study examined motor vehicle incident data collected between 1998 and 2007 from Caltrans' Safety Information Management System (SIMS), the repository for safety data available for statistical analysis at Caltrans. During this period, preventable backing crashes cost Caltrans at least $5.45 million in vehicle repairs alone; this figure does not include medical costs, employee lost time, vehicle lost time, and third-party expenses.

According to Caltrans' investigations, 92.3% of backing crashes could have been prevented by the driver, compared with 47% of non-backing crashes. Because most are preventable, these crashes represent a readily accessible opportunity for enhancing safety and saving money.

To eliminate backing crashes there are essentially three approaches that can be taken:
1. Changes to equipment (e.g., mirrors, backing video, radar/sonar).
2. Adjustments to procedures (e.g., use of cones, circle checks, spotters).
3. Changes in workplace safety policies (e.g., training, accountability).

While this report will discuss all three approaches, emphasis will be on procedures and policies since these are applicable to all vehicles, and do not require capital outlay.

The starting point for solving the backing crash problem is to gain a clear understanding of its magnitude and scope, and the SIMS database was used to provide the data for a descriptive statistical analysis of motor vehicle incidents at Caltrans.

In addition, TSC staff conducted a review of the Caltrans safety divisions' current data collection and analysis procedures, and conducted interviews with Caltrans district safety officers and safety representatives from other state departments of transportation (DOTs). This research formed the basis for recommendations to improve backing safety at Caltrans including the following:
- Creating procedures to ensure accident reporting forms are filled out completely and accurately before contents are entered in the database.
- Establishing a linkage between SIMS data and other internal Caltrans safety-related data, such as departmental personal injury files.
- Combining SIMS injury data State Compensation Insurance Fund (SCIF) data.
- Providing supervisors and staff with uniform training in accident and injury investigation and in completing forms.
- Establishing uniform procedures and deadlines for filing reports.
- Limiting database access to personnel trained in the software that runs the database and ensuring that district safety officers are trained in this software use.
- Instituting an effective progressive discipline policy that enforces meaningful consequences for employees who cause preventable incidents.
- Exploring merit rating policies, which include both an "experience rating" and a "schedule rating," as well as regional analysis of claims.
- Conducting a Field Operational Test to evaluate promising technologies.

1 Introduction

From 1998 through 2007, the most recent ten years for which data are available, Caltrans drivers were involved in 2,926 backing crashes, 93.2% of which were determined to have been preventable by the driver. In contrast, only 47% of non-backing crashes were determined to be preventable by the driver.

The estimated average repair cost for each involved vehicle is $2,000, based on 2006 costs to repair the 45 vehicles for which this information is available. Based on this estimate, over the decade studied, preventable backing crashes cost Caltrans at least $5.45 million in vehicle repairs alone; this is not counting medical costs, employee lost time, vehicle lost time, and third-party expenses.

Because these crashes are largely preventable, they represent a readily accessible opportunity for enhancing safety and saving money.

There are essentially three approaches that can be taken to eliminate backing incidents. These involve changes to:

1. Equipment (e.g., mirrors, backing video, radar/sonar).
2. Procedures (e.g., use of cones, chocks, spotters).
3. Policy (e.g., training, accountability).

While this report will discuss all three approaches, it will emphasize procedures and policies since they are applicable to all vehicles, and do not require capital outlay.

2 Crash Data

2.1 SIMS Database Inputs

The SIMS database contains information obtained from three forms that are filled out each time a Caltrans vehicle is involved in an incident:

- Form STD. 269, "Accident Identification Card" (Appendix A) is completed by the driver at the scene and turned over to the driver's first-line supervisor.
- Form STD. 270, "Vehicle Accident Report" (Appendix B) is typically completed by the driver upon returning to the office and turned over to the driver's first-line supervisor.
- Form PM-S-0270, "Data Input for Motor Vehicle Accident" (Appendix C) is a computer input document completed by the first-line supervisor based on information provided by the driver and the results of an investigation (Caltrans 1996a [section revised 2000]). This form contains criteria used to determine whether the driver could have prevented the crash.

2.2 Preventable Backing and Non-Backing Crashes

Figure 1 shows the ten-year trends for preventable backing and non-backing crashes. In 2006, both categories of crashes began a reversal of a multi-year downtrend. When examining the vehicle's action just prior to the crash ("Movement Preceding Collision"), of the 18 possible choices on the data input accident form, "backing" was found to be the single most common, accounting for approximately 30% of total preventable crashes. This was followed by "Driving Straight Ahead" (25.4%) and "Stopped" (10.5%).

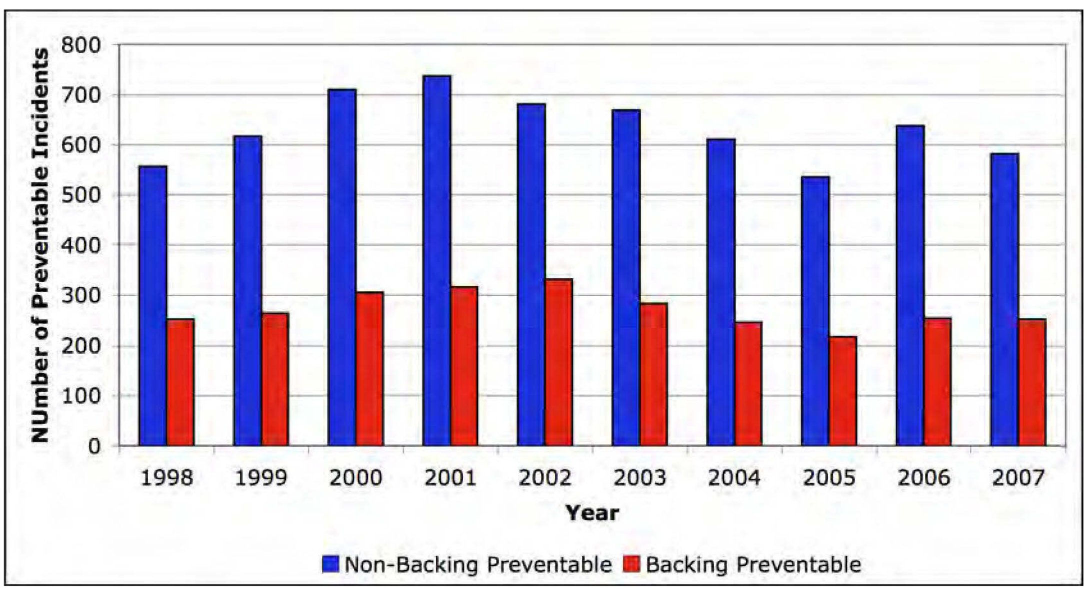

Figure 1: Backing Crashes as a Share of All Preventable Crashes 1998-2007

Source: Caltrans SIMS Database

2.3 Backing Crash Locations

2.3.1 Statewide

A comparison of preventable backing and non-backing crashes by general location (see Table 1) shows that across all Caltrans districts, the single location where preventable backing crashes occur most often (24.6% of the time) is “State Yard or State Property” (as indicated on Form PM-S-0270), followed by “Private Property” at 13.9%, and “Freeway” at 13.8%. For non-backing crashes, these percentages are 17.2%, 7.3%, and 19.7% respectively.

However, the general location category “State Yard or State Property” is not well defined since several other general accident location choices (e.g., “Conventional Highway”) can also be considered state property, and there is no assurance of consistency in how crashes are assigned to general location categories.

Table 1: Overall Preventable Backing vs. Non-Backing Crashes by Location 1998-2007

	Backing		Non-backing	
GENERAL LOCATION	Number	%	Number	%
City Street	286	10.5%	1,235	19.5%
Construction	186	6.8%	244	3.9%
Conventional Highway	216	7.9%	843	13.3%
Freeway	376	13.8%	1,248	19.7%
Freeway Ramp or Connector	195	7.2%	578	9.1%
Lane or Shoulder Closure	191	7.0%	198	3.1%
Maintenance Work Zone	159	5.8%	202	3.2%
Private Property	378	13.9%	465	7.3%
Rural Road	39	1.4%	149	2.4%
State Yard or Property	**670**	**24.6%**	**1,091**	**17.2%**
Tunnel or Tube	2	0.1%	8	0.1%
(blank)	28	1.0%	74	1.2%
Total	2,726	100.0%	6,336	100.0%

Source: Caltrans SIMS Database

In addition to the 11 general location categories listed in Table 1, Form PM-S-0270 offers eight specific location designations, including "Parking Lot." To obtain a clearer understanding of those backing incidents that occur in the general location "State Yard or Property," Figure 2 breaks the category down into two subcategories: "Parking Lot" and "Other." The assumption here is that "Parking Lot" refers to Caltrans yards. Subdivided in this way, it can be determined that Caltrans yards account for the largest location category (20%) of backing incidents.

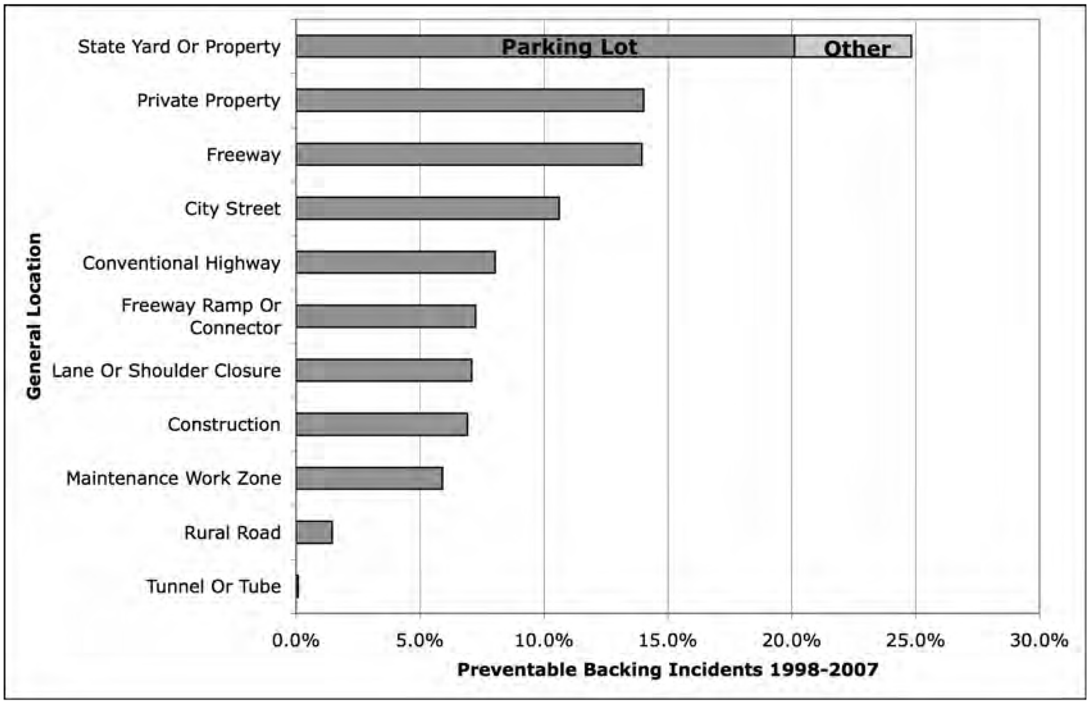

Figure 2: Preventable Backing Collisions by Location 1998-2007

Source: Caltrans SIMS Database

2.3.2 Backing Crashes by District

The total number of preventable backing crashes that occurred between 1998 and 2007 varies dramatically by district (Figure 3), with the highest number in Districts 4 (Bay Area) and 7 (Los Angeles) and the lowest numbers in District 32 (Headquarters) and 9 (Inyo County). Given the differences in district size and number of vehicles in use in each district, this variation is understandable. Information on employee populations, job assignments, and distribution among the districts is needed to gain a clearer picture of the factors that contribute to the variations. The requirement for additional data is discussed further in Section 3.2.2: Additional Data Needs.

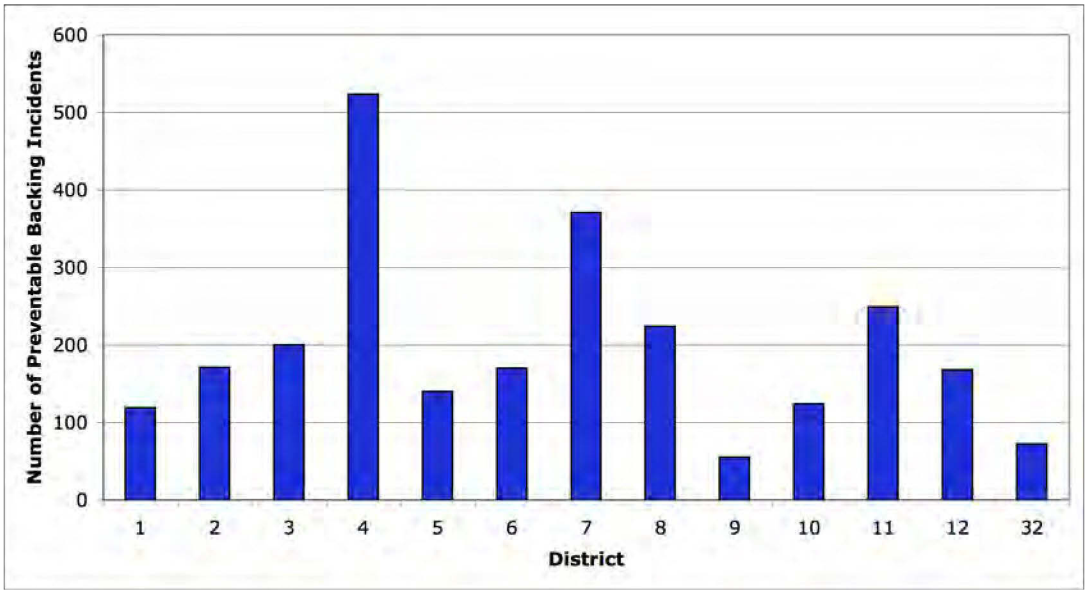

Figure 3: Total Number Preventable Backing Crashes by District 1998-2007

Source: Caltrans SIMS Database

The proportion of preventable backing crashes versus preventable non-backing crashes also varies among districts (Figure 4), with the highest proportion of backing crashes in District 6 (Fresno), with 44%. In the majority of districts, on average, 35% of preventable crashes involved backing.

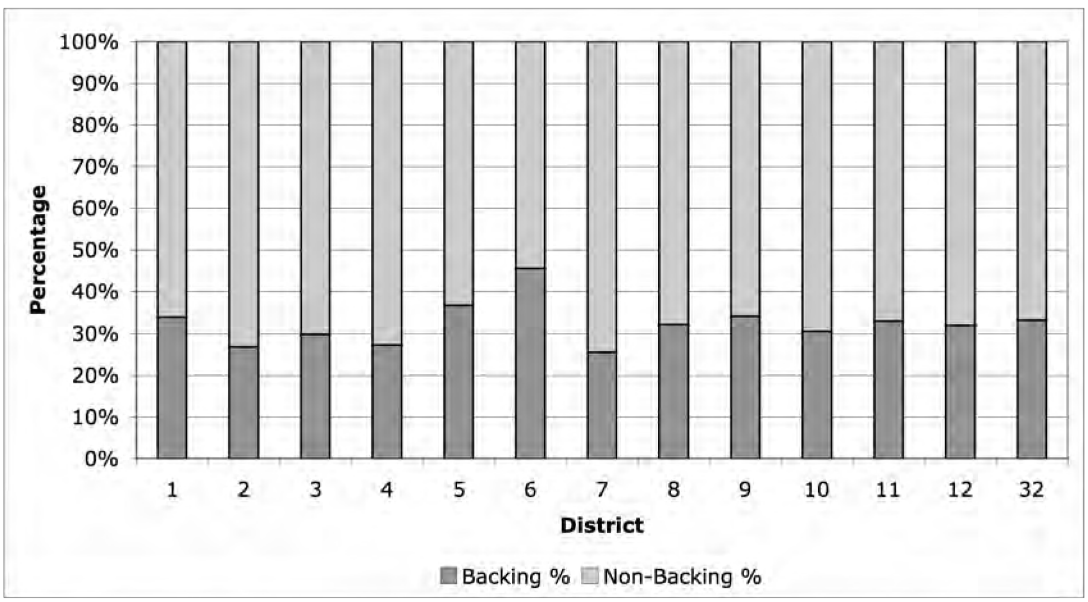

Figure 4: Percentage of Preventable Backing and Preventable Non-Backing Crashes by District 1998-2007

Source: Caltrans SIMS Database

Figure 5 shows the number of preventable backing crashes normalized by the number of vehicles in each district. While displaying less variability than the non-normalized numbers, these figures reveal large variations among Caltrans districts. Further research regarding specific vehicle types and usage (e.g., mileage, road, and weather conditions) in the different districts would help clarify the causes of variation among the districts.

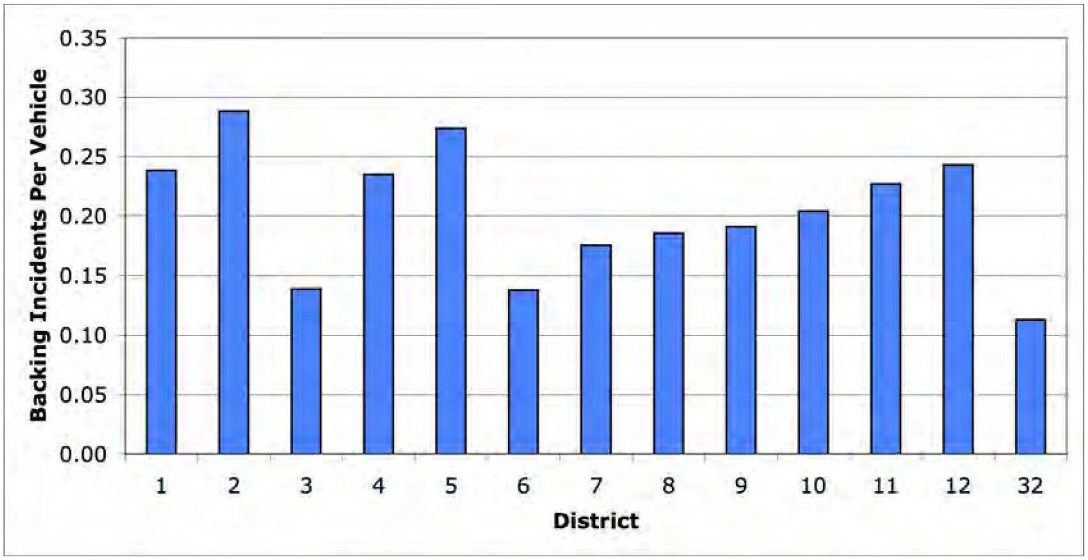

Figure 5: Preventable Backing Crashes by District Normalized for Number of Vehicles 1998-2007

Source: Caltrans SIMS Database

Because this variability between districts could be attributable, at least in part, to the differences in miles the vehicles are driven, we calculated the number of incidents per 100,000 miles driven. Mileage information is a rough estimate derived from data collected on an ad hoc basis from the Division of Equipment's vehicle repair records. The analysis results are shown in Figure 6. Again, the numbers vary considerably among districts. From 1998 to 2007, the highest number of preventable backing collisions per 100,000 miles driven occurred in District 5 (Monterey), District 1 (Eureka), District 2 (Redding), District 10 (Stockton), District 11 (San Diego), and District 12 (Irvine). The lowest number occurred in District 6 (Fresno).

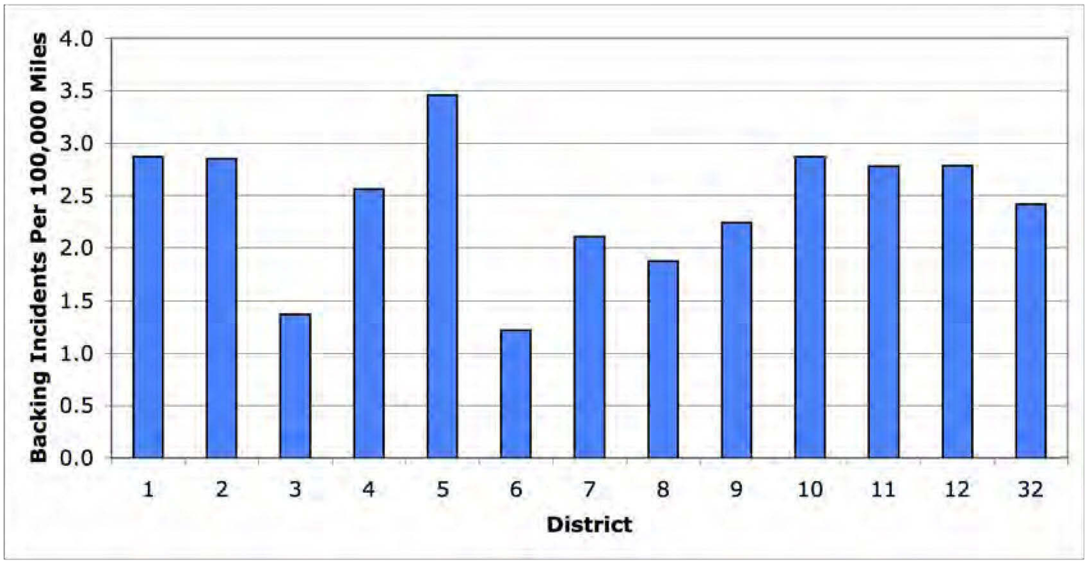

Figure 6: Preventable Backing Crashes Per 100,000 Miles by District 1998-2007

Source: Caltrans SIMS Database

The total number of preventable backing crashes that occurred in Caltrans yards also differs significantly by district, as shown in Figure 7. Betweem 1998 and 2007, 121 preventable backing incidents occurred in District 4 (Bay Area) compared with 68 in District 7 (Los Angeles). District 4 recorded a greater number of drivers and vehicles than District 7 and may also have more pickup trucks or wreckers. More research will be necessary to understand what might be responsible for increased rates of backing collisions in the Bay Area.

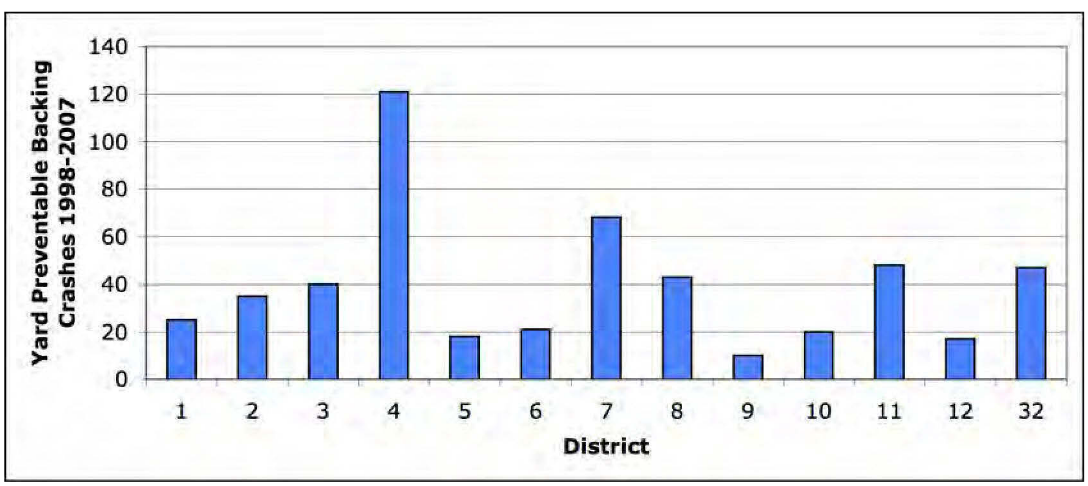

Figure 7: Preventable Backing Crashes in Caltrans Yards by District 1998-2007

Source: Caltrans SIMS Database

Figure 8 illustrates the rates of yard crashes per 100 vehicles, which also vary across districts, from a low of 1.7 in District 6 (Fresno) to a high of 8.4 in District 32 (Headquarters). On average, there were 3.7 preventable yard backing incidents per 100 vehicles per year per district. The outsized number of yard crashes in District 32 (Headquarters), over two times the average, is a cause for concern. Further research is needed to identify the reasons for this high crash rate.

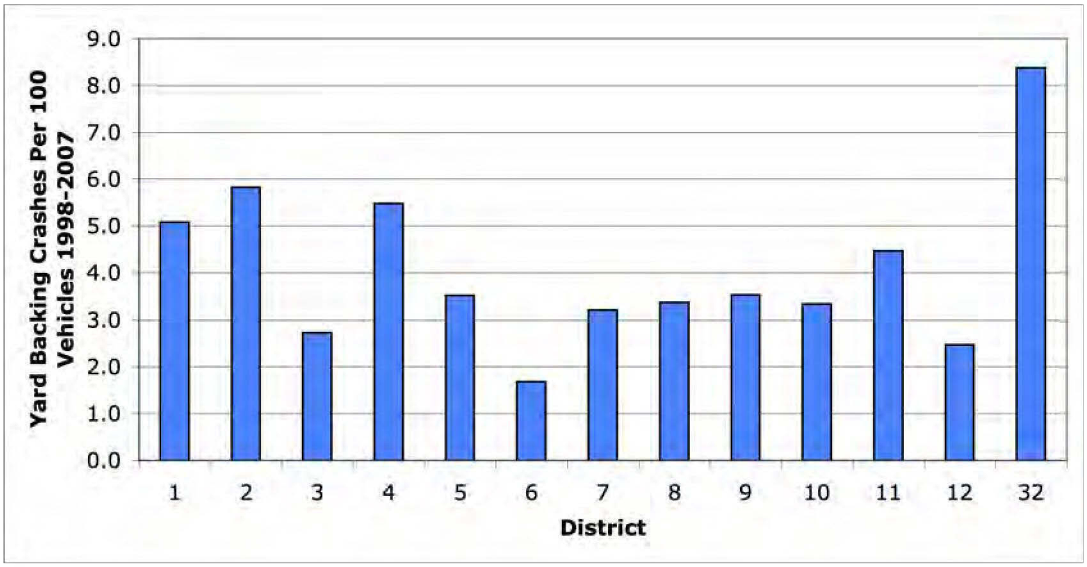

Figure 8: Preventable Backing Crashes 1998-2007 per 100 Vehicles in Caltrans Yards by District

Source: Caltrans SIMS Database

2.4 Types of Vehicle Involved in Backing Crashes

Between 1998 and 2007, pickup trucks were involved in more preventable backing crashes (682) than any other vehicle category, comprising 25% of all preventable backing crashes (Figure 9). Although this data is not normalized (there are more pickup trucks than other types of vehicles in the Caltrans fleet), it provides a focus for potential remedial actions. By addressing backing problems in pickups, sedans, vans, SUVs, and station wagons (vehicles whose size and rear visibility are not likely to be contributing crash factors), 37% of backing crashes could be eliminated. This could be achieved through changes to policies and procedures and would need not involve new equipment.

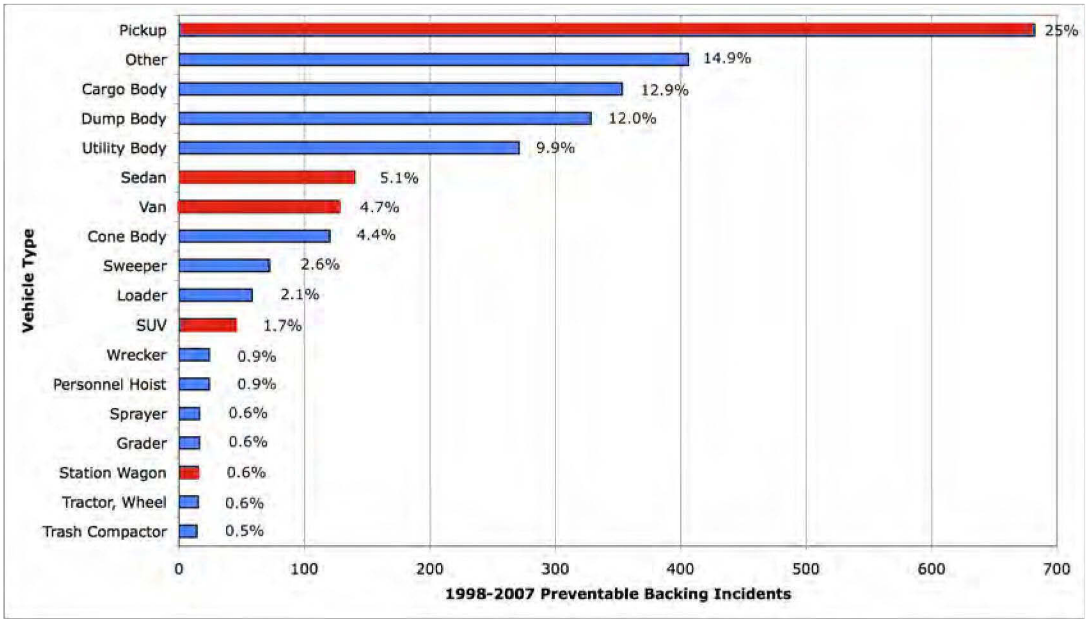

Figure 9: Number of Preventable Backing Crashes by Vehicle Type 1998-2007

Source: Caltrans SIMS Database

When the incident data by vehicle type are normalized—that is, when the number of each type of vehicle is taken into consideration—a different picture emerges (Figure 10). In this analysis the larger vehicles, many with limited visibility to the rear, have the highest preventable backing crash rates. Wreckers have the most incidents, which could be due in part to the backing-intensive nature of the work they perform. However, because of their small numbers, wreckers' high incident rates account for less than 1% of all backing incidents, or roughly three crashes per year. Still, wrecker operations may be a productive focus for remedial programs.

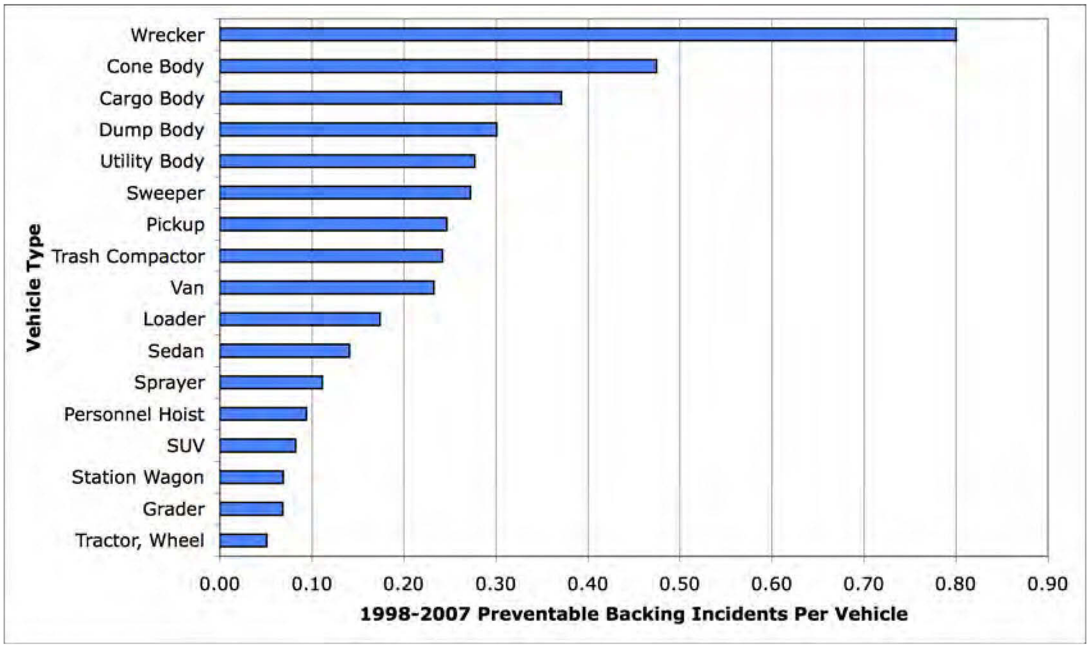

Figure 10: Preventable Backing Crashes by Vehicle Type Normalized for Number of Vehicles 1998-2007

Source: Caltrans SIMS Database

As Figure 10 shows, overall crash rates for different types of vehicles vary substantially. Crash rates by vehicle type also vary among Caltrans districts. As shown in Figure 11, for example, the average annual crash rate for cargo-body vehicles in District 12 is three times that of District 6. It may be that usage for these vehicles (by miles or hours, neither of which is currently available in the SIMS database) may be substantially higher in District 6. Alternatively, operating methods, procedures, or factors in the working environment may play a role. Further investigation is needed to understand factors that impact different rates.

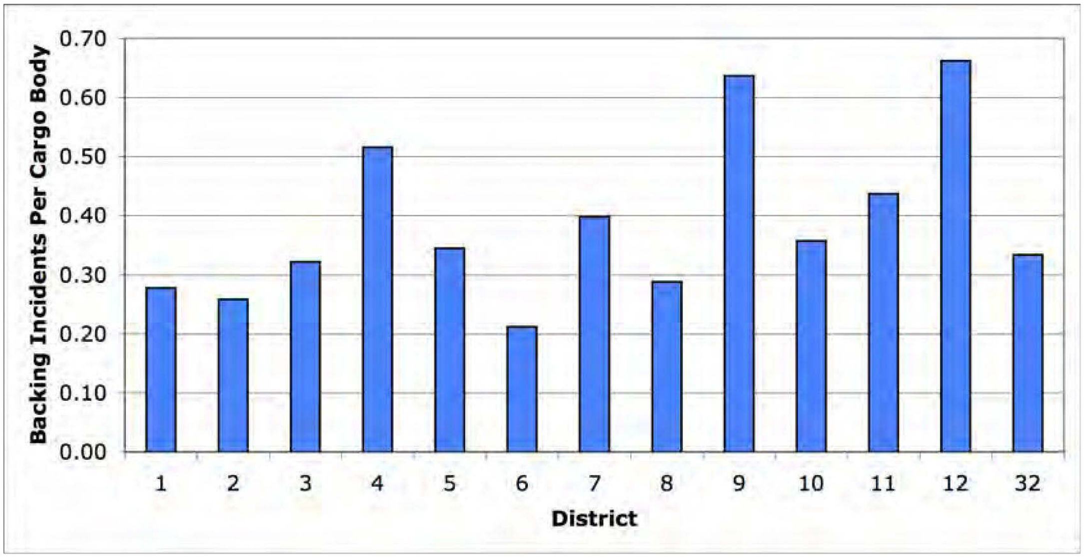

Figure 11: Average Annual Number of Cargo-Body Vehicle Preventable Backing Crashes by District 1998-2007

Source: Caltrans SIMS Database

3 Information Management: Suggestions for Current and Future Practices

The SIMS database has the potential to provide information about the causes of preventable backing crashes and to offer solutions to the problem. Based on a review of the current SIMS database as well as interviews with Caltrans district safety officers and safety representatives from other state departments of transportation, the TSC staff developed the following suggestions to make SIMS a more powerful tool for safety and prevention.

3.1 Improvements Needed in Filling Out Forms

3.1.1 Incomplete Information

A common problem with the SIMS system is that forms containing the data to be entered into SIMS are not filled out completely. For example, in the ten-year period between 1998 and 2007, “Basic Cause” was missing in 3,636 (22%) of the incidents, “Type of Collision” was missing in 1,087 (6.7%), and “Driver’s Condition” was missing in 836 (5.1%). Personal injury report data were also missing in several categories that are important for statistical analysis, including: “Hire date” (missing on 10.5% of the forms); “Time of Injury” (missing on 15%); “Preventability” (missing on 7%); and “Accident Location” (missing on 2%). Current procedures should be reviewed to ensure that the forms are completely filled out before the information for each incident is entered into SIMS.

3.1.2 Incorrect Information

Another common problem is that the information that is entered is incorrect. This is particularly apparent in the “Movement Preceding Collision” field. Out of a sample of 100 forms in which “Movement Preceding Collision” was described as “Stopped,” 64 included crash narratives which contradicted this designation. The descriptions of these crashes included such statements as:

- Employee rear-ended private vehicle at stoplight.
- State vehicle struck guardrail while backing.
- Pulled out from a stop sign and hit another vehicle.
- Caltrans vehicle rear-ended private party at railroad crossing.

Lack of understanding of the terms used in incident forms also leads to incorrect entries. Under “Movement Preceding Collision,” two of the choices involve the vehicle being stationary. One is “Stopped,” meaning that the vehicle is not moving but that the driver is still in the vehicle, and “Parked,” which indicates that the operator has exited the vehicle. A significant number of entries under “Stopped” include accident descriptions which should be in the “Parked” category, such as:

- Left truck and forgot to set parking brake, vehicle rolled over an embankment.
- Employee parked in shoulder left truck running. When employee returned to vehicle it had rear-ended contractor's vehicle.
- Operator left tractor to talk to citizen parked in work zone. Tractor was not completely in park and rolled forward into rear bumper of parked vehicle.

Before data is entered in the SIMS database, it should be reviewed to confirm that it is complete and that each field entry is consistent with the crash narrative.

3.2 Suggested Improvements in Clarity, Structure, and Functionality of Forms and SIMS Database

3.2.1 Clarify Confusing Incident Location Fields

The location choices on the P-MS-0270 form often make it difficult to ascertain accurate locations for many incidents because the 11 “General Location” choices do not always correlate well when used in conjunction with the six ”Specific Locations”:

General Locations	**Specific Locations**
City Street	At Intersection
Conventional Highway	Median
Construction	Off Street or Hwy in R/W
Freeway	On Bridge
Freeway Ramp or Connector	Parking Lot
Lane or Shoulder Closure	Shoulder
Private Property	Traveled Way
Rural Road	
State Yard or Property	
Tunnel or Tube	
Maintenance Work Zone	

The problem lies in the fact that incidents that occur on a “City Street,” “Conventional Highway,” “Freeway,” “Freeway Ramp or Connector,” “Rural Road,” or “Tunnel or Tube” could be recorded on the incident report in those general location categories, or they could be placed in the general location category “State Yard or Property,” since all of these locations could be considered state property.

An example of this ambiguity is evident in data for the 252 (14% of total preventable) incidents with a general location of “State Yard or Property” and a specific location of “Off Street or Hwy in R/W,” where R/W means “right-of-way.” There is no way to know whether these incidents occurred off to the side of a conventional highway, city street, or freeway.

3.2.2 Additional Data Needs

The reporting forms should collect more information for input into SIMS. These additional data categories include:

- Hire date for Caltrans employee involved in the incident. This information allows time on the job to be calculated to determine if refresher training is necessary.
- Date employee started current job.
- Birth date for the employee to determine whether any trends could be age-related.
- Vehicle mileage to determine incidents per mile driven per vehicle.
- Complete crash costs.

As an early result of this project, work is now underway to make it possible to access repair cost information through SIMS. This data will help determine which types of vehicles and locations generate the greatest losses. Cost data should include both direct and indirect costs. Direct costs include vehicle repair costs, medical costs for injured Caltrans personnel, and third-party costs (property damage and personal injury). Indirect costs include vehicle down time, additional vehicles for use during repairs, crash investigation time, SCIF service fees, and data entry.

At present, there is no automatic link in SIMS between motor vehicle and personal injury files. Each motor vehicle incident is assigned an “M” number, and each personal injury is assigned a “P” number. In order to establish a link, an operator is required to go through all of the motor vehicle accident forms and observe which ones have the “Caltrans Employee Injured” box checked “Yes,” then search the personal injury forms using the vehicle driver’s name or ID number to look for a match. A more effective system would list the employee’s “P” number as part of the motor vehicle incident file and list the “M” number in the personal injury file.

Presently, in addition to the injury information that SIMS collects, the State Compensation Insurance Fund (SCIF), which serves as Caltrans’ claims administrator, gathers extensive data on Caltrans employees’ workers’ compensation claims. Currently, the SIMS and SCIF data are not linked. Combining the injury and claims data would generate useful information, such as the specific types of injuries likely to result in workers’ compensation claims, their costs, and the extent to which such claims were successfully disputed. This information would provide a context for calculating the potential return on investment gained through injury prevention activities targeted at specific injuries and specific types of incidents (such as backing).

Extensive information is currently available from SCIF in an electronic format, making integration into SIMS feasible. SCIF records: (1) payment date; (2) payment code; (3) claim number; (4) check number; (5) fiscal year injury occurred; (6) first and last name and middle initial of payee (injured worker); (7) breakdown of amounts paid for: compensation, medical, miscellaneous, and total costs; and (8) program code. Other information available from SCIF under the state master agreement could be used to establish a departmental claims tracking system. For each claim, SCIF can furnish the name of the office administering the claim, the adjuster name and telephone number, names of SCIF attorneys involved in the case, the WCAB case number from the Caltrans Return to Work Unit, information on whether the claim has been litigated, name of the applicant attorney, and whether liability in the case was accepted, delayed, or denied. SCIF can also provide start and end dates for the claim as well as type of current benefits.

3.3 Suggested Improvements in Data Collection, Entry, Database Access, and Accident Investigation Training

Supervisors should receive uniform training in investigating accidents and injuries and in filling out forms. A uniform procedure for filing reports needs to be established, including agency-wide deadlines for completion.

Data entry and database use training could be improved. Currently, SIMS data entry is conducted by a range of personnel not necessarily trained for that job, including temporary workers and light-duty employees. Additionally, district safety officers should be trained to use the database management software, so that they can generate reports and analysis of SIMS data on a district level. Currently, most district safety officers must request such reports from Sacramento.

Currently, each Caltrans district regularly generates statistics that include year-to-date accident and injury rates. Additionally, Caltrans headquarters produces reports that include district accident summaries, individual incident and claims histories for both personal and motor vehicle injuries, and Cal/OSHA district injury logs and summaries. To make this data more useful, analysis should take place at least twice yearly to determine injury and incident rates and trends. Finally, the data need to be distributed in a regular, systematic manner to all employees, from top-level to rank-and-file.

3.3.1 Data Collection Lessons from Other State Departments of Transportation (DOTs)

Other state DOTs use data collection methods that could serve as models for Caltrans to strengthen its current system. Below are several examples:

Idaho Transportation Department
Each of the six districts of the Idaho Transportation Department (ITD) has a designated data entry employee and all data are entered into the safety database at least once a week. The data are drawn from a wide array of sources including employee accident forms, tort claim forms, and safety meeting records. Only the seven safety staff members, six district business managers, and the employees who enter data in each district may log onto the database. The ITD's chief safety staff members generate comprehensive quarterly reports from this database. The safety manager first issues these statistics to top management in summary form and then distributes a full formal report with complete accident descriptions to all forepersons and section supervisors. The quarterly reports are discussed in detail during monthly safety committee meetings.

New York State Department of Transportation
The New York State Department of Transportation (NYSDOT) created a safety campaign to reduce motor vehicle backing accidents after annual trend reports generated from the accident and injury database revealed that crashes of this type were increasing. As part of the new safety campaign, NYSDOT created driving maps for the maintenance yards and instituted routine reviews and updates of backing policies listed in the employee manual.

Texas Department of Transportation
At the Texas Department of Transportation (TxDOT), as soon as an incident occurs, district staff sends an e-mail message to the central safety office, the Division of Occupational Safety, which triggers the creation of an entry in their database. The database, established 1989, is maintained by trained staff and tracks workplace injuries and workers' compensation claims on a daily basis, compiling data from a wide variety of sources. For example, the finance division provides the employee's hours worked while the fleet equipment operations office submits information about the vehicle, including its mileage.

Recently, after analyzing department injury data and concluding that backing was a major source of injuries, TxDOT installed detectors, cameras, and back-up alarms in some vehicles in several "pilot" districts. An analysis of the data shows that backing incidents have been reduced from an average of 100-130 per year to 80.

Washington Department of Transportation
The Washington Department of Transportation (WSDOT) established an internal injury database in 2005 when its new chief safety officer was hired. Regional safety officers input injury, lost time, and medical data. The database is capable of generating analyses and reports from a number of different perspectives, depending on the information needed by the safety officers. WSDOT provides managers with breakdowns of claim costs and information regarding open cases within their individual regions on a regular basis.

4 Caltrans Policies and Procedures

4.1 Caltrans Manuals

Caltrans guidelines for backing maneuvers of department vehicles are contained in both the Department's Safety Manual (Section 17.13) and the Maintenance Manual (Section 8.36) (Appendix D). A review of these two manuals as well as interviews with other state DOTs indicate that Caltrans policies and procedures cover the topic of backing well. If these policies and procedures were closely followed, backing incidents could be greatly reduced.

The Caltrans Safety Manual states: "The department recognizes that there is an increased risk of vehicle accidents during vehicular backing maneuvers." To decrease the likelihood of a backing accident, the manual instructs that whenever feasible operations will be modified to eliminate backing. Additionally, all sides of the vehicle are to be visually inspected to assure there are no obstacles, and when two or more employees work together, one employee shall act as a spotter at the rear of the vehicle.

Suggested modifications to the Safety Manual's backing procedures are:

- Any time a vehicle is backed, if another Caltrans employee is present, that person will act as a spotter.
- If a vehicle has been stopped or parked for any length of time, the driver shall exit the vehicle and perform a visual inspection.
- In all procedures, the word "shall" will be used rather than "should."

In the Maintenance Manual, backing policies and procedures are divided into three sections: (1) Prior to Job/Planning the Work; (2) Safety at the Worksite; and (3) Personal Responsibilities.

In the first section, Prior to Job/Planning the Work, supervisors are advised to plan work projects to minimize the need for backing. At the tailgate safety meeting held prior to the job, they are told to discuss how and when drivers are to conduct backing maneuvers within the work zone, and to establish specific measures that will be taken to prevent an accident.

In the second section, Safety at the Worksite, the emphasis is on workers who are on foot in the work zone. Procedures include staying clear of moving vehicles, making sure that employees never move equipment without first making positive visual contact with any workers on foot around or near the equipment, and using a spotter.

The third part, Personal Responsibilities, requires that employees operating vehicles and equipment be familiar with the blind spots for the specific equipment they are operating. Workers and equipment operators must be trained in appropriate communication methods for situations in which workers on foot are required to be in the same area as equipment.

In addition, drivers should conduct a walk-around inspection of the vehicle before entering.

A suggested modification for the Maintenance Manual is that in all procedures, the word “shall” be used rather than “should” in order to emphasize that the procedure is mandatory.

4.2 Spotters’ Guide

Based on information in the Safety and Maintenance manuals, a review of other state DOTs’ procedures, and interviews with Caltrans safety personnel, the Traffic Safety Center has designed a spotters’ guide that could be printed and distributed at tailgate meetings. The guide includes general rules, driver responsibilities, spotter responsibilities, and uniform hand signals for spotters. It is shown in Appendix E.

4.3 Accountability, Discipline, and Work Rules

A review of best practices for preventing workplace incidents and injuries revealed that an essential component of any safety program is the establishment of a strong safety culture, a key element of which is establishing a system of accountability at all levels of the organization.

Such a system institutes safety goals and measures safety activities, with all employees playing by the same rules and being held accountable for fulfilling their responsibilities. The system also provides a means for helping employees to understand how their individual performance contributes to maintaining workplace safety and teaching employees to take personal responsibility for their own performance.

> “Accountability ranks right at the top with management commitment as a critical ingredient in a company's safety and health management system. In fact, if employees don't believe they're going to be held accountable (experience consequences) for the decisions they make related to safety, you can be sure that any safety effort is ultimately doomed to failure” (Oregon OSHA).

According to the United States Department of Labor OSHA recommendations, an effective accountability system should include the following five elements:

1. Established standards in the form of company policies, procedures or rules that clearly convey standards of performance in safety and health to employees. Before individuals can be held accountable, they must be told what is expected. Performance objectives must be attainable, clearly stated, realistic, challenging, and measurable.
2. Resources needed to meet the standards, such as a safe and healthful workplace, effective training, and adequate oversight of work operations.
3. A measurement system which specifies acceptable performance. It's important that *behaviors*, rather than results, be evaluated. What action, or inaction, led to the incident?

4. Consequences, both positive and negative. Without an *expectation* of effective consequences, accountability is not believable and has no credibility.
5. Application at all levels means that consequences are consistently applied throughout the organization—top to bottom and across functions.

U. S. Occupational Safety and Health Review Commission (OSHRC) decisions have long demonstrated a core belief that safe work practices are not effective if their use is not enforced. Typically the employer is held responsible if the organization does not enforce its own rules. "[A]n employer must make a diligent effort to discourage, by discipline if necessary, violations of safety rules by employees."(OSHRC 1980). To prove adequate enforcement of its safety rules, an employer must present evidence of having a disciplinary program that was effectively administered when work rule violations occurred. (OSHRC 1996)

In its review of *Secretary of Labor v. American Sterilizer Company* (1997), the OSHRC stated that if a company wishes to defend itself by claiming unpreventable employee misconduct, the "employer is required to prove: (1) that it has established work rules designed to prevent the violation, (2) that it has adequately communicated these rules to its employees, (3) that it has taken steps to discover violations, and (4) that it has effectively enforced the rules when violations are discovered." Further, "It is not enough that an employer has developed an exemplary safety program on paper. Rather, the proper focus in employee misconduct cases is on the effectiveness of the employer's implementation of its safety program...Effective program implementation requires a diligent effort to discover and discourage violations of safety rules by employees."

In 1984, the "*Caltrans Guide To Employee Conduct and Discipline*"[1] was issued to offer "supervisors a constructive approach for handling situations related to employee discipline...[The guide is to serve] as a general reference and will have served its purpose if it brings about a better understanding of discipline as a positive factor in personnel management."

In March of 1985, in a section titled "Offenses and Corresponding Adverse Actions," a disciplinary matrix was added that more specifically defined offenses and matched offenses with suggested adverse actions. By 1992, the matrix included a section that specifically addressed backing incidents.

[1] Three versions of the disciplinary guide were available for this paper: March 1985, July 1992, and April 1998. There may have been other versions that were issued between the original issue date of December 1984 and the April 1998 version.

In 1994, the Department of Personnel Administration (DPA) issued the "Supervisor's Handbook, A Guide to Employee Conduct and Discipline," which was intended for use as a general guide to State law only and was not designed to supplant individual state departments' policies. Nevertheless, Caltrans issued a revised guide in April 1998 that was more in line with the DPA guide, having dropped the offense/adverse action matrix. With no further revisions or changes to the Caltrans guide since 1998, and based on conversations with Caltrans safety personnel, it appears that the DPA guide has become the de facto Caltrans guide to employee conduct and discipline

In 2008, the DPA's Supervisors Guide, which had been revised in 2004, was pulled from the DPA website because it no longer reflected current law and because it "was not DPA's responsibility to maintain such a guide."[2] This has the effect of leaving Caltrans without a current conduct and discipline guide.

Two State of California agencies that still use an employee discipline matrix are the Department of Corrections and Rehabilitation (CDCR) and the Department of Forestry and Fire Protection (CDF). At the CDF, the minimum action for a first backing incident is a five percent reduction in pay for three months.

Ideally, there would be studies that investigate the effects of a change in enforcement of progressive discipline for preventable motor vehicle crashes carried out by a state department of transportation. By comparing the long-term difference in crash rates for the before and after periods, we would have proof of the efficacy of such a change in enforcement. Unfortunately, such research has not been conducted.

There is, however, a large body of work demonstrating the efficacy of enforcement in deterring unsafe behaviors, especially in the area of traffic safety. The objective of increased safety enforcement is not to see how many employees can be disciplined, but rather to try to reach the point where no one needs to be. By the time a driver receives disciplinary action, the costs to Caltrans have already been incurred. No one knows how severe the next motor vehicle incident will be. The same type of crash that causes no injury today may take someone's life tomorrow. The only way to eliminate injury and fatal crashes is to eliminate all crashes.

Interviews with safety personnel at Caltrans and at other state DOTs strongly suggest that by implementing tougher enforcement policies and by emphasizing safety and accountability at tailgate and staff meetings, Caltrans has the opportunity to achieve

[2] DPA Chief Counsel, interviewed 6/08

significant improvements in workplace safety. Based on these interviews as well as a review of the literature, the following actions are recommended:

- The consequences for preventable incidents should be made severe enough that people will want to avoid them.
- The minimum action for a first preventable backing incident should be a formal letter of warning.
- There should be no discretion regarding the minimum action
- Any supervisors who fail to follow Caltrans policy regarding applying minimum disciplinary actions for safety violations will, themselves, be reprimanded.

These rules must apply to everyone, regardless of job classification, or previous performance, and all employees must be made aware that this is the case. Mandatory disciplinary action, with an established minimum level (e.g., formal letter of warning), is the only way to ensure uniformity of application. Even the most well-intentioned supervisor is likely to favor certain workers or groups, and as soon as this happens the system breaks down. Lack of discretion has the added benefit of removing pressure from supervisors because they can no longer be asked by at-fault drivers to overlook the violation since they do not have the ability to do so.

If the backing incident is merely the latest in a string of violations, or if the driver's behavior was particularly egregious, there is no reason that stronger action cannot be taken. However, there must be no discretion at the minimal level, even in regards to an employee who has an excellent record; the mandatory disciplinary action be applied.

4.4 Zero Incidents

There is a growing consensus that the only appropriate goal for safety in the workplace is zero incidents. If we maintain that incidents and injuries are preventable, how can any other number be acceptable? Unlike private industry, where the costs of injuries and motor vehicle incidents (MVIs) directly affect operating budgets as well as company profits, at Caltrans the monetary costs of MVIs are neither felt nor seen by most managers. This is not to say that managers are indifferent to worker injuries: quite the opposite is true. It is simply that the associated costs are not readily apparent.

Given the financial structure of Caltrans and other government agencies, it is necessary to implement a strategy that does not depend on financial accounting changes. The establishment of a strong safety culture, a key element of which is a system that holds drivers and supervisors accountable for preventable motor vehicle incidents, has the potential to greatly reduce, if not eliminate, occupational incidents.

Safety is considered a core value of the organization (Oklahoma DOL). Establishing a strong safety culture at Caltrans requires management commitment and employee involvement. This would include insuring that:

- Safety is ingrained into every aspect of its operations.
- Employees understand their right to a safe workplace.
- Each person in the organization accepts responsibility for ensuring his/her own health and safety.
- Each person in the organization believes that he/she has a duty to protect the safety and health of their co-workers.
- All employees, regardless of job or position, are held to the same standards.

5 Other Approaches for Possible Incorporation

Merit rating policies, which include both an “experience rating” and a “schedule rating,” are worth exploring. An “experience rating,” which retrospectively compares a firm’s ratio of losses to all comparable employers (in terms of business classification and size) in the state, can be used to give employers and employees incentives to reduce the cost of claims that might be excessive relative to other firms. A “schedule rating” rewards intentional behavior to reduce hazards, and works prospectively.

Regional analysis of claims might lead to Caltrans to “price” workers’ compensation coverage differentially for different districts or regions, or provide other region-specific benefits based on differences in true workers’ compensation costs. But when considering this approach, it is critical to avoid encouraging the organization to focus on how to reduce claims at the expense of seeking ways to prevent injuries.

6 Technology Solutions

6.1 Findings of the Literature Review

According to the TSC's review of the literature, the most effective backing accident prevention systems integrate multiple technologies including video, radar, and back-up alarms, in addition to traditional devices adapted to the special requirements of the backing maneuver. The following are highlights of the findings. For the complete review, please see Appendix I.

A report on highway work zones suggested the following solutions might effectively reduce backing accidents:

- Parabolic mirrors on construction equipment.
- Vibrating alarms that give notice of approaching vehicles.
- Sensing devices that sound an alarm when an object is near the vehicle.
- Closed-circuit television cameras, mirrors, and devices that stop a vehicle nearing a collision (Pratt et al. 2001).

A National Institute of Occupational Safety and Health (NIOSH) investigation of backing prevention equipment on job sites found that radar-video systems were successful at alerting drivers to danger and directing their attention to a monitor (Schneider 2008). NIOSH-commissioned studies of radar- and sensor-based collision-warning systems for construction equipment, heavy equipment, and off-road dump trucks found that:

- Camera and sensor systems are more reliable under warmer conditions and experience difficulties under cold, snowy conditions (Ruff 2005).
- Sensor systems do not perform well in congested work areas (Ruff 2002).
- The tendency to produce false alarms suggest that sensor-based systems for proximity warning should be used in combination with devices such as cameras, to allow the operator to check the alarm source (Ruff 2005).
- Radar systems installed in large, off-road dump trucks reliably detected small vehicles, people, and other equipment (Ruff 2004).

Mirrors are not the most effective means of increasing truck drivers' visual range. However, truck drivers believe supplemental mirrors have the potential to significantly reduce blind-side and backing crashes (Zeyher 2007).

Back-up warnings that alerted drivers that they were approaching known obstacles were more successful in preventing incidents than warnings that sounded in response to a surprise event (Ayers et al. 2002). Some argue that audible alarms do not always protect pedestrians, due to malfunctions and work site noise (Zeyher 2007).

An analysis of backing collision data found that older drivers were over-represented in backing crashes. Minivans and SUVs were also over-represented in backing crashes. The authors suggested that older drivers might benefit from warning systems that incorporated higher-transmittance windows, higher-intensity backup lamps, and rearward detection and warning devices. (Ayers et al. 2002).

Durability and reaction time studies showed that radar and sonar systems generally perform reliably, except under the following conditions:

- Cold and snow (Ruff 2005).
- Congested work areas (especially affects sonar systems) (Ruff 2002).
- Cluttered conditions, when objects that pose no immediate danger set off false alarms (Ruff 2005).
- When vehicles' speeds exceed that at which most pedestrian collisions occur (this especially affects sonar) (Glazduri 2005).

A study of particular relevance is the Arizona Department of Transportation (ADOT) evaluation of ETON brand Backspotter rear cameras on ADOT's heavy vehicles. These cameras were well received by field crews on dump trucks and stripers, but did not work with trailers and medium trucks (Owen 2006).

Recent innovations have made cameras less costly, smaller, and easier to operate under a wide variety of conditions. These developments suggest that cameras may become one of the most popular and affordable approaches to reducing work zone backing incidents (Madison 2004).

A 1992 National Highway Traffic Safety Administration (NHTSA) study found that video systems performed well under good lighting conditions. Auxiliary mirror systems covered a limited area and displayed distorted images. Sensor-based systems were generally poor at detecting pedestrians behind the vehicle (Mazzae and Garrott 1992).

In 1993, Tijerina et al. looked at Intelligent Vehicle Highway Systems (IVHS)—separate sonar, radar, or wireless units that comprise a flexible system that can respond to traffic congestion. Their assessments showed that the majority of backing incidents occur because drivers do not see or check for a vehicle, object, or pedestrian. The suggested countermeasure was a rear-zone detection system.

In 1996, Eberhard et al. assessed electronics-based collision avoidance systems for drivers of passenger vehicles, focusing on testing of sensor performance and driver interface quality. Findings suggested that while none of the systems had an "ideal" interface, most were ergonomically acceptable and aided in preventing backing collisions.

An analysis conducted by Lerner, et al. in 1997 brought together data from three studies that sought to determine the potential effectiveness of visual warnings. The analysis concluded that because drivers glance in many locations, it is difficult to place a display where it will be reliably conspicuous. Therefore, the authors suggested, visual warnings should supplement, not replace, acoustic warnings.

A 2005 study reports that CMOS (complimentary metal-oxide semiconductor) and CCD (Charged Couple Device) image sensor cameras, FMCW (Frequency Modulated Continuous Wave) radar, and lidars (light-detection and ranging devices) are the most frequently used sensors. To overcome problems in pedestrian detection, thermopile and infrared sensors were applied to intelligent vehicle systems; but this solution is costly. The report also suggested that protocols should be developed to enable products from different manufacturers to communicate with each other (Li et al. 2005).

6.2 Rear Radar Detection Devices Currently Installed in Caltrans Vehicles

Between 2003 and 2006, Caltrans installed rear radar detection systems designed to alert vehicle operators to obstacles in fifteen vehicles. The equipment IDs, vehicle descriptions, and installation dates are shown in Appendix F. At the time of this report, all but one of the devices were still installed.

The systems operate in a pre-defined coverage area and report the distance of the closest object via visual range indicators and an audible signal to a vehicle operator. The in-cab display is shown in Figure 12.

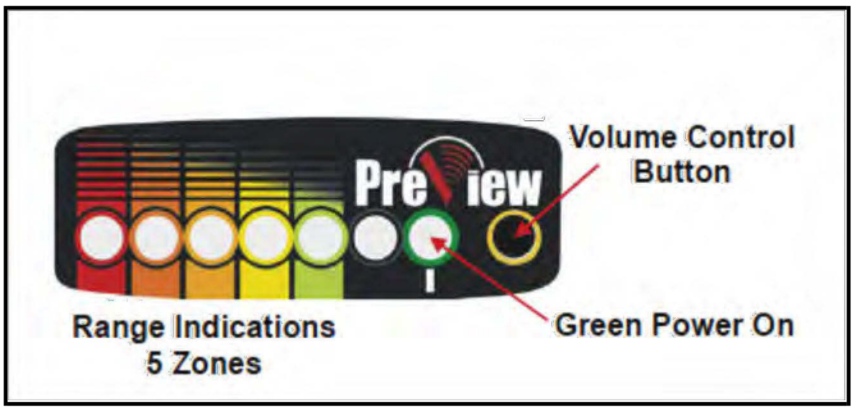

Figure 12: The Preco PreView™ Display

In order to assess equipment operator experience with and reaction to the radar devices, a questionnaire (Appendix G) was sent out to the supervisors overseeing these operators. At the time of this report, ten questionnaires had been returned, almost all of which registered positive responses to the device. Before Caltrans proceeds to procure additional back-up safety systems, Field Operational Tests (FOTs) could be used to determine how certain models perform under ordinary working conditions. A sample FOT design is shown in Appendix H.

7 Conclusions

Two potentially powerful tools for eliminating incidents and injuries emerged from our research: enhancement of the Safety Information Management System (SIMS) database to allow a clearer understanding of the scope and magnitude of the problem, and management action to instill and support a strong culture of safety throughout the organization.

The current SIMS system can be improved by closer supervision of data gathering and input and by adding additional data fields. Our review found many examples of incomplete or incorrect information. We also found that some of the fields are confusing or subject to different interpretations.

Authority to enter data into SIMS should be limited to employees who have received specific training so that information contained in the incident report may be checked for accuracy and completeness as the data is entered. Training district safety officers to generate different reports will enhance Caltrans' understanding of incident and injury trends. Additionally, SIMS can be made more powerful with the addition of SCIF claims data, driver background information, and data from the Caltrans Division of Equipment. This would allow for in-depth analyses which help determine which types of injury incur the most workers' compensation claims and the highest costs, what equipment and locations have high incident rates, and which employee cohorts might benefit from refresher training. This analysis would also provide a context for calculating the return on investment gained through prevention activities. As an early result of this project, work is currently underway to make it possible to access repair cost information through SIMS.

At the present time, there are no consistently followed policies for dealing with employees who are involved in preventable motor vehicle incidents. Best practices suggest that a highly effective safety tool is the establishment of a strong safety culture, a key element of which is a clear system of accountability. Caltrans' Safety and Maintenance manuals provide detailed guidelines for safely backing a department vehicle. However, a series of changes in policy at a statewide level have left Caltrans without a current conduct and discipline guide. Because the vast majority of backing crashes are caused by failure on the part of the driver to follow backing guidelines, enforcing adherence will enhance safety and reduce costs. Policies in place at other state Departments of Transportation (DOTs) present discipline ideas that can be used at Caltrans.

Caltrans has installed fifteen rear radar detection systems. Until recently, when an equipment operator questionnaire was sent out, there has been little in the way of feedback regarding the usefulness of the devices. Before Caltrans proceeds to procure additional back-up safety systems, Field Operational Tests (FOTs) could be used to determine how certain models perform under ordinary working conditions. We offer an outline of a FOT in Appendix G.

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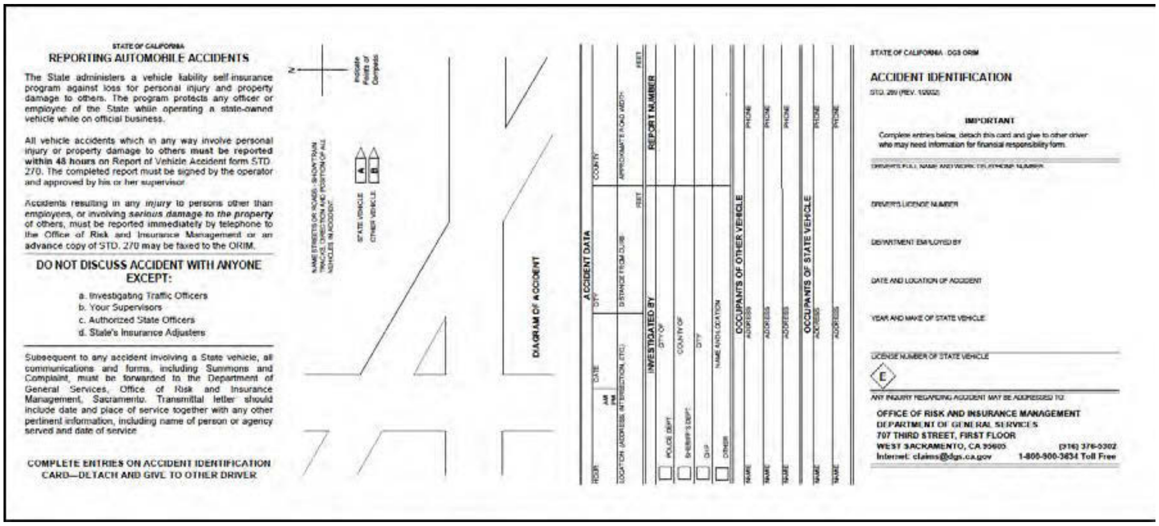
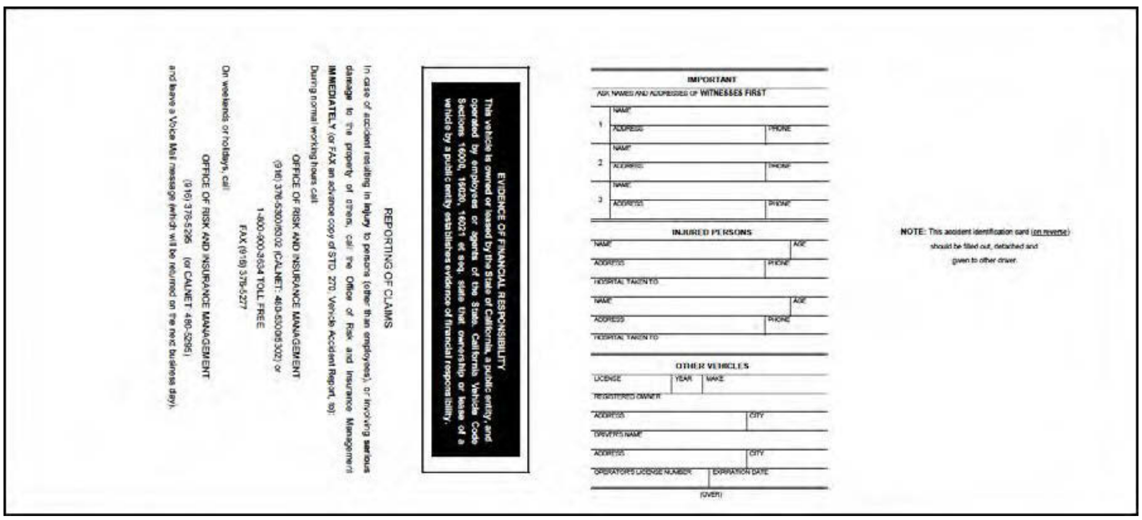
9 Appendices

Appendix A: Accident Identification Card Form STD.269





Appendix B: Vehicle Accident Report Form STD. 270

STATE OF CALIFORNIA
VEHICLE ACCIDENT REPORT
STD. 270 (REV. 04/2002)

ACCIDENT PREVIOUSLY REPORTED TO ORIM? (If yes, give date)
☐ YES ☐ NO ______

THIS REPORT MUST BE MAILED WITHIN 48 HOURS AFTER ACCIDENT (ACCIDENTS INVOLVING INJURY SHOULD BE FIRST CALLED OR FAXED TO ORIM AT (916) 376-5300 - FAX (916) 376-5277.
**** CONFIDENTIAL INFORMATION ****
DO NOT RELEASE TO OTHER PARTIES WITHOUT CONSENT OF THE OFFICE OF RISK AND INSURANCE MANAGEMENT

DISTRIBUTION:
ORIGINAL -
District or Headquarters Office of Safety and Health

Page ___ of ___

STATE DRIVER

NAME		AGE	EMPLOYING DEPARTMENT **CALTRANS -**	AGENCY BILLING CODE
DRIVER'S LICENSE NO.	ACCIDENT DATE	TIME	OFFICE ADDRESS	AGENCY DOCUMENT NO. **District/Cost Center**
WAS VEHICLE BEING USED ON OFFICIAL STATE BUSINESS? *(If NO, attach explanation)* ☐ YES ☐ NO				
APPROXIMATE DATE DRIVER LAST COMPLETED STATE DEFENSIVE DRIVER TRAINING	Month/Year ☐ NOT TAKEN		JOB TITLE	BUSINESS PHONE

STATE VEHICLE

VEHICLE LICENSE NUMBER	VEHICLE YEAR, MAKE, MODEL	**VEHICLE OWNER** ☐ DEPT OWNED ☐ DGS POOL ☐ RENTAL ☐ EMPLOYEE OWNED	EQUIPMENT ID NO.
BRIEFLY DESCRIBE DAMAGES TO STATE VEHICLE	ESTIMATED REPAIR COST	IF DEPARTMENT OWNED OR RENTAL, ENTER OWNER'S NAME	

ACCIDENT DETAILS *(See Reverse for Diagram and Description)*

ACCIDENT LOCATION *(Address/Area)*	ROAD CONDITIONS	
	WEATHER CONDITIONS	
(City/State)	TRAFFIC CONDITIONS	
(County)	HOW FAST WERE YOU DRIVING	EST. SPEED OF OTHER CAR
POLICE REPORT MADE ☐ YES ☐ NO AGENCY ☐ CHP ☐ OTHER	NAME AND ADDRESS OF INVESTIGATING AGENCY NCIC# BADGE #	

OTHER VEHICLE

DRIVER'S NAME		AGE/DOB	VEHICLE LICENSE NO.	VEHICLE YEAR, MAKE, MODEL	NO. OF PASSENGERS
DRIVER'S LICENSE NO.	HOME TELEPHONE	WORK TELEPHONE	REGISTERED OWNER		
DRIVER'S ADDRESS *(Street, City, State, Zip Code)*			OWNER'S ADDRESS		HOME TELEPHONE WORK TELEPHONE
BRIEFLY DESCRIBE DAMAGES TO OTHER VEHICLE OR PROPERTY			NAME AND ADDRESS OF OTHER PARTY'S INSURANCE COMPANY		

INJURED

NAME	AGE	ADDRESS	HOSPITAL
NAME	AGE	ADDRESS	HOSPITAL

WITNESS

NAME	TELEPHONE	ADDRESS
NAME	TELEPHONE	ADDRESS

VEHICLE PASSENGERS

STATE	NAME	ADDRESS
	NAME	ADDRESS
OTHER	NAME	ADDRESS
	NAME	ADDRESS

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(CONTINUED ON REVERSE)

STATE OF CALIFORNIA

VEHICLE ACCIDENT REPORT

STD. 270 (REV. 04/2002) (REVERSE)

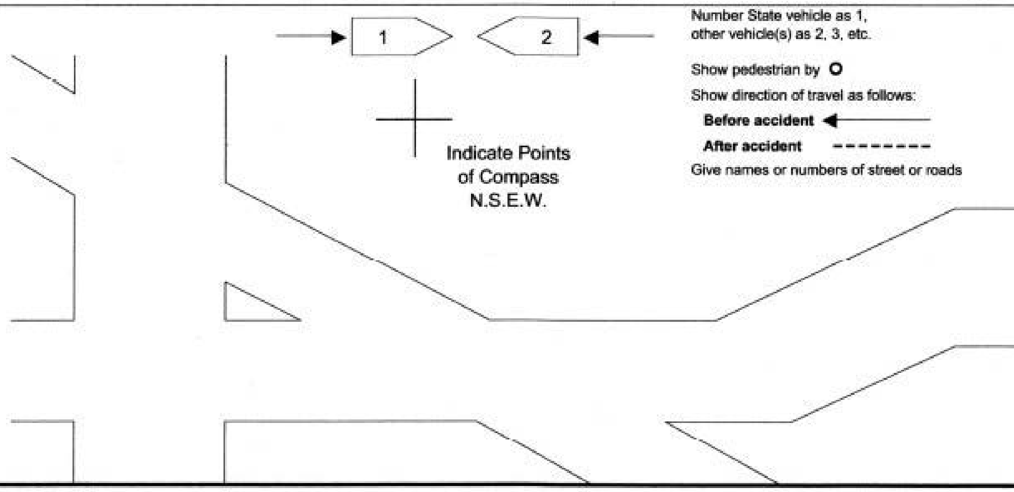
*** CONFIDENTIAL INFORMATION ***

DO NOT RELEASE TO OTHER PARTIES WITHOUT CONSENT OF THE OFFICE OF RISK AND INSURANCE MANAGEMENT

ACCIDENT DETAILS - DESCRIPTION

STATE FULLY HOW ACCIDENT OCCURRED *(Give Details, attached additional sheets if necessary)*

ACCIDENT DETAILS - DIAGRAM



Number State vehicle as 1, other vehicle(s) as 2, 3, etc.

Show pedestrian by O

Show direction of travel as follows:

Before accident ◄———

After accident - - - - - - - -

Give names or numbers of street or roads

ADDITIONAL VEHICLE/PASSENGER(S)

VEHICLE

DRIVER'S NAME		AGE/DOB	VEHICLE LICENSE NO.	VEHICLE YEAR, MAKE, MODEL
DRIVER'S LICENSE NO.	HOME TELEPHONE	WORK TELEPHONE	REGISTERED OWNER	

DRIVER'S ADDRESS *(Street, City, State, Zip Code)*	ADDRESS (Street, City, State, Zip Code)	HOME TELEPHONE / WORK TELEPHONE
BRIEFLY DESCRIBE DAMAGES TO OTHER VEHICLE OR PROPERTY	NAME AND ADDRESS OF OTHER PARTY'S INSURANCE COMPANY	

INJURED

NAME	AGE	ADDRESS	HOSPITAL
NAME	AGE	ADDRESS	HOSPITAL

PASSENGER

NAME	TELEPHONE	ADDRESS
NAME	TELEPHONE	ADDRESS

The answers in this report contain a true and full account of the accident, and the vehicle was being operated on official business of the state at the time of the accident. *Attach extra pages as necessary.*

Employee Signature and Date	Supervisor Signature and Date	Print Supervisor Name and Title / Supervisor Telephone Number

Appendix C: Data Input for Motor Vehicle Accident Form PM-S-0270

STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

DATA INPUT FOR MOTOR VEHICLE ACCIDENT

PM-S-0270 (REV. 5/95)

CONFIDENTIAL

This document contains personal information and pursuant to Civil Code 1798.21 it shall be kept confidential in order to protect against unauthorized

ACCIDENT INFORMATION
(This Form to be completed by First Line Supervisor)

DATE OF ACCIDENT	TIME *(24 Hour)*	CALTRANS EMPLOYEE INJURED? ☐ Yes ☐ No OTHER CALTRANS VEHICLE(S) INVOLVED? ☐ Yes ☐ No	ACCIDENT NUMBER M -

ACCIDENT DESCRIPTION *(Briefly describe Accident - Provide Details not included below)*

WAS A POLICE REPORT FILED? ☐ Yes ☐ No *IF YES, ENTER FROM TOP OF POLICE REPORT***	N.C.I.C. #	OFFICER'S BADGE #

EMPLOYEE INFORMATION

LAST	FIRST	MI	SEX	DATE OF HIRE

SOCIAL SECURITY NUMBER	BIRTHDATE	DRIVER LICENSE NUMBER	DRUG TEST *(Sensitive Positions Only)* ☐ Yes ☐ No

CLASS CODE	MTCE ACTIVITY NUMBER ☐	EMPLOYMENT STATUS *(Check one)* ☐ PFT ☐ PI ☐ LT ☐ PPT ☐ TAU ☐ SPP ☐ RA ☐ SA ☐ †CE

DISTRICT NUMBER	UNIT/COST CENTER*	ITEM NUMBER	C-NUMBER	LICENSE NUMBER	ESTIMATED REPAIR COST

DETAILED INFORMATION
(Circle one appropriate for each Category)

A. WEATHER
01 CLEAR
02 CLOUDY
03 FOG
04 RAIN
05 SNOW
06 WIND

B. VISIBILITY
01 OVER 1/2 MILE
02 LESS THAN 1/2 MILE
03 LESS THAN 100 YARDS

C. ROAD CONDITION
01 DRY
02 WET
03 SNOW/ICE
04 SLIPPERY (MUDDY, OILY, ETC)
05 NOT A FACTOR

D. PREVENTABILITY
01 BY DRIVER
02 NON PREVENTABLE
03 BY OTHER CALTRANS EMPLOYEE
04 BY CALTRANS MANAGEMENT
05 BY PRIVATE PARTY

IF 03 IS CIRCLED ENTER EMPLOYEE'S SOCIAL SECURITY NUMBER

E. VEHICLES
01 SOLO
02 TWO OR MORE MOVING VEHICLES

F. TYPE OF VEHICLE
01 STATE
02 PRIVATE
03 RENTAL

G. VEHICLE FUNCTION
01 EQUIPMENT
02 TRANSPORT PERSONNEL
03 TRANSPORT EQUIPMENT
04 TRANSPORT MATERIAL
05 SNOW REMOVAL
06 SHADOW
07 BARRIER
08 ADVANCE WARNING

H. CRASH CUSHION
01 HIT
02 NOT HIT
03 NOT APPLICABLE

I. PROTECTIVE BELT IN USE
01 LAP BELT
02 SHOULDER HARNESS
03 BOTH LAP BELT & SHOULDER HARNESS
04 NONE USED

J. GENERAL LOCATION
01 CITY STREET
02 CONVENTIONAL HIGHWAY
03 CONSTRUCTION
04 FREEWAY
05 FREEWAY RAMP OR CONNECTOR
06 LANE OR SHOULDER CLOSURE
07 PRIVATE PROPERTY
08 RURAL ROAD
09 STATE YARD OR PROPERTY
10 TUNNEL OR TUBE
11 MAINTENANCE WORK ZONE

K. SPECIFIC LOCATION
01 AT INTERSECTION
02 MEDIAN
03 OFF STREET OR HWY IN R/W
04 ON BRIDGE
05 PARKING LOT
06 SHOULDER
07 TRAVELLED WAY

L. BASIC CAUSE
ST. OTH.
01 01 EXCESSIVE SPEED
02 02 FOLLOWING TOO CLOSE
03 03 IN WRONG LANE
04 04 AVOIDING AUTO OR OBJECT
05 05 IMPROPERLY PARKED
06 06 IMPROPER BACKING
07 07 DISREGARD OF SIGNS, SIGNALS ETC.
08 08 FAILURE TO OBSERVE CONDITIONS
09 09 POOR JUDGEMENT
10 10 IMPROPER OPERATION OF VEHICLE
11 11 UNKNOWN
12 12 BLOCKED VISION
13 13 DEFECTIVE EQUIPMENT
14 14 LOST LOAD

M. DRIVERS CONDITION
ST. OTH.
01 01 NORMAL
02 02 DRUG/ALCOHOL IMPAIRED
03 03 ILL
04 04 SLEEPY OR FATIGUED
05 05 INATTENTIVE
06 06 OTHERWISE IMPAIRED

N. MOVEMENT PROCEEDING COLLISION
01 STOPPED
02 PROCEEDING STRAIGHT
03 RAN OFF ROAD
04 MAKING RIGHT TURN
05 MAKING LEFT TURN
06 MAKING U TURN
07 BACKING
08 SLOWING/STOPPING
09 PASSING OTHER VEHICLE
10 CHANGING LANE
11 PARKING MANEUVER
12 ENTERING TRAFFIC
13 EVASIVE MANEUVER
14 CROSSING INTO OPPOSING LANE
15 PARKED
16 MERGING
17 TRAVELING WRONG WAY
18 LOST CONTROL

O. TYPE OF COLLISION
01 HEAD ON
02 SIDESWIPE
03 HIT IN REAR
04 BROADSIDE
05 HIT OBJECT
06 OVERTURNED
07 VEHICLE/PEDESTRIAN
08 HIT REAR OF OTHER

P. MOTOR VEHICLE INVOLVED WITH
01 NON COLLISION
02 PEDESTRIAN
03 OTHER MOTOR VEHICLE
04 MOTOR VEHICLE ON OTHER ROADWAY
05 TRAIN
06 BICYCLE
07 ANIMAL
08 FIXED OBJECT
09 RUNAWAY VEHICLE

Q. PEDESTRIAN INVOLVEMENT
01 NO PEDESTRIAN INVOLVED
02 CROSSING- IN CROSSWALK
03 CROSSING- NOT IN CROSSWALK
04 WALKING ALONG ROADWAY

R. ACCIDENT CLASS
(SEE REVERSE FOR DETAILS)
01 I (a)
02 I (b)
03 II (a)
04 II (b)
05 II (c)
06 III

S. OCCUPATION
01 ADM -ALL OFFICE WORK
02 LAB - LAB TESTING, FIELD AND LAB
03 SHP - MECHANICS, WELDERS, ETC.
04 CON -FIELD CONSTRUCTION
05 SUR -FIELD SURVEYS
06 FTR - FIELD TRAFFIC
07 TOL - TOLL SERVICES
08 FMT - FIELD MAINTENANCE
09 SPP - SPECIAL PROGRAM PEOPLE
10 CEM -CONTRACTORS EMPLOYEE †

*ENTER THE UNIT NUMBER THE EMPLOYEE WAS CHARGED TO AT THE TIME OF THE ACCIDENT

**THIS INFORMATION IS INCLUDED TO ENABLE COMPARISON OF SUPERVISOR'S REVIEW TO THAT OF LAW ENFORCEMENT OFFICER

† INCLUDED FOR TRACKING PURPOSES ONLY

*This Form **must be certified** correct by the Safety Officer before Data Input* ☐ Certified correct O.K. for Data Entry

SAFETY OFFICER'S SIGNATURE	ENTERED BY *(Initial)*	DATE

DATA INPUT FOR MOTOR VEHICLE ACCIDENT
PM-S-0270 (REV. 5/95)

REPORTING MOTOR VEHICLE ACCIDENTS

EMPLOYMENT STATUS:
LT: LIMITED TERM; PI: PERMANENT INTERMITTENT; TAU: TEMPORARY AUTH; RA: RETIRED ANNUITANT; PFT: PERMANENT FULL TIME; PPT: PERMANENT PART TIME; SPP: SPEC. PROGRAM PEOPLE; SA: STUDENT ASSISTANT; CE: CONTRACTOR EMP.

SELECTION OF BASIC CAUSE: The supervisor, after discussing the accident with the driver or worker and making such investigation as is necessary, shall select and indicate a BASIC CAUSE for the accident for either of both - **(1)** the State driver or worker, **(2)** the other car, other worker, pedestrian, or object.

ACCIDENT CLASSIFICATION: The following definitions from Section 16.02 of the Equipment Manual will be used to determine the appropriate classification of an accident. All class III accidents require that the full details of the accident investigation be included on the reverse of this form. Whether or not class I or class II accidents shall be included on the reverse of this form shall be subject to direction from each individual Division or District. Consult with the District or Headquarters Safety Officer for direction in your area.

CLASS I (a) - State vehicle indirectly involved - when a state vehicle is in the proximity of an accident and it may be alleged that the accident was due, in whole or in part, to the operation or position of the state-owned vehicle or equipment;

CLASS I (b) - Work damage to others - when an adverse vehicle or property is damaged by being sprayed or by material falling or thrown from a state-owned vehicle or equipment;

CLASS II (a) - Work damage - Unavoidable damage to state vehicle or equipment that occurs during proper use but not in the case of a traffic accident;

CLASS II (b) - Vandalism/Theft - Damages as a result of vandalism or theft must be reported on Std. Form 270. In both cases, local law enforcement officials, as well as claims officer, must be notified immediately;

CLASS II (c) - Operational damage to others - damage to another vehicle or property because of normal and operational use of state equipment or vehicles. This category does not include traffic accidents;

CLASS III - Any accident which does not fall in Class I or II is a Class III accident. Every accident in which a state owned motor vehicle is involved and results in a reportable personal injury or in a death and any accident that is caused by driver error.

PREVENTABILITY

Except for accidents involving mechanical failure, the decision as to whether the accident is preventable is to be based solely on whether or not the driver exercised prudent and careful judgement in his/her attempt to avoid the accident regardless of any legal rights (such as right-of-way at intersection) to which he/she may have been entitled under the vehicle code.

This rule imposes on each driver the positive duty of doing all that can be done within reason under the particular circumstances to avoid accidents. He/she is expected to carefully anticipate emergency situations, and to make every possible effort to avoid accidents. If the driver fails to avail himself/herself of the "last clear chance" to avoid an accident, the accident is preventable regardless of the question of primary responsibility for the accident. The test to be applied is one of preventability, taking all facts and circumstances under consideration.

In addition to examining the actions of the driver regarding his/her taking the "last clear chance" to avoid this accident, please examine the facts of the accident to determine if the accident could have been prevented by **1)** another Caltrans employee, **2)** Caltrans management (yourself included) or **3)** another party. If so circle the appropriate code. If another Caltrans employee could have prevented the accident, enter that employee's Social Security Number in the space provided and provide comments in the accident description as to what that employee could have done to prevent the accident.

FOR FIRST LINE SUPERVISOR **ACCIDENT PREVENTION PLAN**

1) I HAVE TAKEN THE FOLLOWING ACTION(S) TO PREVENT RECURRENCE OF THIS TYPE OF ACCIDENT.

2) I RECOMMEND THE FOLLOWING ADDED ACTION(S) TO PREVENT THIS TYPE OF ACCIDENT.

1ST LINE SUPERVISOR *(Signature)* DATE

FOR SECOND LINE SUPERVISOR

☐ I agree ☐ disagree with 1st line supervisor actions and/or recommendations

COMMENTS:

2ND LINE SUPERVISOR *(Signature)* DATE

FOR SAFETY OFFICER

☐ I agree ☐ disagree with actions and/or recommendations ☐ This accident was preventable based on the facts as presented or as determined by Safety Office review or investigation.

COMMENTS:

SAFETY OFFICER *(Signature)* DATE

Appendix D: Backing Sections of Caltrans Safety and Maintenance Manuals

Caltrans Safety Manual, Chapter 17 Motor Vehicle Safety
17.13 Vehicle Backing Policy
The Department recognizes that there is an increased risk of vehicle accidents during vehicular backing maneuvers. To decrease the likelihood of a backing accident, the following procedures shall be adhered to:

- Whenever feasible, operations will be modified to eliminate backing. If backing is necessary, the affected supervisor, operator and employees will discuss the backing maneuvers before beginning operations.
- Before backing any vehicle, the operator shall visually inspect all sides of the vehicle to assure there are no obstacles, clearances or employees in the area. It may be necessary for the operator to exit and walk around the vehicle to perform a visual inspection.
- The driver should be alert to any other pedestrian or vehicular traffic that may enter the backing zone. If pedestrian traffic is anticipated, a spotter shall be utilized whenever practicable while backing.
- When two or more employees work together, the driver shall ask the other employee to act as a spotter at the rear of the vehicle before starting the backing movement. The operator and spotter shall have a clear understanding of the backing maneuver before moving the vehicle.
- If the operator must stop or park the vehicle in a position that will require backing, the vehicle should be positioned to maximize visibility to the rear and critical areas adjacent to the vehicle.

Caltrans Maintenance Manual, Chapter 8: Protection Of Workers
8.13 Planning Work To Reduce Worker Exposure
Supervisors shall plan all work methods to minimize the need for the backing of equipment and vehicles at the work site.

8.36 Backing of Vehicles and Equipment
Backing accidents have always been the most prevalent type of vehicle accident. Because so many of the tasks Maintenance employees perform involve the backing of vehicles and equipment, the potential for serious accidents exists, and extra emphasis must be placed on preventing their occurrence.

Prior to Job/Planning the Work:

1. Supervisors should plan work projects to minimize the need for backing of vehicles and equipment whenever possible. For example, the forward mode of cone retrieval should be utilized for retrieving lane closures.
2. Design the work space to eliminate or decrease backing and blind spots; when feasible pull trucks into the work zone and let the operation catch up to them.
3. At tailgate safety meetings, prior to the job, discuss how and when vehicles will be backing within the work zone and specific measures that will be taken to prevent an accident.

Safety at the Worksite:

1. Workers on foot will be separate from equipment as much as possible: ensure that employees on foot stay out of the work area and in clear view of those who are operating equipment.
2. Minimize the distance heavy equipment needs to back up in order to gain access to the work area.
3. Employees should never move equipment without making positive visual contact with any workers on foot around or near the equipment.
4. In work zones where moving equipment has the potential to strike a worker on foot, employees shall not place themselves in or near the path of backing vehicles and should not enter the work area until it is clear for hand work. One person should be designated as a lookout while vehicles/equipment are moving within the work area.
5. Every backing situation is new and different. Even if you work at the same location several times a day, you should be watchful for changes and any new obstacles.
6. Use a spotter. The driver and spotter should use hand signals instead of verbal ones and make sure they understand each other's signals. Don't have the spotter walking backwards while giving instructions.
7. During shoulder or pavement rolling operations, make sure all workers on foot are clear of the work area before moving any vehicles/equipment.

Personal Responsibilities

1. Employees operating vehicles and equipment must be familiar with the blind spots for the particular equipment they are operating. Remember that mirrors can never give the whole picture while backing.
2. Train workers on foot and equipment operators in appropriate communication methods (e.g., using hand signals and maintaining visual contact) to be used when workers on foot are required to be in the same area as equipment.
3. Do a walk-around of your vehicle before entering. Check for obstructions, low-hanging trees and wires, and any other potential clearance-related problems.
4. On-foot personnel need to make sure they are a safe distance from vehicles in the work area. Do not stand where the operator cannot see you; a vehicle that has the potential to back up could run you over.

Appendix E: Backing and Spotters Guide

Backing continues to be one of the most common vehicle incident problems.

These incidents have resulted in serious injury and fatalities to employees, substantial property damage costs, equipment downtime, and lost productivity.

Since virtually all backing incidents are preventable, the following guidelines are to be followed whenever operating a Caltrans vehicle.

General Rules

The most effective rule is to avoid backing whenever possible. Plan in advance at the job site so that both entering and exiting can be accomplished without backing. In parking lots, choose easy-exit parking spaces that don't crowd neighboring vehicles and park your vehicle in the center of the parking space. If possible, drive through to a space that allows you to exit forward.

When another employee is present, that person shall act as a spotter for the driver of the backing vehicle if this can be done without exposing the spotter to moving traffic. Even when using a spotter, however, the driver is responsible for safe vehicle operation. This fact does not relieve other involved employees from their responsibilities. If the spotter is careless or inattentive and his/her directions result in an incident, that incident may also be considered preventable against the spotter.

Driver's Responsibilities

When using another employee to back a vehicle, the driver shall establish eye contact with the spotter before proceeding and keep him/her in sight at all times while backing. The driver shall immediately stop if he or she loses sight of the spotter and wait until eye-contact is re-established. If this does not occur quickly, the driver shall secure and exit the vehicle to determine the spotter's location.

If no other employees are present, prior to backing, the driver shall put the vehicle in "Park" for an automatic transmission or neutral for a standard transmission and set the parking brake before exiting to check behind the vehicle. The driver shall completely circle the vehicle to ensure that there are no obstructions or other dangers. This should include overhead clearance. The driver must also be alert to the possibility of pedestrian or vehicular traffic which might enter the area. Return to the vehicle and start backing within a few seconds after finishing the walk-around.

If the driver is returning to the vehicle after having left it for any length of time, the circle check will be performed as described above, prior to entering the vehicle.

Always sound the horn to alert those in the area before backing.

Spotter's Responsibilities

Prior to backing the spotter shall discuss with the driver where the vehicle is to be backed and what hand signals will be used.

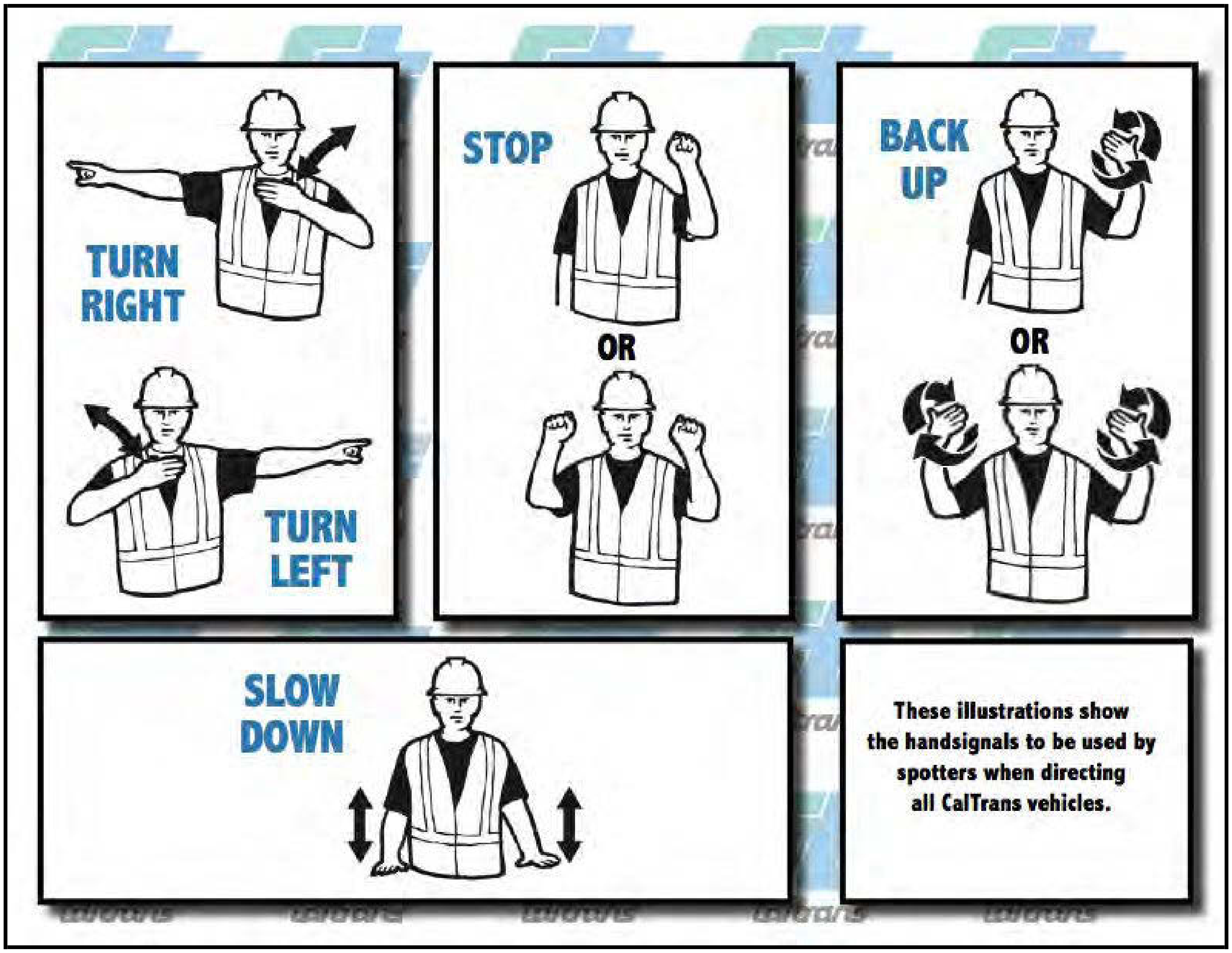
Conduct a "circle of safety" check, surveying the backing area and all other sides of the vehicle looking for hazards including overhead clearances.

While giving guidance in backing a vehicle, place yourself ten to fifteen feet to the left rear of the unit, when room and safety permits. Spotters must stand far enough behind the vehicle to observe the backing path and any obstructions, including pedestrians, and to allow for sufficient stopping distance in an emergency.

When directing vehicles with trailers, the spotter will normally give signals for the trailer rather than the towing vehicle, all the while being careful to observe hazards for both vehicles. As long as it is agreed to ahead of time with the driver, the spotter may give signals for the trailer or the towing vehicle as deemed appropriate.

Caltrans

Vehicle Backing and Spotters Guide


TURN RIGHT
TURN LEFT
STOP
OR
BACK UP
OR
SLOW DOWN
These illustrations show the handsignals to be used by spotters when directing all CalTrans vehicles.

Appendix F: Caltrans Vehicles Installed with Preco Rear Radar Systems

Eq. ID	Description	Installation Date
0088952	UTILITY BODY CREW CAB	3/2/2006
0334142	DUMP BODY W/LOADER TILT CAB	3/24/2006
7001826	PICKUP SUPER 1/2TON EXTCAB AFV	2/1/2006
7000565	LOADER FRONT END 2-1/2 C.Y.	11/1/2006
0137274	CONE BODY	3/30/2006
0237039	CARGO BODY W/HOIST12FT DIESEL	11/1/2006
7002018	SWEEPER CONV. 3-4 CY DIESEL	10/1/2005
0538490	CATCH BASIN & SEWER LINE CLEAN	11/1/2005
0537535	CATCH BASIN & SEWER LINE CLEAN	11/9/2005
0538808	BRIDGE REPAIR	6/15/2006
0537534	CATCH BASIN & SEWER LINE CLEAN	5/20/2003
0537174	CATCH BASIN & SEWER LINE CLEAN	2/6/2006
0538301	CATCH BASIN & SEWER LINE CLEAN	2/1/2006
3636911	GRADER-6 WHL DR W/ PLOW 150	5/20/2003
0538302	CATCH BASIN & SEWER LINE CLEAN	2/1/2006

Appendix G: Equipment Review Questionnaire for Caltrans Equipment Operators

Backing Warning Device Review Sheet

Eq. Id#______________Type of Vehicle ________________________________

District_______Location ____

Device Type_____________Device Manufacturer___________Model #_________
(Radar, Sonar, Camera)

Today's Date________How long have you used this device?__________________

Please rate the following qualities about the device (circle your answer):

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
Usefulness					
Device was helpful in avoiding potential backing accidents:	5	4	3	2	1
On occasion the device failed to warn of potential obstacles:	5	4	3	2	1
On occasion the device gave false warnings:	5	4	3	2	1
Overall, the device was worth having	5	4	3	2	1
Design					
The meanings of warnings are obvious to novice users:	5	4	3	2	1
The brightness and loudness can be easily adjusted:	5	4	3	2	1
Sensitivity of system's sensors can be easily adjusted:	5	4	3	2	1
Visual warning displays and the side view mirror can be seen at the same time	5	4	3	2	1

What do you like most about the device?___________________________________

____

____

What do you like least about the device? ______________________________

____

____

What would you change about the device and why? ______________________

____

____

IF you were an independent contractor and owned the vehicle you are currently operating for Caltrans, would you purchase and install this device on your vehicle?
Yes No

Name ________________________ **Classification** ____________________

Would you be willing to be contacted if we have further questions? Yes No

If Yes, contact information:

Phone Number

Email

Appendix H: Field Operational Test Scope and Requirements

Before any large-scale investment of resources is made in warning devices, it must be determined whether the expected benefits (both monetary and social) outweigh the expected costs. One way to test this is through a field operational test (FOT).

The FOT of any backing warning device should be conducted on vehicles used in normal service at the normal location of the vehicle. Overall, this project should take place over a period of 26 months. The formal FOT will be conducted over a 25-month period composed of one month of training/acclimatization and 24 months of use/observation. This will be preceded by a one-month period during which the warning device will be installed and tested.

The purpose of the pilot test is to collect information on device effectiveness as well as driver comments and suggestions. It will focus on:

- Reliability and quality of warning information.
- Driver reaction to the warning device.
- Equipment reliability.
- Changes in the number of incidents (this will be highly dependent on the number of units installed).

An advisory board should be formed and meet four times during the project; at the beginning, after installation and training, at the end of the first operational year, and at the end of the second operational year.

Data analysis will be conducted both during and after the field tests. The analysis will use before-and-after design.

EVALUATION GOALS

The following three broad evaluation goals (benefits, acceptance and human factors, performance) will be used for this system evaluation.

Goal 1: Achieve an in-depth understanding of the benefits of the rear radar/video warning system. This goal can be subdivided into a number of different categories, two of which, safety, and productivity, will be used here.

Goal 1 A: Achieve an In-Depth Understanding of Safety Benefits. The primary safety benefit expected from the deployment of the warning devices is a reduction in the number and/or severity of backing incidents. Because such incidents are relatively rare events, a statistically significant reduction during the FOT is unlikely unless a relatively large number of devices are installed. If this does not occur, surrogates, such as observed behavior and driver reported incidents avoided, will have to be used.

Goal 1 B: Achieve and In-Depth Understanding of Productivity Benefits. Deployment of the warning devices can result in productivity increases through cost savings from reduced numbers and/or severity of crashes, reduced workers comp costs, and reduced third-party costs. Any cost savings resulting from productivity gains would have to take into account the cost increases associated with the purchase and maintenance of the systems, training costs for drivers and mechanics, and possibly operating costs.

Goal 2: Assess User Acceptance and Human Factors. Interviews and surveys will be used to determine drivers' perceptions of the value of the device.

Goal 3: Assess Performance and Capability Potential. This goal addresses the ability of the system to perform its specified functions while meeting reliability and maintenance requirements. Performance will be measured using incidents and driver feedback, while assessment of system reliability will be based on the need for servicing during the FOT.

EVALUATION DATA SOURCES

In order to conduct the evaluation of the back-up warning devices, data will be collected from the following sources:

Historical and FOT Crash/Incident Data. Historical data will be from the Caltrans SIMS database. Annual rates of crashes, injuries, and costs will be based on 10-year averages from the database. This information will be examined in a four-step process to identify problem areas as follows:

- Separate data by crash type
- Identify the predominant critical events and critical reason that led to the vehicle's involvement in the crash for the crash type of interest
- Identify the movements prior to those critical events
- Use the combination of the critical events and the movements prior to define the driving problem.

Surveys and Interviews. All personnel involved in the FOT, including drivers, supervisors, mechanics, and managers will be asked to participate in at least one written survey or personal interview, in order to understand how the backing devices affect their job performance and working conditions. Those directly involved with the driving task will be surveyed several times over the course of the FOT. Information from these contacts will be the primary source for assessing user acceptance and human factors.

As the FOT progresses, drivers will be asked to comment on the usefulness of the system and how it has affected their driving. The final interview, at the end of the FOT, will seek in-depth attitudes and opinions regarding the system, the overall effect it had on their driving, and what changes they would make in the system.

Supervisors will follow a pattern similar to the drivers. As the FOT progresses they will be asked to comment on driver attitudes and system acceptance. As with the drivers, the final interview will seek in-depth attitudes and opinions regarding the system, the overall effect they feel it had on the drivers, and what changes they would make.

Fleet Operations Records. System reliability, operating costs, and savings created through use of the devices will be established by using Caltrans maintenance and operational records.

Caltrans will provide its historic incident data as well as relevant maintenance records and costs. This information will be used to estimate the costs and benefits of extending installation to the entire fleet.

EVALUATION METHODS

In this section we will explain how the various data elements collected during the FOT will be brought together to meet the goals established above.

Goal 1A: Safety Benefits

As previously discussed, the primary purpose of the warning devices is to prevent fatal, injury, and property-only-crashes. Since Caltrans experiences an average of approximately 250 backing incidents a year, distributed throughout the state, the only way to potentially observe a change in the incident rate would be to:

- Install a large number of devices (e.g., 100).
- Install all devices in a single district.
- Install all devices in a specific type of vehicle (e.g., cone body or dump body) or, at most, two vehicle types.

Goal 1B: Productivity Benefits

If installation of the warning devices can reduce the number or severity of crashes, reduce injuries and fatalities as well as lower the level of what is considered “normal” wear-and-tear, cost savings will accrue to both Caltrans and the public. To the extent that output remains unchanged or increases, the end result will be an increase in productivity. The value of this gain will be used as an input to the benefit/cost analysis.

Goal 2: User Acceptance and Human Factors

The objectives for this goal will focus on driver acceptance, perceptions of usefulness, and product quality. If the warning device is viewed as obtrusive by drivers, a burden by supervisors, or difficult to operate and maintain by maintenance, then deployment will be difficult even if benefits could be shown. Information from surveys and interviews will be the primary source for this goal. Some questions are designed to be asked several times over the course of the FOT in order to gather longitudinal data representing the change in opinions or perceptions over time.

Goal 3: Performance and Functionality
Measures of the performance and functionality of the warning devices will be based on driver feedback, incident reduction, and maintenance records.

BENEFIT-COST ANALYSIS (BCA)
Even if an FOT meets all of its operational goals, the system must still be economically feasible if it is to progress to large-scale implementation. A BCA carried out on public sector projects involves more than measuring corporate net benefits. Social benefits and costs, opportunity costs, and other, often intangible, impacts that may be difficult to value also must be monetized and factored into the analysis. Ultimately, though, the final question remains the same, are total benefits greater than total costs? If the answer is yes, the project can be said to be economically feasible.

The framework of BCA involves:
- Identifying all the benefits and disbenefits of the project.
- Quantifying all benefits and disbenefits in dollars or some other unit of measure.
- Selecting an appropriate interest rate at which to discount benefits and costs to a present value.

For the backing warning devices, the list of potential benefits include savings due to reduced number and severity of crashes and the resulting gains in productivity. Costs include initial startup costs and maintenance.

Appendix I: Literature Review

Literature Review for Caltrans Backing Safety Report

Sarah Duffy, MPP
UC Berkeley Traffic Safety Center
December 2008

INTRODUCTION

The purpose of this literature review by the UC Berkeley Traffic Safety Center (TSC) is to help Caltrans assess possible technologies for use in the workplace to prevent backing incidents that result in accidents and injuries, most of which are deemed preventable, even in noisy work zones. Based on 10 years of SIMS data (1998-2007), 93.2% of backing incidents at Caltrans were determined to have been preventable by the driver, indicating that this is an area of workplace safety that merits close scrutiny.

As of 2006, Caltrans had installed at least 15 radar devices in maintenance vehicles. This chapter considers additional collision avoidance systems and driving enhancement systems that Caltrans might consider implementing. These systems interact with the driver by issuing alarms or by informing the driver of potential crash risks, including rear obstructions (2). They can reduce the frequency and severity of crashes associated with backing incidents (2). The more sophisticated versions of these devices use radar, sonar, still cameras, video, and warning alarm systems.

Workers in construction zones can become desensitized to the presence of vehicles, often because they work in close proximity to them in a loud environment. While visibility garments and back-up alarms can improve work-zone safety, they don't go far enough if the driver still cannot see what's behind him. The following example taken from a Fatality Assessment Causation Assessment (FACA) report attests to this fact: "A thirty-six-year-old construction inspector died when an asphalt dump truck backed over him. The decedent was wearing an orange reflective vest and hard hat at the time of the incident. The dump truck's backup alarm was operational and functioning properly. The driver of the truck stated that he never saw the decedent." (8)

TECHNOLOGY OVERVIEW

The primary use of technology in preventing backing collisions is to warn the driver and others in the vehicle's vicinity of a potential risk. This must be done in a manner that allows sufficient time for preventative action: for the driver that is the equivalent of reaction time plus stopping time (1). In this section we provide a review of studies that compared different technologies (e.g. radar versus camera). Later sections focus on individual technology types.

One of the earliest comprehensive studies of back-over prevention technologies was a 1992 National Highway Traffic Safety Administration (NHTSA)-commissioned study of 11 commercially available back-over prevention technologies for light vehicles. Its objective was to assess how well they detected objects at the rear of the vehicle. (22). Video systems performed well in good lighting conditions (22). Auxiliary mirror systems covered a limited area and displayed distorted images because of mirror convexity and other factors (22). Sensor-based systems were generally poor at detecting pedestrians located behind the vehicle (22). Since the publication of these results, considerable additional investigation has been directed toward back-over prevention technology.

Another early report, published by Tijerina et al. in 1993, examined the potential of Intelligent Vehicle Highway Systems (IVHS). IVHS refers to separate sonar, radar, or wireless units that comprise a flexible system that can respond to traffic congestion (33). This report examined IVHS capabilities by modeling types of backing crashes and pairing them with potential IVHS crash avoidance countermeasures. The assessments by Tijerina et al. showed that approximately 87% of backing incidents occurred because drivers did not see or check for a vehicle, object, or pedestrian; the suggested countermeasure was a rear-zone detection system (31).

In their 1996 study, Eberhardt et al. assessed several electronics-based collision avoidance systems for drivers of passenger vehicles in avoiding collisions (11). One element of their research was an evaluation of how well collision avoidance systems studied were designed from the point of view of human factors (11). They studied Side-Looking Collision Avoidance Systems (SCAS), which had detectors on the right and left sides, and Rear-Looking Collision Avoidance Systems (RCAS), which used video cameras to enhance the driver's ability to see objects to the rear (11). They focused their testing the systems' sensors performance and the quality of the systems' driver interfaces. Overall, while none of the Collision Avoidance Systems had an "ideal" interface, most of were ergonomically acceptable , and they aided in preventing backing collisions (11).

Eberhardt et al. were not the only researchers to find that CAS interfaces were less than ideal. A 1997 analysis by Lerner, et al. brought together data from three prior studies that sought to determine the potential effectiveness of visual warnings as a primary means of alerting the backing driver and concluded that because drivers glance in many locations it is difficult to place a display where it will be reliably conspicuous (1). Therefore, if visual warnings are used, they should supplement, not replace, acoustic warnings (1). The sub-headings below contain discussions of studies that examined specific acoustic and visual backing technologies.

In terms of the most recent technological developments, a 2005 study reports that CMOS (complimentary metal-oxide semiconductor) and CCD (Charged Couple Device) image sensor cameras, FMCW (Frequency Modulated Continuous Wave) radar, and lidars (light-detection and ranging devices) are the three most frequently used surround sensors for environment sensing. However, conventional vision-based pedestrian detection is difficult to perfect because pedestrians usually wear clothes in different styles and colors and might also carry items such as hats or bags of varied shapes (4) To conquer such problems, researchers have applied thermopile and infrared sensors to intelligent vehicle systems that can detect pedestrians passively without illuminating the environment (4). The shortcoming with this solution is cost, so realizing reliable, low cost on-vehicle thermopile or infrared sensors should be a current goal (4).

This report also suggest that inter-vehicle, vehicle-roadside, and vehicle-driver information sharing is currently the most attractive trend in intelligent vehicle research and that it will be important to set up communication protocols so that products from different manufacturers can communicate with each other (4). We did not locate any research indicating that technology manufactures have since decided to share communication protocols.

In terms of qualitative feedback, in 2001 the U.S. Department of Health and Human Services published a report on highway workforce zones based on information obtained during a workshop attended by participants from government, labor, industry, academia, and state departments of transportation (26). The participants suggested that the following engineering solutions might effectively reduce accidents:

1) Parabolic mirrors on construction equipment
2) Individual vibrating alarms that can give workers 8-10 seconds notice of approaching vehicles
3) Sensing devices that sound an alarm when an object is near the vehicle
4) Closed-circuit television cameras, mirrors, and devices that stop a vehicle nearing a collision
5) Transmitters worn by workers that signal approaching construction equipment
6) Tapes that sound an alarm when a person or vehicle crosses them (26)

This report addresses the first four of these six suggestions. We did not locate any significant research or investigatory journalism addressing the latter two.

Lastly, in 2006 the National Highway Traffic Safety Administration issued a report to Congress assessing vehicle back-over avoidance technology. Results of this study showed that ultrasonic and radar backing aids did poorly in detecting child pedestrians behind the vehicle (32). Rearview camera systems typically allowed drivers to see pedestrians in the majority of the rear blind zones (32). It should be noted that this study focused on passenger, rather than construction and maintenance, vehicles and did not focus on work-zone safety. Because countermeasure effectiveness also depends on the ability of drivers to use the technology, available human factors research was examined (32). Their analysis of driver behavior suggested that drivers who are not expecting objects to be behind their vehicles will not stop soon enough to avoid striking them (32). The researchers commented that additional human factor research is needed to estimate the effectiveness of new systems (32).

DRIVER AND VEHICLE CHARACTERISTICS AND BACKING TECHNOLOGY

How driver and vehicle characteristics affect the likelihood of a backing collision merits consideration in assessing the effectiveness of backing prevention technologies.

A 2002 report published by Kim et al. used quantitative and qualitative methods to test the hypothesis that the capability of collision avoidance would not be same among drivers, vehicles, and environment groups with different characteristics (18). Their findings showed that heavy trucks had a higher susceptibility to fatal rear-end accidents than cars and light trucks. They also found significant differences in Required Minimum Warning Distance (RMWD) among different vehicle types and braking systems, but only small differences among age and gender groups, (18) suggesting that designers of collision avoidance systems should focus on vehicles, rather than drivers.

A 2001 dynamic field experiment both confirms and undermines Kim et al.'s findings. Tests were conducted to examine how rear-window transmittance and back-up lamp intensity affected drivers' backing behavior (20). Results indicated that drivers did not adjust their behavior to take into account variations in available light, at least under conditions where they experienced little uncertainty regarding obstacles (20). Alongside reviewing the results of the field experiment, researchers analyzed three years of crash data from the General Estimates System (GES) file for backing crashes. Variables of interest in the GES data were driver age, ambient light condition, and the type of passenger vehicle involved. The crash data indicated that older drivers were over-represented in backing crashes. The crash data also indicated that minivans and sport utility vehicles were over-represented in backing crashes. Based on the results of the field experiment and GES data analysis, the authors suggested that older drivers might benefit from warning systems that incorporated higher-transmittance windows, higher-intensity backup lamps, and rearward detection and warning devices (20).

MIRRORS

Mirrors are important tools for eliminating some blind spots that cause truck driver backing accidents. In the 1970s, the National Highway Traffic Safety Administration made an abortive attempt to mandate the use of a very large West Coast mirror on the right side of new trucks, but the idea was dismissed because the mirror obstructed forward vision (15). Nonetheless truck drivers still find supplemental mirrors have the potential to significantly reduce blind-side and backing crashes.

An analysis performed by Lerner et al. offers an important description of driver mirror use in the course of normal backing in passenger cars. The research team found that there was a great deal of variability in where drivers directed their glances while backing, with glance location affected by the type of maneuver, the point during the maneuver, individual differences, and vehicle characteristics (1). Older drivers showed more mirror use and less over-the-shoulder looking than younger drivers, and the most frequent glance location was over the right shoulder. Only roughly 10% of the time were drivers looking forward while backing (1). This research suggests that mirrors better serve as supporting rather than primary backing prevention equipment.

Passenger-side rear-view mirrors (PRMs) address restricted driver view and have been standard equipment on motor vehicles sold in the US for many years, although they are not required by the federal motor vehicle safety standards. Numerous studies have documented the value of PRMs in providing rearview visual information. Very few studies have proven, however, regarding the actual safety benefit of PRMs. A review of the research literature and several initial studies (driver observation and accident-data analysis), suggest that PRMs may not be associated with any substantial accident prevention, perhaps because they are not consistently used (20).

As it regards tucks, a driver's direct field of view in a truck is significantly more restricted than in other vehicle types. Trucks without a right fender mirror are significantly over-involved in crashes (11). Observational data collected by reporter John Bower indicated that only about 70 percent of trucks with conventional cabs have right fender mounted mirrors, which can fill in the driver's view along the front right side. (10). In 1995 Eberhard et al. published an analysis of crash data, measurements of fields of view, and observational data on the variety and distribution of mirror configurations in trucks, which suggested a need for improved driver vision to address specific truck crash types including backing (11). The results illustrate a safety problem in the area where the driver's view is more restricted, but researchers do not recommend that mirrors are the most effective means of increasing truck driver s' visual fields.

BACK-UP ALARMS

Back-up alarms emit a noticeable sound when a vehicle nears an object in order to warn pedestrians of moving vehicles. Reaction and stopping time algorithms are typically used to inform back-up alarm onset times for warning systems.

Time to collision (TTC), the amount of time for vehicle to contact a target object from its current location, became the metric used in reference to back-up alarms after Lerner et al. conducted a 1997 study of reaction and stopping times. It showed that TTC appeared to be a useful basis for a warning algorithm (1). The distance at which drivers felt that a warning would be appropriate was a function of backing speed, with longer distances required for higher speeds (1). For the danger alarm, this change in distance was roughly proportional to speed, so that the desired TTC was relatively constant across backing speeds, although somewhat shorter at the highest speed (1). Given the observed backing speeds and stopping distances, the reaction times of the drivers appear consistent with an average TTC of approximately 2.0 seconds (1).

A number of factors complicate the implementation of an effective warning system, including the fact that drivers who are parallel parking or backing to a wall or curb often intentionally bring their vehicles into close proximity to objects. Because there is no way for the system to know the driver's intentions, there is a high potential for nuisance warnings, which, in terms of user acceptance, must be minimized while maintaining adequate warning for truly unaware drivers (1). Warning systems must be effective over a wide range of speeds and scenarios. Backing out of an angled parking space, backing along an extended driveway, or parallel parking, require different speeds, glance locations, reaction times, and stopping distances. An effective back-up warning system needs to accommodate all of these scenarios (1).

Based on the results of a two-part study consisting of a field experiment and a laboratory experiment, Harpster et al. suggested that it might be beneficial to have two distinct back-up warnings: those for imminent crashes versus cautionary warnings (3).

An *imminent* crash avoidance situation is one in which the potential for a collision requires an immediate vehicle control response that modifies a planned response (3). The desired point for imminent crash warnings in terms of TTC was consistent across the range of vehicle speeds, with a mean of 1.6 seconds (3). This suggests that TTC may be an appropriate basis for warnings, one that is consistent with subjective judgments and with the manner in which backing drivers actually perform (3).

A *cautionary* crash avoidance situation is one in which the potential for a collision requires immediate attention from the driver, which may require a vehicle maneuver, but does not meet the definition of an imminent crash avoidance situation (3). For cautionary warnings, a major concern is determining the sensitivity of the alarm to avoid false alarms. Excessive false alarms can cause drivers to ignore or disable the alarm. Alternatively, if the alarm is not sensitive enough, the driver may not receive timely warning, and an accident could result. One approach is to have the cautionary alarm vary. Three acoustic variations in various combinations were examined. Participants felt the greatest match between their sense of danger in the backing scene and the danger portrayed by the alarm was when the loudness increased as the car approached the target. The best acoustic warning design includes a constant pulse rate, constant pitch, and fast variation of loudness (3).

Llaneras et al. completed a 2005 study concerned with the development of criteria for developing driver interfaces for a rear obstacle detection system and different timing algorithms to set off the alarm (34). The researchers tested drivers in a minivan and a passenger sedan equipped with a prototype rear obstacle detection system (34). The appropriateness of the warning timing algorithms was tested using an alerted backing procedure wherein drivers backed to known obstacles and braked in response to the warning. Additionally, a surprise event scenario was included in order to examine driver reaction to the warning under unexpected conditions (34). While both timing algorithms led to few target strikes, one algorithm elicited more acceptable ratings with fewer target strikes and close calls, and less urgent braking (34). However, none of the interface warning conditions reliably induced avoidance braking under the surprise event condition (34). The research was intended for use in developing improved warning systems;

however we did not find any indication that manufactures have used the results to inform new equipment designs.

Critics of using back-up alarms alone argue that they are not always enough to protect pedestrian workers because the alarms do not always function, and on a noisy site workers may hear back-up multiple alarms or get confused about the location of the vehicle (15).

RADAR AND SONAR

Radar sensors emit high-frequency radio waves that detect objects' position and velocity relative to the vehicle on which they're mounted. Sonar detectors use a sound transmitter and receiver. Both are typically mounted on the rear of the vehicle. They emit an audio warning inside the vehicle to alert the equipment operator (27). Both radar and sonar technologies can work in conjunction with back-up alarms to comprise a comprehensive warning system.

An early examination into radar systems published in 1991 looks at how contractors avoid backing accidents by using motion detectors installed on trucks and heavy equipment (7). The U.S. Bureau of Mines tested three principal types of motion detectors (Doppler radar, ultrasonic wave, and infrared light) and concluded the following:

- Ultrasonic systems had a limited range but worked well in rough or dirty environments.
- Infrared sensors worked despite a build-up of grime, but malfunctioned at slow speeds or in bright light.
- Radar systems were the most immune to weather conditions (7).

A 1996 study explored community transportation vehicles and backing accidents and referenced Caltrans' evaluation of the Echovision rear obstacle detection system as a means of reducing accidents and improving safety. Caltrans then listed the system as an approved option in 1996 and as standard equipment in 1997 (16).

In 1997, Moffa et al. published an important report on radar and lidar crash countermeasure technologies. The researchers focused on radar and lidar technologies because of the relatively long ranges required for accident avoidance at a high closing velocity (24). Results indicated that both radar and lidar are dependable and use for low-cost, highly reliable components. Digital signal processors were also examined, and requirements for processor speed, architecture, and memory were derived (24). In the decade since the publication of this report, new research findings about into radar and sonar systems may affect future equipment purchases.

The 2007 report, "Front and Rear Vehicle Detection and Tracking in The Day and Night Times Using Vision and Sonar Sensor Fusion," proposed a vehicle detection and tracking method that used vision and sonar sensors to detect objects and estimate distances under different light and road conditions (17). In the daytime, the system could create an image that allowed the driver to clearly visualize the features and distance of objects behind the vehicle. At night, it was able to detect bright regions caused by the headlights, taillights, brake lights, an the like and aided the driver's ability to see objects behind the vehicle (17).

Another report, "Hardware Evaluation of Heavy Truck Side and Rear Object Detection Systems," focuses on two types of electronics-based object detection systems for heavy truck applications: rear-sensing, and those sensing the presence of objects on the vehicle's right side (13). Three types of evaluation were performed: a hardware performance measurement, a human factors assessment of driver/system interfaces, and an assessment of subjective driver reactions. The results of these evaluations indicated that object detection system technology is still in the early stages of its development and user-acceptance (13). Drivers of heavy trucks appreciate the value of these aids, but improvements in the technology are needed before their full potential for preventing crashes can be realized (13).

A series of four studies commissioned by the National Institute for Occupational Safety and Health (NIOSH) and the Spokane Research Laboratory evaluated radar and sensor based collision-warning systems for construction equipment, heavy equipment, and off-road dump trucks (27-29). Below are some key findings from three of the studies that contained particularly relevant results:.

- Camera and sensor systems are more reliable under warmer conditions and experience difficulties under cold, snowy conditions. (29)
- They do not perform well in congested work areas. (27)
- The tendency to produce false alarms suggest that sensor-based systems for proximity warning should be used in combination with devices such as cameras to allow the operator to check the alarm source. (29)
- A radar system installed in large, off-road dump trucks reliably detected small vehicles, people, and other equipment. (28)

A 2005 report published in Canada investigated the performance of different types of sonar equipment in monitoring back-up proximity to reduce pedestrians' risks from reversing vehicles (14). Six commercial reversing aid systems that used ultrasonic sensor technology were evaluated in laboratory tests consisting of 3-dimensional mapping of detection zones, system response time, and durability, especially concerning the effects of dust and dirt (14). In terms of durability and reaction times, all six systems performed reliably (14). Their performance did not decrease significantly even with the sensors covered with dust; however, they weren't effective in protecting pedestrians, primarily due to their limited detection distances (14). Even under ideal conditions, their effectiveness was limited to vehicle speeds that were lower than those at which most pedestrian collisions occur (14). The researchers suggest that other technologies could be effective at higher vehicle speeds and that video cameras would be feasible because their cost is steadily decreasing (14).

CAMERAS AND VIDEO

Over the past 20 years, several works about automated driving systems dedicated to collision avoidance have demonstrated the usefulness of still cameras and video in providing information that allows the driver to easily process information while driving or parking. Camera and video technologies may work in conjunction with back-up alarms to comprise a comprehensive warning system.

A list of features included in the Safety Vision rear-vision camera system illustrates the multi-faceted safety components of a camera system:

- Heavy duty design that can withstand harsh environments
- Black and white or color systems
- Infra-red illuminators for low-light working conditions
- Threaded and sealed connectors for water-tight connections
- Multi-sectional cables for easy maintenance
- Wide field of view
- Built-in microphone for crisp, clear audio
- High-impact-resistant housing
- Backlight compensation to control picture quality in all lighting conditions (5)

In 2006, the National Highway Traffic-Safety Administration (NHTSA) issued a report to Congress titled "Vehicle Back-over Avoidance Technology Study" (31). The report addressed the results of a NHTSA study of crashes involving passenger vehicles backing over pedestrians and evaluated backing aids and educational efforts. NHTSA researchers analyzed crash data, spoke with vehicle and equipment manufacturers, tested a representative sample of backing aids, and performed a literature review. Of the technologies tested, researchers determined that camera-based systems had the greatest potential to provide drivers with reliable assistance in identifying people in the path of a backing vehicle (31). The report cautioned, however, that it was important to obtain a clear understanding of the environmental factors limiting the camera's effectiveness and the limits of the improvements in driver performance using such systems (31).

A 2005 evaluation of Eaton VORAD's Backspotter radars conducted by the Arizona Department of Transportation (ADOT) found that the cameras were very well-received in the construction field, especially on stock fleet units of one-ton and heavier trucks (25). The Backspotter was favored over rear cameras for the medium and heavier truck classes. The Backspotter's main drawbacks were that the camera system did not work with trailers, and rear-view cameras were not successful on medium trucks (25). Despite these weaknesses, the long-term research results suggested that installing camera warning devices on appropriate vehicles in field-level organizations is advisable (25).

A 2003 report published by Fintzel et al. proposed a "circumstance recognition system" that provides the driver with a 3-D representation of the scene surrounding his vehicle from images acquired by a rear CCD camera (12). The biggest drawback of most back-view 2-D systems is that the driver can never see the whole scene at one time. This new technology is able to render a virtual 3-D model from several shots taken while the vehicle is moving. Using this virtual 3-D model, the driver can observe the scene from any point of view at every moment. While this approach appears promising, it has not yet been tested (12).

Several non-academic articles have addressed recent developments in camera technology. A 2004 article in a trade magazine reported on rear-vision camera and monitoring systems that eliminate drivers' blind spots (21). The article was based on interviews with manufacturer representatives as well as managers at aggregate suppliers who had installed cameras in their vehicles. It found that innovations in cameras, including lighter weights, smaller sizes, clear screens, and the elimination of static caused by CB radios had improved their usefulness(21). It also noted that their cost was dropping making them affordable (21).

A number of construction companies find the investment in camera systems well worth the cost. For example, following a rash of backing incidents, Cortez Gold Mines in Crescent Valley, Nevada, installed camera systems on haul trucks and mining shovels (8). said investing in a camera system is a "no-brainer" Today, the mining operation has 18 haul trucks, three water trucks, two P&H electric shovels, one hydraulic shovel, and several wheel loaders equipped with camera systems (8). "If you prevent one serious injury, the cost of the video system is insignificant… but when you also consider the impact an accident can have in downtime of equipment and lost production to conduct an investigation, it further validates the investment. The cameras just have a way of increasing the ease of operation and the efficiency of the job at hand. They improve safety by eliminating backing incidents, and I think it's because drivers are much more attentive. With a monitor in their cab, they really have no excuse for not knowing what's behind them," notes Chris Chrestensen, mine trainer. (8)

CONCLUSION

Based on this review of literature examining backing prevention equipment and technology, it is reasonable to conclude that the most effective backing accident prevention system integrates multiple technologies including video, radar, and back-up alarms. The following list highlights the TSC's research findings, which are described in detail in the sections above.

- A report on highway work zones based on qualitative information obtained from government, labor, industry, academia, and state departments of transportation suggested that the following engineering solutions might effectively reduce backing accidents:
    - Parabolic mirrors on construction equipment
    - Individual vibrating alarms that can give workers 8-10 seconds notice of approaching vehicles
    - Sensing devices that sound an alarm when an object is near the vehicle

    - Closed-circuit television cameras, mirrors, and devices that stop a vehicle nearing a collision (26)

- NIOSH investigated equipment on job sites to see what backing accident prevention technologies worked best and in 2006 concluded that back-up video systems are very helpful and work best when used in conjunction with a radar system that alerts the driver that something may be behind the vehicle and directs his attention to a monitor (6).

- Mirrors are not the most effective means of increasing truck drivers' visual range. However, truck drivers believe supplemental mirrors have the potential to significantly reduce blind-side and backing crashes (15).

- Back-up warnings that alerted drivers approaching known obstacles were more successful in preventing backing incidents than warnings that sounded in response to a surprise event (20). However, some argue that audible alarms do not always protect workers outside vehicles due to malfunctions and work site noise (15).

- Durability and reaction time studies showed that radar and sonar systems generally perform reliably (14), with except under the following conditions:
    - cold and snow (29)
    - congested work areas (especially affects sonar systems) (27)
    - cluttered conditions, when objects that posed no immediate danger set off false alarms (29)
    - when vehicles' speeds exceed that at which most pedestrian collisions occur (especially affects sonar) (14).

- One study of particular relevance to Caltrans is the Arizona Department of Transportation (ADOT) evaluation of ETON brand Backspotter rear cameras on ADOT's heavy vehicles, including dump trucks, stripers, and tractor-trailers. They were very well received by field crews, but the camera system did not work with trailers, and rear-view cameras were not effective on medium trucks (25).

- Recent innovations in cameras, including lighter weight, smaller size, and clear screens, and models that eliminate static caused by CB radios suggest that cameras may currently be one of the most popular and affordable approaches to reducing work zone backing incidents (21).

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