Advanced Highway Maintenance and Construction Technology Research Center

Department of Mechanical and Aerospace Engineering
University of California at Davis

Scientific Evaluations of Operational Performance, Procedures, Impacts, and Benefits of Highway Construction Zone Enhanced Enforcement Program (COZEEP) and the Highway Maintenance Zone Enhanced Enforcement Program (MAZEEP)

Executive Summary

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AHMCT Research Report: UCD- ARR-13-10-28-01
Final Report of Contract: 65A0418, Task ID: 2249

October 28, 2013

California Department of Transportation

Division of Research and Innovation

Technical Documentation Page

1. Report No. CA 13 2249	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle: Scientific Evaluations of Operational Performance, Procedures, Impacts, and Benefits of Highway Construction Zone Enhanced Enforcement Program (COZEEP) and the Highway Maintenance Zone Enhanced Enforcement Program (MAZEEP).		5. Report Date October 28, 2013
		6. Performing Organization Code AHMCT
7. Author(s): Bahram Ravani, Chao Wang, Wilderich A. White, and Patricia Fyhrie		8. Performing Organization Report No. UCD-ARR-13-10-28-01
9. Performing Organization Name and Address AHMCT Research Center UCD Dept. of Mechanical & Aerospace Engineering Davis, California 95616-5294		10. Work Unit No. (TRAIS) 11. Contract or Grant 65A0418, Task ID 2249
12. Sponsoring Agency Name and Address California Department of Transportation PO Box 942873, MS #83 Sacramento, CA 94273-0001		13. Type of Report and Period Covered Final Report July 2011 – June 30th, 2013 14. Sponsoring Agency Code Caltrans

15. Supplementary Notes

16. Abstract.

Caltrans contracts with CHP (California Highway Patrol) for enhanced enforcement in construction and maintenance zones under the Construction Zone Enhanced Enforcement Program (COZEEP) and the Maintenance Zone Enhanced Enforcement Program (MAZEEP). These programs provide traffic management strategies to improve project safety using supplemental CHP units to assist in the enforcement of speed restriction and provide faster incident response through the selected work zones. There is however insufficient information available to determine the degree of drivers' adherence and their level of compliance to speed reduction requirements with the use of COZEEP and MAZEEP. Furthermore, there is no quantitative data on safety benefits, best implementation configurations, and cost benefits of the COZEEP/MAZEEP programs in highway work zones. The goal of this study is to gather data and perform analysis to address the following research questions: Does the CHP presence together with Caltrans operations in work zones help achieve the safety and mobility goals? Is COZEEP/MAZEP cost effective in terms of its impact on safety? What are some of the most effective configurations in terms of the utilization of CHP officers in implementation of COZEEP/MAZEEP? Tests were performed over 10 nights in urban areas as well as two day times in rural areas that included construction as well as maintenance operations. In COZEEP tests, a condition referred to Augmented COZEEP (ACOZEEP) was also tested involving additional police units and ticketing of speed violators. A total of 34 tests were performed evaluating different configurations COZEEP and MAZEEP and COZEEP versus ACOZEEP effectiveness. In addition, the tests were augmented with a comprehensive survey of those who work or are involved with highway work sites as well as evaluation of 1,868 accidents that occurred with direct interactions with work zones in California from 2008-2010. The results indicate that COZEEP, MAZEEP and ACOZEEP are effective in reducing speeds in free flowing, mid-to-long distance work zones where drivers have an uninhibited field of view. Furthermore, in longer length work zones, ACOZEEP resulted in vehicles maintain their speed reduction for a longer period of time. In addition ACOZEEP resulted in additional highway safety improvements in identifications of DUI (Driving Under the Influence) drivers. Furthermore, the results also provide data on some of the most effectiveness configurations in terms of location of Police units in the work zone and best practices as well as clear cost and safety benefits in reduction of fatalities and reduction of injury severity due to reduced traffic speeds as a result of COZEEP/MAZEEP.

17. Key Words Work Zone Safety, Changeable Message Sign, Highway Safety, Work Zone Signing, Speed Management, Speed Reduction	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

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

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

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LIST OF ACRONYMS AND ABBREVIATIONS

Acronym	Definition
ACOZEEP	Augmented Construction Zone Enhanced Enforcement Program
AHMCT	Advanced Highway Maintenance and Construction Technology Research Center
Caltrans	California Department of Transportation
CHP	California Highway Patrol
COZEEP	Construction Zone Enhanced Enforcement Program
DRISI	Caltrans Division of Research, Innovation, and System Information
ECOZEEP	Enhanced Construction Zone Enhanced Enforcement Program
LED	Light Emitting Diode
LIDAR	Light Detection and Ranging
LLC	Limited Liability Corporation
MAZEEP	Maintenance Zone Enhanced Enforcement Program
MPH	Miles per Hour
MUTCD	Manual on Uniform Traffic Control Devices
NCHRP	National Cooperative Highway Research Program
No.	Number
OEM	Original Equipment Manufacturer
PC	Personal Computer
PDO	Property Damage Only
RTMS	Remote Traffic Microwave Sensor
vs	versus

ACKNOWLEDGMENTS

The authors thank the California Department of Transportation (Caltrans) for their support, in particular Randy Woolley, Hassan Ghotb, and Homar Noroozi from the Division of Research, Innovation and System Information. The authors also thank CHP (California Highway Patrol) in particular John Keller, Bob Nannini and Mary Uhazi as well as all the members of the Technical Advisory Group for this study.

EXECUTIVE SUMMARY

Background

Traffic on California highways has been observed to exceed the posted speed limit in construction and maintenance work zones. These elevated speeds increase the risk of injury and death to workers and vehicle occupants as well as cause property damage. To reduce these travel speeds and potential for traffic accidents within a work zone, in selected locations, the California Department of Transportation (Caltrans) currently employs the California Highway Patrol (CHP) to enforce the posted work zone speed limits using COZEEP (Construction Zone Enhanced Enforcement Program) and MAZEEP (Maintenance Zone Enhanced Enforcement Program). Previous studies from other states and nationally have indicated a prevalent opinion on the benefits of the speed enforcement through use of additional officers (similar to COZEEP and MAZEEP) at the work zone. Much of the previous studies, however, have either been based on conducting surveys or have used limited testing. Furthermore, there is lack of data on effective implementation practices, safety and cost benefits related to the presence of police officers at work zones in general and COZEEP/MAZEEP in particular.

Approach

This research used a multimodal approach consisting of actual testing and data collection at highway work zones in both COZEEP and MAZEEP configurations, conducting a comprehensive survey of work zone practitioners, and computer simulations and reconstruction of a large number of actual work zone collisions. The results were used to develop a better understanding of the parameters that could improve the effectiveness and cost benefits of these operations while improving mobility and safety in highway work zones.

Tests were performed in highway work zones at eleven different dates including urban (San Diego area) and rural areas (Redding and Weed) in California. In these tests the speed of traffic was measured using iCones at different locations in the approach as well as within the highway work zone under conditions with and without police presence and in the case of some of the tests with and without enforcement and ticketing. The testing in the urban areas spanned over eight nights in construction work zones and included testing a total of 17 different conditions. These included a condition referred to as Augmented or Enhanced COZEEP (ACOZEEP). This condition involved regular COZEEP configuration with additional CHP units used for enforcement and ticketing of speeding drivers. During COZEEP operations using only one CHP unit in the work zone, the officer normally does not leave the work zone except when observing serious violations. In ACOZEEP there are additional CHP units that can pursue violators. Testing in rural areas spanned over a period of four days and included both COZEEP as well as MAZEEP conditions. A total of thirteen different conditions were tested in rural areas.

A test layout was designed to capture speed of traveling public at different locations near or within the work zone while having minimal impact on highway infrastructure as well as driver attention while allowing for rapid deployment and tear down of the sensing system at a highway work zone.

All tests involved measurements of speed of traveling public using iCones. The following conditions were tested:

1. COZEEP Conditions (12 tests)
2. ACOZEEP Conditions (13 tests)
3. MAZEEP Conditions (9 tests)

In all the tests, the following speeds were also measured:

4. Speeds Upstream of the Closure for reference on location dependent travel speed.
5. Speeds throughout work zone with no CHP to evaluate the effect of closure alone on speed.

In order to supplement information gathered in the testing a detailed survey questionnaire was prepared, a survey was conducted and data was collected from those who work or are involved with highway work sites. The survey was provided through an external web site and it could be filled out by workers using a smart phone or other mobile devices with internet access. The survey could also be printed and filled out manually and submitted. A total of 529 responses were collected in a six week period with 60% to 65% of responses being from highway workers. The responses fairly represented all area with highways within California. A plot of responses from different Caltrans districts is depicted in Figure 1.

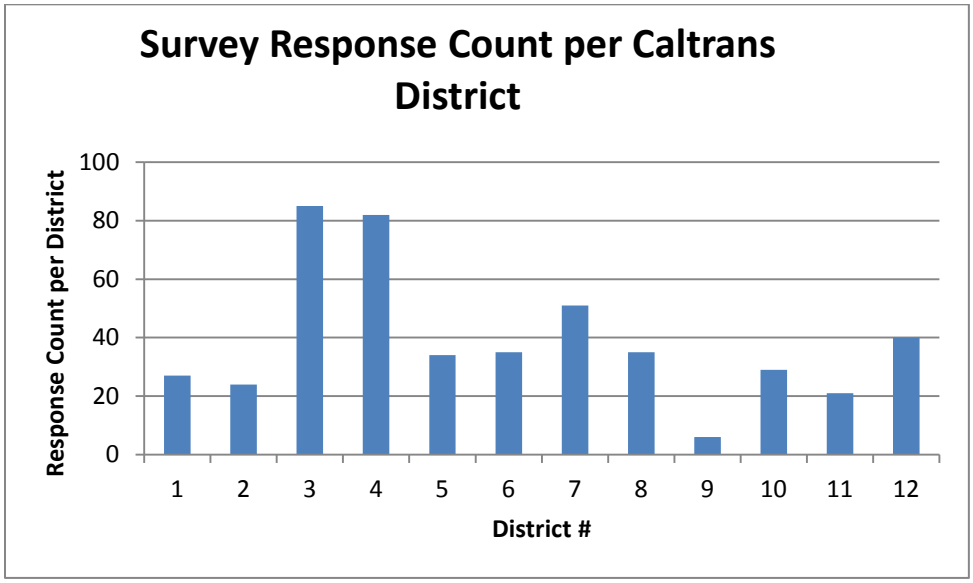

Figure 1. Survey Response Count by Caltrans Districts.

The chart in Figure 1 indicates that the survey was effective in soliciting responses well across California. The data in the survey responses provided valuable information on highway workers views on safety benefits of COZEEP/MAZEEP and some of the best operational configurations for COZEEP/MAZEEP implementation.

A proper assessment of the cost benefits of COZEEP/MAZEEP operations that would be quantitative and would provide an assessment of the level of the benefits achieved is very difficult and requires much detailed data. In order to provide estimates of such cost benefits, CHP traffic accident reports for a period of three years from 2008 to 2010 was collected for all accidents in California that the accident occurred in or near a highway work zone. A total of 13,125 CHP reports were identified and reviewed. These reports were studied with redacted identification data to ensure confidentiality of personal information. A total of 1,868 of these accidents were identified that had direct interactions with the work zone active area. These accidents consisted of 347 accidents that involved intrusions into the work zone and 1,521 non-intrusion work zone accidents. The distribution of these accidents in terms of fatalities, non-fatal injury accidents, and Property Damage Only (PDO) accidents for each set is shown in the pie charts depicted in Figure 2. 167 involved injuries and 136 only had property damage). From the remaining 1,403 non-intrusion accidents, a total of 469 resulted in injuries and the rest only involved property damage to the traveling public. The distribution of work zone accidents for each type is depicted in Figure 2.

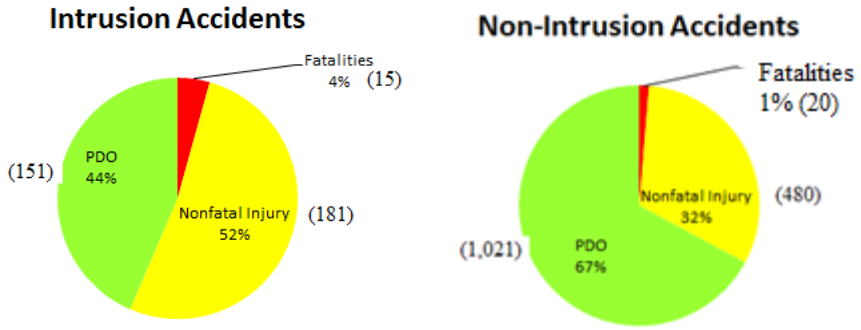

Figure 2. Work Zone Accident Distribution by Type for Intrusion and Non-intrusion Accidents.

The cost of these accidents were then calculated considering the cost of property damage as well as injury and fatality costs using standard cost data for Caltrans. The cost data used for such calculations is summarized in Table 1. The actual costs of these collisions are discussed in the next section.

Accident Outcome	Cost
Accident involving a Fatality	$5.8 Million
Non-fatal Injury Accident	$67,400
Property Damage Only Accident	$10,200

Table 1. Cost Data for Injuries, Fatalities, and Property Damage Only.

A sub-set of all these accidents were then selected that had consistent and sufficient data for reconstruction and simulation. These included 90 intrusion accidents and 50 injury and fatality accidents having direct interactions with the work zone. These two sets of accidents were

reconstructed using PC-Crash accident reconstruction software and simulated to evaluate the impact of COZEEP/MAZEEP and the resulting cost and safety benefits. The results are discussed at the end of the next section.

Conclusions, Recommendations, and Limitations

Conclusions From Actual Testing in Highway Work Zones

The speed of traffic at different locations within the highway work zone varies. Therefore, in order to discuss speed reduction due to use of COZEEP/MAZEEP, one has to choose an appropriate reference location within the work zone. In the conclusions discussed here two reference locations are selected for discussing speed comparisons. In addition, the maximum speed reduction observed at any locations within the work zone is also discussed. The two reference locations are the end of taper and the end of buffer area as shown in the diagram in Figure 3. This figure depicts a typical highway work zone in California. The location of maximum speed reduction varied in different tests conducted and consisted of locations varying from the beginning of taper to some point in the active work area.

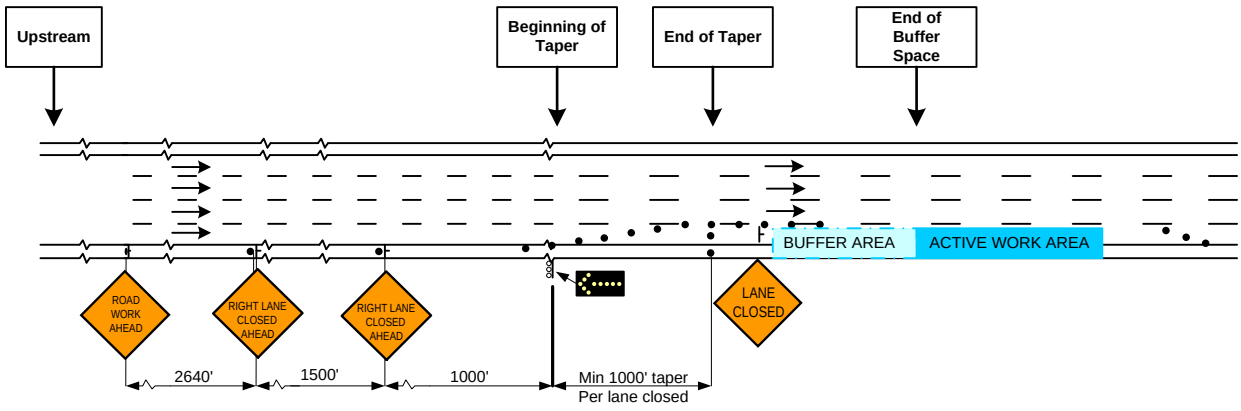

Figure 3. Definition of Reference Locations in a Highway Work Zone.

In the series of tests conducted in urban as well as rural areas, average traffic speeds were measured using iCones at several locations within the work zones under conditions with no CHP presence (no COZEEP/MAZEEP conditions) and with COZEEP/MAZEEP conditions. Comparing the tests data at each reference location provides an indication of speed reduction at such locations as a result of COZEEP/MAZEEP operations. The range of speed reductions for different speed limits within the work zone as observed in the tests conducted is summarized in . The data in this table reflects the speed reduction over and above any reductions due to the lane closure alone. In other words, the speed reductions listed in this table, are incremental reductions when police was present (COZEEP or MAZEEP conditions) as compared to what was observed at the same locations within the work zones without police presence and only due to the lane

closure. It should be noted that the location of the largest incremental speed reduction varied among the tests and occurred at different locations in the work zones tested varying from the beginning of taper to some point in the active work area.

Incremental Speed Reductions (Due to COZEEP/MAZEEP)									
	End of Taper			End of Buffer			At The Location of Largest Reduction		
Speed Limit	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
55 MPH	3.3	6.9	0.2	2.6	6.4	-0.1	4.3	6.9	1.4
65 MPH	3.0	5.2	0.4	3.5	6.6	2.0	4.8	7.0	3.5
70 MPH*	3.8	7.6	1.2	4.4	7.4	1.7	12.4	20.8	5.6

Table 2: Incremental Speed Reduction Due to COZEEP/MAZEEP as Compared to When There was no Police Present. Note: *Not including the 2nd night of Redding tests ("CHP end of taper" and "rolling traffic break" conditions) due to absence of "No CHP" condition.

The incremental speed reduction values listed in Table 2 are with respect to and above the values observed as a result of signage and closure alone without any Police presence.

The following conclusions are derived from the data in Table 2:

- In urban areas (urban freeway, 65 MPH speed limit), deployment of COZEEP resulted in an average incremental speed reduction of 3.0 MPH and up to a maximum reduction of approximately 5.2 MPH (range of 0.4 to 5.2 MPH) at the end of taper and an average incremental average speed reduction of 3.5 MPH and up to a maximum reduction of 6.6 MPH (range of 2.0 to 6.6 MPH) at the end of the buffer area. At the location where the incremental speed reduction was largest throughout the work zone, the incremental speed reduction was an average of 4.8 MPH and up to a maximum of 7 MPH (range of 3.5 to 7.0 MPH).

- In rural areas (rural freeway, when speed limit was reduced from 70 MPH and posted at 55 MPH), deployment of MAZEEP/COZEEP (first day of the testing involved COZEEP and the second day of the testing involved MAZEEP type conditions: shorter work zones) resulted in

an average incremental speed reduction of 3.3 MPH and up to a maximum of 6.9 MPH (range 0.2 to 6.9 MPH) at the end of taper and an average incremental speed reduction of 2.6 MPH and up to a maximum of 6.4 MPH (range of -0.1 to 6.4 MPH) at the end of the buffer area. At the location where the incremental speed reduction was largest throughout the work zone, the incremental speed reduction was an average of 4.3 MPH and up to a maximum of 6.9 MPH (range of 1.4 to 6.9 MPH).

- In rural areas (rural freeway, speed limit 70 MPH, NOT including rolling traffic break), deployment of MAZEEP resulted in an incremental speed reduction of average of 3.8 MPH and up to a maximum of 7.6 MPH (range 1.2 to 7.6 MPH) at the end of taper and an incremental speed reduction of an average of 4.4 MPH and up to a maximum of 7.4 MPH (range of 1.7 to 7.4 MPH) at the end of the buffer area.

- At the location where the incremental speed reduction was largest throughout the work zone, there was rolling traffic break. In this location, the incremental speed reduction was an average of 12.4 MPH and up to a maximum of 20.8 MPH (range of 5.6 to 20.8 MPH). In this test, the Police vehicle in addition to providing rolling traffic break, it was also shadowing the maintenance vehicle. Such events may have larger impact on traffic flow than a typical MAZEEP operation where the Police vehicle is at a stationary location outside of the traveling lanes. Another potential cause for the slow traffic speed observed in Redding is the narrowed traveling lane. Due to the nature of the maintenance work being done, traffic control cones were placed beyond the lane markers of the closed lane. As a result, the lane width of the traveling lane was reduced. ***The data in this test was therefore excluded for consideration with other test data.***

- The maximum speed reduction observed at the end of buffer was consistently higher as compared to the speed reduction observed at the end of taper. This could have been due to the localized effect of the location of the police vehicle being closer to the end of taper under the test conditions.

In the tests that were performed in the urban San Diego area, a condition referred here to as ACOZEEP (Augmented COZEEP) was also tested. This condition involved using extra Police vehicle units for pursuing and ticketing speeding vehicles. The range of speed reductions for the same test locations performed with COZEEP alone in urban San Diego area are summarized in Table 3.

Incremental Speed Reductions (Due to ACOZEEP)									
	End of Taper			End of Buffer			At The Location of Largest Reduction		
Speed Limit	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
65 MPH	3.8	8.2	0.7	4.6	6.4	2.6	6.0	8.2	2.6

Table 3: Incremental Speed Reduction Due to ACOZEEP as compared to when there was no Police present. (Notes: *ACOZEEP is only tested in San Diego, urban freeway with speed limit of 65 MPH.)

The following conclusions are derived from the data in this table:

- For the same urban freeway, signage, and lane closure with a speed limit of 65 MPH as in the case of the COZEEP tests, when additional CHP units with enforcement and ticketing of speed violators (ACOZEEP) were added, the incremental speed reduction was an average of 3.8 MPH and up to 8.2 MPH (range of 0.7 to 8.2 MPH) at the end of taper and an average of 4.6 MPH and up to 6.4 MPH (range of 2.6 to 6.4 MPH) at the end of the buffer area. At the location where the incremental speed reduction was largest throughout the work zone, the incremental speed reduction was an average of 6.0 MPH and up to 8.2 MPH (range of 2.6 to 8.2 MPH).

- It is clear from the above data that ACOZEEP slightly increased the incremental speed reduction from an average of 3 MPH to 3.8 MPH and up to a maximum reduction from 5.2 to 8.2 MPH for the same work zone conditions and speed limit (speed limit of 65 MPH).

The following conclusions are derived from actual observations at the testing sites combined with the collected data:

- COZEEP/MAZEEP operations are effective in reducing speeds in free flowing, mid- to long- distance work zones where drivers have an uninhibited field of view.

- In the longer length work zones, ACOZEEP resulted in vehicles maintaining their speed reductions for a longer distance as compared to COZEEP.

- In ACOZEEP configurations for the eight test sets in urban freeways, enforcement data collected throughout the study from the California Highway Patrol (CHP) officers (deployed at the work zone sites) resulted in the following data for all the eight test sets combined:
    - At least nine verbal warnings for speeding
    - Nine citations for speeding
    - Two Driving Under the Influence (DUI) arrests
    - Nine undefined stops (most likely for speeding).

- ACOZEEP enforcement data (collected at night time) indicates identification and reduction of DUIs on the highway which in general is expected to improve highway safety.

Data collected at the actual work zones was also used to evaluate the degree of traffic compliance with the posted speed limits in the work zones. The results are summarized in Table 4. The data in this table indicate the percentage of vehicles going above three speed thresholds. The speed thresholds considered are the posted speed limit for the work zone, 5 MPH above the posted speed limit, and 10 MPH above the posted speed limit for the work zone. A measure of the degree of traffic compliance with the posted speed limit can be obtained by looking at percentage drop from these thresholds when COZEEP/MAZEEP or ACOZEEP are used as compared to the data for standard closure with no Police presence.

The following conclusions are derived from the data in this table:

- Test data indicates that in both urban and rural areas there is a clear drop in the average percentage of vehicles going above the speed limit when COZEEP/MAZEEP operations are used.

- In the urban areas, test data indicates that COZEEP operations resulted in a drop of 14% (40%-26%=14%) in the average number of vehicles going above the speed limit.

Percentage of Vehicles Traveling At or Above Speed Threshold										
	Speed Threshold*	Standard Closure			Closure + COZEEP/MAZEEP			Closure + ACOZEEP		
		Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Urban	Speed Limit	40%	57%	26%	26%	50%	9%	24%	34%	9%
	Speed Limit + 5 MPH	18%	30%	7%	9%	27%	1%	7%	14%	0%
	Speed Limit + 10 MPH	5%	11%	0%	3%	10%	0%	2%	4%	0%
Rural (Redding)	Speed Limit	8%	8%	8%	2%	5%	0%			
	Speed Limit + 5 MPH	1%	1%	1%	0%	0%	0%		N/A	
	Speed Limit + 10 MPH	0%	0%	0%	0%	0%	0%			
Rural (Weed)	Speed Limit	51%	61%	45%	28%	45%	13%			
	Speed Limit + 5 MPH	17%	21%	15%	5%	10%	1%		N/A	
	Speed Limit + 10 MPH	6%	9%	4%	1%	3%	0%			

Table 4: Data on Degree of Traffic Compliance with the Posted Speed Limits. Note: *Speed Limits: Urban – 65 MPH, Rural (Redding) – 70 MPH, Rural (Weed) – 55 MPH, reduced from 70 MPH due to work zone

- In urban areas when ACOZEEP was used there was an additional 2% drop in the average percentage of traffic going above the speed limit.

- In the rural areas the percentage reduction in the average number of vehicles going above the speed varied from 6% in the Redding test to 23% in the Weed test. These tests involved both COZEEP as well as MAZEEP type conditions.

Conclusions From the Practitioner Survey

The practitioner survey captured data from construction and maintenance crew in terms of their field experiences, observations, and perceptions.

The following conclusions are derived from the responses:

- **On Speed Reduction and Safety Benefits:**
    - 78% of COZEEP workers who responded and 82% of MAZEEP workers who responded indicated that CHP presence had a very large effect on drivers adhering to the posted speed limits.
    - 84% of COZEEP respondents and 92% of MAZEEP respondents indicated that CHP presence improved worker safety.
    - 72% of COZEEP respondents and 81% of MAZEEP respondents indicated that presence of CHP improved public safety.
    - 88% of COZEEP responders and 82% of MAZEEP respondents indicated that the CHP presence improved driver attentiveness.
    - 88% of COZEEP respondents and 94% of MAZEEP respondents indicated that driver attentiveness was increased when COZEEP and MAZEEP operations were used in a work zone.
    - 62% of COZEEP respondents and 60% of MAZEEP respondents indicated that COZEEP/MAZEP operations had no effect on **traffic congestion** in the work zone.

- **On Implementation and Most Effective Configuration**

  - In terms of identifying the conditions when it is most effective to utilize COZEEP/MAZEEP, the respondents indicated "Nighttime" conditions as the highest priority with "High Traffic Volume" and "Curved/Graded Roads" as the next priority.

  - In terms of the location for the CHP units in the work zone, for both one and two lane closures, the higher percentage of the respondents recommended the placement of the CHP units in a safe area in the "Buffer Space".

  - In terms of the preferred number of CHP units, a larger percentage of the respondents recommended use of two CHP units instead of one unit for both COZEEP as well as MAZEEP operations.

Conclusions From the Cost Benefit Analysis

The total costs due to injuries, fatalities, and property damage only for accident having direct interaction with the work zones in California for the three-year period considered (a total of 1,868 accidents) were calculated using the cost basis discussed earlier in Table 1. The results are summarized in Table 5.

Total number	Associated Cost Accident	Cost for all 3 years	Average Cost Per Year
35 Fatalities	$5.8 Millions	$203 Millions	$67.7 Millions
661 Non-fatal Injury collisions	$67,400	$44.55 Millions	$14.85 Millions
1172 PDO collisions	$10,200	$11.95 Millions	$3.98 Millions
	total:	$259.5 Millions	$86.5 Millions

Table 5. Accidents Involving Direct Interactions with a Work Zone in California - 3 Year Period.

The following conclusions are derived from the data in Table 5:

- The average yearly cost of accidents that have direct interactions with the work zone can be approximately $86.5 Million per year. This includes the cost of such accidents to the traveling public combined with those of the highway workers (note: the same

cost basis is used for both the traveling public and highway workers for consistency purposes).

- The average cost of fatalities (considering both the traveling public as well as highway workers) alone can be approximately $67.7 Million per year. It should be pointed out, however, that there may be no cost value that can replace the life of a person but in order to have a way of comparing the impact of a fatality, some standard cost (in this case based on Caltrans data) is used.

- The average cost of non-fatal injuries (considering both injuries to traveling public as well as highway workers) can be approximately $14.8 Million a year and the cost of property damage alone can be approximately $3.98 Million per year.

Assessing the quantitative effect of the level of the benefits of COZEEP/MAZEEP on reducing costs of injuries and fatalities in highway work zone accidents is very difficult. However, to obtain some indication of the level of such benefits is determined here by using the following methodology utilizing the accident reconstruction software PC-Crash:

a. Reconstructing the accidents using PC-Crash to understand parameters such as collision severity, trajectory, and timing of driver reactions as well as the factors leading to the cause of the accident.

b. Simulating the same accidents using PC-Crash but this time reducing the speed of the vehicle in the work zone by the incremental reductions when COZEEP/MAZEEP is utilized as observed in the test data discussed earlier.

c. Evaluating the injury severity potential and outcome in the simulated accidents and comparing them to that of the actual accidents to determine the level of reduction (if any) in injury or fatalities due to incremental speed reductions observed when using COZEEP/MAZEEP operations.

Out of all the accidents considered, 696 involved fatalities or injuries. However data on details of injuries did not exist in all the CHP reports. Furthermore, even for cases were data on injuries was included in the CHP reports, only injuries such as broken bones, damage to internal organs, and skull fractures were noted. Data on soft tissue injuries or other types of injuries were not available for evaluation limiting the results of this analysis. Since injury accidents can typically also involve soft tissue injuries, the analysis presented is presumably more conservative.

There was another factor that also limited the number of accidents that could be reconstructed. Not all CHP reports had enough data on accident parameters that the

accident could be fully reconstructed. For example, all accidents involving roll overs had to be excluded due to lack of detailed data for proper accident reconstruction. Since such accidents typically involved injuries, the results presented are even more conservative.

A total of only 56 out of the 696 accidents analyzed had enough data on injuries, fatalities, and important accident parameters that could be reconstructed for evaluation of injury outcome due to incremental speed reduction as expected from COZEEP/MAZEEP operations. Since the test data as discussed earlier showed average incremental speed reduction of approximately 3 MPH to maximum speed reductions of approximately 5 to 7 MPH (using round numbers) in COZEEP/MAZEEP operations, these 56 reconstructed accidents were simulated for the speed reductions of 3, 5, and 7 MPH. These accidents consisted of 14 accidents involving fatalities and 42 non-fatal injury accidents. They included both intrusions as well as non-intrusion accidents. The results in terms of number of fatal, serious injury, and moderate injury accidents prevented, had a severity reduction, or had no change are summarized in Table 6.

3 mph Reduction			
Injury Severity	Moderate	Serious	Fatal
Prevented	7%	8%	7%
Severity Reduction	27%	27%	7%
No Change	67%	65%	87%
5 mph Reduction			
Injury Severity	Moderate	Serious	Fatal
Prevented	33%	19%	27%
Severity Reduction	20%	35%	7%
No Change	47%	46%	67%
7 mph Reduction			
Injury Severity	Moderate	Serious	Fatal
Prevented	47%	31%	27%
Severity Reduction	27%	27%	7%
No Change	27%	42%	67%

Table 6: The Outcome of 56 Injury Accident Simulations with 3 mph, 5 mph, and 7 mph Initial Speed Reduction Represented by Injury Severity Levels.

The data in this table clearly shows the safety benefit of the incremental speed reduction due to use of COZEEP/MAZEEP operations.

The following conclusions are derived from the data in Table 6:

- For a 3 MPH incremental reduction in speed, 7% of fatal accidents would be prevented and in 7% of non-fatal injury accidents there would be a reduction of injury severity.
- For a 5 MPH as well as a 7 MPH incremental reduction in speed, 27% of fatal accidents would be prevented and in 7% of non-fatal injury accidents there would be a reduction of injury severity.

If we assume that this data applies to all work zone accidents summarized in Table 5, then the standard cost values indicated in Table 1 can be used to evaluate the incremental cost benefits associated with each of these speed reductions as a result of COZEEP/MAZEEP operations.

The following conclusions can be reached:

- Considering only the outcome of fatal accidents (in order to simplify the analysis) as a result of incremental speed reductions, then the cost benefit of COZEEP/MAZEEP are as follows:
    - For an incremental speed reduction of only 3 MPH, there will be a reduction in cost of fatalities of approximately $9.3 Million per year.
    - For an incremental speed reduction of 5 MPH and 7 MPH, the reduction in cost of fatalities will increase to approximately $22.9 Million per year.
    - If we consider the reduction of severity of other injuries then the benefits would even have higher values.

In order to evaluate the extent to which the number of accidents involving errant vehicles entering a work zone will be affected by COZEEP/MAZEEP operations, the 696 CHP accident reports were re-evaluated. A total of 347 of these involved intrusion into the work zone. Re-evaluating the CHP accident reports for these in more detailed indicated that only 90 of these accident reports had sufficient data on collision parameters that could be reconstructed using PC-Crash. It should be noted that injuries were not considered in this evaluation only accident causation was analyzed using simulation of these reconstructed accidents. The simulations were used to determine how many of such accidents could be prevented if there was incremental speed

reductions of 3, 5, and 7 MPH as expected from COZEEP/MAZEEP operations. The results are tabulated in Table 7. It should be pointed out that the 90 intrusion accidents reconstructed all had some level of property damage.

3 mph Reduction		
	Number of Simulations	Percent Outcome
Prevented	3	3%
Intrusion	16	18%
Intrusion with PDO	71	79%
5 mph Reduction		
	Number of Simulations	Percent Outcome
Prevented	10	11%
Intrusion	26	29%
Intrusion with PDO	54	60%
7 mph Reduction		
	Number of Simulations	Percent Outcome
Prevented	18	20%
Intrusion	23	26%
Intrusion with PDO	49	54%

Table 7: Percentage Reduction in the Number of Intrusion Accidents as a Result of Incremental Speed Reductions.

In the data in Table 7 the "Prevented" accidents refers to the accidents that would result in no intrusions as a result of the specified speed reductions. Those indicated as "Intrusion" refers to those accidents would still involve intrusion into the work zone but resulted in no property damage.

The following conclusions are derived from the data in Table ***7:***

- For a 3 MPH incremental reductions in speed, 3% of intrusions into highway work zones were prevented and 18% of the intrusion accidents although not prevented, did not resolve in any property damage.

- For a 5 MPH incremental reductions in speed, 11% of intrusions into highway work zones were prevented and 29% of the intrusion accidents, although not prevented, did not resolve in any property damage.

- For a 7 MPH incremental reductions in speed, 20% of intrusions into highway work zones were prevented and 26% of the intrusion accidents, although not prevented, did not resolve in any property damage.

- The overall data show a steady increase in prevention of accidents involving intrusions into the highway work zone with increased incremental reduction in the average traffic speeds.

Limitations

1. The results obtained are based on relatively limited data and are not based on statistical analysis. They should, therefore, be used cautiously.

2. The traffic and other conditions at the test sites varied depending on the actual construction and maintenance work being performed as well as the traffic conditions at the time of the test and were not completely uniform.

3. Data collection in the rural areas was much more limited due to lower number of tests that could be scheduled during this study as compared to those performed in the urban areas.

4. The cost benefit analysis results only provide sample type calculations and should be used carefully accounting for the assumptions made and the limited number of accidents reconstructed.