STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

TECHNICAL REPORT DOCUMENTATION PAGE

TR0003 (REV 10/98)

ADA Notice
For individuals with sensory disabilities, this document is available in alternate formats. For information call (916) 654-6410 or TDD (916) 654-3880 or write Records and Forms Management, 1120 N Street, MS-89, Sacramento, CA 95814.

1. REPORT NUMBER	2. GOVERNMENT ASSOCIATION NUMBER	3. RECIPIENT'S CATALOG NUMBER
CA 21-3236	N/A	N/A

4. TITLE AND SUBTITLE

Work Zone Safety Improvements Using Automated Injury Data Collection

5. REPORT DATE
01-07-2021

6. PERFORMING ORGANIZATION CODE
AHMCT Research Center, UC

7. AUTHOR
Patricia B. Fyhrie, PhD, Ankyd Ji, Travis Swanston, Amir A. Nasrollahzadeh, PhD & Bahram Ravani, PhD: Principal Investigator

8. PERFORMING ORGANIZATION REPORT NO.
UCD-ARR-20-09-30-02

9. PERFORMING ORGANIZATION NAME AND ADDRESS
AHMCT Research Center
UCD Dept. of Mechanical & Aerospace Engineering
Davis, California 95616-5294

10. WORK UNIT NUMBER
N/A

11. CONTRACT OR GRANT NUMBER
65A0560 and 65A0749; Task ID 3236

13. TYPE OF REPORT AND PERIOD COVERED
Final Report
Period: 10/1/2018 – 9/30/2020

12. SPONSORING AGENCY AND ADDRESS
California Department of Transportation
P.O. Box 942873, MS #83
Sacramento, CA 94273-0001

14. SPONSORING AGENCY CODE
Caltrans

15. SUPPLEMENTARY NOTES
N/A

16. ABSTRACT

This research study collected data from approximately 39,000 traffic collision reports including diagrams and narratives for years 2011 through 2017. These reports had to be tracked down, scanned, creating image files made of the diagrams and organizing the data into a searchable database. Furthermore, the narrative portions of each report needed to be converted to digital text and used to populate the data base. A web-based tool was also developed to illustrate how a user can use the collected data to query information and develop understanding of collision trends and attributes. A number of collision attributes are identified and combined with injury and collision cost models that can be used to assess societal cost of such collisions. The result is a data set and an analysis tool that can be used to assess attributes related to work zone collisions and can serve as a decision support tool for mitigation and improvement of highway safety.

17. KEY WORDS	18. DISTRIBUTION STATEMENT	
Work Zone Collisions, Collision Costs	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.	
19. SECURITY CLASSIFICATION *(of this report)*	20. NUMBER OF PAGES	21. COST OF REPORT CHARGED
Unclassified	72	N/A

DISCLAIMER

The research reported herein was performed by the Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center, within the Department of Mechanical and Aerospace Engineering at the University of California – Davis, for the Division of Research, Innovation and System Information (DRISI) at the California Department of Transportation. AHMCT and DRISI work collaboratively to complete valuable research for the California Department of Transportation.

This document is disseminated in the interest of information exchange. The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. This publication does not constitute a standard, specification or regulation. This report does not constitute an endorsement by the Department of any product described herein.

The contents of this report do not necessarily reflect the official views or policies of the University of California. This report does not constitute an endorsement by the University of California of any product described herein.

For individuals with sensory disabilities, this document is available in alternate formats. For information, call (916) 654-8899, TTY 711, or write to California Department of Transportation, Division of Research, Innovation and System Information, MS-83, P.O. Box 942873, Sacramento, CA 94273-0001.

Advanced Highway Maintenance and Construction Technology Research Center

Department of Mechanical and Aerospace Engineering
University of California at Davis.

Work Zone Safety Improvements Using Automated Injury Data Collection

Authors: Patricia B. Fyhrie, PhD, Ankyd Ji, Travis Swanston, Amir A. Nasrollahzadeh, PhD & Bahram Ravani, PhD: Principal Investigator

Report Number: CA 21-3236
AHMCT Research Report: UCD-ARR-20-09-30-02
Final Report of Contract: 65A0560 and 65A0749, Task ID 3236
January 7, 2021

California Department of Transportation

Division of Research, Innovation and System Information

Executive Summary

Improving safety along California highway work zone sites is a notable component of California's Strategic Highway Safety Program (SHSP). Each work zone site is relatively unique with respect to configuration, number of open/closed lanes, presence of cones or barriers, etc. In order to improve safety and reduce the risk/severity of collisions, a thorough description of the cause(s) and locations of the collisions relative to the work zone are critical.

Problem, Need, and Purpose of Research

Traffic collision reporting databases available today such as SWITRS (Statewide Integrated Traffic Records System) and TASAS (Traffic Accident Surveillance and Analysis System) contain "check-box form" data. These data bases do not provide the information that can be used to justify particular mitigation measures, because they report outcomes and locations, but not information such as driver behavior, intrusion, work zone configuration and comments by drivers, witnesses, and officers. To obtain this level of information, data from the entire collision report is needed including the diagrams and narratives provided in the write-up.

The purpose of this research was to collect data from traffic collision reports including diagrams and narratives for years 2011 through 2017. Data was collected from approximately 39,000 traffic collision reports. These reports had to be tracked down, scanned, creating image files made of the diagrams and organizing the data into a database. Furthermore, the narrative portions of each report needed to be converted to digital text and used to populate the data base. A web-based tool was also developed to illustrate how a user may query the collected data and use the information for safety and other decision-making purposes.

Major Results and Recommendations

This research resulted in collection of data for work zone accidents from all 12 Caltrans districts for the years 2011-2017. Data from over 39,000 accidents that occurred in California work zones during this period were collected, codified, and stored in a searchable database for future analysis.

Since most road work activities need to address the unique features and risks of individual work sites, detailed information about collisions that have occurred at similar sites is required. This database provides the required information that otherwise would have been nearly impossible or difficult to obtain by conventional methods.

A generalized analysis of the data collected and codified in this research study indicates:

- The rates of injury causing collisions between those at a work zone and all collisions are approximately the same for years 2016 and 2017. The rate of injury causing collisions for years 2011 through 2015 are higher for work zone collisions than all collisions. Comparing the results for these two periods indicate that there was an overall safety improvement in 2016 and 2017.
- There are about 50% more rear-end plus sideswipe collisions in work zones than with all highway collisions of the same outcome grouping.
- The predominant primary collision factor for rear end collisions is "Traveling too fast".
- The cost of work zone collisions averages at $820 million per year over the 2011-2017 period. The average cost per collision based on injury severity has decreased from $167,214 (2011) to $136,650 (2017) which is a decrease of 18% for this seven-year period.

Recommendations & Future Work

This research study has put together a searchable data set integrated with analysis tools for assessing collision and injury costs providing a resource for any professional looking into work zone collisions. To allow these professionals to utilize the various types of information contained in the database the following future work is recommended:

- The prototype web support tool was developed solely to provide access to the database contents. Since different groups within Caltrans need specialized data, a production level web support tool should be developed so this resource can effectively support different groups and applications.
- The database should be continually updated on a yearly basis to include collision data for every year beyond 2017.
- The keyword search function should be expanded from matching exact words or combination of words. A language-based search engine is recommended to be integrated into the web tool so that broader spectrum searches could be accomplished. In this way the word or phrase could be expanded into actual language employed by police generating the report.
- Other applications based on specific interest areas such as motorcycle safety can also be considered using the research presented here. A new database could be developed and populated with existing digital CHP collision reports contained in database developed in this research study.

- Consideration should be given to enhancing the TASAS database such that each TASAS entry related to work zone injuries will have a corresponding TCR that can be retrieved which will be used to extract additional data for analysis.

Table of Contents

Executive Summary ii
Problem, Need, and Purpose of Research ii
Major Results and Recommendations ii
Recommendations & Future Work iii
Table of Contents v
List of Figures vii
List of Tables ix
List of Acronyms and Abbreviations x
Acknowledgments xii
Chapter 1: Introduction 13
Problem 13
Objectives 14
Scope 14
Background 14
Previous Work and the Relevant Literature 15
Research Methodology 15
Overview of Research Results and Benefits 16
Chapter 2: Data Collection 17
Methodology 17
Chapter 3: Data Integrity Analysis 23
Collision Details 23
Scanned Traffic Collision Reports 23
Electronic Traffic Collision Reports 24
Injury Details 25
Injury Cost Data Coding 25
Chapter 4: Work Zone Safety Analysis 27
Work zone Collisions vs. All California Collisions 27
Collision Severity and Cost 28
Collision Attributes 31
Type of Collision 31
Primary Collision Factors 37
Vehicle Type 40
Driver Age 42
Tow-Away 43

Lighting Conditions 43
Time and Day 44
Chapter 5: Work Zone Traffic Collision Report and Injury Database Support Web Application (WZTCRINJDB) 47
Accessing the WZTCRINJDB Support Tool 47
Using the Search Functionality WZTCRINJDB Support Tool 49
Chapter 6: Conclusions and Recommendations for Future Research 56
General Conclusions from the Data Analysis 57
Limitations of the Data Set 57
The Significance of the Web Tool 58
Future Research 58
References 60
Appendix A: WZSafety Website User Guide 61
Overview 61
Accessing the WZSafety Website 61
System Requirements 61
Website URL 61
Welcome Page: 62
Using the Search Functionality 63
Results Page 65
Displaying Report Details 67

List of Figures

Figure 2.1- Typical TCR First Page with Location Data and Personal Information. 18
Figure 2.2- Typical TCR Second Page Containing Roadway Condition, Collision Information, and other information. 19
Figure 2.3- Typical TCR Third Page Containing Injuries, Witnesses, and Passengers Information. 20
Figure 4.1- Graph illustrating the relationship between percentages of work zone collisions versus all CAHW collisions. Also shown are the percentages of work zone injury and fatal collisions. 28
Figure 4.2- Average cost in dollars for any person injured or killed in a work zone collision. Values are for years 2011-2017. 31
Figure 4.3- Distribution of Collision type on numbers of work zone collisions. Crash severity types are also indicated in the bottom portion of this figure showing the influence of collision severity on types of collision. 32
Figure 4.4- Bar chart illustrating the differences between work zone collisions and all CAHW collisions. The horizontal axis designates the type of collision as the outcome. 33
Figure 4.5- Pie chart illustrating how Types of Collision are distributed amongst fatal collisions that are associated with work zones. 34
Figure 4.6- Pie chart illustrating how Types of Collision are distributed amongst fatal collisions for all CAHW collisions. 34
Figure 4.7- Pie chart showing how collision types are distributed among Property Damage Only outcomes from work zone collisions. 35
Figure 4.8- Pie chart showing how collision types are distributed among Property Damage Only outcomes from all CAHW collisions. 35
Figure 4.9- Bubble chart for all CAHW collisions. 36
Figure 4.10-Bubble chart for work zone collision. 36
Figure 4.11- Distribution of Primary Collision Factor frequencies involving work zone collisions. 37
Figure 4.12- Number of work zone collisions associated with each Primary Collision Factor. Each individual grouping represents the distribution for each crash severity level. 38
Figure 4.13- Frequency distribution of work zone frequency collisions between Primary Collision Factors and Types of Collision. 39
Figure 4.14- Average work zone injury cost associated with sideswipe, rear end and Hit Object collisions. 39
Figure 4.15- Frequency of Vehicle type categories that are involved with work zone collisions in years 2011 through 2017. 42
Figure 4.16- Distribution of driver's ages from 16 to 90 in work zone collisions broken down in 5-year increments. 42

Figure 4.17- Percentage of collisions where at least one vehicle is towed away (YES), and those where all vehicles are not towed away (NO). 43
Figure 4.18- Distribution of work zone collisions with respect to lighting conditions. Also shown is the effect of lighting conditions on crash severity. 44
Figure 4.19- Histogram of work zone collisions for each month of the year. The data shown is for years 2011 through 2017. 45
Figure 4.20- Histogram of work zone collisions for each day of the week. The data shown is for years 2011 through 2017. 45
Figure 4.21- Histogram of work zone collisions for each hour of the day for 2011 through 2017 46
Figure 5.1- A screenshot of the first page when the user types in wzsafety.ahmct.ucdavis.edu. 48
Figure 5.2- A screenshot of the main "Search" page for the Work Zone Traffic Collision Report and Injury Database Support Web Application (WZTCRINJDB) 48
Figure 5.3- A screenshot of the main search page expanded to reveal all the possible parameters to search work zone traffic collision reports. 51
Figure 5.4- A sample screenshot of the results of a database query. A listing of the collision reports is provided as well as a map of the collision's resepc5tive locations 52
Figure 5.5- Screenshot of a collision report result from the "Search" page. This page is displayed after a "SHOW" button is selected 53
Figure 5.6- Screenshot of the first page from a collision report result after the "View Narrative" text is selected when viewing the "SHOW" page. 53
Figure 5.7- Sample collision diagrams from a collision report. These are shown after the "Images" text is selected. 54

List of Tables

Table 2.1- Number of Work zone Related Reports found in SWITRS 21
Table 2.2- Frequency of Work zone Related traffic collisions for 2011 to 2017. 22
Table 4.1- Table showing the number of people injured and killed for both Work zone collisions and all CAHW collisions for years 2011-2017. 27
Table 4.2- Distribution of collisions of all 5 crash severities ranging from 0 to 4. Data is shown for years 2011-2017. 29
Table 4.3- Table of total costs ($ million) for Work zone collisions based on severity of collision years 2011-2017. 29
Table 4.4- Table of people injured and killed in work zone collisions along with the effect on average number of people harmed per collision and Cost per person harmed. Note that number of people injured plus the number of people killed equals number of people harmed. 30
Table 4.5- Distribution of Collision Outcomes for both Work zone collisions and all CAHW collisions. Shown values are percentages of all collisions. 32
Table 4.6- Definition of Vehicle Type Categories based on CHPs available designations for the type of vehicle for all Parties involved in a work zone collision. 40

List of Acronyms and Abbreviations

Acronym	Definition
AAAM	Association for Advancement of Automotive Medicine
AIS	Abbreviated Injury Scale
AHMCT	Advanced Highway Maintenance and Construction Technology
CAHW	California Highway
Caltrans	California Department of Transportation
CHP	California Highway Patrol
COTS	Commercial Off–The-Shelf
DOT	Department of Transportation
DRISI	Division of Research, Innovation and System Information
DRS	Document Retrieval System
eTCR	electronic Traffic Collision Report
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
ID	Identification
iTCR	image Traffic Collision Report
NHTSA	National Highway Traffic Safety Administration
OCR	Optical Character Recognition
OSHA	Occupational Safety and Health Administration
PDF	Portable Document Format
SR	State Route

Acronym	Definition
SHSP	Strategic Highway Safety Program
SWITRS	Statewide Integrated Traffic Records Systems
↑↓	Higher and Lower, respectfully
TASAS	Traffic Accident Surveillance and Analysis System
TCR	Traffic Collision Report

Acknowledgments

The authors thank the California Department of Transportation (Caltrans) for their support, in particular the panel members: Theresa Drum with the Division of Maintenance, Blair Anderson and Marvin Guinez with the Division of Construction, Jack Broadbent with the Division of Design and the task manager Hamid Ikram and Juan Araya with the Division of Research, Innovation and System Information. The authors acknowledge the dedicated efforts of the AHMCT team who have made this work possible.

Chapter 1: Introduction

Work zone accidents and injuries are a major safety concern and data is needed to understand the nature and causes of these so that mitigation measures can be developed. Estimates suggest that work zone accidents and injuries cost over $800 million per year but there is no real data to back this up scientifically. There are costs associated with property damage, lost earnings, lost household production, travel delay, vocational rehabilitation, workplace costs, administrative costs, legal costs, pain and suffering, and lost quality of life. According to the Federal Highway Administration (FHWA) one work zone-related injury occurs every 14 minutes and one work-zone related fatality occurs every 15 hours resulting in 96 injuries and 1.6 fatalities a day [G]. It is therefore important to evaluate actual accident data to understand the frequency and the nature of work zone accidents and develop cost models that would provide a basis for consideration and justification of different mitigation methods. This research study was conducted to collect detailed data on work zone accidents that occurred on California Highways for a period of seven years from 2011 through 2017. The objective was to have a comprehensive data set that would allow planners and decision makers to consider for addressing different issues and to make their decisions and assessments data driven rather than based on partial and incomplete information.

Problem

Improving safety along California highway's work zone sites is a notable component of California's Strategic Highway Safety Program (SHSP) [A]. Since each work zone site is relatively unique with respect to configuration, number of open/closed lanes, presence of cones or barriers, etc. In order to improve safety and reduce the risk/severity of collisions, a thorough description of the cause(s) and location of the collision relative to the work zone are critical in developing countermeasures and improving safety of highway workers and the traveling public.

Although there exist useful databases and data sources such as the Statewide Integrated Traffic Records Systems (SWITRS) based upon California Highway Patrol (CHP)Traffic Collision Reports (TCRs), NHTSA's FARS database or OSHA (Occupational Safety and Health Administration) databases, and Caltrans TASAS (Traffic Accident Surveillance and Analysis System), none can provide the information that can be used to justify particular mitigation measures. This is because they report outcomes and locations, but not information such as driver behavior, work zone intrusion, work zone location, number of lanes, and comments by drivers, witnesses, and officers. TASAS provides basic outcome information such

as how many people were hurt or killed or what was the basic event that took place (e.g. auto accident, car hitting the barrier, etc.)? For mitigation purposes, however, much more information is needed. These include data on the nature and severity of injuries, methods to estimate medical costs associated with the injuries, more information about the collision in terms of "what hit what", localized information about the actual location in the work zone where the accident occurred (taper, activity zone or transition area), and finally more information about contributing factors related to the causation of the accidents. All such information is not included in TASAS and can play crucial role in developing and planning for mitigation measures and for performing safety assessments.

This research study was aimed at collecting detailed traffic collision data for the evaluation of their causes and outcomes. The research was also intended to develop an injury cost model so that some of the economic impacts of work zone accidents can be quantified. The research involved collecting data for a seven-year period for all accidents that occurred near or at a work zone identified by California Highway Patrol. This data was codified and was combined with injury cost models and used to populate a searchable database that can be used for analysis and other evaluation purposes.

Objectives

The objectives of this research was to provide an updated database of injury and collision data that can be used for safety and other assessments as well as providing a decision support tool for planning and developing potential countermeasures.

Scope

This proposed research task involved collecting, codifying and classifying all Traffic Collision Reports for accidents occurring near or at a work-zone from 12 Caltrans districts for a period from 2011 to 2017 which is the most recent date for which the data was available. The scope of this research also included extracting data from these reports and codifying them in terms of factors and outcomes and made part of a decision support system with integrated injury cost models designed to allow analysis of the data.

Background

Analysis of CHP TCRs is labor intensive and complicated. Until very recently, only paper copies of collision reports were available along with the fact these reports are distributed throughout all of California. What was performed in this research study was to collect TCRs for work zone related accidents from all 12 Caltrans districts, analyze the data and codify it into a searchable data base for a span of seven years. This allowed a better understanding of nature, cause, and cost of injuries in work zone accidents as well as an understanding of the effect of different

highway corridors on accident and injury frequencies. It also allowed adding other important information to the data set that can potentially facilitate work zone planning. The results also provide a statistically valid set of data for analysis related to work zone injuries and accidents. This work enhanced an earlier database developed by AHMCT research center that collected and codified data for an earlier period from 2006 to 2010.

Previous Work and the Relevant Literature

As part of the "Scientific Evaluation of the ArmorGuard Mobile Barrier System" project, AHMCT researchers collected partial data on work zone accidents from three Caltrans districts [B] which involved evaluating the full text of CHP 555 TCRs for a two-year period – a total of 2370 Traffic Collision reports. These collision reports were matched with 18,100 Caltrans TASAS records which allowed for analyzing work zone collision severity. This data was used to categorize work zone collisions with respect to their severity according to Abbreviated Injury Scale (AIS) developed by the Association for Advancement of Automotive Medicine (AAAM). As a result, the cost of all injuries for roadside maintenance workers in California for a period of 10 years was estimated to be $4.2 million on an annual basis.

Seeing the potential of this work, through a Caltrans sponsored research project we integrated Optical Character Recognition (OCR) techniques (which converted text from the reports narratives to a legible format), and developed an automatic information redaction technique (to protect personal information) and enhanced this database to allow for broader applications and uses [C]. This research resulted in collection of 22,355 work zone TASAS reports for 2006 to 2010. Also, 17,651 TCRs were successfully tracked down, scanned, and were made available through the AHMCT Injury Database for the same period.

The current research starts with the database and its associated web tool and adds seven years of data as well as modifies the user interface to make it a more robust and user-friendly system.

Research Methodology

This research study used a methodology combining data collection, data integrity management, and analysis. It consisted of eight tasks as follows:

1. Form the Project Panel
2. Develop an Updated Data Collection Protocol
3. Identify Liaison persons at Caltrans Districts
4. Data Collection
5. Data Integrity Analysis
6. Data Coding

7. Work zone Safety Improvement Analysis Based on the Data Collected
8. Documentation and Presentation of Research Results to Caltrans

Overview of Research Results and Benefits

An important benefit of this research is providing codified data in a searchable database allowing for a data driven decision-making process. The database will provide information that can be used for planning purposes. For example, it can be used to identify relevant work site attributes, identify what positive protection devices or other mechanism might be used to mitigate both risk and injury in intrusion accidents, and determine the frequency and conditions of "close call" collisions.

This research resulted in collection of data for work zone accidents from all 12 Caltrans districts for the years 2011-2017. Data from over 39,000 accidents that occurred in California work zones during this period were collected, codified, and stored in a database for analysis.

The benefits of this research include the data and analysis results that would allow responses to at least the following questions:

- What is the nature and severity of work zone accidents?
- What factors, outcomes and attributes are important in terms of injuries and fatalities?
- What are the factors that affect causation of work zone accidents?
- What are estimates of injury costs and what factors influence injury severity?

Such data with proper analysis and simulation can provide the basis for evaluating different mitigation strategies and will result in improvement of highway safety for both highway workers and the traveling public.

Chapter 2:
Data Collection

Methodology

In order to analyze injury data from motor vehicle accidents in work zone areas, the data must first be collected from various sources and combined into a database. CHP collects traffic collision data for all incidents that are reported into a database called the SWITRS. This collision information is captured in a TCR which is filled out by the investigating officer. More recently, TCRs have been digitalized and can be filled out electronically and are called electronic TCRs (eTCRs). Caltrans has their own database called TASAS which is essentially a subset of SWITRS containing only TCRs on Caltrans highways.

TASAS data from 2011-2017 was extracted and used in this research. It provided rudimentary data regarding work zone injuries on highways covered by Caltrans and included information such as number of injured or fatalities and the type of auto accident (hit object, auto accident, etc.). Additional data such as injury details, intrusion area, traveling speed, diagrams, narratives, and other contributing factors regarding work zone collisions were extracted from individual TCRs synchronized and matched to TASAS data set. Obtaining this additional data, required gathering of the original TCRs. A sample TCR is shown in Figure 2.1, Figure 2.2, and Figure 2.3.

STATE OF CALIFORNIA
DEPARTMENT OF CALIFORNIA HIGHWAY PATROL

TRAFFIC COLLISION REPORT

CHP 555 PAGE 1 (REV. 04-11) OPI 060 PAGE OF

SPECIAL CONDITIONS	NUMBER INJURED / NUMBER KILLED	HIT & RUN FELONY / HIT & RUN MISDEMEANOR	CITY / COUNTY	JUDICIAL DISTRICT / REPORTING DISTRICT / BEAT	LOCAL REPORT NUMBER / DAY OF WEEK / TOW AWAY YES NO
COLLISION OCCURRED ON:	MO DAY YEAR	TIME (2400)	NCIC #	OFFICER I.D.	
MILEPOST INFORMATION:	GPS COORDINATES LATITUDE LONGITUDE		PHOTOGRAPHS BY: NONE		
AT INTERSECTION WITH: / OR:	STATE HWY REL YES NO				

PARTY	DRIVER'S LICENSE NUMBER	STATE	CLASS	AIR BAG	SAFETY EQUIP.	VEH. YEAR	MAKE / MODEL / COLOR	LICENSE NUMBER	STATE
DRIVER	NAME (FIRST, MIDDLE, LAST)								
PEDES-TRIAN	STREET ADDRESS					OWNER'S NAME	SAME AS DRIVER		
PARKED VEHICLE	CITY / STATE / ZIP					OWNER'S ADDRESS	SAME AS DRIVER		
BICY-CLIST	SEX / HAIR / EYES / HEIGHT / WEIGHT / BIRTHDATE MO DAY YEAR / RACE					DISPOSITION OF VEHICLE ON ORDERS OF:	OFFICER DRIVER OTHER		
OTHER	HOME PHONE / BUSINESS PHONE					PRIOR MECH. DEFECTS	NONE APP. REFER TO NARRATIVE		
	INSURANCE CARRIER / POLICY NUMBER					VEHICLE IDENTIFICATION NUMBER:			
	DIR OF TRAVEL / ON STREET OR HIGHWAY / SPEED LIMIT					VEHICLE TYPE	DESCRIBE VEHICLE DAMAGE: UNK NONE MINOR MOD MAJOR ROLL-OVER / SHADE IN DAMAGED AREA		
						CA DOT			
						CAL-T TCP/PSC MC/MX			

PARTY	DRIVER'S LICENSE NUMBER	STATE	CLASS	AIR BAG	SAFETY EQUIP.	VEH. YEAR	MAKE / MODEL / COLOR	LICENSE NUMBER	STATE
DRIVER	NAME (FIRST, MIDDLE, LAST)								
PEDES-TRIAN	STREET ADDRESS					OWNER'S NAME	SAME AS DRIVER		
PARKED VEHICLE	CITY / STATE / ZIP					OWNER'S ADDRESS	SAME AS DRIVER		
BICY-CLIST	SEX / HAIR / EYES / HEIGHT / WEIGHT / BIRTHDATE MO DAY YEAR / RACE					DISPOSITION OF VEHICLE ON ORDERS OF:	OFFICER DRIVER OTHER		
OTHER	HOME PHONE / BUSINESS PHONE					PRIOR MECHANICAL DEFECTS	NONE APP. REFER TO NARRATIVE		
	INSURANCE CARRIER / POLICY NUMBER					VEHICLE IDENTIFICATION NUMBER:			
	DIR OF TRAVEL / ON STREET OR HIGHWAY / SPEED LIMIT					VEHICLE TYPE	DESCRIBE VEHICLE DAMAGE: UNK NONE MINOR MOD MAJOR ROLL-OVER / SHADE IN DAMAGED AREA		
						CA DOT			
						CAL-T TCP/PSC MC/MX			

PARTY	DRIVER'S LICENSE NUMBER	STATE	CLASS	AIR BAG	SAFETY EQUIP.	VEH. YEAR	MAKE / MODEL / COLOR	LICENSE NUMBER	STATE
DRIVER	NAME (FIRST, MIDDLE, LAST)								
PEDES-TRIAN	STREET ADDRESS					OWNER'S NAME	SAME AS DRIVER		
PARKED VEHICLE	CITY / STATE / ZIP					OWNER'S ADDRESS	SAME AS DRIVER		
BICY-CLIST	SEX / HAIR / EYES / HEIGHT / WEIGHT / BIRTHDATE MO DAY YEAR / RACE					DISPOSITION OF VEHICLE ON ORDERS OF:	OFFICER DRIVER OTHER		
OTHER	HOME PHONE / BUSINESS PHONE					PRIOR MECHANICAL DEFECTS	NONE APP. REFER TO NARRATIVE		
	INSURANCE CARRIER / POLICY NUMBER					VEHICLE IDENTIFICATION NUMBER:			
	DIR OF TRAVEL / ON STREET OR HIGHWAY / SPEED LIMIT					VEHICLE TYPE	DESCRIBE VEHICLE DAMAGE: UNK NONE MINOR MOD MAJOR ROLL-OVER / SHADE IN DAMAGED AREA		
						CA DOT			
						CAL-T TCP/PSC MC/MX			

PREPARER'S NAME	DISPATCH NOTIFIED	REVIEWER'S NAME	DATE REVIEWED
	YES NO N/A		

AN INTERNATIONALLY ACCREDITED AGENCY

Figure 2.1- Typical TCR First Page with Location Data and Personal Information.

STATE OF CALIFORNIA
DEPARTMENT OF CALIFORNIA HIGHWAY PATROL

TRAFFIC COLLISION CODING

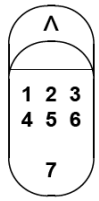
CHP 555 CARS PAGE2 (REV. 04-11) OPI 060

PAGE OF

DATE OF COLLISION (MO. DAY YEAR)	TIME(2400)	NCIC #	OFFICER I.D.	NUMBER

PROPERTY DAMAGE	OWNER'S NAME	OWNER ADDRESS	NOTIFIED ☐ YES ☐ NO
	DESCRIPTION OF DAMAGE		

SEATING POSITION



1 - DRIVER
2 TO 6 - PASSENGERS
7 - STATION WAGON REAR
8 - REAR. OCC TRK. OR VAN
9 - POSITION UNKNOWN
0 - OTHER

SAFETY EQUIPMENT

OCCUPANTS
A - NONE IN VEHICLE
B - UNKNOWN
C - LAP BELT USED
D - LAP BELT NOT USED
E - SHOULDER HARNESS USED
F - SHOULDER HARNESS NOT USED
G - LAP/SHOULDER HARNESS USED
H - LAP/SHOULDER HARNESS NOT USED
J - PASSIVE RESTRAINT USED
K - PASSIVE RESTRAINT NOT USED
P - NOT REQUIRED

CHILD RESTRAINT
Q - IN VEHICLE USED
R - IN VEHICLE NOT USED
S - IN VEHICLE USE UNKNOWN
T - IN VEHICLE IMPROPER USE
U - NONE IN VEHICLE

M/C BICYCLE HELMET

DRIVER	PASSENGER
V - NO	X - NO
W - YES	Y - YES

AIR BAG
B - UNKNOWN
L - AIR BAG DEPLOYED
M - AIR BAG NOT DEPLOYED
N - OTHER
P - NOT REQUIRED

EJECTED FROM VEHICLE
0 - NOT EJECTED
1 - FULLY EJECTED
2 - PARTIALLY EJECTED
3 - UNKNOWN

INATTENTION CODES
A - CELL PHONE HANDHELD
B - CELL PHONE HANDSFREE
C - ELECTRONIC EQUIPMENT
D - RADIO / CD
E - SMOKING
F - EATING
G - CHILDREN
H - ANIMALS
I - PERSONAL HYGIENE
J - READING
K - OTHER

ITEMS MARKED BELOW FOLLOWED BY AN ASTERISK (*) SHOULD BE EXPLAINED IN THE NARRATIVE.

PRIMARY COLLISION FACTOR
LIST NUMBER (#) OF PARTY AT FAULT

- A — VC SECTION VIOLATED: CITED ☐ YES ☐ NO
- B — OTHER IMPROPER DRIVING*
- C — OTHER THAN DRIVER*
- D — UNKNOWN*

WEATHER (MARK 1 TO 2 ITEMS)
- A CLEAR
- B CLOUDY
- C RAINING
- D SNOWING
- E FOG / VISIBILITY FT.
- F OTHER:*
- G WIND

LIGHTING
- A DAYLIGHT
- B DUSK - DAWN
- C DARK - STREET LIGHTS
- D DARK - NO STREET LIGHTS
- E DARK - STREET LIGHTS NOT FUNCTIONING*

ROADWAY SURFACE
- A DRY
- B WET
- C SNOWY - ICY
- D SLIPPERY (MUDDY, OILY, ETC.)

ROADWAY CONDITION(S)
(MARK 1 TO 2 ITEMS)
- A HOLES, DEEP RUT*
- B LOOSE MATERIAL ON ROADWAY*
- C OBSTRUCTION ON ROADWAY*
- D CONSTRUCTION - REPAIR ZONE
- E REDUCED ROADWAY WIDTH
- F FLOODED*
- G OTHER*:
- H NO UNUSUAL CONDITIONS

TRAFFIC CONTROL DEVICES
- A CONTROLS FUNCTIONING
- B CONTROLS NOT FUNCTIONING*
- C CONTROLS OBSCURED
- D NO CONTROLS PRESENT / FACTOR*

TYPE OF COLLISION
- A HEAD - ON
- B SIDE SWIPE
- C REAR END
- D BROADSIDE
- E HIT OBJECT
- F OVERTURNED
- G VEHICLE / PEDESTRIAN
- H OTHER*:

MOTOR VEHICLE INVOLVED WITH
- A NON - COLLISION
- B PEDESTRIAN
- C OTHER MOTOR VEHICLE
- D MOTOR VEHICLE ON OTHER ROADWAY
- E PARKED MOTOR VEHICLE
- F TRAIN
- G BICYCLE
- H ANIMAL:
- I FIXED OBJECT:
- J OTHER OBJECT: **CEMENT WALL**

PEDESTRIAN'S ACTIONS
- A NO PEDESTRIANS INVOLVED
- B CROSSING IN CROSSWALK - AT INTERSECTION
- C CROSSING IN CROSSWALK - NOT AT INTERSECTION
- D CROSSING - NOT IN CROSSWALK
- E IN ROAD - INCLUDES SHOULDER
- F NOT IN ROAD
- G APPROACHING / LEAVING SCHOOL BUS

SPECIAL INFORMATION
- A
- B
- C
- D
- E
- F
- G
- H
- I
- J
- K
- L
- M
- N
- O

OTHER ASSOCIATED FACTORS
(MARK 1 TO 2 ITEMS)
- A — VC SECTION VIOLATED: CITED: ☐ YES ☐ NO
- B — VC SECTION VIOLATED: CITED: ☐ YES ☐ NO
- C — VC SECTION VIOLATED: CITED: ☐ YES ☐ NO
- D
- E VISION OBSCUREMENT:
- F INATTENTION*:
- G STOP & GO TRAFFIC
- H ENTERING / LEAVING RAMP
- I PREVIOUS COLLISION
- J UNFAMILIAR WITH ROAD
- K DEFECTIVE VEH. EQUIP.: CITED ☐ YES ☐ NO
- L UNINVOLVED VEHICLE
- M OTHER*:
- N NONE APPARENT
- O RUNAWAY VEHICLE

MOVEMENT PRECEDING COLLISION
- A STOPPED
- B PROCEEDING STRAIGHT
- C RAN OFF ROAD
- D MAKING RIGHT TURN
- E MAKING LEFT TURN
- F MAKING U TURN
- G BACKING
- H SLOWING / STOPPING
- I PASSING OTHER VEHICLE
- J CHANGING LANES
- K PARKING MANEUVER
- L ENTERING TRAFFIC
- M OTHER UNSAFE TURNING
- N XING INTO OPPOSING LANE
- O PARKED
- P MERGING
- Q TRAVELING WRONG WAY
- R OTHER*: **UNSAFE TURN**

SOBRIETY - DRUG PHYSICAL
(MARK 1 TO 2 ITEMS)
- A HAD NOT BEEN DRINKING
- B HBD - UNDER INFLUENCE
- C HBD - NOT UNDER INFLUENCE*
- D HBD - IMPAIRMENT UNKNOWN*
- E UNDER DRUG INFLUENCE*
- F IMPAIRMENT - PHYSICAL*
- G IMPAIRMENT NOT KNOWN
- H NOT APPLICABLE
- I SLEEPY / FATIGUED*

SKETCH

INDICATE NORTH

MISCELLANEOUS

AN INTERNATIONALLY ACCREDITED AGENCY

Figure 2.2- Typical TCR Second Page Containing Roadway Condition, Collision Information, and other information.

STATE OF CALIFORNIA
DEPARTMENT OF CALIFORNIA HIGHWAY PATROL

INJURED / WITNESSES / PASSENGERS**
CHP 555 CARS PAGE 3 (REV 04-11) OPI 065

PAGE OF

DATE OF COLLISION (MO. DAY YEAR)	TIME (2400)	NCIC #	OFFICER I.D.	NUMBER

WITNESS ONLY	PASSENGER ONLY	AGE	SEX	EXTENT OF INJURY ('X' ONE)				INJURED WAS ('X' ONE)					PARTY NUMBER	SEAT POS.	AIR BAG	SAFETY EQUIP.	EJECTED
				FATAL INJURY	SEVERE INJURY	OTHER VISIBLE INJURY	COMPLAINT OF PAIN	DRIVER	PASS.	PED.	BICYCLIST	OTHER					
☐ #	☐			☐	☐	☐	☐	☐	☐	☐	☐	☐					

NAME / D.O.B. / ADDRESS TELEPHONE

(INJURED ONLY) TRANSPORTED BY: TAKEN TO:

DESCRIBE INJURIES:

☐ VICTIM OF VIOLENT CRIME NOTIFIED

WITNESS ONLY	PASSENGER ONLY	AGE	SEX	FATAL INJURY	SEVERE INJURY	OTHER VISIBLE INJURY	COMPLAINT OF PAIN	DRIVER	PASS.	PED.	BICYCLIST	OTHER	PARTY NUMBER	SEAT POS.	AIR BAG	SAFETY EQUIP.	EJECTED
☐ #	☐			☐	☐	☐	☐	☐	☐	☐	☐	☐					

NAME / D.O.B. / ADDRESS TELEPHONE

(INJURED ONLY) TRANSPORTED BY: TAKEN TO:

DESCRIBE INJURIES:

☐ VICTIM OF VIOLENT CRIME NOTIFIED

WITNESS ONLY	PASSENGER ONLY	AGE	SEX	FATAL INJURY	SEVERE INJURY	OTHER VISIBLE INJURY	COMPLAINT OF PAIN	DRIVER	PASS.	PED.	BICYCLIST	OTHER	PARTY NUMBER	SEAT POS.	AIR BAG	SAFETY EQUIP.	EJECTED
☐ #	☐			☐	☐	☐	☐	☐	☐	☐	☐	☐					

NAME / D.O.B. / ADDRESS TELEPHONE

(INJURED ONLY) TRANSPORTED BY: TAKEN TO:

DESCRIBE INJURIES:

☐ VICTIM OF VIOLENT CRIME NOTIFIED

WITNESS ONLY	PASSENGER ONLY	AGE	SEX	FATAL INJURY	SEVERE INJURY	OTHER VISIBLE INJURY	COMPLAINT OF PAIN	DRIVER	PASS.	PED.	BICYCLIST	OTHER	PARTY NUMBER	SEAT POS.	AIR BAG	SAFETY EQUIP.	EJECTED
☐ #	☐			☐	☐	☐	☐	☐	☐	☐	☐	☐					

NAME / D.O.B. / ADDRESS TELEPHONE

(INJURED ONLY) TRANSPORTED BY: TAKEN TO:

DESCRIBE INJURIES:

☐ VICTIM OF VIOLENT CRIME NOTIFIED

WITNESS ONLY	PASSENGER ONLY	AGE	SEX	FATAL INJURY	SEVERE INJURY	OTHER VISIBLE INJURY	COMPLAINT OF PAIN	DRIVER	PASS.	PED.	BICYCLIST	OTHER	PARTY NUMBER	SEAT POS.	AIR BAG	SAFETY EQUIP.	EJECTED
☐ #	☐			☐	☐	☐	☐	☐	☐	☐	☐	☐					

NAME / D.O.B. / ADDRESS TELEPHONE

(INJURED ONLY) TRANSPORTED BY: TAKEN TO:

DESCRIBE INJURIES:

☐ VICTIM OF VIOLENT CRIME NOTIFIED

WITNESS ONLY	PASSENGER ONLY	AGE	SEX	FATAL INJURY	SEVERE INJURY	OTHER VISIBLE INJURY	COMPLAINT OF PAIN	DRIVER	PASS.	PED.	BICYCLIST	OTHER	PARTY NUMBER	SEAT POS.	AIR BAG	SAFETY EQUIP.	EJECTED
☐ #	☐			☐	☐	☐	☐	☐	☐	☐	☐	☐					

NAME / D.O.B. / ADDRESS TELEPHONE

(INJURED ONLY) TRANSPORTED BY: TAKEN TO:

DESCRIBE INJURIES:

☐ VICTIM OF VIOLENT CRIME NOTIFIED

PREPARER'S NAME	I.D. NUMBER	MO. DAY YEAR	REVIEWER'S NAME	MO. DAY YEAR

AN INTERNATIONALLY ACCREDITED AGENCY

Figure 2.3- Typical TCR Third Page Containing Injuries, Witnesses, and Passengers Information.

The first page of each TCR contains the date, time, location data, personal information of the involved parties, and much more as can be seen in Figure 2.1. Following this is a Traffic Collision Coding page (Figure 2.2) which contains various boxes and coding factors for the officer to mark regarding roadway conditions, traffic conditions, and other influential conditions. An Injured/Witness/Passengers page (Figure 2.3) comes after this which describes all the injuries of each passenger, lists any additional witnesses and passengers to the scene for future reference. Although these standard pages provide decent details of the scene, there is typically some additional data that can be extracted from the pages directly following which can include schematics of the roadway, additional statements from each involved party, and finally summary from the CHP officers. Although SWITRS and TASAS stores all the basic data, there is much more data that can be useful in analysis including work zone information and sketches. Further information regarding work zones can be extracted from the narratives and diagrams/schematics that may be included at the end of each TCR depending on what information the CHP officer deems necessary to include.

In order to complement the TASAS data set, TCRs were extracted from the online Document Retrieval System (DRS) and some were extracted in person. Data that was collected from TASAS and SWITRS can both be filtered for relevant work zone areas by a field called Roadway Condition "D – Construction – Repair Zone". The total amount of work zone related cases compared to all other reports are summarized in Table 2.1.

Table 2.1- Number of Work zone Related Reports found in SWITRS

Year	All Collisions	Work zone Related Collisions	% Work zone to All Collisions
2011	152074	4028	2.65%
2012	148522	4982	3.35%
2013	151049	5887	3.90%
2014	152288	6525	4.28%
2015	86991	7381	8.48%
2016	191931	5899	3.07%
2017	192128	4677	2.43%
2011-2016	1074983	39379	3.66%

It is clear from Just for 2011 to 2017, there are 39582 work zone related reports which is only about 3.7% of the overall reports available to gather from SWITRS. For the more recent years of 2015 to 2017, approximately 13,320 eTCRs are available as seen in Table 2.2.

Table 2.2- Frequency of Work zone Related traffic collisions for 2011 to 2017.

District	2011	2012	2013	2014	2015	2016	2017	Total
1	58	42	30	31	74	69	75	379
2	76	72	23	34	43	61	49	358
3	493	346	204	421	438	388	160	2450
4	556	443	819	1154	1327	497	624	5420
5	194	346	248	149	131	161	151	1380
6	297	442	671	411	473	260	267	2821
7	756	1063	1143	1162	916	950	1835	7825
8	577	834	1432	1879	2585	2178	674	10159
9	4	7	1	0	5	14	17	48
10	169	327	501	582	640	500	180	2899
11	275	257	208	130	217	302	233	1622
12	573	803	607	572	528	518	411	4012
Total	4028	4982	5887	6525	7377	5898	4676	39373

For the year 2011, hard copies of collision reports were scanned for all districts. Beginning from 2012 scanned pdf copies of a portion of collision reports were available. For these two years, the TCRs were manually collected from each district. A list of all necessary files was created which are uniquely identified by the date, time, county, highway, and post mile marker. Each district was contacted regarding access to TCRs. Every district was very cooperative in providing various amounts of support in gathering all the TCR reports which helped to reduce the workload. Visits were scheduled which spanned from one to three days with each district to extract the TCRs using a scanner. Proper procedure was used to have personal information redacted for each scanned TCR and the non-personal data was saved on an encrypted flash drive.

Chapter 3:
Data Integrity Analysis

Collection of the data as described in the previous chapter is predominantly focused on: 1) Determining where and how work zone collision reports are stored, and 2) Acquiring the raw data from each collision report. This chapter describes what was done to process the raw data to ensure data integrity and accuracy as it was imported into the searchable database. All processing was done at the AHMCT research center.

Collision Details

As indicated in the previous chapter, the TCRs came in 2 distinctive formats. The first is a scanned image *.pdf file also referred to as an "iTCR" (image Traffic Collision Report). The other report format is referred to as the "eTCR" since the reports originated in an electronic form. Collision reports in the past have been generated as hard copy documents by CHP up until the fall of 2015 when CHP officially adopted an electronic version. Since our research encompasses years 2011-2017, iTCRs were gathered from 2011 through most of 2015. The eTCRs were gathered from database tables obtained from Caltrans and are associated with the eTCRs in their possession.

Since the processing of the two different formats required different methodologies, both formats will be discussed regarding how Collision details were extracted from the work zone collision reports.

Scanned Traffic Collision Reports

Once the TCRs are obtained, the image data from the work zone collision report provides an internal incident ID which can be matched with collision attributes from TASAS. The next step was to convert the narrative portion of the report into searchable text by means of an Optical Character Recognition (OCR) software package that was developed by AHMCT in a previous project [B][C]. If full page diagrams were present in the report, they were converted into separate picture files and saved along with incident IDs. If an "Injured/Witness/Passengers" page was present, manual processing was performed to obtain injury information. This page is typically in a TCR as Page #3 only if there are 3 parties or fewer in a collision. Figure 2.3 shows the layout of this page.

The collision attributes for each iTCR was obtained by using the TASAS reference information provided. The TASAS related collision attributes used in the work zone injury database are as follows:

- Location, date and time
- Number of parties, number injured, number killed
- Type of collision, primary cause, party type
- Environment conditions and road surface type

Since Vehicle type, "Tow-away" status, and crash severity were not provided by TASAS, we relied on SWITRS data to provide these details. To find the appropriate SWITRS record that corresponds to the collision report, we had to find matches on District, County, Route, Post-mile marker value, Date and Time. The corresponding SWITRS collision ID was saved with the work zone collision record as well as the data itself.

Electronic Traffic Collision Reports

In a previous joint project between AHMCT and Caltrans, we were provided access to the meta data for TCRs that were electronically generated by CHP starting in the latter part of 2015 and continuing through 2017. As of date, these eTCRs are the predominant form that CHP stores, tracks and this information gets shared with Caltrans. [D].

In a similar way that the SWITRS database is constructed to contain collision, party, and victim data in separate tables, the current form of the eTCR has many tables which contain the data captured in a TCR. The narrative and diagrams, however, are not contained in this meta data. We had to obtain and retain the narratives and diagrams for the electronic reports.

The table names that we use to obtain collision data from eTCRs are listed below:

- OTM_CHP_COLLISION_DATA_TABLE.csv
- OTM_CHP_COLLISIONROADCONDITION_DATA_TABLE.csv
- OTM_CHP_COLLISIONWEATHER_DATA_TABLE.csv
- OTM_CHP_INJUREDWITPASS_DATA_TABLE.csv
- OTM_CHP_PARTY_DATA_TABLE.csv
- OTM_CHP_VEHICLE_DATA_TABLE.csv
- For future ref: K_STATEHWY_PARTY_DATA_TABLE.csv
- VEHICLETYPEID 1 PASSENGER_CAR_STATION_WAGON_JEEP

It should be pointed out here that obtaining all the data needed from eTCRs for traffic collision analysis, whether work zone related or not, is straight-forward, robust and accurate. This is far different than extracting data for iTCRs where some pieces

are from TASAS and some pieces are from SWITRS. The amount of time and resources needed to check the data integrity of eTCRs was significantly less since all the data was in place and did not need to be pre- processed as it was the case for iTCRs. This means that data collections for years beyond 2017 will be easy if the approach developed for eTCRs in this research is used.

Injury Details

For each person injured or killed, there is typically detailed information in a TCR such as what type of injury occurred, and which body region was injured. CHP also includes the severity level of each injured party for a more complete description of the injury. Severity ranking is as follows: 0=No injury, 1=Fatality, 2=Serious injury, 3=Other visible injury, and 4=Complaint of pain.

Typically, when analyzing traffic safety trends, objective values such as the number of people killed and injured, or the crash severity of the collision are used as indicators of safety. The most direct piece of injury data is those found on Page 3 of the TCR. The reporting officer can indicate if the injured party is transported to a medical facility or if they will seek medical attention later in time. The officer can also describe the injuries in a separate area of the report. For the iTCRs, these 2 pieces of injury data needed to be extracted manually. The eTCR reports however, stores this information which can be found in one of the associated database tables known as "OTM_CHP_INJUREDWITPASS_DATA_TABLE.csv".

After collecting all the available injury data, the injury information was analyzed for each report to find the physical description of the injury along with its body part. Typical descriptions are lacerations, complaint of pain, burns, and abrasions. The body parts named are (typically): head, shoulder, chest, stomach, hips, legs, feet, arms, and hands.

For the group of work zone TCRs that were from scanned hard copies, crash severities and injury descriptions were obtained by analyzing each report. For those reports where no image copy in the form of Portable Document Format (PDF) was available, we relied on SWITRS data to get the injury severity data for each victim.

Injury Cost Data Coding

The previous section described what data was collected that can be used to assess injury potential with work zone collisions. The following section discusses how the injury data is used to determine the societal cost as a result of these collision types.

The Federal Highway Administration (FHWA) has a cost model as a function of crash severity [FHWA-SA-17-071]. The attributed costs in terms of 2018 dollars is as follows:

If severity = 0 (PDO), cost = 11900

If severity = 1 (Fatality), cost = 11295400

If severity = 2, cost = 655000

If severity = 3, cost = 198500

If severity = 4, cost = 125600

Using this model provides an objective measure of costs for a particular collision grouping. Even though more than 1 person could be killed in a collision, the applied cost of only 1 value works for large data sets such as those we are applying here within California.

Chapter 4:
Work Zone Safety Analysis

The purpose of this chapter is to describe the identified characteristics of work zone collisions based on the data set for collisions near or at a work zone in California from 2011 to 2017.

Work zone Collisions vs. All California Collisions

To understand the nature and attributes of work zone collisions in California, we need to analyze the data to identify trends. From Chapter 2 (Table 2.1) the percentage of work zone collisions for all California highway (CAHW) collisions ranges from 2.41% in 2017 to 8.57% in 2015 during the period of study for this research. Comparing these percentages to those shown in Table 4.1, we can determine the distribution of injuries and fatalities occurring in work zone collisions and compare them to those that occur in all CAHW collisions. For example, in 2011 the percentage of work zone collisions to all CAHW collisions is 2.65%. For that year, the percentage of injuries between the two groups of collisions is 4.01% with the percentage of fatalities 3.86%. This suggests that, in 2011, there are more injuries and fatalities occurring in work zones than in CAHW collisions (2.65%). In Figure 4.1, it can be seen that there are higher percentages of injury and fatal collisions for years 2011-2013. Starting in 2014, we see the percentage of fatal collisions drop lower than the CAHW collision percentage with that trend continuing through to 2017. The percentage of injury collisions starts to decrease after 2015 and more closely matches the overall percentage in 2017. These trends shown in Figure 4.1 indicate that work zone safety in California highways has improved in between 2011 to 2017 to the point where the percentage of fatal and injury collisions start to resemble the percentage of total collisions.

Table 4.1- Table showing the number of people injured and killed for both Work zone collisions and all CAHW collisions for years 2011-2017.

Year	% of Work zone to All CA Collisions	#People Injured in Work zone Collisions	#People Injured in All CA Collisions	%People Injured in WZ vs. All Collisions	#People killed in Work zone Collisions	#People killed in All CA Collisions	%People killed in WZ vs. All Collisions
2011	2.65%	2075	51768	4.01%	42	1087	3.86%
2012	3.35%	2462	52121	4.72%	47	1090	4.31%
2013	3.90%	2743	54128	5.07%	51	1110	4.59%
2014	4.28%	3016	52611	5.73%	43	1163	3.70%
2015	8.48%	2000	30324	6.60%	57	1392	4.09%
2016	3.07%	2889	84914	3.40%	41	1478	2.77%

Year	% of Work zone to All CA Collisions	#People Injured in Work zone Collisions	#People Injured in All CA Collisions	%People Injured in WZ vs. All Collisions	#People killed in Work zone Collisions	#People killed in All CA Collisions	%People killed in WZ vs. All Collisions
2017	2.43%	2049	83799	2.45%	32	1425	2.25%

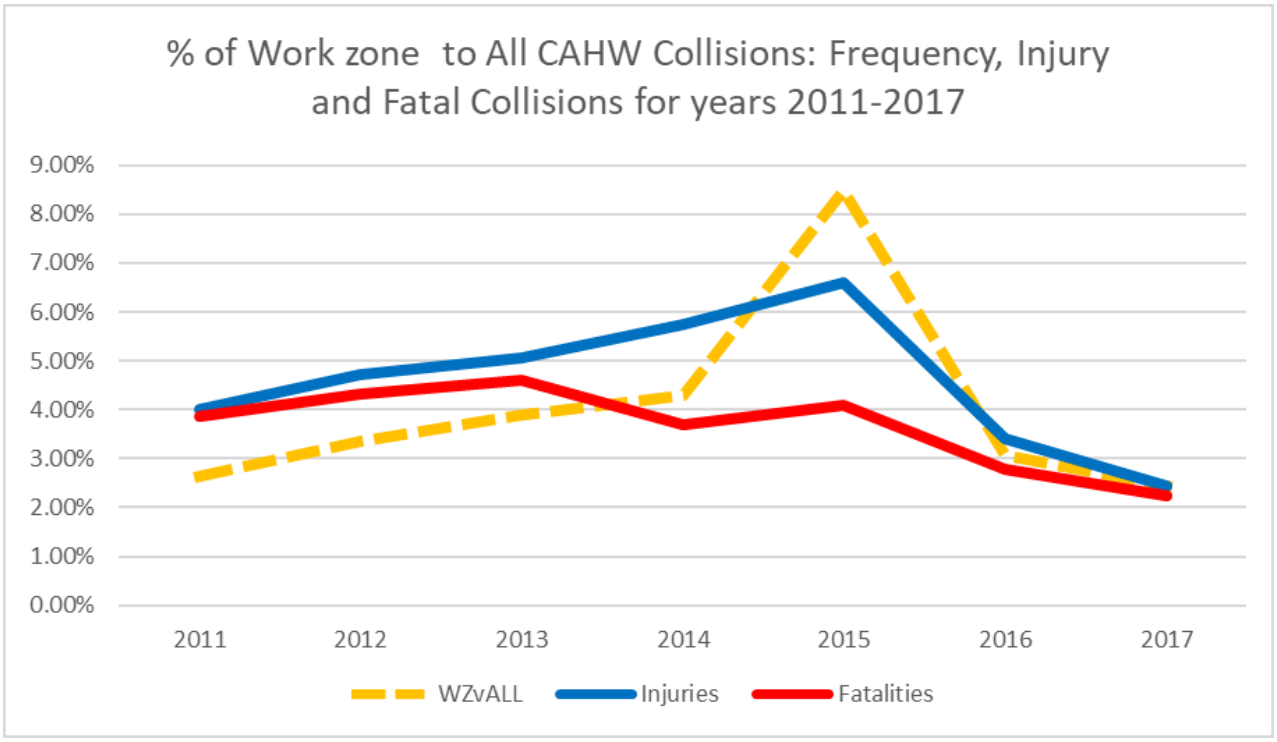


Figure 4.1- Graph illustrating the relationship between percentages of work zone collisions versus all CAHW collisions. Also shown are the percentages of work zone injury and fatal collisions.

Collision Severity and Cost

When analyzing work zone safety, understanding the trends in collision severity is especially important. Table 4.2 below shows the distribution count of collision severity for years 2011 through 2017. It can be seen from Table 4.2 that the number of fatal collisions average out to be approximately 41 per year. There does not appear to be a strong trend in frequency direction. It is interesting to note the lowest number of work zone collisions of any severity is at its lowest in 2011 and then steadily increases until 2015 and then decreases towards similar values in 2011. This could be interpreted that more construction work was ongoing during the high frequency years and/or the volume of vehicles on the highway has increased but there is a need for further investigation to determine the real cause of such a variation.

Table 4.2- Distribution of collisions of all 5 crash severities ranging from 0 to 4. Data is shown for years 2011-2017.

Year	#Fatal Collisions (Severity=1)	#Severe Collisions (Severity=2)	#Collisions with Visible Injuries (Severity=3)	#Collisions with Pain Complaints (Severity=4)	#Property Damage Only Collisions (Severity=0)	Total
2011	36	80	373	858	2680	4027
2012	44	101	448	1052	3337	4982
2013	47	93	454	1276	4016	5886
2014	42	98	527	1376	4463	6506
2015	53	125	630	1711	4862	7381
2016	35	108	454	1325	3977	5899
2017	31	111	342	866	3327	4677
Total	288	716	3228	8464	26662	39358
Total Number of Collisions (2011-2017): 39358						

We can apply the cost model described in Chapter 3 to the collision counts shown in Table 4.2. To assess the societal costs due for work zone collisions, Table 4.3 shows the results of cost calculations. Between years 2011 through 2017, society has paid a minimum of $820 million each year solely on work zone collisions. In 2015, the total cost of work zone collisions was over $1 billion and the total for all 7 years is over $5 billion.

Table 4.3- Table of total costs ($ million) for Work zone collisions based on severity of collision years 2011-2017.

Year	Total cost of Fatal Collisions	Total cost of Severe Collisions	Total cost of Collisions with Visible Injuries	Total cost of Collisions with Pain Complaint	Total cost of Property Damage Only Collisions	Total cost ($ million)
2011	406.6344	52.4	74.0405	107.7648	31.892	672.7317
2012	496.9976	66.185	88.928	132.1312	39.7103	823.9521
2013	530.8838	60.925	90.119	160.2656	47.7904	889.9838

Year	Total cost of Fatal Collisions	Total cost of Severe Collisions	Total cost of Collisions with Visible Injuries	Total cost of Collisions with Pain Complaint	Total cost of Property Damage Only Collisions	Total cost ($ million)
2014	474.4068	64.33	104.6095	172.8256	53.1097	869.2816
2015	598.6562	81.875	125.055	214.9016	57.8578	1078.346
2016	395.339	70.74	90.119	166.42	47.3263	769.9443
2017	350.1574	72.705	67.887	108.7696	39.5913	639.1103
Total	3253.075	469.16	640.758	1063.078	317.2778	5743.349
Total cost for Work zone collisions (2011-2017): $5.743 Billion						

To evaluate the impact of total cost for each year, we estimated the cost per collision and the cost per person killed or injured. The results of these calculations are shown in Table 4.4. These values were calculated to see if there were significant differences from year to year. Figure 4.2 is a graphical version of the cost per collision and cost per person harmed as those shown in Table 4.4. It can be seen that the cost per collision remains steadfast over years 2011-2017 but the cost per person harmed is significantly higher in 2015 than any other year.

Table 4.4- Table of people injured and killed in work zone collisions along with the effect on average number of people harmed per collision and Cost per person harmed. Note that number of people injured plus the number of people killed equals number of people harmed.

Year	Total # People Harmed	Total count WZ Collisions	Total Cost ($million)	$ Cost per Person Harmed)	$ Cost per Collision
2011	2117	4028	672.7317	$317776	$167014
2012	2509	4982	823.9521	$328399	$165386
2013	2794	5887	889.9838	$318534	$151178
2014	3059	6525	869.2816	$284172	$133223
2015	2057	7381	1078.346	$524232	$146098

Year	Total # People Harmed	Total count WZ Collisions	Total Cost ($million)	$ Cost per Person Harmed)	$ Cost per Collision
2016	2930	5899	769.9443	$262780	$130521
2017	2081	4677	639.1103	$307117	$136650

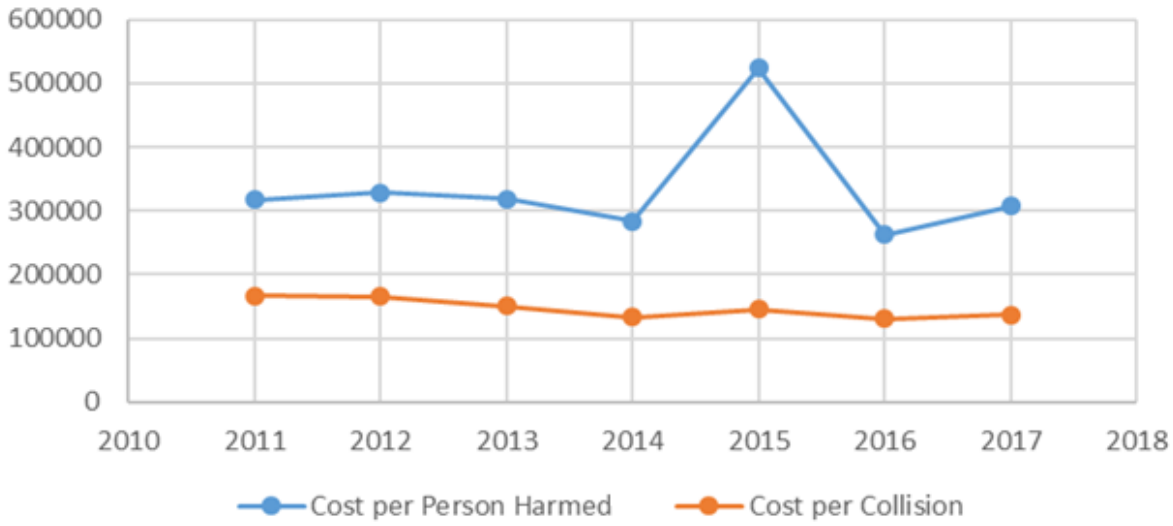


Figure 4.2- Average cost in dollars for any person injured or killed in a work zone collision. Values are for years 2011-2017.

Collision Attributes

There are many collision attributes that could affect safety performance. This section of the report discusses the trends amongst specific collision attributes such as collision type and primary collision factors.

Type of Collision

The "Type of Collision" indicates what type of crash occurred for example, Head-on or rollover collision. The graphs in Figure 4.3 show that "Hit Object", "Rear-end", and "Sideswipe" collisions are the most prominent. This is especially true for the PDO or minor injury collisions. For the more sever to fatal collisions, it can be seen in the lower portion of Figure 4.3 the influence of Broadside, Head-on and Vehicle-Pedestrian types of collision.

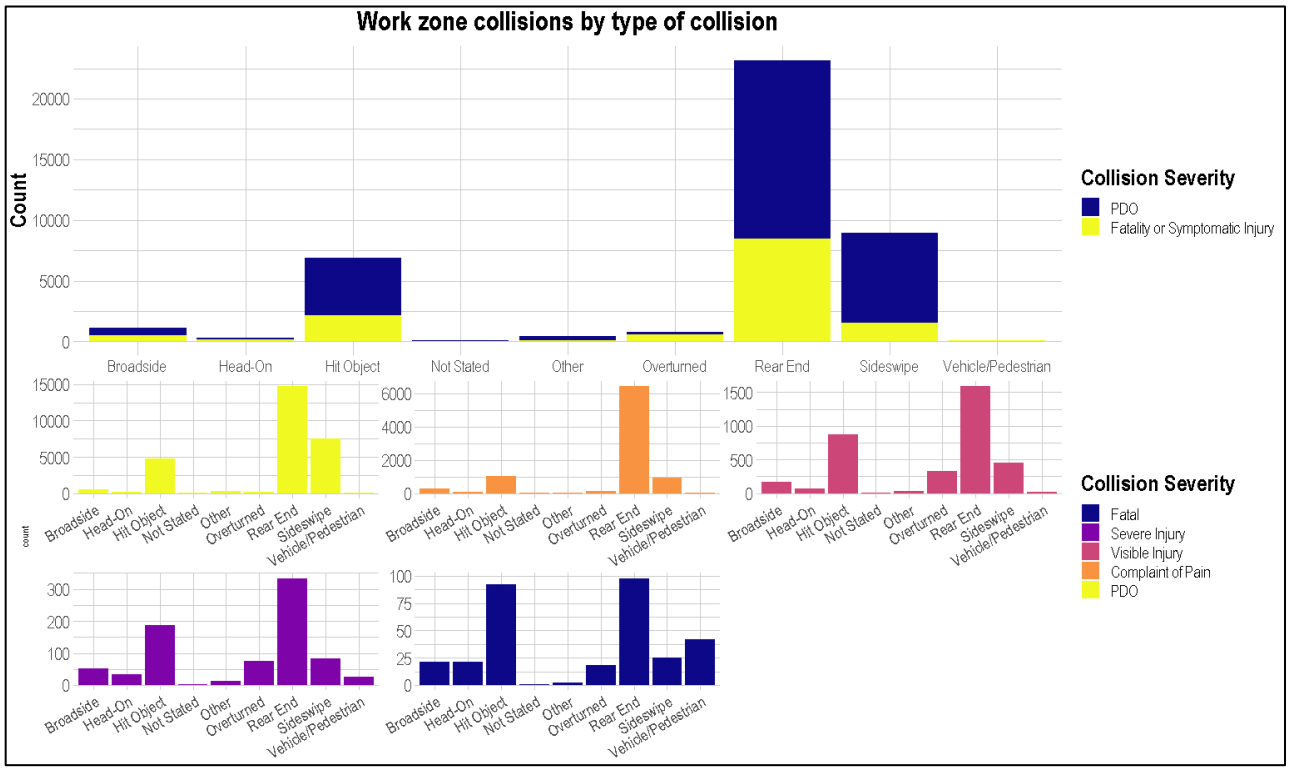


Figure 4.3- Distribution of Collision type on numbers of work zone collisions. Crash severity types are also indicated in the bottom portion of this figure showing the influence of collision severity on types of collision.

When comparing work zone collisions with all CAHW collisions, it can be seen in Table 4.5 that rear end collisions are more prevalent in work zone collisions (55.9%) as opposed to all CAHW collisions (18.5%). Broadside collisions, however, are much more prominent in all CAHW collisions (48.7%) than in work zone collisions (2.5%).

Table 4.5- Distribution of Collision Outcomes for both Work zone collisions and all CAHW collisions. Shown values are percentages of all collisions.

	WZ Collisions	CAHW WZ Collisions
Head-On	0.7%	0.7%
Sideswipe	21.0%	1.3%
Rear End	55.9%	18.5%
Broadside	2.5%	48.7%
Hit Object	16.4%	19.4%
Overturned	2.0%	3.6%
Vehicle/Pedestrian	0.3%	6.0%
Other	1.2%	1.8%

Figure 4.4 shows pictorially the results found in Table 4.5. From this figure we can also see that "Hit Object" and "Overturn" types of collisions are somewhat similar between work zone collisions and all CAHW collisions.

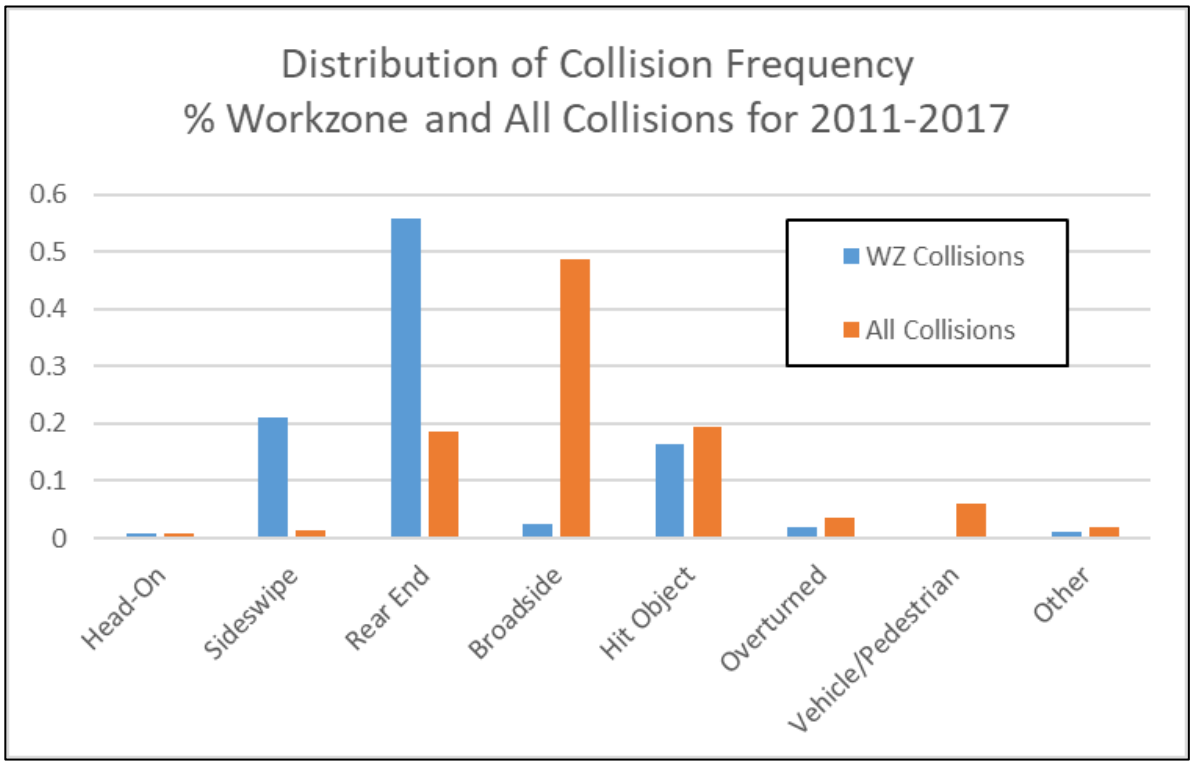


Figure 4.4- Bar chart illustrating the differences between work zone collisions and all CAHW collisions. The horizontal axis designates the type of collision as the outcome.

Figure 4.5 through Figure 4.8 show the distribution of collision types for both fatalities and Property Damage Only collisions. In Figure 4.5, work zone collisions show that "Hit Object" and Rear-end collisions have the greatest percentage of fatal collisions. It can be seen that the Vehicle-Pedestrian fatality prevalence is at 13% of all fatal work zone collisions. For all CAHW fatal collisions, Figure 4.6 shows a more widely dispersed distribution of collision types as associated with fatal collisions.

Figure 4.7 shows for PDO work zone collisions that rear-end and sideswipe collision account for nearly 80% of PDO work zone collision types. For PDO collisions from all CAHW collisions, broadside types of crashes account for the majority of a single type although both sideswipe and Hit Object also play a strong role in a similar way as work zone collisions.

In a similar way as the pie charts in Figure 4.5-Figure 4.8, Figure 4.9 and Figure 4.10 illustrate how collision severity is distributed amongst various collision types. In these bubble charts, the size of the bubble indicates how much of a percentage a certain combination of variable types corresponds to the total. Figure 4.9 is for all CAHW collisions and Figure 4.10 show the distribution for work zone collisions.

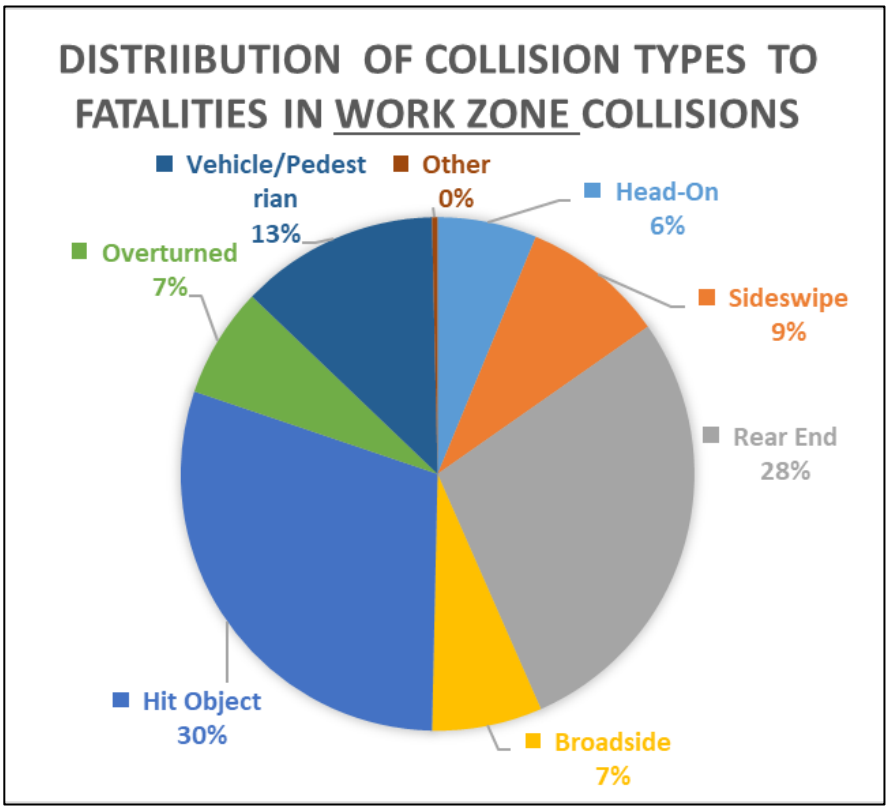


Figure 4.5- Pie chart illustrating how Types of Collision are distributed amongst fatal collisions that are associated with work zones.

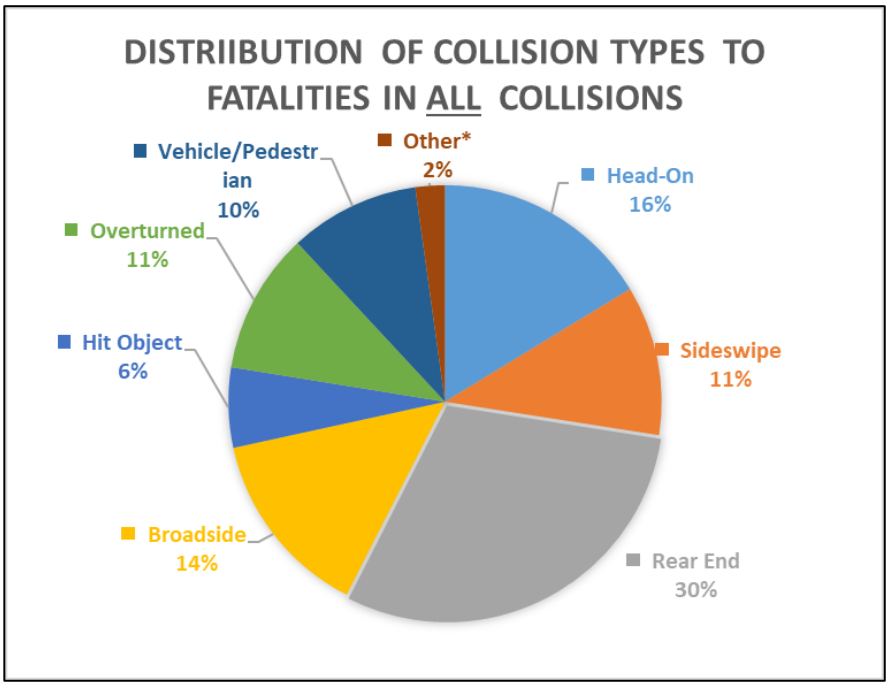


Figure 4.6- Pie chart illustrating how Types of Collision are distributed amongst fatal collisions for all CAHW collisions.

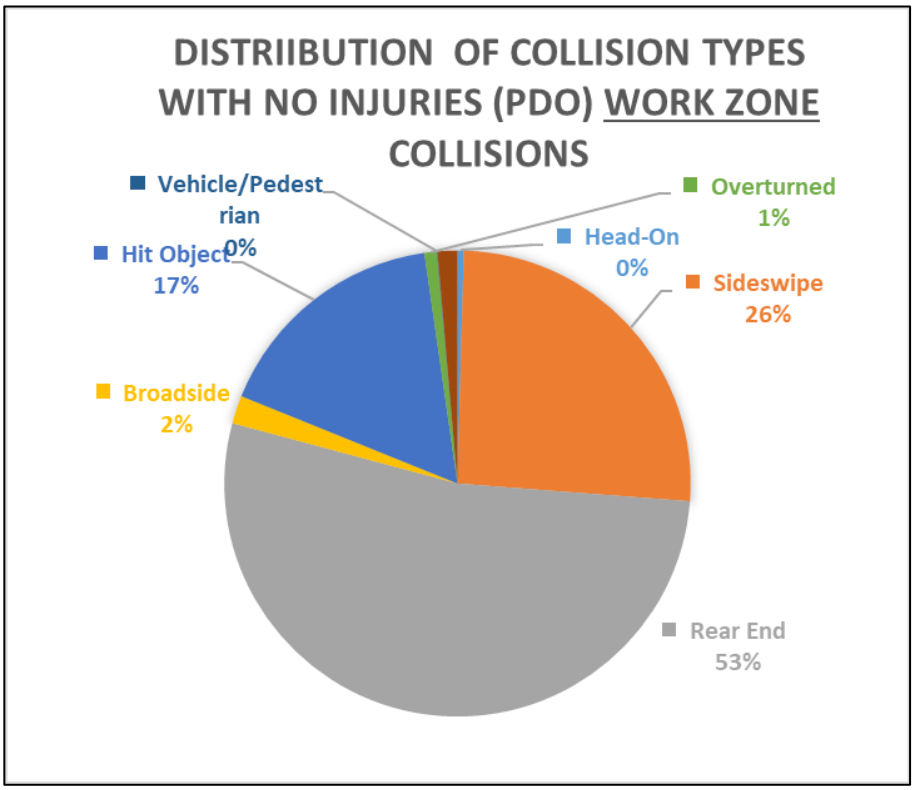


Figure 4.7- Pie chart showing how collision types are distributed among Property Damage Only outcomes from work zone collisions.

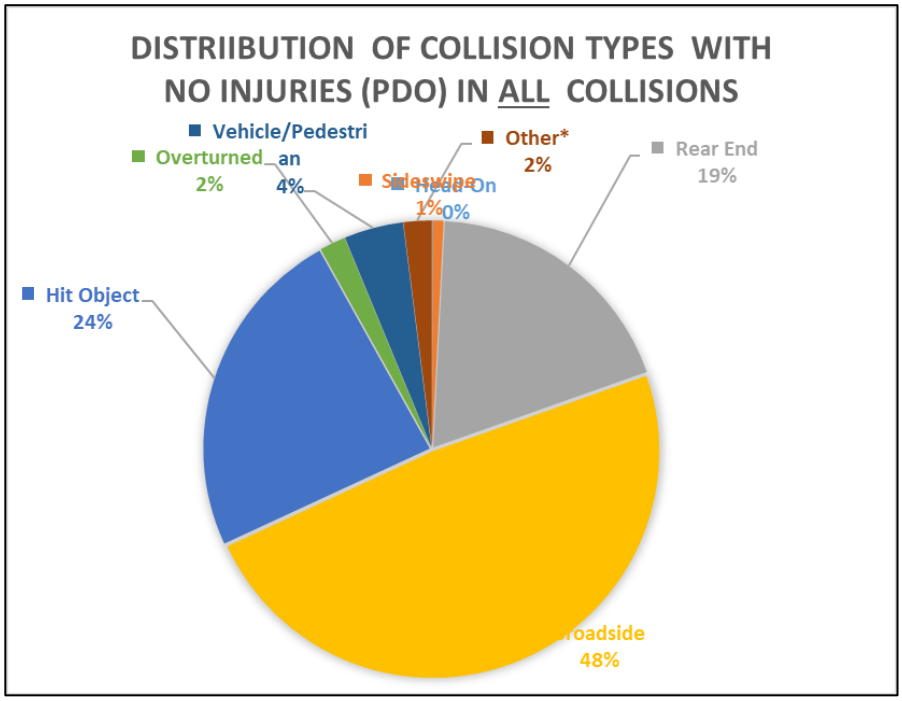


Figure 4.8- Pie chart showing how collision types are distributed among Property Damage Only outcomes from all CAHW collisions.

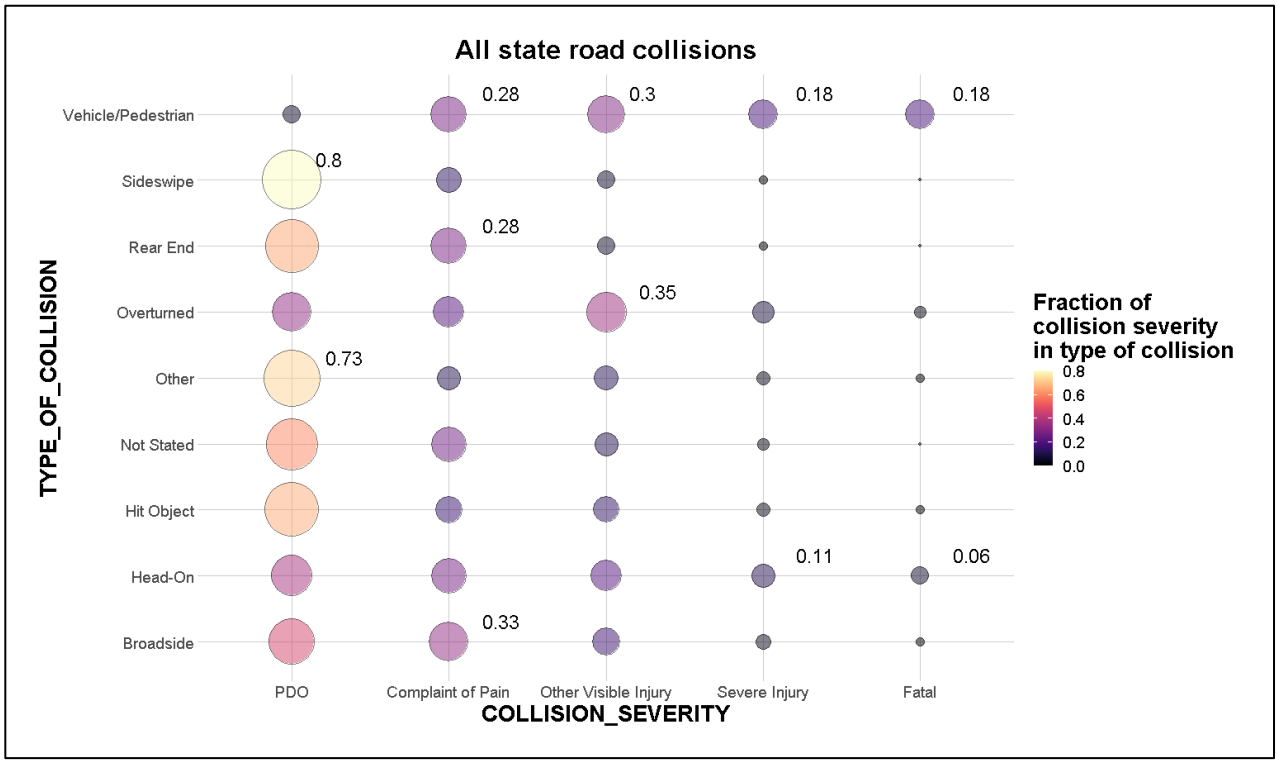


Figure 4.9- Bubble chart for all CAHW collisions.

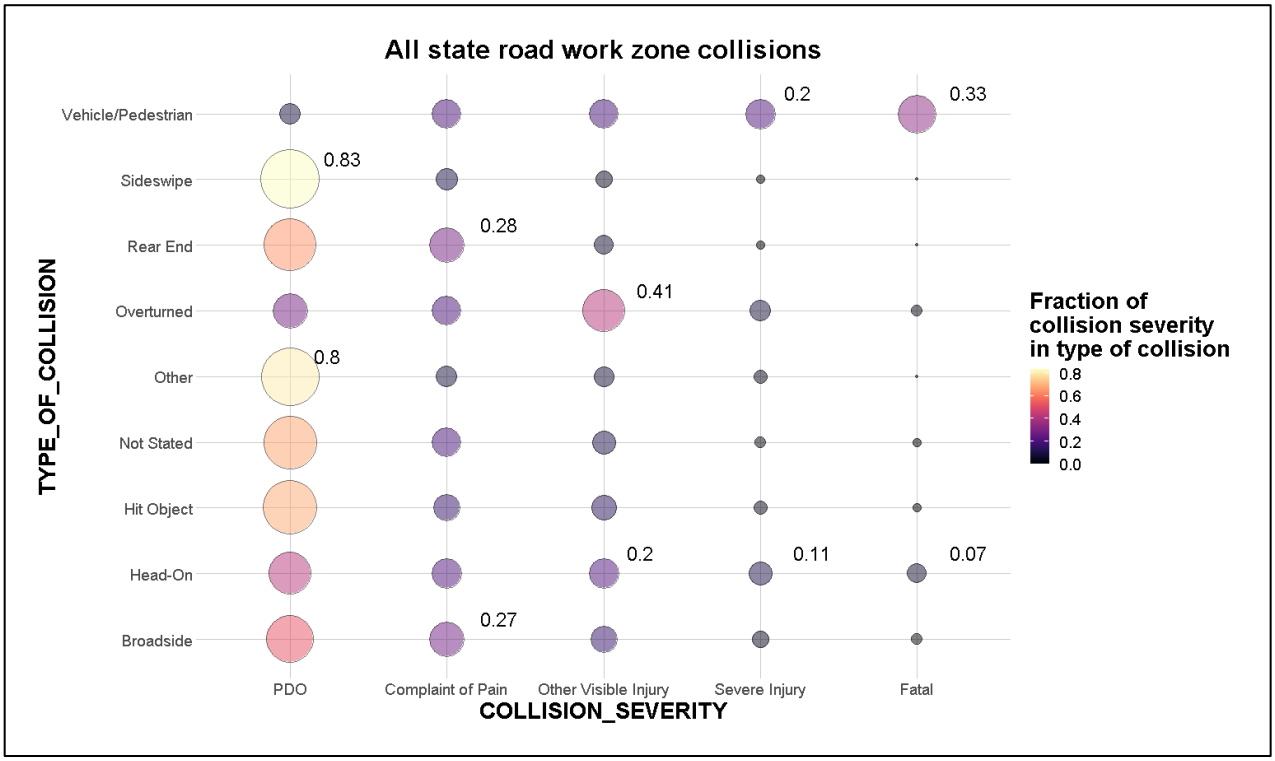


Figure 4.10-Bubble chart for work zone collision.

Primary Collision Factors

Primary Collision Factors are indicated by the reporting officer at the scene of the collision and describe the officers' evaluation of what caused the collision to occur. In Figure 4.11 shows the frequency of all factors for years 2011-2017. Here we see that unsafe speed, improper lane change, and improper turning are the top three reasons for work zone collisions.

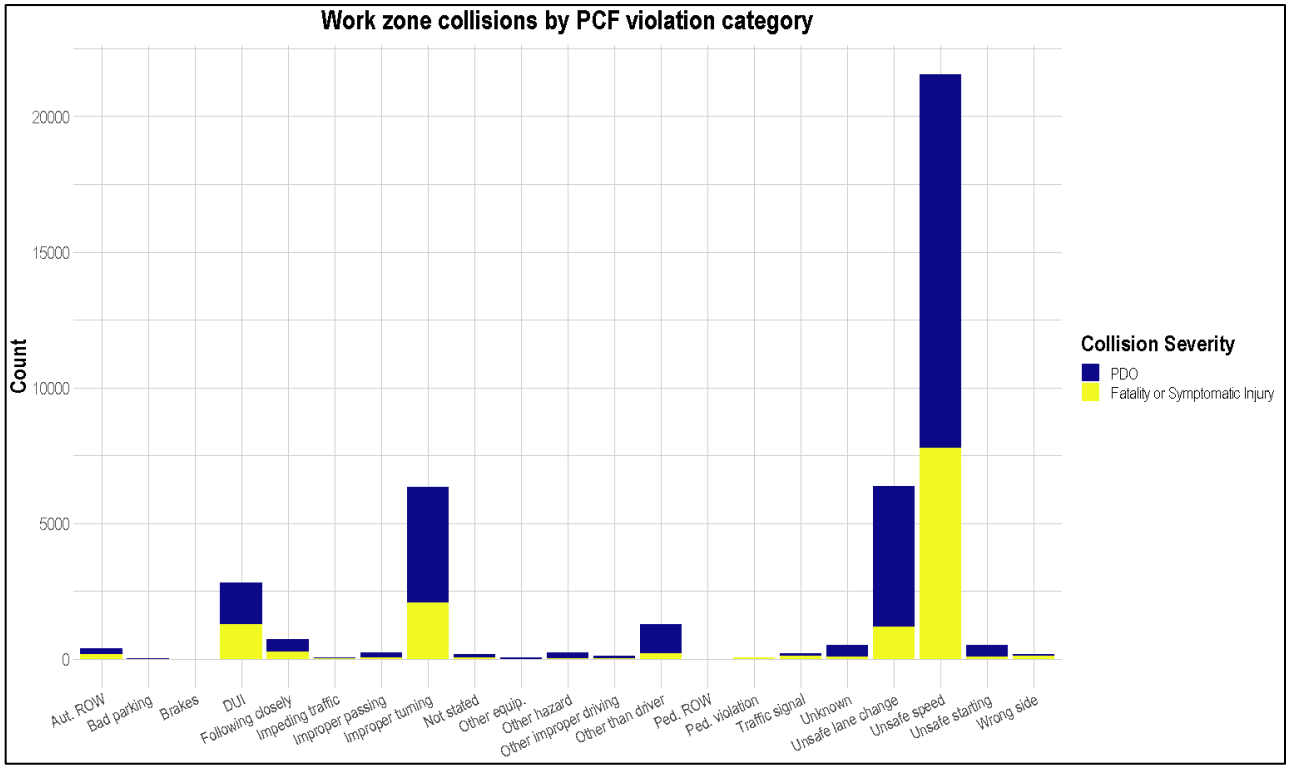


Figure 4.11- Distribution of Primary Collision Factor frequencies involving work zone collisions.

To understand more comprehensively the effect of collision factors on collision severity, Figure 4.12 shows the number of collisions broken down by each crash severity level. For minor collisions, the "Unsafe Lane Change" factor remains prominent. For severe injuries and fatalities however, the factors "DDUI" and "Pedestrian Violation" play a noticeable role.

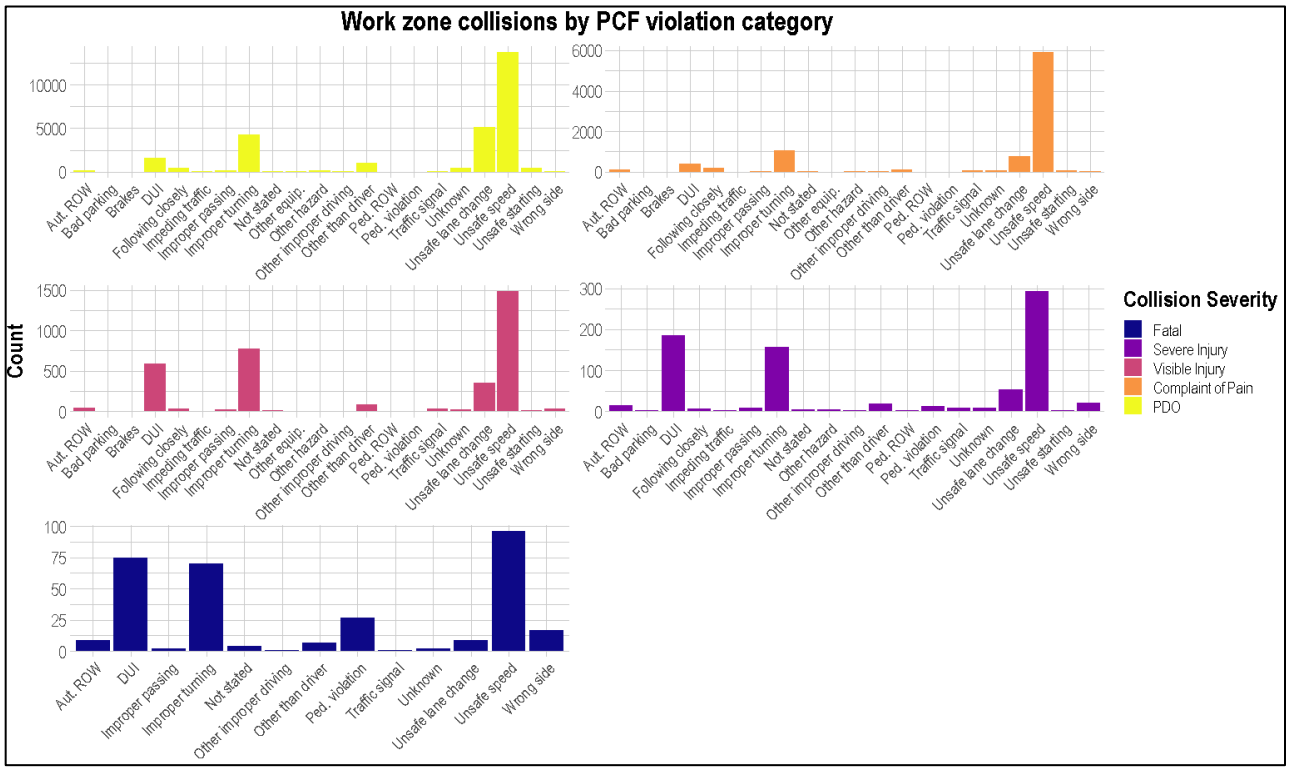


Figure 4.12- Number of work zone collisions associated with each Primary Collision Factor. Each individual grouping represents the distribution for each crash severity level.

Figure 4.13 shows the collision factor distribution for three types of collisions: Sideswipe, Rear-end, and Hit Object. This chart reflects that 19,473 work zone collisions had stated Collision Factors for these three collision types. The highest number of collisions (numbering over 12,000) are for Rear-end collisions that are caused by the drivers traveling too fast. 17,303 collisions did not have a stated primary factor.

It is interesting to note that when comparing the average cost of the same collision type-primary factor combination, the highest average cost is due to driving under the influence of alcohol (over $300,000) or drugs and improper driving (over $400,000).

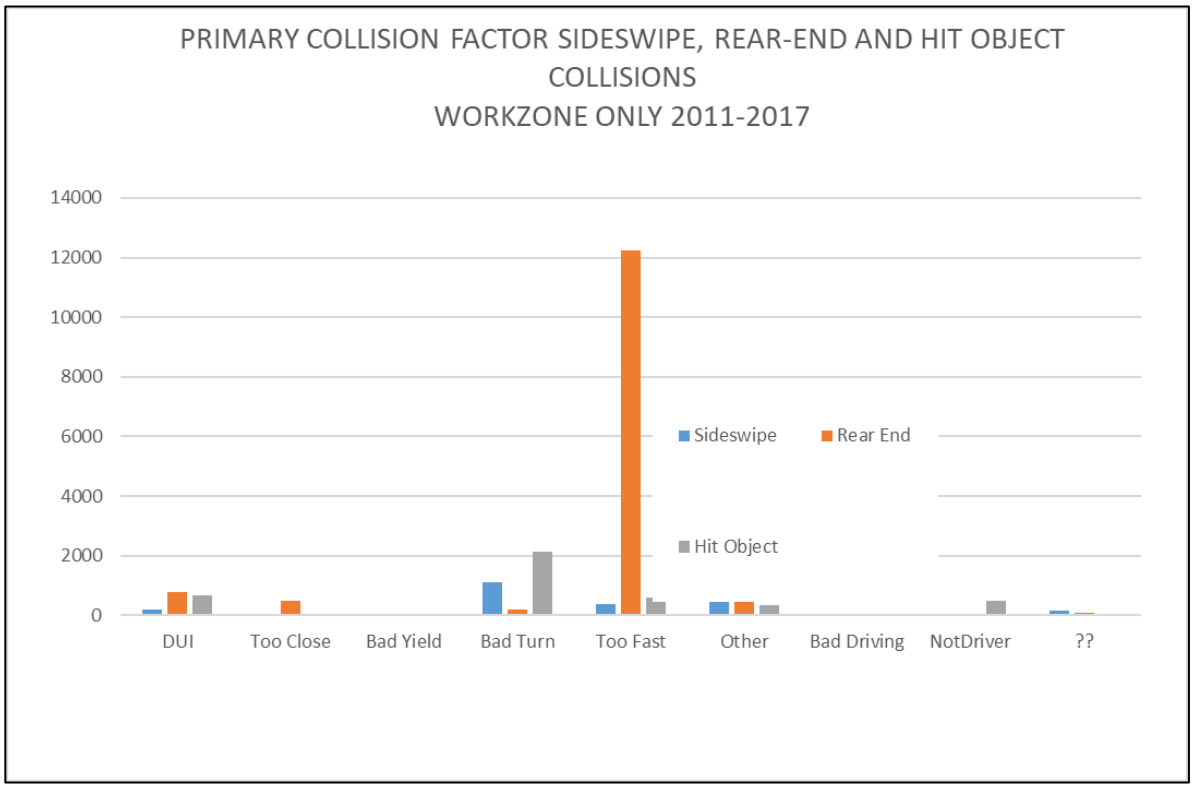


Figure 4.13- Frequency distribution of work zone frequency collisions between Primary Collision Factors and Types of Collision.

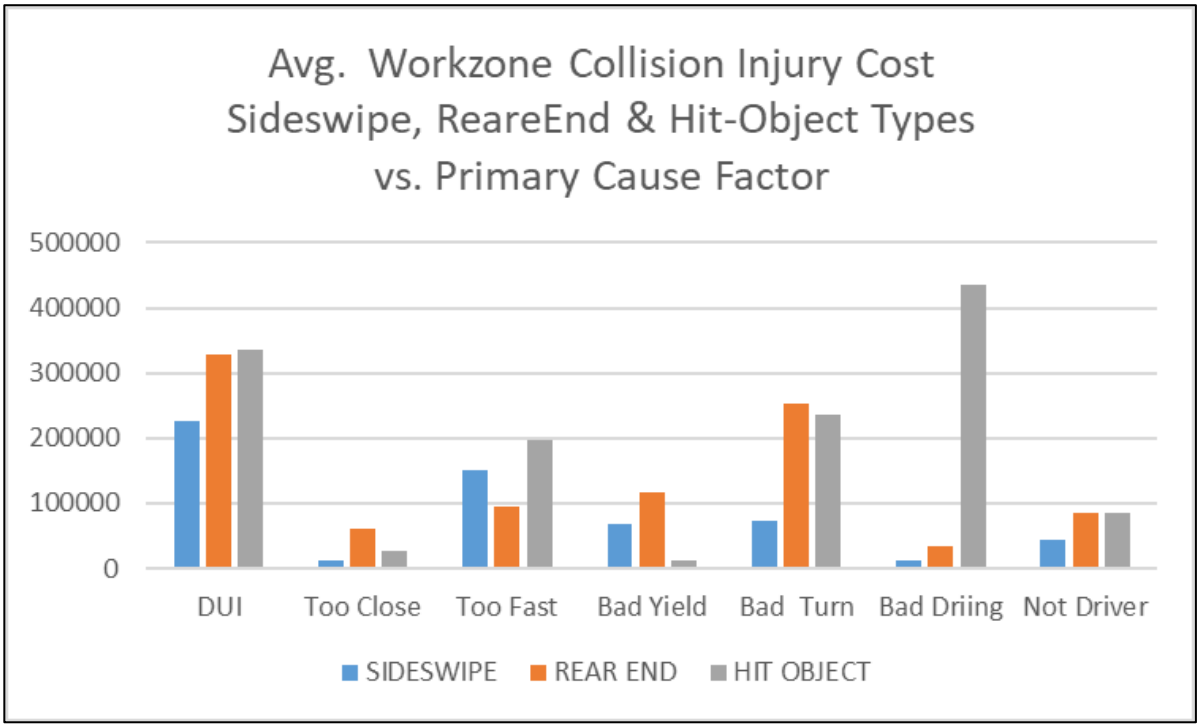


Figure 4.14- Average work zone injury cost associated with sideswipe, rear end and Hit Object collisions.

Vehicle Type

When a reporting officer indicates the vehicle type for any given party, they have the choice of approximately 100 categories. To analyze the effect of vehicle type on work zone collisions, it was decided to group some of the vehicle types into categories that contain similar attributes for work zone safety analysis. The specific CHP Vehicle Type designations are identified in Table 4.6 as well as the category name. Also shown in Table 4.6 is the total number of the vehicle type categories that are involved with work zone collisions for years 2011-2016.

Table 4.6- Definition of Vehicle Type Categories based on CHPs available designations for the type of vehicle for all Parties involved in a work zone collision.

Vehicle Type Category	Total Count	Associated CHP Vehicle Types
Bus	304	Other bus School bus Tour bus Noncommercial bus School bus public type I Public transit authority paratransit School bus contractual type
Car w/trailer or truck with trailer	688	Pickup or Panel Truck with Trailer Passenger Car with Trailer Motor home 40 feet or less in length Pickup with camper Motor home greater than 40 feet in length
Construction	40	Highway construction equipment Other commercial Highway construction equipment Three axle tow truck
Emergency	537	Emergency vehicle Police car Two axle tow truck Police motorcycle Emergency vehicle on emergency run or pursuit Fire truck Ambulance
Hit and Run	854	Other unknown hit and run driver
Large Truck	6628	Two axle tank truck Hm truck tractor Semi tank trailer Semi-trailer
Misc.	72	Farm labor transporter Moped

Vehicle Type Category	Total Count	Associated CHP Vehicle Types
		Motorized bicycle School bus contractual type II Special mobile equipment Extralegal permit load Fifth wheel travel trailer General public paratransit vehicle Hm three or more axle truck Hm two axle tank truck Hm two axle truck Implement of husbandry Misc. motor vehicle snowmobile golf cart Motor driven cycle scooter 15 hp or less Pull tank trailer School bus private type I School bus public type II
Motorcycle	1445	Motorcycle, scooter
Passenger Car	58014	Passenger car station wagon jeep
Pick-up Trucks	15565	Pickup or Panel Truck Sport utility vehicle Pickups and panels

To visualize the distribution of each category, a pie chart is shown in Figure 4.15. This pie chart was constructed using the counts from Table 4.6. Figure 4.15 shows that 69% of all vehicles involved in work zone collisions are considered "Passenger Cars". The next largest group is "Pickup Trucks" at 18% followed by "Large Trucks" at 8%.

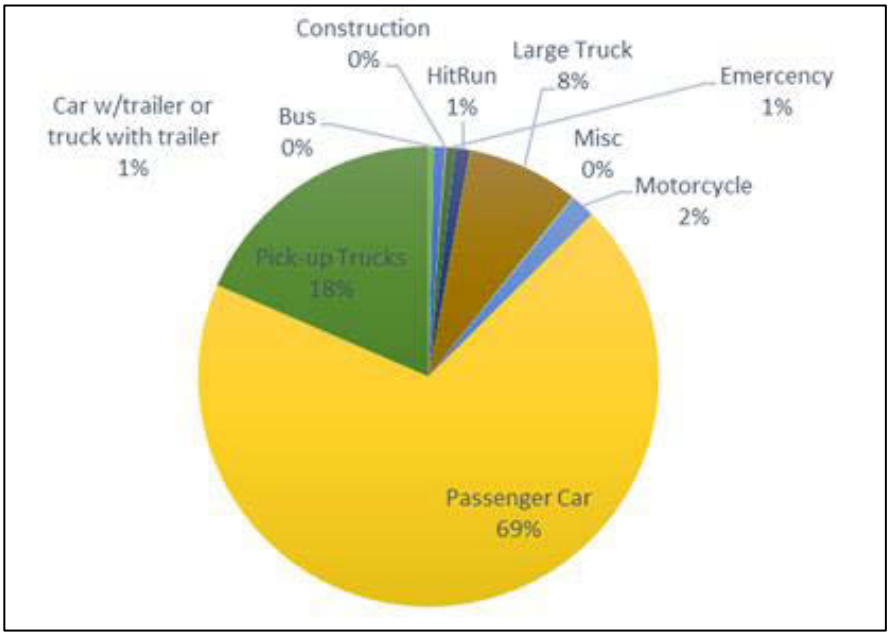


Figure 4.15- Frequency of Vehicle type categories that are involved with work zone collisions in years 2011 through 2017.

Driver Age

When discussing traffic safety, the driver's age may be a factor which needs to be investigated. The database provides the age of the driver of each party associated with work zone collisions. The distribution of driver ages can be seen in Figure 4.16. It shows that the age range of 21-25 has the highest distribution of collisions with a steady decline as driver ages increase. Speculations as to the reason for this may include use of distracting technology and having less experience driving on highways in general in California.

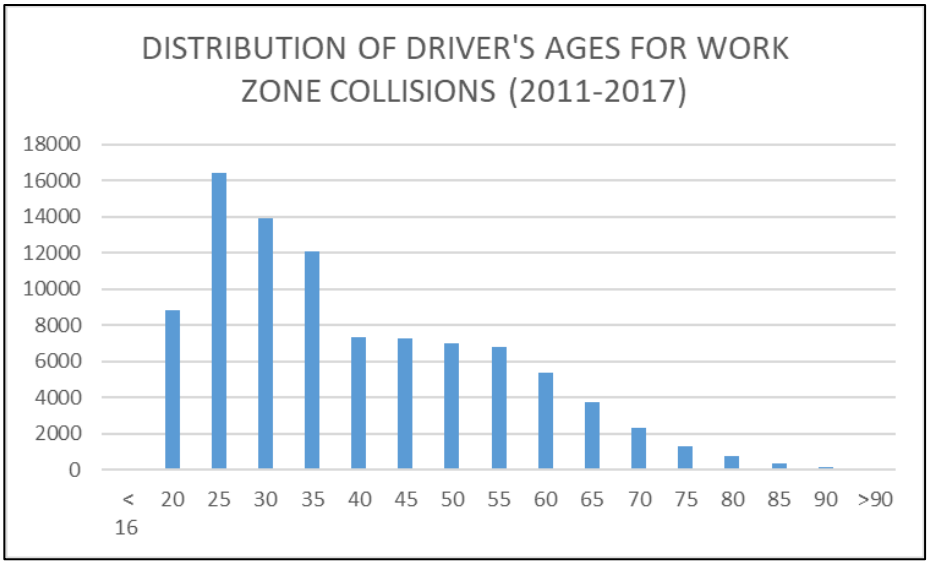


Figure 4.16- Distribution of driver's ages from 16 to 90 in work zone collisions broken down in 5-year increments.

Tow-Away

When one or more vehicles need to be towed after a collision has occurred, it is an indication that the difference in speed between parties or objects was high. If a sufficient amount of "force" has been applied to any one vehicle to cause such damage, then there is sufficient force to cause an injury to the occupants, depending on circumstances such as safety belt usage. In Figure 4.17, we can see the percentage of collisions for each severity group that has or has not been towed. Consistent with what is known about fatal collisions, it can be seen in Figure 4.17 that 94% of fatal collisions are a "Tow-away" collision. Again, consistent with injury causing collisions, there is a large percentage difference between collisions resulting in tow-away and collision that did not require a tow away. When it comes to minor injury crashes, the percentage of tow-away collisions is 71%. When no injury has occurred, the percentage of collision requiring tow-away is less than that of collisions without tow-away by a difference of 14%. When looking at the percentages for all work zone collisions the distribution is more even with tow-away at 54% and non-tow collisions at 46%.

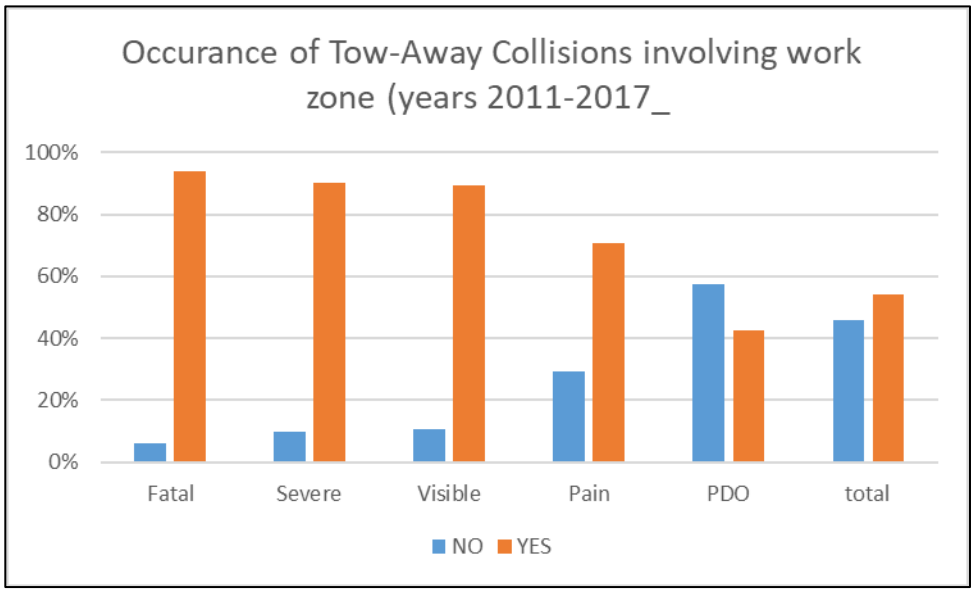


Figure 4.17- Percentage of collisions where at least one vehicle is towed away (YES), and those where all vehicles are not towed away (NO).

Lighting Conditions

Figure 4.18 shows the effect of daylight versus nighttime work zone collisions. The upper portion of this figure shows that most work zone collisions occurs during the daylight. When looking at the lower portion where lighting is distributed for fatalities, it can be seen that night and low light scenarios play a noticeable role in work zone collisions.

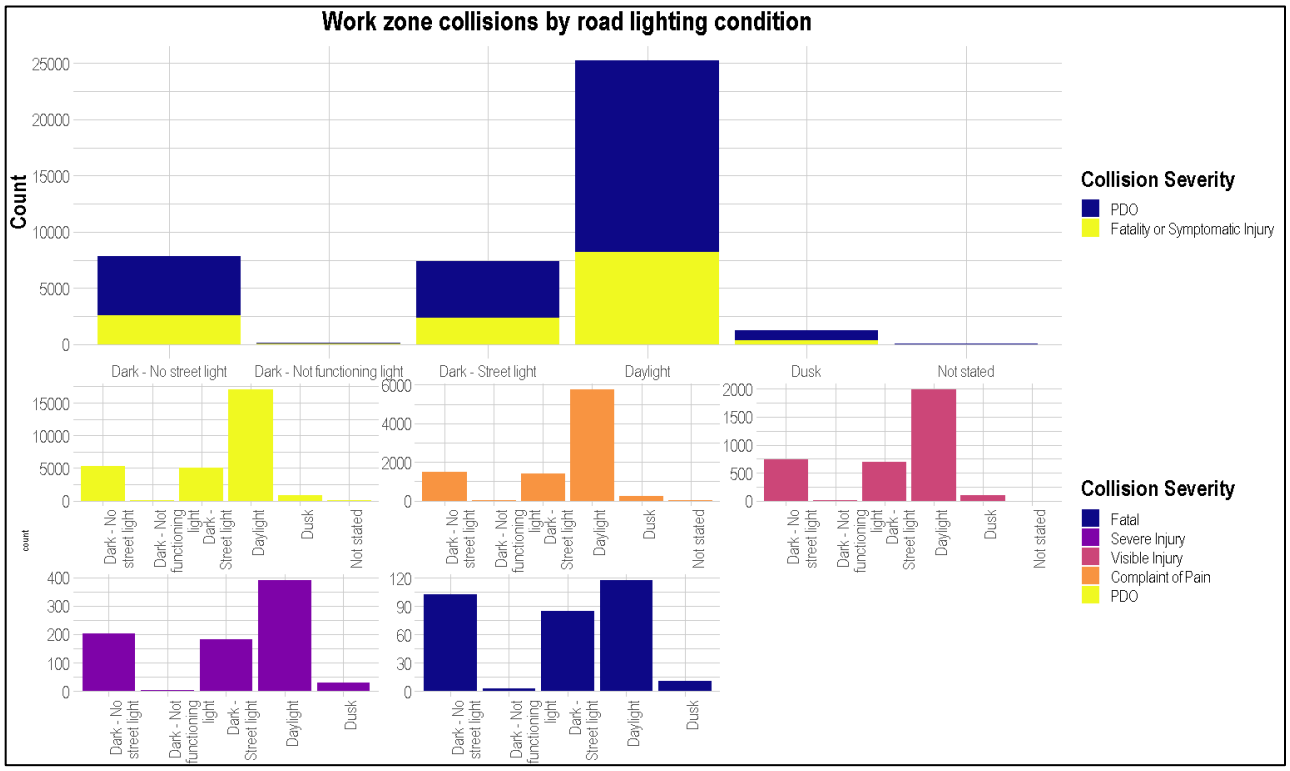


Figure 4.18- Distribution of work zone collisions with respect to lighting conditions. Also shown is the effect of lighting conditions on crash severity.

Time and Day

To verify when the majority of work zone collisions occur, histograms of time periods were generated using the date and time of work zone collisions between 2011 and 2017. In Figure 4.19, it can be seen that the majority of work zone collisions occurred in October followed by August and then September. In Figure 4.20, we see that Tuesday through Friday have the highest number of work collisions. These two figures indicate that work zone collisions predominantly occur when construction is being done. This makes sense logically because most construction occurs during the non-rainy season and during the week. Recall that a work zone collision cannot occur unless road work is ongoing.

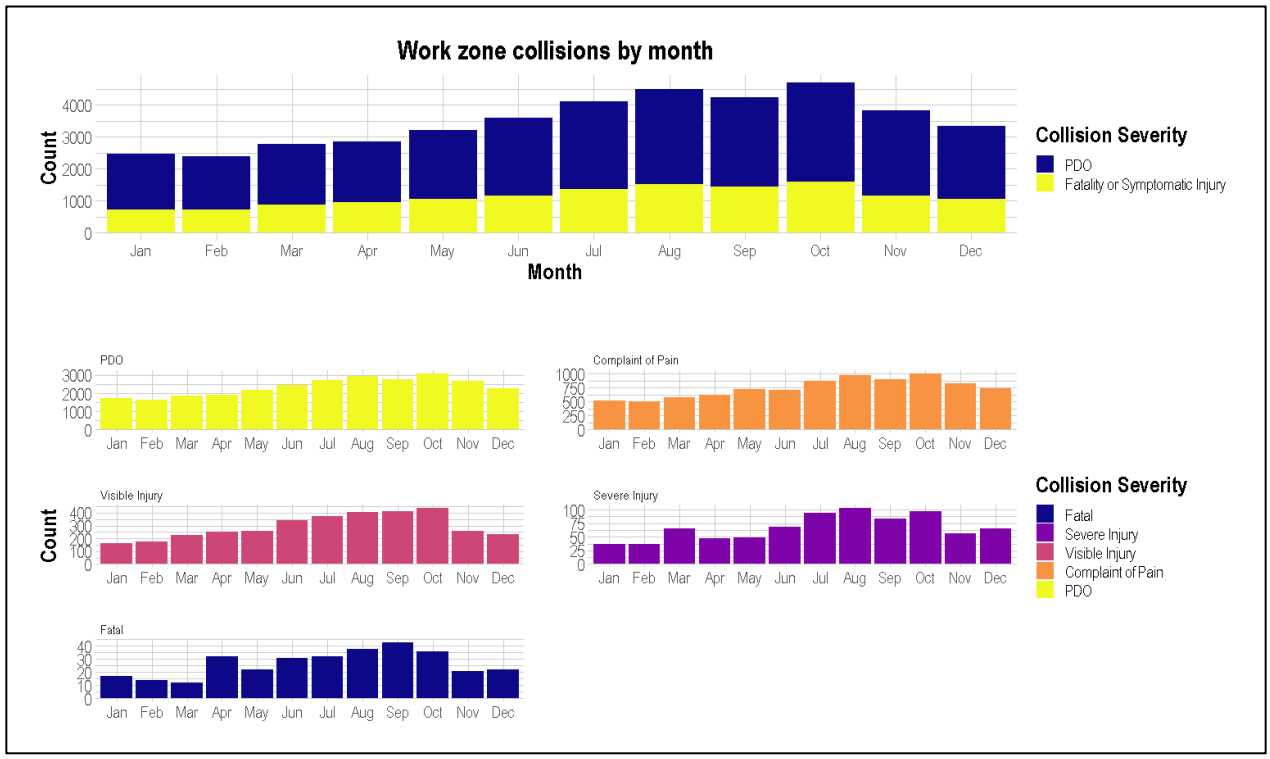


Figure 4.19- Histogram of work zone collisions for each month of the year. The data shown is for years 2011 through 2017.

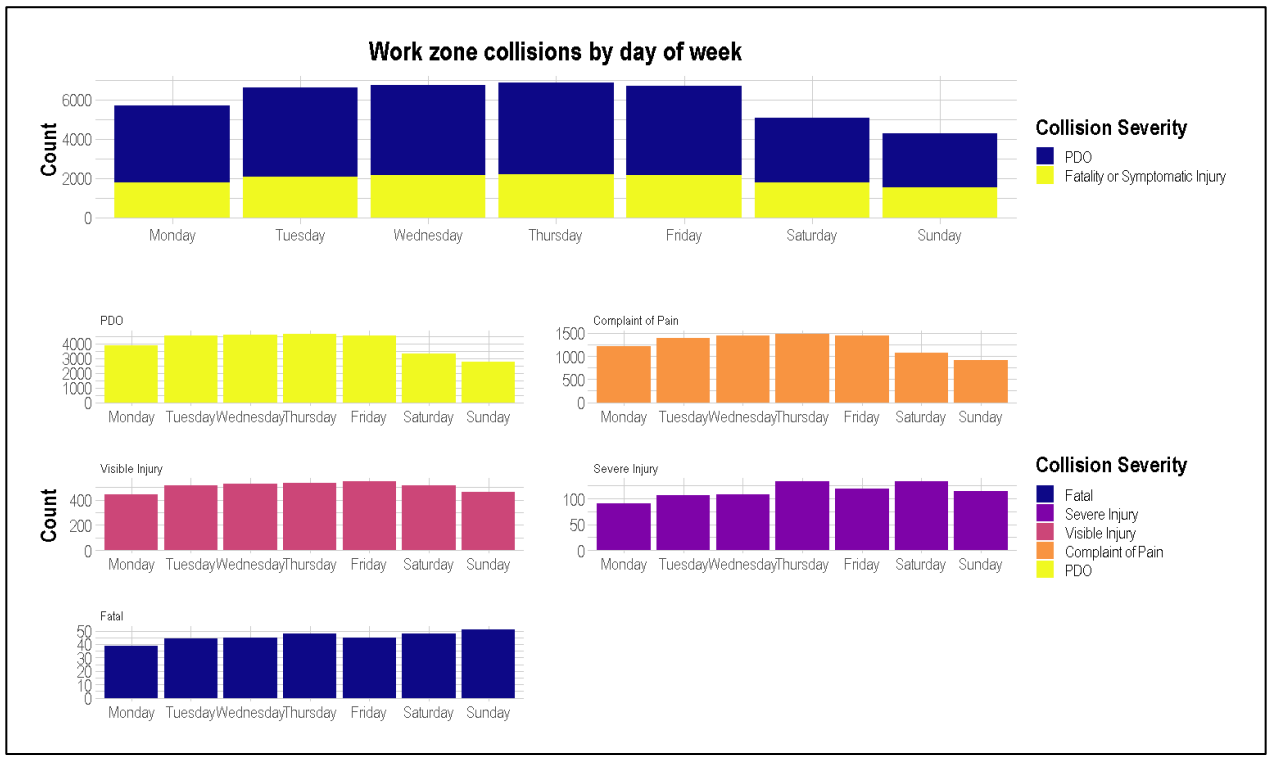


Figure 4.20- Histogram of work zone collisions for each day of the week. The data shown is for years 2011 through 2017.

Figure 4.21 shows the distribution of work zone collisions for different hours of the day which results in interesting features. The first is that 3 p.m. has the highest frequency of collisions. The plot also shows that 10 p.m. to midnight time frame has an elevated frequency of collisions. Until a deeper investigation occurs into the specifics of these work zone collisions, only speculations can be made about their cause. It is worth noting however, that these attributes exist and thus affect the risk of a collision at a work zone.

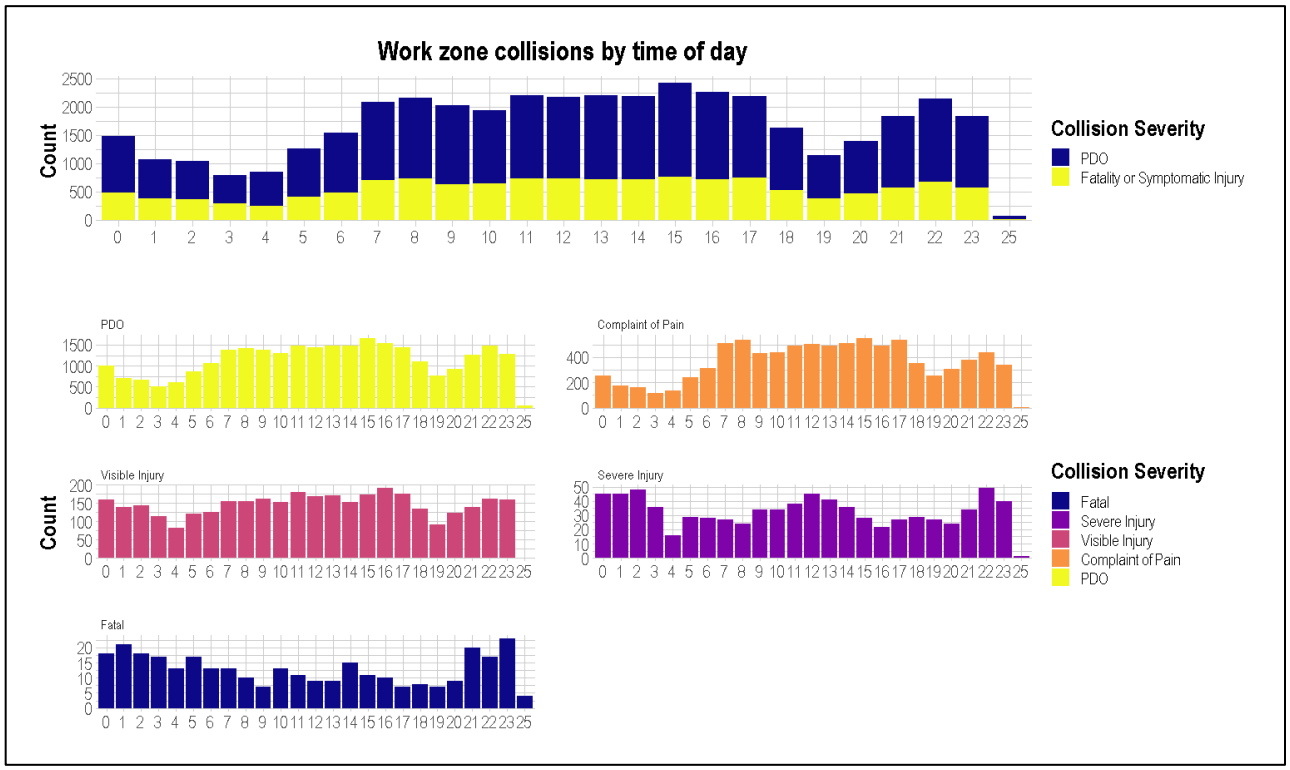


Figure 4.21- Histogram of work zone collisions for each hour of the day for 2011 through 2017.

Chapter 5:
Work Zone Traffic Collision Report and Injury Database Support Web Application (WZTCRINJDB)

In order to provide easy access to the data collected as part of this research study, a searchable database was developed and was populated with the data extracted from the iTCRs, eTCRs, TASAS data, and SWITRS data.

Accessing the WZTCRINJDB Support Tool

In order to improve the usability of the Work Zone Injury database, a support tool with a web interface was designed and implemented in a previous research [AHMCT-UCD-ARR-15-06-30-01]. This web support tool can be accessed through the Work Zone Safety website (wzsafety.ahmct.ucdavis.edu). The original web support tool interface was modified and data from years 2011-2017 was added.

The WZSAFETY website is a secure web-based application based on current web framework. The user must have an authenticated username and password to access the website. Accessing the web site requires the use of the web browser Chrome 4 or a more recent version. A welcome page as shown in Figure 5.1 will appear when the web site is first accessed which will then require username and password information to continue. After logging in, the website redirects the user to the search page (see Figure 5.2) that can be used to filter the reports or the data from the reports. As can be seen in Figure 5.2, the search categories are: Keyword, Location and Time, Collision attributes, Injury, Environment and Road Barrier Attributes. This is described in more detail in the next section.

Figure 5.1- A screenshot of the first page when the user types in wzsafety.ahmct.ucdavis.edu.

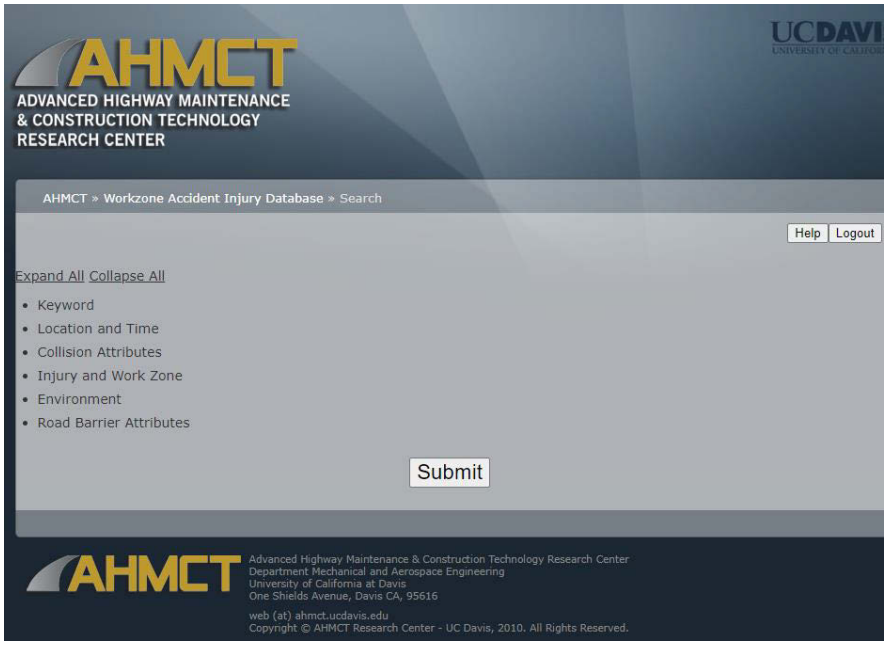


Figure 5.2- A screenshot of the main "Search" page for the Work Zone Traffic Collision Report and Injury Database Support Web Application (WZTCRINJDB).

Using the Search Functionality WZTCRINJDB Support Tool

As indicated previously, the website redirects the user to the search page after successfully logging in. There is an "Expand All" function shown in Figure 5.2 which when selected, displays the individual filters, which can be used to search the work zone collision reports. The filters are as follows:

- Keyword (returns reports whose Narrative's contain the Keyword)
- Location and time
    - Year (2006-201)7 or between two specific dates
    - Day of the Week
    - Caltrans district number
    - County
    - State route number
- Collision Attributes
    - Type of collision (Head-on, Rear end etc.)
    - Primary cause of collision (e.g. Speeding, DUI, etc.)
    - Tow away (Yes or No)
    - Number of involved parties
    - Party type (both TASAS and SWITRS)
    - Driver's Age
- Injury and Work Zone Attributes
    - Number of injuries
    - Number of fatalities
    - Crash severity
- Environment
    - Weather
    - Lighting
    - Population code
- Road Conditions
    - Access type
    - Highway and Caltrans Road type

- Road surface and number of lanes
- Barrier type and Median type

One can click on each category name to display the sub-categories. It is also possible to click on the expand-all button to show all subcategories. The category search function is illustrated in Figure 5.3.

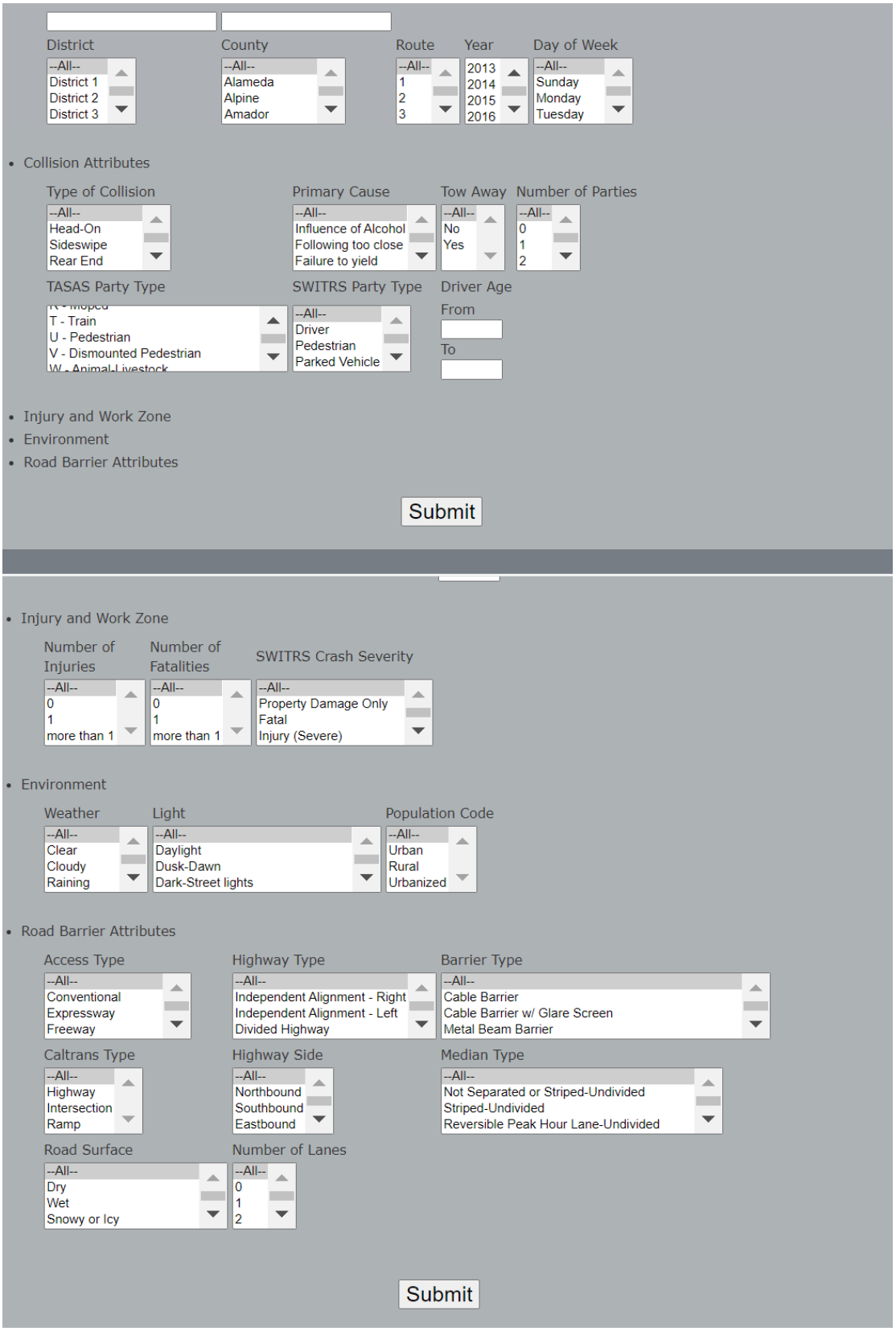


Figure 5.3- A screenshot of the main search page expanded to reveal all the possible parameters to search work zone traffic collision reports.

After the search criteria are entered and the user selects "Submit" at the bottom of the screen, the search results are then displayed as shown in Figure 5.4, A listing of the traffic collision reports meeting the criteria is provided along with a map of the collision's locations. The list can be ordered as desired and any single report can be further investigated by selecting the "Show" button.

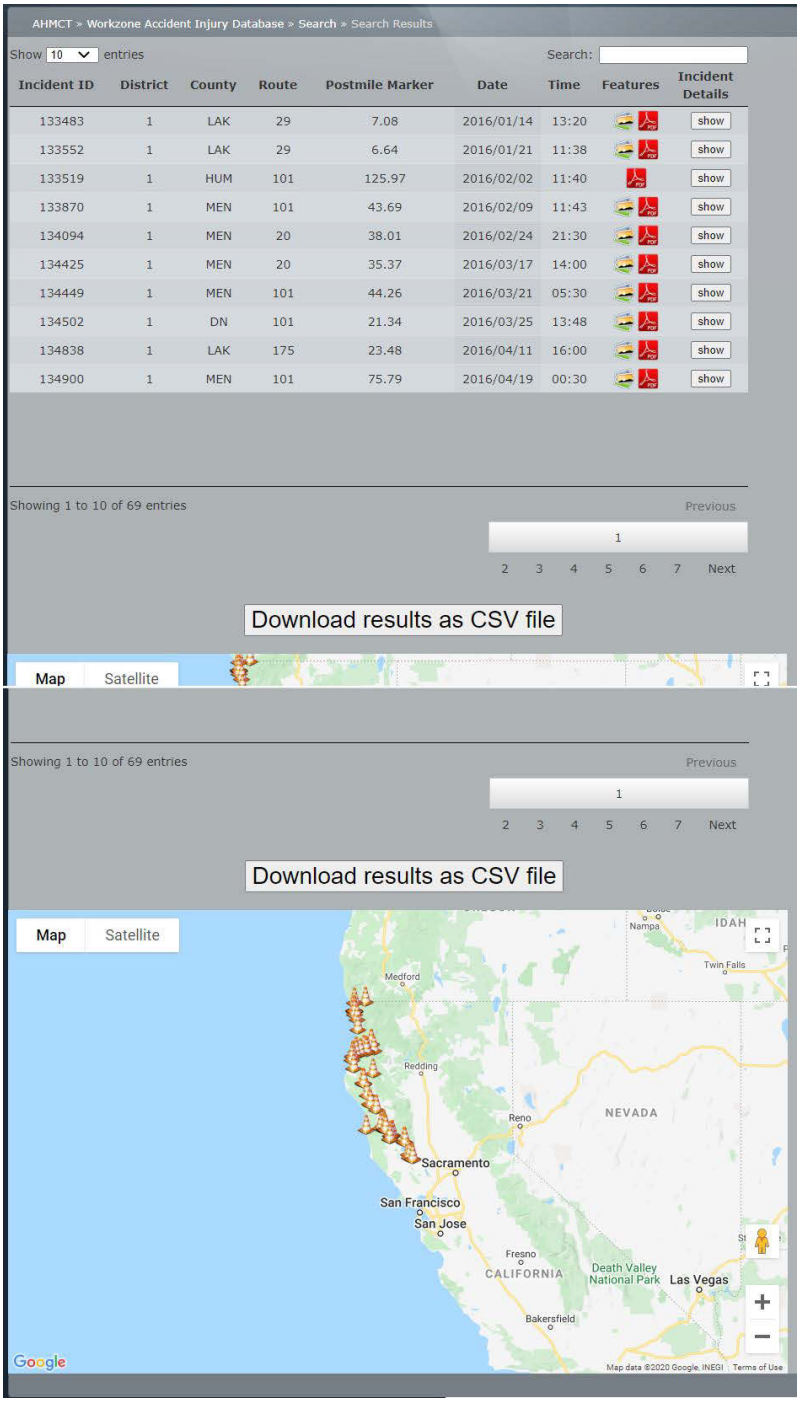


Figure 5.4- A sample screenshot of the results of a database query. A listing of the collision reports is provided as well as a map of the collision's resepc5tive locations.

After the listing is displayed in Figure 5.4 and the User selects a "SHOW" button for any report, detailed information regarding the report is then displayed. An example of such a display is shown in Figure 5.5. A detailed map of the collision location is displayed along with the collision details. Selecting the collision detail headings can be expanded or contracted as needed. As also seen in Figure 5.5, is the "View Narrative" option. When selecting this item, the text from the Narrative pages of the traffic collision report are displayed.

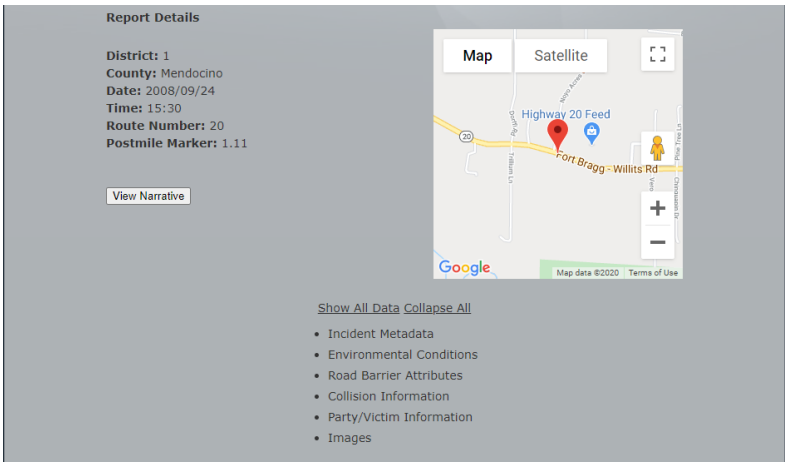


Figure 5.5- Screenshot of a collision report result from the "Search" page. This page is displayed after a "SHOW" button is selected.

Figure 5.6 is an example of what is seen when viewing the narrative. Please recall that this narrative is obtained by means of Optical Character Recognition (OCR) software and may contain elements that seem erroneous. For example, the number 1 can be used in place of the letter "I" and vice versa. In general, these anomalies can be easily understood when reading the text in context.

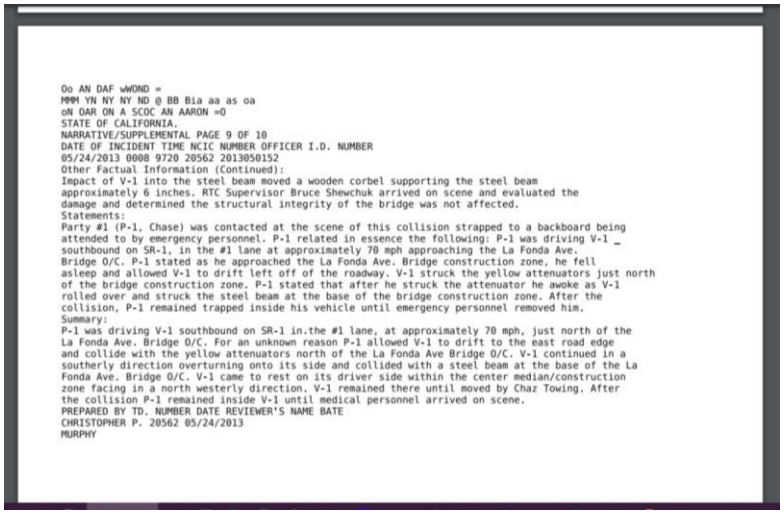

Oo AN DAF wWOND =
MMM YN NY NY_ND_@ BB_Bia aa as oa
oN OAR ON A SCOC AN AARON =0
STATE OF CALIFORNIA.
NARRATIVE/SUPPLEMENTAL PAGE 9 OF 10
DATE OF INCIDENT TIME NCIC NUMBER OFFICER I.D. NUMBER
05/24/2013 0008 9720 20562 2013050152
Other Factual Information (Continued):
Impact of V-1 into the steel beam moved a wooden corbel supporting the steel beam
approximately 6 inches. RTC Supervisor Bruce Shewchuk arrived on scene and evaluated the
damage and determined the structural integrity of the bridge was not affected.
Statements:
Party #1 (P-1, Chase) was contacted at the scene of this collision strapped to a backboard being
attended to by emergency personnel. P-1 related in essence the following: P-1 was driving V-1 _
southbound on SR-1, in the #1 lane at approximately 70 mph approaching the La Fonda Ave.
Bridge O/C. P-1 stated as he approached the La Fonda Ave. Bridge construction zone, he fell
asleep and allowed V-1 to drift left off of the roadway. V-1 struck the yellow attenuators just north
of the bridge construction zone. P-1 stated that after he struck the attenuator he awoke as V-1
rolled over and struck the steel beam at the base of the bridge construction zone. After the
collision, P-1 remained trapped inside his vehicle until emergency personnel removed him.
Summary:
P-1 was driving V-1 southbound on SR-1 in.the #1 lane, at approximately 70 mph, just north of the
La Fonda Ave. Bridge O/C. For an unknown reason P-1 allowed V-1 to drift to the east road edge
and collide with the yellow attenuators north of the La Fonda Ave Bridge O/C. V-1 continued in a
southerly direction overturning onto its side and collided with a steel beam at the base of the La
Fonda Ave. Bridge O/C. V-1 came to rest on its driver side within the center median/construction
zone facing in a north westerly direction. V-1 remained there until moved by Chaz Towing. After
the collision P-1 remained inside V-1 until medical personnel arrived on scene.
PREPARED BY ID. NUMBER DATE REVIEWER'S NAME BATE
CHRISTOPHER P. 20562 05/24/2013
MURPHY

Figure 5.6- Screenshot of the first page from a collision report result after the "View Narrative" text is selected when viewing the "SHOW" page.

When the "Images" text shown at the bottom portion of Figure 5.5 is selected, the diagrams contained in the collision report are displayed. Figure 5.7 is an example of these diagrams. If no diagrams have been provided however, then there will be no images to display.

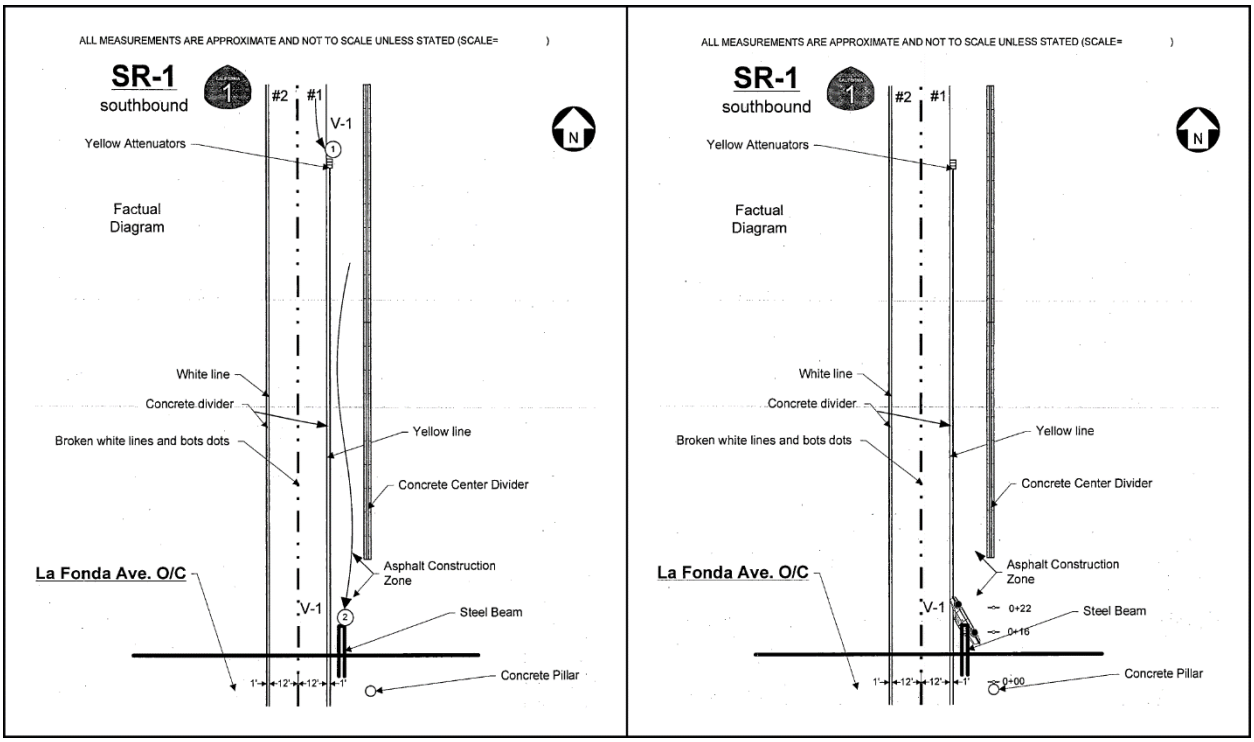


Figure 5.7- Sample collision diagrams from a collision report. These are shown after the "Images" text is selected.

If the user wishes to save information on all the collisions found from a resulting query, the list shown in Figure 5.4 can be downloaded as a CSV file if the "Download results as CSV file" button is selected. The information provided in row format are shown as follows:

- Incident ID
- WZSAFETY ID
- eTCR Collision ID
- SWITRS Collision ID
- DRS (Document Retrieval System) ID
- County
- Route
- Post-mile Prefix
- Post-mile value
- Date

- Time
- Crash Severity
- Type of Collision
- Injuries
- Fatalities
- Cost (in millions of dollars)

As can be seen from this chapter, there is quite a bit of detail to be discovered from each work zone collision. The narrative describes what happened along with the causes of the collision and who was involved. If a work zone is described in the text and diagrams, then this data can be extremely helpful when analyzing work zone collisions.

Chapter 6:
Conclusions and Recommendations for Future Research

The key contribution of this research study was the collection of data for the comprehensive analysis of work zone traffic collisions on California highways. This research has put together a framework where safety engineers can search through work zone collisions starting from 2006 and continuing through 2017. This is because the data collected from 2006 to 2010 in a previous research study were integrated with the data collected from 2011 to 2017 in this study.

The issues surrounding work zone collisions are:

- High-speed highways were not designed to accommodate both the traveling public as well as maintenance/construction activities. Road work is a necessity that can put both the traveling public and the maintenance crews at a risk not normally experienced. Road work can involve pedestrians (e.g. highway workers) working alongside high speed traffic with minimal protective equipment.
- Road work provides a unique set of challenges such as the thousands of permutations in geometry, extent of damage, feature to be repaired or built, the number of crew and machinery needed to perform the job, time of day in which to perform the work, the normal traffic volumes seen at the work site, etc. When considering all these variables, it seems unlikely that there will be a single set of best practices applicable to all work zone activities. It is anticipated that each work site will need to be considered on a unique basis in order to assess work zone safety.
- The reporting method of work zone collisions further complicates data analysis and the ability to draw objective conclusions. Specifically, it is up to the reporting CHP officer whether road work was a notable condition at the time of the collision. There are reports where no mention of roadwork in the narrative other than a situation where "stop and go" traffic was the cause of the collision. This means it is assumed that the flow of traffic was altered due to downstream road work and the collision occurred in the advanced zone of the road work. There are also many reports where little is known regarding the current activity at the road work site. It is assumed that there are cases where a collision is not indicated as a work zone collision even though a long-term lane outage may have led to the collision.

General Conclusions from the Data Analysis

When comparing work zone collisions with all collision on state road highways, we find that there is:

- A trend where collisions involving injuries and fatalities tend to have similar percentages when compared with number of collisions of all CAHW collisions. As seen in Figure 4.1, there are more injury and fatal collisions comparatively with all collisions starting in 2011. This seems to suggest that work zones are at a higher risk of injuries and fatalities. In 2016 and 2017 however, the trend changes and the injury and fatality collisions become consistent with all other collisions on California highways.
- There are about 50% more rear-end plus sideswipe collision in work zones than in all CAHW collision (Figure 4.4).
- The predominant primary collision factor for rear end collisions is "Traveling too fast" (see Figure 4.13).
- The cost of work zone collisions averages at $820 million per year over the 2011-2017 period. The average cost per collision based on injury severity has decreased from $167,214 (2011) to $136,650 (2017) which is a decrease of 18% for this seven-year time period.

Limitations of the Data Set

The data collected for this research study is a substantial body of work. When gathering data, it is critical to understand where the data came from, where shortcomings may lie, its usefulness, and its limitations. Consequently, the following points are made to highlight these features:

- From our previous research, we relied on manual inspection of the collision diagrams to see whether intrusion into the work zone had occurred. This is a time-consuming process and was not achievable for this research project. We have learned from other AHMCT research that other emerging technologies such as machine vision may be possible in the future but for this research study, it was not within the scope and budget to implement it. Consequently, the database does not contain "intrusion" as an attribute since there is no automated way to provide this data. It is suggested that the "Hit Object" collision type indicates something in the work zone area has been hit and therefore can be an indication of intrusion.
- To further investigate what went on in a Hit Object collision, we need to identify the objects themselves which is occasionally provided in the collision report. Sometimes this particular detail may need to be extracted from the narrative. It is not always possible to collect this data

for collisions reliant on iTCR data, but it is easily extracted from eTCRs thanks to previous AHMCT projects.

- As indicated in Chapter 3, we relied on SWITRS Data to supplement the TASAS data such as vehicle type, driver age, and severity of injury per person injured in each party. For this research project however, we found that 1459 records did not have corresponding SWITRS data. The majority of these were from 2014 (1278 reports) with the rest from 2011-2013 and 1 from 2015. This is clearly a shortcoming of the public access to the SWITRS data. If a collision record is found in the TASAS database, then there must be an originating collision report initiated at CHP.
- For data from 2015, there are two sources of data: those from TASAS and those from eTCRs. We expected there would be a significant overlap between the two for the latter portion of 2015 when eTCRs were beginning to be deployed. In fact, the two sets had very little overlap and the duplicate collision records were deleted. We thought this had been the source of the noticeable increase in number of work zone collisions for 2015 (see Figure 4.1), but all collision records were determined to be valid. At this point, we still do not know the reason for the influx of collisions for that year.

The Significance of the Web Tool

As indicated earlier, where, when, and how a maintenance or construction activity is executed creates a situation that is unique in some aspect. For the safety engineer assessing the risks involved, it is a tremendous benefit to be able to search for work zone collisions that have occurred in the past while matching similar set of attributes. There will never be an exact replication, but significant parameters will be identified by the engineer and those will be the ones the engineer will focus their attention.

For this reason, having a tool that provides detailed data about work zone collisions is critical. A flexible search function is important as well as having multiple data display options. The web tool developed for this research project displays all these functionalities. Furthermore, data was incorporated from the previous project. The database now contains 12 years of collision data has potential to accommodate a great number of safety and analysis questions. It should also be noted that years 2018 and beyond can easily be added to the current dataset with minimal effort due to the existence of the eTCR collision format.

Future Research

This research project has shown to provide an effective set of data and analysis tool partly because it was able to leverage resources from earlier projects

with Caltrans. In a similar fashion, a great deal more can be achieved with the following research:

- Refine the Web tool to include:
    - Expand the Keyword Search option to include phrases such as "driver distraction" and include a more sophisticated search engine to help decipher context, phrases, and associated meanings.
    - Expand the web tool to bring in lane closure data so that a work zone collision could be linked with deployed lane closures. Once linked, the web tool could then provide the user specific information about the work site at the time of the collision.
- Directly tie in the eTCR format with this database. Automating eTCR can reduce processing that needed to be done to collect the work zone collision data. The database can also be kept up to date if eTCR format is incorporated. This does not necessarily mean it has to be a streamed process but rather can be done in batches as eTCRs become available or when it is convenient to Caltrans.
- Develop another tool similar to the work zone injury database to focus on other sets of data that safety researchers are interested in such as improving the safety of motorcycles, senior drivers, adaptable road geometries, etc.
- To study traffic safety, tie in injury causing collisions with medical records. This can help answer questions such as do rear end collisions cause a chronic pain condition in the neck or back? Medical people could have access to the collision details in an effort to be able to make the treatment more quickly and effective.

References

[A] 2020-2024 California Strategic Highway Safety Plan. California Safe Roads Publication. Accessible at: https://dot.ca.gov/-/media/dot-media/programs/safety-programs/documents/shsp/2020-2024-shsp-report.pdf

[B] Scientific Evaluation of the ArmourGuard Mobile Barrier System; Bahram Ravani, Jessica Wong, Patricia Fyhrie, Robert Bosler; Report Number: UCD-ARR-10-06-30-01. Accessible at: https://dot.ca.gov/-/media/dot-media/programs/research-innovation-system-information/documents/f0016950-armorguard-final-rpt.pdf

[D] TASAS (Traffic Accident Surveillance and Analysis System) Data Base Development: Patricia Fyhrie, Grachya Hovhannisyan, Travis Swanston and Bahram Ravani: Principal Investigator Report Number: UCD-ARR-19-06-30-02. Accessible at: https://dot.ca.gov/-/media/dot-media/programs/research-innovation-system-information/documents/final-reports/ca19-2906-finalreport-a11y.pdf

[C] Work Zone Injury Data Collection and Analysis; Bahram Ravani, Patricia Fyhrie, Kristopher Wehage, Arash Gobal, and Hiu Y. Hong, AHMCT Research Report: UCD-ARR-15-06-30-01, August 18, 2015. Accessible at: http://ahmct.ucdavis.edu/pdf/UCD-ARR-15-06-30-01.pdf

[E] Revised Departmental Guidance 2016: Treatment of the Value of Preventing Fatalities and Injuries in Preparing Economic Analyses, 2016 Update by Molly J. Morran and Carlos Momje, August 8, 2016 US DOT. Accessible at: https://www.transportation.gov/sites/dot.gov/files/docs/2016%20Revised%20Value%20of%20a%20Statistical%20Life%20Guidance.pdf

[F] Crash costs for Highway Safety Analysis, Publication of FHWA highway safety program: FHWA-SA-17-071, http://safety.fhwa.dot.gov.

[G] Fatality Analysis Reporting System (FARS) 2016 Final and 2017 Annual Report File, National Highway Traffic Safety Administration (NHTSA). FARS data shown here are from the 50 States and the District of Columbia. Accessible at: https://www.workzonesafety.org/crash-information/work-zone-fatal-crashes-fatalities/ national.

Appendix A: WZSafety Website User Guide

Overview

The WZSafety website provides easy access to the data stored in the workzone accident injury database. Registered users can search for collisions having special attributes and view all the details of selected collisions as well as download collision reports.

"This user guide explains how to use the WZSafety website"

Accessing the WZSafety Website

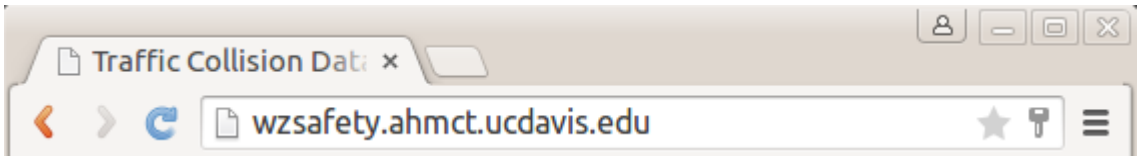
The WZSafety website is a secure, web-based application based on the Django web framework. The user must have a registered account in order to access the website.

System Requirements

The WZSafety website works with a variety of browser applications, but it has been tested most thoroughly with Google Chrome, versions 4 and later.

Website URL

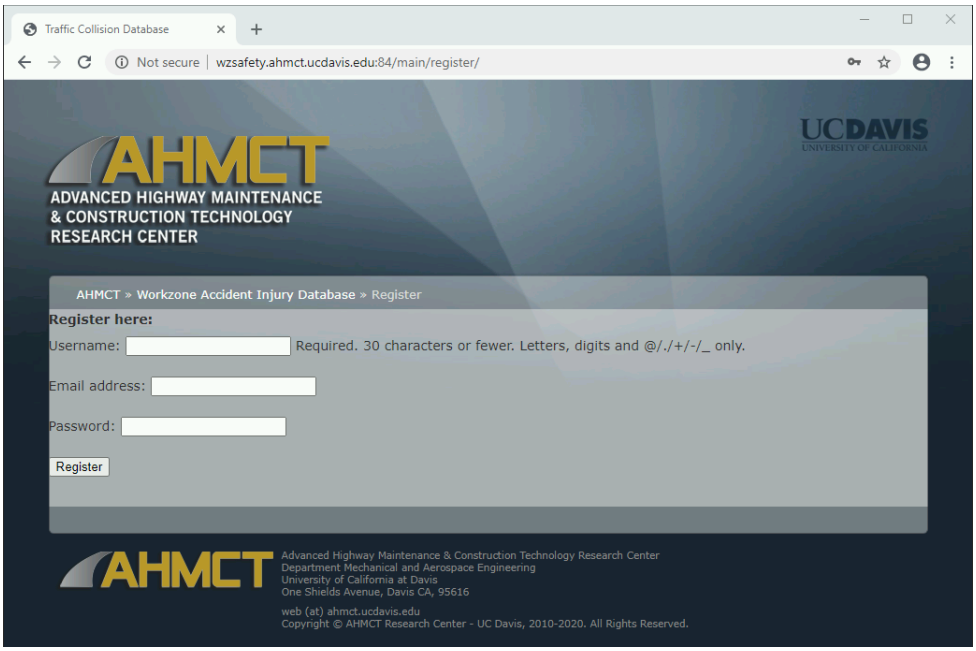
Use the address below to access the WZSafety website:



Welcome Page:

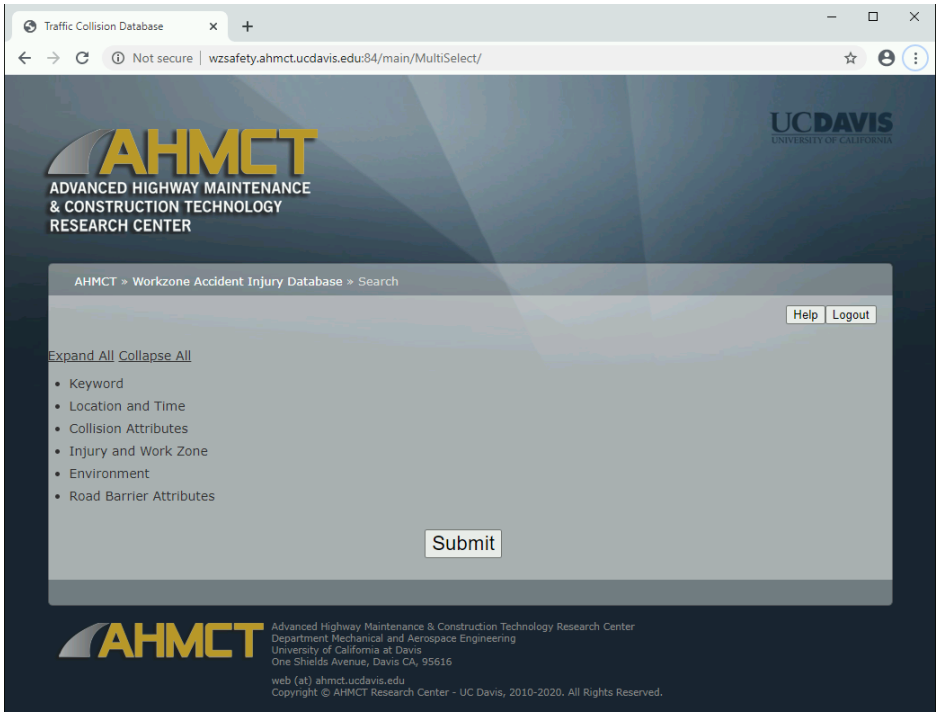
Enter your registered username and password, then click the "Login" button to access the site.

If you don't yet have an account, click "Register" to create one. This will take you to the registration screen.



Using the Search Functionality

After logging in, the website presents the user with the incident search page.

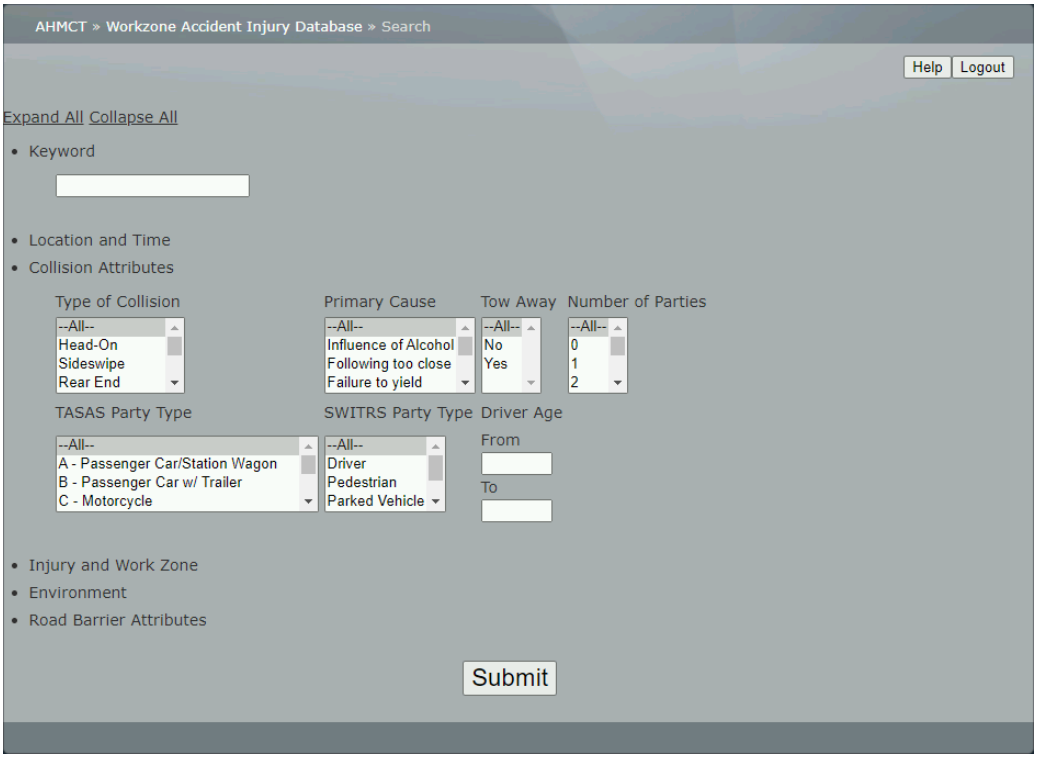


Here, incident searches may be performed using a variety of filters:

- ***Keyword***
  - Shows only the reports having the keyword in their text
- ***Location and time***
  - Date range
  - Caltrans district
  - County
  - Route
  - Year
  - Day of week
- ***Collision Attributes***
  - Type of collision (head-on, rear-end etc.)
  - Primary cause of collision
  - Tow-away
  - Number of involved parties
  - TASAS party type
  - SWITRS party type
  - Driver age range
- ***Injury and Work Zone***
  - Number of injuries
  - Number of fatalities
  - SWITRS crash severity
- ***Environment***
  - Weather conditions
  - Lighting conditions
  - Population code (urban, rural, etc.)
- ***Road attributes***
  - Access type

- Highway type
- Barrier type
- Caltrans road type
- Highway side
- Median type
- Road surface conditions
- Number of lanes

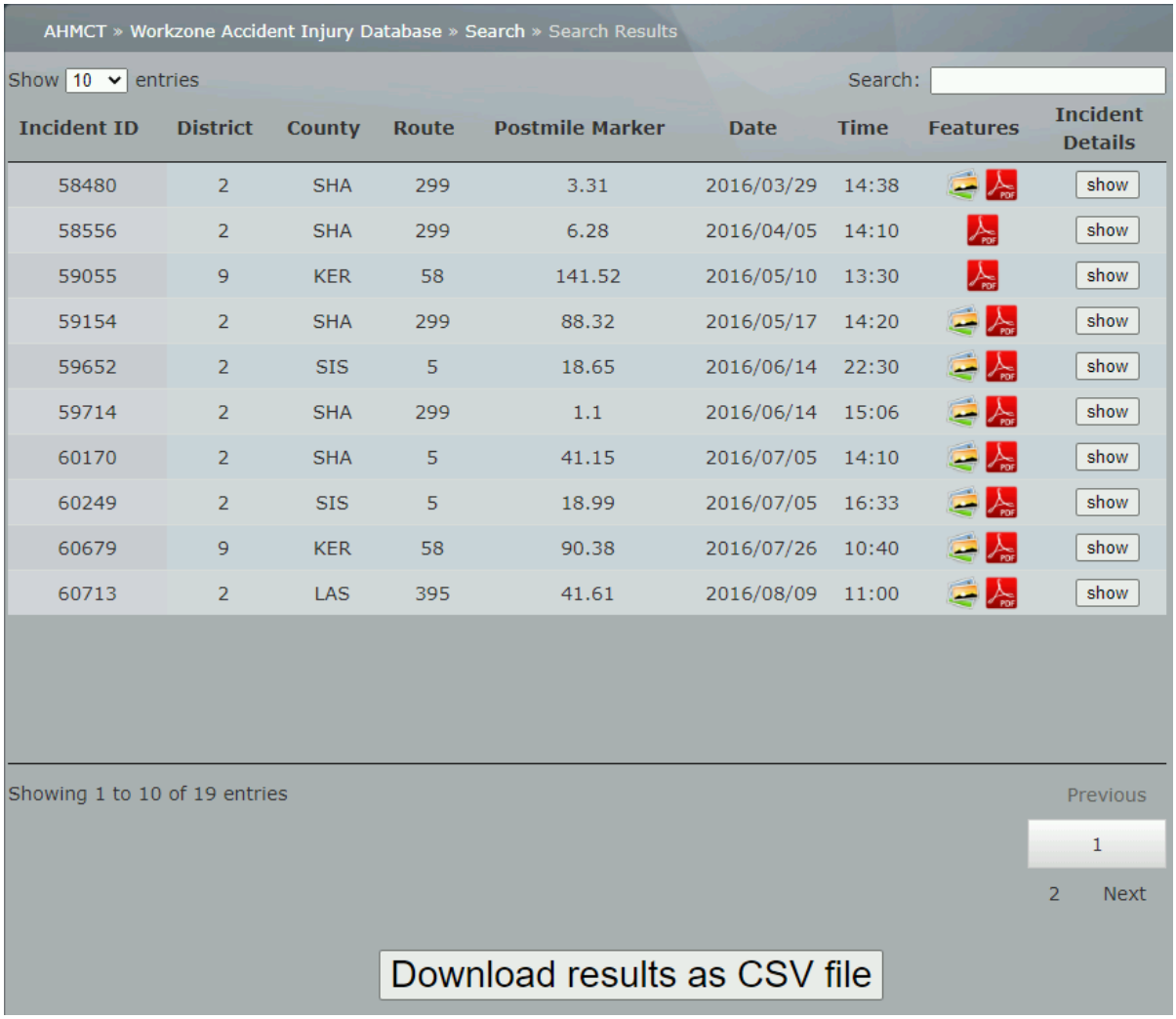
Click on each category name to display the subcategories within it. "Expand All" may also be clicked in order to display all subcategories.



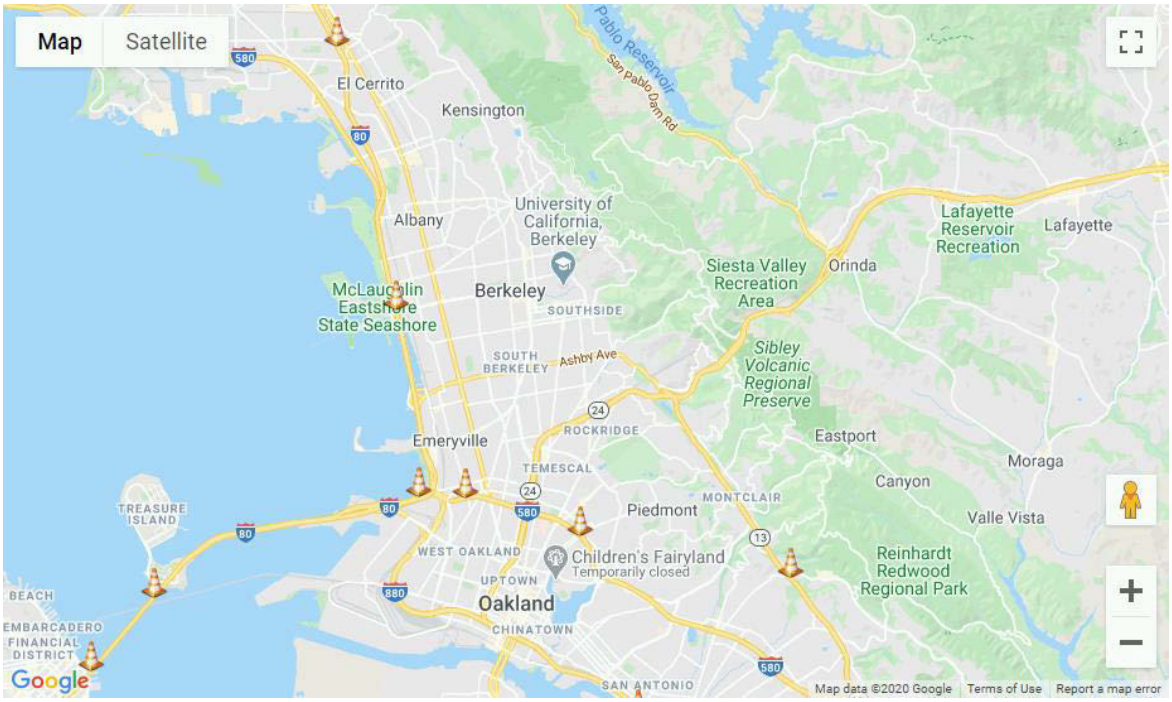
Results Page

After clicking the "Submit" button, a list of all reports that match the search criteria will be displayed. By clicking on each field of the top row of the table, the table contents may be sorted by the corresponding column. The user may also search for any keyword through the table using the "Search" field. In addition, a

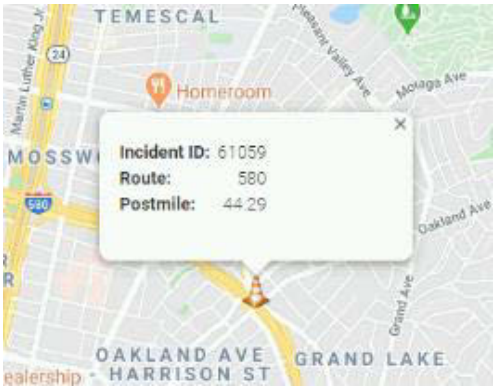
summary of the search results may be downloaded by pressing the "Download results as CSV file" button.



At the bottom of the results page, a clickable map shows the location of all reports in the table. Clicking on each circle shows the reports within that area.



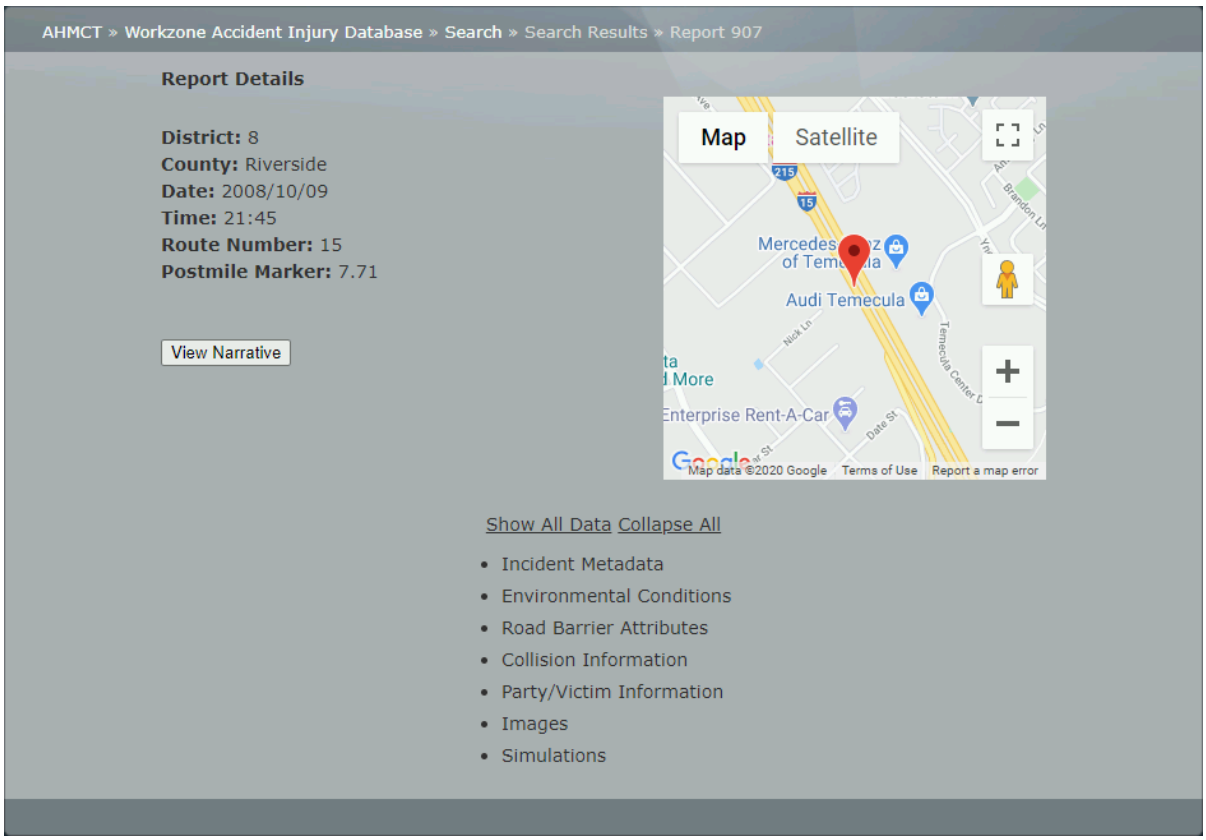
Each traffic cone on the map represents a collision. Clicking on a cone displays the Incident ID, route, and postmile of that collision.



Displaying Report Details

The "Features" column of the table contains icons that indicate whether the database has diagrams, narrative text, or PC crash simulations available for each incident.

Each incident's details may be viewed by clicking on its "show" button. This function will display the incident's details as well as its location on a map. The incident's collision report narrative (if available) may be opened by clicking on the "View Narrative" button.



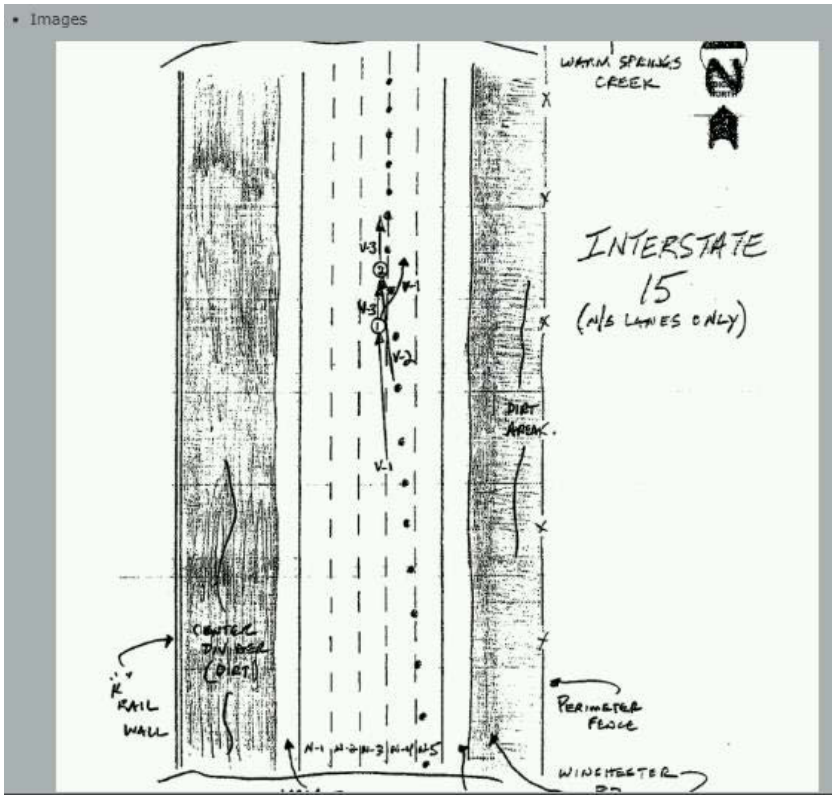
In addition to the general incident information, incident details from the following categories are also displayed:

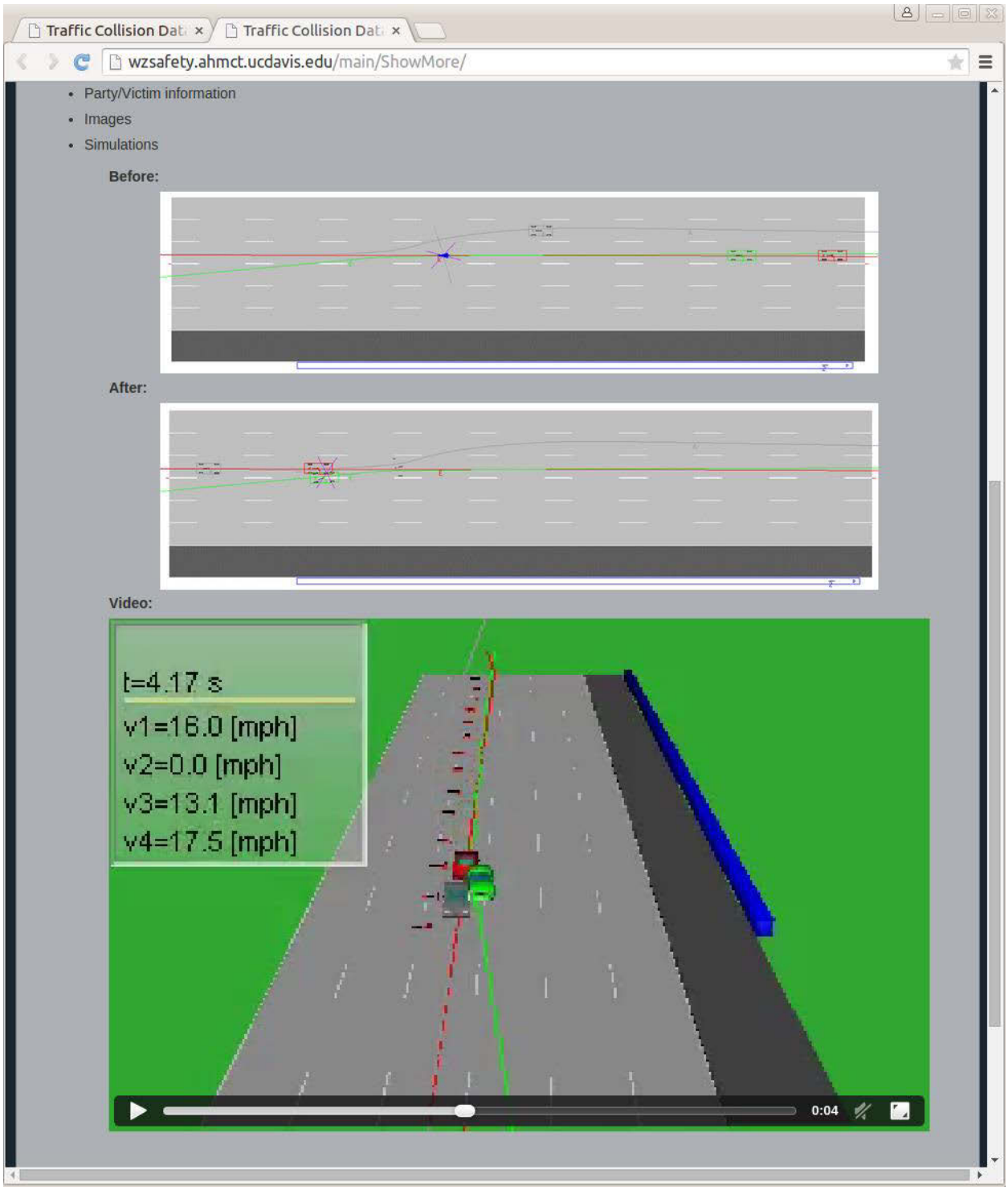
- Incident Metadata
- Environmental conditions

- Road Barrier Attributes
- Collision Information
- Party/Victim Information
- Images
    - Factual and Sketch diagrams from the report (if available)
- Simulations
    - PC crash simulation of the report (if available)

Each category's details may be displayed by clicking the category title. Alternatively, every category's details may be displayed at once by clicking "Show All Data".

See below for example views of the "Images" and "Simulations" categories.




Traffic Collision Dat
Traffic Collision Dat
wzsafety.ahmct.ucdavis.edu/main/ShowMore/
Party/Victim information
Images
Simulations
Before:
After:
Video:
t=4.17 s
v1=16.0 [mph]
v2=0.0 [mph]
v3=13.1 [mph]
v4=17.5 [mph]
0:04