Title

Pedestrian Safety Improvement Program

Permalink
https://escholarship.org/uc/item/2c85n5xt

Authors
Grembek, Offer
Bosman, Crakg
Bigham, John M.
et al.

Publication Date
2014-03-31

Peer reviewed

STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

TECHNICAL REPORT DOCUMENTATION PAGE

TR0003 (REV 10/98)

1. REPORT NUMBER	2. GOVERNMENT ASSOCIATION NUMBER	3. RECIPIENT'S CATALOG NUMBER
CA14-2209		

4. TITLE AND SUBTITLE

Pedestrian Safety Improvement Program

5. REPORT DATE

March 31, 2014

6. PERFORMING ORGANIZATION CODE

7. AUTHOR

Grembek, Bigham, Bosman, Fine, Griswold, Medury, Sanders, Schneider, Yavari, Zhang

8. PERFORMING ORGANIZATION REPORT NO.

UCB-0406

9. PERFORMING ORGANIZATION NAME AND ADDRESS

University of California, Berkeley
Safe Transportation Research & Education Center
2614 Dwight Way, #7374
Berkeley, CA 94720-7374

10. WORK UNIT NUMBER

11. CONTRACT OR GRANT NUMBER

65A0406

12. SPONSORING AGENCY AND ADDRESS

California Department of Transportation
Division of Research, Innovation and System Information, MS-83
1227 O Street
Sacramento CA 95814

13. TYPE OF REPORT AND PERIOD COVERED

Final report

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

The Pedestrian Safety Improvement Program is an effort of the California Department of Transportation (Caltrans) to identify and address systemic problems with regard to pedestrian safety in California, with the long-term goal of substantially reducing pedestrian fatalities and injuries in California. The efforts and findings presented in this report reflect the work of a team of experts in transportation engineering, transportation planning, public health, geographic information systems, and urban design from the UC Berkeley Safe Transportation Research & Education Center.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
Safety, pedestrian, collisions, volumes, hotspots, data, countermeasures, institutionalization	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161

19. SECURITY CLASSIFICATION *(of this report)*	20. NUMBER OF PAGES	21. COST OF REPORT CHARGED
Unclassified	273	N/A

PEDESTRIAN SAFETY IMPROVEMENT PROGRAM

FINAL TECHNICAL REPORT

PREPARED BY THE
UC BERKELEY SAFE TRANSPORTATION RESEARCH AND EDUCATION CENTER
FOR THE
CALIFORNIA DEPARTMENT OF TRANSPORTATION

MARCH 31, 2014

OFFER GREMBEK
CRAIG BOSMAN
JOHN M. BIGHAM
SARA FINE
JULIA B. GRISWOLD
ADITYA MEDURY
REBECCA L. SANDERS
ROBERT J. SCHNEIDER
AFSANEH YAVARI
YUANYUAN ZHANG
DAVID R. RAGLAND

DISCLAIMER STATEMENT

ACKNOWLEDGEMENTS

The authors would like to thank the California Department of Transportation for their support of this project. We especially acknowledge the support and guidance of Brian Alconcel, Richard Haggstrom, Dario Senor, Lucia Saavedra, Dean Samuelson, and Jerry Kwong from Caltrans. We also appreciate the contribution of Nicole Foletta, Meghan Weir, Meghan Mitman, Jill Cooper, Swati Pande, Frank Proulx, Wendy Tang, Yunjae Baek, Grace Felschundneff, and many other who have been involved in this effort.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Introduction

The Pedestrian Safety Improvement Program is an effort of the California Department of Transportation (Caltrans) to identify and address systemic problems with regard to pedestrian safety in California, with the long-term goal of substantially reducing pedestrian fatalities and injuries in California. The efforts and findings presented in this report reflect the work of a team of experts in traffic engineering, transportation planning, public health, geographic information systems, and urban design from the UC Berkeley Safe Transportation Research & Education Center.

The effort is well-timed. Available data indicate that pedestrians are 37 times more vulnerable than the rest of roadway users in California—that is, they suffer 37 times more injuries than they inflict on others. Additionally, while California has seen major gains in traffic safety over the last few years, these gains disproportionately reflect improvements in passenger vehicle safety. For example, while there was a nearly 20% decrease in overall traffic injury from 2006-2011, pedestrian injury declined by only 7%. Similarly, the State saw a 43% decline in passenger vehicle fatalities from 2006-2012, but only a 15% decline in pedestrian fatalities. This imbalance is further carried through investment in pedestrian infrastructure and programs. While over 13% of all trips in California are made on foot, pedestrians continue to receive less than 2% of the transportation budget. Thus, pedestrians need more protection and investment but receive less of both than motorized users.

This report represents an effort to provide the knowledge and identify the resources needed to address this imbalance between pedestrians and motorized roadway users in California. The approach presented here is intentionally pragmatic, aiming not for an ideal plan, but for one that can help Caltrans and the State make gradual progress toward goals to improve pedestrian safety in California.

Key Components

The report is divided into ten chapters that describe the overall project and findings. The Introduction elaborates on the purpose and background of the project. The next three chapters examine pedestrian safety from a higher level:

Chapter 1 – Data Access describes the rich collision data to which Caltrans has access, and give Caltrans better access to the data in multiple forms.

Chapter 2 – Pedestrian Volume and Infrastructure explores the importance of pedestrian exposure data to understanding true collision risk, and presents a pilot model to estimate pedestrian exposure data for the state highway system.

Chapter 3 – Data Evaluation examines the macro-level data pertaining to pedestrian collisions and trip patterns at the State level, and presents the data in an easily-digestible “pedestrian report card” that can be disseminated to stakeholders as a snapshot of pedestrian safety in California.

The next five chapters build upon one another for a more focused approach toward examining pedestrian safety.

Chapter 4 – Hazard Assessment explores both systemic analysis and hotspot identification, and proposes a new approach for identifying particularly hazardous places (i.e., hotspots) on the state highway system.

Chapter 5 – Countermeasure Selection presents a comprehensive analysis of pedestrian collision characteristics and explores methods for choosing various countermeasures to address issues with pedestrian safety.

Chapter 6 – Economic Appraisal proposes a manner of prioritizing countermeasures through cost-benefit analysis.

Chapter 7 – Funding Sources and Strategies discusses the various funding sources available to implement countermeasures and programs to improve pedestrian safety, and presents results from a survey of the Pedestrian Coordinators for each Caltrans district.

Chapter 8- Institutionalization discusses the people working on pedestrian safety in California and how they might benefit from the findings of the PSIP.

The Conclusion summarizes the findings and discusses the policy implications for Caltrans in the short- and long-term. It also proposes future research to help Caltrans further its progress toward increasing pedestrian safety.

Overall, this report represents a tremendous amount of analysis and exploration of pedestrian safety in California. It is hoped that this analysis will provide Caltrans and stakeholders with the information they need to address current challenges and develop plans to continue progress in the future.

INTRODUCTION

What is the PSIP?

The Pedestrian Safety Improvement Program is an effort of the California Department of Transportation (Caltrans) to identify and address challenges with regard to pedestrian safety in California, with the long-term goal of substantially reducing pedestrian fatalities and injuries in California. This report represents an effort to provide foundational knowledge and identify the resources needed to address the imbalance between pedestrian needs and pedestrian safety in California. The approach presented here is intentionally pragmatic, aiming not for an ideal plan, but for one that can help Caltrans and the State make gradual but concrete progress toward goals to improve pedestrian safety in California.

Importance of the PSIP

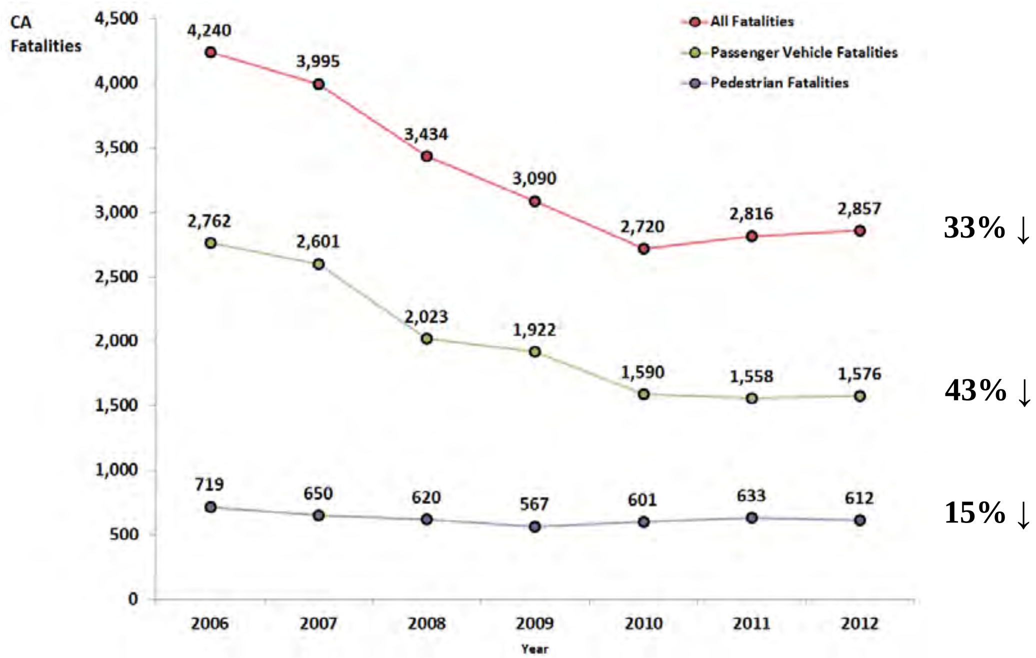
The PSIP effort is well-timed. As Figure I-1 displays, available collision data indicate that from 2005-2009, pedestrians in California suffered 40,202 injuries, but only inflicted 1,088 injuries on other roadway users. The resulting relative vulnerability score from these numbers (40,202 / 1,088) is 37—that is, pedestrians suffer 37 times more injuries than they inflict on others (Grembek, 2010). In contrast, passenger vehicles suffer 432,822 injuries and inflict 352,269 injuries on others, for a relative vulnerability score of 1.2.

Figure I-1. Relative Vulnerability Matrix for Collisions in California

Injury crashes in California (2005-2009)		Mode *j* Inflicted an injury								
		Foot	Bicycle	PTW	Car	Transit	SUV	Truck	Object	Total
Mode *i* Suffered an injury	Foot	31	488	327	32,455	631	5,736	531	3	**40,202**
	Bicycle	195	1,551	213	28,657	320	4,833	397	1,655	**37,821**
	PTW	159	106	4,847	21,036	118	4,199	647	8,864	**39,976**
	Car	607	331	2,814	221,444	2,655	76,543	18,323	110,105	**432,822**
	Transit	28	15	10	2,829	578	596	347	474	**4,877**
	SUV	66	46	332	43,543	330	23,403	3,262	19,213	**90,195**
	Truck	2	5	18	2,305	58	578	1,638	1,663	**6,267**
	Object	0	0	0	0	0	0	0	0	**0**
	Total	**1,088**	**2,542**	**8,561**	**352,269**	**4,690**	**115,888**	**25,145**	**141,977**	**652,160**

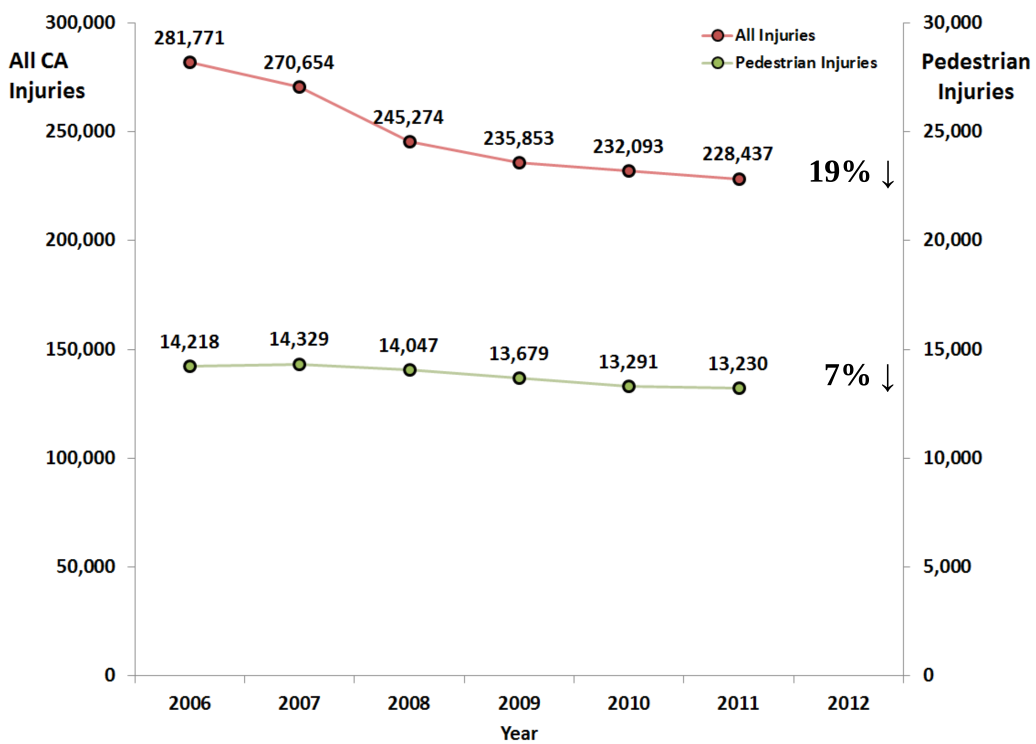
Additionally, while California has seen major gains in traffic safety over the last few years, these gains disproportionately reflect improvements in passenger vehicle safety. As Figure I-2 shows, the State experienced a 43% decline in passenger vehicle fatalities from 2006-2012, but only a 15% decline in pedestrian fatalities.

Figure I-2. Pedestrian Fatalities on Slow Decline Compared to Passenger Vehicles



The trend was similar for injuries, as displayed in Figure I-3. While there was a 19% decrease in overall traffic injury from 2006-2011, pedestrian injury declined by only 7%.

Figure I-3. Pedestrian Injuries on Slow Decline Compared to Passenger Vehicles



This imbalance is further carried through investment in pedestrian infrastructure and programs. While over 13% of all trips in California are made on foot, pedestrians continue to receive less than 2% of the transportation budget (National Household Travel Survey, 2009; FHWA, 2012). Thus, pedestrians need more protection and investment than motorized roadway users, but receive less of both.

Additionally, this focus on improved pedestrian safety in California dovetails well with efforts already underway. For example, Challenge Area 8 of the Strategic Highway Safety Plan has worked for several years to represent the needs of pedestrians at the State level and to develop achievable goals for improved pedestrian safety. Furthermore, Caltrans recently underwent an external evaluation by the State Smart Transportation Initiative (SSTI) to understand how it can improve its performance going forward. While rightly pointing out the leadership Caltrans has displayed in the past, the SSTI report also highlighted the need for Caltrans to modify its efforts and programming to better reflect statewide goals of improved safety and mobility for non-motorized modes (SSTI, 2014). The PSIP effort shows that Caltrans has already made progress in this direction, and provides avenues to further the progress through suggested future research.

Chapter Organization & Summary of Findings

This *Introduction* is followed by eight substantive chapters that describe the project findings. Chapters 1-3 examine pedestrian safety from a higher level, while Chapters 4-8 build upon the broader foundation, as well as one another, for a more focused approach toward examining pedestrian safety. Following is a brief description of the chapter efforts:

Chapter 1 – Data Access describes the rich collision data to which Caltrans has access and proposes a system to connect data sources that are currently administratively burdensome to combine. The result of Chapter 1 is an Excel spreadsheet that can be generated from TSAR and into which injury severity can be populated—a key capability needed to satisfy MAP-21 funding requirements.

Chapter 2 – Pedestrian Volume and Infrastructure explores the importance of exposure data to understanding true collision risk, and presents a pilot model to estimate pedestrian exposure data for the state highway system. Additionally, Chapter 2 proposes a protocol for generating infrastructure data on a large scale.

Chapter 3 – Data Evaluation examines the macro-level data pertaining to pedestrian collisions and trip patterns at the State level, and presents the data in an easily-digestible “pedestrian report card” that can be disseminated to stakeholders as a snapshot of pedestrian safety on an annual basis and over time in California.

Chapter 4 – Hazard Assessment explores both systemic analysis and hotspot identification, and proposes a new approach for identifying particularly hazardous places (i.e., hotspots) on the state highway system.

Chapter 5 – Countermeasure Selection comprehensively examines pedestrian collisions to determine common characteristics, and then explores methods for choosing various countermeasures to address issues with pedestrian safety. The chapter concludes with suggestions about potential countermeasures.

Chapter 6 – Economic Appraisal evaluates attributes of countermeasures and proposes a manner of prioritizing them through cost-benefit analysis.

Chapter 7 – Funding Sources and Strategies discusses the various funding sources available to implement countermeasures and programs to improve pedestrian safety. The chapter also presents the results of a survey of Pedestrian Coordinators throughout the Caltrans system and their opinions on funding challenges particular to pedestrian safety efforts.

Chapter 8- Institutionalization discusses the people working on pedestrian safety in California and how they might benefit from the findings of the PSIP. The chapter includes information about the pedestrian materials currently available to Caltrans, gaps in the training materials, and recommendations for how to fill the gaps.

The *Conclusion* summarizes the findings and discusses next steps for Caltrans in the short- and long-term.

1 Expansion of Data Access

A common theme expressed by local agencies and Caltrans personnel seeking to address pedestrian safety issues is the need for better access to data. SHSP Challenge Area 8 calls for data to be in a "readily available format for local research and investigation," yet that has frequently not been the case in the past. Recent efforts by SafeTREC to develop the Transportation Injury Mapping System (TIMS) have helped bridge the gap through tools to query and map SWITRS collision data. However, TIMS still needed more focus on pedestrian related data and also did not provide a means for Caltrans personnel to review their TASAS database. The goal of this task was to improve the accessibility and usability of pedestrian collision data for both Caltrans personnel and local agencies.

1.1 TASAS Pedestrian Monitoring Report Tool

The Traffic Accident Surveillance and Analysis System (TASAS) is used by Caltrans to analyze collision, traffic, and highway data for California. A report called "Table C" is prepared quarterly by Caltrans to identify high collision concentration locations on the State Highway System (SHS) using TASAS data. However, it does not focus on pedestrian collisions, and high concentrations of pedestrian collisions are usually not identified in Table C. To identify pedestrian collision clusters, locations must be determined by manually viewing an output of the TASAS database known as the TASAS Selective Accident Retrieval (TSAR). A TSAR Accident Detail report provides a list of accidents on a section of highway/ramp/
intersection (see example in Figure 1-1), but includes very limited capabilities to explore the data. Moreover, a TSAR report cannot be imported into an Excel spreadsheet for further analysis.

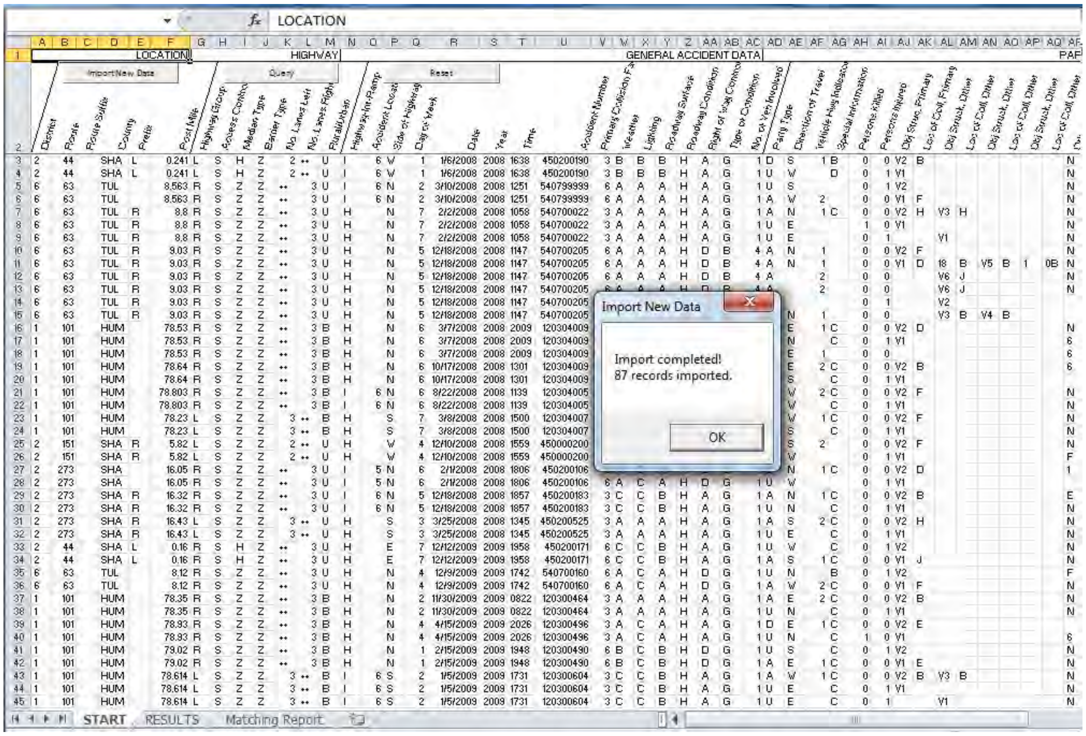
Figure 1-1. Example TSAR Accident Detail Report*

```
TSAR - ACCIDENT DETAIL

 REPORT PARAMETERS:                                               Total Accidents Retrieved:

       REPORT DATE      :  MM/DD/YYYY                                     736
       REFERENCE DATE   :  MM/DD/YYYY

       SUBMITTOR        :  XXXXXX

       REPORT TITLE     :  ST fatal/injury accidents involving
       EVENT ID         :  ped/dismounted ped for year YYYY on
                           conventional highways
                           NNNNNNN
 LOCATION CRITERIA:

     STATEWIDE


 SELECTION CRITERIA:

     1 1 AND 600 - PARTY TYPE IN U,V
     1 2 AND 110 - SEVERITY IN F,I
     1 3 AND 242 - ACCESS CONTROL = C


 Accidents Date Range:

    From -- MM/DD/YYYY               To -- MM/DD/YYYY
♀
OTM22200                                     TASAS SELECTIVE RECORD RETRIEVAL                                Page 1
MM/DD/YYYY                                        TSAR - ACCIDENT DETAIL
04:01 PM             ST fatal/injury accidents involving ped/dismounted ped for year YYYY on conventional


                          -------HIGHWAY--- I S D ACCIDENT       COMMON    P ENVIR   R T NO     D V S PERSO O L O L O L O L OA M SD
   RTES       P           H A M B LANES R F R O A DATE      TIME ACCIDENT  C COND  R W O MTR P I H I  K  I S O S O S O S O  F O  P
      U       R POST      G C T A LT RT U T L H Y MM-DD-YY HHMM NUMBER    F W L S C C C VEH T R I        P C O C O C O C 12 V 12
  DI NO F CO  E MILE

  12 00X  ORA  00X.860 D C G Z 02 02 U H   N 6 MM-DD-YY 1929 NNNNNNNNN 6 A C A H A G 01  A N 1 C 00 00 V2F --- --- --- 3< 2 A<
                                                                                        U E - C 00 01 V1- --- --- --- E< 2 D<

  12 00X  ORA  00X.860 D C G Z 02 02 U H   S 3 MM-DD-YY 2222 NNNNNNNNN 1 A C A H A G 01  A S 1 < 00 00 V2D --- --- --- 3< 2 B<
                                                                                        U W - < 00 01 V1- --- --- --- N< 2 A<

  12 00X  ORA  00X.860 D C G Z 02 02 U H   N 3 MM-DD-YY 2033 NNNNNNNNN 3 A C A H A G 01  A N 1 C 00 00 V2D V3D --- --- E< 2 A<
                                                                                        U E - D 01 00 V1- --- --- --- N< 2 G<
                                                                                        U E - D 00 01 --- V1- --- --- N< 2 G<

  12 00X  ORA  00X.501 U C B Z 02 02 U I 6 N 7 MM-DD-YY 0902 NNNNNNNNN D B A A H A G 01  A W 2 C 00 00 V2F --- --- --- N< 2 A<
                                                                                        U S - D 00 01 V1- --- --- --- N< 2 A<

  12 00X  ORA  00X.620 U C B Z 02 02 U H   S 7 MM-DD-YY 0144 NNNNNNNNN 5 A C A H D G 01  M S 1 D 00 00 V2F --- --- --- F< 5 G<
                                                                                        U < - C 00 01 V1- --- --- --- << 5 <<

  12 00X  ORA  00X.720 U C B Z 02 02 U H   N 1 MM-DD-YY 1310 NNNNNNNNN 6 A A A H D G 01  A N 1 C 00 00 V2D --- --- --- << 2 A<
                                                                                        U W - C 00 01 V1- --- --- --- << 2 A<

  12 00X  ORA  00X.430 D C G Z 02 02 U H   S 7 MM-DD-YY 1848 NNNNNNNNN C A A A H A C 04  A S 1 < 00 00 V2D V3D --- --- N< 2 A<
                                                                                        A S 1 < 00 01 V1F --- --- --- N< 2 A<
                                                                                        A S 1 < 00 00 --- V1D V4D --- N< 2 A<
                                                                                        A S 1 C 00 00 --- V3D V5D --- N< 2 A<
                                                                                        U E - C 00 01 --- V4- --- --- N< 2 A<

  12 00X  ORA  0XX.420 D C G Z 02 02 U H   N 5 MM-DD-YY 1000 NNNNNNNNN 6 A A A H D G 01  A N 1 C 00 00 V2F --- --- --- F< 5 A<
                                                                                        U N - C 00 01 V1- --- --- --- N< 5 A<
```

*Note that the time and location of the collisions have been removed from this example report.

To facilitate examination of pedestrian collision data, the SafeTREC team developed an Excel-based tool to directly import TSAR Accident Detail files. This Pedestrian Safety Monitoring Report (PSMR) tool can import TSAR data into an easily managed spreadsheet. An example of data that has been imported into the tool is shown in Figure 1-2.

Figure 1-2. Example of TSAR data imported into the PSMR tool



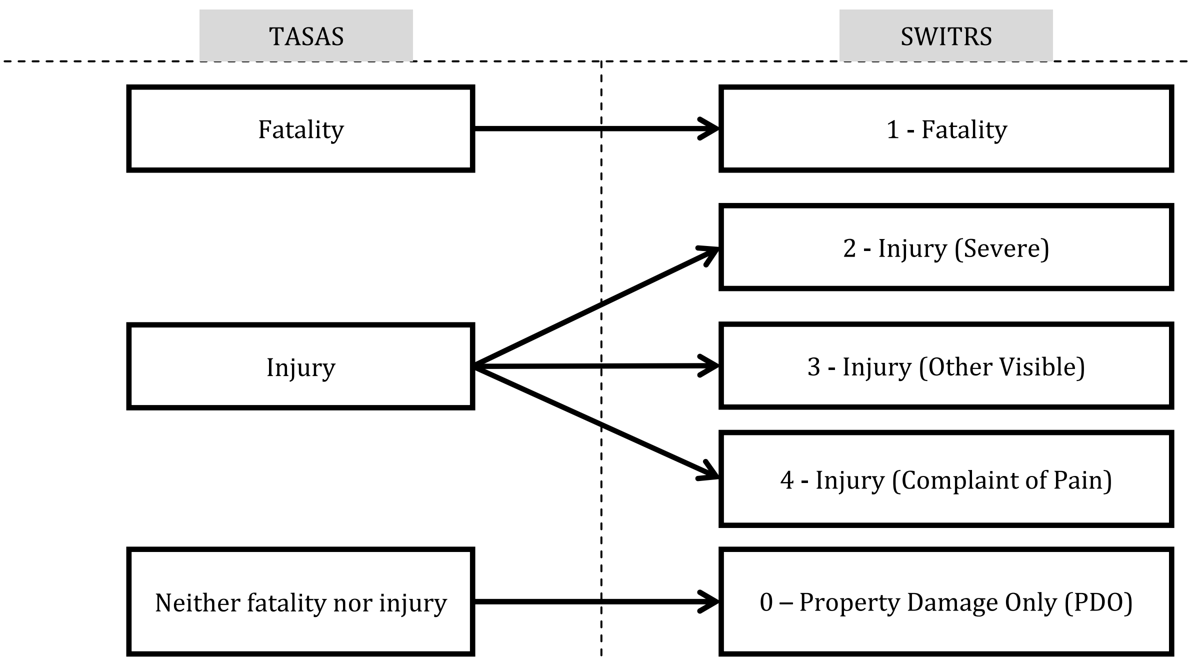
The data importing features of the tool allow a Caltrans District Coordinator to work more efficiently with TSAR data. However, moving forward within the guidelines of MAP-21, any future analyses will likely need to focus on a specific set of injury level collisions: fatal and severe injury. This cannot be done using the TASAS database since collision severity is a simplified aggregate value without any way to differentiate the injury levels. In preparation for this scenario, the second part of the tool development focused on a methodology for linking TASAS records to collision records from the Statewide Integrated Traffic Records System (SWITRS), which include the desired differentiation in injury severity. This process is detailed in the next section.

1.1.1 TASAS-SWITRS Matching

The SWITRS database is maintained by the California Highway Patrol (CHP) and contains all police-reported injury collisions in the state. SWITRS collisions on state highways are reviewed by Caltrans personnel and assigned specific location information such as the postmile, route number, etc. Those collisions are subsequently extracted by Caltrans for incorporation into the TASAS database, but many of the fields in SWITRS are not retained in TASAS. A prime example is the difference in collision injury levels available in the two databases.

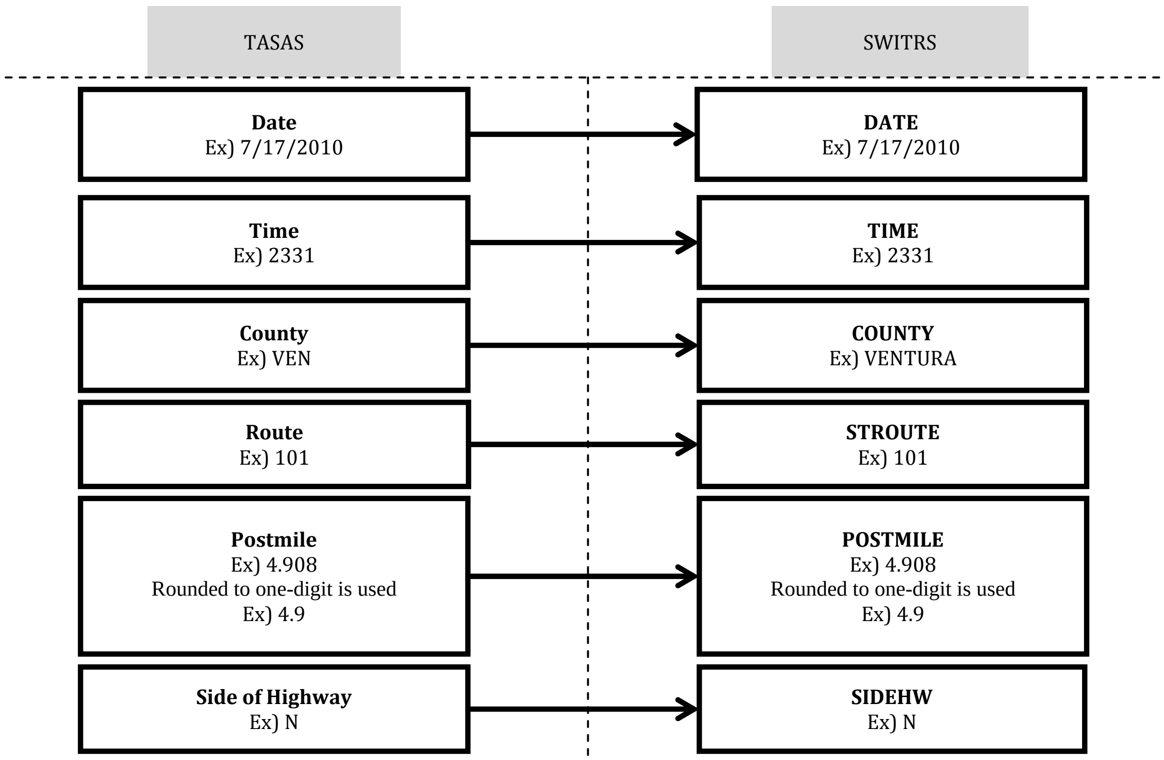
SWITRS collisions are assigned one of five injury levels: fatal, severe injury, other visible injury, complaint of pain, and property damage only (no injury). TASAS records Fatal, Injury or Non-Injury. Figure 1-3 shows how the injury levels match between the two databases.

Figure 1-3. Severity Level Match Between TASAS and SWITRS



Since TASAS records are derived from SWITRS, a probabilistic match can be made based on fields common to both databases. This will allow the exact injury level or any other fields available in SWITRS to be extracted for a TASAS record. The common fields used to match databases are: date, time, county, route number, postmile value, and side of highway. Figure 1-4 shows an example of those fields within TASAS and SWITRS.

Figure 1-4. Example Fields Used for Matching



Using the proposed attributes for matching, the SafeTREC team evaluated a sample of pedestrian-related collisions and then all collisions in District 4. Table 1-1 shows the matching result of all pedestrian collisions over 6 years: out of 5,688 collisions, there were 5,685 matches between SWITRS and TASAS, an accuracy rate of 99.95%.

Table 1-1. Matching Results of Pedestrian Collisions Statewide From 2005 to 2010

Year	Collisions	Duplicate	Non-Matched
2005	1,246	0	3
2006	1,076	0	0
2007	899	0	0
2008	880	0	0
2009	822	0	0
2010	765	1	0
Total	5,688	1	3

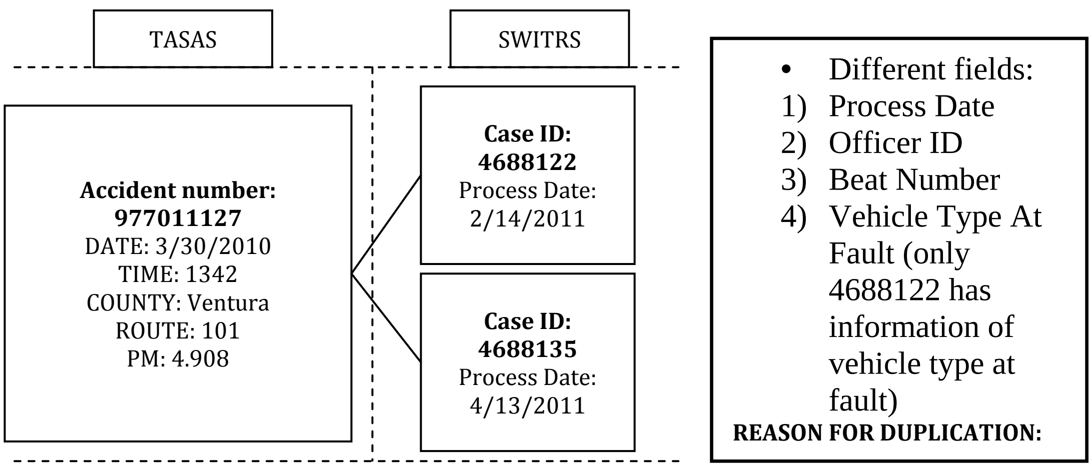
Table 1-2 shows the matching percentages of injury collisions occurring in District 4 over a four-year period. Once again, the match rate was extremely high at 35,283 out of 35,514 collisions (99.35%) matched.

Table 1-2. Matching Results in District 4 Collisions Between 2005 and 2008

Year	Collisions	Duplicate	Non-Matched
2005	9,737	4	81
2006	9,064	2	67
2007	9,141	0	58
2008	8,353	0	25
Total	35,514	6	231

The rare cases of unmatched records were further investigated and categorized as duplicates or non-matched. An example of a duplicate record that appears to have been caused by multiple officers entering the same SWITRS record is shown in Figure 1-5.

Figure 1-5. Duplicate Match



The other cases where records simply did not match are most likely due to the fact that Caltrans updates TASAS records over time while SWITRS remains unchanged. In those cases the attributes that were used for matching may no longer sync and therefore the records would be excluded from any hotspot analysis.

Due to the success rate of the matching, it is viable to include SWITRS collision severity in the PSMR tool. Figure 1-6 shows the option and injury severity levels available in the tool. Figure 1-7 shows the output from a query that used only severe injuries and fatalities. If all injuries or only fatalities had been used, the number of results would likely be higher or lower. Being able to query by SWITRS injury severities gives greater specificity to collision investigations.

Figure 1-6. Collision Severity Selection Feature in Tool

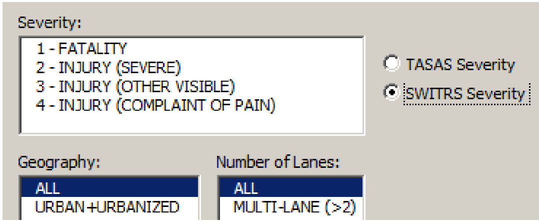
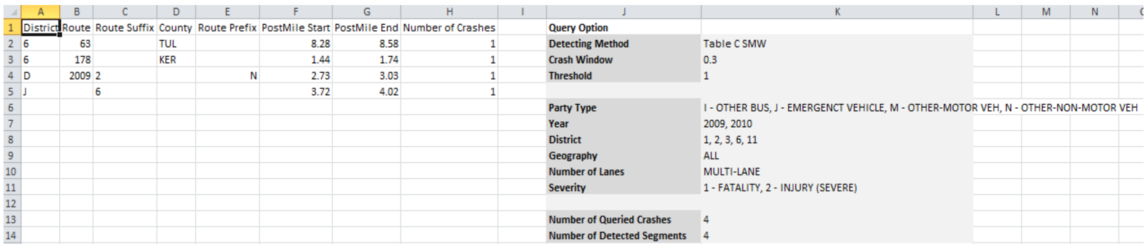


Figure 1-7. A Sample Result from a Query Involving SWITRS Severity Level



	A	B	C	D	E	F	G	H	I	J	K
1	District	Route	Route Suffix	County	Route Prefix	PostMile Start	PostMile End	Number of Crashes		Query Option	
2	6	63		TUL		8.28	8.58	1		Detecting Method	Table C SMW
3	6	178		KER		1.44	1.74	1		Crash Window	0.3
4	D	2009	2		N	2.73	3.03	1		Threshold	1
5	J		6			3.72	4.02	1			
6										Party Type	I - OTHER BUS, J - EMERGENCT VEHICLE, M - OTHER-MOTOR VEH, N - OTHER-NON-MOTOR VEH
7										Year	2009, 2010
8										District	1, 2, 3, 6, 11
9										Geography	ALL
10										Number of Lanes	MULTI-LANE
11										Severity	1 - FATALITY, 2 - INJURY (SEVERE)
12											
13										Number of Queried Crashes	4
14										Number of Detected Segments	4

By default the SWITRS matching options are not activated and only the data imported from the TSAR file is used. The tool was designed in this way because the SWITRS matching requires that optional SWITRS data files are included in the working folder and those files may not be distributed. This will allow all Caltrans users a seamless experience regardless of whether SWITRS files are present. A step-by-step tutorial for importing TSAR data and using the SWITRS matching in this tool is provided in Appendix 1-A.

A separate feature of the PSMR tool gives the ability for Caltrans Headquarters to analyze the data and search for potential pedestrian collision hotspots. The tool gives the user the option to select a hotspot detection method (e.g., sliding window method) and a specific collision window size and threshold for the number of collisions. A more detailed description of the available detection methods and a comparative analysis of these are described in Chapter 4 – Hotspot Identification Algorithm.

A final aspect of the TASAS-SWITRS matching ability goes beyond simply including SWITRS fields within the PSMR tool. Having a unique SWITRS case ID means that the collisions can be accessed from within the publicly available TIMS mapping applications. This feature and other pedestrian collision-related functionalities in TIMS are discussed in the next section.

1.2 TIMS Pedestrian Data Access

While SWITRS collision data has always been publicly available, it has not been provided in a simple format that could also be utilized in web mapping tools. TIMS changed that by mapping the data and building tools for traffic safety-related research, policy, and planning. The site has now become a central hub for working with and visualizing collision data in California. Many of the tools can be applied to pedestrian safety research and new tools developed during the course of this research project have targeted pedestrian data components.

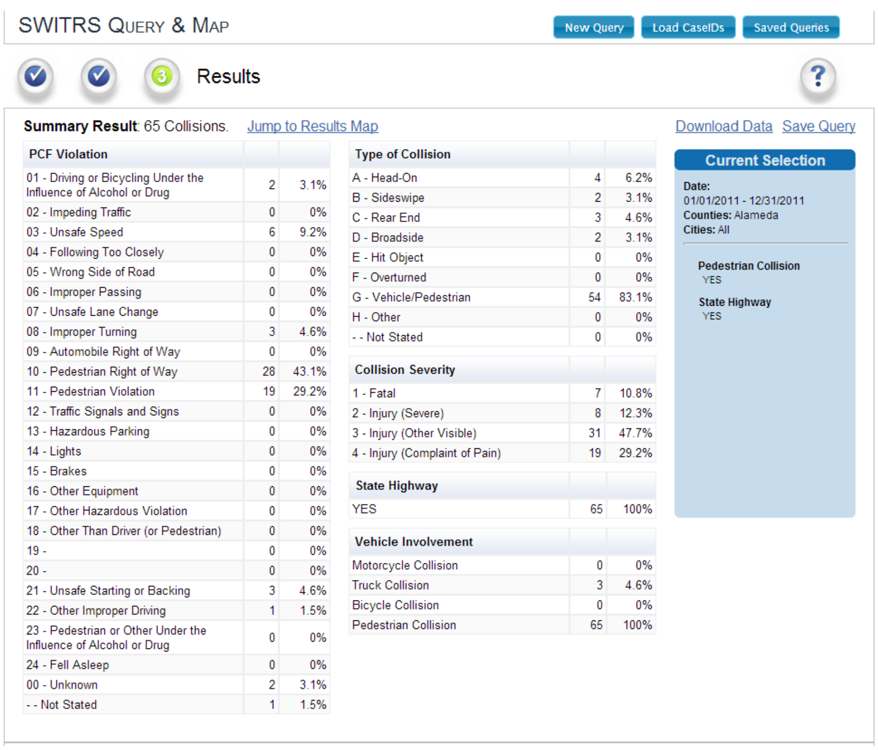
To access the tools on TIMS, a free account is required and can be registered on the home page: http://tims.berkeley.edu. The following sections describe the two main mapping tools in TIMS, as well as additional TIMS functionalities. These tools may be directly accessed via: http://tims.berkeley.edu/page.php?page=tools.

1.2.1 SWITRS Query & Map

The SWITRS Query & Map is one of the two main collision data query and mapping tools in TIMS. Although the tool provides access to all types of collisions, users can easily restrict queries to pedestrian collisions on state highways. Users can also restrict data by time frame, location, and other collision factors to produce a subset table from SWITRS. The associated collision, party and victim data files can be downloaded.

The SWITRS Query & Map provides a simple interface to build queries and display a results summary page with an interactive Google Maps™ map view. The summary page breaks the results down by primary collision factor, collision type, collision severity, and involvement with pedestrians, motorcycles, bicycles or trucks. An example set of results is shown in Figure 1-7.

Figure 1-7. A Sample Result of Pedestrian State Highway Collisions



SWITRS QUERY & MAP

New Query | Load CaseIDs | Saved Queries

Results

Summary Result: 65 Collisions. Jump to Results Map

Download Data Save Query

PCF Violation		
01 - Driving or Bicycling Under the Influence of Alcohol or Drug	2	3.1%
02 - Impeding Traffic	0	0%
03 - Unsafe Speed	6	9.2%
04 - Following Too Closely	0	0%
05 - Wrong Side of Road	0	0%
06 - Improper Passing	0	0%
07 - Unsafe Lane Change	0	0%
08 - Improper Turning	3	4.6%
09 - Automobile Right of Way	0	0%
10 - Pedestrian Right of Way	28	43.1%
11 - Pedestrian Violation	19	29.2%
12 - Traffic Signals and Signs	0	0%
13 - Hazardous Parking	0	0%
14 - Lights	0	0%
15 - Brakes	0	0%
16 - Other Equipment	0	0%
17 - Other Hazardous Violation	0	0%
18 - Other Than Driver (or Pedestrian)	0	0%
19 -	0	0%
20 -	0	0%
21 - Unsafe Starting or Backing	3	4.6%
22 - Other Improper Driving	1	1.5%
23 - Pedestrian or Other Under the Influence of Alcohol or Drug	0	0%
24 - Fell Asleep	0	0%
00 - Unknown	2	3.1%
- - Not Stated	1	1.5%

Type of Collision		
A - Head-On	4	6.2%
B - Sideswipe	2	3.1%
C - Rear End	3	4.6%
D - Broadside	2	3.1%
E - Hit Object	0	0%
F - Overturned	0	0%
G - Vehicle/Pedestrian	54	83.1%
H - Other	0	0%
- - Not Stated	0	0%

Collision Severity		
1 - Fatal	7	10.8%
2 - Injury (Severe)	8	12.3%
3 - Injury (Other Visible)	31	47.7%
4 - Injury (Complaint of Pain)	19	29.2%

State Highway		
YES	65	100%

Vehicle Involvement		
Motorcycle Collision	0	0%
Truck Collision	3	4.6%
Bicycle Collision	0	0%
Pedestrian Collision	65	100%

Current Selection

Date: 01/01/2011 - 12/31/2011
Counties: Alameda
Cities: All

Pedestrian Collision YES

State Highway YES

The map shown in Figure 1-8 displays pins that each represent multiple collisions. As the user zooms individual collision markers will appear instead of the cluster pins. By clicking on individual collisions in the map, a collision profile page can be displayed that shows basic details and an interactive Google Street View (Figure 1-9). The user can also create a heatmap to show a continuous distribution of collision concentrations.

Finally, all the collisions can be exported to a Google KML file that can easily be shared with others and viewed in Google Earth.

Figure 1-8. A Sample Result Map of Pedestrian State Highway Collisions

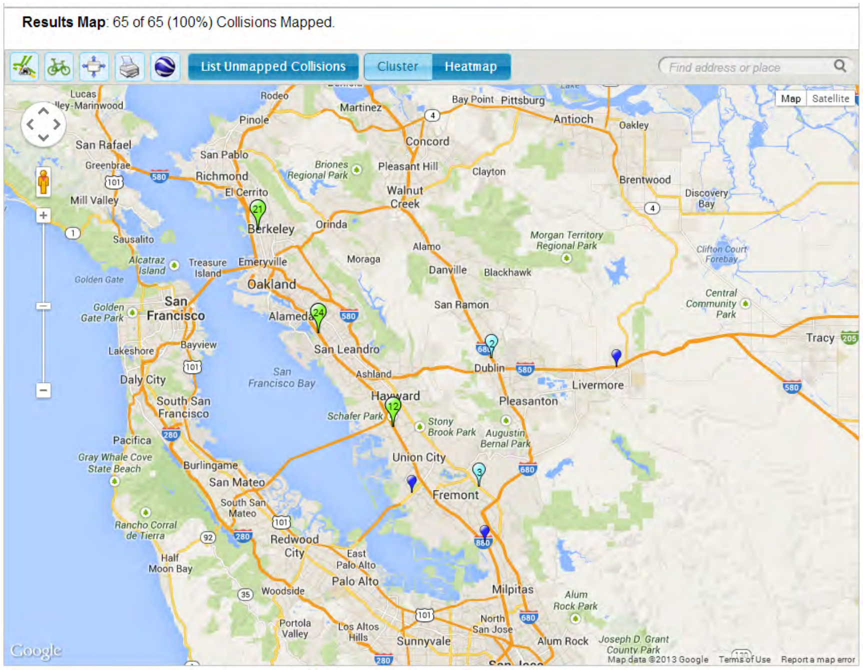
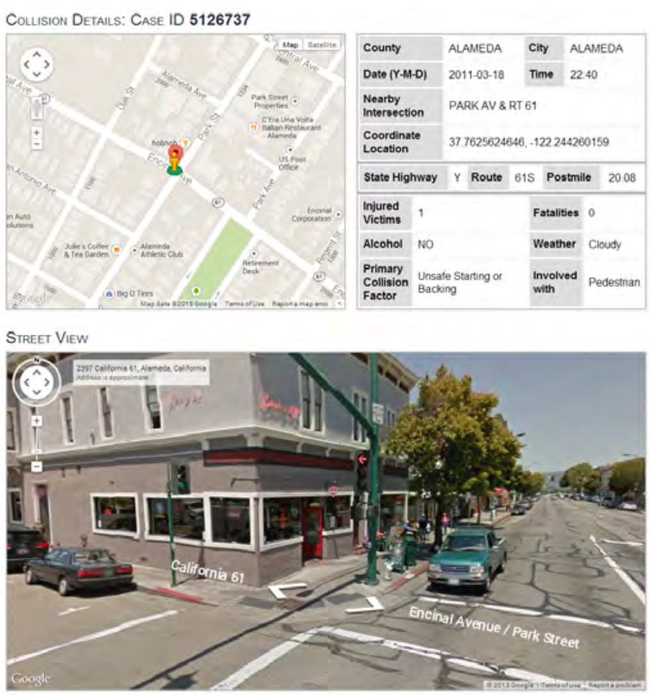


Figure 1-9. A Sample Collision Profile Page

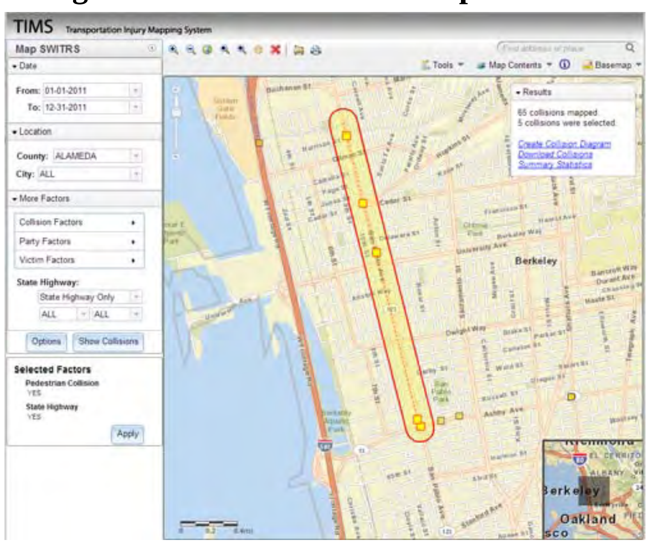


A final feature of the SWITRS Query & Map tool is the ability to load a specific SWITRS Case ID. This allows a Caltrans user who may have obtained a SWITRS ID from the TASAS-SWITRS matching feature in the PSMR tool to directly link to the collision in TIMS. This would enable all the fields from the collision, party or victim files for the collision to be downloaded. It would also allow the collision profile page such as the one shown in Figure 1-9 to be accessed to quickly explore the details and Street View. In the future, it would even be possible to directly hyperlink to the collision profile page from a record in the PSMR tool. This means that by simply matching TASAS records to their original SWITRS collision, Caltrans users could benefit from a fully interactive mapping and summary tool without any needed integration of internal data systems.

1.2.2 SWITRS GIS Map

The SWITRS GIS Map is the second mapping tool in TIMS, with a more map-centric focus to complement the SWITRS Query & Map. The SWITRS GIS Map has the same ability to query and download collision data, but also gives more functionality for users when interacting with the map. The SWITRS GIS Map allows spatial queries (i.e. selecting all collisions along a corridor by drawing on the map), gives different collision symbolization options and has other types of layers to display on the map (i.e. census tracts, public schools, traffic analysis zones). Figure 1-10 shows an example screenshot of the interface.

Figure 1-10. SWITRS GIS Map interface



Although the SWITRS GIS Map does not have the ability to directly load an individual SWITRS collision by Case ID, it does give more advanced users the ability to narrow queries to specific intersections or corridors. Therefore, the SWITRS GIS Map and SWITRS Query & Map tools have complementary functions to serve most users' needs. Other tools in TIMS provide a more direct pedestrian collision focus and are detailed next.

1.2.3 Safe Routes to School Collision Map Viewer

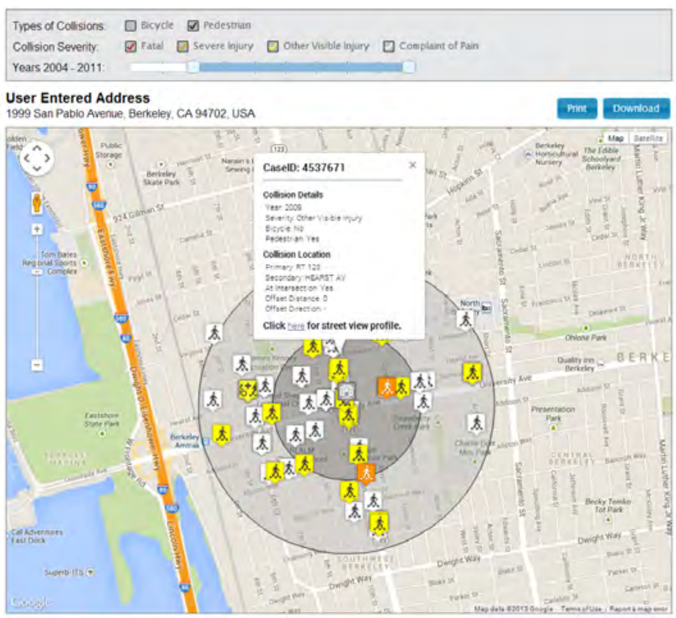
SafeTREC has worked closely with the Caltrans Division of Local Assistance (DLA) during the past several years developing tools to help guide evidence-based distribution of funds by Caltrans through the Highway Safety Improvement Program (HSIP). Many of the applications through the program focus on Safe Routes to School or Active

Transportation projects to reduce pedestrian related collisions. However, many applicants exploring collision data through TIMS desired a simplified means to focus on pedestrian collisions within a quarter or half mile of a particular school. The most recent contract with DLA attempted to address this issue.

The Safe Routes to School Collision Map Viewer provides a simple means to explore pedestrian and bicycle collisions near public schools in California. Users can select a county/city/school or an address and then show collisions by injury severity. A map and list of collisions are displayed along with quarter- and half-mile buffer zones around the school. By clicking on individual collisions, a window opens with a single page profile that contains an interactive Google Street View.

User can also select a specific address if the school is not listed. Figure 1-11 shows a user entered address on State Highway 123 in Berkeley. While the results cannot be restricted to state highway collisions, it is a quick and simple means to generate a map of pedestrian collisions in a particular location.

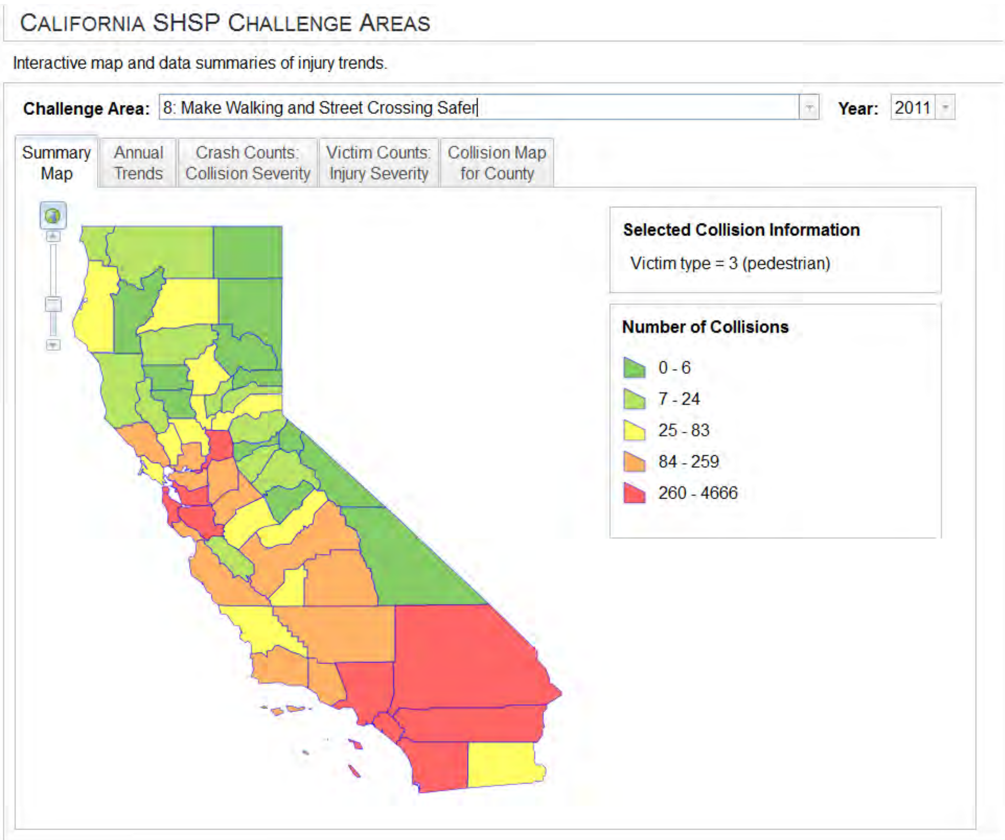
Figure 1-11. Example Output of a User Entered Address



1.2.4 SHSP Data Viewer

The SHSP Data Viewer tool was developed in conjunction with the California SHSP to allow users to visualize summaries and trends over the years for the different challenge areas. The tool provides a high-level summary of the data, including county maps, annual trends, collision and victim counts, and an individual-point collision map for a county to view and download the actual collision data. Figure 1-12 shows an example of the data for Challenge Area 8 of the SHSP, which is specifically focused on reducing pedestrian related fatalities and injuries and can be accessed through the tool. While this data is high-level, it can be a useful starting point for many discussions and analysis of pedestrian safety in California.

Figure 1-12. Summary Map of Challenge Area 8 for 2011



1.3 Conclusion

The PSMR tool and additional mapping tools in TIMS provide better accessibility to pedestrian collision data in California for Caltrans personnel and local agencies. The PSMR tool improves the usability of TSAR Accident Detail files and provides a more structured means for identifying pedestrian collision clusters. The automated detection of pedestrian hotspots using built-in analysis functions will be outlined in Chapter 4. Having the ability to subsequently match TASAS records to SWITRS collisions further aids the investigation into collision patterns. Finally, the availability of TIMS as a general resource for querying, mapping and downloading SWITRS data is invaluable for widespread sharing and analysis of pedestrian collision data.

2 Pedestrian Volume Assessment

2.1 Background

Pedestrian volume data are important to include in the Caltrans State Highway System information database. Volumes are needed to estimate the relative risk of pedestrian collisions for people traveling along state highways (i.e., pedestrian collisions/pedestrian volume). Identifying locations that have higher relative pedestrian risk can show which roadway design features or other characteristics of a location should be modified to reduce pedestrian collisions and injuries. Volume data can also be used to identify how common pedestrian activity is on the State Highway System, showing the importance of designing roadways for safe and convenient pedestrian access.

However, it is impractical to count pedestrians at every intersection and along every segment of the 15,000-mile State Highway System on a routine basis. This problem can be addressed by collecting counts at a sample of locations and applying statistical models to estimate volumes at other locations. These models typically estimate pedestrian volumes using site and surrounding area characteristics.

Previous pedestrian volume models have been developed for specific jurisdictions in California and other parts of North America. A common modeling approach involves the following steps:

- Pedestrian counts are taken at a sample of locations in a community. These counts are often collected manually over short periods of time, but automated detection techniques that collect data over weeks, months, or even years can also be used.
- Short-period counts may be expanded to represent annual volume estimates (annual volume estimates can be compared with collision data that is reported on a yearly basis).
- The annual (or other duration) pedestrian volumes are used as the dependent variable in a predictive model. Statistical software is used to identify significant relationships between the pedestrian volumes at each study location and explanatory variables describing the characteristics of the study location (e.g., land use characteristics, transportation system features, demographic factors, or any other factors thought to be relevant to pedestrian volumes).
- The preferred statistical model equation can be used to estimate pedestrian volumes in other locations throughout the community.

In addition to the volume modeling efforts presented in this chapter, SafeTREC is working to develop a plan to collect data on pedestrian infrastructure and volumes for the Caltrans SHS. This work is done under contract number 65A0452 and a summary of these efforts are described in Appendix 2-A.

2.2 Existing Pedestrian Volume Models

A number of pedestrian volume models have been developed for both road segments and intersections to provide a more accurate representation of pedestrian behavior than available from conventional automobile-based travel models. To date, pedestrian volume models for intersections have been developed more fully than along street segments (Pulugurtha and Repaka, 2008; Schneider, Arnold, and Ragland, 2009; Miranda-Moreno and Fernandes, 2011; Liu and Griswold, 2009; Jones, et al., 2010; Haynes and Andrzejewski, 2010; Haynes et al., 2010). Examples of pedestrian intersection volume models are summarized in Table 2-1.

Table 2-1. Examples of Existing Pedestrian Intersection Volume Models

General information		Pedestrian count information				Statistically-significant predictive variables				Model information	
Model Location	**Developed by**	**Intersections Used for Model**	**Pedestrian Count Description**	**Type of Count Sites**	**Count Period(s) Used for Model**	**Land Use**	**Transportation System**	**Socioeconomic Characteristics**	**Other**	**Model Output**	**Model Type**
Charlotte, NC	UNC Charlotte (Pulugurtha & Repaka 2008)	176	Pedestrians counted each time they arrived at the intersection from any direction	Signalized intersections	7 am-7 pm	• Pop. within 0.25 mi. • Jobs within 0.25 mi. • Mixed land use within 0.25 mi. • Urban residential area within 0.25 mi.	• Number of bus stops within 0.25 mi.			Total pedestrians approaching intersections from 7 am to 7 pm (shorter periods also modeled)	Linear
Alameda County, CA	UC Berkeley SafeTREC (Schneider, Arnold, & Ragland 2009)	50	Pedestrians counted every time they crossed a leg of the intersection (pedestrians within 50 feet of the crosswalk were counted)	Signalized and unsignalized arterial and collector roadway intersections	Tu, W, or Th: 12-2 pm or 3-5 pm; Sa: 9-11 am, 12-2 pm, or 3-5 pm	• Population within 0.5 mi. • Employment within 0.25 mi. • Commercial properties within 0.25 mi.	• BART (regional transit) station within 0.1 mi.			Total pedestrian crossings at arterial and collector roadway intersections during a typical week	Linear
San Francisco, CA	San Francisco State (Liu & Griswold 2009)	63	Pedestrians counted each time they crossed a leg of the intersection (no distance to crosswalk specified)	Signalized and unsignalized intersections	Weekdays 2:30-6:30 pm	• Population density (net) within 0.5 mi. • Employment density (net) within 0.25 mi. • Patch richness density within 0.063 mi. • Residential land use within 0.063 mi.	• MUNI (light-rail transit) stop density within 0.38 mi. • Presence of bike lane at intersection		• Mean slope within 0.063 mi.	Total pedestrian crossings at intersections from 2:30-6:30 pm on typical weekday	Linear
Santa Monica, CA	Fehr & Peers (Haynes *et al*. 2010)	92	Pedestrians counted each time they crossed a leg of the intersection (no distance to crosswalk specified)	Signalized and unsignalized intersections	Weekdays 5-6 pm	• Employment density within 0.33 mi. • Within a commercially-zoned area	• Afternoon bus frequency • Average speed limit on the intersection approaches		• Distance from Ocean	Total pedestrian crossings at intersections from 5-6 pm on typical weekday	Linear

Table 2-1 (cont.). Examples of Existing Pedestrian Intersection Volume Models

General information		Pedestrian count information				Statistically-significant predictive variables				Model information	
Model Location	Developed by	Intersections Used for Model	Pedestrian Count Description	Type of Count Sites	Count Period(s) Used for Model	Land Use	Transportation System	Socioeconomic Characteristics	Other	Model Output	Model Type
San Diego, CA	Alta Planning + Design (Jones *et al.* 2010)	80	Pedestrians counted each time they arrived at the intersection from any direction	Signalized and unsignalized intersections (includes some trail/roadway intersections)	Weekdays 7-9 am	• Population density within 0.25 mi. • Employment density within 0.5 mi. • Presence of retail within 0.5 mi.	• Greater than 6,000 transit ridership at bus stops within 0.25 mi. • 4 or more Class I bike paths within 0.25 mi.	• More than 100 households without vehicles within 0.5 mi.		Total pedestrians approaching intersections from 7 am to 9 am	Log-linear
Montreal, Quebec	McGill University (Miranda-Moreno & Fernandes 2011)	1018	Pedestrians counted each time they crossed a leg of the intersection (no distance to crosswalk specified)	Signalized intersections	Weekdays 6-9 am, 11 am-1 pm, and 3:30-6:30 pm	• Population within 400 m • Commercial space within 50 m • Open space within 150 m • Schools within 400 m	• Subway within 150 m • Bus station within 150 m • % Major arterials within 400 m • Street segments within 400 m • 4-way intersection		• Distance to downtown • Daily high temp. >32°C	Total pedestrian crossings at intersections over 8 count hours (shorter periods also modeled)	Log-linear (also used Negative binomial)
San Francisco, CA	UC Berkeley SafeTREC (Schneider, Henry, Mitman, Stonehill, & Koehler 2012)	50	Pedestrians counted every time they crossed a leg of the intersection (pedestrians within 50 feet of the crosswalk were counted)	Signalized and unsignalized intersections	Tu, W, or Th: 4-6 pm	• Households within 0.25 mi. • Employment within 0.25 mi. • Within high-activity zone (with parking meters) • Within 0.25 mi. of university campus	• Intersection is controlled by a traffic signal		• Maximum slope of any approach leg	Total pedestrian crossings at intersections during a full year	Log-linear

In order to apply a model to estimate pedestrian volumes along the California State Highway System, it is necessary to gather the appropriate model input data. These inputs are simply the explanatory variables in the model equation. While there are a variety of models that could be applied to the State Highway System, some have inputs that are easier than others to gather statewide. For example, population density is provided by the U.S. Census at the block level for the entire country, so this information would be relatively easy to obtain for any location along the State Highway System. In contrast, there are no statewide databases of commercial property locations (this information has been gathered in previous studies through special requests to county tax assessors). An estimate of the ease of data collection for existing pedestrian model inputs is shown in Table 2-2.

Table 2-2. Pedestrian Volume Model Inputs from Literature

Model Input	Study Location (area used)	Ease of Collection
Land Use		
Population within a given distance	Charlotte, NC[1] (0.25 mi.); Alameda County[2] (0.5 mi.); Montreal, QC[3] (400 m)	Easy (block level)
Population density within a given distance	San Francisco (1)[4] (0.5 mi.); San Diego County[5] (0.25 mi.)	Easy (block level)
Employment density within a given distance	San Francisco (1) (0.25 mi.); Santa Monica[6] (0.33 mi.); San Diego County (0.5 mi.)	Moderate – Need to look to at each jurisdiction
Households within a given distance	San Francisco (2) (0.25 mi.)	Easy (block level)
Commercial space within a given distance	Montreal, QC (50 m)	Moderate – Need to look to each jurisdiction, but all should have this information
Commercial properties within a given distance	Alameda County (0.25 mi.)	Moderate – Need to look to each jurisdiction, but all should have this information

[1] Pulugurtha, S. and Repaka, S. 2008. "Assessment of Models to Measure Pedestrian Activity at Signalized Intersections," *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2073, No. 1, pp. 39–48.
[2] Schneider, R., Arnold, L., and Ragland, D. 2009. "Pilot Model for Estimating Pedestrian Intersection Crossing Volumes," *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2140, No. 1, pp. 13–26.
[3] Miranda-Moreno, L.F., and Fernandes, D. 2011."Modeling of Pedestrian Activity at Signalized Intersections," *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2264, No. 1, pp. 74–82.
[4] Liu, H., and Griswold, J. 2009. "Pedestrian Volume Modeling: A Case Study of San Francisco," *Yearbook of the Association of Pacific Coast Geographers*, Vol. 71, No. 1, pp. 164–181.
[5] Jones, M.G., Ryan, S., Donlon, J., Ledbetter, L., Ragland, D., and Arnold, L.S. 2010. "Seamless Travel: Measuring Bicycle and Pedestrian Activity in San Diego County and Its Relationship to Land Use, Transportation, Safety, and Facility Type," *PATH Research Report*.
[6] Haynes, M. and Andrzejewski, S. 2010. "*GIS Based Bicycle & Pedestrian Demand Forecasting Techniques*," Presentation for US Department of Transportation, Travel Model Improvement Program, Fehr & Peers Transportation Consultants.

Model Input	Study Location (area used)	Ease of Collection
Land Use		
Presence of retail within 0.5 mi.	San Diego County	Easy – Economic Census (ZIP code)
Within a given distance of major university campus	San Francisco (2) (0.25 mi.)	Easy
Jobs within a given distance	Charlotte, NC (0.25 mi.), Alameda County (0.25 mi.), San Francisco (2) (0.25 mi.)	Moderate – Need to look to each jurisdiction
Mixed land use within a given distance	Charlotte, NC (0.25 mi.)	Difficult – Need to look to each jurisdiction, requires complex calculation
Residential land use within a given distance	San Francisco (1) (0.063 mi.)	Moderate – Need to look to each jurisdiction, but all should have this information
Urban residential area within a given distance	Charlotte, NC (0.25 mi.)	Moderate – Need to look at each jurisdiction, but all should have this information
Within a commercially zoned area	Santa Monica	Moderate – Need to look at each jurisdiction, but all should have this information
Open Space within a given distance	Montreal, QC (150 m)	Moderate – data must be aggregated, but should be possible to find
Schools within a given distance	Montreal, QC (400 m)	Easy
Patch richness density within a given distance	San Francisco (1) (0.063 mi.)	Difficult – requires complex calculation and a variety of data sources
Transportation System		
Street segments within a given distance	Montreal, QC (400 m)	Easy
4-way intersection	Montreal, QC	Easy
% Major arterials within a given distance	Montreal, QC (400 m)	Moderate – need vehicle volumes on roads
Number of bus stops within a given distance	Charlotte, NC (0.25 mi.)	Difficult – data inconsistent between jurisdictions
Bus station within a given distance	Montreal, QC (150 m)	Difficult – data inconsistent between jurisdictions
Subway within a given distance	Montreal, QC (150 m)	Difficult – data inconsistent between jurisdictions
Presence of bike lane at intersection	San Francisco (1)	Difficult – inconsistent data

Model Input	Study Location (area used)	Ease of Collection
Afternoon bus frequency	Santa Monica	Difficult – data inconsistent between jurisdictions
Average speed limit on the intersection approaches	Santa Monica	Moderate – Available in TASAS, but needs to be connected from segments to intersections
Greater than 6,000 transit ridership at bus stops within 0.25 mi.	San Diego County	Difficult – Need to consult transit agencies
4 or more Class I bike paths within a given distance	San Diego County (0.25 mi.)	Difficult – inventories of facilities do not exist statewide
Parking meters on at least one approach to intersection ("high-activity zone")	San Francisco (2)	Difficult – few jurisdictions are likely to have this data available.
Signalized intersection	San Francisco (2)	Easy – available in TASAS
BART station within a given distance	Alameda County (0.1 mi.)	Location specific (SF Bay Area)
MUNI stop density within a given distance	San Francisco (1) (0.38 mi.)	Location specific (San Francisco)
Socioeconomic Characteristics		
More than 100 households without vehicles within a given distance	San Diego County (0.5 mi.)	Easy – ACS data
Other Factors		
Mean slope within a given distance	San Francisco (1) (0.063 mi.)	Easy – USGS data
Maximum slope of any intersection approach	San Francisco (2)	Easy – USGS data
Distance from Ocean	Santa Monica	Easy
Daily high temperature > 32C	Montreal, QC	Easy – NOAA data
Distance to downtown	Montreal, QC	Moderate – Need to define "downtown" for every jurisdiction

2.3 Pilot Model for State Highway System

The first phase of adding pedestrian volumes to the State Highway System database was to estimate a pilot model of pedestrian crossing volumes for urban arterial intersections. These roads are a high priority for pedestrian risk because they represent 6 percent of the road network in the SHS and were the location of 22 percent of the pedestrian injuries between 2005 and 2009. Pedestrian counts from 66 state road intersections were available from the existing modeling projects in California cities, and all of these intersections are on urban arterials. Models for urban arterials in the SHS were estimated using these counts, and the model can be calibrated in the future for the entire system as data are collected at additional locations by each district.

An alternative approach was to apply one of the existing models to the SHS. However, one major shortcoming of current pedestrian volume models is that they are tailored to predict volumes in a specific community. Variability in the effects of factors between communities means that these models are not easily transferable. For instance, the model cited for Santa Monica, CA, includes distance from the ocean as a determining factor, which likely arises from Santa Monica's status as a beachside tourist destination (Haynes and Andrzejewski, 2010). While this may be a telling factor for Santa Monica, it is unlikely to prove significant in locations in the Central Valley of California. Many of the model inputs from existing models, described in Table 4, are also difficult to collect at the state level because they require compilation of local data sets.

2.3.1 Study Intersections

The 66 study intersections were selected from previous pedestrian modeling studies that included locations along the state highway system (Figure 2-1). Thirty-three of the count locations were in Los Angeles County, in the cities of Santa Monica and Los Angeles in 2011. Thirty-two of the count locations were in western Alameda County, in various cities in 2008 and 2009. The final location was in San Francisco, where counts were collected in 2009.

Figure 2-1. Map of Pedestrian Count Locations

2.3.2 Pilot Model Specification

The model was specified as a loglinear regression and estimated using ordinary least square regression. The model structure was as follows:

$$\ln(Y_i) = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_j X_{ji}$$

where:

Y_i = annual pedestrian crossing volume at intersection *i*;
X_{ji} = value of explanatory variable *j* at intersection *I*; and
B_j = model coefficient for explanatory variable *j*.

Using the logarithm of the dependent variable prevents the model from returning negative values. Linear and Poisson models were also tested, but the loglinear model had the best fit.

2.3.3 Model Inputs

The project team used several criteria to select independent variables to test as inputs for the pilot model. Variables were the same or similar to model inputs from a previous model, or there was evidence in other literature that they may be significant. The TASAS database contains several variables that describe the pedestrian environment, but would be difficult to collect otherwise, including the number of lanes in the road, street lighting, intersection control, and annual average daily traffic. Variables used in previous models were limited to those that could be derived from easily attainable statewide datasets, which significantly reduced the potential variable set. See Table 2-3 for a list of the variables, their descriptions, and sources.

Table 2-3. Variables Tested in Pilot SHS Model

Variable	Description	Source
Land Use		
Pop	Total population within a distance*	US Census 2010
HH	Total households within a distance*	US Census 2010
Retail	Retail businesses within a given distance*	Economic Census 2007
School	Schools within a given distance*	CA Department of Education
Transportation System		
StSeg	Street segments within a given distance	Street Map Pro
Lighting	Presence of lighting at intersection	TASAS
MainLanes	Number of lanes on mainline roadway	TASAS
CrossLanes	Number of lanes on cross street	TASAS
MainAADT	AADT on mainline roadway	TASAS
CrossAADT	AADT on cross street	TASAS
TotalAADT	Sum of AADT on main and cross streets	TASAS
Signal	Presence of traffic signal at intersection	TASAS
Socioeconomic Characteristics		
VehAv	Number of homes with no vehicle available within a given distance*	American Community Survey 2012 5-year estimates
Other Factors		
MaxSlope	Maximum slope of any intersection approach	National Elevation Dataset, USGS 2013

*0.1 mile, 0.25 mile, and 0.5 mile

Most of the variables were calculated using ArcGIS 10.2 software. The Model Builder tool allowed for standardization and replication of processes.

The land use variables provide proxies for the density of origins and destinations near the intersection. They present a particular problem for a statewide model, since land use data are generally stored at the municipal level. Population and household data are available at high resolution (block level) from the U.S. Census Bureau, but the other variables are more difficult to accurately estimate. Employment data are not available statewide by the location of the business. The data on retail businesses from the Economic Census are collected at the ZIP code level and are thus relatively granular.

The transportation system variables can be calculated accurately, given the good quality street network data available with StreetMapPro for ArcGIS and the TASAS database. The *StSeg* is designed to estimate the density of the local street network, which indicates level of street connectivity for pedestrians. The variables pulled from the TASAS database give a sense of the pedestrian environment at each intersection.

VehAv provides a measure of the socioeconomic status of the surrounding neighborhood, as well as indicator of whether residents may be more likely to travel on foot. This variable is based on a 5-year sample that was aggregated to the Census Tract level, so distinctions between nearby intersections may be reduced. *MaxSlope* is an indicator of the terrain near each intersection. Pedestrians tend to prefer the easiest path, so will often choose one that avoids hilly terrain.

2.3.4 Dependent Variable

The dependent variable was annual pedestrian volume at the given intersection. For the San Francisco and Alameda County studies, these volumes had already been estimated. Annual volumes for the Los Angeles area (Los Angeles and Santa Monica) were extrapolated using the factoring method outlined in the Traffic Monitoring Guide (FHWA 2013). This method uses multiplicative factors based on continuous counts to convert short-term (e.g. 2- or 4-hour) counts to annual estimates.

Factors to adjust to daily and weekly volumes are based on three automated pedestrian counters that were installed in the Santa Monica area during the summer of 2012. Counters were installed on Santa Monica Blvd in Los Angeles at the intersections of Detroit, Gardner, and Van Ness. These three counters show similar volume patterns for both the hour of day totals and day of the week totals, so a single set of factors was calculated for use at all of the sites in the data set. Separate hour-of-day factors were calculated for weekdays and weekends. Figures 2-2 through 2-4 show the average volume profiles (normalized to the daily or weekly total) for each site, as well as the average across all three sites. Fortunately, while the automated counters were only installed for part of the year, they were installed at the same time of year that the manual counts were conducted. Thus, the daily activity profiles should be fairly representative (as opposed to during the off-tourist season).

Figure 2-2. Weekday Pedestrian Volumes by Hour of Day

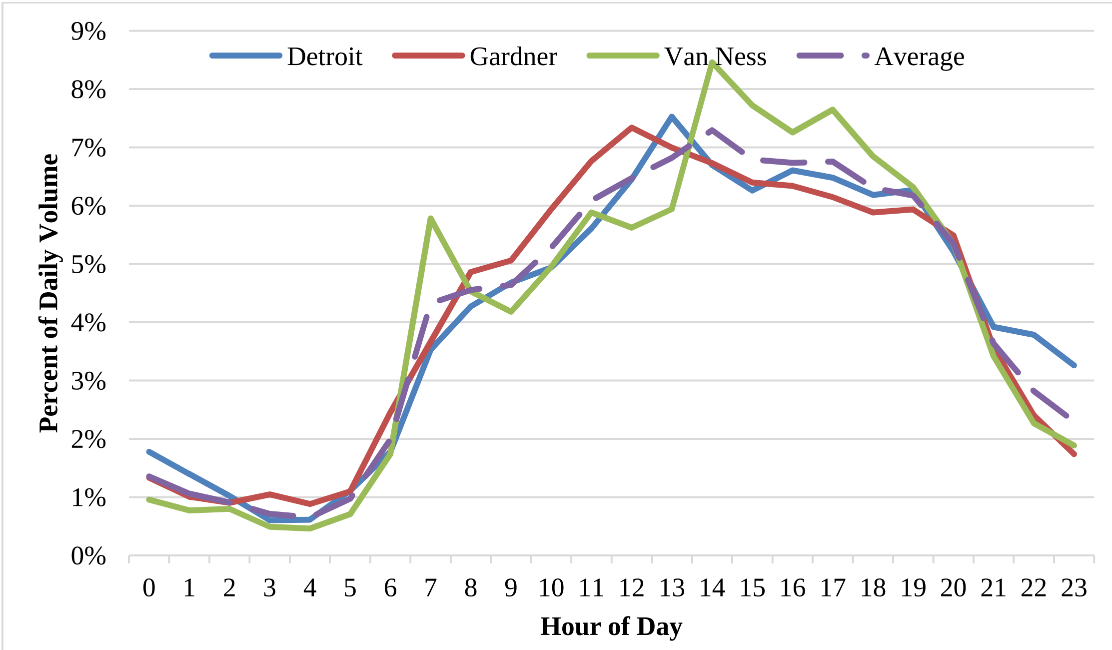


Figure 2-3. Weekend Pedestrian Volumes by Hour of Day

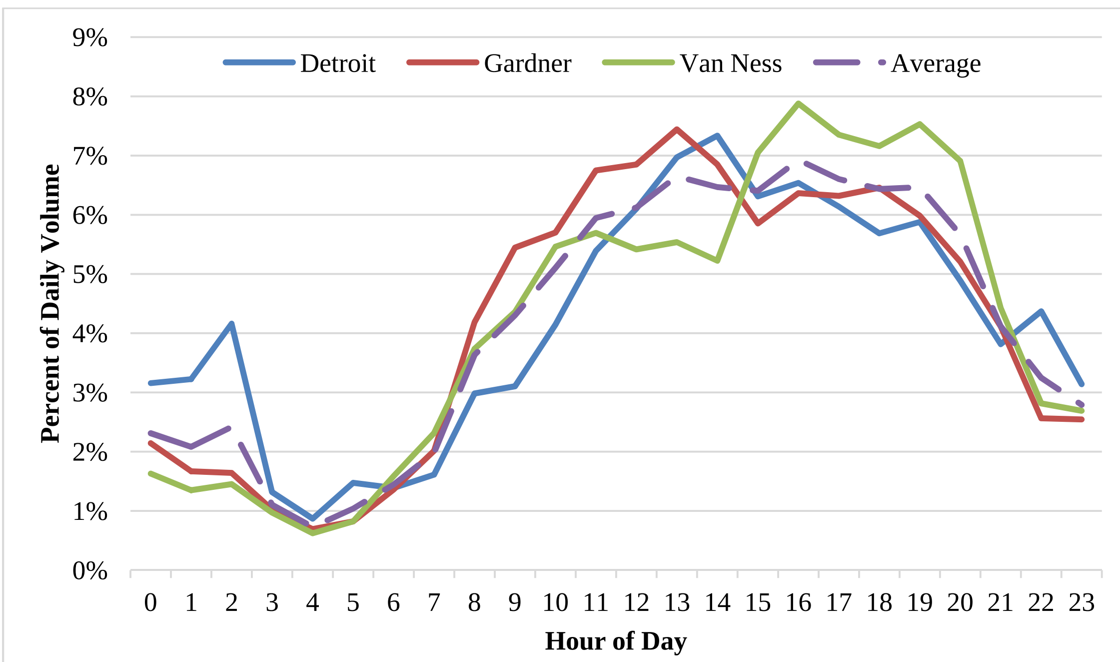
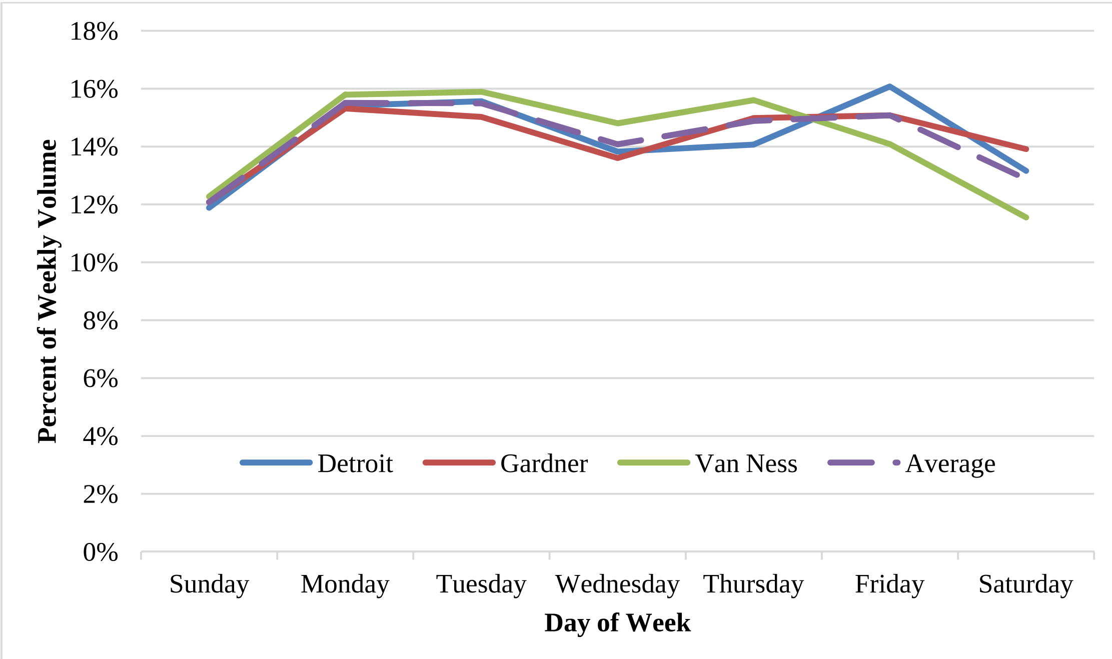


Figure 2-4. Pedestrian Volumes by Day of Week



Adjustment factors were calculated based on the averages of these counters. Adjustment factors are simply the proportion of the total daily/weekly/monthly/annual traffic that a given smaller time period is expected to represent. These factors are calculated for each hour of the day to estimate daily volumes. If multiple hours of counts are collected, their corresponding factors are simply added together. The resultant factor for calculating daily volumes is as follows:

$$\widehat{V_{daily}} = \frac{\sum_i^n V_i}{\sum_i^n \alpha_i}$$

Where V_I is the observed volume in hour *i*, and α_i is the extrapolation factor calculated for hour i. The factors that were estimated to adjust for the hour of day and day of week are presented in Tables 2-4 through 2-6.

Table 2-4. Hour-of-Day Factors – Weekdays

	Detroit	Gardner	Van Ness	Average
12:00 AM	1.78%	1.33%	0.96%	1.36%
1:00 AM	1.40%	1.01%	0.77%	1.06%
2:00 AM	1.02%	0.90%	0.80%	0.91%
3:00 AM	0.60%	1.05%	0.49%	0.71%
4:00 AM	0.61%	0.88%	0.46%	0.65%
5:00 AM	1.11%	1.10%	0.71%	0.97%
6:00 AM	1.78%	2.45%	1.74%	1.99%
7:00 AM	3.53%	3.66%	5.78%	4.32%
8:00 AM	4.27%	4.86%	4.53%	4.55%
9:00 AM	4.68%	5.06%	4.18%	4.64%

	Detroit	Gardner	Van Ness	Average
10:00 AM	4.94%	5.94%	4.95%	5.28%
11:00 AM	5.61%	6.77%	5.88%	6.09%
12:00 PM	6.45%	7.34%	5.62%	6.47%
1:00 PM	7.53%	7.00%	5.94%	6.82%
2:00 PM	6.70%	6.73%	8.46%	7.30%
3:00 PM	6.26%	6.40%	7.72%	6.79%
4:00 PM	6.61%	6.34%	7.26%	6.74%
5:00 PM	6.48%	6.15%	7.65%	6.76%
6:00 PM	6.18%	5.88%	6.85%	6.31%
7:00 PM	6.27%	5.94%	6.32%	6.17%
8:00 PM	5.22%	5.49%	5.34%	5.35%
9:00 PM	3.92%	3.56%	3.42%	3.63%
10:00 PM	3.79%	2.40%	2.27%	2.82%
11:00 PM	3.26%	1.74%	1.89%	2.30%

Table 2-5. Hour-of-Day Factors – Weekends

	Detroit	Gardner	Van Ness	Average
12:00 AM	3.16%	2.14%	1.63%	2.31%
1:00 AM	3.23%	1.67%	1.35%	2.08%
2:00 AM	4.16%	1.64%	1.45%	2.42%
3:00 AM	1.32%	1.02%	0.97%	1.10%
4:00 AM	0.87%	0.69%	0.62%	0.73%
5:00 AM	1.47%	0.82%	0.82%	1.04%
6:00 AM	1.39%	1.36%	1.59%	1.44%
7:00 AM	1.61%	2.02%	2.31%	1.98%
8:00 AM	2.98%	4.19%	3.74%	3.64%
9:00 AM	3.10%	5.45%	4.36%	4.30%
10:00 AM	4.14%	5.70%	5.46%	5.10%
11:00 AM	5.39%	6.75%	5.70%	5.95%
12:00 PM	6.10%	6.85%	5.42%	6.12%
1:00 PM	6.97%	7.44%	5.54%	6.65%
2:00 PM	7.33%	6.85%	5.22%	6.47%
3:00 PM	6.31%	5.86%	7.05%	6.41%
4:00 PM	6.54%	6.37%	7.88%	6.93%
5:00 PM	6.14%	6.32%	7.35%	6.60%
6:00 PM	5.69%	6.46%	7.16%	6.44%
7:00 PM	5.88%	5.98%	7.53%	6.46%
8:00 PM	4.89%	5.21%	6.91%	5.67%
9:00 PM	3.81%	4.11%	4.43%	4.12%
10:00 PM	4.37%	2.56%	2.81%	3.25%
11:00 PM	3.14%	2.54%	2.69%	2.79%

Table 2-6. Day-of-Week Factors

	Detroit	Gardner	Van Ness	Average
Sunday	11.89%	12.08%	12.27%	12.08%
Monday	15.42%	15.32%	15.79%	15.51%
Tuesday	15.57%	15.02%	15.89%	15.49%
Wednesday	13.83%	13.60%	14.80%	14.08%
Thursday	14.07%	14.99%	15.61%	14.89%
Friday	16.07%	15.08%	14.08%	15.08%
Saturday	13.16%	13.91%	11.55%	12.88%

Once an estimate of the weekly volume is determined, a monthly volume is calculated assuming each week in the month is the same by multiplying by the number of weeks in the month. Finally, to estimate annual totals, month-of-year factors from the National Bicycle and Pedestrian Documentation Project (NBPDP) are used (http://bikepeddocumentation.org/). Specifically, the NBPDP's factors for a "moderate climate" were used. For June, the estimated factor is 8% and for July it is 12%.

Two datasets were used for manual counts. The first had 4-hour counts conducted in June/July of 2012. For this dataset, the metadata was sufficiently good that no assumptions on time of year had to be made. The other dataset, however, has very poor metadata. The dates of each count were not given, simply that they took place on a weekend between 7:30 and 9:30 AM and between 5:00 and 7:00 PM. Counts were assumed to have taken place in June (for purposes of determining the number of weeks in the month and for selecting a month-to-year factor). Additionally, the adjustment factors that have been calculated are based on hourly data that begins on the hour, so linear interpolation was used to estimate factors for the 7:30-9:30 manual count interval.

To clarify the extrapolation process, a case example follows. Data was collected at the intersection of Santa Monica Boulevard and Gower Street on 6/21/2012 from 2:00-6:00 PM. The total pedestrian volume for these four hours on a Thursday was 661. First, Table 6 yields hourly factors of 7.30%, 6.79%, 6.74%, and 6.76% for these consecutive hours. Hence,

$$\widehat{V_{day}} = \frac{661}{7.3\% + 6.79\% + 6.74\% + 6.76\%} = \frac{661}{0.2759} = 2396$$

As this is a Thursday, Table 4.6 shows a day-to-week factor of 14.89%, so

$$\widehat{V_{week}} = \frac{2396}{0.1489} = 16096$$

Because there are 30 days in June,

$$\widehat{V_{month}} = 16096 * \frac{30}{7} = 68982$$

And finally, given the 8% adjustment factor from the NBPD,

$$\widehat{V_{year}} = \frac{68982}{0.08} = 862{,}000$$

Thus, the beginning count of 661 pedestrians crossing at this intersection results in an annual estimate of 862,272 pedestrians crossing at this intersection.

2.3.5 Preferred SHS Pilot Model

The project team went through an iterative process for model estimation. Following the methodology used in Schneider et al. (2012), variables were tested in the model and removed if:

- The variable was strongly correlated ($\rho < -0.5$ or $\rho > 0.5$) with other explanatory variables.
- The coefficient estimates were imprecise ($p > 0.10$).
- The coefficient estimate for the variable showed a counterintuitive relationship. For example, the variable *Signal* had a negative sign on its coefficient, but it was found that this variable was strongly correlated with the value of *TotalAADT* for Los Angeles. The variable was replaced with $TotalAADT^2$, which helped capture a non-linear relationship between AADT and pedestrian volumes.

The preferred model, shown in Table 2-7, had a good fit with an adjusted R-square of 0.85. It was selected because it had a good fit and the coefficients suggest logical relationships between the explanatory variables and pedestrian volumes.

Table 2-7. Preferred Pedestrian Volume Model

Variable	Estimate	Std. Error	t-stat	p-value
Constant	12.547	0.4416	28.413	7.01×10^{-37}
HH10	0.0036361	0.00077558	4.6883	1.59×10^{-05}
TotalAADT	-7.17×10^{-05}	1.36×10^{-05}	-5.2617	1.95×10^{-06}
$TotalAADT^2$	8.96×10^{-10}	1.08×10^{-10}	8.3105	1.29×10^{-11}
CrossLanes	0.36723	0.072139	5.0905	3.68×10^{-06}
R-square	0.8570			
Adjusted R-square	0.8476			

The preferred model used three explanatory variables, two of which are available in the TASAS database, making the estimation of the model for other intersections easier.

- HH10 – Number of households with 0.1 miles of the intersection measures the number of potential trip origins near the intersection. The coefficient shows a positive relationship between the density of households and pedestrian volumes.
- TotalAADT – The sum of mainline and cross street vehicle volumes was negatively associated with pedestrian volumes. However, as the value of AADT increases the relationship is less strongly negative. This variable is an indicator of the pedestrian environment; the comfort level for pedestrians tends to be lower on streets with more vehicle traffic. This relationship may be non-linear because the negative impact of heavy traffic reduces as traffic increases.
- CrossLanes – The number of lanes on the cross street is positively associated with pedestrian volumes. It is not immediately clear why this would be, although there may be some relationship to land use such that the larger intersections modeled in

this pilot tended to be surrounded by pedestrian generators such as retail and dining destinations. Further research is needed to clarify this finding.

2.4 Considerations

There are several limitations to the model presented here. First, the intersections included were taken from a convenience sample—locations that had existing pedestrian count data. Ideally, to be used for modeling purposes, the count locations should be selected carefully and stratified across factors expected to influence pedestrian volume levels.

Additionally, the model results show associations between the explanatory variables and the outcome variable, pedestrian volume, but causal relationships cannot be inferred.

Furthermore, the intersection counts were collected over a period of three years. Ideally, they would have been collected over a period of a few months to a year, and the data for the explanatory variables would have matched the time that the counts were collected. Finally, full metadata on all the counts was not available, so it cannot be confirmed that identical methodologies were used. The time period for counts varied between two and four hours, and these values were normalized to annual counts, but the methodology used depended on the availability of local automated counter data.

2.5 Next Steps

The project team has identified additional steps for continuation of this task that are beyond the scope of this project.

- Estimate volumes at urban arterial intersections using the pilot model developed here. This step requires calculating the model inputs at each intersection and applying the regression model. These volumes would be rough, order-of-magnitude estimates.
- Revise model estimation using counts collected by Caltrans districts. Counts collected as part of intersection safety studies, using Myovision technology or collected manually, can be used to improve and refine the pilot model. As new count locations are added, the sample will be large enough to set some locations aside for validation. This will allow the estimation of a model using a selection of intersection counts (60% to 90%), and then testing of the estimation using the remaining counts. Additionally, some count locations may be located in rural locations. Once there is a large enough sample of non-urban intersections, the model can be revised to include the entire portion of the SHS with no limited access.

These steps will help to improve the quality of the model, creating estimates that can then be used to calculate collision risk at modeled intersections.

2.6 References

Haynes, M. and Andrzejewski, S. 2010. "*GIS Based Bicycle & Pedestrian Demand Forecasting Techniques*," Presentation for US Department of Transportation, Travel Model Improvement Program, Fehr & Peers Transportation Consultants.

Jones, M.G., Ryan, S., Donlon, J., Ledbetter, L., Ragland, D., and Arnold, L.S. 2010. "*Seamless Travel: Measuring Bicycle and Pedestrian Activity in San Diego County and Its Relationship to Land Use, Transportation, Safety, and Facility Type*," PATH Research Report.

Liu, H., and Griswold, J. 2009. "Pedestrian Volume Modeling: A Case Study of San Francisco," *Yearbook of the Association of Pacific Coast Geographers*, Vol. 71, No. 1, pp. 164–181.

Miranda-Moreno, L.F., and Fernandes, D. 2011."Modeling of Pedestrian Activity at Signalized Intersections," *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2264, No. 1, pp. 74–82.

Pulugurtha, S. and Repaka, S. 2008. "Assessment of Models to Measure Pedestrian Activity at Signalized Intersections," *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2073, No. 1, pp. 39–48.

Schneider, R., Arnold, L., and Ragland, D. 2009. "Pilot Model for Estimating Pedestrian Intersection Crossing Volumes," *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2140, No. 1, pp. 13–26.

3 Data Evaluation & Improvement: Developing a Pedestrian Report Card

Pedestrian safety consists not only of actual safety as recorded through collision statistics, but also the perception of safety as reported by those who walk. This report card aims to provide a format for evaluating these two aspects of safety over time. It uses data that is readily available at the State level to produce a yearly picture of actual pedestrian safety in the state, as well as trends in pedestrian safety over time. In addition, it provides a section for data on perceived pedestrian safety, as measured through attitudes and behavior, which can be updated as the data are available. This report card can help transportation professionals, policymakers, and community members to better understand pedestrian safety in the state of California, celebrate successes, and identify areas for improvement.

3.1 Methodology

The Pedestrian Report Card is divided into two parts—one that can be updated annually, and a supplement that is relevant when new, sporadically-released data (e.g., National Household Travel Survey data) is available. The report card is based on a few key data inputs, from which calculations, charts, and tables are made. This section describes the data sources used, as well as how they are formatted for the report card and supplement.

3.1.1 Data Sources

There are many inputs needed to create a holistic picture of pedestrian safety in California. Foremost among them include data about pedestrian collisions, data on exposure and behaviors leading to or deterring from safety, and data that can provide context for behavior, such as attitudes toward walking. Each of these categories is discussed in further detail below, along with the limitations of the specific data sources used to generate the report card.

3.1.1.1 Collision Data

Collision data was obtained from the California Highway Patrol's Statewide Integrated Traffic Records System (SWITRS) database, which contains all police-reported injury collisions in the state. SWITRS collisions are associated with information about the collision, parties involved, and victims, which allows further exploration of trends in the data, such as the number of collisions involving pedestrians aged 65 and older. SWITRS data represents the most comprehensive data available for pedestrian collisions in California, but is limited in the sense that the database only contains reported collisions and any numbers therefore likely represent an underestimate of pedestrian collisions in the state.

The SWITRS data were accessed through the tims.berkeley.edu website, which contains the most recent ten years of collision information for the State. Note that because the collision files take time to be finalized and cleaned, there is a lag of approximately two years before the files are released. Due to this lag, the most recent collision data for the report tends to be limited to two years prior to the current year (e.g., 2011 data for a 2013 report).

3.1.1.2 Exposure and Behavioral Data

Exposure data is a critical complement to collision data in the sense that it gives context to the collision numbers. For example, an increase in pedestrian collisions when pedestrian travel has been increasing is expected; an increase in collisions along with decreasing pedestrian travel is alarming. The difficulty in using exposure data is that the current sources are limited either in the type of data they gather or by the frequency with which they are gathered. The two main sources of exposure data are the American Community Survey (ACS) and the National Household Travel Survey (NHTS).

3.1.1.2.1 American Community Survey Data

The American Community Survey compiles data on how people commute to work, including the percentage of people who walk to work. This data is gathered annually and considered reliable at the state level. However, there are several notable issues with using ACS data as a measure of pedestrian exposure. First, the ACS measures only the mode someone "usually" used to commute to work in the week prior to the survey. If the respondent uses more than one mode to get to work, the survey specifically instructs the respondent to list only the mode used for longest distance. Thus, the survey almost definitely consistently underestimates pedestrian travel that is done in conjunction with other modes like transit, and may not represent even the main mode someone usually uses if they for some reason traveled differently in the week prior to taking the survey.

Second, data from the National Household Travel Survey (NHTS) suggests that work trips comprise only about 20% of all travel, and are not necessarily representative of the way people travel for other trips. Thus, any estimate of pedestrian travel to work as obtained from the ACS necessarily leaves out a large portion of other potential pedestrian trips and cannot be reliably extrapolated to estimate the percentage of those trips made on foot. Additionally, due to the survey methodology, annual estimates are not considered reliable at the county or city level for smaller counties and cities, and thus can only be used in 3-year (for cities with populations of less than 65,000 inhabitants) or 5-year (for cities of less than 20,000 inhabitants) increments. At those time-intervals, estimates are considered reliable. ACS data can be obtained through the U.S. Census website: http://www.census.gov/acs/www/.

3.1.1.2.2 National Household Travel Survey Data

The other main option for pedestrian exposure at the state level is the NHTS. This survey asks about all types of trips, thus providing a more accurate picture of the percentage of trips made on foot. There are two main disadvantages to using NHTS data, however. The first is that the NHTS is conducted approximately every seven years, resulting in data that grows less accurate as years pass. This is particularly true for years in which major events known to affect travel patterns, such as a national recession, occur.

The second main disadvantage of the NHTS is that its sampling plan included a relatively small sample of households from California, so extrapolating data from these surveys to the state level may produce a relatively inaccurate estimate of total pedestrian trips. In particular, a large portion of the 2009 NHTS California sample came from San Diego County, so the resultant data is considered unreliable for the county level or anything smaller, with the possible exception of very large counties.

A third limitation pertains to limitations in the data available. The NHTS trip database does not include all pedestrian travel, including walking to and from transit, to and from parked vehicles, and some trips within shopping districts. However, when NHTS data is current, it does provide more detailed pedestrian trip information than the ACS data. Data for the NHTS can be accessed via http://nhts.ornl.gov/.

3.1.1.2.3 Exposure Data used in This Report Card

Given the limitations of the data sources, this pedestrian report card uses the ACS data to provide a snapshot of pedestrian collision rates and trends over time, as it is more consistently gathered. However, it is recommended that a report card supplement be published each year that NHTS data is made available. This data can be reported over time showing longer-term trends in pedestrian collision and trip rates in California, and can provide an informative contrast to the pedestrian commute collision and trip rates determined through the use of the ACS data.

3.1.1.3 Attitudinal Data

Attitudinal data is critical to understanding why people do or do not walk. However, this data is not gathered consistently and is therefore not featured in the current version of the Pedestrian Report Card. It is recommended that this data be added to the report card if a reliable data source becomes available through, for example, surveys conducted either by Caltrans, the Office of Traffic Safety, or other external organizations. The NHTS collects data on pedestrian attitudes that can be updated every few years, and is recommended as an input for the Report Card Supplement.

3.1.1.4 Additional Data

Additional data sources include information such as funding for pedestrian safety and vehicle miles traveled. Where these data sources are used, they are described in the following section.

3.2 Format of the Annual Report Card

This section describes the inputs for the annual version of the Pedestrian Report Card, as well as where they can be found and how they can be updated. The latest version of the report card (using 2013 data when available) can be found in Appendix 3-A.

3.2.1 Annual Report Card Inputs

The annual version of the Pedestrian Report Card contains information about the following aspects of pedestrian safety:

- Amount of state funding spent on pedestrian and bicycle travel
- Pedestrian fatalities and injuries (in general and specifically for those aged 65+) at the state level

- Pedestrian commute trips (in general and specifically for those aged 65+) at the state level
- Pedestrian fatalities per million commute trips at the state level
- Pedestrian fatalities per million VMT at the state level
- Pedestrian fatality and injury rates at the county level (normalized by both the percentage of commute trips and the population)
- A comparison of California to other states and the U.S. average for:
- The percent of total traffic fatalities that are pedestrians
- The number of pedestrian traffic fatalities per 100,000 state residents

These inputs are elaborated upon below. Where possible, they are linked to performance measures proposed by SafeTREC for Caltrans' Complete, Green Streets Performance Measure Framework (Macdonald, Sanders, and Anderson, 2009). These performance measures are indicated by the phrase "CGS performance measure" in the text below.

These inputs are also based in part on the requirements of MAP-21 (http://www.fhwa.dot.gov/map21/pm.cfm). The applicable goals and performance measures include:

- Safety - To achieve a significant reduction in traffic fatalities and serious injuries on all public roads
- PM: Fatalities and serious injuries—both number and rate per vehicle mile traveled—on all public roads (specifically interested in older (>65) pedestrian safety)
- Infrastructure condition - To maintain the highway infrastructure asset system in a state of good repair
- Pavement condition on the Interstate System and on remainder of the National Highway System (NHS)

Note: These inputs should eventually reflect the targets set by the state for urbanized and rural areas.

3.2.1.1 State Funding

Information on state funding for pedestrian infrastructure is important to monitor. Research has demonstrated a clear connection between pedestrian safety and basic infrastructure like sidewalks and crosswalks, yet there are still many communities in California that lack such infrastructure, or in which the infrastructure needs to be updated and better-maintained. State funding is critical to these communities' abilities to move forward with plans to build or upgrade facilities.

Information on state funding is obtained through the Federal Highway Administration (FHWA) website (http://www.fhwa.dot.gov/environment/bicycle_pedestrian/funding/bipedfund.cfm). It should be noted that this information may not represent all of the funding California spends on pedestrian safety. According to the FHWA, "These figures represent state-reported spending (rounded to the nearest dollar) of Federal-Aid Highway Program funding on pedestrian and bicycle facilities and programs." Further, "Federal pedestrian and bicycle funding data include Federal-aid highway program obligations that were coded as Bicycle and Pedestrian Improvements (bicycle and pedestrian facility, bicycle and pedestrian safety, and rail-trail). [These data do] not include some projects that benefit pedestrian and bicyclists, but were not coded as bicycle and pedestrian projects: a typical example may be sidewalks constructed as part of a larger highway or bridge project. This table includes all Safe Routes to School and Nonmotorized Transportation Pilot Program obligations, whether or not they were coded as bicycle and pedestrian projects, because these programs are solely intended to benefit nonmotorized transportation, however, some States have not coded the projects as bicycle and pedestrian projects." Funding from the American Recovery and Reinvestment Act of 2009 is included, so the funding amounts for 2009 and 2010 were higher than previous years.

This information could partially satisfy proposed CGS performance measure 2.1d:
PM 2.1d: Percentage of urban arterial projects designed as Complete Streets.

Funding sources for pedestrian safety improvements is discussed in more detail in Chapter 7.

3.2.1.2 Pedestrian Fatalities and Injuries

Data on pedestrian fatalities and injuries may be obtained via the Statewide Integrated Traffic Records System (SWITRS) Reported Collision Data. SWITRS collision data for the years 2002-2011 can be accessed through TIMS (tims.berkeley.edu). If needed, collision data predating 2002 may be available in the Caltrans collision database. (Note that injury data from before the year 2000 appear to include injured *and* killed pedestrians. These numbers will need to be adjusted to subtract the number of fatalities from the original injuries numbers.)

This information could satisfy proposed CGS performance measure 1.4a and could be combined with other information in this report card to satisfy CGS performance measures 1.1a-b, as follows:
PM 1.1a: Number of pedestrian fatalities per x walking trips.
PM 1.1b: Number of pedestrian injuries per x walking trips.
PM 1.4a: Overall number of pedestrian collision hotspots on urban arterials.

3.2.1.3 Pedestrian Commute Trips

Data on the percentage of pedestrians commuting on foot can be obtained through estimates of trips from the American Community Survey (ACS) data. As discussed in Section 3.1.1.2.1 above, the 1-year estimates are appropriate for the State level, but county data should be based on the 5-year estimates, given the small size of some California counties.

This data source could be used to partially satisfy CGS performance measure 2.1e:
PM 2.1e: Number of pedestrian trips on urban arterials.

3.2.1.4 Pedestrian Fatalities per Million Commute Trips

This input is derived from a combination of fatality data from SWITRS and commute data from the ACS.

This information could partially satisfy proposed CGS performance measure 1.1a:
PM 1.1a: Number of pedestrian fatalities per x walking trips.

3.2.1.5 Pedestrian Fatalities per Million VMT

This input is derived from a combination of fatality data from SWITRS and VMT estimates obtained from Table 1 of the Caltrans Highway Performance Monitoring System annual report (http://www.dot.ca.gov/hq/tsip/hpms/datalibrary.php).

3.2.1.6 Pedestrian Fatality and Injury Rates at the County Level

This input is derived from a combination of fatality and injury data from SWITRS, and commute and population data from the ACS. The pedestrian risk by county is calculated as follows:

$$\frac{(County\ Pedestrian\ Fatality + Injury\ Collisions)}{(County\ Population\ Estimate)(County\ Walk\ Mode\ Share)}$$

3.2.1.7 Comparison of California With Other States and the U.S. Average

Data for this section of the report card is obtained through annual pedestrian safety statistics published by the National Highway Traffic Safety Administration (NHTSA). As with the SWITRS data, these statistics tend to be released with a two-year lag (e.g., 2011 statistics are released in 2013). These data are available from the NHTSA website: http://www.nhtsa.gov/Pedestrians.

3.3 Format of the Report Card Supplement

This section describes the inputs for the supplemental version of the Pedestrian Report Card, as well as where the necessary data can be found and how it can be updated. The latest version of the report card supplement (using data from the 2009 NHTS) can be found in Appendix 3-B.

3.3.1 Supplemental Report Card Inputs

The supplemental version of the Pedestrian Report Card contains information that is available on a sporadic basis, but which is more detailed about pedestrian safety. For the purposes of this write-up, it is assumed that the supplemental data will come from the NHTS. However, those who compile the information should feel free to use additional data sources as appropriate. Based on the NHTS, the following inputs are recommended:

- Percentage of Californians making walking trips, by age, sex, and household income
- Perceived safety barriers to walking more in California
- Pedestrian fatalities per million walk trips at the state level
- Pedestrian fatality and injury rates at the county level (normalized by both the percentage of walk trips and the population)

3.3.1.1 Percentage of Californians Making Walking Trips

Data on the percentage of pedestrians making walking trips can be obtained through estimates of trips from the NHTS data. As discussed in Section 3.1.1.2.2, this data is reliable at the state level, but should be used with caution at the county level or smaller given the sampling methodology.

This data source could be used to satisfy proposed CGS performance measure 2.1e:
PM 2.1e: Number of pedestrian trips on urban arterials.

3.3.1.2 Perceptions of Pedestrian Safety and Mobility

This input aims to establish an understanding of how safe Californians feel walking along state routes (safety), and how possible it is for them to walk along state routes (mobility). Information about perceptions of safety and mobility is found most reliably in the NHTS data, although this data is subject to the limitations described above. In the future, questions about perceived safety and mobility could be added to surveys such as the Caltrans External Stakeholder Survey or the Office of Traffic Safety (OTS) Annual Traffic Safety Survey (safety only). In both cases, only small changes to the existing survey would be needed.

This information could satisfy proposed CGS performance measure 1.2:
PM 1.2: Percentage of Californians who feel safe using non-motorized modes on urban arterials.

3.3.1.3 Pedestrian Fatalities per Million Walk Trips

This input is derived from a combination of fatality data from SWITRS and pedestrian trip data from the NHTS.

This information could satisfy proposed CGS performance measure 1.1a:
PM 1.1a: Number of pedestrian fatalities per x walking trips.

3.3.1.4 Pedestrian Fatality and Injury Rates at the County Level

This input is derived from a combination of fatality and injury data from SWITRS, and population and walking trip estimates from the NHTS. The pedestrian risk by county is calculated as follows:

$$\frac{(County\ Pedestrian\ Fatality + Injury\ Collisions)}{(County\ Population\ Estimate)(County\ Walk\ Mode\ Share)}$$

Note: Information on county respondent numbers for 2009 was taken from "2008-9 National Household Travel Survey Data with California Add-Ons" fact sheet, which was produced Leonard Seitz, Caltrans TSI, Leonard.Seitz@dot.ca.gov, 916-654-2610. It is assumed, although not guaranteed, that California will continue to pay the NHTS to produce a California “add-on” that contains California-specific information about household travel.

3.4 Proposed Future Report Card Inputs

Via the combination of inputs derived from SWITRS, the ACS, the NHTS, and the FHWA, the pedestrian report card provides a substantial amount of information about pedestrian safety trends in California. This section describes an additional data input that could help complete the picture of pedestrian safety by providing information about the state of pedestrian infrastructure.

3.4.1 Proposed Input: Pedestrian Infrastructure along State Highway Routes

Data on the availability of pedestrian infrastructure along state highways would complement the data on state funding for pedestrian infrastructure. For example, it would be helpful to understand, the quality of the infrastructure in order to understand the need for funding at the state level.

Data in this section is not readily available, but could be tabulated through observations (e.g., via Google Maps™), construction documents, or fieldwork. The intention would be to develop a database of pedestrian facilities—including sidewalk mileage and ADA-compliant intersections—and their associated quality rankings along state routes in California that could then be updated annually through construction reports.

This information could satisfy the following proposed CGS performance measures:
PM 2.1a: On urban arterials, ratio of sidewalk mileage to roadway mileage, bi-directionally.
PM 2.1c: On urban arterials, percentage of intersections that are ADA compliant.
PM 4.2a: Percent of urban arterial sidewalk mileage in fair or better condition.

3.5 Conclusion

The Pedestrian Report Card is intended to provide a snapshot of pedestrian safety in California each year, as well as a picture of pedestrian safety trends over time. The benefit of the report card is that it uses readily available data to create such snapshots and trends, and can therefore be easily produced. It can serve as a high-level tool for transportation professionals, policymakers, and community members to monitor pedestrian safety in the state and celebrate successes as well as identify areas for future work.

3.6 References

Macdonald, E., Sanders, R., and Anderson, A. 2009. "*Performance Measures for Complete, Green Streets: A Proposal for Urban Arterials in California."* Berkeley, CA: California Dept. of Transportation.

4 Hotspot Identification Algorithm

4.1 Motivation

In this chapter, methodologies to identify high-frequency pedestrian collision segments, or hotspots, along the California State Highway System are proposed. Typically, individual collision data are spatially dispersed, due to natural variation in collision locations. To account for this spatial dispersion, these individual collision locations are aggregated so as to represent a potentially hazardous segment of the road network.

An additional complexity associated with pedestrian hotspot identification is that pedestrian collisions are typically fewer in number than the corresponding automobile collisions. In addition, obtaining information about pedestrian volumes is also much harder than for automobiles. Consequently, it is difficult to model risk to pedestrians in terms of collision rates or account for regression-to-means bias in the hotspot identification process.

Finally, a major difference between pedestrian and car hotspots is that pedestrian-based conflicts are more likely to arise in localized regions, such as near intersections, mid-blocks, and/or other crossings, as opposed to large stretches of roadway. As a result, pedestrian hotspots are more likely to be smaller and more dense in nature. In addition, a small road segment tries to ensure that the collisions covered within a hotspot are affected by similar road conditions and pedestrian infrastructure elements.

Based on this discussion, two collision frequency-based hotspot identification methods are proposed in the subsequent sections. The first method is referred to as the *sliding window method* and involves a hotspot window of a fixed length which slides along the road network to identify a segment which matches the necessary conditions for it to be defined as a hotspot. This technique is similar to the sliding window method described in chapter 4 of the Highway Safety Manual (2010), and used for automobile-based hotspots. The second method utilizes an optimization technique called *dynamic programming* which seeks to maximize the coverage of collisions covered by the hotspots over the entire road network.

In addition to the hotspot efforts presented in this chapter SafeTREC is working on developing a systemic approach to pedestrian safety. This work is done under contract number 65A0509 and a summary of these efforts are described in the Appendix 3-A.

4.1.1 Sliding Window Method

The first step towards identifying the hotspots is to select the input parameters which define a hotspot. While defining the sliding window method, there are two parameters of interest which are required to be defined by the user: the hotspot window length and the minimum number of collisions per hotspot. The hotspot window length is a fixed road segment length which is used to aggregate pedestrian collisions. The hotspot window is assumed to have homogeneous pedestrian and road infrastructure elements so that all the collisions covered by that road segment can be expected to have occurred under similar conditions. The minimum number of collisions per hotspot defines a critical threshold which determines whether a road segment should be a hotspot or not. While frequency-based identification of hotspots does not account for the pedestrian volumes at a location, in the absence of pedestrian exposure data, the concept of risk associated with a road segment cannot be adequately quantified.

Thereafter, the sliding window method works as follows: a fixed hotspot window length is moved across the entire road network to identify locations which meet the critical collision threshold criterion. Herein, the window moves in a manner that the starting location of a potential hotspot window is always a collision. The rational for this implementation is that a hotspot should be as dense as possible, and hence any empty space, either at the start or at the end of a hotspot is excessive. However, with a restriction of a fixed hotspot length, it is only possible to ensure that a hotspot either begins or ends with a collision. Once a hotspot satisfying critical collision threshold is identified, the search for other hotspots continues from the next available collision that does not overlap with any hotspot.

In order to illustrate the algorithm, consider a hypothetical road section with pedestrian collisions, as illustrated by Figure 4-1. The figure indicates nine collisions marked out as circles spread across the entire road section. Table 4-1 lists the postmiles associated with these nine collisions.

Figure 4-1. An Illustration of a Small Road Section with Pedestrian Collisions

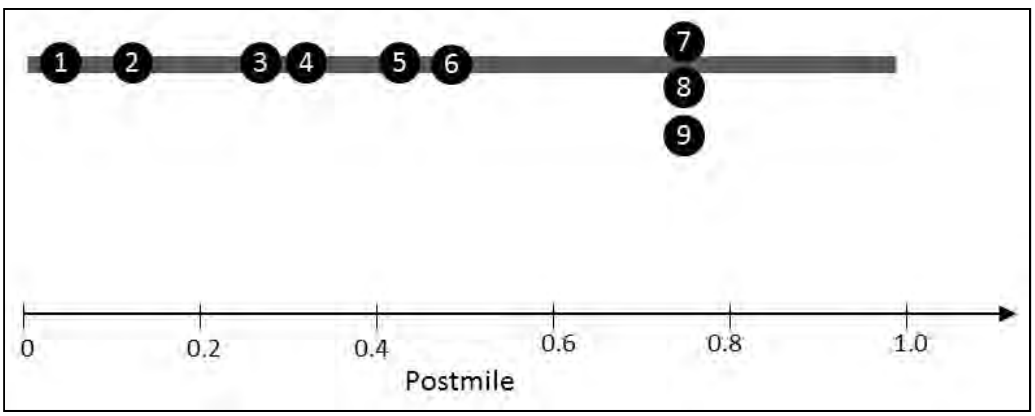


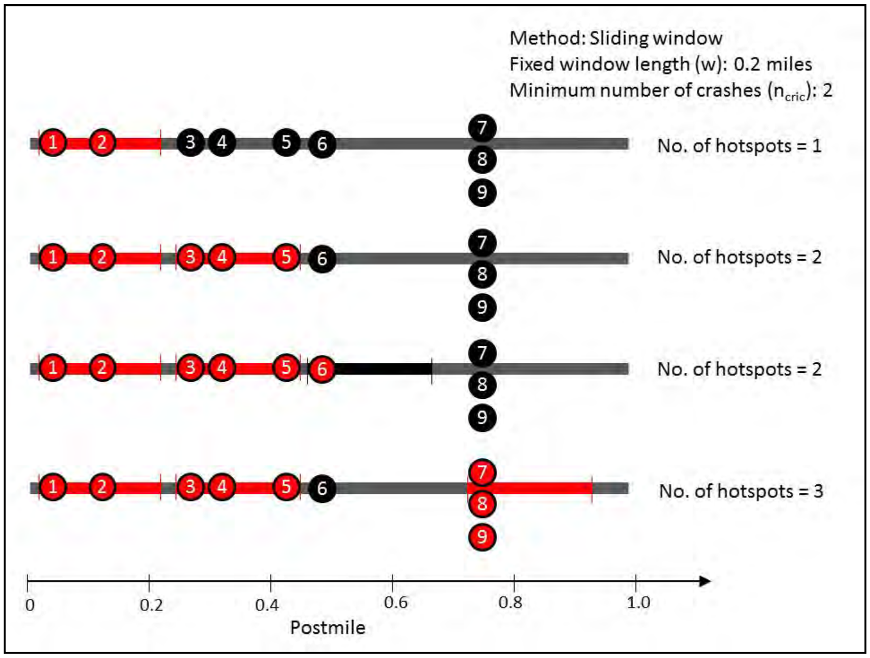
Table 4-1. Postmiles of the Nine Collisions

Collision ID	Postmile	Collision ID	Postmile
1	0.075	6	0.529
2	0.116	7	0.748
3	0.286	8	0.748
4	0.315	9	0.748
5	0.443		

4.1.1.1 Implementation of Sliding Window Method

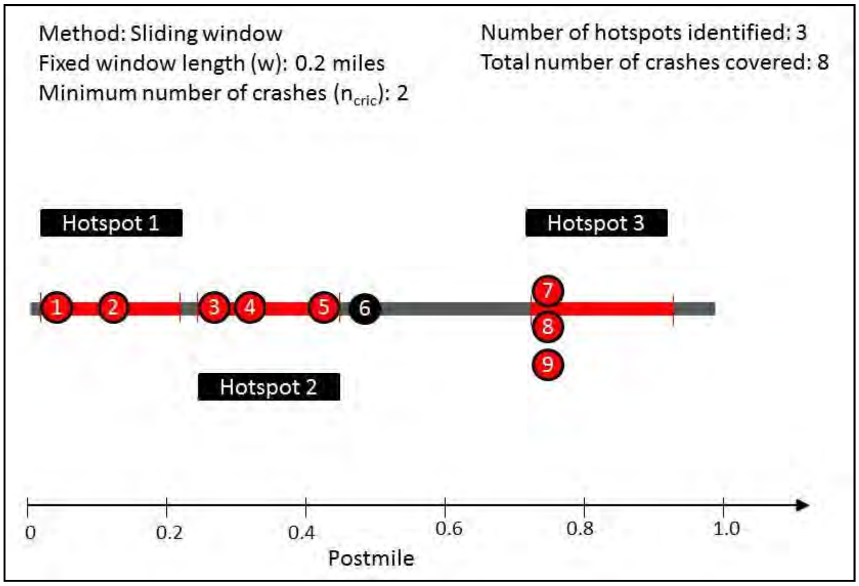
The implementation of the sliding window method is illustrated in Figure 4-2, wherein the input parameters for the hotspot selection were a fixed window length (*w*) of 0.2 miles, and a minimum of two collisions per hotspot (n_{cric}). In Figure 4-2, the hotspot identification process is initiated by checking for the presence of a hotspot with a fixed window length of 0.2 miles starting with the first collision. Since the window length covers two collisions, which is equal to the threshold, it is designated as a hotspot, and the next hotspot is checked for, starting with collision 3. Similarly, collisions 3, 4 and 5 lie within 0.2 miles of each other, and hence are designated as the second hotspot. However, when a hotspot starting with collision 6 is checked for, it only includes one collision. As a result it is deemed to not be a hotspot, and then next window length to be checked begins with collision 7, which forms a hotspot along with collisions 8 and 9.

Figure 4-2. Implementation of the Sliding Window Method



The final set of hotspots obtained by using the sliding window methods are shown in red in Figure 4-3.

Figure 4-3. Hotspots Identified by Using the Sliding Window Method



Several observations with regards to the hotspots indicated in Figure 4-3 are as follows:

- In hotspots 1 and 3, there is excess space at the end of the windows which introduces inefficiency while defining these hotspots.
- If the window length was smaller, it is possible that hotspot 2 could have been divided into two smaller hotspots, with collisions 3 and 4 forming one hotspot, and collisions 5 and 6 forming another.

In summary, a significant limitation of the sliding window method is that the fixed window length assumption results in hotspots with unutilized space, and the resulting lack of flexibility prevents the algorithm from covering more collisions through these hotspots. In the subsequent section, a dynamic programming-based algorithm is proposed which relaxes the assumption of a fixed window length, and instead interprets it as the maximum possible window length.

4.1.2 Dynamic Programming

Dynamic programming (DP) is a decision-making framework used to solve problems involving multiple, sequential sub-problems. It involves generating and storing the solutions of each intermittent sub-problem before identifying the overall optimal solution. In this particular instance, the sub-problems are generated when, starting from the first postmile of the road section, the hotspot windows associated with each collision are investigated as feasible hotspots.

In proposing a dynamic programming-based hotspot identification algorithm, the objective under consideration is to maximize the total number of collisions covered by the selected hotspots which satisfy the minimum number of collisions per hotspot criterion. In addition, the size of each hotspot should be no bigger than the maximum window length prescribed by the user (which is a relaxation of the fixed window length assumption). An outcome of relaxing the fixed hotspot length assumption is that a hotspot can begin and end with a collision. In other words, the collisions can now be defined to be as dense as possible.

As described earlier, the dynamic programming approach breaks down the task of optimally identifying the hotspots across the entire road network to smaller sub-problems of identifying whether a collision *i* should form an extreme end of a hotspot or not. To illustrate this option, let V_i be defined as the maximum number of collisions that can be covered by hotspots from the start of the road network up to the given collision, *i*. Also, let a_i be a variable that defines whether collision *i* belongs to a hotspot or not. If collision *i* lies at the end of a hotspot, a_i identifies the collision situated at the beginning of that hotspot, which can be a value between 1 (the first collision) and $i - n_{cric} + 1$ (the collision which defines the smallest possible hotspot at this location). Otherwise, it is attributed a value of 0. Using this notation, the optimization problem is formulated as follows:

$$V_i = \max_{1 \leq j \leq i - n_{cric} + 1 | (d_i - d_j) \leq w} \{V_{i-1}, V_{j-1} + (i - j + 1)\}, \quad (1)$$

$$a_i = \arg\max_{1 \leq j \leq i - n_{cric} + 1 | (d_i - d_j) \leq w} \{V_{i-1}, V_{j-1} + (i - j + 1)\} \; (0 \; if \; no \; hotspot \; feasible). \quad (2)$$

Herein, equation 1 states that V_i is equal to the number of collisions associated with the hotspot defined by the current collision *i* and a potential starting point j, summed up with V_{j-1}, the maximum number of collisions that can be covered by hotspots from the start of the network up to collision j-1. This introduces an element of recursion in equation 1 wherein the calculation of V_i requires knowing the value of V_{j-1}. Hence, in order to implement the dynamic programming algorithm, V_i is first computed for collision i = 1 (the first collision of the network), followed by *i* = 2,3,…, *N* (the last collision of the network). Once all the computations are completed, the value of V_N indicates the maximum number of collisions that can be covered using hotspots.

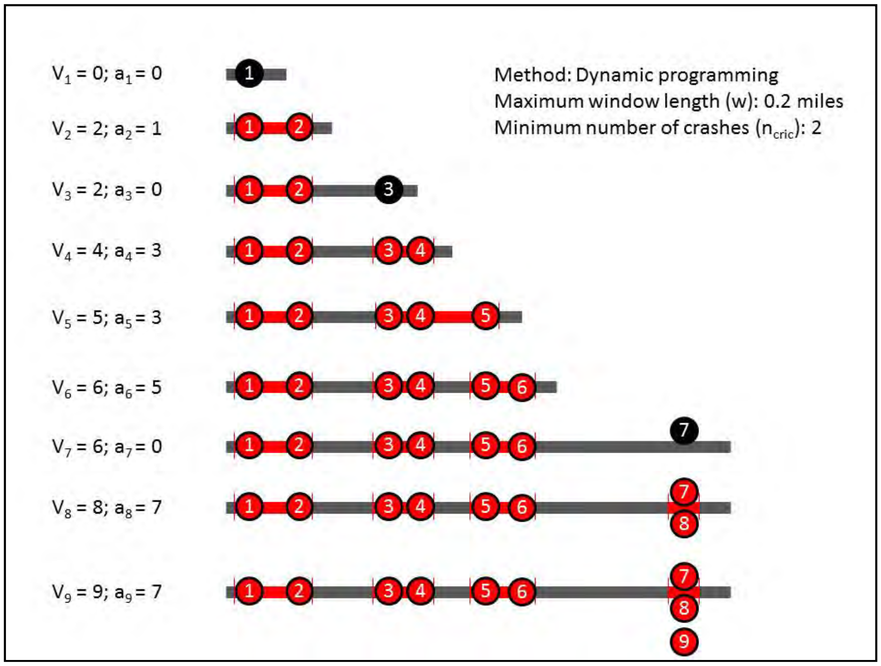
Similarly, $a_i \neq 0$ indicates the starting location of the hotspot which ends with collision *i*. Alternately, if $a_i = 0$, it indicates that collision *i* is not a part of a hotspot. Finally, the condition $(d_i - d_j) \leq w$ implies that the length of the hotspot, calculated using the postmiles of collisions *i* and j, d_i and d_j respectively, should not exceed the maximum possible window length, *w*.

It is important to understand the objective of the underlying query algorithm. A performance measure based on identifying the highest number of hotspots cannot distinguish between the variable numbers of collisions per hotspot. Consequently, a more objective metric, which is to maximize the total number of collisions covered by the chosen hotspots, is used as part of this dynamic programming framework.

4.1.2.1 Implementation of Dynamic Programming Method

Consider the road section previously described in Figure 16. In this concluding part of the document, the dynamic programming algorithm is applied to that road section so as to identify the best possible arrangement of hotspots. The parameters of the study, the minimum number of collisions per hotspot (2) and the maximum window length (0.2 miles), are the same as the sliding window method implementation. A sequential implementation of the different steps of the dynamic programming algorithm is shown in Figure 4-4.

Figure 4-4. Implementation of the Dynamic Programming Algorithm



As can be seen from Figure 4-4, some of the hotspots identified in the intermediate steps may not actually be a part of the final selection when the entire road network is traversed. For instance, when considering the network up to collision 5, the optimal hotspot cluster features a three-collision cluster involving collisions 3-5. However, when the network is extended to include collision 6, the three-collision cluster cannot be extended to a four-collision cluster since the maximum window length is 0.2 miles. Instead, Figure 4-4 reveals that an alternate arrangement of hotspots is possible which covers all six of the collisions.

Finally, it should be noted that once the dynamic programming algorithm traverses the entire network, the set of V's and a's do not automatically reveal the hotspots. In order to identify these hotspots, a backward recursive method is adopted, starting with the last collision. Herein, $a_N = k \neq 0$ reveals that the region from collision k to collision N is a hotspot. Once this hotspot is revealed, the value of a_{k-1} is checked in order to locate the next hotspot. In the event that $a_i = 0$ for any given collision i, it implies that a hotspot is not located at that location, and the value of a_{i-1} is checked. This process is repeated until the first collision is checked for hotspot coverage.

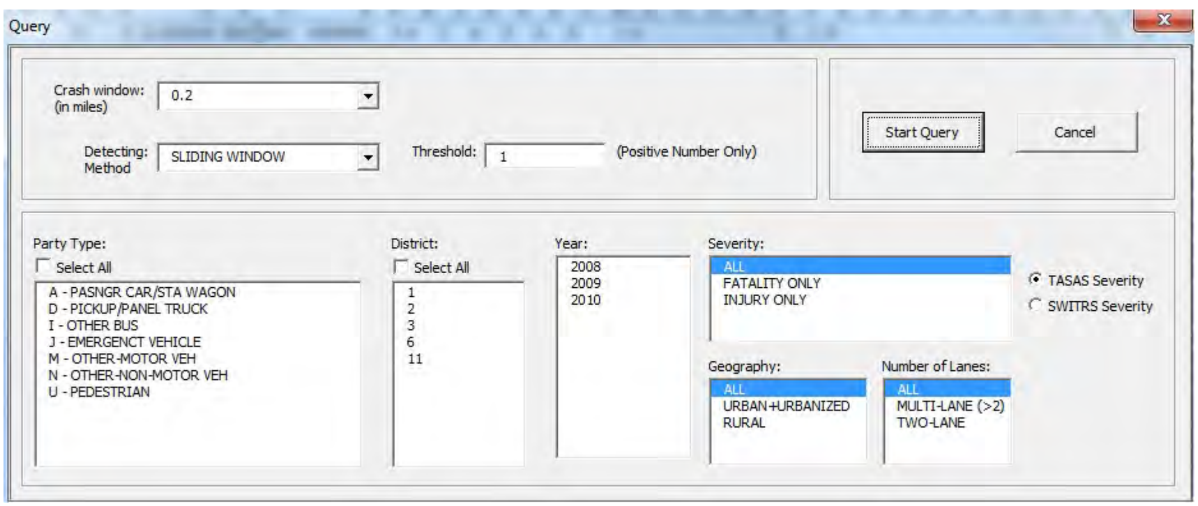
To illustrate this final step, consider the results of the case study shown in Figure 4-4. Starting with collision 9, $a_9 = 7$ reveals that there is a hotspot comprised by the collisions 7, 8 and 9. Next, collision 6 is checked, wherein $a_6 = 5$ provides the next hotspot (5,6). Subsequently, $a_4 = 3$ yields the hotspot (3,4), and finally $a_2 = 1$ reveals the remaining hotspot (1,2).

In conclusion, the dynamic programming algorithm helps identify an arrangement of hotspots which facilitates the highest possible coverage of collisions. The algorithm also ensures that the chosen hotspots satisfy the maximum window length and the minimum collision threshold criteria chosen by the user.

4.2 Comparison Between Sliding Window and Dynamic Programming

This section compares the performance of the sliding window approach and the dynamic programming framework using the TASAS collision database. In particular, the discussion is based on the query results undertaken by using the Pedestrian Safety Monitoring Report tool for all non-fatal collisions in the TASAS database. The hotspots can be queried by different fields available in the original TSAR data such as party type, district, year and/or collision severity. Additional fields such as the geography or number of lanes, are also derived from the original TSAR data. Figure 4-5 shows an example of the available query options in the tool. For a more detailed discussion of the query-making procedure within the PSMR tool, please refer to appendix 4-C.

Figure 4-5 Query Options in the PSMR Tool



4.2.1 Aggregate Results

Table 4-2 provides the summary statistics comparing the performance of the two hotspot identification approaches for the different case studies. In these case studies, the value of the minimum number of collisions per hotspot (n) is varied from 2 to 6, and the fixed/maximum window length (w) is varied to be 0.1, 0.2 and 0.3 miles. The collision database consists of pedestrian collisions for the years 2005-2010 extracted from TASAS Selective Accident Retrieval (TSAR) files.

Tables 4-2(a) and 4-2(b) show the total number of collisions and hotspots identified by sliding window and dynamic programming approaches, respectively, while Table 4-2(c) displays the difference between the two approaches. The results indicate that the dynamic programming framework yields more hotspots and collisions than the sliding window approach for all collision threshold-hotspot window length combinations. However, as Table 4-2(c) shows, the dynamic programming framework leads to a disproportionate increase in the number of hotspots as compared to the increase in the number of collisions covered by these hotspots. For instance, for $n \geq 2$, $w \leq 0.1$, dynamic programming identifies 355 more hotspots but only 73 more collisions.

Table 4-2. Summary Statistics for the Sliding Window and Dynamic Programming Results

(a) Sliding Window						
Minimum number of collisions per hotspot, n_{cric}	Fixed hotspot window length, w					
	0.1 miles		0.2 miles		0.3 miles	
	#collisions	#hotspots	#collisions	#hotspots	#collisions	#hotspots
2	3456	1256	4200	1399	4711	1469
3	1938	497	2676	637	3207	717
4	1089	214	1665	300	2187	377
5	685	113	1169	176	1543	216
6	395	55	839	110	1138	135
(b) Dynamic Programming						
Minimum number of collisions per hotspot, n_{cric}	Maximum hotspot window length, w					
	0.1 miles		0.2 miles		0.3 miles	
	#collisions	#hotspots	#collisions	#hotspots	#collisions	#hotspots
2	3529	1611	4306	1984	4803	2235
3	2060	617	2849	864	3404	1035
4	1153	250	1818	402	2404	545
5	794	141	1305	232	1771	320
6	465	68	950	141	1312	191
(c) Difference between dynamic programming and sliding window						
Minimum number of collisions per hotspot, n_{cric}	Fixed/Maximum hotspot window length, w					
	0.1 miles		0.2 miles		0.3 miles	
	#collisions	#hotspots	#collisions	#hotspots	#collisions	#hotspots
2	73	355	106	585	92	766
3	122	120	173	227	197	318
4	64	36	153	102	217	168
5	109	28	136	56	228	104
6	70	13	111	31	174	56

In order to clarify the trade-off between the total number of collisions and hotspots, Table 4-3 provides some additional statistics with regard to the average number of collisions per hotspot and the average length of the hotspots. By comparing the average number of collisions per hotspot for the sliding window and the dynamic programming approach, it can be seen that the sliding window approach yields a higher number of collisions per hotspot. However, the table also shows that the average hotspot length obtained using dynamic programming is significantly smaller than that obtained from the sliding window method, since the former relaxes the fixed hotspot assumption. Finally, Table 4-3 also shows that in spite of identifying a greater number of hotspots, the total miles covered by the hotspots of dynamic programming are fewer in number than the hotspots of sliding window. As a result, it can be argued that the dynamic programming approach yields denser hotspots than the sliding window approach.

Table 4-3. Additional Summary Statistics

(a) Sliding Window

Threshold number of collisions per hotspot, n_{cric}	Fixed hotspot window length, w								
	0.1 miles			0.2 miles			0.3 miles		
	Average number of collisions per hotspot	Average hotspot length (in miles)	Total miles covered by hotspots	Average number of collisions per hotspot	Average hotspot length (in miles)	Total miles covered by hotspots	Average number of collisions per hotspot	Average hotspot length (in miles)	Total miles covered by hotspots
2	2.75	0.1	125.6	3.00	0.2	279.8	3.21	0.3	440.7
3	3.90	0.1	49.700	4.20	0.2	127.40	4.47	0.3	215.1
4	5.09	0.1	21.400	5.55	0.2	60.00	5.80	0.3	113.1
5	6.06	0.1	11.300	6.64	0.2	35.20	7.14	0.3	64.8
6	7.18	0.1	5.500	7.63	0.2	22.00	8.43	0.3	40.5

(b) Dynamic Programming

Threshold number of collisions per hotspot, n_{cric}	Maximum hotspot window length, w								
	0.1 miles			0.2 miles			0.3 miles		
	Average number of collisions per hotspot	Average hotspot length (in miles)	Total miles covered by hotspots	Average number of collisions per hotspot	Average hotspot length (in miles)	Total miles covered by hotspots	Average number of collisions per hotspot	Average hotspot length (in miles)	Total miles covered by hotspots
2	2.19	0.032	52.20	2.17	0.066	130.23	2.15	0.097	216.01
3	3.34	0.048	29.41	3.30	0.096	82.71	3.29	0.140	144.79
4	4.61	0.054	13.47	4.52	0.117	47.13	4.41	0.176	96.03
5	5.63	0.065	9.15	5.63	0.126	29.15	5.53	0.195	62.25
6	6.84	0.071	4.84	6.74	0.141	19.85	6.87	0.215	41.01

4.2.2 Hotspot Distributions

In order to get a better understanding of the hotspots obtained using the two methodologies, the use of aggregate measures does not suffice. In comparison, the distributions of the hotspot parameters such as window lengths, and number of collisions per hotspot showcase the range of values observed. In this section, three parameters are investigated in greater detail: (a) number of collisions per hotspot, (b) hotspot window length, and (c) average spacing between collisions within a hotspot. While the first two attributes have been discussed previously, the average spacing combines these attributes to indicate how closely the collisions are located within each hotspot. For instance, the largest possible spacing within a hotspot is observed when a hotspot is defined over the maximum possible window length but only includes the threshold number of collisions. If n=2 and w=0.1, the spacing would be equal to 0.1 miles.

The distributions pertaining to these parameters have been plotted to indicate the value of each parameter at a given percentile value, which is varied from 10^{th} to 90^{th} percentile. The graphs are available in Appendix 4-A for each parameter and for both methodologies. Observations made through these graphs are discussed below.

(a) Number of collisions per hotspot:

- Dynamic programming (Figures 4-A.1-3):

The distributions indicate that, across the different collision thresholds and window length combinations, the number of collisions per hotspot remains equal to the critical threshold collision number up until 50^{th} percentile. This implies that at least half the hotspots identified by the dynamic programming framework cover only the threshold number of collisions.

After the 50^{th} percentile, the number of collisions per hotspot increase by up to two collisions more than the threshold in most cases. The only exception to this trend is $n \geq 6$, wherein for $w \leq 0.2$ and $w \leq 0.3$, the 90^{th} percentile values are three greater than the collision threshold.

- Sliding window (Figures 4-A.10-12):

The number of collisions per hotspot remains equal to the collision threshold up until the 30^{th} percentile across the different collision thresholds and window length combinations. After the 30^{th} percentile, an increase of up to three, four and five collisions is observed for the fixed window lengths of 0.1, 0.2 and 0.3 miles respectively, across the different collision threshold levels.

- Comparison between the two methodologies:

The limited variation in the collision distribution for the dynamic programming method helps explain the lower average of collisions per hotspot vis-à-vis the sliding window method. In comparison, the sliding window method displays a wide range in the number of collisions per hotspot, including a few hotspots which have significantly more collisions than the prescribed threshold.

(b) Hotspot window lengths:

- Dynamic programming (Figures 4-A.4-6):

For $w \leq 0.1$ and $n \geq 2$, the hotspot lengths are zero up until the 20^{th} percentile. This implies that 20% of the hotspots observed in this scenario are "point" hotspots, i.e. they occur at a unique location. Such point hotspots are also visible for maximum window lengths of 0.2 and 0.3 miles, but only until 10^{th} percentile.

Overall, for small collision thresholds such as $n \geq 2$ and across different w values, the distribution of hotspot window lengths tends to be skewed towards smaller window lengths and the values are much smaller than the maximum window length for most percentile values. However, as the critical collision threshold is increased, the hotspot lengths become larger. For example, for $n \geq 5$ and 6, the hotspot lengths reach approximately 90% of the maximum possible hotspot lengths by around 80% percentile.

- Sliding window:

Since the sliding window method has fixed window lengths, all hotspots are forced to have the same size.

- Comparison between the two methodologies:

As indicated by the large variation in the distributions of the hotspot lengths in the dynamic programming results, the assumption of a fixed hotspot length can be too restrictive. The starkest difference between the two techniques is reflected in the presence of point hotspots in the dynamic programming case.

(c) Average spacing within a hotspot:

- Dynamic programming (Figures 4-A.7-9):

The average spacing distribution varies the most for $n \geq 2$, which ranges from 0 (for point hotspots) to a value of 0.076 miles, 0.15 miles, and 0.23 miles for w less than 0.1, 0.2 and 0.3 miles, respectively, at the 90th percentile.

As the collision threshold is increased, the range of average spacing becomes narrower. The range is observed to be narrowest for $n>6$ across all maximum hotspot window lengths.

- Sliding Window (Figures 4-A.13-15):

For all the collision threshold-window length combinations in the case studies, a common feature among the sliding window results is that the maximum achievable average spacing is achieved by the 70th percentile. This observation can be corroborated by the discussion of the number of collisions distribution which indicated that up until the 30th percentile, the number of collisions per hotspot was equal to the critical collision threshold. Consequently, since the window length is constant, these hotspots yield the maximum average spacing.

- Comparison between the two methodologies:

While the sliding window results yield the maximum possible spacing for 30% of the hotspots, the dynamic programming results do not achieve these values.

At the other extreme, the 10th percentile values for sliding window are consistently larger than those for dynamic programming, indicating that the densest sliding window hotspots also have larger spacing than the dynamic programming counterparts.

Finally, since a large spacing is equivalent to a less dense hotspot, it can be inferred from the average spacing distributions that dynamic programming yields denser hotspots than sliding window.

4.2.3 Discussion

Based on the results of the case study, it can be argued that dynamic programming is a more efficient hotspot identification algorithm. It produces hotspots which are as dense as possible, and even though it produces more hotspots than the sliding window method, the relaxation of the fixed hotspot assumption leads to the total miles covered by these hotspots being lower than what is covered by the sliding window approach. The only limitation of the dynamic programming method is that for a given collision threshold, the resulting hotspots do not exhibit a large range of collisions per hotspot. However, this shortcoming can be easily overcome by experimenting with larger collision thresholds. An important benefit of having dense hotspots is that it allows the traffic engineers to focus only on regions that are relevant to the hotspot. While the choice of the maximum hotspot window length must be small enough to ensure that the pedestrian and roadway infrastructure elements contained with it are homogeneous, the flexilibity to generate even smaller windows makes it more likely that all collisions located within a hotspot took place under similar road conditions. In addition, the smaller sizes are more meaningful for pedestrian hotspots since pedestrian-based conflicts are more likely to arise in localized regions, such as near intersections, mid-blocks, and/or other crossings, as opposed to large stretches of roadway.

4.2.4 Practical Implementation of Hotspot Identification Process

In this section, some tips for a practical implementation of the hotspot identification process are suggested. In particular, the recommendations are directed towards generating a manageable list of hotspots for CalTrans engineers to investigate further. As indicated by the empirical case studies discussed earlier, the user input in identifying hotspots plays a very influential role. Increasing/decreasing the hotspot window length and the threshold number of collisions changes the total number of hotspots obtained. Consequently, it is important that the parameters are chosen in a manner that the list of hotspots generated by the hotspot identification algorithm is both manageable and meaningful.

4.2.4.1 Choice of Maximum/Fixed Window Length

It is crucial for both algorithms that the maximum/fixed window length is representative of a road segment and that the roadway/pedestrian infrastructure elements do not change much in the distance by the hotspot. In particular, near locations such as intersections and mid-block crossings, a hotspot should be not longer than the influence exerted by the location. Figure 4-6 shows an example of a road segment extending on either side of an intersection for half a block. The length of the road segment is 449 ft., which is a little less than 0.1 miles (528 ft). However, under this setting, a length of 0.3 miles can cover up to three blocks, which can lead to a hotspot with collisions associated with multiple intersections. While the choice of a window length may vary from an urban to a rural setting, this example illustrates how short window lengths can help ensure that the collisions taking place within each hotspot experience similar road conditions. Herein, the advantage of dynamic programming is also that the hotspots obtained through its algorithm can be significantly shorter than the prescribed maximum length.

Figure 4-6. Example of a Window Length Size Along an Urban Highway

4.2.4.2 Choice of Minimum Collision Threshold

The empirical case studies showed that, for a given maximum/fixed window length size, as the collision threshold increases, the total number of hotspots generated by either algorithm also decreases. An additional benefit of the collision threshold, especially in the context of dynamic programming, is that it makes the hotspots denser, and makes it more likely to identify locations where pedestrian collisions are a recurring phenomenon.

Given the the impact of the collision threshold on the list of hotspots generated, a strategy of choosing different collision threshold values for each district is proposed here. The dynamic choice of the collision threshold is based on the rationale that each district may have different collision patterns, and the resources available with each district to conduct pedestrian hotspot investigations may also vary. As a result, generating a list of many hundred hotspots does not help isolate the densest hotspots. However, by implementing the hotspot identification algorithm on each district's collision database, it is possible to increase the choice of the threshold until a list of only 20 hotspots are generated for each district. The list can then be processed further by the district engineers to select the locations which require further investigation. While the length of the final list of hotspots can be varied based on user experience, the strategy of using the collision threshold as a means to generate a short list of dense hotspots is appealing from a managerial point of view.

4.3 Conclusion

In this chapter, a new pedestrian hotspot identification methodology was developed which seeks to maximize the total number of collisions covered by the hotspots over the entire road network. It improves upon the existing sliding window-based hotspot identification techniques which are limited by their fixed window length assumption. An empirical evalution of the two techniques shows that the proposed hotspot identification technique covers more collisions than the sliding window approach. The results also indicate that the hotspots generated by the proposed hotspot identification approach are also more dense than those obtained from using the sliding window approach. Finally, the chapter suggests a few tips for a practical implementation of the hotspot identification algorithm so as to allow for a more efficient allocation of Caltrans resources.

4.4 References

National Research Council (US). 2010. Transportation Research Board. Task Force on Development of the Highway Safety Manual, Transportation Officials. Joint Task Force on the Highway Safety Manual, and National Cooperative Highway Research Program. *Highway Safety Manual*. Vol. 1. AASHTO.

5 Contributing Factor Analysis and Countermeasure Selection

Through five sections, this chapter compares the incidence and severity of pedestrian collisions reported on the California State Highway System from 2005-2009 with the roadway characteristics on which they occurred.

The first section is a preliminary analysis of the distribution of pedestrian collisions on state highway facilities. Both the pedestrian collisions and highway facilities are broken down into different groups by characteristics. The mapping offering a general picture of the whole state highway system about what types of pedestrian collisions occur on what types of facilities. The second section is the analysis of roadway characteristics overrepresented in pedestrian collisions and fatalities which reveals some clear findings and some characteristics that need further analysis, and points to future needs and recommendations. In the third section, different intersection related collision aggregation methods are evaluated to determine the most appropriate way to obtain intersection pedestrian collisions for analysis. The fourth section uses the data aggregated from the third section and then develops a Negative Binomial regression model to investigate the potential causing factors of pedestrian intersection collisions on state highway system. In the last section, countermeasures are summarized and linked to the causing factors which are highlighted in the statistical analysis. Countermeasures are also recommended for the state highway system to improve pedestrian safety.

Pedestrian collision data from TASAS and TSAR are both used in this chapter. For overrepresentation analysis in Section 5.2.1-5.2.5, TASAS collision data were used because they offer the most details about the collision and the roadway features. For analysis in Section5.1, 5.2.6, 5.3, and 5.4, the TSAR data were used because of the severity level information offered by matching TSAR data to SWITRS data.

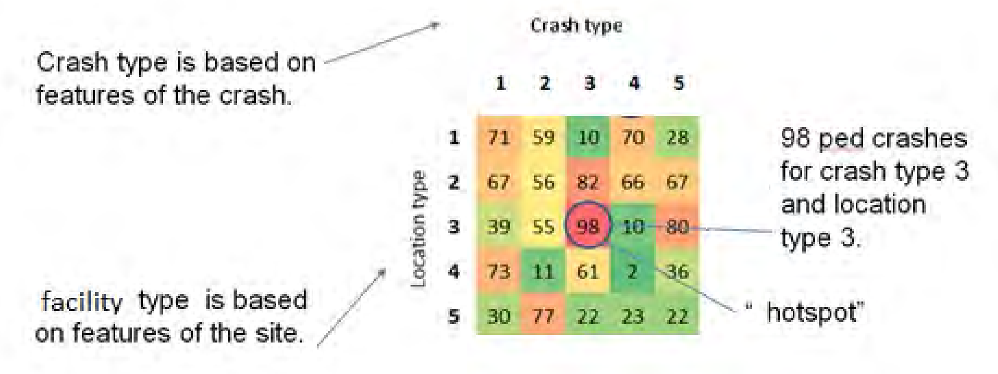
5.1 Mapping Pedestrian Collision Types on Differently Featured Facilities

The mapping of collision types on facility types is represented by a matrix with collision types listed in the first row and facility types listed in the first column. See the example in Figure 5-1. It allows us to identify what types of collisions are occurring on what type of facilities. For example the red cell in Figure 5-1 shows there are 98 pedestrian collisions in type 3 occur on the facility in type 3. The matrix gives us the big picture of the distribution of the collisions and also shows the hot spot indicating the most dangerous facilities and most frequent collisions.

The procedure to develop the matrix is as following.

1. Classify the collisions and facilities by the combination of different features.
2. Count the number of collisions of specific collision type and at a specific facility type
3. Insert the numbers into a matrix to map the distribution of collisions across all facility types
4. Showing the cells in a color scheme to highlight the hot spot in the matrix.

Figure 5-1. Example of the Matrix of Facility Types and Collision Types



5.1.1 Facility Types and Collision Types

The data used in this analysis was obtained from TSAR and SWITRS. The facility types were classified based on the features of main approaches connected to each intersection, including the access control type, median type, area type, and number of lanes. The collision types were classified based on the primary collision factor and movement preceding collision. Overall, 57 collision types and 106 facility types for the years 2005-2009 were identified and applied in this study. The descriptions of collision types and facility types are shown in Tables 5-1 and 5-2.

Table 5-1. Description of Facility Types

Collisoin Type	Description
1	PCF_BLANK,MPC_BLANK
2	PCF_BLANK, crossing in crosswalk at intersection
3	PCF_BLANK, crossing in crosswalk not at intersection
4	PCF_BLANK, cross-not in crosswalk
5	PCF_BLANK, in roadway-include shoulder
6	PCF_BLANK, not in roadway
7	under influence of alcohol, MPC_BLANK
8	under influence of alcohol, crossing in crosswalk at intersection
9	under influence of alcohol, crossing in crosswalk not at intersection
10	under influence of alcohol, cross-not in crosswalk
11	under influence of alcohol, in roadway-include shoulder
12	under influence of alcohol, not in roadway
13	following too closely, MPC_BLANK
14	following too closely, crossing in crosswalk at intersection
15	following too closely, cross-not in crosswalk
16	following too closely, in roadway-include shoulder
17	failure to yield, MPC_BLANK
18	failure to yield, crossing in crosswalk at intersection
19	failure to yield, crossing in crosswalk not at intersection

Collision	Description

Type	
20	failure to yield, cross-not in crosswalk
21	failure to yield, in roadway-include shoulder
22	failure to yield, not in roadway
23	improper turn, MPC_BLANK
24	improper turn, crossing in crosswalk at intersection
25	improper turn, crossing in crosswalk not at intersection
26	improper turn, cross-not in crosswalk
27	improper turn, in roadway-include shoulder
28	improper turn, not in roadway
29	speeding, MPC_BLANK
30	speeding, crossing in crosswalk at intersection
31	speeding, crossing in crosswalk not at intersection
32	speeding, cross-not in crosswalk
33	speeding, in roadway-include shoulder
34	speeding, not in roadway
35	other violations, MPC_BLANK
36	other violations, crossing in crosswalk at intersection
37	other violations, crossing in crosswalk not at intersection
38	other violations, cross-not in crosswalk
39	other violations, in roadway-include shoulder
40	other violations, not in roadway
41	other violations, approaching/leaving school bus
42	other improper driving, MPC_BLANK
43	other improper driving, crossing in crosswalk at intersection
44	other improper driving, in roadway-include shoulder
45	other improper driving, not in roadway
46	other than driving, MPC_BLANK
47	other than driving, crossing in crosswalk at intersection
48	other than driving, crossing in crosswalk not at intersection
49	other than driving, cross-not in crosswalk
50	other than driving, in roadway-include shoulder
51	other than driving, not in roadway
52	unknown, MPC_BLANK
53	unknown, crossing in crosswalk at intersection
54	unknown, crossing in crosswalk not at intersection
55	unknown, cross-not in crosswalk
56	unknown, in roadway-include shoulder
57	unknown, not in roadway

Table 5-2. Description of Pedestrian Collision Types

Facility Types	Descriptions
1	one-way city street-no access control, Med_other, 2-4 lanes, rural
2	conventional-no access control, Med_other, 2-4 lanes, urban
3	conventional-no access control, Med_other, 5-7 lanes, urban
4	conventional-no access control, Med_other, 10+lanes, urban
5	conventional-no access control, undivided striped, 2-4 lanes, urbanized
6	conventional-no access control, undivided striped, 2-4 lanes, rural
7	conventional-no access control, undivided striped, 2-4 lanes, urban
8	conventional-no access control, undivided striped, 5-7 lanes, rural
9	conventional-no access control, undivided striped, 5-7 lanes, urban
10	conventional-no access control, divided two-way left turn lane, 2-4 lanes, urbanized
11	conventional-no access control, divided two-way left turn lane, 2-4 lanes, rural
12	conventional-no access control, divided two-way left turn lane, 2-4 lanes, urban
13	conventional-no access control, divided two-way left turn lane, 5-7 lanes, rural
14	conventional-no access control, divided two-way left turn lane, 5-7 lanes, urban
15	conventional-no access control, divided continuous left-turn lane, 2-4 lanes, urbanized
16	conventional-no access control, divided continuous left-turn lane, 2-4 lanes, rural
17	conventional-no access control, divided continuous left-turn lane, 2-4 lanes, urban
18	conventional-no access control, divided continuous left-turn lane, 5-7 lanes, urban
19	conventional-no access control, divided continuous left-turn lane, 8-9 lanes, urban
20	conventional-no access control, divided unpaved median, 2-4 lanes, urbanized
21	conventional-no access control, divided unpaved median, 2-4 lanes, rural
22	conventional-no access control, divided unpaved median, 2-4 lanes, urban
23	conventional-no access control, divided unpaved median, 5-7 lanes, urban
24	conventional-no access control, divided unpaved median, 8-9 lanes, urban
25	conventional-no access control, divided unpaved median, 10+lanes, urban
26	conventional-no access control, divided separate grade, 2-4 lanes, urbanized
27	conventional-no access control, divided separate grade, 2-4 lanes, rural
28	conventional-no access control, divided separate grade, 2-4 lanes, urban
29	conventional-no access control, divided separate grade, 5-7 lanes, urban
30	conventional-no access control, divided separate structure, 2-4 lanes, urban
31	conventional-no access control, divided separate structure, 10+lanes, urbanized
32	conventional-no access control, divided separate structure, 10+lanes, urban
33	conventional-no access control, Med_other, 2-4 lanes, urban
34	conventional-no access control, Med_other, 2-4 lanes, rural
35	expressway-partial access control, Med_other, 2-4 lanes, urban
36	expressway-partial access control, undivided striped, 2-4 lanes, urbanized
37	expressway-partial access control, undivided striped, 2-4 lanes, rural

Facility Types	Descriptions
38	expressway-partial access control, undivided striped, 2-4 lanes, urban
39	expressway-partial access control, divided two-way left turn lane,2-4 lanes, urbanized
40	expressway-partial access control, divided two-way left turn lane, 2-4 lanes, rural
41	expressway-partial access control, divided continuous left-turn lane, 2-4 lanes, rural
42	expressway-partial access control, divided continuous left-turn lane, 5-7 lanes, urbanized
43	expressway-partial access control, divided continuous left-turn lane, 5-7 lanes, urban
44	expressway-partial access control, divided unpaved median, 2-4 lanes, urbanized
45	expressway-partial access control, divided unpaved median, 2-4 lanes, rural
46	expressway-partial access control, divided unpaved median, 2-4 lanes, urban
47	expressway-partial access control, divided unpaved median, 5-7 lanes, urbanized
48	expressway-partial access control, divided unpaved median, 5-7 lanes, urban
49	expressway-partial access control, divided separate grade, 2-4 lanes, urbanized
50	expressway-partial access control, divided separate grade, 2-4 lanes, rural
51	expressway-partial access control, divided separate grade, 2-4 lanes, urban
52	expressway-partial access control, divided separate grade, 5-7 lanes, urbanized
53	expressway-partial access control, divided separate grade, 5-7 lanes, rural
54	expressway-partial access control, divided separate grade, 5-7 lanes, urban
55	expressway-partial access control, divided separate structure, 2-4 lanes, rural
56	expressway-partial access control, divided separate structure, 2-4 lanes, urban
57	expressway-partial access control, Med_other, 2-4 lanes, rural
58	freeway-full access control, Med_other,2-4 lanes, urban
59	freeway-full access control, Med_other,5-7 lanes, urban
60	freeway-full access control, Med_other,8-9 lanes, urbanized
61	freeway-full access control, Med_other,8-9 lanes, urban
62	freeway-full access control, Med_other,10+lanes, rural
63	freeway-full access control, Med_other,10+lanes, urban
64	freeway-full access control, undivided striped, 2-4 lanes, rural
65	freeway-full access control, divided unpaved median, 2-4 lanes, urbanized
66	freeway-full access control, divided unpaved median, 2-4 lanes, rural
67	freeway-full access control, divided unpaved median, 2-4 lanes, urban
68	freeway-full access control, divided unpaved median, 5-7 lanes, urbanized
69	freeway-full access control, divided unpaved median, 5-7 lanes, rural
70	freeway-full access control, divided unpaved median, 5-7 lanes, urban
71	freeway-full access control, divided unpaved median, 8-9 lanes, urbanized
72	freeway-full access control, divided unpaved median, 8-9 lanes, rural
73	freeway-full access control, divided unpaved median, 8-9 lanes, urban

Facility Types	Descriptions
74	freeway-full access control, divided unpaved median, 10+lanes, rural
75	freeway-full access control, divided unpaved median, 10+lanes, urban
76	freeway-full access control, divided separate grade, 2-4 lanes, urbanized
77	freeway-full access control, divided separate grade, 2-4 lanes, rural
78	freeway-full access control, divided separate grade, 2-4 lanes, urban
79	freeway-full access control, divided separate grade, 5-7 lanes, urbanized
80	freeway-full access control, divided separate grade, 5-7 lanes, rural
81	freeway-full access control, divided separate grade, 5-7 lanes, urban
82	freeway-full access control, divided separate grade, 8-9 lanes, urbanized
83	freeway-full access control, divided separate grade, 8-9 lanes, rural
84	freeway-full access control, divided separate grade, 8-9 lanes, urban
85	freeway-full access control, divided separate grade, 10+lanes, urbanized
86	freeway-full access control, divided separate grade, 10+lanes, rural
87	freeway-full access control, divided separate grade, 10+lanes, urban
88	freeway-full access control, divided separate structure, 2-4 lanes, urbanized
89	freeway-full access control, divided separate structure, 2-4 lanes, rural
90	freeway-full access control, divided separate structure, 2-4 lanes, urban
91	freeway-full access control, divided separate structure, 5-7 lanes, urbanized
92	freeway-full access control, divided separate structure, 5-7 lanes, urban
93	freeway-full access control, divided separate structure, 8-9 lanes, rural
94	freeway-full access control, divided separate structure, 8-9 lanes, urban
95	freeway-full access control, divided separate structure, 10+lanes, rural
96	freeway-full access control, divided separate structure, 10+lanes, urban
97	freeway-full access control, Med_other, 2-4 lanes, rural
98	freeway-full access control, Med_other, 2-4 lanes, urban
99	freeway-full access control, Med_other, 5-7 lanes, urbanized
100	freeway-full access control, Med_other, 5-7 lanes, urban
101	freeway-full access control, Med_other, 8-9 lanes, urban
102	freeway-full access control, Med_other, 10+lanes, urban
103	freeway-full access control, Med_other, 10+lanes, urbanized
104	one-way city street-no access control, Med_other, 10+lanes, urban
105	one-way city street-no access control, divided unpaved median, 10+lanes, urban
106	one-way city street-no access control, divided separate structure, 10+lanes, rural

5.1.2 Matrix of Facility Types and Collision Types

This analysis calculates the number of a specific type of collision from year 2005-2009 that occurs on California's State Highway System. The resulting matrix is shown in Figures 5-2 through 5-7. The number in each cell indicates the number of collisions for a specific collision type and intersection type.

Generally speaking, collisions are concentrated on specific facility types and collision types. Figures 5-2 through 5-7 show that there are certain groups of facility types on which collisions of almost every type occur. For example, 37% of collisions of more than 58% of collision types occur on "conventional-no access control, undivided striped/ divided two-way left turn lane/ divided unpaved median, 2-4 lanes" facilities (facility types #5 - #12 and #17 - #19). Similarly, 33% of collisions of 18% - 63% of collision types occur on "freeway-full access control, divided unpaved median, more than 7 lanes" facilities (facility type #73 - #75) and "freeway-full access control, divided separate grade, less than 10 lanes" facilities (facility type #76 - #84). Also, there are some certain types of collisions which occur on nearly every type of facility. For example, "failure to yield" collisions (collision type #18) comprise 20% of overall collisions and occur on 66% of facility types. Collisions labeled as "other violations, in roadway-include shoulder" (collision type #39) comprise 14% collisions and also occur on 66% of facility types. Similarly, "other violations, cross-not in crosswalk" collisions (collision type #38) comprise 17% of collisions and occur on 64% facility types.

Figures 5-2 to 5-4 display the distribution of collision types from "not stated" (collision type #1) to" improper turn, not in roadway" (collision type #28) across all the facility types. It is clear from the green and yellow that most facility types experience relatively low frequencies of collisions of any one type. However, the orange and red suggest that this is not always the case. For example, note that "failure to yield" collisions (collision type #18) occur on nearly every road type, and occur in very high numbers on certain road types. There were 164 "failure to yield" collisions on conventional, uncontrolled, undivided, 2-4 lane urban highways (facility type #7) from 2005-2009. On conventional, uncontrolled, divided urban highways with 2-4 lanes and a continuous left-turn lane (facility type #17), there were 179 of these collisions. There were 101collisons on both "freeway-full access control, divided unpaved median, 8-9 lanes, urban" (facility type # 73) and "conventional-no access control, divided unpaved median, 5-7 lanes, urban"(facility # 23).

Figure 5-2. Matrix of Pedestrian Collision Types (type 1 - 28) and Facility Types (type 1 - 35)

Collision types / Facility Types	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1																												
2																		4		1								1
3						1												2										
4												1						8										
5		2		1				1			3	1			1		3	76	3	6	1	4	1	1		2	4	2
6				2	1		5	3		1	14	6	3			1	7	38	4	8		3	8			2	35	6
7		2			1		2	3			8	4	1				1	164	10	8	3	4	3	5	1		11	6
8																		1										
9								1									1	4									1	
10		1	1	3	2	1		1		1		1		1			1	44	3	2		1		2		2		1
11								1									3	29	5		1	1	1			1	2	
12				3							3	3						103	5	8	5	15		1	1	3	4	3
13																												
14					1								1				1	18				1						
15	1													1			1	18	1		1	1				1	1	
16																		3		1							1	
17	1	10		2	1	1	1	3		2	5	1					6	179	3	5	4	6		1	2	2	2	6
18		3		1	1	1	1	2		2	1	1					3	86	3	4	2	4						2
19								1									2	15				1						2
20								1				1						11	1	3				2				
21							1											1		2							1	
22		1			1		1		1	2	4	1					4	59	3	1	4	4		1			1	4
23		2				1		1		1	1						2	101	2	1	4	7		3		2	3	1
24																		4	1									
25																		2										
26																		4		2								
27																											1	
28											2							43	1	2						1		2
29		1						1			1	1					4	86	1	4	1	9		3				
30																		3										
31														1				2										
32																		1										
33																												
34																												
35																		1										

Figure 5-3. Matrix of Pedestrian Collision Types (type 1 - 28) and Facility Types (type 36 - 70)

Collision types / Facility Types	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
36																		1										
37											1						1	1			1		1				2	3
38																		2										
39																		1		1							1	
40																		1										
41																		1										
42																												
43																												
44																		1										
45							1				1		1														1	
46							1																					
47																		1										
48																		2										
49																		1										
50											1	1											1				2	
51											1							5				1					1	1
52																												
53																												
54																		4		1		1						
55																												
56																											1	
57																												
58																		2					1				1	
59		2			1						1							2									2	
60																												
61							1				3							9	2				1	1			5	
62											1												1				1	
63											2	1						3	1				2				4	
64																												
65																			1								1	
66																		1					2				5	1
67											2							5								1		
68																		2										
69					1																		1				5	
70		1	1				6	1	1		17	2				1		50	6	2			9			1	15	2

Figure 5-4. Matrix of Pedestrian Collision Types (type 1 - 28) and Facility Types (type 71 - 106)

Collision types / Facility Types	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
71																		1										
72																			1								2	
73		1	1		1		5				51						1	101	19	2			21		1		56	13
74												1															1	
75	1	2					5	1			26	2	1				2	78	8	2		1	25				59	11
76							1											13		2			3	1			6	1
77					1		4				11	1					1	4					6				25	5
78							2			1	8	1						24	4	1	1		2	1		1	18	3
79					1		1				2							3										
80											4												1				9	1
81		2			1		4	1			18	2						52	1	2	1	1	5	1			22	3
82		1									1							1	1								1	
83							2				2												2				10	3
84	1	4					2				23	1	1					38	4	2			4			1	32	4
85																												
86																											1	
87							1				5		1					7				1					8	2
88																											1	
89																											1	1
90																												
91											1																	1
92																		3										
93																							1					
94											2						1	2	1				1				3	
95					1						1																4	
96							2				5							2					1				2	
97											1																1	
98																											2	
99																												
100											1	2						3					3				4	
101																		7					1	1			1	1
102																		1										
103								1										19		1								
104																		20		2								
105																		1										
106														1														

Figures 5-5 to 5-7 display the distribution of collision types from "speeding, MPC_BLANK" (collision type #29) to "unknown, not in roadway" (collision type #57) across all the facility types. It is clear from the distribution of the colorful cells that collision are concentrated from type #29 to type #39. Based on the distribution of red cells, there are 161 and 131 "other violations, in roadway-include shoulder" collisions (collision type #29) occur on "freeway-full access control, divided unpaved median, 8-9 lanes, urban" facilities (facility type #73) and "freeway-full access control, divided unpaved median, 10+lanes, urban" facilities (facility type #75) respectively. And there are 126 "speeding, in roadway-include shoulder" collisions (collision type #33) occur on "freeway-full access control, divided unpaved median, 8-9 lanes, urban" facilities (facility type #73).

Figure 5-5. Matrix of Pedestrian Collision Types (type 29 - 57) and Facility Types (type 1 - 35)

Collision types / Facility Types	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57
1											3																		
2								3																					
3		1								1	1																		
4								1				1																	
5	2	4		4	6	1	2	29	1	89	26	4										2		1	4		1	6	
6	37	1	1	17	68	10	35	19	2	122	115	3	1	1		5		3	1			10		1	1			11	1
7	5	4		8	7	3	7	67	2	107	36	7		1		1			1			1	2		11		4	2	
8																													
9								5		3						1	2								1				
10	1	1		3	1	2		25	1	69	17	1										1			1		1		1
11		2		1	2		1	7	3	45	13	1										2	1		2			2	
12	1	4		1	3		1	52	1	94	18	5	1						1		1	1	1		9		1	1	2
13																									1				
14	1	1	1	2	3			12		19	3	1															1		
15		3		3			1	3	1	15	4										1				3				
16					1					2																			
17	1	1		2	7	3	2	65	1	110	20	5			1		1		1		1	4	2		12	1	4	1	
18	1	4		1	2	3	1	58		58	9	4					1					1			6			1	
19	1	1		2	1			17		31	3	2							1		1				8		2	1	1
20				2	2	1		1		12	3																	1	
21	2				3					6	2							1											
22	2	3		2	4	1	4	38		64	14	1									1				3		3	2	
23		6		2	5		4	63	1	86	13	6									1	2			8		1	1	1
24								10		3	2																		
25																													
26				2				1		5											1								
27										3	2																		
28		2			2		2	30	1	44	10														1		2	3	
29	1	2		2	1	3	3	48		62	11	4				1						1	1	1	10		1	2	1
30	1									2		1										1							
31								2		1						1									1				
32										1																			
33											2																		
34											1																		
35																													

Figure 5-6. Matrix of Pedestrian Collision Types (type 29 - 57) and Facility Types (type 36 - 70)

Collision types / Facility Types	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57
36								2																					
37	3				10	1	4	2		7	11							1									1		
38										1	1																		
39							1	1		5	2																		
40							1			1																			
41																													
42										1																			
43								1																					
44								2																					
45	2				4		1			1	2							1				1	1					1	
46					1	1		4		2	2	2																	
47																													
48					1						1																		
49						1		2		2	1																		
50	2				5	1		1		11	14	1										2					1		
51	1				1		1	9		2															1				
52										1																			
53										1												1							
54					1					1																			
55					2						1																		
56																													
57					1																								
58	1	1			9		1			4	1						1									1			
59	1		1		2			1		2	11							1											
60	1																												
61	5				5		4	4	1	3	10							1				1	1		1				
62	1										2	1																	
63	5				6		3	3		4	15											1						1	
64							1																						
65					1					2	6																		
66	1				5	1		1		1	5						1					1							
67	3				8	1	1	2		6	6										1								
68								1			1																		
69	1				7					1	6							2											
70	25	2		1	41	3	14	17	3	28	77	2						1				8	2		3		1	7	

Figure 5-7. Matrix of Pedestrian Collision Types (type 29 - 57) and Facility Types (type 71 - 106)

Collision types / Facility Types	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57
71						1																							
72					3					1	1											1							
73	58	3	3	1	126	4	16	35	7	51	161	4		1		2		4				15		1	12			5	
74	1				1		1																						
75	55	3	1	2	106	1	32	36	3	32	131	3		1			1	2		1		15			13	3		2	2
76	2	2			6	1		4	1	18	16														2			2	
77	5				35	1	2	1		8	39					2	1					8	2					5	
78	5			1	20		2	13	1	19	44											1			1		4	1	
79	1							1		4	12			1														1	
80					10	1				1	16						1					1						1	
81	16	1		1	34	1	7	16	1	29	52	1									1	2			3			3	
82					1	1					5	1					1					1						1	
83	2				11		1			1	13											2							
84	20	4	1	1	34	4	10	21	2	25	69	1						2				2			7			1	
85					2						2											1							
86	1						1				2																		
87	8			1	10		3	3	2	2	25	1													1			1	1
88																													
89					1						3																		
90					1						2																		
91					1						1																		
92					2		1				3																	1	
93					1						1																		
94					4		1	2		2	5																		
95					5	1					2																		
96	4				9		2	3		1	4											1							
97					2																								
98	2				6			1		2	2																		
99					1																								
100					5		2				7																	1	
101	4			1	6	2	2	1		2	6														1				
102					1	1				3	5														1				
103								4		5		1																	
104								3	2	8	2	1																	
105								3																					
106				1						1											1								

5.1.3 Findings

Table 5-3 displays the 10 largest numbers of combinations of collision types and facility types, as determined from the preceding matrix.

Table 5-3. Top Ten Largest Numbers in the Matrix of Collision Types and Facility Types

Number of Collisions	Collision Types	Facility Types
179	failure to yield, crossing in crosswalk at intersection	conventional-no access control, divided continuous left-turn lane, 2-4 lanes, urban
164	failure to yield, crossing in crosswalk at intersection	conventional-no access control, undivided striped, 2-4 lanes, urban
161	other violations, in roadway-include shoulder	freeway-full access control, divided unpaved median, 8-9 lanes, urban
131	other violations, in roadway-include shoulder	freeway-full access control, divided unpaved median, 10+lanes,urban
126	speeding, in roadway-include shoulder	freeway-full access control, divided unpaved median, 8-9 lanes, urban
122	other violations, cross-not in crosswalk	conventional-no access control, undivided striped, 2-4 lanes, rural
115	other violations, in roadway-include shoulder	conventional-no access control, undivided striped, 2-4 lanes, rural
110	other violations, cross-not in crosswalk	conventional-no access control, divided continuous left-turn lane, 2-4 lanes, urban
107	other violations, cross-not in crosswalk	conventional-no access control, undivided striped, 2-4 lanes, urban
106	speeding, in roadway-include shoulder	freeway-full access control, divided unpaved median, 10+lanes, urban

According to the matrix, most of the large numbers of collisions are concentrated on:

- Failure to yield, crossing in crosswalk at intersection collisions or other violation, cross-not in crosswalk collisions occurring at conventional-no access control, divided continuous left-turn lane or undivided striped, 2-4 lanes, urban facilities；
- Speeding or other violations, in roadway-include shoulder collisions occurring at freeway-full access control, divided unpaved median, more than 7 lanes, urban facilities
- Other violations, cross-not in crosswalk collisions occurring at conventional-no access control, undivided striped, 2-4 lanes, rural facilities

Understanding the patterns between collision types and facility types is important for Caltrans to target systemic strategies to reduce pedestrian morbidity. These findings show that most of the pedestrian collisions happen in urban areas where pedestrian activity is more intensive. Also, highways without access control are more accessible for pedestrians, thereby increasing potential pedestrian exposure to collisions. In contrast, pedestrian activity is lower in rural areas, leading to different infrastructure types and therefore different collision patterns. For example, pedestrian collisions in rural areas are less likely to occur in a crosswalk due to a lack of crosswalks. It is notable that in urban areas, even highways with full access control still have large numbers of pedestrian collisions caused by speeding or other violations in roadway.

5.2 Roadway Factors Overrepresented in California State Highway System

The analysis uses the data from TASAS database from 2005 to 2009. It covers the following:

- 7,560 reported pedestrian collisions, of which 72% occurred on highway segments, 13% at intersections, and 15% on ramps.
- 1,000 (13%) fatalities out of all reported collisions, with 888 (16%) fatalities out of all segment collisions, 70 (6%) fatalities out of all intersection collisions, and 42 (4%) fatalities out of all ramp collisions.

The purpose of this study is to identify road characteristics that are highly correlated with pedestrian collisions and fatal injuries on the California State Highway System (SHS). This is an exploratory analysis intended to guide future studies that will explore the relationship between road characteristics and pedestrian collisions in more depth. These analyses will ultimately lead to countermeasures to reduce pedestrian injuries.

For this analysis, we identify the characteristics of highway segments (defined as the roadway between intersections and ramps), intersections, and ramps that are overrepresented among pedestrian collisions. Overrepresentation is defined as a higher-than-expected number of reported pedestrian collisions or fatalities occurring on SHS segments, intersections, or ramps with a particular design feature. The first part of this report presents roadway features overrepresented in all pedestrian collisions, and the second part focuses on roadway features overrepresented in pedestrian collisions with fatal injuries.

The distribution of all reported pedestrian collisions on the California SHS is important to explore because it may show that certain roadway features experience more collisions. Upon further investigation, it may be possible to estimate the number of pedestrian collisions that could be reduced by changing a particular roadway feature or installing a pedestrian safety treatment (e.g., constructing sidewalks, adding median crossing islands, providing pedestrian crossing beacons). This section presents an early, exploratory step toward identifying pedestrian collision countermeasures on the SHS.

Pedestrian volume is an integral part of understanding the relationship between infrastructure and collision frequency. More pedestrian collisions are likely to occur in locations where there is more pedestrian activity. This means that roadway features that are more common in areas with higher pedestrian volumes (e.g., sidewalks, median crossing islands) may experience more collisions, even though they generally increase the safety of individual pedestrians. Therefore, the actual benefit of pedestrian safety features cannot be assessed accurately without accounting for pedestrian volume.

In the absence of pedestrian volume data on the SHS, we created a rough approximation of exposure by separating the available statewide data by geography. The geographic categories rural, urban, and urbanized (similar to, but not technically the same as, the common use of “suburban”) are identified in Caltrans’ collision and highway databases, and separating the collision data into these categories allows us to make observations about overrepresented infrastructure at collision sites within specific geographies through the state highway system. In general, the highest pedestrian volumes are in urban areas and diminish through urbanized into rural areas.

5.2.1 Roadway Features Overrepresented in All Pedestrian Collisions

5.2.1.1 Methodology

Combining Caltrans' TASAS collision and highway databases, we tabulated pedestrian collisions that occurred on parts of the SHS with specific roadway characteristics. The distribution of collisions throughout the SHS was then compared with the overall number of miles (for segments) or number of features (for intersections or ramps) with each roadway characteristic on the SHS. Using segments as an example, we then calculated: A) the proportion of collisions that occurred on segments exhibiting a particular characteristic, and B) the proportion of highway miles with the same characteristic. As a final step, we calculated a relationship between these two proportions:

- If A > B, then the characteristic was overrepresented, and the relationship was calculated as (A-B)/B. This was multiplied by 100 to produce a positive percentage.
- If B > A, then the characteristic was underrepresented, and the relationship was calculated as, (A-B)/A. This was multiplied by 100 to produce a negative percentage.

The analysis was then disaggregated by geography, creating separate tabulations for collisions that occurred in rural, urbanized, or urban locations. Statistics relating over- and underrepresentation of collisions for certain roadway characteristics by geography were then calculated. Overrepresentation was noted by a light orange color for all values over 100% and a dark orange color for all values greater than 200%. Underrepresentation was identified by a light green color for values less than -100% and a dark green color for values less than -200%. Since small sample sizes produce highly-variable results, over- or underrepresentation was not classified for roadway features that had fewer than 30 reported collisions. All data used in the analysis are presented in Appendices 5-A-L. Summary statistics for the SHS segment, intersection, and ramp characteristics are provided below (Table 5-4).[7]

Table 5-4. State System Summary Statistics

	Urban		Urbanized		Rural		Total	
Infrastructure	**Crashes**	**Miles/Facilities**	**Crashes**	**Miles/Facilities**	**Crashes**	**Miles/Facilities**	**Crashes**	**Miles/Facilities**
Highways	3788	716	576	3115	1113	11594	5477	15425
Intersections	685	5894	173	2294	97	10056	955	18244
Ramps	1043	10713	60	984	25	2860	1128	14557

[7] Segments, intersections, and ramps on the State Highway System are defined as "urbanized" if they are within local areas with greater than 50,000 residents per square mile, "urban" if they are within local areas of 5,000 to 50,000 residents per square mile, and "rural" if they are within local areas of fewer than 5,000 residents per square mile. Locations are considered to be "suburban" if they are 1) "rural" and inside a city, 2) "urban" and outside a city, or 3) "urbanized" and outside a city.

5.2.2 Results Pertaining to Facilities for All Pedestrian Collisions

A total of 7560 pedestrian collisions were reported on the California SHS from 2005 to 2009. These collisions occurred in different locations.

- 5477 (72%) were on state highway segments. Of these collisions, 3788 were in urban areas, 576 were urbanized, and 1113 were rural.
- 1128 (15%) occurred at highway ramp locations. Of these collisions, 1043 were in urban areas, 60 were urbanized, and 25 were rural.
- 955 (13%) occurred at highway intersections. Of these collisions, 685 were in urban areas, 173 were urbanized, and 97 were rural.

The exact cause of these collisions is not demonstrated in the data, and any observed relationship between various highway, intersection, and ramp characteristics and pedestrian collisions cannot be deemed causal. However, for each design feature that is overrepresented at pedestrian collision sites, we offer some basic hypotheses about characteristics that may contribute to pedestrian risk.

5.2.2.1 Highways

Highway segments are defined as the road segment between intersections, not including ramps. The following analysis of highway segments highlights several characteristics that are associated with higher-than-expected numbers of pedestrian collisions.

Travel Lanes

Highways with *more than 3 travel lanes* and highways with *more than 25 feet of travel way width* in a single direction of travel are highly overrepresented at collision sites. For example, 20% of pedestrian collisions are on highways with 3 lanes in a single direction of travel, but these roadways account for only 6% of state highway system miles. In contrast, *two-lane roadways* are underrepresented. Only 17% of pedestrian collisions occur on two-lane roadways but they account for 60% of highway miles (Appendix 5-A). Possible explanations for these findings include that wider roadways relate to longer pedestrian crossing distances, which increase the time spent in the road. Multi-lane roadways may also have more potential for multiple-threat situations. It is also possible that these features are overrepresented because they are more common in urban areas where more pedestrians are present. Examining pedestrian collisions only in urban areas (Appendix 5-C) shows that that more than 3 travel lanes and more than 25 feet of travel way width in a single direction is not as widely overrepresented among collision sites, but these features are still associated with higher-than-expected numbers of pedestrian collisions. In addition, two-lane roadways (i.e., one lane in a single direction) are still underrepresented, even in urban areas with higher pedestrian volumes. Therefore, there is evidence suggesting greater pedestrian collision risk on multi-lane roadways and greater safety on two-lane roadways.

Shoulder Width

Overall, there is no evidence for strong overrepresentation among any amount of *outside shoulder treated width*, although there is some underrepresentation of pedestrian collisions on highways with fewer than six feet of outside shoulder treated width

(Appendix 5-A). This may be due to the presence of fewer pedestrians in rural areas with limited shoulders. Looking only at urban highways, the data does suggest that outside shoulder treated widths of less than two feet are slightly overrepresented, but some wider shoulders are also overrepresented (Appendix 5-C).

Medians

Among all median types, the most significant overrepresentation occurred where a *two-way left turn lane or a continuous left turn lane* was present (Appendix 5-A). These two features are very similar in that they potentially subject pedestrians to two directions of traffic and do not provide a raised center refuge for pedestrians crossing the roadway. These features may also be more common in urban areas with higher pedestrian volumes. In urban areas, however, these features are still overrepresented. Twenty-four percent of pedestrian collisions occurred on urban highways with either two-way or continuous left turn lanes, but these features are present on only 7% of urban highway miles (Appendix 5-B).

Curbed medians with landscaping were also overrepresented in pedestrian collisions. Curbed medians and curbed medians with trees and shrubs each show an overrepresentation of more than 500% (Appendix 5-A). Without specific collision narratives, it is unclear, for instance, whether landscaping obstructs the view of drivers and contributes to the pedestrian collision. However, the presence of landscaping and its overrepresentation at pedestrian collision sites may indicate that landscaping is more common in urban areas or more likely to be present in areas appealing to pedestrians, thus related to higher levels of pedestrian exposure. Considering only urban highways, curbed medians with landscaping are still overrepresented in pedestrian collisions, but the level of overrepresentation is lower (Appendix 5-B). These results should be studied in more depth after accounting for differences in pedestrian volume levels.

Posted Speed Limits

Likewise, pedestrian collision overrepresentation on highways with *posted speeds of less than 40 mph* may simply indicate that there are higher pedestrian volumes along these roadways than along high-speed rural roadways (Appendix 5-D). Dividing the analysis by geography highlights an important trend in rural areas. Just 43 miles of rural highways (0.4%) have design speeds of 25 mph, but 35 pedestrian collisions (3.1%) occurred on these particular SHS segments between 2005-2009 (Appendix 5-D). This may be due to a greater number of collisions occurring where rural highways pass through small towns, (these short sections of highway often have reduced speed limits). It is likely that more pedestrians walk along and cross state highways in these small communities, so this finding needs further exploration after controlling for pedestrian exposure.

AADT

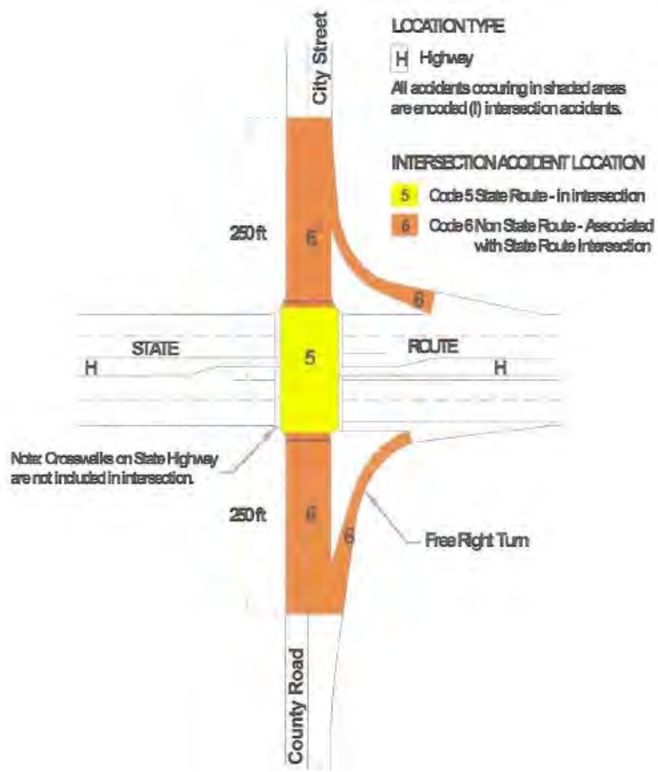
Finally, highways with *higher ADT* (average daily traffic) are overrepresented at pedestrian collision sites. Across all geographies, highways with greater than 20,000 vehicles a day are overrepresented among pedestrian collisions. Highways with greater than 30,000 ADT are even more overrepresented—63% of all pedestrian collisions occurred on highways with greater than 30,000 ADT but these roadways comprise just

26% of the SHS. (Appendix 5-A.) However, ADT is also associated with higher pedestrian volumes. On urban highways, where there are more roadways with greater ADT and generally greater pedestrian volumes, there is also an overrepresentation of pedestrian collisions. Of the 5,477 total pedestrian collisions on the SHS, 2990 occurred on urban highways with greater than 30,000 ADT (55% of all pedestrian collisions on highways). At the same time, rural highways with greater than 30,000 ADT account for just 10% of rural highways but comprise 25% of pedestrian collisions on rural highways. (Appendices 5-B and 5-D.)

5.2.2.2 Intersections

Intersections on the SHS are defined as areas where other roadways cross or join the state highway. Specifically, collisions that occur on the state highway between the extension of the intersecting roadway curb lines are classified as intersection collisions. Collisions that occur on the intersecting roadway up to 250 feet from the state highway right-of-way line are also classified as intersection collisions (Figure 5-8). Note that collisions occurring in the crosswalk that crosses the state highway are not considered to be intersection collisions. They are classified as segment collisions.

Figure 5-8. State Highway System Intersection Crash Classification Diagram



Source: Caltrans Division of Transportation System Information

To analyze collision counts for all intersection data, the research team normalized the number of pedestrian collisions by the number of intersections with that characteristic.

Lighting - A significant underrepresentation of pedestrian collisions occurred at intersections *without lighting* (-530%), which seems counterintuitive (Appendix 5-E). However, there is less lighting in rural areas, so this finding may simply reflect lower pedestrian activity in areas without lighting. Indeed, lighting was only slightly overrepresented in pedestrian collisions at urban intersections (Appendix 5-G).

Left Turn Lanes - *Designated left turn lanes* were associated with higher-than-expected pedestrian collision frequencies. For both main and crossing streets, left turn channelization treatments were overrepresented among collision sites. Curbed and painted channelization treatments were 237% and 36% overrepresented on main streets but no left turn channelization was underrepresented (-111%) (Appendix 5-E). Similarly, cross streets with left turn channelization treatments were all more than 272% overrepresented versus cross streets with no channelization treatments, which demonstrated underrepresentation (-32%) (Appendix 5-E). This may show some relationship between left-turn movements and pedestrian collisions, but it could also be due to more left-turn lanes being provided in urban areas with higher levels of pedestrian activity. This relationship was also observed for urban intersections, though it was not as strong (Appendix 5-G). *Left-turn channelization* is also overrepresented among pedestrian collisions in highway intersections. One theory is that a combination of factors including channelization, vehicle volume, and pedestrian movement before the collision could be compounding causes.

Intersection Legs and Lanes - *Four legged* intersections comprise the greatest share of pedestrian collision sites, but they are less often fatal collisions in comparison to “T” intersections, which have the second highest collision frequency. (Appendix 5-Q.)

Pedestrian collisions were underrepresented at *intersections with two lanes* (one lane in each direction) on the intersecting roadways. These intersections are among the most common in California: more than half of intersections on the SHS (62%) are comprised of two lanes on the main street; a majority (91%) are marked by two lanes on the crossing street (Appendix 5-E). While these characteristics are among the most common, they are underrepresented among pedestrian collision sites (-190% and -24% respectively. However, this finding may also reflect that intersections with fewer lanes are more common in rural areas with fewer pedestrians. Indeed, of all two-lane mainline intersections in the state, those in rural areas comprise 78% of the total, while only 11% are in urban areas.

Traffic Signals - Comparing intersections with stop signs to those controlled by signals, *signalized intersections* are overrepresented at collision sites. Thirteen percent of intersections on California highways are signalized, but they make up 56% of collisions. Meanwhile, 75% of California highway intersections are controlled by stop signs only, but only 43% of pedestrian collisions occurred at these intersections. Significantly, signalized intersections are more common in urban areas with higher pedestrian volumes. Looking specifically at urban intersections to control for volume, we found that 63% of urban intersections are controlled by stop signs, flashers, and yield signs and 33% are controlled by signalization (4% are not controlled). However, signalized intersections account for 66% of collisions, while stop signs, flashers and yield signs 33%. This result should also be explored further after controlling for pedestrian and vehicle volumes. Signalized urban intersections typically have higher automobile volumes than unsignalized urban intersections. Vehicle volume is one of the factors that can be used for a signal warrant. In addition, signalized intersections may also have higher pedestrian volumes. A more detailed analysis of urban signalized intersections shows that 57% (1108 of 1951) of these intersections have a mainline ADT greater than 30,000. The 1108 intersections that share these qualities—signalized, urban intersections with ADT greater than 30,000—comprise just 6.3% of total intersections but account for 33% of all pedestrian collisions at intersections.

5.2.2.3 Ramps

Ramps are components of highway interchanges. The two basic types of ramps are on-ramps (lead from a local roadway to a grade-separated highway) and off-ramps (lead from the grade-separated highway to a local roadway). In the aggregate, there were no significantly overrepresented characteristics among pedestrian collisions on highway ramps in this analysis. The largest of margins of underrepresentation occur within sample sizes too small to be significant. However, an important relationship can be identified by comparing collisions that occurred at on- versus off-ramp locations.

Of all pedestrian collisions at ramp locations, 65% were at off-ramps and 34% were at on-ramps. In this case, one can assume that pedestrian exposure off- and on-ramps is nearly equal, since most interchanges across the SHS have both types. Therefore, the actual risk of a collision per pedestrian crossing is higher at off-ramp locations than on-ramp locations. It is unclear why this should be, although it is possible that off-ramp designs create difficult sight lines between pedestrians and drivers or encourage high-speed turns that pedestrians do not expect. This may also reflect a higher level of risk where drivers transition from driving on a freeway (a high-speed environment without pedestrians, bicyclists, or controlled intersections) to local roadways (lower-speed, more complex environments with pedestrians and other roadway users).

Isolating the findings by type of ramp offers some explanation of where the on-off disproportion is occurring. *Diamond type ramps* are the most common type of highway ramp in the California system, comprising 44% of all ramps. They're also among the most collision-prone, with 64% of all collisions on highway ramps occurring on diamond type ramps. Of all collisions on diamond ramps, 522 occurred on the off-ramp. This figure represents 46% of all ramp collisions. Considering that diamond type off-ramps represent only 24% of all ramp infrastructure, this is a marked overrepresentation.

This overrepresentation highlights an interesting statistic within the on- and off-ramp question. The balance of on- and off-ramps in the state system is nearly even, with 49% of ramps categorized as off-ramps and 50% as on-ramps (1% are categorized by TASAS as "other"). However, among the different types of ramps, the count of on- and off-ramp varies. There are markedly more diamond off-ramps than diamond on-ramps (3477 to

2935), and more right direct or semi-direct connector off-ramps than on-ramps (869 to 1176). Similarly, on-ramps categorized as *direct or semi-direct connector (right)* were represented at 201 pedestrian collision sites (18% of total collisions) but comprise only 8% of ramps on the total highway system.

The combination of overrepresentation at collision sites of diamond off-ramps and direct or semi-direct connector (right) on-ramps suggests that many highway interchanges are comprised of a mix of ramp types. The degree to which the overrepresentation of pedestrian collisions is attributable to design versus pedestrian and vehicle volumes is unclear, as the data indicate that the ramps with greater pedestrian collision overrepresentation are often located in areas with high pedestrian and vehicle volumes. Of the 6412 diamond type ramps in California, 3960 are located in urban areas. These ramps accounts for 27% of all ramps, and were the sites of 661 pedestrian collisions (59% of all collisions). These findings should be further explored in future research.

5.2.3 Results Pertaining to Pedestrian Movement for All Pedestrian Collisions

The TASAS database includes information on the movement preceding collisions. Examining this data can be a useful proxy for collision narratives, which are not always available.[8] In this way, we can assess both a very general assessment of the pedestrian activity preceding the collision against design features of the roadway to assemble a kind of ad-hoc collision narrative. TASAS-reported ADT and design speeds provide a measurement of vehicle volume and likely vehicle speeds at the time of the collision, and geographic codes can stand in for a rough approximation of pedestrian volume. Using these elements, we can isolate significant figures from the TASAS dataset.

5.2.3.1 Highways

Between 2005-2009, there were 5477 pedestrian collisions on highways. Of those, 3788 occurred on urban highway, and of that figure, 1757 occurred on urban highways classified as freeways. Within that, 1261 collisions occurred when the *pedestrian was in the roadway and shoulder*—not crossing at an intersection or crosswalk. These collisions comprise 23% of all highway collisions and 72% of urban freeway collisions. Because the movement preceding collision is not a crossing action, these collisions likely occur when a driver pulls to the shoulder and the driver or occupants get out of the car. Additionally, the wide majority of these collisions—1206—occurred on roads with design speeds of 70mph. The speed differential is likely a compounding factor in the collision and severity of the collision.

Of the 5477 pedestrian collisions on highways in California, 47% occurred after a *pedestrian crossed the highway*. This figure includes crossings in crosswalks at intersections, crossings at crosswalks not in intersections, and crossing not at crosswalks. This figure also includes all geographies.

[8] It should be noted that one of the most frequently cited pedestrian movement codes among highway collisions is "crossing crosswalk – intersection," which would suggest the collision may be more accurately counted under the intersection category.

Second in frequency to in-roadway pedestrian collisions are collisions occurring when a pedestrian is crossing a crosswalk. These collisions comprise 1293 of 5477 pedestrian collisions on highways. The TASAS database does not include information on the kind of crosswalk treatment present on highway segments, but a variety of treatments exist and many have been shown to be inadequate treatments for roadways with high volume and high-speed vehicle travel. It has been found that on highway segments with high ADT and high design speeds, some current crosswalk treatments may not be appropriate. (Zegeer, C. V., 2005)

5.2.3.2 Ramps

Overall, 571 (or 51%) of pedestrian collisions on ramps occurred when the pedestrian was crossing an intersection in a crosswalk. The next highest share (249 collisions or 22%) of pedestrian collisions occurred when the pedestrian was in the roadway. Because the largest share of pedestrian collisions on ramps occurred on the off-ramps of diamond type ramps, we also looked specifically at pedestrian movement preceding collision. Of the 522 collisions that occurred on diamond type off-ramps, 359 (69% of diamond type ramps) occurred when the pedestrian was crossing an intersection in a crosswalk. This combination of roadway features and pedestrian activity comprises 31% of all ramp collisions.

5.2.3.3 Intersections

The data indicate that 214 of the 317 pedestrian collisions that occurred at signalized urban intersections with ADT >30,000 (68%) occurred when the pedestrian was *crossing the roadway in a crosswalk.* Again, this points to an issue of exposure: pedestrians are encouraged to cross at a signalized intersection, then channelized into crosswalks, so the relative concentration of pedestrian activity would be higher at crosswalks at signalized intersections. That said, perhaps the signalized crosswalks are not providing adequate safety treatment for pedestrian crossing at intersections with higher ADTs.

5.2.4 Roadway Features Overrepresented in Fatal Pedestrian Collisions

This section explores the roadway features overrepresented specifically in pedestrian collisions resulting in severe injury. Of the 7560 pedestrian collisions reported on the California SHS from 2005 to 2009, 1000 (13%) were fatal and 5497 (73%) resulted in injuries. The proportion of fatal collisions varied by location:

- Of the 5477 state highway segment collisions, 888 (16%) were fatal and 3750 (68%) had a reported injury.
- Of the 1128 highway ramp collisions, 70 (6%) were fatal and 936 (83%) had a reported injury.
- Of the 955 highway intersection collisions, 42 (4%) were fatal and 811 (85%) had a reported injury.

5.2.4.1 Methodology

To understand which features were associated with the highest rates of fatal collisions, we assessed the number of fatal pedestrian collisions in each category against the total collisions for that category. This analysis used Caltrans' TASAS collision and highway databases. Specifically, the analysis compared the following: A) the proportion of pedestrian collisions on specific types of segments, intersections, or ramps that resulted in a fatal injury, and B) the proportion of pedestrian collisions on all segments, intersections, or ramps on the entire SHS that resulted in a fatal injury:

- If A > B, then the characteristic was overrepresented, and the relationship was calculated as (A-B)/B. This produced a positive percentage.
- If B > A, then the characteristic was underrepresented, and the relationship was calculated as (A-B)/A. This produced a negative percentage.

Note that this analysis evaluates the severity of a pedestrian collision injury, given that a collision occurred. Since the focus is on injury severity, the results are not directly related to pedestrian volumes, so they do not have the same exposure caveat as the overall collision analysis.

All data used in the analysis are presented in Appendices 5-M-X. Summary statistics for the SHS segment, intersection, and ramp characteristics are provided below (Table 5-5).[9]

Table 5-5. State System Fatality Summary Statistics

	Urban		Urbanized		Rural		Total	
Infrastructure	**Fatalities**	**Miles/Facilities**	**Fatalities**	**Miles/Facilities**	**Fatalities**	**Miles/Facilities**	**Fatalities**	**Miles/Facilities**
Highways	96	716	608	3115	184	11594	888	15425
Intersections	15	5894	18	2294	9	10056	42	18244
Ramps	1	10713	67	984	2	2860	70	14557

5.2.5 Results Pertaining to State Highway Facilities for Fatal Pedestrian Collisions

5.2.5.1.1 Highways

In general, fatal pedestrian collisions are associated with *higher roadway design speeds.* Roadway features that show overrepresentation among fatal collisions are generally features present on highways, ramps, or intersections with high design speeds. Additionally, exposure plays a pivotal role in assessing relationships between design specifications and the severity of pedestrian collisions.

The spectrum of design speed categories on California highways offers a clear demonstration of the difference that speed makes in the severity of a pedestrian collision. Highways with *design speeds of 70mph* accounted for 39% of collisions but only make up 28% of the California system. Of all fatal pedestrian collisions in California, 58% occurred on highways with design speeds of 70 mph. Highways with *design speeds lower than 60mph*, on the other hand, were all underrepresented at fatal pedestrian collision sites, with the greatest underrepresentation among highways with posted speeds less than 30mph.

[9] Segments, intersections, and ramps on the State Highway System are defined as "urbanized" if they are within local areas with greater than 50,000 residents per square mile, "urban" if they are within local areas of 5,000 to 50,000 residents per square mile, and "rural" if they are within local areas of fewer than 5,000 residents per square mile. Locations are considered to be "suburban" if they are 1) "rural" and inside a city, 2) "urban" and outside a city, or 3) "urbanized" and outside a city.

Other roadway features echo this spectrum. *Highways with four or more lanes* on a side were overrepresented at fatal collision sites, while *highways with three or fewer lanes* on a side were underrepresented at fatal collision sites. This is largely because highways with greater numbers of lanes have higher design speeds, and roadways with fewer lanes have lower design speeds (Appendix 5-M).

Another compounding factor in the severity index of a roadway feature is vehicle volume. Among all highways, those with ADT under 30,000 are underrepresented at fatal pedestrian collision sites. This is echoed within each geographic distribution, as well—rural highways begin to see overrepresentation of fatal collisions in the ADT range of 20,000-30,000, and urban and urbanized highways see overrepresentation at 30,000. Notably, urban highways with ADT over 30,000 were the sites of 543 fatal collisions. This figure accounts for 61% of the 888 total fatal collisions on California highways (Appendixes 5-N, 5-O, 5-P).

Additionally, highways with *continuous and two-way left turn lanes* are overrepresented among total collision sites but underrepresented at fatal collision sites. Again, without collision narratives the research team cannot hypothesize how individual collisions occurred, but one explanation may be that although the continuous and two-way left turn feature is dangerous for pedestrians crossing both the main and cross streets (crossing against the direction of a left turn, for instance), vehicles turning must slow down to make the left turn maneuver, thereby decreasing the speed differential that is so associated with fatal pedestrian collisions.

5.2.5.1.2 Intersections

Intersections without channelization are overrepresented among fatal pedestrian collision sites, while *painted and curbed left turn channelization* treatments are underrepresented among fatal pedestrian collisions (Appendix 5-Q). Additionally, it should be noted that the collisions that occurred at intersections with lighting were less often fatal collisions, as compared to unlit intersections. This, however, may also be a factor linked to the geography of the collision site. Urban areas may have more pedestrian activity, increasing pedestrian volume around collision sites, but vehicles may also go slower, decreasing the severity of the collisions.

5.2.6 Results Pertaining to Pedestrian Movement for Fatal Pedestrian Collisions

Again, assessing relationships between roadway design and pedestrian movement preceding collision is useful in lieu of actual collision narratives. Assessing the severity of collisions, likewise, can identify roadway features and designs that may be more or less safe. Unsurprisingly, the movements preceding collisions that lead to the highest severity involve pedestrians being in the roadway. However, crossing at the crosswalk is underrepresented among fatal collisions.

The available collision and infrastructure data provide strong evidence supporting the following findings. Importantly, these results seem unlikely to be influenced by measures missing from the existing database, such as pedestrian exposure.

- Pedestrian collisions are overrepresented for off-ramps, while on-ramps are underrepresented.
- Pedestrian collisions are overrepresented on freeway segments, and the severity is higher (i.e., more fatalities) for those collisions.
- Speed kills: collisions at higher design speeds are more severe.
- Collision severity is also higher for higher numbers of roadway lanes.

5.2.7 Findings

5.2.7.1 Characteristics for Further Analysis

Beyond the unambiguous findings presented above, the data suggest a number of characteristics that may have an effect on collision incidence and/or severity. However, further analysis is required. One important consideration is that no pedestrian exposure measure exists, meaning that characteristics that are more common in urban areas (such signalization and continuous left-turn lanes) may be overrepresented simply because there are more people walking in locations with these characteristics. Additionally, there may be correlated collision factors that complicate the findings, such as number of lanes and traffic volume, number of lanes and freeways, and speed and volume. With these caveats, the data show that pedestrian collisions are overrepresented on roadways with the following infrastructure characteristics. These features are worthy of further analysis:

- Roadways with more lanes
- Signalized intersections
- Two-way left turn lanes, continuous left turn lanes, and paved medians
- Rural highways with design speeds of 25 m.p.h., which may indicate that pedestrian collisions are more common where state highways pass through small towns and other clusters of rural development.
- Differences between urban, urbanized, and rural areas in general

5.2.7.2 Additional Pedestrian Data Needs

The following pedestrian data is needed to obtain a more complete picture of what roadway characteristics influence pedestrian collisions and severity:

- Pedestrian exposure measures, including trips, crossings, and distance traveled
- Pedestrian facility data
- A refined definition of intersection crossings, to include all crosswalks and pedestrian crossings that occur within a certain distance from the intersection (e.g., 50 feet, 250 feet)
- Posted, design, and actual speed data
- Police collision narratives, because collision descriptions may suggest the underlying causes of collisions, which are not always related to infrastructure

5.2.7.3 Additional Pedestrian Analysis Needs

Finally, this report points to further analysis that should be undertaken to more fully understand pedestrian collisions and what infrastructure changes can be made to reduce their frequency and severity:

- Analysis of the underlying causes of pedestrian collisions, be they infrastructure or behaviors (speeding, distraction, alcohol, etc.)
- Multivariate analysis: after controlling for exposure, which factors show the strongest associations with collisions?
- Cost-benefit analysis: where will collision countermeasures have the greatest safety payoff?

5.2.8 Comparison of Patterns Between Fatal and Fatal Plus Severe Collisions

Before proceeding to the analysis of the fatal plus severe injury index, it is important to reconsider the intuitive notion that fatal injuries are less likely to occur than severe injuries. While one might expect that the likelihood of a fatal collision is less than the likelihood of a severe collision, the TSAR data prove otherwise. Just over 1030 of 4742 highway collisions were fatal, while 1019 of 4742 highway collisions were severe—a near equal likelihood for an collision to be fatal/severe, dispelling the common notion that more serious collisions are less likely to occur. With this in mind, the fatal plus severe injury index pools together the fatal injuries along with the severe injuries. This section investigates the contribution of the severe collisions: *will they highlight the same features as the fatal injury index?*

5.2.8.1 Methodology

The fatal plus severe injury index aims to answer the questions: What is the difference between the severe and fatal injury index? Can the added severity index aggregate the effects of potentially fatal roadway features? The fatal plus severe injury index of a feature was assessed by calculating the proportion of fatal/severe collisions among all collisions in that category and calling this value A. This value is then compared with value B, the overall fatal plus severe injury index that is calculated by dividing the total number of fatal collisions by the total number of collisions.

- If A > B, then the characteristic was more fatal/severe, and the relationship was calculated as (A-B)/B. This produced a positive percentage.
- If B > A, then the characteristic was less fatal/severe, and the relationship was calculated as (A-B)/A. This produced a negative percentage.

For example, in urban highways, the overall fatal plus severe injury index is 42%. Compared to the 873 fatal/severe collisions on urban freeways among the collective 1545 collisions on urban freeways (57%) urban freeways are thus (57% - 42%) / (42%) = 35% overrepresented.

The indices are listed in Figures 5-9, 5-10, and 5-11, and the comparisons are described in below.

5.2.8.1.1 Highways

In the case of the highway group, the fatal plus severe injury index tends to be *a less extreme version of the fatal injury index.* Taking into account the respective fatal injury index and fatal plus severe injury index, the divided highway group is considered 4% more fatal/severe, while by the fatal injury index it is 7% more fatal.

A similar trend is observed between the fatal injury index and fatal plus severe injury index when it comes to access control. *Full access control freeways* are 54% more fatal and 32% more fatal/severe than the overall fatal injury index. In rural areas, collisions on full access control freeways are 15% more fatal and 14% more fatal/severe than the respective indices. Indeed, the fatal plus severe injury index does downplay the results from the fatal injury index but to different extents depending on the setting.
The divided, separate grades median type is one feature not highlighted by the fatal injury index but more noticeable by the fatal plus severe injury index. On the urban highway, 60% of collisions occurring on divided, separate grades were fatal/severe. By the fatal plus severe injury index, they were 44% more fatal/severe, though keeping in mind that there were just 30 observations. Furthermore, *divided paved medians and divided unpaved medians* are 12% and 21% more fatal/ severe than the overall fatal injury index. With respect to the fatal injury index, they were 20% and 34% more fatal.

The same barrier types are highlighted by the fatal plus severe injury index as the fatal injury index, in addition to the metal beam barr. The *metal beam barr, metal beam barrier with glare screen, concrete barrier, concrete barrier with glare screen, thrie beam barr, and concrete barrier (both ways inside both shoulders)* are 14%, 42%, 28%, 30%, 42%, and 30% more fatal/severe, respectively, compared to the 43% overall index. Though the metal beam barr was not featured in the prior analysis, a greater aggregate analysis points out that it might also be associated with a greater fatal/ severe injury index.

Aggregated across all settings, the fatal plus severe injury index suggests that collisions on highways with *4-7 lanes on the right and left* have a greater likelihood of being fatal/severe.

Figure 5-9. Fatal Index and Fatal+Severe Index for Highway Segments in Urban, Urbanized, and Rural Settings

		Fatal Index			Fatal+sever Index		
		Urban Highway	Urbanized Highway	Rural Highway	Urban Highway	Urbanized Highway	Rural Highway
Higway group							
R	Independent Alignment - Left	NA	NA	NA	NA	NA	NA
L	Independent Alignment - Right	NA	NA	NA	NA	NA	NA
D	Divided Highway	7.080%	23.790%	9.377%	3.945%	10.686%	10.218%
U	Undivided Highway	NA	NA	-6.644%	-56.478%	-15.362%	-7.633%
Access code							
C	conventional	-106.403%	-61.961%	-9.224%	-45.989%	-20.579%	-6.594%
E	expressway	NA	NA	NA	NA	NA	-4.649%
F	freeway	58.728%	167.116%	15.156%	35.310%	67.496%	13.905%
S	one-way city street	NA	NA	NA	NA	NA	NA
Median type							
A	Not Striped or Separated	NA	NA	NA	NA	NA	NA
B	Striped	NA	NA	-6.419%	-56.478%	-15.362%	-7.405%
C	Reversible Peak Hour Lane(s) - Undivided	NA	NA	NA	NA	NA	NA
E	Reversible Peak Hour Lane(s) - Divided	NA	NA	NA	NA	NA	NA
F	Two-Way Left Turn Lane	NA	NA	NA	-44.466%	-18.866%	-1.987%
G	Continuous Left Turn Lane	-102.475%	NA	NA	-45.164%	NA	NA
H	Paved Median	25.595%	NA	NA	16.575%	NA	3.159%
J	Unpaved Median	18.703%	173.878%	28.790%	13.177%	74.647%	21.915%
K	Separate Grades	NA	NA	NA	43.680%	NA	NA
L	Separate Grades w/ Retaining Wall	NA	NA	NA	NA	NA	NA
M	Sawtooth - Unpaved	NA	NA	NA	NA	NA	NA
N	Sawtooth - Paved	NA	NA	NA	NA	NA	NA
P	Ditch	NA	NA	NA	NA	NA	NA
Q	Separate Structure	NA	NA	NA	NA	NA	NA
R	Railroad	NA	NA	NA	NA	NA	NA
S	Bus Lanes	NA	NA	NA	NA	NA	NA
T	Paved Area Occasional Traffic Lane	NA	NA	NA	NA	NA	NA
U	Railroad & Bus Lanes	NA	NA	NA	NA	NA	NA
V	Contains Reversible Pk Hr Ln(s)	NA	NA	NA	NA	NA	NA
Z	Other	NA	NA	NA	NA	NA	NA
		Fatal Index			Fatal+sever Index		
		Urban Highway	Urbanized Highway	Rural Highway	Urban Highway	Urbanized Highway	Rural Highway
Barrier type							
A	Cable Barrier	NA	NA	NA	NA	NA	NA
B	Cable Barrier w/ Glare Screen	NA	NA	NA	NA	NA	NA
C	Metal Beam Barrier	NA	NA	NA	14.291%	NA	NA
D	Metal Beam Barrier w/ Glare Screen	83.484%	NA	NA	47.195%	NA	NA
E	Concrete Barrier	54.605%	NA	NA	31.951%	NA	NA
F	Concrete Barrier w/ Glare Screen	50.233%	NA	NA	35.585%	NA	NA
G	Bridge Barrier Railing	NA	NA	NA	NA	NA	NA
H	Chain Link Fence	NA	NA	NA	NA	NA	NA
J	Guardrail in Median Both Roadway	NA	NA	NA	NA	NA	NA
K	Guardrail in Median Left Roadway	NA	NA	NA	NA	NA	NA
L	Guardrail in Median Right Roadway	NA	NA	NA	NA	NA	NA
M	Two-Way, One Lane Road	NA	NA	NA	NA	NA	NA
N	Thrie Beam Barrier	68.306%	NA	NA	44.505%	NA	31.692%
P	Thrie Beam Barrier w/ Glare Screen	NA	NA	NA	NA	NA	NA
Q	Conc. Barrier, Both Ways Inside Both Sh.	NA	NA	NA	34.700%	NA	NA
R	Conc. Barrier, Left Rdwy Median Sh. Area	NA	NA	NA	NA	NA	NA
S	Conc. Barrier, Right Rdwy Median Sh. Area	NA	NA	NA	NA	NA	NA
X	External Barriers on Median Type = C or E	NA	NA	NA	NA	NA	NA
Y	Other Not Included Above	NA	NA	NA	NA	NA	NA
Z	No Barriers	-73.639%	-13.123%	-3.645%	-35.188%	-5.410%	-2.171%
Number of lanes, left side							
1		NA	NA	-8.158%	-19.763%	-18.466%	-9.496%
2		-65.488%	8.796%	6.794%	-38.662%	2.387%	11.523%
3		-16.639%	NA	NA	-6.475%	NA	NA
4		51.304%	NA	NA	37.500%	NA	18.442%
5		69.447%	NA	NA	34.350%	NA	NA
6		60.399%	NA	NA	36.118%	NA	NA
7		NA	NA	NA	NA	NA	NA
++		NA	NA	NA	NA	NA	NA
Number of lanes, right side							
1		NA	NA	-8.667%	-16.927%	-16.966%	-10.055%
2		-58.078%	8.796%	10.726%	-37.406%	-0.979%	13.102%
3		-20.785%	NA	NA	-8.359%	NA	NA
4		47.241%	NA	NA	35.094%	NA	NA
5		63.650%	NA	NA	34.893%	NA	NA
6		58.728%	NA	NA	28.135%	NA	NA
7		NA	NA	NA	NA	NA	NA
++		NA	NA	NA	NA	NA	NA

5.2.8.1.2 Intersections

Although not a point of attention according to the fatal injury index, *undivided highways* may be a feature worth noticing for the fatal/severe injury index. Among all of the collisions occurring on undivided highways, 22% are fatal/severe, but only 18% of collisions at intersections are fatal/severe. Undivided highways were also drastically underrepresented by the representation by mileage index.

A majority of the collisions occurred on conventional, no access control highway intersections. They did not indicate a fatal plus severe collision index greater than the overall.

The same 52 observations from the undivided highways are represented in the *undivided, striped* median type. Undivided, striped median types are also 21% more fatal/severe than the overall fatal/severe injury index of 18%.

A majority of the collisions occurred on intersections with no barrier. Collisions on intersections with no barrier did not indicate any significant difference from the overall fatal/severe injury index.

Recall that there was a decrease in percentage of fatal collisions as the number of right and left lanes increased in the previous intersection section. The same trend is observed in the fatal/severe injury index. From the collisions occurring on highways with one to three right lanes, 25%, 18%, and 13%, respectively, were fatal/severe.

Figure 5-10. Fatal Index and Fatal+Severe Index for Intersections in Urban, Urbanized, and Rural Settings

		Fatal Index			Fatal+sever Index		
		Urban intersection	Urbanized intersection	Rural intersection	Urban intersection	Urbanized intersection	Rural intersection
Higway group							
R	Independent Alignment - Left	NA	NA	NA	NA	NA	NA
L	Independent Alignment - Right	NA	NA	NA	NA	NA	NA
D	Divided Highway	11.193%	NA	NA	-6.339%	-6.071%	55.556%
U	Undivided Highway	NA	NA	NA	30.135%	8.722%	-26.429%
Access code							
C	conventional	-3.973%	4.000%	-1.429%	-1.741%	-0.446%	-14.107%
E	expressway	NA	NA	NA	NA	NA	NA
F	freeway	NA	NA	NA	NA	NA	NA
S	one-way city street	NA	NA	NA	NA	NA	NA
Median type							
A	Not Striped or Separated	NA	NA	NA	NA	NA	NA
B	Striped	NA	NA	NA	30.135%	8.722%	-26.429%
C	Reversible Peak Hour Lane(s) - Undivided	NA	NA	NA	NA	NA	NA
E	Reversible Peak Hour Lane(s) - Divided	NA	NA	NA	NA	NA	NA
F	Two-Way Left Turn Lane	NA	NA	NA	NA	NA	NA
G	Continuous Left Turn Lane	NA	NA	NA	-5.489%	NA	NA
H	Paved Median	NA	NA	NA	NA	NA	NA
J	Unpaved Median	NA	NA	NA	NA	NA	NA
K	Separate Grades	NA	NA	NA	NA	NA	NA
L	Separate Grades w/ Retaining Wall	NA	NA	NA	NA	NA	NA
M	Sawtooth - Unpaved	NA	NA	NA	NA	NA	NA
N	Sawtooth - Paved	NA	NA	NA	NA	NA	NA
P	Ditch	NA	NA	NA	NA	NA	NA
Q	Separate Structure	NA	NA	NA	NA	NA	NA
R	Railroad	NA	NA	NA	NA	NA	NA
S	Bus Lanes	NA	NA	NA	NA	NA	NA
T	Paved Area Occasional Traffic Lane	NA	NA	NA	NA	NA	NA
U	Railroad & Bus Lanes	NA	NA	NA	NA	NA	NA
V	Contains Reversible Pk Hr Ln(s)	NA	NA	NA	NA	NA	NA
Z	Other	NA	NA	NA	NA	NA	NA

		Fatal Index			Fatal+sever Index		
		Urban intersection	Urbanized intersection	Rural intersection	Urban intersection	Urbanized intersection	Rural intersection
Barrier type							
A	Cable Barrier	NA	NA	NA	NA	NA	NA
B	Cable Barrier w/ Glare Screen	NA	NA	NA	NA	NA	NA
C	Metal Beam Barrier	NA	NA	NA	NA	NA	NA
D	Metal Beam Barrier w/ Glare Screen	NA	NA	NA	NA	NA	NA
E	Concrete Barrier	NA	NA	NA	NA	NA	NA
F	Concrete Barrier w/ Glare Screen	NA	NA	NA	NA	NA	NA
G	Bridge Barrier Railing	NA	NA	NA	NA	NA	NA
H	Chain Link Fence	NA	NA	NA	NA	NA	NA
J	Guardrail in Median Both Roadway	NA	NA	NA	NA	NA	NA
K	Guardrail in Median Left Roadway	NA	NA	NA	NA	NA	NA
L	Guardrail in Median Right Roadway	NA	NA	NA	NA	NA	NA
M	Two-Way, One Lane Road	NA	NA	NA	NA	NA	NA
N	Thrie Beam Barrier	NA	NA	NA	NA	NA	NA
P	Thrie Beam Barrier w/ Glare Screen	NA	NA	NA	NA	NA	NA
Q	Conc. Barrier, Both Ways Inside Both Sh.	NA	NA	NA	NA	NA	NA
R	Conc. Barrier, Left Rdwy Median Sh. Area	NA	NA	NA	NA	NA	NA
S	Conc. Barrier, Right Rdwy Median Sh. Area	NA	NA	NA	NA	NA	NA
X	External Barriers on Median Type = C or E	NA	NA	NA	NA	NA	NA
Y	Other Not Included Above	NA	NA	NA	NA	NA	NA
Z	No Barriers	0.683%	0.000%	0.000%	-0.402%	0.000%	0.000%
Number of lanes, left side							
1		NA	NA	NA	NA	5.461%	-7.143%
2		NA	NA	NA	2.928%	5.105%	NA
3		NA	NA	NA	-13.623%	NA	NA
4		NA	NA	NA	NA	NA	NA
5		NA	NA	NA	NA	NA	NA
6		NA	NA	NA	NA	NA	NA
7		NA	NA	NA	NA	NA	NA
++		NA	NA	NA	NA	NA	NA
Number of lanes, right side							
1		NA	NA	NA	NA	7.280%	-11.555%
2		NA	NA	NA	3.276%	-5.330%	29.630%
3		NA	NA	NA	-15.593%	NA	NA
4		NA	NA	NA	NA	NA	NA
5		NA	NA	NA	NA	NA	NA
6		NA	NA	NA	NA	NA	NA
7		NA	NA	NA	NA	NA	NA
++		NA	NA	NA	NA	NA	NA

5.2.8.1.3 Ramps

Note that the urban ramps have a great deal of influence on our aggregated results since 211 of 223 fatal/severe collisions occurred there. Twelve other ramp collisions occurred in urbanized and rural settings. Because the realization of ramp collisions in urbanized and rural settings is so scarce, we can determine their set of characteristics. The fatal/severe collisions are often in the *divided highway group leading to a full access* *control freeway, on an unpaved median with either a concrete barrier or no barrier spanning 2-3 right and left lanes.* Equally as important to take note is that across all settings, the overall fatal injury index for intersections is 8% while the overall fatal/severe injury index is 22%.

Due to the fact that most ramps lead to full-access control freeways, and urban freeways are commonly divided highways, we observed 1027 of 1036 ramp collisions on divided highways. Twenty-two percent of the 1027 collisions on divided highways were fatal.

Full-access control freeways also constitute 1027 of the 1036 ramp collisions and contribute greatly to the overall fatal/severe injury index.

Between highways with a divided, paved median and those with a divided, unpaved median, highways with *divided, unpaved medians* were underrepresented on the whole. Approximately 20% of the 356 ramp collisions on divided, unpaved medians were fatal/severe, of which 35% were fatal.

Additionally, 27% of collisions occurring on ramps *without barriers* were fatal/severe. In other words, they were 27% more fatal/severe than the index. The *concrete barrier with glare screen* feature also has a greater percentage of fatal/severe collisions than the index by 14%.

A majority of ramp collisions occurred on highways ramps spanning *2-5* right and left lanes, none of which indicated a significant deviation from the overall fatal or severe injury index.

Figure 5-11. Fatal Index and Fatal+Severe Index for Ramps in Urban, Urbanized, and Rural Settings

		Fatal Index			Fatal+sever Index		
		Urban ramp	Urbanized ramp	Rural ramp	Urban ramp	Urbanized ramp	Rural ramp
Higway group							
R	Independent Alignment - Left	NA	NA	NA	NA	NA	NA
L	Independent Alignment - Right	NA	NA	NA	NA	NA	NA
D	Divided Highway	-0.342%	NA	NA	-0.501%	NA	NA
U	Undivided Highway	NA	NA	NA	NA	NA	NA
Access code							
C	conventional	NA	NA	NA	NA	NA	NA
E	expressway	NA	NA	NA	NA	NA	NA
F	freeway	-1.645%	NA	NA	-0.020%	NA	NA
S	one-way city street	NA	NA	NA	NA	NA	NA
Median type							
A	Not Striped or Separated	NA	NA	NA	NA	NA	NA
B	Striped	NA	NA	NA	NA	NA	NA
C	Reversible Peak Hour Lane(s) - Undivided	NA	NA	NA	NA	NA	NA
E	Reversible Peak Hour Lane(s) - Divided	NA	NA	NA	NA	NA	NA
F	Two-Way Left Turn Lane	NA	NA	NA	NA	NA	NA
G	Continuous Left Turn Lane	NA	NA	NA	NA	NA	NA
H	Paved Median	-2.800%	NA	NA	-2.111%	NA	NA
J	Unpaved Median	NA	NA	NA	-8.038%	NA	NA
K	Separate Grades	NA	NA	NA	NA	NA	NA
L	Separate Grades w/ Retaining Wall	NA	NA	NA	NA	NA	NA
M	Sawtooth - Unpaved	NA	NA	NA	NA	NA	NA
N	Sawtooth - Paved	NA	NA	NA	NA	NA	NA
P	Ditch	NA	NA	NA	NA	NA	NA
Q	Separate Structure	NA	NA	NA	NA	NA	NA
R	Railroad	NA	NA	NA	NA	NA	NA
S	Bus Lanes	NA	NA	NA	NA	NA	NA
T	Paved Area Occasional Traffic Lane	NA	NA	NA	NA	NA	NA
U	Railroad & Bus Lanes	NA	NA	NA	NA	NA	NA
V	Contains Reversible Pk Hr Ln(s)	NA	NA	NA	NA	NA	NA
Z	Other	NA	NA	NA	NA	NA	NA
		Fatal Index			Fatal+sever Index		
		Urban ramp	Urbanized ramp	Rural ramp	Urban ramp	Urbanized ramp	Rural ramp
Barrier type							
A	Cable Barrier	NA	NA	NA	NA	NA	NA
B	Cable Barrier w/ Glare Screen	NA	NA	NA	NA	NA	NA
C	Metal Beam Barrier	NA	NA	NA	NA	NA	NA
D	Metal Beam Barrier w/ Glare Screen	NA	NA	NA	NA	NA	NA
E	Concrete Barrier	NA	NA	NA	-12.935%	NA	NA
F	Concrete Barrier w/ Glare Screen	NA	NA	NA	12.814%	NA	NA
G	Bridge Barrier Railing	NA	NA	NA	NA	NA	NA
H	Chain Link Fence	NA	NA	NA	NA	NA	NA
J	Guardrail in Median Both Roadway	NA	NA	NA	NA	NA	NA
K	Guardrail in Median Left Roadway	NA	NA	NA	NA	NA	NA
L	Guardrail in Median Right Roadway	NA	NA	NA	NA	NA	NA
M	Two-Way, One Lane Road	NA	NA	NA	NA	NA	NA
N	Thrie Beam Barrier	NA	NA	NA	NA	NA	NA
P	Thrie Beam Barrier w/ Glare Screen	NA	NA	NA	NA	NA	NA
Q	Conc. Barrier, Both Ways Inside Both Sh.	NA	NA	NA	NA	NA	NA
R	Conc. Barrier, Left Rdwy Median Sh. Area	NA	NA	NA	NA	NA	NA
S	Conc. Barrier, Right Rdwy Median Sh. Area	NA	NA	NA	NA	NA	NA
X	External Barriers on Median Type = C or E	NA	NA	NA	NA	NA	NA
Y	Other Not Included Above	NA	NA	NA	NA	NA	NA
Z	No Barriers	NA	NA	NA	39.913%	NA	NA
Number of lanes, left side							
1		NA	NA	NA	NA	NA	NA
2		NA	NA	NA	NA	NA	NA
3		NA	NA	NA	3.331%	NA	NA
4		-4.247%	NA	NA	-4.412%	NA	NA
5		NA	NA	NA	-1.681%	NA	NA
6		NA	NA	NA	NA	NA	NA
7		NA	NA	NA	NA	NA	NA
++		NA	NA	NA	NA	NA	NA
Number of lanes, right side							
1		NA	NA	NA	NA	NA	NA
2		NA	NA	NA	NA	NA	NA
3		NA	NA	NA	-15.339%	NA	NA
4		NA	NA	NA	-2.265%	NA	NA
5		NA	NA	NA	-4.716%	NA	NA
6		NA	NA	NA	NA	NA	NA
7		NA	NA	NA	NA	NA	NA
++		NA	NA	NA	NA	NA	NA

5.3 Intersection Related Collisions

This analysis focuses on pedestrian collisions reported on the California State Highway System from 2005-2009. There are two data sources: TASAS 2005-2009 pedestrian collision data, and TSAR data. TASAS data includes an collision file, intersection file, highway segment file, and ramp file. The data are already matched to intersections, highways, and ramps. TSAR data is also from 2005-2009 and has been matched to SWITRS. Because TASAS data and TSAR data have been used in previous research, the analysis presented in this section will focus on them for collision data. Intersection, highway segment and ramps data are from the TASAS raw data.

The intersection facility records are obtained from Caltrans TASAS database updated in 2012 with 152,537 records. Because the TASAS intersection database contains all the records for intersections in different years, each intersection can have multiple rows of records describing the condition for that specific year. In order to have a database that only contains the records close to the year range 2005-2009 (used to analyze the collision data), duplicate intersection records were removed by the intersection placement ID. The resulting data consisted of 24,009 intersections.

In order to analyze the collisions at different severity levels, the TSAR data which had already been matched to SWITRS data were used. There were 17,055 records in TSAR during 2005 to 2009. A similar process to remove duplicate records was followed, including the removal of records with the same collision ID (different party records from the same collision). Pedestrian party records were then selected in order to obtain intersection pedestrian collisions, after which duplicated records with same SWITRS Case ID were removed. The final data set consisted of 6592 pedestrian collisions that occurred on the state highway system from 2005-2009. The details of the pedestrian collisions on different facility types are listed in Table 5-6.

Table 5-6. Percentages of Collisions Occurring on Intersections, Highways Segments and Ramps

Number of Collisions labeled as Intersection	818	12.4%
Number of Collisions labeled as highway	4734	71.8%
Number of collisions labeled as ramp	1040	15.8%
Total	6592	100%

Note that in Table 5-6, the intersection collisions only comprise 12.4% of all collisions. This could be caused by the definition of intersection collisions implemented by Caltrans as discussed in Section 5.2.6. Intersection has been widely accepted as the facility with the highest possibility of conflict between road users—especially for conflict between pedestrians and motorists. Therefore, the analysis in this section focuses on intersection collisions. In order to obtain intersection related collisions, the collisions labeled as “ramp” were excluded in the aggregation of intersection related collisions. The resulting *5,552* collisions labeled as “intersection” or “highway” were used to select intersection related collisions which will be used in the analysis of potential causing factors for pedestrian collisions at intersections. .

5.3.1 Aggregate Collisions onto Intersections by Different Buffer Distance

What kind of collisions can be called intersection collisions or intersection-related collisions? To answer this question, previous research and reports were reviewed. Generally, there are two methods to define an intersection collision.

First, a specific distance from the center of an intersection is chosen. If a collision takes place within this distance, it counts as a collision for this intersection. Different agencies and research have different figures for this distance, such as 250 feet for "influenced by intersection" (Abdel-Aty, Lee, et al., 2006; Indiana DOT, 2010; Harwood, D.W., et.al, 2003), 150 feet for only red light camera related rear-end collisions at intersections (Persaud, et al., 2005), and 125 feet for pedestrian collisions (Chicago Department of Transportation, 2011). At times, researchers define the distance according to the data and local situation. For example, they find the distance within which 89% of the collisions occur (New York City Department of Health and Mental Hygiene). They may also choose to focus on a small distance such as 50 feet for "at intersection" collisions according to the study objects (Schneider, et al., 2012). There even can be dynamic distance regarding to the regional characteristics, for example using 0.05 miles for rural intersections and 0.02 miles for urban intersections (Green and Agent, 2003). Using these fixed criteria to aggregate pedestrian collisions in this study, the numbers of collisions are shown in Table 5-7.

The procedure to aggregate collisions on to intersections by buffers is listed below.

1. Identify all the intersections having the same "route+county" with a collision.
2. Calculate the distance between those intersections and that collision.
3. Identify the intersection having the smallest distance.
4. There are 925 out of 5552 (16.7%) collisions don't have matched intersections, which means those collisions occurred on routes where there is no intersection.
5. All the collisions within a specific buffer distance will be summed if they have the same intersection ID.

Table 5-7. Aggregate Intersection Collisions by Different Buffer Distance

Buffer Dist. (ft.)	No. of Inter-section Colli-sions	No. of High-way Colli-sions	No. of Ramp Colli-sions	Total No. of Colli-sions	Percen-tage of Inter-section Colli-sions	Percen-tage of High-way Colli-sions	Percen-tage of Ramp Colli-sions
50	1318	4234	1040	6592	20.0%	64.2%	15.8%
125	2680	2872	1040	6592	40.7%	43.5%	15.8%
150	2727	2825	1040	6592	41.4%	42.8%	15.8%
250	2972	2580	1040	6592	45.1%	39.1%	15.8%

5.3.2 Aggregate Collisions to Intersections by Movement Preceding Collisions

The second method to define an intersection collision is to refer to the pre-collision events of each collision to see whether the parties in a collision have intersection-related actions like turning left or right at an intersection, or crossing over an intersection (U.S.

Department of Transportation National Highway Traffic Safety Administration, 2010). For pedestrian collisions, the movement related to the intersection is pedestrian crossing in crosswalk at intersection. For those collisions with pedestrian movements in other categories, for example crossing in crosswalk not at intersection, on roadway or not in roadway, approach/leave school bus, the researcher must check the movement of vehicles determine whether their movements were related to an intersection. Using these criteria ("party movement preceding collisions"), the research team classified collisions as shown in Table 5-8.

Table 5-8. Aggregate Intersection Collisions by Different Party Movement Preceding Collision

Party Movement Preceding Collision	Number of Pedestrian Collisions	Percentage
Pedestrian collisions labeled as Intersection	818	12.4%
Pedestrian crossing in crosswalk at intersection	1080	16.4%
Other pedestrian movement with vehicle intersection related movement	797	11.3%
Total pedestrian collisions related to intersection	2695	40.9%
Total pedestrian collisions	6592	

After selecting all of the collisions related to intersections, the 2695 collisions have to be assigned to the related intersections. To define these intersections, each collision should be identified if it is in the upstream or downstream of an intersection. Only the upstream collisions of an intersection can be counted as related to a specific intersection.

- According to the Caltrans instructions (California Highways), the postmile starts at zero at the western or southern end of the route or at the western or southern boundary of the county through which the route is travelling.

Use the information of "side of highway," "postmile" to find out all the intersections in the downstream of a collision. The closest intersection will be the right one. This method reflects the design of an intersection and the corresponding movement of the vehicle so that it is more accurate and rational than the first method. So the 2695 intersection related collisions will be used in the analysis of potential causing factors for pedestrian collisions at intersections.

-

5.4 Contributing Factor Analysis for Intersection-Related Pedestrian Collisions

5.4.1 Intersection Characteristics

In order to determine the potential causal factors for intersection-related collisions, characteristics which are already highlighted in existing studies and overrepresentation analysis are summarized first. The research team reviewed 13 studies from 2007-2013 that focused on pedestrian safety. Table 5-9 lists the causal factors identified in those studies.

Table 5-9. Published Studies About Pedestrian Safety and Causal Factors (2007-2013)

Literature	Location	Dependent Variables	Study Unit	Model	Independent Variables	Year
Mohamed, MG	New York City and Montreal	severity	case	combines data mining and statistical regression methods	demographic environment Roadway: Geometric	2013
H. M. Abdul Aziz	New York City	severity levels	case	random parameter logit models	land use: parking facilities, commercial and industrial land use roadway: number of lanes, grade, light condition, road surface, presence of signal control traffic: type of vehicle	2013
Andi Camden	Toronto, Canada	frequency	intersection	poisson regression	location: urban vs inner suburbs party: pedestrian age	2013
Ukkusuri, S		Frequency (total, fatal)	census tract, zip code zone.	NB, and GNB	demographics environment: road network land use roadway: road design transit: transit supply travel: travel characteristics	2012
Richard Tay	South Korea	severity levels	case	multinomial logit model	environment: weather location party: vehicles, drivers(alcohol, gender, who is drunk, male, under 65; ped who were over 65 or female roadway: speed, function, width, light	2011
Dajun Dai	Atlanta, Georgia	risk	case	Logistics regression	Environment: weather, light and surface conditions. party: age, sex, and intoxication of pedestrian ad driver, and pedestrian maneuvers;	2012
Shakil Mohammad Rifaat	Calgary	severity	case	partially constrained generalized ordered logit model	environment party: drivers roadway: street pattern, road traffic: traffic characteristics	2012

Literature	Location	Dependent	Study	Model	Independent Variables	Year

		Variables	Unit			
Linda Rothman	Toronto	severity	case	multinomial logistic regression	location: crossing location roadway: road type	2012
Robert J. Schneider	Alameda county, CA	frequency	intersection	negative binomial regression	demographic: neighborhood socioeconomic characteristics land use roadway: intersection site characteristics, transportation sys. characteristics traffic: ped crossing volume, vehicle volume	2010
Dajun Dai	Georgia State University	frequency	intersection, segment	network-based kernel density estimation, network-based k-function	environmental: streetscape (location branding signs, street compactness, land use composition) roadway: road infrastructure (width, road condition, crosswalk signs, pedestrian signals) traffic: traffic flow one way two way transit: public transit	2010
Megan Wier	San Francisco	frequency	census tract	simple bivariate models	demographic: population char., employee, resident population, poverty, age environmental land use street traffic: traffic volume transit travel: commute behaviors	2009
Dilum Dissanayake	Great Britan	child pedestrian casualty numbers	ward	generalized linear models	land use: trip attractor land use type, secondary retail, high density residential land use, education sites, primary retail, low density residential land use roadway: junction density,	2009

Literature	Location	Dependent Variables	Study Unit	Model	Independent Variables	Year
Kelly J. Clifton	Baltimore City, Maryland	Frequency	School buffer	Ordinary least squares linear regression	demographic: population density land use: recreational facility, commercial access roadway: driveway, turning bay on school entrance transit: transit access	2007

The research team also identified specific characteristics from the exploration of overrepresentation in Section 5.2. These characteristics should be considered in future analysis. For example, overrepresented and underrepresented roadway features have different patterns in *urban, urbanized, and rural areas*. This is probably caused by the different levels of pedestrian activity in those areas. There will be more pedestrians walking in urban area more than urbanized and rural areas. Also, different patterns of overrepresented and underrepresented features can be related to the different roadway characteristics in the area. For example, curbed *medians* with green plants are overrepresented in urban areas but not in the urbanized and rural areas. This may be related to the smaller presence of the landscaping feature in rural areas.

Roadway features also have different patterns among the different severity levels. For example, highway segments with a *design speed* of < 40 mph are overrepresented for the frequency of all collisions, but underrepresented for fatal collisions. The reason could be that lower design speeds often occur in areas where there are more pedestrians. The high pedestrian volume then creates more opportunity for a pedestrian to be involved in a collision. However, lower speed may also lead to a less injurious collision, resulting in the underrepresentation of lower design speeds for fatal collisions. Other intersection features highlighted in the analysis include the following:

- Design code: four-legged, multi-legged, offset, tee, WYE, and other.
- Presence of lighting
- Signal mast arm presence
- Main/crossing street left channelization presence
- Main/crossing street right channelization presence
- Main/crossing street flow code: two-way traffic-no left turns permitted, two-way traffic-left turns permitted, one-way traffic, other.
- Intersection control: no control, signs, signals-multi phase, signals-2 phase, other
- Number of lanes on main/crossing street
- Highway group
- Main/crossing street average daily traffic (ADT)

In the TASAS intersection database, there are 54 variables describing the construction, information updating, physical features, and management information of each intersection on the State Highway System. Useful variables need to be selected based both on the data availability and what is suggested in existing studies and overrepresentation analysis. Because the goal of the causal factor analysis is to guide the countermeasure selection, variables which are often considered when countermeasures are chosen should be considered as well. The mapping of useful variables is conducted and shown in Table 5-10.

Table 5-10. Mapping of Variables From CM List, Literature, Overrepresentation Analysis and TASAS Database

Variables from CM	Variables in Literature	Variables Highlighted in Overrepresentation Analysis	Variables Available in TASAS Database
vehicle volume (minor street)		crossing ADT	crossing ADT
vehicle design speed			design speed
roadway class (freeway, arterial, railroad track, ramp, corridor, local, collector, etc.)			functional class
		highway group (divided/undivided)	highway group (divided/undivided)
intersection type (3-way)	T-intersection	intersection design code	intersection design code
left/right turn channelization	left/right turn only lanes, right turn islands	main left/right channel code	intersection mainline left or right channelization code
lighting condition		presence of lighting	lighting
		crossing flow channel code	main/cross road flow code (one way, two way)
vehicle volume (mainline)	vehicular volume	mainline ADT	mainline ADT
			mainline median type
			mainline median width
		number of lanes on crossing street	number of lanes on crossing street
	number of lanes on minor street		number of lanes on crossing street
number of lanes (mainline)		number of lanes on main street	number of lanes on main street
			population group (urban/rural)

Variables from CM	Variables in Literature	Variables Highlighted in	Variables Available in

		Overrepresentation Analysis	TASAS Database
		signal mast arm	signal mast arm (no/yes/invalid)
phasing design/signal control	traffic signal	control code	traffic control
area type (school zone, residential, commercial, downtown, senior service, hospital, local neighborhoods, etc.)	commercial properties, schools		
crossing distance			
crosswalk marking	proportion of crosswalks across the cross street that are marked		
curb radii	curb radii		
intersect angle			
intersection type(skewed)			
on street parking lane presence			
pedestrian age	proportion of population over 64 within 0.25 mi.		
pedestrian crossing indicator presence			
pedestrian push button presence			
pedestrian signage presence			
ped. signage type			
pedestrian volume			
pedestrian volume (night)			
sight			
signage presence			
signage type (yield, stop, etc.)			
vehicle speed			
vehicle volume (left turn)			
vehicular turning speed			
	0 vehicle pop		
Variables from CM	**Variables in Literature**	**Variables Highlighted in**	**Variables Available in**

		Overrepresentation Analysis	**TASAS Database**
	Bus stops		
	freeway presence		
	mainline width		
	male		
	median income		
	missing sidewalks		
	number of non-residential driveways within 50 ft of intersection crosswalks		
	proportion of crosswalks across the mainline/ cross roadway that have medians		
	Rail stations		
	street miles		
	total employment		
	total pop		
	trail miles		
	under 18		

The variables highlighted in pedestrian countermeasures, literature and overrepresentation analysis in Table 5-10, which are also available in TASAS database, would be selected for further analysis. Those variables are listed in Table 5-11.

Table 5-11.Variables Selected for Modeling

	Variables from TASAS	CM	Literature	Overrepresentation
1	number of lanes on main street	Y		Y
2	number of lanes on crossing street		Y	Y
3	mainline ADT	Y	Y	Y
4	Crossing street ADT	Y		Y
5	mainline median width			Y
6	design speed	Y		
7	intersection design code	Y	Y	Y
8	intersection mainline left channelization code	Y	Y	Y
9	intersection mainline right channelization code	Y	Y	Y
10	main road flow code (one way, two way)			Y
11	Intersection cross road left channelization code	Y	Y	Y
12	intersection cross road right channelization code	Y	Y	Y
13	cross road flow code (one way, two way)			Y
14	traffic control	Y	Y	Y
15	population group (urban/rural)			Y
16	functional class	Y		
17	Presence of lighting	Y	Y	Y
18	Intersection mainline signal mast arm			Y
19	Intersection cross road signal mast arm			Y
20	Highway group			Y
21	Access code			Y
22	Mainline median type			Y

Note: "Y" means this variable is considered or highlighted in the specific resource.

The dependent variables are divided into numerical variables and categorical variables. The description statistics of the selected variables are shown in Table 5-12. The independent variable is the frequency of collisions at each intersection.

Table 5-12. Descriptive Statistics of the Selected Variables

Independent Variable	Min.[a]	Max.[b]	Mean[c]	Std[d]	Var[e]
Frequency of pedestrian intersection collisions, all severity levels	0	11	0.11	0.46	0.21
Dependent Variables					
Numerical Variables					
Main street number of lanes	1	12	3	1.22	1.49
Crossing street number of lanes	0	8	2	0.57	0.32
Main street adt	51	206,000	16,939	15,438	238,341,200
Crossing street adt	0	980,119	1,738	10,779	116,177,200
Median width	0	99	12	22	502
Design speed	0	70	52	13	177

Categorical Variables	Categories	Indicators[f]	Frequency[g]
Intersection design code	Four-legged	1	7803
	Multi-legged	2	236
	Offset	3	841
	"T" (three-legged)	4	13519
	WYE	5	1355
	Other	6	255
Mainline left channelization	Yes	2	9365
	No	1	14644
Mainline right channelization	Yes	2	2364
	No	1	21645
Mainline traffic flow code	Two-way traffic-no left turns permitted	1	1058
	Two-way traffic-left turns permitted	2	22154
	One-way traffic	3	742
	Other	4	55
Crossing street left channelization	Yes	2	2029
	No	1	21980
Crossing street right channelization	Yes	2	1835
	No	1	22174
Crossing street traffic flow code	Two-way traffic-no left turns permitted	1	1053
	Two-way traffic-left turns permitted	2	22234
	One-way traffic	3	672
	Other	4	50

Categorical Variables	Categories	Indicators[f]	Frequency[g]
Intersection control	No control	1	2338
	Signs	2	17806
	Signals-multi phase	3	2404

	Signals-2 phase	4	1418
	Other	5	43
Population group	Urban	1	8791
	Rural	2	11739
	Urbanized	3	3479
Highway functional class	None	1	914
	Arterial	2	21631
	collector	3	1453
	Local	4	11
Intersection lighting presence	Yes	2	11369
	No	1	12640
Intersection mainline signal mast arm presence	Yes	2	3566
	No	1	20433
Intersection crossing street signal mast arm presence	Yes	2	2296
	No	1	21712
Highway group	Undivided	1	15376
	Divided	2	7756
	Right or left alignment	3	877
Highway access control	Conventional	1	19821
	Expressway	2	2063
	Freeway	3	1572
	One-way city street	4	483
	Other	5	70
Median type	Not striped	1	23
	Striped	2	13782
	Travel Lanes/railroad	3	30
	Left turn lanes	4	3997
	Paved/unpaved median	5	5210
	Grades/sawtooth/ditch/ structure	6	436
	Other	7	531

Notes:
a The minimum value of the variable
b The maximum value of the variable
c The average value of the variable
d The standard deviance of the variable
e The variance of the variable
f The indicator used in model to represent each category for the categorical variables
g The frequency of the collisions fall under the specific category group.

5.4.2 Methodology

The purpose of this analysis is to identify intersection characteristics that had a statistically significant relationship with the occurrence of pedestrian collisions on the State Highway System. The total number of collisions reported at each intersection from 2005-2009 was the dependent variable used in the modeling process. Collision data is count data, which are typically modeled through Poisson and Negative Binomial regression. As can be seen in Table 5-13, the variance of frequency of collisions at intersections is 0.2072, which is higher than the mean of 0.1123. This statistic indicates that the Negative Binomial regression model will better fit the data. Equation (1) shows the model structure:

$$y_i = e^{(\beta_0+\beta_1 x_{i1}+\beta_2 x_{i2}+\beta_3 x_{i3}+\cdots)} \quad (1)$$

Where

y_i=collision frequency at intersection i from 2005-2009.

x_{ij}=quantitative measure of each characteristic j associated with intersection i.

β_j= coefficient corresponding to x_{ij} to be determined by negative binomial regression.

Table 5-13. Description Statistics of Collision Frequency at Intersection in All Severity Level, Fatal Plus Severe Injured, and Fatal Only

Severity Level	Total Number of Collisions	Min.	1st Qu	Median	Mean	3rd Qu	Max.	Var.
All	2695	0.0000	0.0000	0.0000	0.1123	0.0000	11.0000	0.2072
Fatal and severe injured	745	0.0000	0.0000	0.0000	0.03103	0.0000	8.0000	0.042562
Fatal	308	0.0000	0.0000	0.0000	0.01283	0.0000	4.0000	0.015746

Variables Tested

A variety of model specifications were tested to explore the effects of all of the variables listed in Table 5-12. Each of the model specifications that were considered included mainline vehicle volume plus other explanatory variables. Several steps were used to narrow the list of variables. First, to reduce potential bias because of co-linearity, pairs of variables were tested by the Pearson product moment correlation coefficient. The correlation coefficients are listed in Table 5-14. Based on the results, pairs of variables with coefficient absolute values of >0.6 were not included in the same model.

Table 5-14. Pearson Product Moment Correlation Coefficients

	Main Lanes	Cross Lanes	Main ADT	Cross ADT	Median Wdith	Design Speed	Inx Design	Main Left Channel	Main Right Channel	Main Flow	Cross Left Channel	Cross Right Channe l	Cross Flow	Inx Control	Pop Group	Func. Class	Inx Lighting	Main Signal Mast	Cross Signal Mast	Hwy Group	Hwy Access	Med Type
Main lanes	1.00	0.25	0.71	0.11	0.29	0.03	-0.20	0.40	0.08	-0.20	0.22	0.15	-0.13	0.35	-0.42	-0.14	0.48	0.35	0.25	-0.67	0.10	0.56
Cross lanes	0.25	1.00	0.23	0.23	0.11	0.00	-0.23	0.25	0.17	0.08	0.51	0.21	-0.05	0.44	-0.18	-0.07	0.24	0.50	0.53	-0.19	0.06	0.19
Main adt	0.71	0.23	1.00	0.10	0.21	0.04	-0.17	0.44	0.09	-0.21	0.25	0.17	-0.12	0.34	-0.42	-0.13	0.45	0.33	0.24	-0.59	0.05	0.47
Cross adt	0.11	0.23	0.10	1.00	0.05	0.00	-0.10	0.11	0.11	0.03	0.20	0.12	0.04	0.18	-0.07	-0.02	0.11	0.21	0.20	-0.08	0.03	0.08
Median wdith	0.29	0.11	0.21	0.05	1.00	0.16	-0.16	0.14	0.06	0.27	0.07	0.05	0.00	0.19	-0.09	-0.08	0.23	0.15	0.14	-0.26	0.69	0.72
Design speed	0.03	0.00	0.04	0.00	0.16	1.00	-0.03	0.07	0.05	-0.04	0.01	0.00	0.00	-0.03	-0.03	0.22	-0.13	-0.02	-0.01	-0.04	0.17	0.05
Inx design	-0.20	-0.23	-0.17	-0.10	-0.16	-0.03	1.00	-0.23	-0.11	-0.14	-0.24	-0.13	-0.10	-0.37	0.08	0.04	-0.28	-0.37	-0.34	0.15	-0.14	-0.19
Main Left channel	0.40	0.25	0.44	0.11	0.14	0.07	-0.23	1.00	0.23	0.05	0.30	0.22	0.06	0.35	-0.19	-0.11	0.36	0.38	0.30	-0.53	0.02	0.36
Main Right channel	0.08	0.17	0.09	0.11	0.06	0.05	-0.11	0.23	1.00	-0.02	0.29	0.41	0.04	0.18	-0.04	-0.03	0.12	0.25	0.25	-0.12	0.04	0.09
Main flow	-0.20	0.08	-0.21	0.03	0.27	-0.04	-0.14	0.05	-0.02	1.00	0.02	-0.04	0.31	0.11	0.08	-0.01	0.01	0.09	0.10	0.21	0.29	0.08
Cross Left channel	0.22	0.51	0.25	0.20	0.07	0.01	-0.24	0.30	0.29	0.02	1.00	0.42	0.06	0.44	-0.17	-0.05	0.26	0.57	0.61	-0.21	0.02	0.16
Cross Right channel	0.15	0.21	0.17	0.12	0.05	0.00	-0.13	0.22	0.41	-0.04	0.42	1.00	0.04	0.24	-0.10	-0.04	0.18	0.34	0.31	-0.16	0.04	0.13
Cross flow	-0.13	-0.05	-0.12	0.04	0.00	0.00	-0.10	0.06	0.04	0.31	0.06	0.04	1.00	0.07	0.08	0.01	-0.03	0.10	0.10	0.11	0.03	-0.07
Inx control	0.35	0.44	0.34	0.18	0.19	-0.03	-0.37	0.35	0.18	0.11	0.44	0.24	0.07	1.00	-0.23	-0.10	0.43	0.77	0.57	-0.27	0.13	0.29
Pop group	-0.42	-0.18	-0.42	-0.07	-0.09	-0.03	0.08	-0.19	-0.04	0.08	-0.17	-0.10	0.08	-0.23	1.00	0.05	-0.26	-0.24	-0.19	0.30	0.02	-0.25
Func class	-0.14	-0.07	-0.13	-0.02	-0.08	0.22	0.04	-0.11	-0.03	-0.01	-0.05	-0.04	0.01	-0.10	0.05	1.00	-0.14	-0.09	-0.07	0.11	-0.11	-0.18
Inx lighting	0.48	0.24	0.45	0.11	0.23	-0.13	-0.28	0.36	0.12	0.01	0.26	0.18	-0.03	0.43	-0.26	-0.14	1.00	0.39	0.31	-0.37	0.11	0.39
Main Signal mast	0.35	0.50	0.33	0.21	0.15	-0.02	-0.37	0.38	0.25	0.09	0.57	0.34	0.10	0.77	-0.24	-0.09	0.39	1.00	0.76	-0.30	0.08	0.27
Cross Signal mast	0.25	0.53	0.24	0.20	0.14	-0.01	-0.34	0.30	0.25	0.10	0.61	0.31	0.10	0.57	-0.19	-0.07	0.31	0.76	1.00	-0.23	0.08	0.22
Hwy group	-0.67	-0.19	-0.59	-0.08	-0.26	-0.04	0.15	-0.53	-0.12	0.21	-0.21	-0.16	0.11	-0.27	0.30	0.11	-0.37	-0.30	-0.23	1.00	-0.01	-0.62
Hwy access	0.10	0.06	0.05	0.03	0.69	0.17	-0.14	0.02	0.04	0.29	0.02	0.04	0.03	0.13	0.02	-0.11	0.11	0.08	0.08	-0.01	1.00	0.53
Med type	0.56	0.19	0.47	0.08	0.72	0.05	-0.19	0.36	0.09	0.08	0.16	0.13	-0.07	0.29	-0.25	-0.18	0.39	0.27	0.22	-0.62	0.53	1.00

After estimating a model with all of the remaining variables, the variables were selected based on a Backward Elimination process. This is the simplest of all variable selection procedures and can be easily implemented without special software. In situations where there is a complex hierarchy, backward elimination can be run manually while taking account of what variables are eligible for removal. The process follows below:

1. Start with all the predictors in the model
2. Remove the predictor with highest *p*-value greater than 0.05
3. Run the model and go to 2
4. Stop when all *p*-values are less than 0.05

Because the pedestrian volume at intersection is not available at this point, the model doesn't contain exposure variables for pedestrian collisions. All the predictors are impacting the frequency of the collisions, not the risk.

5.4.3 Results

The intersection pedestrian collision prediction model is presented in Table 5-15. This model has 16 explanatory factors that are statistically significant (p-value < 0.05). Equation 2 shows the model formula.

$$y_i = e^{\left(-4.93+0.1795x_{i1}+0.00001891x_{i2}-0.0161x_{i3}-0.2718x_{i4}+0.1685x_{i5}+0.3244x_{i6}+1.282x_{i7}+0.7018x_{i8} +0.6312x_{i9}+1.413x_{i10}+1.437x_{i11}-0.2779x_{i12}-0.2592x_{i13}+0.5224x_{i14}-0.4351x_{i15}-0.4006x_{i16}\right)}$$

(2)

Where

y_i=collision frequency at intersection i from 2005-2009.
x_{i1}=number of lanes on mainline at intersection i.
x_{i2}=mainline vehicle ADT at intersection i,
x_{i3}=design speed on mainline at intersection i,
x_{i4}=rural area presence at intersection i,
x_{i5}=urbanized area presence at intersection i,
x_{i6}=lighting presence at intersection i,
x_{i7}=arterial presence at intersection i,
x_{i8}=collector presence at intersection i,
x_{i9}=intersection controlled by signs at intersection i,
x_{i10}=intersection controlled by multi-phase signals at intersection i,
x_{i11}=intersection controlled by 2-phase signals at intersection i,
x_{i12}=expressway presence at intersection i,
x_{i13}=freeway presence at intersection i,
x_{i14}=two-way traffic- left turns permitted on crossing street at intersection i,
x_{i15}=tee intersection type at intersection i,
x_{i16}=WYE intersection type at intersection i.

Table 5-15. Intersection Pedestrian Collision Model

Variable	Coef-ficient	SE	Z-test	P-value	X_{min}[a]	X_{max}[b]	$Y(X_{min})$[c]	$Y(X_{max})$[d]	% raise[e]
Number of Lanes on Mainline	0.1795	0.02547	7.048	0.000	1	12	0.0052	0.0371	613%
Mainline ADT	0.00001891	0.000001844	10.251	0.000	51	20600	0.0054	0.0079	46%
Design speed	-0.0161	0.002214	-7.27	0.000	0	70	0.0171	0.0055	-68%
Rural	-0.2718	0.08421	-3.228	0.001	0	1	0.0074	0.0056	-24%
Urbanized	0.1685	0.07244	2.326	0.02	0	1	0.0074	0.0087	18%
Lighting Present	0.3244	0.07771	4.149	0.000	0	1	0.0074	0.0102	38%
Arterial	1.282	0.1726	7.429	0.000	0	1	0.0074	0.0266	259%
Collector	0.7018	0.2428	2.891	0.004	0	1	0.0074	0.0149	101%
Signs	0.6312	0.1514	4.168	0.000	0	1	0.0074	0.0139	88%
Signals-Multi Phase	1.413	0.1634	8.652	0.000	0	1	0.0074	0.0303	309%
Signals-2 Phase	1.437	0.1681	8.549	0.000	0	1	0.0074	0.0311	320%
Expway	-0.2779	0.1092	-2.546	0.01	0	1	0.0074	0.0056	-24%
freeway	-0.2592	0.1074	-2.413	0.02	0	1	0.0074	0.0057	-23%
Two-Way Traffic - Left Turns Permitted on Crossing Street	0.5224	0.09135	5.719	0.000	0	1	0.0074	0.0125	69%
Tee Interx	-0.4351	0.05519	-7.884	0.000	0	1	0.0074	0.0048	-35%
WYE Interx	-0.4006	0.1499	-2.674	0.008	0	1	0.0074	0.0049	-34%

Note:
a The minimum value of the predictor
b The maximum value of the predictor
c The value of y when using the minimum value of the corresponding predictor and mean values for other numerical predictors and 0 for other categorical predictors
d The value of y when using the maximum value of the corresponding predictor and mean values for other numerical predictors and 0 for other categorical predictors
e The percentage raise of the collision frequency when increase the value of predictor from the minimum value to the maximum value

5.4.4 Intersection characteristics associated with pedestrian collisions

The model shows 16 characteristics that have a statistically significant relationship with pedestrian collisions propensity at intersections. This section suggests possible reasons for the relationships.

After other factors were controlled for, intersection with *higher mainline traffic volumes* tended to have more pedestrian collisions. More traffic can lead to higher possibility of conflicts between vehicles and pedestrians. An intersection with the highest traffic volume can have 46% more pedestrian collisions than those intersections with the lowest volumes.

The *number of lanes on the main street* also has a positive impact on pedestrian collisions at intersections. With the number of lanes rising from 1 to 12, the frequency of the collision could increase 613% (from 0.65 to 4.68). A higher number of lanes on the main street means longer crossing distance for pedestrians. The longer exposure time may increase the possibility of a collision.

The *design speed* has a negative impact on pedestrian collisions. This is reasonable because higher design speed always happens on freeways or expressways which are fully access controlled. Because pedestrians are not typically allowed on these facilities, there is little opportunity for a pedestrian collision.

Rural areas are less crowded than urban and urbanized areas so that the pedestrian activity is accordingly less. This could lead to the negative relationship between rural area presence and pedestrian collision frequency. On the other hand, urbanized area will have more pedestrians walking around so that it raises the possibility of collisions.

The presence of *lighting* at intersections is associated with more pedestrian collisions. The result shows that an intersection with light can have 38% more collisions than one without light. Possible explanation could be that the light always is installed at places where more pedestrian activity is expected.

Arterial and collector roads are associated with increased pedestrian collisions compared to local roads. The result shows roads classified as arterials can have 259% more collisions than those classified as local or not classified. Collector roads are also associated with more pedestrian collisions than local and not classified roads, but with a smaller percentage (101%) than arterials.

Intersections which are sign-controlled or signal-controlled have more pedestrian collisions than uncontrolled intersections. A signal-2 phase controlled intersection is associated with a 320% increase in collisions, while signal-multi phase controlled intersections are associated with a 309% increase. In contrast, sign-controlled intersections are associated with an 88% increase.

Expressways and freeways are negatively associated with the pedestrian collisions. This is reasonable because they are fully access-controlled roadways which limit the activity of pedestrians.

Intersections at which the *cross street has two-way traffic and left turn permitted flow* are positively related with the pedestrian collisions. The results show that changing the cross street traffic flow from “two-way, no left turns permitted” or “one way” or “other” to “two-way, left turns permitted” increases the collisions by 69%.

Intersections in the shape of T or Y have fewer collisions than typical four-legged ("+") intersections and those that are offset. This may be attributable to the fact that three-legged intersections tend to have less conflict between road users than 4-legged or multi-legged ones.

Based on the findings, the 16 variables are all significantly associated with the occurrence of pedestrian collisions. Among them, the signal control, the function class and number of lanes on the main street have very strong impact (with the % increase larger than 100%).

5.5 Countermeasure Recommendation

5.5.1 Pedestrian Safety Countermeasures

There are two main resources for this analysis to collect the pedestrian countermeasures. One is The "Local Roadway Safety–a Manual for California's Local Road Owners" which was developed by Caltrans to provide an easy-to-use, straightforward, comprehensive framework of the steps and analysis tools needed to identify locations with roadway safety issues and the appropriate countermeasures (SafeTREC, 2012). In this manual, different recommended countermeasures are listed, with detailed descriptions and guidelines for implementation. There are 14 countermeasures for pedestrian safety, 8 of which are for intersections. Another resource is the "Pedestrian safety guide and countermeasure selection system" developed by FHWA, which discusses 67 countermeasures.

Based on these resources, the pedestrian safety countermeasures and their associated location characteristics are listed in Table 5-16. In this table, each row represents the specific roadway facility characteristics and the corresponding countermeasure.

Table 5-16. Countermeasures to Improve Pedestrian Safety at Intersections

Countermeasure	Resources	Where to Use/Purpose	Variables
1,Install pedestrian countdown signal heads	Pedsafe, Caltrans	Signals that have **signalized pedestrian crossing** with walk/don't walk **indicators** and where there have been **pedestrian vs. Vehicle collisions**.	Signal control, crosswalk mark, indicator presence
2,Install pedestrian crossing	Caltrans	**Signalized intersections** with **no marked crossing** and **pedestrian signal heads**, where pedestrians are known to be crossing intersections that involve **significant turning** movements. They are especially important at intersections with (1) **multiphase traffic signals**, such as left-turn arrows and split phases, (2) **school crossings**, and (3) **double-right or double left turns**.	signal control, phasing design, crosswalk mark, area type (school zone), left/right channelization

Countermeasure	Resources	Where to Use/Purpose	Variables
3,Install advanced stop/yield bar before crosswalk	Pedsafe, Caltrans	**Signalized intersections** with a **marked crossing**, where **significant bicycle and or pedestrian volumes** are known to occur. It reduces the likelihood of a multiple-threat collision at **unsignalized midblock crossing** or at crosswalks on **multilane** roadway.	Signal control, crosswalk mark, pedestrian volume, number of lanes on mainline.
4,Install pedestrian overpass/ underpass	Pedsafe, Caltrans	Areas noted as having **many pedestrian-vehicle conflicts**. Possible installation sites include **a freeway or other high-speed, high volume arterial street.**	Roadway class (freeway, arterial, railroad)
5,Leading pedestrian interval	Pedsafe	LPIs give pedestrians time to establish their presence in the crosswalk before motorists can start turning. LPIs can be programmed into **traffic signals** to minimize conflicts between pedestrians crossing a roadway and **left or right turning vehicles.**	Signal control, pedestrian volume, left or right turn vehicle volume.
6,Push buttons and information signs on pedestrian push buttons	Pedsafe	Push buttons are installed at **signalized intersections** where **pedestrian volumes are significant** or compliance is poor.	Signal control, pedestrian push button presence, pedestrian volume
7,Install crosswalk (signs and markings only)	Pedsafe, Caltrans	**Non-signalized intersections** with **no marked crossing** where pedestrian are known to be crossing intersections that involve **significant vehicular traffic**. They are especially important at **school crossings** and intersection with **right and/or left turns pockets**.	Signal control, crossing mark, vehicle volume, area type (school zone), left/right channelization
8,Install raised medians/refuge island	Pedsafe, Caltrans	Intersections with **long ped. crossing distance**, a **higher number of peds** or a collision history. Can be installed at uncontrolled locations and signalized crossings with **enough roadway width**, especially when pedestrians have to cross **high-volume** roadways **at midblock crossings**. It reduces conflicts, **vehicle speeds**, calls greater attention, offers more opportunities **for additional signs** in the middle of the road, and reduce exposure time for pedestrians. The FHWA recommends particular consideration in **areas with mixtures of significant ped. and veh. traffic** (more than 12,000 ADT) and intermediate or high **travel speeds**.	Signal control, crossing distance /roadway width/ number of lanes, pedestrian volume, vehicle speed, vehicle volume, signage presence

Countermeasure	Resources	Where to Use/Purpose	Variables
9,Install pedestrian signal	Pedsafe, Caltrans	Intersections noted as having a history of pedestrian vs. Vehicle collisions and in areas where the **likelihood of a pedestrian is significant**. **Corridors** should also be assessed to determine if there are adequate safe opportunities for non-motorists to cross and if a pedestrian signal, hawk or hybrid beacons are needed to provide an active warning to motorists when a pedestrian is in the crosswalk.	Pedestrian volume, vehicle volume, roadway class (corridor), vehicle volume, signal control, phasing design.
10,Install pedestrian crossing (with enhanced pedestrian safety features/curb-extensions)	Caltrans	**Non-signalized intersections** with or without a marked crossing, where pedestrians are known to be crossing intersections that involve **significant vehicular traffic**. They are especially important at **school crossing** and intersections with **turn pockets**.	Signal control, Vehicle volume, area type (school zone), left or right turn channelization,
11,Curb extension	Pedsafe	Curb extensions improve safety because they increase **visibility**, **reduce speed of turning vehicles**, encourage pedestrians to cross at designated locations, **shorten the crossing distance**, and prevent vehicles from parking at corners. It should be installed only where there is an **on street parking lane**.	Crossing distance, sight, parking lane presence, turning speed, vehicle speed
12,Mini-circles/ roundabout	Pedsafe, Caltrans	Roundabouts are circular intersections designated to **eliminate left turns** by requiring traffic to exit to the right of the circle. They are installed to **reduce vehicular speeds,** improve safety at intersections through eliminating angle collisions. They often work best where the **traffic flows are balanced on all approaches**. Roundabouts are not meant for high-speed roadways (no higher than **15-18 mph**). Mini-circles are suit for low speed and volume non-arterial streets.	Vehicle speed, area type (residential), vehicle volume on main and minor roads.
13,Raised pedestrian crossings/ intersections	Pedsafe	Raised pedestrian crossings can be installed where **vehicle speeds** on **local and collector roads** are relative high. It can reduce vehicle speeds and enhance pedestrian crossing environment. A raised pedestrian crossing is typically located at a midblock crossing	Roadway class (local, collector), vehicle speed,

Countermeasure	Resources	Where to Use/Purpose	Variables
14,Lighting	Pedsafe	It is best to place streetlights along both sides of **arterial streets** and to provide a consistent level of lighting along a roadway. **Nighttime pedestrian crossing areas** may be supplemented with brighter or additional lighting. In **commercial areas or in downtown areas**, specialty pedestrian-level lighting may be placed over the sidewalks to improve pedestrian comfort, security, and safety.	Lighting condition, road class (arterial), area type (commercial, downtown), pedestrian night volume
15,Parking restrictions at crossing locations	Pedsafe	Removing a parking space from the roadway can help improve pedestrian and motorist **sightlines** through an intersection. Generally vehicles should not be parked within at least 20 feet of an intersection.	Parking lane presence, sight, number of lanes on major road.
16,Modified t-intersection	Pedsafe	Where speeding is of concern at **t-intersections** on **low-volume residential or collector streets**. It should be considered when **vehicle volumes are low** to moderate and **slower traffic speeds are desired**.	Intersection type, vehicle design speed, roadway class (residential, collector)
17,Intersection median barriers	Pedsafe	They are located in the center of an intersection where a **minor or local street intersects a major or main street**. They are used to **restrict left turn and cross-street movements** of vehicle traffic at the minor street to reduce cut-through routes in **local neighborhoods**. It reduces **traffic volumes**, preventing **turning conflicts**, and reducing pedestrian **crossing distances**.	Roadway class (mainline and cross roads), vehicle volume, crossing distance, area type (local neighborhoods)
18,Curb radius reduction	Pedsafe	Smaller **radii** can improve pedestrian safety by requiring motorists to **reduce vehicle speed** by making sharper turns and shortening pedestrian **crossing distances**.	Curb radii, vehicle turning/through speed, crossing distance
19,Modify skewed intersections	Pedsafe	They should be installed for improving pedestrian safety at **existing skewed intersection** crossings include providing high visibility marked crosswalks and adding medians or channelization islands to reduce crossing distance.	Intersect angle, intersection type (skewed or not)

Countermeasure	Resources	Where to Use/Purpose	Variables
20,Pedestrian accommodation at complex interchanges (signal, lighting, medians, barriers)	Pedsafe	Signal treatments are often appropriate at the intersection of **ramps on the surface streets**, and these can be timed to facilitate safe pedestrian travel.	Roadway class (intersection of ramps and surface roads)
21,Right-turn-on-red restrictions	Pedsafe	RTOR should be considered where **exclusive pedestrian phases or high pedestrian volumes** are present. They are used at every intersection with crossing guards or with **inadequate sight distances**. It should be used at **school crossing**.	Signal control, area type (school zone), pedestrian volume, sight
22,Left turn phasing	Pedsafe	Protected left turn phasing is particularly appropriate for locations with relatively **high left turn volumes**.	Left turn volume
23,Pedestrian hybrid beacon	Pedsafe	Pedestrian hybrid beacon (known as hawk, high intensity activated crosswalk) is to assist pedestrians at **unsignalized locations with a marked crosswalk on the major street**. The pedestrian volume thresholds required by the MUTCD for a pedestrian hybrid beacon are significantly lower than for a traffic signal. They are best suited for **uncontrolled crossings of multi-lane, higher speed or volume roadways** where there is a need to provide occasional pedestrian crossings.	Signal control, crosswalk marking, pedestrian volume, roadway class (major road), number of lanes on mainline, vehicle speed, vehicle volume
24,Rectangular rapid flash beacon	Pedsafe	RRFBs is a device using led flashing beacons in combination with pedestrian warning signs, to provide a **high-visibility** strobe-like warning to drivers when pedestrians use a crosswalk. It should supplement **standard crossing warning signage and markings**. Should not be used in conjunction with **yield, stop, or traffic signal control**. RRFBs are good for **two-lane streets**, but less well-suited for multi-lane roadways.	Control type, signage presence, signage type, number of lanes on mainline

Countermeasure	Resources	Where to Use/Purpose	Variables
25,Puffin crossing	Pedsafe, Caltrans	Puffin (pedestrian user friendly intelligent intersection) are not needed at all signalized locations, but may be appropriate for **signalized crossings** where a relatively **high frequency of pedestrian aged 65 and above and/or pedestrians with disabilities** which result in slower walking speeds. It is intended for use where there are **traditional traffic signals with pedestrian signals** and may be used with the **pedestrian hybrid beacons**.	Crossing distance, signal control, resident/pedestrian age, area type (senior center, hospital), pedestrian signage presence and type

5.5.2 Countermeasure Selection

The countermeasure list offers the description and where to use information to extract the critical characteristics for intersections. The significant variables are matched to the critical variables for countermeasures. See Table 5-17. By matching these critical variables and the significant predictors from the model, we can select the countermeasures which are useful to improve pedestrian safety on the state highway system.

Table 5-17. Recommended Countermeasures to Improve Pedestrian Safety on State Highway System

Variable	Influence	Countermeasures[a]
Number of lanes on main streets	Reduce crossing distance	3,8,11,15,17,25
Main street vehicle volume	Reduce traffic volume	8,17
Arterial and collector road presence	Reduce traffic volume, reduce traffic speed	4,11,12,17
Signal-2 phase control, signal-multi phase control	Reduce the conflict between left turning vehicles and pedestrians	2,5,10,22
Signs	Install signals	1,2
Two-way traffic and left turn permitted flow presence	Reduce the conflict between left turning vehicles and pedestrians	5,10,22
Tee and WYE intersection presence	Reduce the through traffic, reduce the traffic speed	11,12,19

a The order of the countermeasures in listed in Table 5-16.

According to the modeling results, the number of lanes on the main street has a strong positive impact the occurrence of pedestrian collisions. Reducing the number of lanes or the crossing distance can improve pedestrian safety.

The high volume of traffic on the main street is associated with increased pedestrian collisions, suggesting that countermeasures which reduce traffic volumes can also improve pedestrian safety.

Arterial and collector roadways carry more vehicle traffic and more pedestrian activities than local roads. Therefore, countermeasures suitable for these two types of roadways were selected. For example, countermeasures reducing traffic speed and traffic volume can be recommended.

The signal-2 phase controlled intersection is more strongly related to pedestrian collisions than the signal-multi phase controlled intersections (although not by much). This could be caused by the conflict between left turning vehicles and pedestrians crossing the perpendicular street. Also, it could be the same reason that the intersection with two-way traffic and left turn permitted flow on the cross street has more collisions. To counter these trends, countermeasures which can reduce the conflict between left turning vehicles and pedestrians will be selected.

The Tee and WYE intersections have fewer collisions than other types. The potential reason could be the lower speed, lower through traffic flow at the intersection. As a result, the countermeasures which can reduce the speed or avoid the through traffic will be selected. Such as remodeling the four-way intersection to three-way intersection by blocking one approach or re-construction will be an option.

Some of the significant variables from the model are not used to select the countermeasures—particularly those which are associated with higher or lower pedestrian volumes (and thus limited or increased exposure). For example, even though design speed is negatively associated with pedestrian collisions, this is attributable to the fact that once a roadway is designed as a high-speed road, the pedestrian activity is supposed to be very limited. Therefore, one cannot conclude that higher speeds lead to a safer environment. Similarly, urban and urbanized areas have more pedestrians than rural areas, and thus greater pedestrian exposure. The same is true of lighting at an intersection—this is generally associated with areas with higher pedestrian volumes.

5.6 Conclusion

This chapter aimed to locate the potential causing factors for pedestrian collisions on state highway system. In order to achieve the goal, analyses had been conducted in different grains.

The mapping of collisions across facility types displays the general map of how different types of collisions distributed on different types of facilities. From this mapping the “hot” facility type and collision type are highlighted.

In a greater grain, overrepresentation analysis shows how heavily roadways with each feature take the burden of collisions. Also it presents how fatal a roadway facility with specific features can be using the fatal index measurement. The comparison of the patterns between fatal collisions and fatal plus severe injured collisions describes how much different the results can be if we put the fatal and severe collisions together for analysis. Additionally, these results help highlighted some critical features to be noticed in the modeling variable selection.

To identify the causing factors for pedestrian collisions on state highway system, the intersection related collisions are aggregated and then input into a statistical regression model with intersection characteristics. Different aggregation methods are tested and the most appropriate one is used to obtain the intersection pedestrian collisions. Then a data set including collision frequency and intersection characteristics is developed by matching collision data to intersection data and roadway data. The negative binomial regression model was applied to investigate the impacts of the intersection characteristics on the frequency of collisions at intersections. Those significantly effective characteristics are highlighted to be the potential causing factors for intersection pedestrian collisions.

Based on the potential causing factors identified in the statistical modeling, corresponding countermeasures are recommended. The pedestrian intersection related countermeasures which are used both in California statewide and nationwide are summarized. By linking the critical element considered in each countermeasure to the causing factors, effective countermeasures are identified to improve pedestrian safety on the state highway system in California.

5.7 References

Abdel-Aty, M., Lee, C., et al. 2006. *Identification of intersections' crash profiles/patterns.* Florida Department of Transportation.

Aziz, H., Ukkusuri, S., and Hasan, S. 2013. Exploring the determinants of pedestrian-vehicle crash severity in New York City. *Collision Analysis and Prevention,* Vol. 50, pp. 1298-1309.

Numbering Conventions: Post Miles. Cahighways. Available online at: http://www.cahighways.org/num-postmiles.html Accessed March 12, 2014.

Camden, A., R. Buliung, L. Rothman, C. Macarthur, and A. Howard. 2012. The impact of pedestrian countdown signals on pedestrian-motor vehicle collisions: a quasi-experimental study. *Injury Prevention,* Vol. 18, No. 4, pp. 210-215.

Chicago Department of Transportation. 2011. *City of Chicago 2011 pedestrian crash analysis.*

Clifton, K., and Kreamer-Fults, K. 2007. An examination of the environmental attributes associated with pedestrian-vehicular crashes near public schools. *Collision Analysis and Prevention,* Vol. 39, No. 4, pp. 708-715.

Dai, D., Taquechel, E., Steward, J., and Strasser, S. The impact of built environment on pedestrian crashes and the identification of crash clusters on an urban university campus. *Western Journal of Emergency Medicine,* Vol. 11, No. 3.

Dai, D. 2012. Identifying clusters and risk factors of injuries in pedestrian vehicle crashes in a GIS environment. *Journal of Transport Geography,* Vol. 24, pp. 206-214.

Dissanayake, D., Aryaija, J., and Wedagama, D. 2009. Modelling the effects of land use and temporal factors on child pedestrian casualties. *Collision Analysis and Prevention*, Vol. 41, No. 5, pp. 1016-1024.

Green, E.R. and Agent, K.R. 2003. *Crash rates at intersections.* Kentucky Transportation Center. KTC-03-21/SPR258-03-2I.

Harwood, D.W., Bauer, K.M., Ingrid B. Potts, Darren J. Torbic, Karen R. Richard, Emilia R. Kohlman Rabbani, Ezra Hauer, Lily Elifteriadou, and Michael S. Griffith. 2003. Safety Effectiveness of Intersection Left- and Right-turn lanes. *Transportation Research Record,* 1840, pp. 131-139.

Indiana 2010 Five Percent Report. 2010. Indiana Department of Transportation. Safety. Available online at: http://www.in.gov/indot/files/2010FivePercentReport.pdf Accessed March 12, 2014.

Mohamed, M., Saunier, N., Miranda-Moreno, L., and Ukkusuri, S. 2013. A clustering regression approach: A comprehensive injury severity analysis of pedestrian-vehicle crashes in New York, US and Montreal, Canada. *Safety Science,* Vol. 54, pp. 27-37.

New York City Department of Health and Mental Hygiene, Parks and Recreation, Transportation, and the New York City Policy Department. *Bicyclist fatalities and serious injuries in New York City 1996-2005*.

Persaud, B., Council, F. M., Lyon, C., Eccles, K., Griffith, M., 2005. Multijurisdictional safety evaluation of red light cameras. *Transportation Research Record,* 1922, 29-37.

Rifaat, S., Tay, R., and de Barros, A. 2011/ Effect of street pattern on the severity of crashes involving vulnerable road users. *Collision Analysis and Prevention,* Vol. 43, No. 1, pp. 276-283.

Rothman, L., Howard, A., Camden, A., and Macarthur, C. 2012. Pedestrian crossing location influences injury severity in urban areas. *Injury Prevention,* Vol. 18, No. 6, pp. 365-370.

Safe Transportation Research and Education Center, University of California at Berkeley. 2012. *Local roadway safety—a manual for California's local road owners, version 1.0.* California Department of Transportation.

Schneider, R.J., Diogenes, M.C., et al. 2010. Association between roadway intersection characteristics and pedestrian crash risk in Alameda County, California. *Transportation Research Record: Journal of the Transportation Research Board.* No. 2198, pp. 41-51.

Tay, R., and Rifaat, S. 2007. Factors contributing to the severity of intersection crashes. *Journal of Advanced Transportation,* Vol. 41, No. 3, pp. 245-265.

Ukkusuri, S., Miranda-Moreno, L., Ramadurai, G., and Isa-Tavarez, J.. The role of built environment on pedestrian crash frequency. *Safety Science*, Vol. 50, No. 4, 2012, pp. 1141-1151.

U.S. Department of Transportation National Highway Traffic Safety Administration. *Crash factors in intersection-related crashes: an on-scene perspective*, DOT HS 811 366, September 2010.

Wier, M., Weintraub, J., Humphreys, E. Seto, E., and Bhatia, R. An area-level model of vehicle-pedestrian injury collisions with implications for land use and transportation planning. *Collision Analysis and Prevention,* Vol. 41, No. 1, 2009, pp. 137-145.

Zegeer, C.V., Stewart, J.R., Huang, H.H., et al. Safety effects of marked versus unmarked crosswalks at uncontrolled locations: final report and recommended guidelines. Federal Highway Administration, 2005.

6 Economic Appraisal

6.1 Background

Economic appraisal is a type of method to evaluate the monetary equivalent of projects that require capital investment. These methods quantify the value associated with the cost of the project and systematically compare it to the value associated with the benefits of the project. Economic appraisal techniques are expected to provide an objective perspective about which projects represent the best investment, and are therefore used to prioritize different projects.

SafetyAnalyst and other tools utilize four different economic criteria to evaluate countermeasures proposed as part of efforts to improve safety:

(1) *Cost-effectiveness* is equal to total cost divided by the expected number of collisions reduced;

(2) *EPDO-based*[10] *cost-effectiveness* is equal to total cost divided by the expected number of collisions reduced a severity weighting scheme;

(3) *Benefit-cost ratio* is the benefit divided by the cost;

(4) *Net benefit* is the difference between benefit and cost.

Benefit-cost ratio is the most commonly used criteria for traffic safety improvement project evaluation. The benefit and costs associated with pedestrian safety improvements may not always be comparable to the ones associated with non-pedestrian safety projects. In light of this, the objective of this effort is to study the considerations that need to be taken into account when evaluating different pedestrian safety project and to identify the appropriate economic appraisal method for pedestrian safety improvements.

6.2 Findings and Analysis

The literature review was conducted in two areas regarding HSIP and PSIP. Generally, most states use the benefit-cost ratio analysis in HSIP because the Highway Safety Manual recommends the method, as shown in Table 6-1. On the other hand, there is no information about the analysis of economic appraisal for PSIP. Even if most states choose benefit-cost ratio analysis in HSIP, the PSIP needs a different method at this time. The research team selected cost-effectiveness to evaluate the cost-benefit calculation for PSIP because this method is relatively simple to calculate and does not require a calculation presented in terms of monetary values for safety benefit, unlike the benefit-cost ratio approach. Additionally, the cost-effectiveness equation allows one to pay more attention to the factor that accounts for the expected number of collisions reduced. To calculate the expected number of collisions reduced in the cost-effectiveness approach, Crash Modification Factors (CMFs) in accordance with each countermeasure are needed. The research team identified 18 different countermeasures for pedestrian safety with 36 CMFs as shown in Table 6-2, although each countermeasure has a different number of CMFs. In choosing a method for PSIP, it is important to consider whether or not this data is available, and how it could be useful for PSIP.

[10] EPDO is Equivalent Property Damage Only

Table 6-1. Economic Appraisal for HSIP in Different States

No	STATE	Cost effectiveness	Benefit-cost ratio	Net benefit
1	Arizona DOT		x	
2	California DOT		x	
3	Colorado DOT			
4	Florida DOT		x	
5	Georgia DOT			
6	Illinois DOT			
7	Indiana DOT		x	
8	Iowa DOT			
9	Kansas DOT			
10	Kentucky Transportation Cabinet			
11	Louisiana Department of Transportation and Development		x	
12	Maryland State Highway Administration			
13	Massachusetts Highway Department			
14	Michigan DOT			
15	Minnesota DOT		x	
16	Mississippi DOT			
17	Missouri DOT			
18	Montana DOT			
19	Nevada DOT			
20	New Hampshire DOT			
21	New York DOT		x	
22	North Carolina DOT			
23	Ohio DOT			
24	Vermont Agency of Transportation			
25	Virginia DOT		x	
26	Washington DOT		x	
27	Wisconsin DOT		x	
28	Delaware Valley Regional Planning Commission			
29	North Jersey Transportation Planning Authority			
30	Traffic Improvement Association, Oakland County, Michigan			

Table 6-2. Thirty-six Crash Modification Factors for Pedestrian Safety by Eighteen Different Countermeasures

Countermeasure	CMF	CRF(%)	Quality	Crash Type	Crash Severity	Area Type
Change number of bus stations from X to Y	F(X)	F(X)	3	Veh/Ped	Fatal, Serious injury	Urban
Change number of bus stops in 50m buffer from X to Y	F(X)	F(X)	3	Veh/Ped	All	Urban and suburban
Change number of subway stations from X to Y	F(X)	F(X)	3	Veh/Ped	Fatal, Serious injury	Urban
Convert Pelican crossing or farside pedestrian signal to Puffin crossing	0.81	19	3	All	Fatal, Serious injury, Minor injury	Not specified
Convert Pelican crossing or farside pedestrian signal to Puffin crossing	0.74	26	3	All	Fatal, Serious injury, Minor injury	Not specified
Convert Pelican crossing or farside pedestrian signal to Puffin crossing	0.83	17	3	All	Fatal, Serious injury, Minor injury	Not specified
Convert Pelican crossing or farside pedestrian signal to Puffin crossing	0.76	24	3	Veh/Ped	Fatal, Serious injury, Minor injury	Not specified
Convert Pelican crossing or farside pedestrian signal to Puffin crossing	0.78	22	3	Veh/Ped	Fatal, Serious injury, Minor injury	Not specified
Convert Pelican crossing or farside pedestrian signal to Puffin crossing	0.84	16	3	Angle, Day time, etc	Fatal, Serious injury, Minor injury	Not specified
Convert Pelican crossing or farside pedestrian signal to Puffin crossing	0.61	39	2	Veh/Ped	Fatal, Serious injury, Minor injury	Not specified
Implement Barnes Dance	0.49	51	2	Veh/Ped	All	Urban
Implement Barnes Dance	1.10	-10	2	Angle, Head on, etc	All	Urban
Implement Safe Routes to School Program	0.839	16.1	3	Veh/Bic, Veh/Ped	Minor injury	.
Implement Safe Routes to School Program	0.87	13	2	Veh/Bic, Veh/Ped	All	.
Implement Safe Routes to School Program	0.884	11.6	2	Veh/Bic	All	.
Implement Safe Routes to School Program	0.861	13.9	2	Veh/Ped	All	.
Implement Safe Routes to School Program	1.28	-28	2	Veh/Bic, Veh/Ped	Fatal, Serious injury	.
Implement Safe Routes to School Program (Age 13-17)	1.05	-5	2	Veh/Bic, Veh/Ped	All	.
Implement to Safe Routes to School Program (Age 5-12)	0.724	27.6	3	Veh/Bic, Veh/Ped	All	.
Increase cycle length for pedestrian crossing	0.50	50	2	Veh/Ped	All	Urban
Increase cycle length for pedestrian crossing	0.55	45	2	Angle, Head on, etc	All	Urban
Install crosswalk on one minor approach	0.35	65	3	All	All	All
Install high-visibility crosswalk	0.60	40	2	Veh/Ped	All	Urban
Install high-visibility crosswalk	0.81	19	2	Angle, Head on, etc	All	Urban
Install high-visibility yellow, continental type crosswalks at schools	0.63	37	3	Veh/Ped	All	Urban
Install raised pedestrian crosswalks	0.64	36	1	All	Serious injury, Minor injury	Urban and suburban
Install raised pedestrian crosswalks	0.55	46	1	Veh/Ped	Serious injury, Minor injury	Urban and suburban
Install raised pedestrian crosswalks	0.70	30	1	All	Serious injury, Minor injury	Urban and suburban
Installation of a HAWK pedestrian-activated beacon at an intersection	0.712	29	4	All	All	Urban and suburban
Installation of a HAWK pedestrian-activated beacon at an intersection	0.849	15	3	All	Fatal, Serious injury	Urban and suburban
Installation of a HAWK pedestrian-activated beacon at an intersection	0.309	69	3	Veh/Ped	All	Urban and suburban
Raised intersections	1.05	-5	1	All	Serious injury, Minor injury	Not specified
Raised intersections	1.13	-13	1	All	Property damage only	Not specified
Raised median with marked crosswalk (uncontrolled)	0.54	46	3	Veh/Ped	All	Urban and suburban
Raised median with unmarked crosswalk (uncontrolled)	0.61	39	2	Veh/Ped	All	Urban and suburban
Widen sidewalks at intersections	1.12	-12	1	All	Serious injury, Minor injury	Not specified

A review of the references suggests that CMFs could be used for PSIP, but some CMFs would need to be excluded due to a lack of applicability. For instance, one would use the CMFs that have a collision type between vehicle and pedestrian, but not those that have collision types such as vehicle to vehicle and vehicle to bicycle as they are not pertinent for evaluating proposed countermeasures for pedestrian safety. When the 36 CMFs within 18 different countermeasures were reorganized based on the vehicle/pedestrian collision type, 13 applicable Crash Modification Factors in accordance with each countermeasure resulted, as shown in Table 6-3.

Table 6-3. Thirteen Crash Modification Factors Pertinent to Vehicle/Pedestrian Collisions

Countermeasure	CMF	CRF(%)	Quality	Crash Type	Crash Severity	Area Type
Change number of bus stations from X to Y	F(X)	F(X)	3	Veh/Ped	Fatal, Serious injury	Urban
Change number of bus stops in 50m buffer from X to Y	F(X)	F(X)	3	Veh/Ped	All	Urban and suburban
Change number of subway stations from X to Y	F(X)	F(X)	3	Veh/Ped	Fatal, Serious injury	Urban
Convert Pelican crossing or farside pedestrian signal to Puffin crossing	0.76	24	3	Veh/Ped	Fatal, Serious injury, Minor injury	Not specified
Implement Barnes Dance	0.49	51	2	Veh/Ped	All	Urban
Implement Safe Routes to School Program	0.861	13.9	2	Veh/Ped	All	.
Increase cycle length for pedestrian crossing	0.50	50	2	Veh/Ped	All	Urban
Install high-visibility crosswalk	0.60	40	2	Veh/Ped	All	Urban
Install high-visibility yellow, continental type crosswalks at schools	0.63	37	3	Veh/Ped	All	Urban
Install raised pedestrian crosswalks	0.55	46	1	Veh/Ped	Serious injury, Minor injury	Urban and suburban
Installation of a HAWK pedestrian-activated beacon at an intersection	0.309	69	3	Veh/Ped	All	Urban and suburban
Raised median with marked crosswalk (uncontrolled)	0.54	46	3	Veh/Ped	All	Urban and suburban
Raised median with unmarked crosswalk (uncontrolled)	0.61	39	2	Veh/Ped	All	Urban and suburban

Figure 1. Algorithms for calculating the expected number of collisions reduced (Reference: Appendix of SafetyAnalyst module 3)

For roadway segments or ramps:

$$X_{Fv(TOT)n} = \frac{X_{H(TOT)}}{\sum_{y=1}^{Y} \kappa_{y(TOT)}} \times \left(C_{Y(TOT)} \times P_{CT(TOT)} \times e^{R} \times \left(ADT_Y \times GF^{(EIY-M+n-1)}\right)^{\beta_1} \times AMF_{v(TOT)}\right)$$

$$X_{Fv(FI)n} = \frac{X_{H(FI)}}{\sum_{y=1}^{Y} \kappa_{y(FI)}} \times \left(C_{Y(FI)} \times P_{CT(FI)} \times e^{R} \times \left(ADT_Y \times GF^{(EIY-M+n-1)}\right)^{\beta_1} \times AMF_{v(FI)}\right)$$

For intersection:

$$X_{Fv(TOT)n} = \frac{X_{H(TOT)}}{\sum_{y=1}^{Y} \kappa_{y(TOT)}} \times$$
$$\left(C_{Y(TOT)} \times P_{CT(TOT)} \times e^{R} \times \left(MajADT_Y \times GF^{(EIY-M+n-1)}\right)^{\beta_1} \times \left(MinADT_Y \times GF^{(EIY-M+n-1)}\right)^{\beta_2} \times AMF_{v(TOT)}\right)$$

$$X_{Fv(FI)n} = \frac{X_{H(FI)}}{\sum_{y=1}^{Y} \kappa_{y(FI)}} \times$$
$$\left(C_{Y(FI)} \times P_{CT(FI)} \times e^{R} \times \left(MajADT_Y \times GF^{(EIY-M+n-1)}\right)^{\beta_1} \times \left(MinADT_Y \times GF^{(EIY-M+n-1)}\right)^{\beta_2} \times AMF_{v(FI)}\right)$$

6.3 Conclusion

This chapter explains the selection and use of an economic criterion for evaluating countermeasures. Based on a review of methods to evaluate proposed countermeasures, the research team determines that using benefit-cost is the appropriate economic criterion for the PSIP. Thirty-six CMFs were then evaluated and prioritized, resulting in 13 CMFs applicable for this project. This chapter also showed the procedure of calculating of the cost-effectiveness. In order to get the collisions reduction by implementing a countermeasure, the CMF of the countermeasure is needed for the algorithms, where it is then used to calculate the benefit-cost, after which the most appropriate countermeasure can be selected.

7 Funding Sources and Strategies

7.1 Introduction

This chapter discusses the existing funding sources for pedestrian safety improvements. The goal is to examine these funding sources and the challenges districts face in funding such projects. Currently, there is no designated funding source specific to pedestrian safety improvements within Caltrans.

There are many potential funding sources for projects promoting the reduction of pedestrian injuries and fatalities. These funds are often used to complement each other when jurisdictions are working to improve pedestrian safety through infrastructure and programs. The policy themes of recent federal acts are flexibility in use of funds, especially between highways and transit, sensitivity to the environment, particularly air quality conformity, and more attention to interagency coordination and public participation.

7.2 Funding Sources

Most Federal-aid highway funding programs require a 20 percent State match of Federal funds. This general rule is adjusted for States with significant Federal land holdings; up to 95 percent Federal funding is determined according to the percentage of Federal land holdings in the State. The matching ratio for bicycle and pedestrian projects is the same as for all other activities under the same program.

7.2.1 Highway Safety Improvement Program (HSIP)

The Safe, Accountable, Flexible, Efficient Transportation Equity Act – a Legacy for Users (SAFETEA-LU) established the Highway Safety Improvement Program (HSIP) as a core Federal-aid highway program. HSIP funds can be used for pedestrian safety improvements. The intent of HSIP is to significantly reduce public roadway fatalities and serious injuries.

For a project to be eligible for HSIP funds, the project must be on a public road or a publicly-owned bicycle or pedestrian pathway or trail. The typical eligible projects related to pedestrian safety include:

- new or retrofitted sidewalks
- New or retrofitted crosswalks
- An intersection safety improvement.
- Curb cuts and ramps
- An improvement for pedestrian or bicyclist safety or safety of persons with disabilities.
- Construction of a traffic calming feature.
- Installation of a traffic control or other warning devices at a location with high collision potential.
- Collection, analysis, and improvement of safety data.

- Installation of yellow-green signs and signals at pedestrian and bicycle crossings and in school zones.
- Systemic safety improvements.
- Spot safety improvements.

7.2.2 State Highway Operational Protection Program (SHOPP)

SHOPP is a multi-year capital improvement program of transportation projects on the State Highway System. The main objective of the SHOPP is to preserve and protect the highway system, not to add capacity to the state highway system. Projects in the SHOPP are limited to capital improvements relative to maintenance, safety, and rehabilitation of State highways and bridges, as well as other capital improvements that do not add capacity to the system. The Minor Program funding which is an annual allocation for projects with construction contract values under $1 million, is used to cover the critical low-cost SHOPP needs in all areas.

Caltrans implements the HSIP for State highways by programming and funding projects in the Collision Reduction Category, one of eight categories that make up the SHOPP. The Collision Reduction Category is further divided into two programs:

- 201.010 Program: Safety Improvement
- 201.015 Program: Collision Severity Reduction

7.2.3 SHOPP 201.010 Program: Safety Improvement

These safety improvement projects are based on collision history in which the improvement is expected to reduce the number and/or severity of collisions. The Traffic Safety Index of greater than 200 at the time of funds request must be obtained to have the project funded in the 201.010 Program. The Traffic Safety Index (TSI) is the tool used for evaluating safety benefits of highway improvement projects. It is a measure of the collision cost saved by motorists expressed as a percentage of the improvement's capital cost. Based on collision history, the TSI is determined by:

- Estimating the number and cost of collisions that may occur on the existing facility if no further improvement is made, and
- Subtracting from it the number and cost of collisions that are expected to occur with the improvement.

This collision cost savings, when divided by the cost of the improvement and converted to percent, is the Traffic Safety Index.

A spot safety improvement that could be funded under this program is a project that is justified on the basis of actual collision experience at a specific location and for which a Traffic Safety Index can be calculated. The following are possible spot safety improvements that could help pedestrian safety:

- New Signals

- Modified Signals
- Flashing Beacons
- New Roadway Lighting or Intersection Lighting

7.2.4 SHOPP 201.015 Program: Collision Severity Reduction

The purpose of this program is to decrease the potential of collisions and/or reduce the severity of collisions. Collision Severity Reduction Improvements that could help pedestrian safety include:

- Crosswalk Safety Enhancements
- School Zone Signals
- Overcrossing Pedestrian Fencing

Crosswalk Safety Enhancement projects are capital improvements designed to encourage drivers to yield to pedestrians at marked or unmarked crosswalks, shorten crossing distances, enhance driver awareness of crossings, and/or provide active warning of pedestrian presence at uncontrolled crossing locations.

School Zone Signals are occasionally necessary to extend or create crossing gaps in the flow of traffic on the “Suggested Route to School.” If the criteria in the Manual on Uniform Traffic Control Devices (MUTCD) are satisfied, the traffic signals can be funded within the 201.015 Program.

Overcrossing Pedestrian Fencing is installed to reduce the risk of objects being dropped or thrown upon vehicles. The protective screening in the form of fence-type railings should be installed along overcrossing structures with sidewalks in urban areas. Screening should also be considered for the opposite side of structures having one sidewalk.

7.2.5 Active Transportation Program (ATP)

On September 26, 2013, Governor Brown signed legislation creating the Active Transportation Program (ATP) in the Department of Transportation. The Active Transportation Program is funded from various federal and state funds and consolidates the following existing federal and California state transportation programs into a single program with a focus to make California a national leader in active transportation:

- Transportation Alternatives Program (TAP)
- Safe Routes To School (SRTS)
- Bicycle Transportation Account (BTA)

The ATP is administered by the Caltrans Division of Local Assistance. The purpose of ATP is to encourage the use of active transportation such as walking and bicycling by achieving the following goals:

- Increase the proportion of trips accomplished by biking and walking.
- Increase the safety and mobility of non-motorized users.

- Advance the active transportation efforts of cities and counties to achieve greenhouse gas reduction goals.
- Enhance public health, including reduction of childhood obesity.
- Ensure that disadvantaged communities share in the benefits of the program.
- Benefit many types of active transportation users.

The first priority for the funding of active transportation plans will be for cities, counties, county transportation commissions, regional transportation planning agencies, MPOs, school districts, and transit districts that have:

- No bicycle plan, pedestrian plan, safe route to schools plan, AND
- No active transportation plan

The second priority for the funding of active transportation plans will be for cities, counties, county transportation commissions, regional transportation planning agencies, and MPOs that have:

- A bicycle plan, OR
- A pedestrian plan

The project types eligible for the Active Transportation Program funding are:

- Infrastructure Projects: Capital improvements that will further the goals of this program.
- Non-infrastructure Projects: Education, encouragement, enforcement, and planning activities that further the goals of this program.
- Infrastructure projects with non-infrastructure components.

Below is a list of pedestrian safety improvement projects which may be considered eligible for Active Transportation Program funding:

- Development of new walkways that improve mobility, access, or safety for pedestrians.
- Improvements to existing walkways, which improve mobility, access, or safety for pedestrians.
- Installation of traffic control devices to improve pedestrian safety.
- Safe Routes to School projects that improve the safety of children walking to school.
- Safe routes to transit projects, which will encourage transit by improving walking routes to mass transportation facilities and school bus stops.
- Development of a pedestrian, safe routes to schools, or active transportation plan in a disadvantaged community.
- Focused enforcement activities around high pedestrian injury and/or fatality locations (intersections or corridors).
- School crossing guard training.
- Development and implementation of programs and tools that maximize use of technology to implement the goals of the Active Transportation Program.

7.2.5.1 Transportation Alternatives Program (TAP)

This program replaced Transportation Enhancement (TE), Recreational Trails, and Safe Routes to Schools (SRTS) programs. Transportation Enhancements (TE) activities were federally-funded, community-based projects that expanded travel choices and enhanced the transportation experience by improving the cultural, historic, aesthetic, and environmental aspects of the transportation infrastructure. TAP eligibility requirements are similar to TE, but more focused on infrastructure. Eligible entities included local & tribal agencies.

TAP provides funding for projects defined as transportation alternatives, including on- and off-road pedestrian facilities. The Federal share for most TAP projects is 80 percent. State or local match is 20 percent.

7.2.5.2 Safe Routes to School (SRTS)

The Safe Routes To School Program (SRTS) is intended to increase the number of children in grades K-8 who walk or bicycle to school by removing the barriers that currently prevent them from doing so. Barriers may include a lack of infrastructure, inadequate infrastructure that poses a safety hazard, or a lack of outreach programs that promote walking/bicycling through education and encouragement for children, parents, and the community. Projects that are eligible for this funding are either under the category of infrastructure (capital improvements), or non-infrastructure (education, encouragement, enforcement).

Safe Routes to Schools infrastructure projects must be located within two miles of a public school or within the vicinity of a public school bus stop. Projects must correct an identified safety hazard or problem on a route that students use for trips to and from school, and may include the following projects: shared use paths; spot improvements; new or retrofitted sidewalks; new or retrofitted crosswalks; signal improvements; curb cuts and ramps; and traffic calming.

The Safe Routes to School non-infrastructure projects may include the following projects: Pedestrian Coordinator position; Safety Education position; safety brochure or book; and training.

This is a 100% federal reimbursement program, with no local match required. Federal funds are apportioned to the states based on the ratio of the total number of children enrolled in grade school and middle school in the state vs. the total number nationwide. The Safe Routes to Schools Program is administered by State Departments of Transportation (DOTs). Eligible applicants include states, counties and cities. Non-profit organizations, federally recognized Native American Tribes, school districts, hospitals and public health departments can partner with states, counties and cities as their responsible applicants.

7.2.6 State Transportation Improvement Program (STIP)

The State Transportation Improvement Program (STIP) is a multi-year capital improvement program to assist the California State, counties, and cities to plan and implement transportation improvements. This program is funded with revenues from the Transportation Investment Fund and other funding sources. All STIP projects must be capital projects and may include improving pedestrian facilities.

7.2.7 Congestion Mitigation and Air Quality Improvement Program (CMAQ)

The Congestion Mitigation and Air Quality Improvement Program (CMAQ) provides funding for transportation projects and programs which contribute to the achievement or maintenance of National Ambient Air Quality Standards. The CMAQ program can be used to fund numerous pedestrian improvements, including the following: shared use paths or trails; spot improvements; new or retrofitted sidewalks; new or retrofitted crosswalks; signal improvements; curb cuts and ramps; Pedestrian Coordinator position; safety brochure or book; and training. The Federal share for most CMAQ projects is generally 80 percent.

7.2.8 Federal Lands Highways Program (FLHP)

The Federal Lands Highway Program provides funding for improvement of public roads and transit facilities serving Federal and Indian lands. Improvements for pedestrians are eligible activities in conjunction with projects on each of the classes of Federal Lands Highways: Forest Highways, Indian Reservation Roads, Park Roads and Parkways, Refuge Roads, and Public Lands Highways. The Federal share is 100 percent.

7.2.9 National Highway System (NHS)

The National Highway System (NHS) is composed of 163,000 miles of urban and rural roads serving major population centers, major travel destinations, international border crossings, and intermodal transportation facilities. Improvements on pedestrian facilities within NHS corridors are eligible for NHS funds. The Federal share is usually 80 percent and State share is 20 percent.

NHS funds are available for the following projects: shared use paths; new or retrofitted sidewalks; new or retrofitted crosswalks; signal improvements; curb cuts and ramps; and pedestrian bridges and tunnels that cross NHS facilities.

7.2.10 Surface Transportation Program (STP)

Pedestrian improvements are eligible for funding under the STP. The following are eligible projects: the development of a pedestrian plan; shared use paths; spot improvement programs; new or retrofitted sidewalks; new or retrofitted crosswalks; signal improvements; curb cuts and ramps; traffic calming; Pedestrian Coordinator position; Safety Education position; safety brochure or book; and training.

7.2.11 Highway Bridge Replacement and Rehabilitation Program

Where a highway bridge deck is being replaced or rehabilitated with federal funding, then the bridge should be replaced or rehabilitated to provide safe accommodations for pedestrians. Under this program, the shared use path and new or retrofitted sidewalks may be funded.

The Federal share for most Highway Bridge Replacement and Rehabilitation Program projects is 80 percent, and State share is 20 percent.

7.2.12 National Scenic Byways Program

The National Scenic Byways Program recognizes roads having outstanding scenic, historic, cultural, natural, recreational, and archaeological qualities by designating them as National Scenic Byways or All-American Roads. Pedestrian improvements include pedestrian information signing, parallel shared-use paths, and crosswalks and sidewalks, provided that such facilities do not destroy the qualities inherent in the Scenic Byway.

The Federal share for most National Scenic Byways Program projects, is generally 80 percent, and State share is 20 percent.

The following four programs are funded by the Federal Transit Administration (FTA):

7.2.13 Urbanized Area Formula Grants (Transit)

The Urbanized Area Formula Grants program provides funding to urbanized areas with populations of more than 50,000. Federal share is typically 80 percent. These funds may be spent to provide stand-alone pedestrian improvements such as pedestrian access to transit stations.

7.2.14 Formula Program for Other than Urbanized Areas

The Formula Program for Other than Urbanized Areas provides transit capital and operating assistance to urbanized areas with populations of less than 50,000. Federal share is typically 80 percent. These funds may be spent to provide stand-alone pedestrian improvements such as pedestrian access to transit stations.

7.2.15 Capital Program Grants and Loans

The Capital Investment Grants and Loans Program provides transit capital assistance for bus and bus related facilities. Federal share is typically 80 percent. Transit agencies are encouraged to include facilities and access for pedestrians in the design of new transit systems.

7.2.16 Federal Transit Administration Capital Funds

These funds may be used to support the design, construction, and maintenance of pedestrian projects that enhance or are related to public transportation facilities. Eligible improvements include capital projects like pedestrian access to a public transportation facility and transit enhancements like pedestrian access and walkways.

7.2.17 State and Community Highway Safety Grant Program (Section 402)

This program is funded by National Highway Traffic Safety Highway Administration (NHTSA). The funds (known as "Section 402 funds") are used to support State and community programs to reduce deaths and injuries on the highways. Pedestrian safety has been identified as a National Priority Area and is therefore eligible for Section 402 funds. Activities such as conducting community-wide pedestrian safety publicity campaigns (safety brochure/book), conducting data analyses, education and training, and enforcement activities related to pedestrian safety are funded under the Section 402. The Federal share for Section 402 projects has generally been 80 percent.

7.2.18 Pedestrian Safety Assessment (PSA) Studies for California Communities

Funding for this program is provided by a grant from the California Office of Traffic Safety, through the National Highway Traffic Safety Administration (NHTSA). Any city, county, or local community within California can apply for an assessment study. The primary objectives of a Pedestrian Safety Assessment (PSA) are:

- To improve pedestrian safety in a city or county
- To create safe, comfortable, accessible, welcoming environments for pedestrians
- To enhance the walkability and economic vitality of local districts

To meet these objectives, two traffic engineers are assigned to a city or county to review the city or county's pedestrian safety conditions, programs, and needs, and suggest new strategies to improve pedestrian safety. Many suggestions in the PSA report may be appropriate for grant applications, including OTS or Safe-Routes-to-School funding. The suggestions for improvement may also be used as the starting point for a Pedestrian Master Plan, a document that would set forth pedestrian and streetscape policies for the city or county and identify and prioritize capital improvement projects.

7.3 Funding Challenges

A survey was sent to the Caltrans' twelve Districts' Pedestrian Coordinators, asking about their experience and the challenges they face in funding the improvements for pedestrian safety in their respective district. Nine of the twelve district coordinators replied. The questions are listed and their replies to each question are summarized below. The response to the questions reflects the coordinators perception of the funding challenges and is not always aligned with the original intention of the funding.

Engineering

1. *What is the main source of funding for your district's pedestrian safety improvements?*

Most of the district coordinators indicated that the State Highway Operations and Protection Program (SHOPP), specifically the SHOPP 201.015 Program, is the main funding source for the pedestrian safety improvement projects in their district. They also indicated Safe Routes to School and the ADA Transition Plan as other sources. Some indicated that the pedestrian improvements, mostly ADA upgrade projects, are funded either through the Minor Program or are included as part of a larger project. Safe Routes to School and Transportation Enhancements have funded many local pedestrian projects. They also indicated that project funding depends on the nature/scope of the project. Some improvements can be rolled into regular maintenance projects, while larger projects need to go through SHOPP/Minor Program process.

2. What kinds of pedestrian safety improvements do you need funding for in your district, (i.e. for installation of pedestrian signals)?

The coordinators indicated that they needed funding for the following pedestrian safety improvements:

- sidewalk infill and inclusion on bridges
- ADA retrofits
- pedestrian separated walkways/trails
- more complex overpass structures
- pedestrian lighting
- rectangular rapid flashing beacons
- pedestrian hybrid beacons
- pedestrian signal heads
- intersection lighting
- pedestrian countdown signals
- center islands
- construction of bulb-outs at curb returns
- re-design of signalized intersections to improve pedestrian safety (e.g., corner curb extensions, radius reduction, median refuge islands installation)
- installation of enhanced pavement markings and signing for crosswalks
- buffered landscaping
- staff training

One district coordinator indicated that whenever their District identifies specific locations, they include them in projects or address them on an as-needed basis.

District 7, Los Angeles, indicated that they need funding for many pedestrian safety improvement projects, such as: installation of curb ramps at various locations, upgrading pedestrian routes to comply with the ADA standards, installation of HAWK signals on Pacific Coast Highway and other locations, upgrading all crosswalk markings to continental pattern, improving on and off-ramp intersection geometrics (i.e. squaring up intersections), converting signalized intersections to roundabouts (e.g. intersection of Route 126 and Route 33), traffic calming, and context sensitive solutions on main streets (Route 126 in the City of Fillmore, Route 150 in the City of Ojai, Route 150 in the City of Santa Paula, Route 19 in the City of Bellflower, etc.).

Another district coordinator indicated that they need funding for treatments to improve the safety of existing uncontrolled crossings at more locations than those already covered by the 015 Program (e.g., ladder-style crosswalk markings, advance yield lines with yield signage, beacons, and median refuge islands).

3. *Do you have a designated funding source for collecting pedestrian-related data (i.e. pedestrian volume)?*

Most coordinators indicated they do not have any designated funding source for collecting pedestrian-related data.

4. *What are the challenges you face for funding pedestrian safety improvement projects?*

The responses to this question revolved overwhelmingly around a lack of sufficient funding. For example, one district coordinator indicated that, due to the wide variety of project types funded under the Minor Program, many projects are postponed to later years because there isn't enough funding. Another coordinator indicated that a lack of sufficient funds, to cover large scale projects, is a challenge. Rather, the need for safety improvements is always great and allocation is always limited; therefore, it is a matter of setting priority. This was echoed by a separate coordinator, who said that the demand outpaces the resources. One reply was that the pedestrian safety improvements rarely compete well for SHOPP funds and the SHOPP criteria needs to be revisited so that pedestrian improvements will be more likely to be funded. Another coordinator indicated, "We are constantly told that there is no money available for pedestrian safety projects, unless there is a problem that shows up in TASAS. We believe that would be too late."

One other district coordinator indicated that it depends mostly on the local agencies to take the initiative, and that "they incorporate 'Complete Streets' and 'Living Streets' concepts into their planning documents." Another coordinator indicated that one of their challenges is prioritizing the locations that need improvements.

Education

5. *How often are training programs or courses related to pedestrian safety provided or shared among district staff?*

Responses to this question ranged between regular training opportunities to once or twice per year to once every five years. For example, one coordinator indicated that there are educational opportunities several times a month, and another indicated that they have training programs regularly. Another indicated that staff members from Freeway Operations, Traffic Operations, Signal Operations, and Safety sometimes attend webinars that focus on pedestrian and bike safety. They also indicated that they are provided with the on the job training. Another coordinator indicated that their Division of Traffic Operations has done internal training related to the crosswalk enhancement program (targeting existing uncontrolled marked crosswalks using 015 funds). They have access to webinars from the University of North Carolina Pedestrian and Bicycle Information Center and the Association of Pedestrian and Bicycle Professionals. Additionally, the SafeTREC-University of California at Berkeley provides seminars, which are available as a webinars.

The Planning Division at one District had recently sponsored a Complete Streets course which was oversubscribed. They also benefitted from the FHWA Pedestrian Safety Design and Action Plan courses that were offered in the district a few years ago, but these were oversubscribed, as well. In general, the coordinators indicated that districts would benefit from more frequent on-site training opportunities to reach more staff, particularly the ones with very large Design Division.

6. *How many participants are typically present for training related to pedestrian safety?*

The coordinators indicated that the number of participants vary depending on the type of training. One indicated there may be from 6-20 per training. Most of the coordinators stated that the courses on pedestrian safety design and complete streets are always full when offered. They typically have about 20 to 30 students per class.

7. *Which department(s) or employee group(s) would benefit most from targeted training?*

In response to this question, the coordinators indicated that employees from Design, Traffic Safety, Traffic Engineering, Planning, Maintenance, Project Management, Construction, Permits, Local Assistance, Freeway Operations, Signal Operations, and Traffic Operations would benefit most. One district coordinator emphasized that Planning and Traffic Safety are the main groups that would benefit from such training. Another district coordinator indicated “All” departments would benefit from these types of training.

8. *How do you fund pedestrian safety training for your district?*

The respondents indicated that the training fund is part of the overhead allocation. One district coordinator indicated that the provision of courses in the districts tailored to Caltrans staff is generally handled by different divisions at Caltrans Headquarters who enter into a contract with consultants or university faculty. Another district coordinator also mentioned that most of their training is funded through headquarters, and no district funds are used for training. They indicated that the Webinars are free, and the Complete Streets Course and Transportation Planning Workshop are funded by the headquarters’ Division of Transportation Planning.

Enforcement

9. *Is the enforcement of pedestrian safety entirely the local agency’s responsibility?*

The coordinators believed that pedestrian safety enforcement is the responsibility of the local law enforcement and sometimes CHP, when there is need along the State Highway System and rural highways.

10. If not, do you have any funding for enforcement of pedestrian safety at the district level?

At this time, Caltrans does not have a funding for enforcement. However, the Office of Traffic Safety can provide funding to local law enforcement agencies to perform enhanced enforcement for pedestrian safety.

Please feel free to write any other issues that you like to be addressed in designating funding sources for pedestrian safety improvements.

One district coordinator indicated that, "Funding for pedestrian projects needs to be reevaluated so that projects can be competitive for funds. It's like trying to fit a square peg into a round hole. Presently, the criteria are balanced in the favor of motorist projects alone. Often, the pedestrian projects are funded using creativity. Some staff members are willing to take responsibility for the risk citing Deputy Directive 64 but most are not. Pedestrian safety projects shouldn't be the result just of pedestrian "champions" but should be easy for all staff to do."

Another coordinator indicated, "Caltrans Districts should be able to identify and fund Pedestrian Safety projects in a collaborative process with Design, Traffic Operations, and the District Pedestrian coordinators, but this does not happen. I have been told that it is due to lack of funding. I would also say that it is due to an inability to fully coordinate between divisions."

7.4 Conclusion

In this chapter the existing funding sources for pedestrian safety improvements and the challenges districts face in funding such projects were discussed. As indicated by the Districts' Pedestrian Coordinators, there is a wide range of funding sources that are used for pedestrian safety improvements. The district coordinators also noted that the priority of the existing funding sources is more towards motorists. The goal for future phase of this project is to make sure there are sufficient streams of funding stream within Caltrans for pedestrian safety improvements.

7.5 References

- TRANSPORTATION FUNDING OPPORTUNITIES GUIDEBOOK, State and Federal Funds Available for Local Agency Projects, Caltrans, Division of Local Assistance, August 25, 2008
- Local Roadway Safety, A Manual for California's Local Road Owners, Caltrans, Version 1.1, April 2013
- DRAFT ACTIVE TRANSPORTATION PROGRAM GUIDELINES, 1/29/14

- Bicycle and Pedestrian Provisions of Federal Transportation Legislation - Guidance - Bicycle Pedestrian - Environment – FHWA.pdf
- Bicycle & Pedestrian - Environment – FHWA.pdf
- The Congestion Mitigation and Air Quality (CMAQ) Improvement Program Under the Moving Ahead for Progress in the 21st Century Act, INTERIM PROGRAM GUIDANCE, November 12, 2013
- The Highway Safety Improvement Program (HSIP) Manual, U.S. Department of Transportation, Federal Highway Administration, January 2010
- Highway Safety Improvement Program Guidelines, 2013, Division of Traffic Operations, California Department of Transportation
- FINAL 2013 TEN-YEAR STATE HIGHWAY OPERATION AND PROTECTION PROGRAM PLAN, March 5, 2013, Caltrans
- Proposed 2014 SHOPP, Caltrans, January 10, 2014

8 Institutionalization

8.1 Background

This chapter discusses the institutional challenges that need to be addressed to successfully implement a program like the PSIP. This task was completed in collaboration with a team of practitioners from Fehr and Peers. As part of the effort to map the institutional knowledge about pedestrian safety, the team interviewed Caltrans personnel to identify the material available about pedestrian safety. The findings are summarized in Appendix 7-A. In addition, the team also developed a recommended procedure to execute a pedestrian safety investigation at the district level in response to a list of pedestrian hotspots which are summarized in Appendix 7-B.

Conclusions and Next steps

This report aimed to create a comprehensive picture of pedestrian safety in California, as well as to lay the foundations for implementing a Pedestrian Safety Improvement Program in California. Each chapter in this report describes an activity that contributes to the overall strategy to enhance pedestrian safety in California. Research presented in the *Introduction* reinforces the need for such an effort, as collision statistics demonstrate clearly that pedestrians are the most vulnerable roadway users in the state. The *Introduction* also makes the case that a pragmatic approach informed by a set of visionary goals is needed to guide efforts toward improving pedestrian safety. Chapters 1-8 then present the progress toward pedestrian safety that the PSIP project has fostered.

Chapter 1 presents a response to the expressed need for better access to pedestrian data—data that is, as Challenge Area 8 has requested, in a "readily available format for local research and investigation." The tools described in *Chapter 1* build on the success of the Transportation Injury Mapping System (TIMS) by increasing the focus on pedestrian-related data and providing a means for Caltrans personnel to review both fatality and severity information in their TASAS database. The resultant Pedestrian Safety Monitoring Report (PSMR) tool and mapping tools in TIMS provide better accessibility to pedestrian collision data in California for both Caltrans personnel and local agencies. The PSMR tool improves the usability of TSAR Accident Detail files and facilitates advanced data exploration efforts at the district level. The tools also provide a more structured means for identifying pedestrian collision clusters, which aids the investigation into collision patterns. Additionally, the availability of TIMS as a general resource for querying, mapping, and downloading SWITRS data is invaluable for widespread sharing and analysis of pedestrian collision data.

Chapter 2 focuses on the need for reliable pedestrian volume data relevant to the Caltrans State Highway System information database. Volume data are critical to accurately estimating the relative risk of pedestrian collisions for people traveling along state highways (i.e., pedestrian collisions/pedestrian volume). Additionally, by identifying locations that have higher relative pedestrian risk, Caltrans can better understand which roadway design features or other characteristics of a location should be modified to reduce pedestrian collisions and injuries. Volume data is also crucial for understanding how common pedestrian activity is along various parts of the State Highway System, knowledge that can help Caltrans better meet statewide goals for increased pedestrian mobility through designing roadways for safe and convenient pedestrian access.

Given the impracticality of counting pedestrians at every intersection and along every segment of the 15,000-mile State Highway System on a routine basis, *Chapter 2* proposes that pedestrian volumes be estimated via a pedestrian volume model based on counts collected at a sample of locations and extrapolated based on site and surrounding area characteristics to other locations via statistical methods. The results of a pilot model are presented and then evaluated in order to propose future research on the topic. This effort can substantially aid Caltrans in developing reliable pedestrian volumes in a resource-conservative manner. In addition to that, SafeTREC has been leading an effort to develop a database structure to store pedestrian volume and infrastructure data that can be linked to the existing Caltrans data systems. The *pedestrian volume database* can accommodate field observation data in addition to annual estimates derived from a model. The *pedestrian infrastructure database* can store design attributes that are associated with pedestrian safety.

Chapter 3 describes a Pedestrian Report Card created from readily-available state-level data that can serve as an annual snapshot of actual pedestrian safety in the state, as well as to depict trends in pedestrian safety over time. In addition, it provides a section for data on perceived pedestrian safety, as measured through attitudes and behavior, which can be updated as the data are available. This report card is proposed as a high-level tool to help transportation professionals, policymakers, and community members better understand and monitor pedestrian safety in the state of California, celebrate successes, and identify areas for improvement.

Chapter 4 proposes and evaluates two methodologies to identify high-frequency pedestrian collision segments ("hotspots") along the California State Highway System. Hotspot identification can help Caltrans efficiently allocate resources to address what are typically rare occurrences that may be spatially-dispersed. Identifying the hotspots along a small road segment has the additional benefit of ensuring that the collisions covered are affected by similar road conditions and pedestrian infrastructure elements.

The research team evaluated hotspot identification via two methods. The first, called the *sliding window method*, involves a hotspot window of a fixed length which slides along the road network to identify a segment which matches the necessary conditions for it to be defined as a hotspot. The second is an optimization technique called *dynamic programming*, which seeks to maximize the coverage of collisions covered by the hotspots over the entire road network. The research team found that the dynamic programming approach captures collisions more consistently and efficiently than the sliding window approach. The chapter concludes with tips for a practical implementation of the hotspot identification algorithm so as to allow for a more effective allocation of Caltrans resources. This tool can be used by Caltrans to identify a set of hotspot across the different districts and trigger pedestrain safety investigations.

In additon to the hotspot approach, SafeTREC has been leading an effort to devleop a systemic approach to improve pedestrain safety. The proposed approach would identify systemic hotspots by highlighting what types of collisions are occurring on what types of facilities. This approach would be incorporated into the PSIP as a complementary and parallel approach to the hotspot method described here.

Chapter 5 presents a five-part analysis of the incidence and severity of pedestrian collisions reported on the California State Highway System from 2005-2009, in addition to an analysis of the roadway characteristics with which they were associated. The first section presents the results of a preliminary analysis of the distribution of pedestrian collisions on state highway facilities, offering a general picture of the whole state highway system about what types of pedestrian collisions occur on what types of facilities. The second section analyzes the roadway characteristics overrepresented in pedestrian collisions and fatalities, and recommends areas for future research. The third section evaluates various intersection-related collision aggregation methods to determine the most appropriate way to obtain intersection pedestrian collisions for analysis. The fourth section presents a Negative Binomial regression model to investigate the potential causal factors of pedestrian intersection collisions on the state highway system. The final section summarizes the available countermeasures and links them to the causal factors highlighted in the statistical analysis. The chapter concludes with recommended countermeasures to improve pedestrian safety on the state highway system.

Chapter 6 presents a cost-benefit approach to prioritizing countermeasures. An economic appraisal approach provides four different criteria to evaluate proposed countermeasures. These are four types of economic criteria: (1) Cost-effectiveness is equal to total cost divided by the expected number of collisions reduced; (2) EPDO-based cost-effectiveness is almost same as the cost-effectiveness except for a severity weighting scheme; (3) Benefit-cost ratio is the benefit divided by the cost; (4) Net benefit is the difference between benefit and cost. Benefit-cost ratio is the most common criteria and has been used for the Highway Safety Improvement Program (HSIP) to analyze proposed countermeasures. Accordingly, we propose using the benefit-cost ratio criterion for pedestrian safety applications.

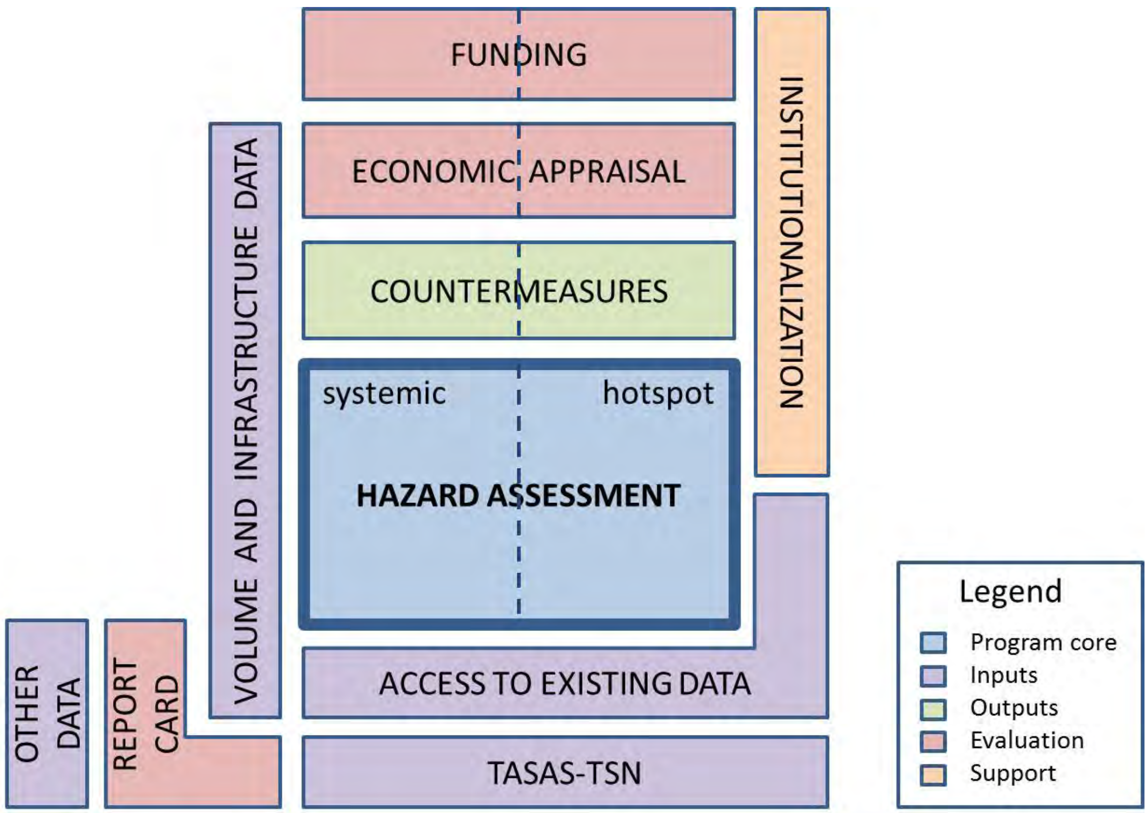
Chapter 7 discusses the existing funding sources for pedestrian safety improvements and examines the challenges districts face in funding such projects. While there are many potential funding sources for projects promoting the reduction of pedestrian injuries and fatalities, survey responses from the district coordinators noted that the priority of the existing funding sources is more towards motorists. The goal for future phase of this project is to make sure there are sufficient streams of funding stream within Caltrans for pedestrian safety improvements.

Chapter 8 discusses the institutional challenges that need to be addressed to successfully implement a program like the PSIP. In addition, the team developed a recommended procedure to execute a pedestrian safety investigation at the district level in response to a list of pedestrian hotspots. As part of the effort to map the institutional knowledge about pedestrian safety, the team also identified the material available to Caltrans personnel about pedestrian safety.

Recommendation for Next Steps

The first phase of the project has identified the components that are needed to implement a PSIP for California. The research team mapped the activities that are needed under each of these components and has conducted the initial steps towards these activities. The next phase for PSIP would be to work closely with Caltrans to streamline the entire components into an implementable program. As depicted in Figure C-1, the core of the program would be a hazard assessment component that would include two parallel approaches: (i) a hotspot approach; and (ii) a systemic approach. Both of these approaches would utilize existing data as well as the pedestrian volume and infrastructure data as described in this report. These two approaches would also be tied to sets of relevant countermeasures. Each pedestrian safety improvement proposed under the different approaches would then be evaluated under different criteria as required by the potential funding sources. The effectiveness of the program and other pedestrian safety efforts would be monitored by an annual Pedestrian Safety Report Card designed to capture pedestrian safety trends. The whole process would be complemented with efforts to institutionalize the program.

Figure C-1. PSIP Implementation Plan



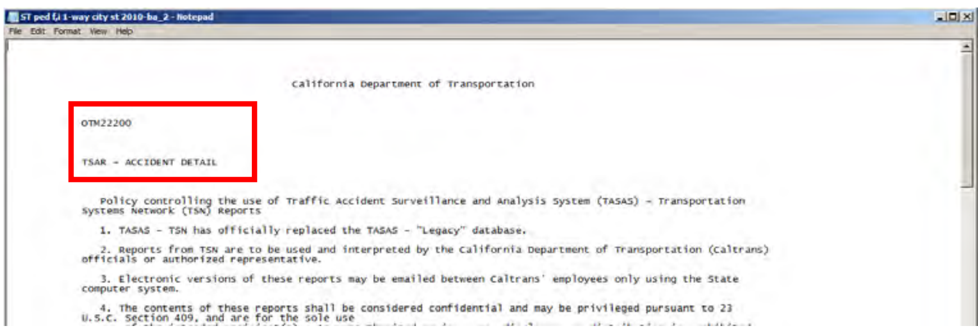
Contents

Appendix 1-A. Importing TASAS Data into the Pedestrian Safety Monitoring Report (PSMR) Tool

1-A.1. About the PSMR Tool

The **T**raffic **A**ccident **S**urveillance and **A**nalysis **S**ystem (TASAS) is used by the California Department of Transportation (Caltrans) to analyze accident, traffic, and highway data for California. An output of the TASAS database is the **T**ASAS **S**elective **A**ccident **R**etrieval (TSAR) accident detail file, which provides a list of collisions which have taken place along the state highway system. Figure 1-A.1 shows a typical TSAR accident detail file which can be identified by the tags “OTM22200” and “TSAR-ACCIDENT DETAIL.”

Figure 1-A.1. Typical TSAR Accident Detail File

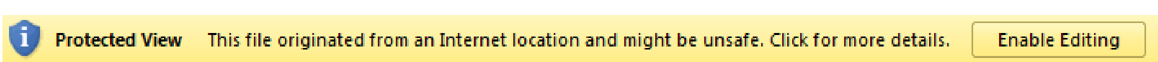


In order to interact better with the TASAS data, the PSMR tool provides the ability to directly import TSAR Accident Detail files and format them into a spreadsheet. In addition, a unique feature of the tool is its ability to match a TASAS accident to a corresponding SWITRS collision, which allows for extracting the detailed collision severity information available in SWITRS (fatal, severe injury, injury and non-injury) and associate it to the TASAS collision records.

1-A.2. Instructions for Use

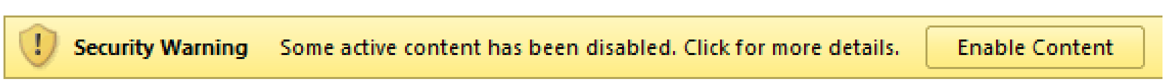
This tool is a Microsoft Excel macro file approximately 3 MB in size. The macro is programmed using Visual Basic for Applications (VBA) within Microsoft Excel 2010. The macro file has a format of Excel 97-2003 (*.xls). Due to security restrictions in the macro file, you may have to enable a couple of options. For instance, upon opening the file from a shared directory, you may have to click the “Enable Editing” button to proceed:

Figure 1-A.2. Protected View Warning



After enabling editing, another security warning will appear requesting you to enable the active content:

Figure 1-A.3 Security Warning

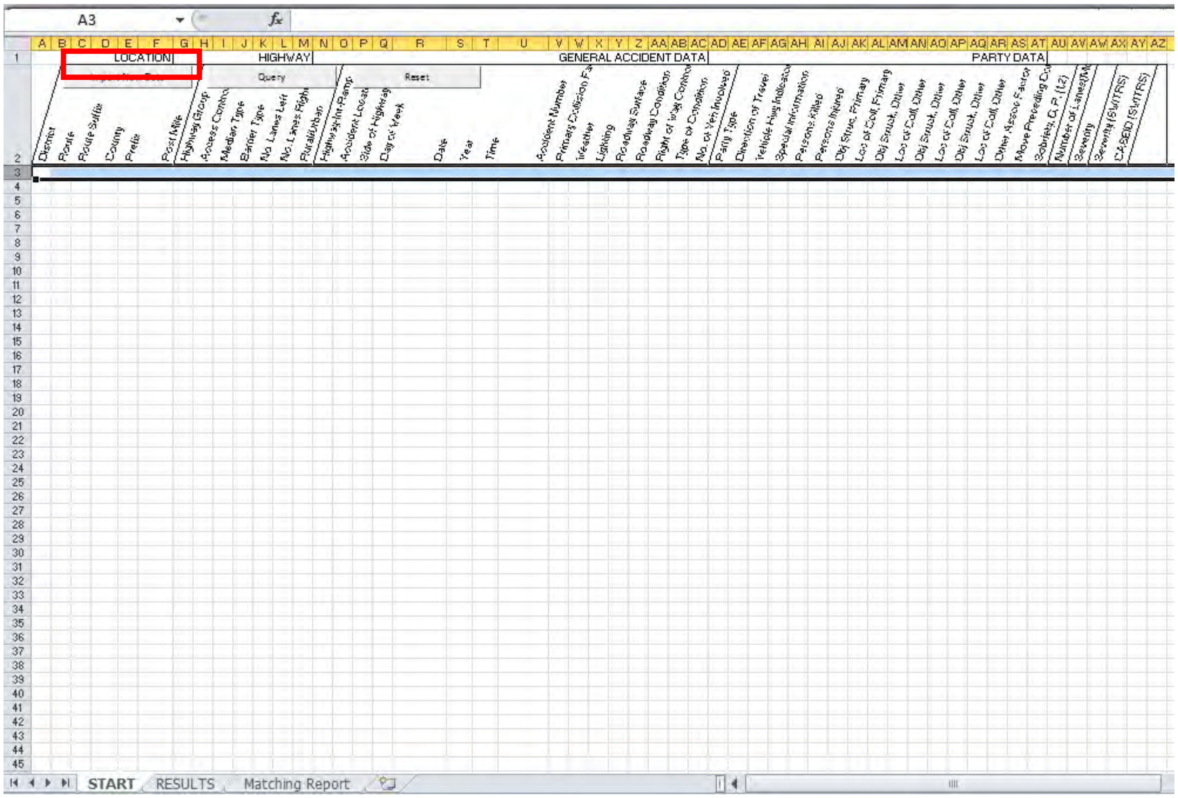


Click “Enable Content” to proceed. Now the tool is ready to use.

1-A.2. Importing New TASAS Data

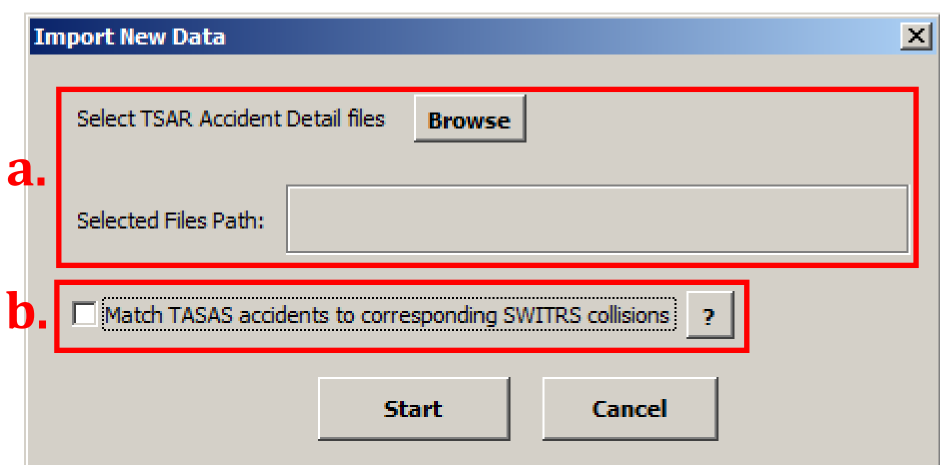
When you first open the macro, the “START” worksheet contains the list of all the TASAS attributes as column headers (figure 1-A.2).

Figure 1-A.4. START worksheet



In order to populate this sheet with the TSAR records, click the “Import New Data” button on the top left on the “START” sheet, which opens up a pop-up a window as shown in below in Figure 1-A.5.

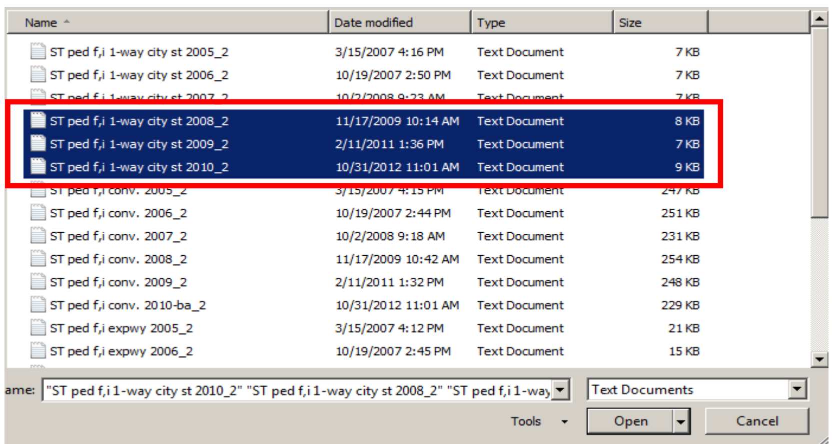
Figure 1-A.5. Selecting TSAR Accident Detail Files



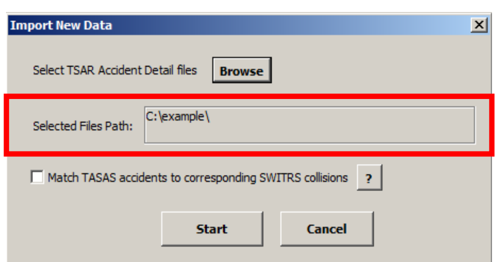
The pop-up window shown in Figure 1-A.5 has two important components, which are indicated as (a) and (b), and are explained below:

i. Section (a) is relevant for selecting the TSAR accident detail files to be imported. Using the "Browse" button, you can select the relevant files by looking through the server directory. A typical TSAR accident detail file is available in a .txt format and should contain the identifiers, "OTM22200", and "TSAR-ACCIDENT DETAIL", as part of the text. You can check format of a data file beforehand by opening the file and confirming the portion highlighted in Figure 1-A.1. The macro also allows for multiple files to be selected at once (Figure 1-A.6i). Once the files are selected, the path of the selected files is shown in the window (Figure 1-A.6ii).

Figure 1-A.6. Selecting the TSAR Files



i. Selecting multiple files

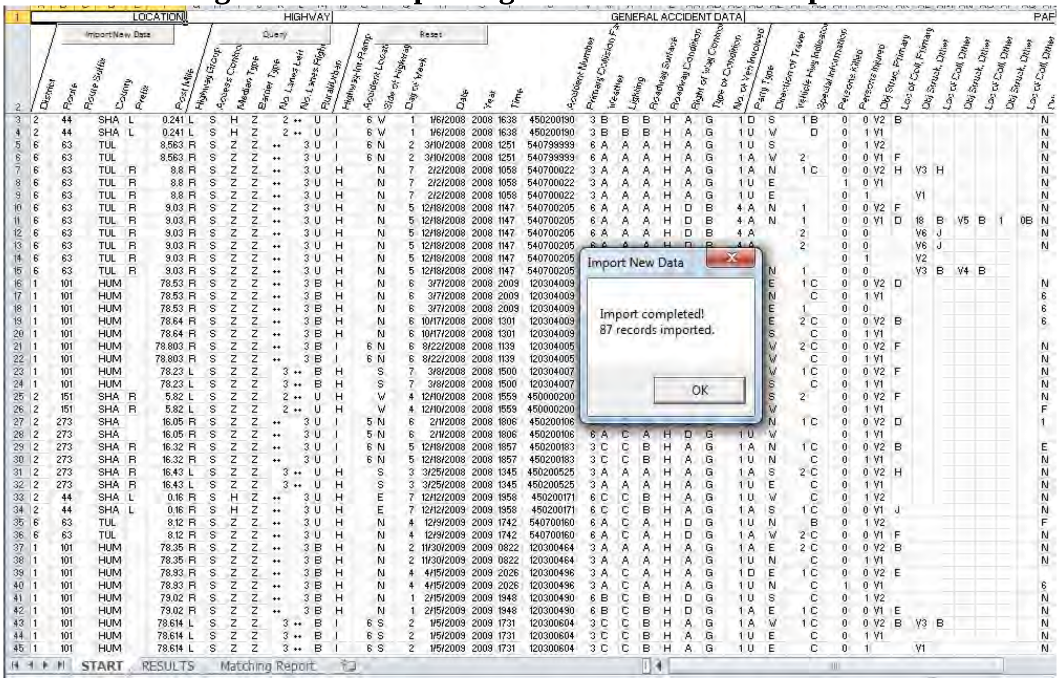


ii. Path of the files selected for import

ii. Section (b) contains the additional feature of matching the TASAS accidents to SWITRS collisions. By ticking the box, the SWITRS collision severity levels can be added to the TASAS collision records. However, not selecting this feature still allows for queries to be made using the TASAS database. The SWITRS matching aspect of the tool is discussed in greater detail in section 1-A.3.

Finally, when the "Start" button is clicked, the import process is completed with a pop-up window indicating the total number of records imported, as shown in figure 1-A.7.

Figure 1-A.7. Importing of TASAS Data Complete

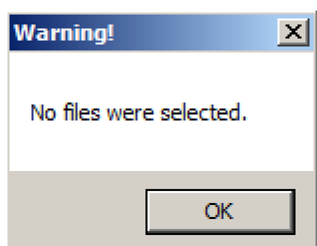


1-A.2.1. Troubleshooting

Some of the common errors obtained during the data importing process are listed below:

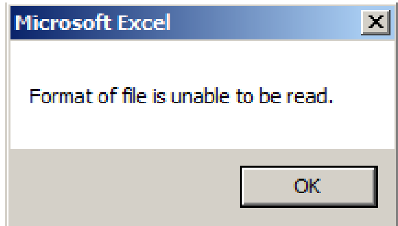
i. If you do not select any file for importing into the macro tool, then the message "No files were selected." will appear.

Figure 1-A.8. "No files were selected" error message



ii. If you select a file with a wrong format, the message “Format of file is unable to be read.” will appear.

Figure 1-A.9. Wrong file format chosen



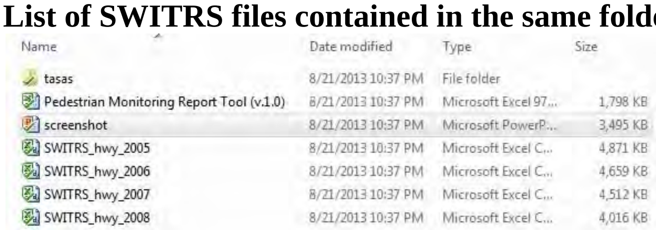
iii. If you select a TSAR file containing the identifiers OTM22215, TSAR-ACCIDENT SUMMARY, the following message will appear:

Figure 1-A.10. Selecting the TSAR summary file instead of the accident detail files

1-A.3. SWITRS Matching

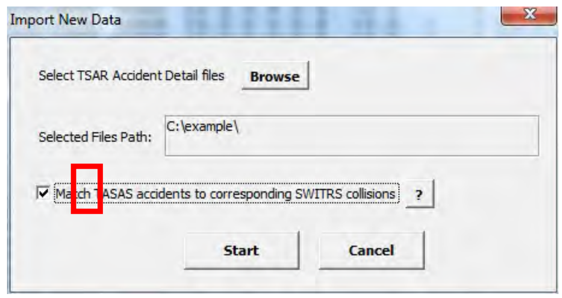
In order to match the collisions in the TASAS database to SWITRS collisions, you must have the SWITRS .csv files in the same directory as the PSMR tool macro (Figure 1-A.11). The files should follow a naming convention: *SWITRS_hwy_YEAR.csv* (e.g., SWITRS_hwy_2005.csv).

Figure 1-A.11. List of SWITRS files contained in the same folder as the macro



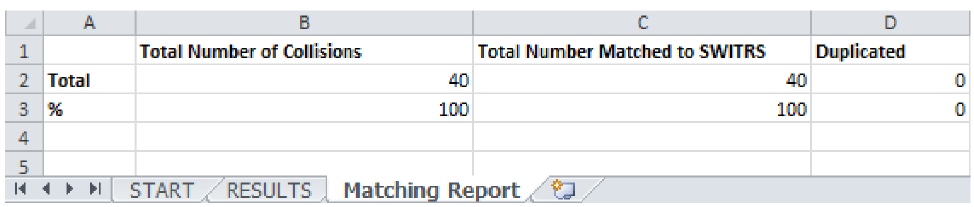
In addition, the SWITRS matching option should be selected during the data importing process, as shown in Figure 1-A.12.

Figure 1-A.12. Selecting the SWITRS matching option during the data importing process



After the underlying SWITRS matching is completed, a summary of the matching results is shown in the "Matching Report" sheet (figure A.13). A 100% match indicates that all the TASAS accidents found a match within the SWITRS database. The 'Duplicated' column counts the instances wherein a TASAS record corresponds to more than one SWITRS case ID.

Figure 1-A.13. SWITRS Matching Report

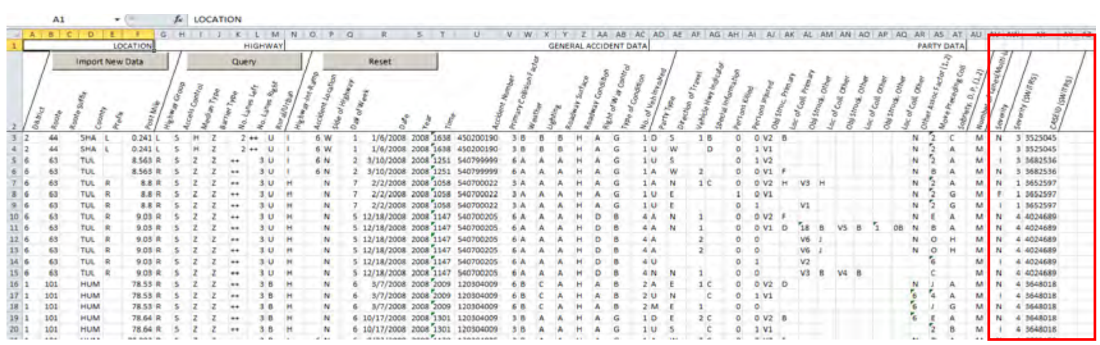


	A	B	C	D
1		Total Number of Collisions	Total Number Matched to SWITRS	Duplicated
2	Total	40	40	0
3	%	100	100	0
4				
5				

START | RESULTS | Matching Report

The results of the matching can be viewed in the "START" worksheet (figure A.19), wherein the TASAS records now include the corresponding SWITRS case ID and the most severe injury severity level associated with the collision.

Figure 1-A.14. SWITRS Matching Results



Appendix 2-A. SHSP CA 08.09 Project information Sheet

SafeTREC Safe Transportation Research & Education Center
UNIVERSITY OF CALIFORNIA, BERKELEY

Caltrans
CALIFORNIA DEPARTMENT OF TRANSPORTATION

SHSP 08.09: Develop a Plan to Collect Pedestrian Infrastructure and Volume Data for Future Incorporation into Caltrans Accident Surveillance and Analysis System Database

Offer Grembek, Yuanyuan Zhang, Frank Proulx, and David Ragland

SafeTREC is working with Caltrans to evaluate the feasibility of building a pedestrian and bicycle infrastructure database and a parallel volume database. Caltrans currently maintains similar data on highways and motor vehicles in the TASAS-TSN database, but does not keep records of where pedestrian or bicycle facilities exist on their highway network. This information is important for safety analysis in cases involving pedestrians and bicyclists and for prioritization of projects.

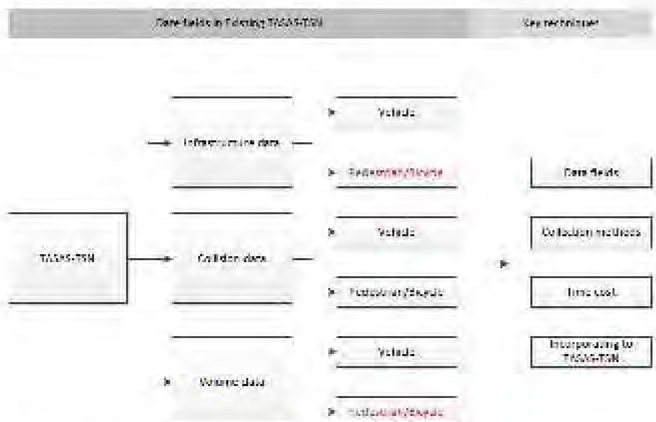


Figure 1. SHSP 08.09 project process showing the data to be collected and how it will be established for future inclusion in the Transportation System Network (TSN) database.

This project involves developing a database structure, establishing a data collection methodology, checking the structure on a short section of highway to ensure operability, and populating the database for 100 miles of state highway across two districts to generate a time-cost estimate for collecting data on the entire state highway network, as suggested in Figure 1. The final stage of this project will be to incorporate the new database into the TSN framework for use by Caltrans.

Infrastructure and volume data will be located in separate databases because the data collection procedures are different for these two types of data. In particular, volume data should be updated more regularly than infrastructure data. Infrastructure data can be collected remotely using tools such as Caltrans' CT Earth or in the field during field visits. Volume data must be collected during field visits either manually or using automated collection methods.

Appendix 3-A. Annual Pedestrian Report Card

California Department of Transportation (Caltrans)
Pedestrian Safety Improvement Program
2013 Pedestrian Safety Report Card

The Pedestrian Safety Improvement Program (PSIP) is a California Department of Transportation (Caltrans) project being conducted by the UC Berkeley Safe Transportation Research and Education Center. It parallels the FHWA Highway Safety Improvement Program (HSIP) in many ways, and is intended to identify the causes and ways to prevent pedestrian fatalities and injuries. This report card, which uses data ranging from 2001-2013, is a systematic analysis of statewide pedestrian injury and mobility trends. It is intended to help California pedestrian safety stakeholders develop and implement programs to improve pedestrian safety in California.

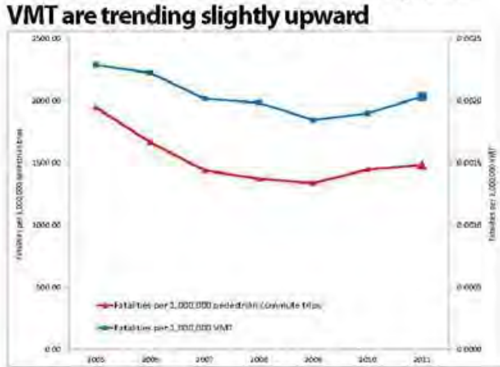
Pedestrian Safety Highlights:

- California is investing sporadically in pedestrian and bicycle transportation facilities
- The share of commute trips by foot in California remains steady at around 2.8%
- Injuries seem to be trending downward, while fatalities are trending slightly upward, both in absolute numbers and in terms of the rate of fatalities per trip
- California ranks fifth nationally for number of pedestrian fatalities, and tenth when normalized by population
- Pedestrian crash risk seems evenly split between urban and rural counties.

California is inconsistently investing in pedestrian (and bicycle) travel

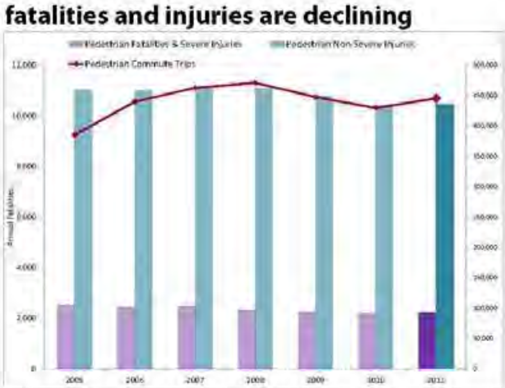
FHWA: State Spending on Ped & Bike Infrastructure

Pedestrian fatalities per commute trip and VMT are trending slightly upward



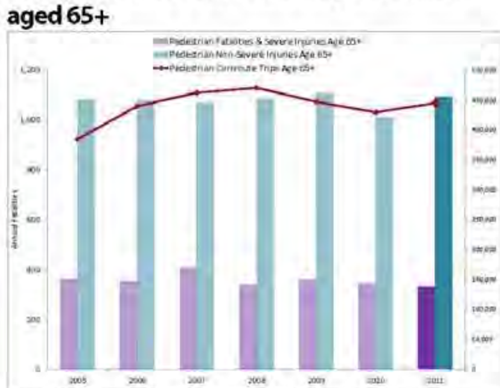
SWITRS, ACS, and Caltrans Highway Performance Monitoring data

Commuting by foot is rising, while fatalities and injuries are declining



American Community Survey and SWITRS

Safety trends are less clear for pedestrians aged 65+



American Community Survey and SWITRS

The rate of fatalities per pedestrian trip and vehicle miles traveled has dropped steadily from a peak in 2005, although data from 2010 and 2011 indicate an upward trend. In 2011, there were 661 fatalities, resulting in a rate of nearly 1484 fatalities per 1 million walking commute trips. When the data is examined by county and normalized for population and pedestrian travel, there is evidence that pedestrian risk is not evenly distributed.

Pedestrian Traffic Risk by County

The map shows fatality and injury risk by county for pedestrians in 2011, calculated as the number of pedestrian injuries and fatalities per county normalized by population and pedestrian mode share.

(2011 SWITRS Pedestrian Fatality + Injury Collisions)/[(2011 American Community Survey 5-Year County Population Estimates)(2011 American Community Survey 5-Year County Journey to Work Estimates)]

Top 10 Highest Traffic Risk California Counties for Pedestrians

1. San Francisco
2. Alpine
3. Mono
4. Humboldt
5. Santa Barbara
6. Alameda
7. Los Angeles
8. Del Norte
9. Santa Cruz
10. Mendocino

Pedestrian traffic risk isn't necessarily highest in the most populous counties, although there does seem to be some correlation between danger and population. More research is needed, but factors explaining traffic risk in rural counties could include higher speeds, driver expectations, and presence (or lack) of infrastructure like lights, sidewalks, and crosswalks.

How California Compares Nationally

Data from the National Highway Traffic Safety Administration allow a comparison of California to the other fifty United States. Following are the statistics from 2011 and 2010:

Percent of total traffic fatalities

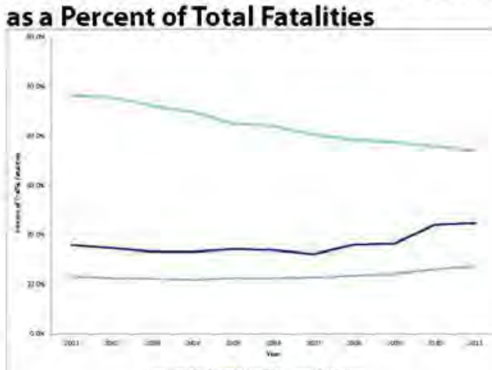
- 2011: #5
- 2010: #5

Pedestrian fatalities/100,000 population

- 2011: #10
- 2010: #13

Note that these numbers do not control for the percentage of people walking.

California and U.S. Pedestrian Fatalities as a Percent of Total Fatalities



This report card is funded by Caltrans and put together by the Safe Transportation Research and Education Center (SafeTREC) at the University of California, Berkeley. For more data and information, write to SafeTREC at 2614 Dwight Way #7374, Berkeley, CA 94720-7374, fax 510-643-9922, or email safetrec@berkeley.edu.

Appendix 3-B. Pedestrian Report Card NHTS Supplement

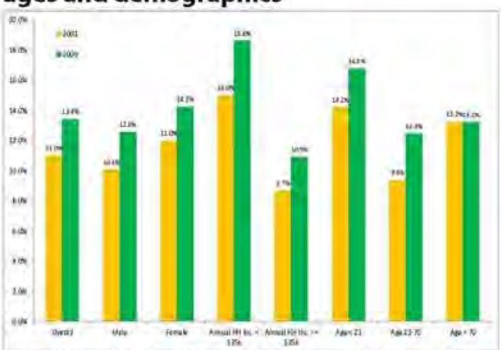
Caltrans Pedestrian Safety Improvement Program
2011 Pedestrian Safety Report Card - NHTS Supplement

This page of the Pedestrian Safety Report Card reports data from the latest version of the National Household Travel Survey (California supplement), which is only available every few years. The trends shown in these figures offer important insights into pedestrian safety in California, and are intended to help California pedestrian safety stakeholders develop and implement programs to improve pedestrian safety in California.

Pedestrian Safety Highlights:

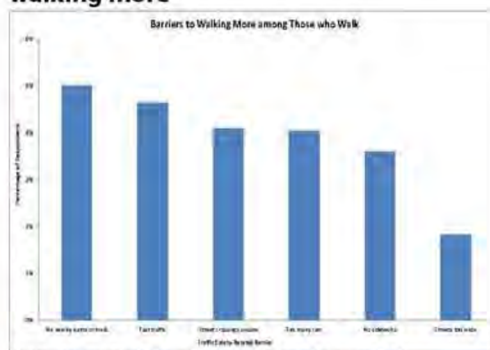
- The share of walking trips in California is at an all-time high of 13.4%
- Walking trips are increasing across all demographic and age groups
- Pedestrian trips are rising and fatalities and injuries are dropping
- When normalized by mode share, pedestrian danger by county seems correlated to population, although not uniformly

Californians are walking more across all ages and demographics



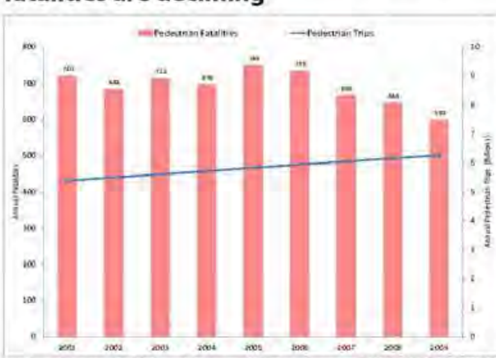
National Household Travel Survey CA Supplement, 2001 to 2009

Californians perceive safety barriers to walking more



National Household Travel Survey CA Supplement, 2009

Pedestrian trips are increasing, while fatalities are declining



National Household Travel Survey CA Supplement 2001-2009, SWITRS

Pedestrian Traffic Risk by County

The map shows the fatality and injury risk by county for pedestrians in 2011, calculated as the number of pedestrian injuries and fatalities per county normalized by the 2011 Census population estimates and the 2009 NHTS pedestrian mode share.

Pedestrian Fatalities and Injuries
Normalized by Population and NHTS Mode Share

Top 10 Highest Traffic Risk CA Counties for Pedestrians

1. San Francisco
2. Los Angeles
3. Santa Barbara
4. Alameda
5. Mono
6. Humboldt
7. Marin
8. San Mateo
9. Mendocino
10. Santa Cruz

Appendix 4-A - Distribution of Hotspot Parameters

4-A.1. Dynamic Programming

4-A.1.1. Number of Collisions Per Hotspot

Figure 4-A.1. Number of Collisions Per Hotspot (w < 0.1)

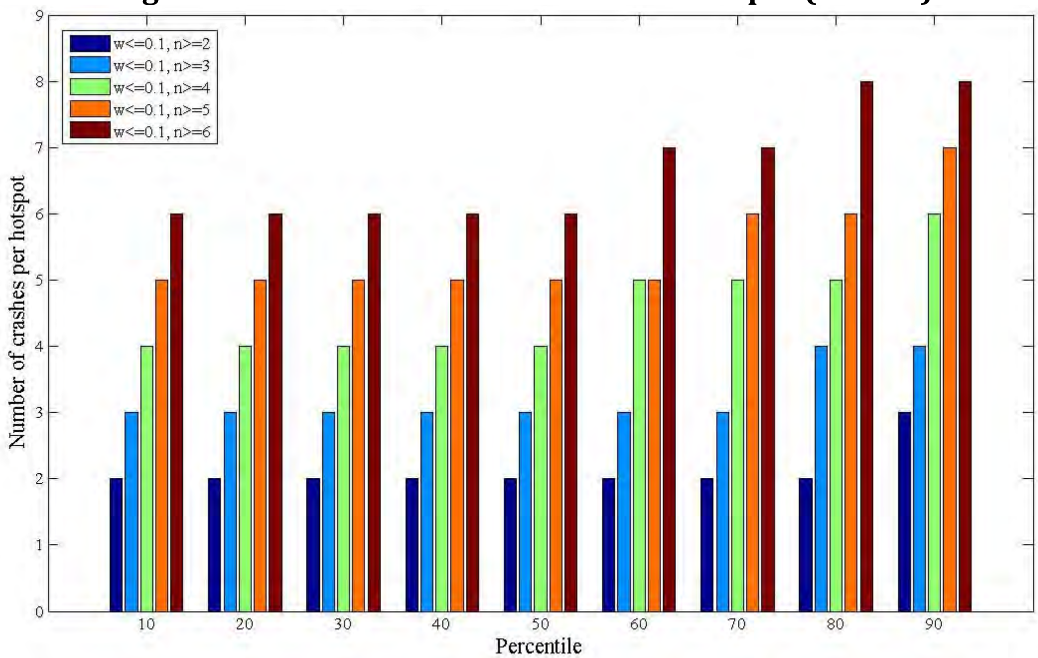


Figure 4-A.2. Number of Collisions Per Hotspot (w < 0.2)

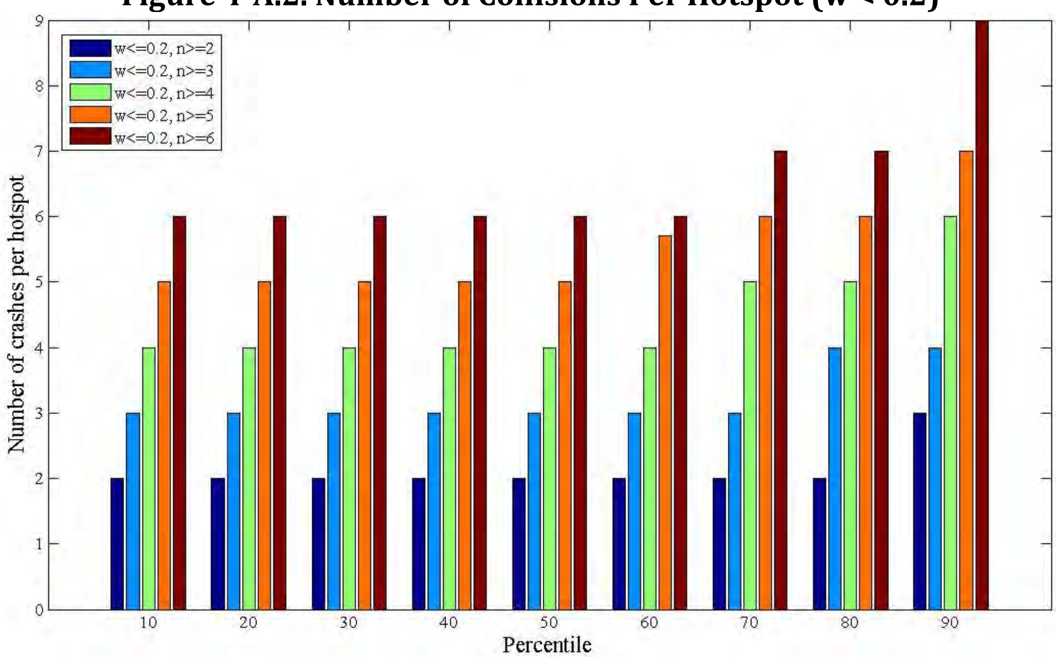
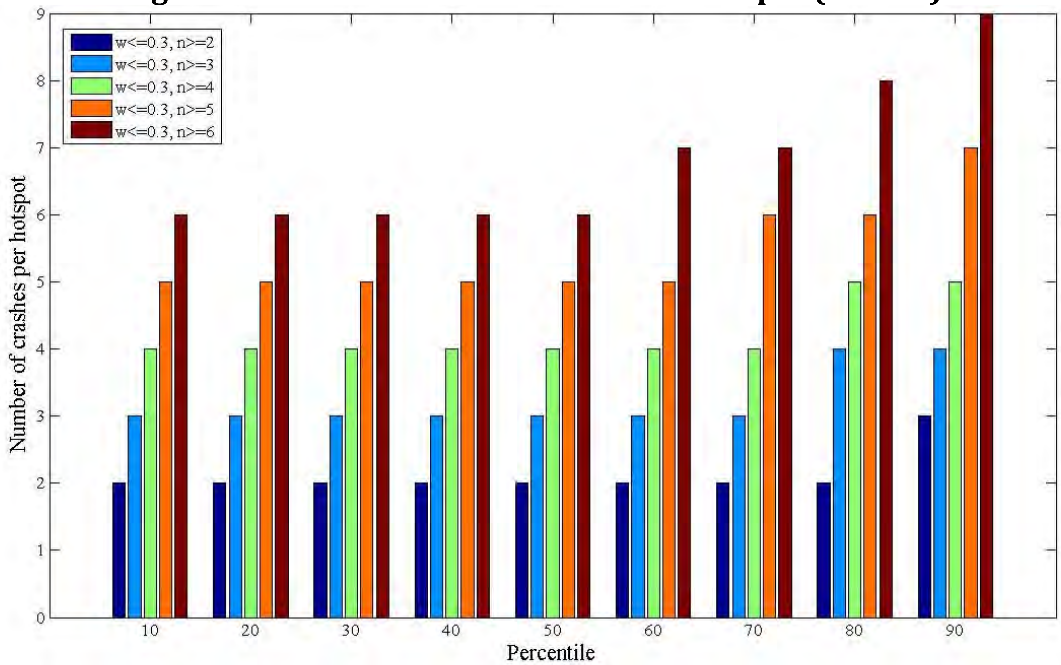


Figure 4-A.3. Number of Collisions Per Hotspot (w < 0.3)



4-A.1.2. Hotspot Window Lengths

Figure 4-A.4. Hotspot Window Lengths (w ≤ 0.1)

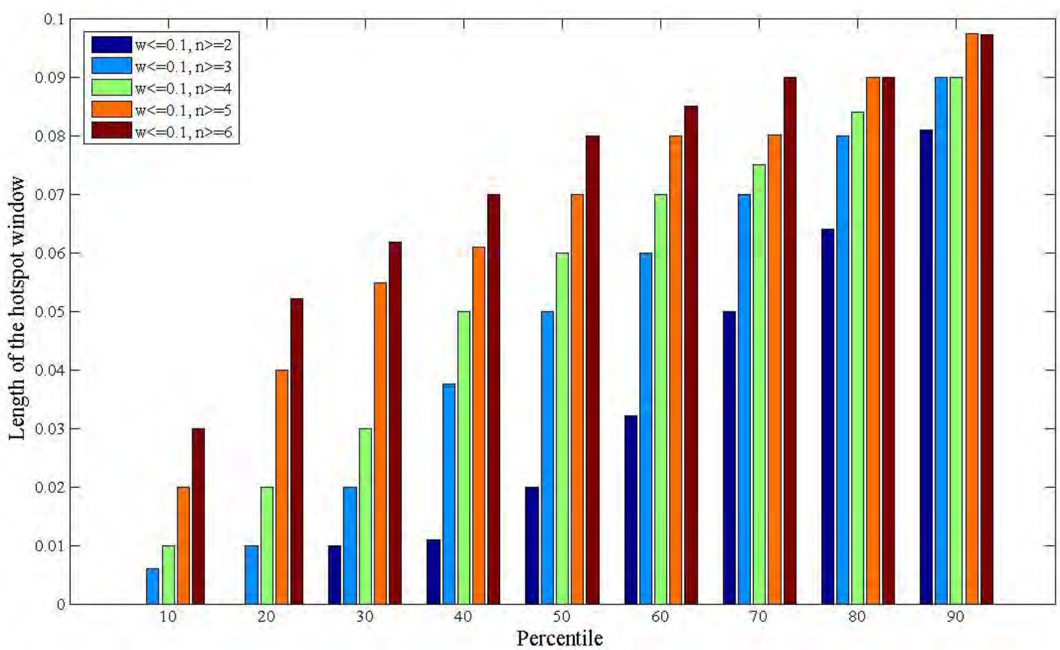


Figure 4-A.5. Hotspot Window Lengths (w < 0.2)

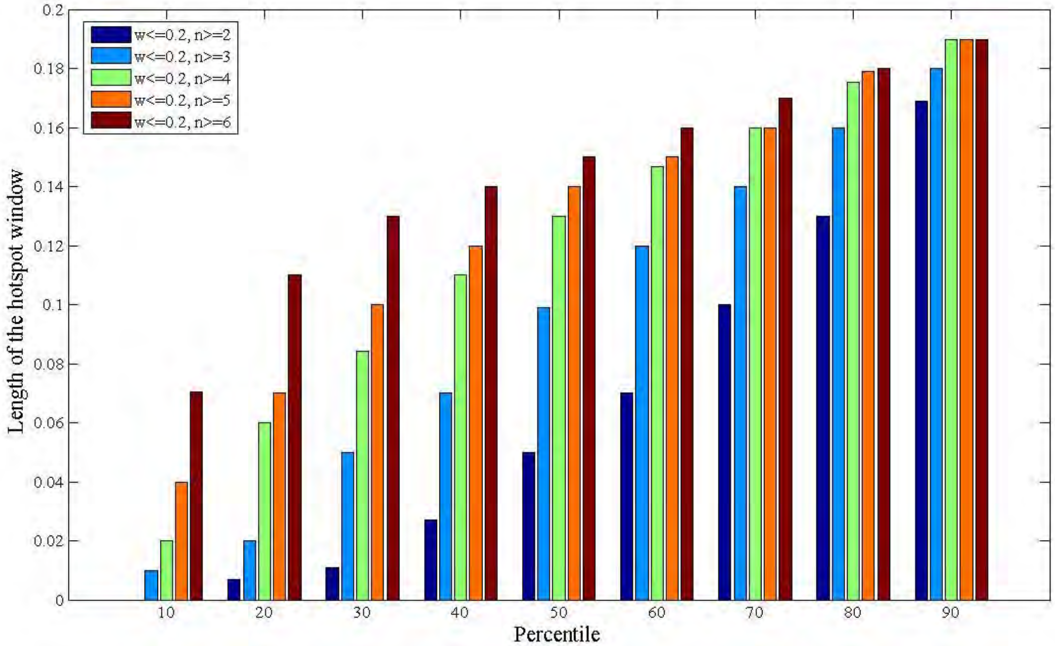
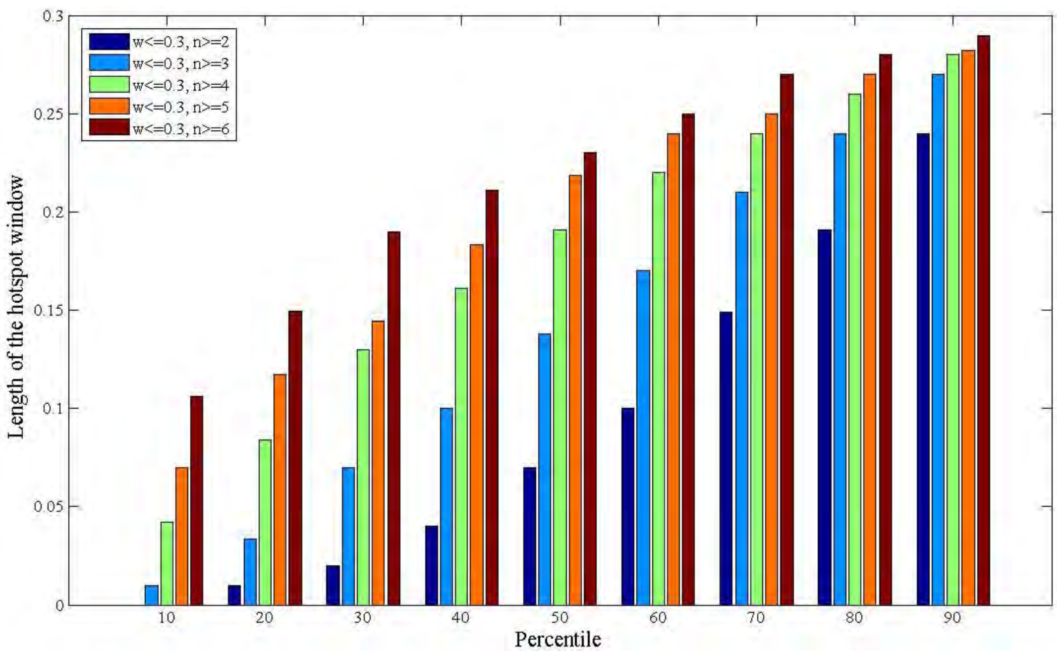


Figure 4-A.6. Hotspot Window Lengths (w < 0.3)



4-A.1.3. Average Spacing of Collisions Within Hotspots

Figure 4-A.7. Average Spacing of Collisions Within Hotspots (w < 0.1)

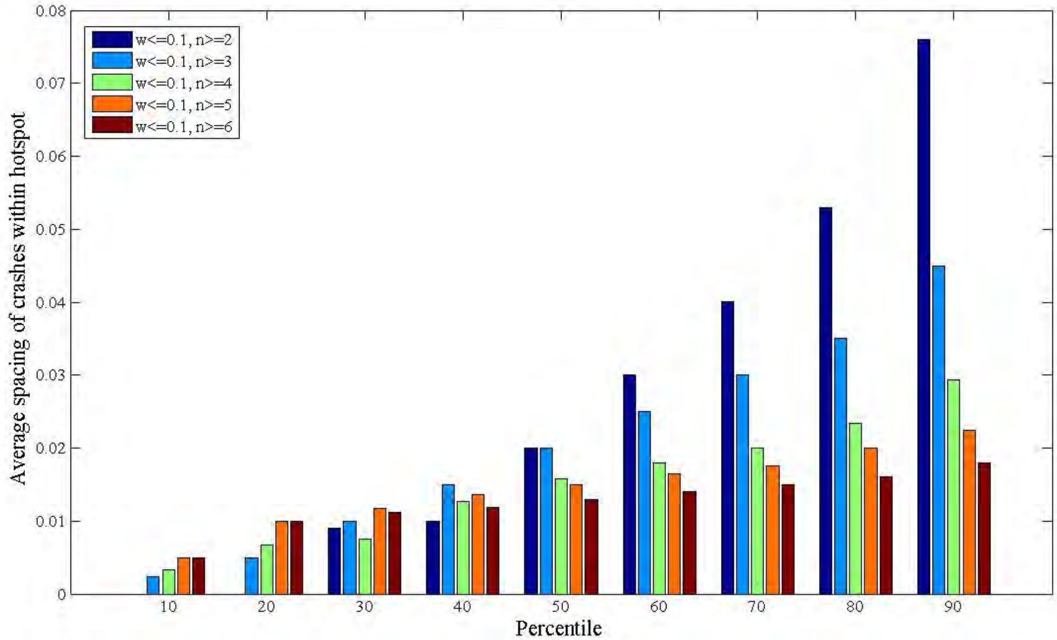


Figure 4-A.8. Average Spacing of Collisions Within Hotspots (w < 0.2)

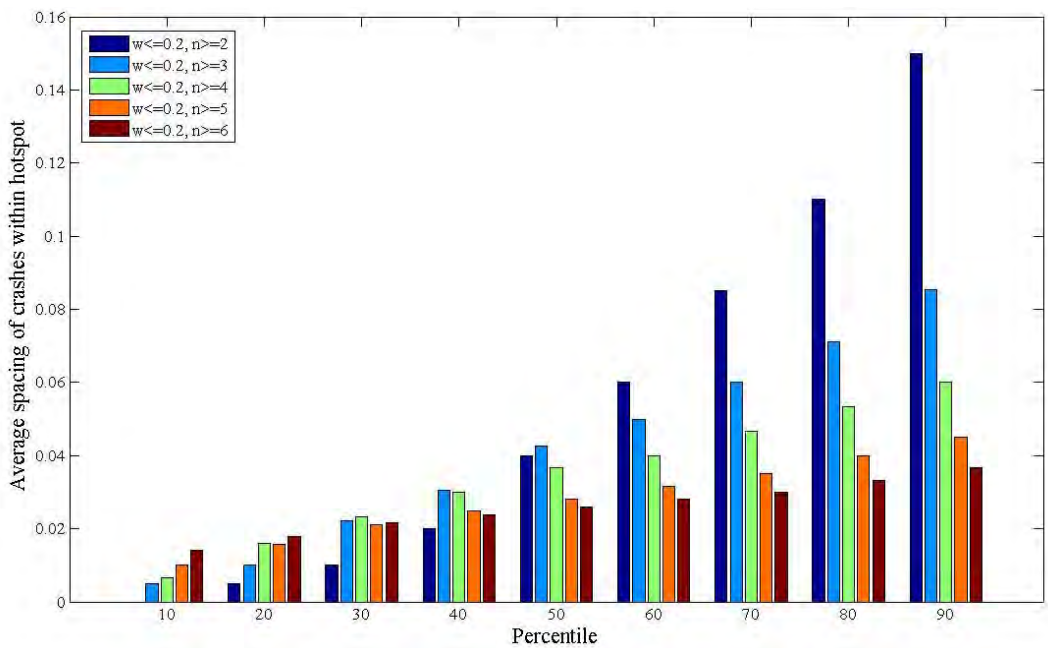
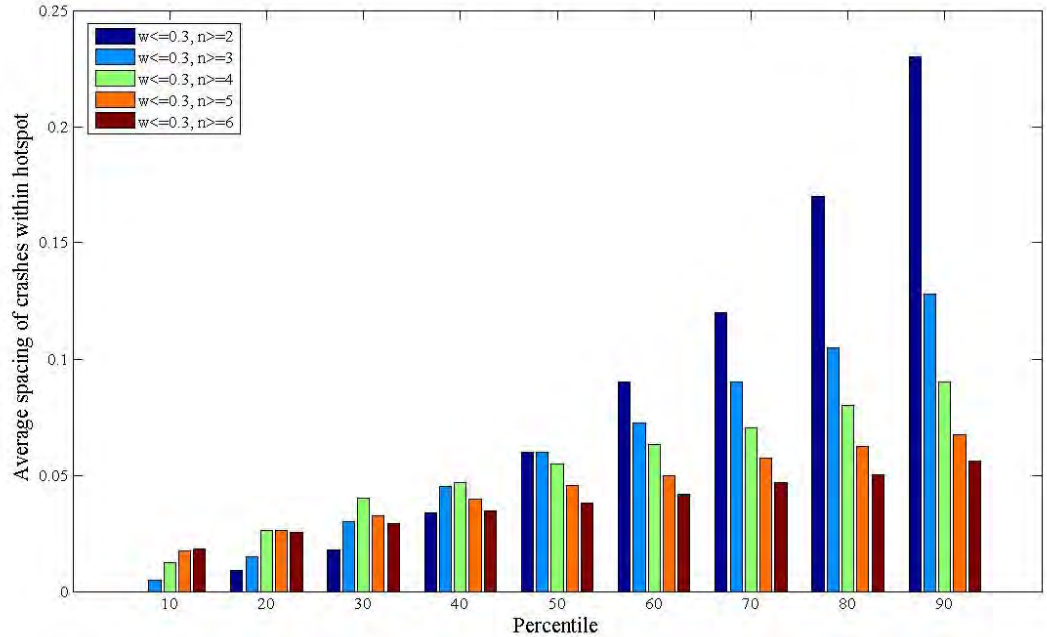


Figure 4-A.9. Average Spacing of Collisions Within Hotspots (w < 0.3)



4-A.2. Sliding Window

4-A.2.1. Number of Collisions Per Hotspot

Figure 4-A.10. Number of Collisions Per Hotspot (w = 0.1)

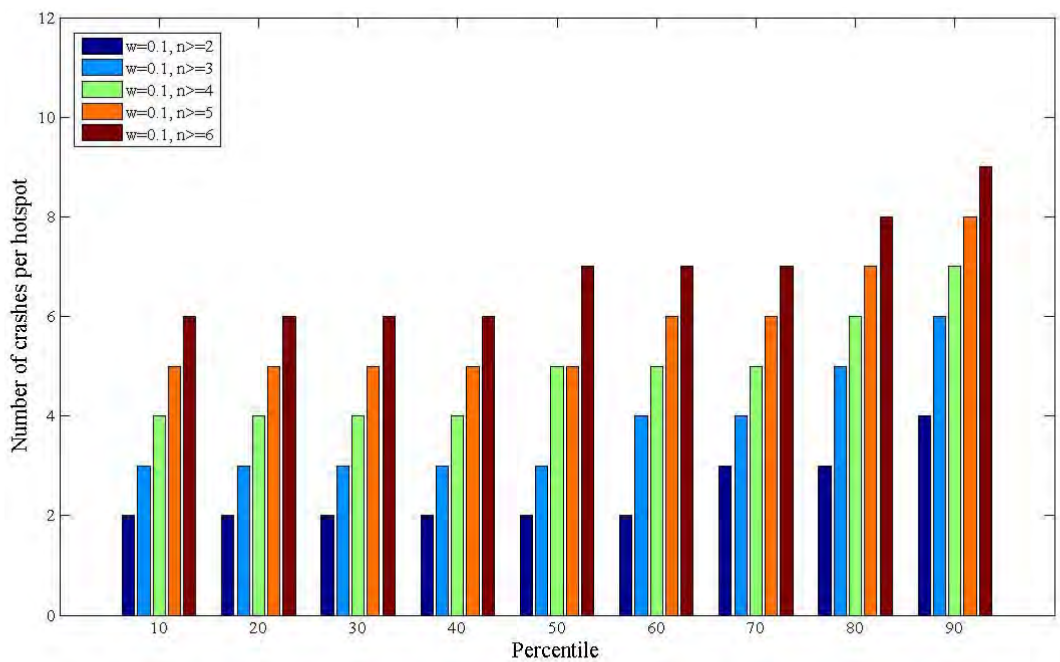


Figure 4-A.11. Number of Collisions Per Hotspot (w = 0.2)

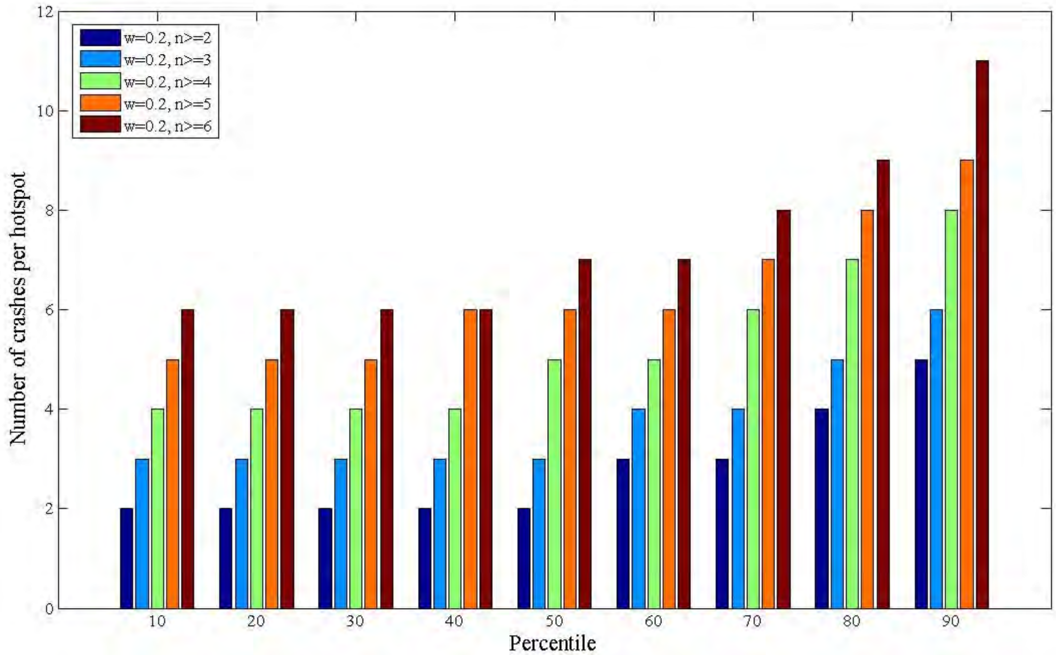
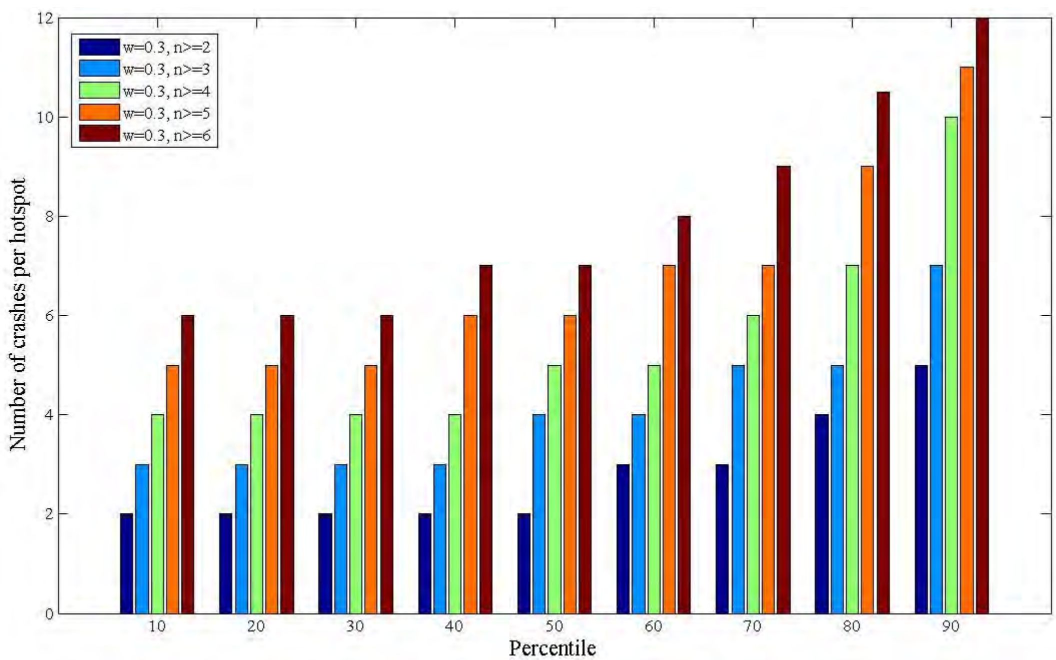


Figure 4-A.12. Number of Collisions Per Hotspot (w = 0.3)



4-A.2.2. Hotspot Window Lengths

Since the window lengths are fixed for the sliding window method, all hotspots are of the same size.

4-A.2.3. Average Spacing of Collisions Within Hotspots

Figure 4-A.13. Average spacing of Collisions Within Hotspots (w = 0.1)

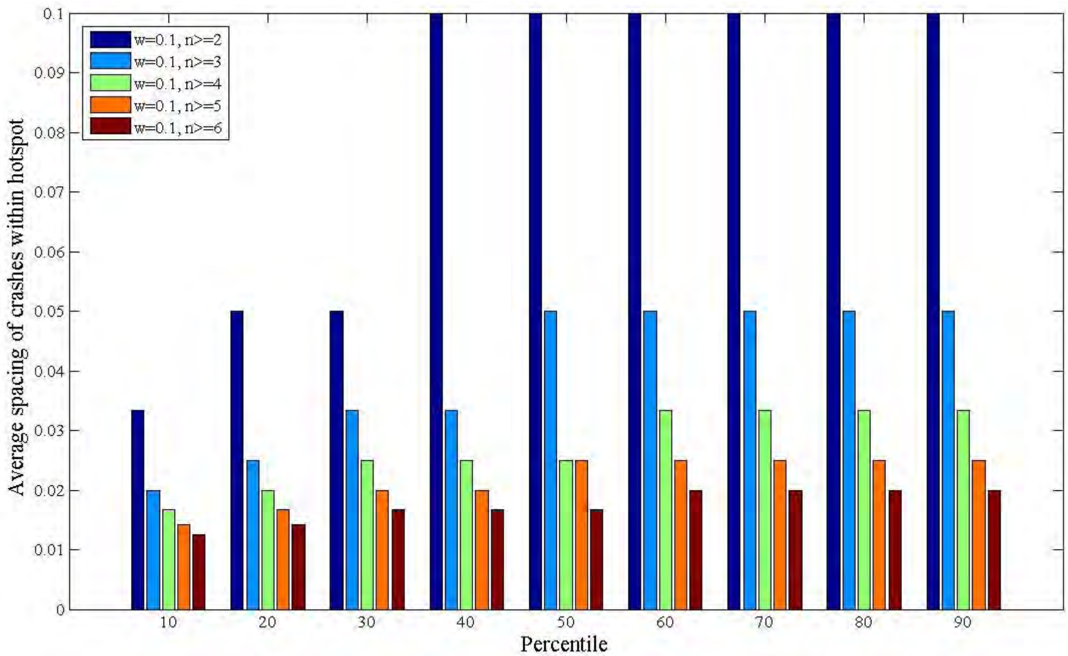


Figure 4-A.14. Average spacing of Collisions Within Hotspots (w = 0.2)

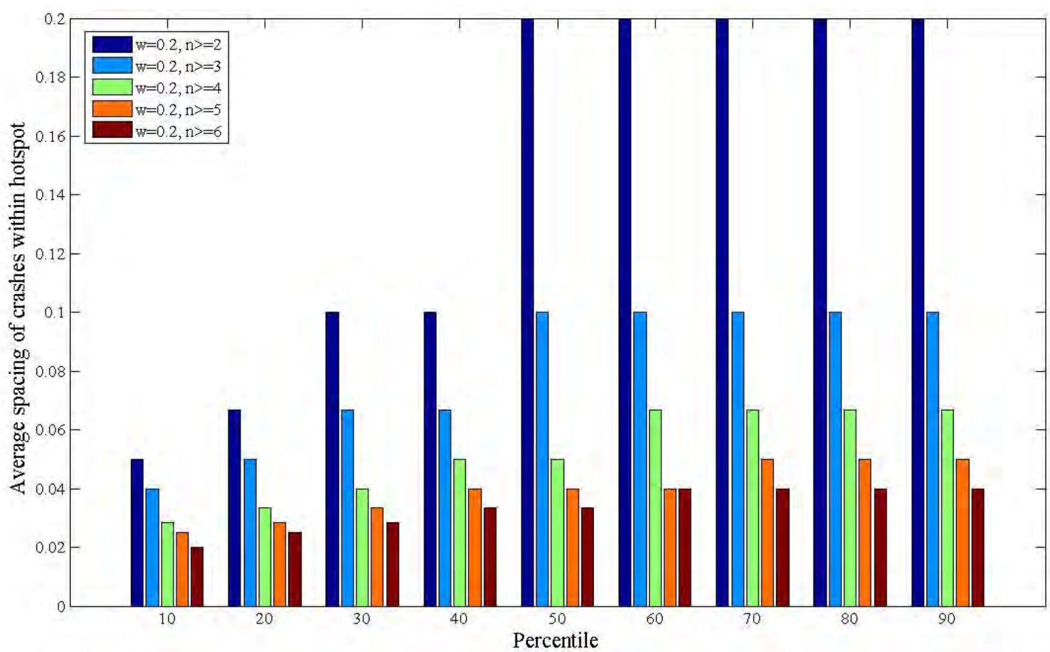
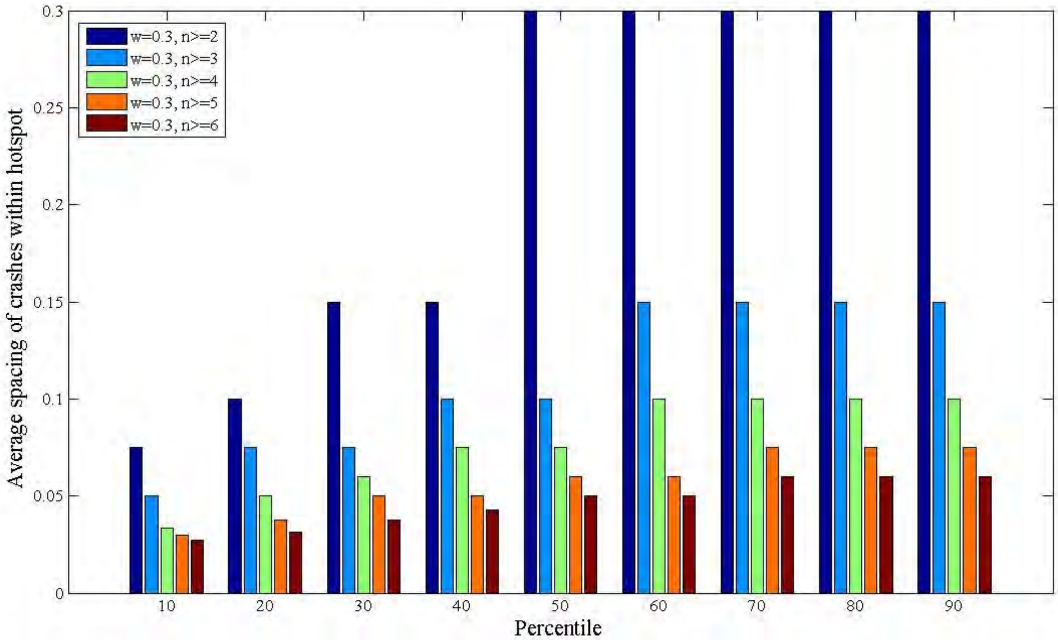


Figure 4-A.15. Average Spacing of Collisions Within Hotspots (w = 0.3)



Appendix 4-B – Systemic Pedestrian Safety

Communication Document

Contract: 65A0407
Task ID#: XXXX

Caltrans

PED-SMARTS
Pedestrian Systemic Monitoring Approach for Road Traffic Safety

WHY WAS THIS RESEARCH UNDERTAKEN?

Injury collisions involving pedestrians are more severe than overall collisions and account for one-fifth of all fatalities in California. In light of this, there is an urgent need for methods to identify pedestrian injury clusters which would be valuable for identifying causal factors as well as for directing resources. This research was undertaken to develop an approach to conduct systemic safety analysis for pedestrians, a technique to identify the crash types and facility types, and to recommend the appropriate pedestrian safety improvements across the network and a mechanism for quantifying the benefits of pedestrian safety improvements implemented through a systemic approach. The systemic approach seeks improvements that can be implemented at various sites across the network, based on specific roadway features that are associated with a particular crash type.

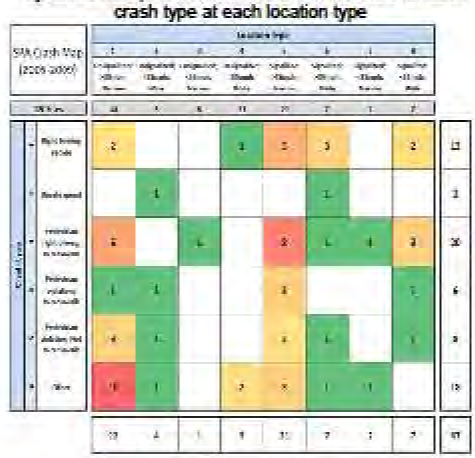
WHAT WAS DONE?

A database structure was developed in this research study to utilize the systemic method of analysis for all Vulnerable Road Users (VRU). The study area is a 16.5-mile section of San Pablo Avenue (SR 123), an arterial corridor in San Francisco's East Bay. It runs from downtown Oakland to Solano Avenue in Richmond, and passes through 5 different cities: Oakland, Berkeley, Albany, El Cerrito, and Richmond. It crosses 180 intersections that are on average approximately 484 feet apart. A database including all VRU collisions was constructed using the Statewide Integrated Traffic Records System (SWITRS) maintained by the California Highway Patrol (CHP). The database includes all pedestrian and bicyclist collisions from 1998 to 2007. The systemic safety method included the following steps: 1) Identify the crash location types, which are based on features of the site, 2) Identify the crash types, which are based on features of the crash, and 3) Identify the appropriate countermeasures. A stratification analysis was conducted to compare the differences between various stratifications. In order to determine the crash types and location types in the systemic hot spot identification matrix, crashes and roadway facilities should be classified in an appropriate way to select the appropriate countermeasures. The database Caltrans uses is the Traffic Accident Surveillance and Analysis System (TASAS). In applying the stratification method to San Pablo Avenue intersections, the following steps were taken:

1. the number of specific crash types were counted at specific location type
2. the number of crashes were added to the matrix to map the distribution of crashes across all infrastructures
3. the systemic hot spots were identified in the matrix
4. the potential countermeasures corresponding to a specific type of crash, at a specific type of location were identified in the countermeasure matrix
5. the preferred countermeasures which could be installed for each crash type at the same location type were identified in the countermeasure table

The following matrices illustrate the proposed method used for the San Pablo Avenue Study area:

"Systemic hot spot identification matrix"; number of each crash type at each location type



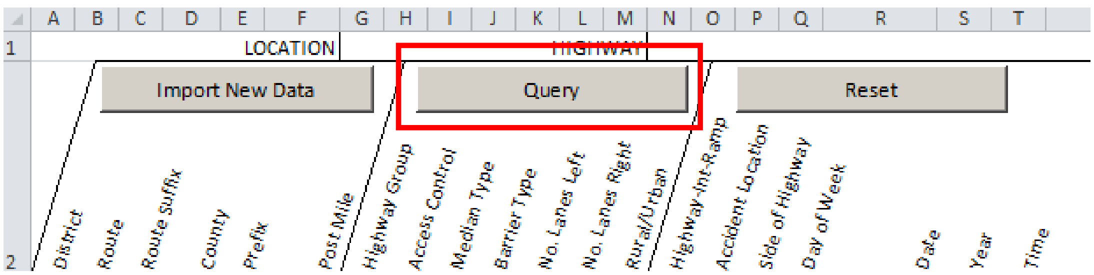
Appendix 4-C. Hotspot Identification using PSMR Tool

In Appendix 1-A, the data importing features of the Pedestrian Safety Monitoring Report (PSMR) tool were outlined. In this appendix, the implementation of the hotspot identification feature of the tool is discussed.

4-C.1. Query System

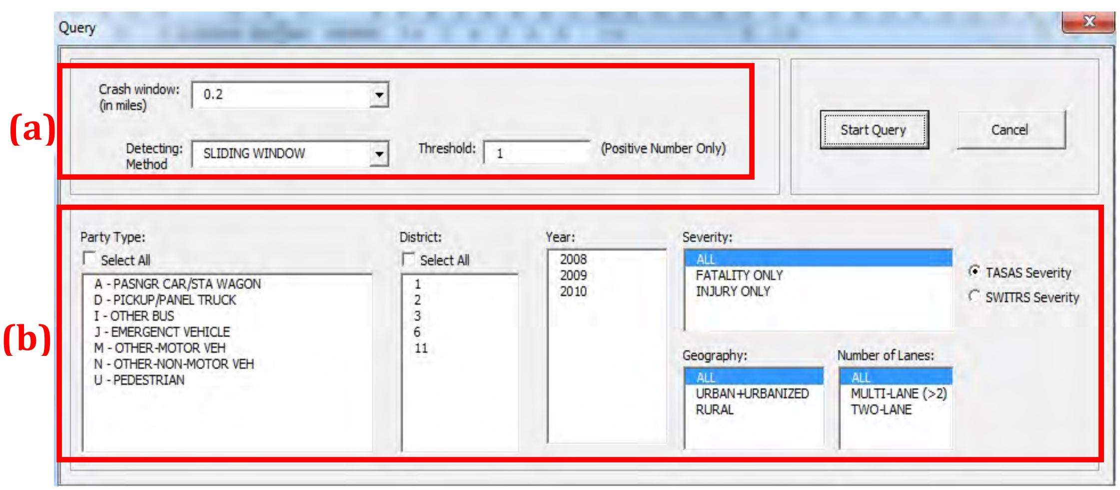
After importing the data from the TSAR accident detail files, a query for the identification of pedestrian hotspots can be made. Click the "Query" button to view the various options available to the user. The "Query" button is next to the "Import New Data" button on the top left corner of the "START" worksheet (Figure 4.C.1).

Figure 4-C.1. Initiating a System Query



After you click the "Query" button, a window will pop up as shown below. Herein, there are two relevant sections, labeled (a), (b) and (f), as shown in Figure 4.C.2 below.

Figure 4-C.2. Query Settings



The two important query settings are discussed in greater detail below:

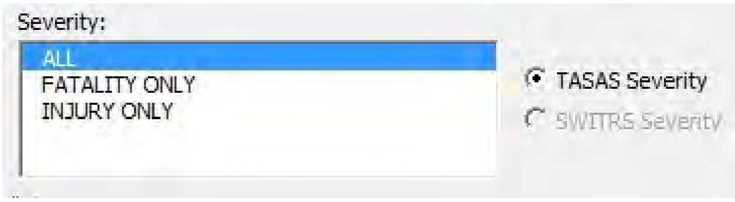
a. Hotspot detection options: As part of the PSMR tool, there are two hotspots detection options: sliding window and dynamic programming.

   i. Sliding window: It is the default hotspot detection method in the macro, wherein the user defines the length of collision window as well as the minimum collision threshold to identify hotspot locations within the TASAS database. The search procedure involves moving the collision window along the road network in small increments identifying hotspots which meet the collision threshold criterion.

ii. Dynamic programming: Unlike the sliding window method, the dynamic programming method relaxes the assumption that the collision window should be of a fixed length. Instead, it uses the user-defined window length as an upper bound, which implies that a hotspot cannot be bigger than the user-defined collision window length. The benefit of allowing collision window lengths to be smaller than the user-defined value is that the dynamic programming technique identifies hotspots in a manner such that the overall number of collisions covered by these hotspots is maximized.

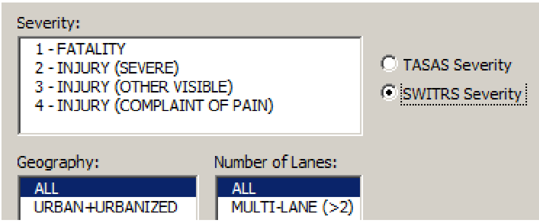
b. Section (b) allows the user to select the choice of the collision types to be used for hotspot identification by selecting additional filtering options such as district, party type, year, severity, geography or number of lanes. It is important to note here that if the SWITRS matching option is not selected, then the collisions can be queried by only the TASAS severity levels (Figure 4-C.3).

Figure 4-C.3. Only TASAS severity level available for query in this scenario



On the other hand, if the SWITRS matching option is selected at the time of data importing, it is possible to choose between either TASAS or SWITRS severity levels (Figure 4-C.4).

Figure 4-C.4. SWITRS severity level available for query if the SWITRS matching is completed



Note: Aside from providing the option of choosing the SWITRS severity levels, the SWITRS matching does not affect the hotspot selection procedure in any other way.

Once all the options are chosen, the query can be started to identify the hotspots.

4-C.1.1. Troubleshooting

Since the party type/district/year do not have any default values in the query window, any of the following errors may appear in case these attributes are not selected for the query:

Figure 4-C.5. At least one party type must be selected by the user

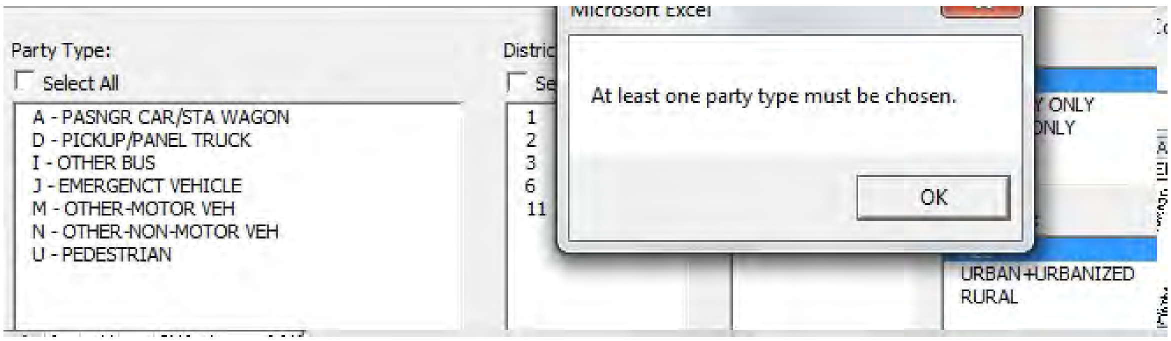


Figure 4-C.6. At least one year must be selected by the user

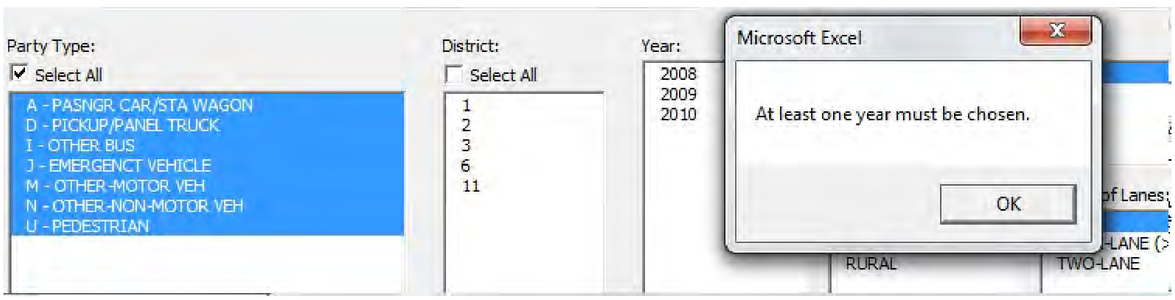
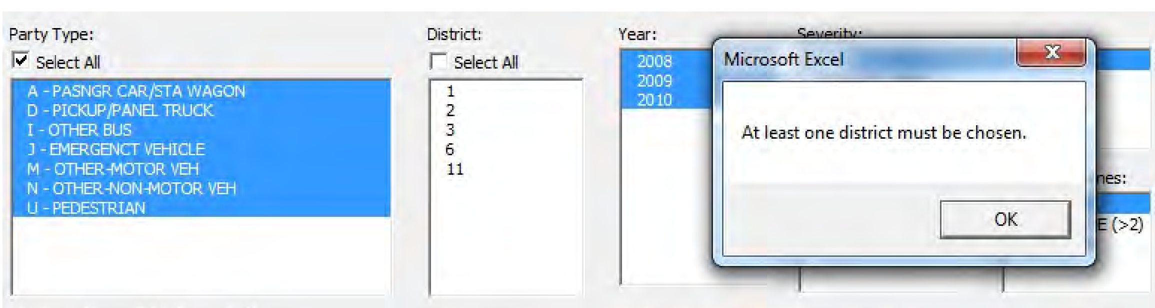


Figure 4-C.7. At least one district must be selected by the user

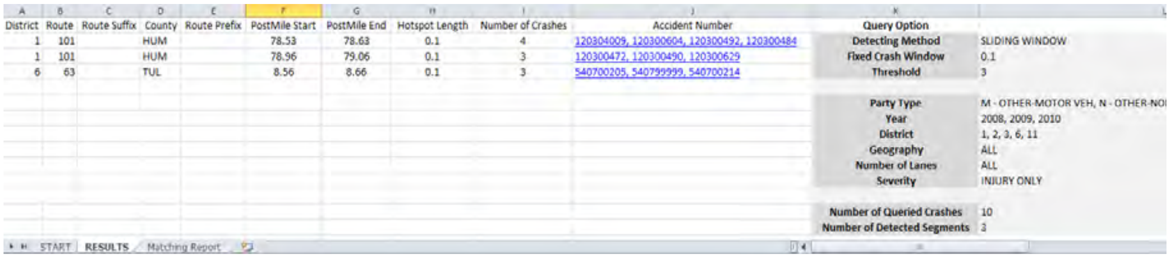


4-C.2. Query Results

4-C.2.1. Sliding Window

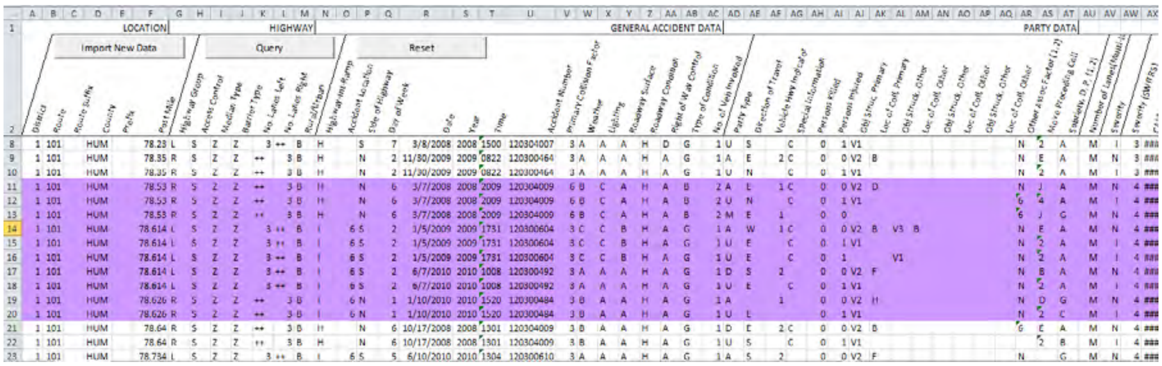
The results of the query are viewed in the "RESULTS" worksheet, as shown in Figure 4-C.8. The sheet includes a list of all the hotspots, represented by their start and end post miles, along with the number of collisions contained in the hotspot as well as their TASAS accident numbers. Since the length of the collision window is fixed in the sliding window approach, the hotspot length remains the same for all the hotspots. Finally, a summary of the query options selected by the user is also provided.

Figure 4-C.8. Sample result from a sliding window query



The cell associated with the accident numbers for each hotspot has an in-built hyperlink which when clicked highlights the relevant collision records in the "START" worksheet.

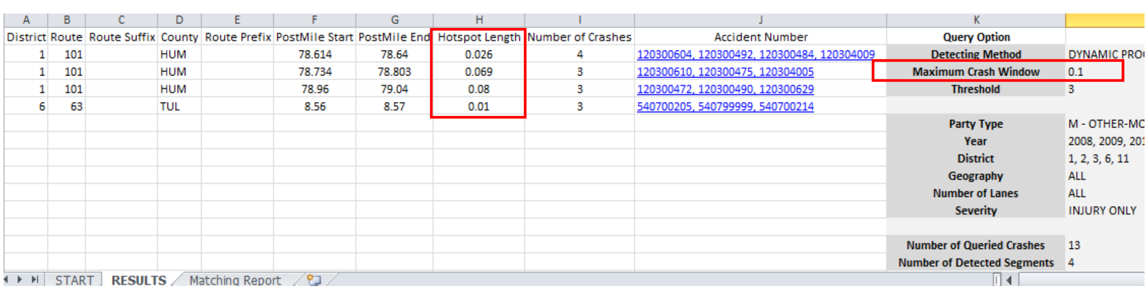
Figure 4-C.9. Highlighted collision records associated with one of the queried hotspots



4-C.2.2. Dynamic Programming

The layout of the "RESULTS" worksheet for a dynamic programming-based hotspot identification procedure is very similar to the sliding window results. However, an important difference between the two approaches is that the length of the hotspots obtained through dynamic programming can be smaller than the user-defined maximum collision window. For instance, in Figure 4-C.10, the hotspot lengths (in column H) are seen to be smaller than the maximum collision window of 0.1 miles.

Figure 4-C.10. Sample result from a dynamic programming query

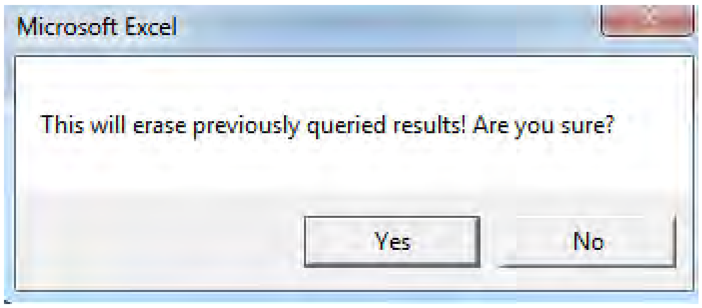


It is also important to keep in mind that the hotspots identified by both approaches may vary due to the inherent differences in the two hotspot identification algorithms.

4-C.3. Query System

As discussed earlier, a new query on the existing imported data is initiated by pressing the “Query” button in the “START” worksheet. However, if a previous query already exists, a pop-up window shows up before the results are displayed which warns the user that the previously queried results will be erased (Figure 4-C.11).

Figure 4-C.11. Warning before a query is overwritten



Appendix 5-A: Highways – All

Crashes by number of lanes, left side

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
1	464	9131.08	0.170	0.600	-253%
2	1026	3860.57	0.376	0.254	48%
3	538	926.14	0.197	0.061	224%
4	390	858.76	0.143	0.056	153%
5	234	337.33	0.086	0.022	287%
6+	78	114.57	0.029	0.008	280%
zero, blank		197.41			NA
Total	**2730**	**15425.86**	**1.000**	**1.000**	**0%**

Crashes by number of lanes, right side

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
1	483	9094.85	0.176	0.597	-240%
2	993	3859.61	0.361	0.253	43%
3	570	947.55	0.207	0.062	234%
4	393	848.56	0.143	0.056	157%
5	210	355.35	0.076	0.023	228%
6+	98	124.02	0.036	0.008	338%
zero, blank		195.93			NA
Total	**2747**	**15425.86**	**1.000**	**1.000**	**0%**

Crashes by lanes on side of crash

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
1	947	9112.96	0.173	0.598	-246%
2	2019	3860.09	0.369	0.253	45%
3	1108	936.84	0.202	0.062	229%
4	783	853.66	0.143	0.056	155%
5	444	346.34	0.081	0.023	256%
6+	176	119.29	0.032	0.008	310%
zero, blank		196.67			NA
Total	**5477**	**15425.86**	**1.000**	**1.000**	**0%**

Crashes by outside shoulder total width, left side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	212	964.47	0.078	0.063	23%
1--2	141	2160.35	0.052	0.142	-175%
3--4	184	2343.13	0.067	0.154	-128%
5--6	113	1109.54	0.041	0.073	-76%
7--8	1052	4401.94	0.385	0.289	33%
9--10	863	3504.22	0.316	0.230	37%
11+	165	748.40	0.060	0.049	23%
Blank		193.81			NA
Total	**2730**	**15425.86**	**1.000**	**1.000**	**0%**

Crashes by outside shoulder total width, right side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	223	943.88	0.081	0.062	31%
1--2	144	2048.49	0.052	0.134	-157%
3--4	164	2423.79	0.060	0.159	-167%
5--6	101	1147.94	0.037	0.075	-105%
7--8	1064	4438.71	0.387	0.291	33%
9--10	882	3501.76	0.321	0.230	40%
11+	169	727.22	0.062	0.048	29%
Blank		194.07			NA
Total	**2747**	**15425.86**	**1.000**	**1.000**	**0%**

Crashes by outside shoulder treated width, left side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	308	4372.81	0.113	0.287	-154%
1--2	138	1596.80	0.051	0.105	-107%
3--4	198	1862.93	0.073	0.122	-69%
5--6	74	459.96	0.027	0.030	-11%
7--8	1023	3194.24	0.375	0.210	79%
9--10	900	3604.79	0.330	0.237	39%
11+	89	140.54	0.033	0.009	253%
Blank		193.81			NA
Total	**2730**	**15425.86**	**1.000**	**1.000**	**0%**

Crashes by outside shoulder treated width, right side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	320	4333.64	0.116	0.285	-144%
1--2	146	1607.30	0.053	0.106	-99%
3--4	159	1929.79	0.058	0.127	-119%
5--6	72	481.79	0.026	0.032	-21%
7--8	1042	3195.94	0.379	0.210	81%
9--10	913	3552.40	0.332	0.233	43%
11+	95	130.94	0.035	0.009	302%
Blank		194.07			NA
Total	**2747**	**15425.86**	**1.000**	**1.000**	**0%**

Crashes by travel way width, left side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0--12	414	8481.08	0.152	0.557	-267%
13--24	956	4388.51	0.350	0.288	22%
25--36	605	987.57	0.222	0.065	242%
37--48	421	853.39	0.154	0.056	175%
49+	334	521.50	0.122	0.034	257%
Blank		193.81			NA
Total	**2730**	**15425.86**	**1.000**	**1.000**	**0%**

Crashes by travel way width, right side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0--12	431	8438.84	0.157	0.554	-253%
13--24	930	4388.79	0.339	0.288	17%
25--36	622	1021.29	0.226	0.067	238%
37--48	420	825.77	0.153	0.054	182%
49+	344	557.12	0.125	0.037	242%
Blank		194.07			NA
Total	**2747**	**15425.86**	**1.000**	**1.000**	**0%**

Crashes by inside shoulder total width, left side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	1506	10182.05	0.552	0.668	-21%
1--2	201	389.88	0.074	0.026	188%
3--4	90	178.03	0.033	0.012	182%
5--6	356	2672.45	0.130	0.175	-35%
7--8	347	1140.63	0.127	0.075	70%
9--10	168	452.46	0.062	0.030	107%
11+	62	216.57	0.023	0.014	60%
Blank		193.81			NA
Total	**2730**	**15425.86**	**1.000**	**1.000**	**0%**

Crashes by inside shoulder total width, right side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	1491	10186.24	0.543	0.669	-23%
1--2	211	386.28	0.077	0.025	203%
3--4	73	191.46	0.027	0.013	111%
5--6	367	2621.33	0.134	0.172	-29%
7--8	381	1171.84	0.139	0.077	80%
9--10	140	452.54	0.051	0.030	72%
11+	84	222.11	0.031	0.015	110%
Blank		194.07			NA
Total	**2747**	**15425.86**	**1.000**	**1.000**	**0%**

Crashes by inside shoulder treated width, left side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	1506	10194.48	0.552	0.669	-21%
1--2	317	1203.83	0.116	0.079	47%
3--4	86	176.03	0.032	0.012	173%
5--6	260	2186.34	0.095	0.144	-51%
7--8	338	832.68	0.124	0.055	126%
9--10	162	446.27	0.059	0.029	103%
11+	61	192.44	0.022	0.013	77%
Blank		193.81			NA
Total	**2730**	**15425.86**	**1.000**	**1.000**	**0%**

Crashes by inside shoulder treated width, right side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	1491	10207.48	0.543	0.670	-23%
1--2	337	1191.30	0.123	0.078	57%
3--4	74	197.11	0.027	0.013	108%
5--6	264	2165.65	0.096	0.142	-48%
7--8	365	839.51	0.133	0.055	141%
9--10	138	432.47	0.050	0.028	77%
11+	78	198.27	0.028	0.013	118%
Blank		194.07			NA
Total	**2747**	**15425.86**	**1.000**	**1.000**	**0%**

Crashes by median type

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
Not Striped or Separated	1	51.22	0.000	0.003	NA
Striped	1151	9156.61	0.210	0.594	-182%
Reversible Peak Hour Lane(s) - Undivided	0	6.92	0.000	0.000	NA
Reversible Peak Hour Lane(s) - Divided	0	1.78	0.000	0.000	NA
Two-Way Left Turn Lane	581	295.80	0.106	0.019	453%
Continuous Left Turn Lane	612	140.77	0.112	0.009	1125%
Paved Median	1658	1703.97	0.303	0.110	174%
Unpaved Median	1173	3370.10	0.214	0.218	-2%
Separate Grades	91	338.42	0.017	0.022	-32%
Separate Grades w/ Retaining Wall	5	2.87	0.001	0.000	NA
Sawtooth - Unpaved	0	3.53	0.000	0.000	NA
Sawtooth - Paved	0	12.14	0.000	0.001	NA
Ditch	0	4.20	0.000	0.000	NA
Separate Structure	68	132.47	0.012	0.009	45%
Railroad	55	57.23	0.010	0.004	171%
Bus Lanes	3	4.43	0.001	0.000	NA
Paved Area Occasional Traffic Lane	0	0.00	0.000	0.000	NA
Railroad & Bus Lanes	0	0.22	0.000	0.000	NA
Contains Reversible Pk Hr Ln(s)	12	7.96	0.002	0.001	NA
Other	67	135.23	0.012	0.009	40%
Blank		0.00			NA
Total	**5477**	**15425.86**	**1.000**	**1.000**	**0%**

Crashes by median curb and landscape

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
Curbed Median	576	263.60	0.105	0.017	515%
Curbed Median with Trees	301	60.18	0.055	0.004	1309%
Curbed Median with Shrubs	146	43.59	0.027	0.003	843%
Raised Traffic Bars	10	4.70	0.002	0.000	NA
Median with Trees	36	103.55	0.007	0.007	-2%
Median with Shrubs	324	593.58	0.059	0.038	54%
No Curbs or Shrubs/No Median	4084	14356.67	0.746	0.931	-25%
Blank		0.00			NA
Total	**5477**	**15425.86**	**1.000**	**1.000**	**0%**

Crashes by type of median barrier

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
Cable Barrier	27	56.56	0.005	0.004	NA
Cable Barrier w/ Glare Screen	10	13.24	0.002	0.001	NA
Metal Beam Barrier	111	118.53	0.020	0.008	164%
Metal Beam Barrier w/ Glare Screen	141	90.21	0.026	0.006	340%
Concrete Barrier	695	921.31	0.127	0.060	112%
Concrete Barrier w/ Glare Screen	411	341.16	0.075	0.022	239%
Bridge Barrier Railing	76	146.14	0.014	0.009	46%
Chain Link Fence	14	14.30	0.003	0.001	NA
Guardrail in Median Both Roadway	8	25.73	0.001	0.002	NA
Guardrail in Median Left Roadway	17	44.05	0.003	0.003	NA
Guardrail in Median Right Roadway	6	22.85	0.001	0.001	NA
Two-Way, One Lane Road	0	0.00	0.000	0.000	NA
Thrie Beam Barrier	188	412.11	0.034	0.027	28%
Thrie Beam Barrier w/ Glare Screen	1	0.55	0.000	0.000	NA
Conc. Barrier, Both Ways Inside Both Sh.	71	70.31	0.013	0.005	184%
Conc. Barrier, Left Rdwy Median Sh. Area	13	18.23	0.002	0.001	NA
Conc. Barrier, Right Rdwy Median Sh. Area	3	10.49	0.001	0.001	NA
External Barriers on Median Type = C or E	0	7.00	0.000	0.000	NA
Other Not Included Above	1	1.83	0.000	0.000	NA
No Barriers	3684	13111.28	0.673	0.850	-26%
Blank		0.00			NA
Total	**5477**	**15425.86**	**1.000**	**1.000**	**0%**

Crashes by median width (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	1152	9219.09	0.210	0.598	-184%
1--4	136	279.90	0.025	0.018	37%
5--8	342	265.67	0.062	0.017	263%
9--12	1114	530.24	0.203	0.034	492%
13--16	663	346.39	0.121	0.022	439%
17--20	217	153.56	0.040	0.010	298%
21--24	527	717.84	0.096	0.047	107%
25--36	353	578.66	0.064	0.038	72%
37+	762	3334.53	0.139	0.216	-55%
99 (no data)	211		0.039		NA
Blank		0.00			NA
Total	**5477**	**15425.86**	**1.000**	**1.000**	**0%**

Crashes by median width variance

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
Variable	640	863.96	0.117	0.056	109%
No Variance	4674	13912.89	0.853	0.902	-6%
Over 100' Median & No Var.	163	649.01	0.030	0.042	-41%
Blank		0.00			NA
Total	**5477**	**15425.86**	**1.000**	**1.000**	**0%**

Crashes by highway group

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
Independent Alignment - Right	66	194.48	0.012	0.013	-5%
Independent Alignment - Left	45	194.07	0.008	0.013	-53%
Divided Highway	4214	5818.24	0.769	0.377	104%
Undivided Highway	1152	9219.09	0.210	0.598	-184%
Blank		0.00			NA
Total	**5477**	**15425.86**	**1.000**	**1.000**	**0%**

Crashes by access code

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
Conventional	3067	9299.39	0.560	0.603	-8%
Expressway	161	1614.56	0.029	0.105	-256%
Freeway	2213	4487.52	0.404	0.291	39%
One-Way City Street	36	24.40	0.007	0.002	316%
Blank		0.00			NA
Total	**5477**	**15425.86**	**1.000**	**1.000**	**0%**

Crashes by design speed

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
25	93	61.07	0.017	0.004	329%
30	97	74.60	0.018	0.005	266%
35	355	393.55	0.065	0.026	154%
40	306	709.53	0.056	0.046	21%
45	496	1254.45	0.091	0.081	11%
50	689	1430.61	0.126	0.093	36%
55	216	1219.93	0.039	0.079	-101%
60	663	2496.17	0.121	0.162	-34%
65	425	3445.01	0.078	0.223	-188%
70	2137	4340.95	0.390	0.281	39%
Blank		0.00			NA
Total	**5477**	**15425.86**	**1.000**	**1.000**	**0%**

Crashes by functional class

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
None	6	14.97	0.001	0.001	NA
Principal Arterial w/ C/L Prin Arterial	2424	6512.08	0.443	0.422	5%
Principal Arterial w/ C/L Minor Arterial	897	626.49	0.164	0.041	303%
Principal Arterial Non-Connecting Link	1384	649.45	0.253	0.042	500%
Minor Arterial	690	6557.08	0.126	0.425	-237%
Major Collector	74	959.84	0.014	0.062	-361%
Minor Collector	2	103.44	0.000	0.007	NA
Local	0	2.51	0.000	0.000	NA
Blank		0.00			NA
Total	**5477**	**15425.86**	**1.000**	**1.000**	**0%**

Crashes by ADT amount

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
<10,000	500	8273.44	0.091	0.536	-488%
10,000 to 20,000	710	2201.83	0.130	0.143	-10%
20,000 to 30,000	812	1007.31	0.148	0.065	127%
30,000	3455	3943.28	0.631	0.256	147%
Blank		0.00			NA
Total	**5477**	**15425.86**	**1.000**	**1.000**	**0%**

Crashes by surface type, left side

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
PCC - Bridge Deck	62	292.49	0.023	0.019	18%
PCC - Concrete	794	2710.68	0.291	0.178	63%
Earth	0	6.86	0.000	0.000	NA
Undetermined	5	2.30	0.002	0.000	NA
AC - Base & Surface >= 7" Thick	1808	9927.77	0.662	0.652	2%
AC - Base & Surface <7" Thick	56	2015.22	0.021	0.132	-545%
AC - Oiled Earth -- Gravel	5	273.68	0.002	0.018	NA
AC - Bridge Deck	0	3.06	0.000	0.000	NA
Blank		193.81			NA
Total	**2730**	**15425.86**	**1.000**	**1.000**	**0%**

Crashes by surface type, right side

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
PCC - Bridge Deck	73	295.76	0.027	0.019	37%
PCC - Concrete	821	2723.82	0.299	0.179	67%
Earth	1	6.86	0.000	0.000	NA
Undetermined	6	2.12	0.002	0.000	NA
AC - Base & Surface >= 7" Thick	1764	9897.41	0.642	0.650	-1%
AC - Base & Surface <7" Thick	75	2013.02	0.027	0.132	-384%
AC - Oiled Earth -- Gravel	6	289.86	0.002	0.019	NA
AC - Bridge Deck	1	2.94	0.000	0.000	NA
Blank		194.07			NA
Total	**2747**	**15425.86**	**1.000**	**1.000**	**0%**

Appendix 5-B: Highways – Urban

Crashes by number of lanes, left side

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
1	89	331.29	0.047	0.108	-132%
2	660	944.58	0.345	0.308	12%
3	501	662.85	0.262	0.216	21%
4	357	689.26	0.187	0.224	-20%
5	228	327.11	0.119	0.107	12%
6+	77	113.20	0.040	0.037	9%
zero, blank		45.03			NA
Total	**1912**	**3115.33**	**1.000**	**1.000**	**0%**

Crashes by number of lanes, right side

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
1	85	335.55	0.045	0.109	-141%
2	623	935.46	0.332	0.305	9%
3	523	656.75	0.279	0.214	30%
4	344	674.47	0.183	0.220	-20%
5	205	345.82	0.109	0.113	-3%
6+	96	121.84	0.051	0.040	29%
zero, blank		44.14			NA
Total	**1876**	**3115.33**	**1.000**	**1.000**	**0%**

Crashes by lanes on side of crash

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
1	174	333.42	0.046	0.109	-136%
2	1283	940.02	0.339	0.306	11%
3	1024	659.80	0.270	0.215	26%
4	701	681.87	0.185	0.222	-20%
5	433	336.46	0.114	0.110	4%
6+	173	117.52	0.046	0.038	19%
zero, blank		44.58	0.000		NA
Total	**3788**	**3115.33**	**1.000**	**1.000**	**0%**

Crashes by outside shoulder total width, left side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	160	163.29	0.085	0.053	60%
1--2	69	79.15	0.037	0.026	43%
3--4	61	110.96	0.033	0.036	-11%
5--6	66	82.30	0.035	0.027	31%
7--8	781	1003.60	0.416	0.327	27%
9--10	672	1447.60	0.358	0.471	-32%
11+	103	183.39	0.055	0.060	-9%
Blank		45.03			NA
Total	**1912**	**3115.33**	**1.000**	**1.000**	**0%**

Crashes by outside shoulder total width, right side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	148	165.93	0.079	0.054	46%
1--2	63	79.27	0.034	0.026	30%
3--4	47	113.08	0.025	0.037	-47%
5--6	41	81.92	0.022	0.027	-22%
7--8	806	1003.06	0.430	0.327	32%
9--10	671	1443.58	0.358	0.470	-31%
11+	100	184.34	0.053	0.060	-13%
Blank		44.14			NA
Total	**1876**	**3115.33**	**1.000**	**1.000**	**0%**

Crashes by outside shoulder treated width, left side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	168	229.33	0.088	0.075	18%
1--2	74	75.13	0.039	0.024	58%
3--4	69	121.47	0.036	0.040	-10%
5--6	57	66.24	0.030	0.022	38%
7--8	793	1003.57	0.415	0.327	27%
9--10	692	1511.33	0.362	0.492	-36%
11+	59	63.23	0.031	0.021	50%
Blank		45.03			NA
Total	**1912**	**3115.33**	**1.000**	**1.000**	**0%**

Crashes by outside shoulder treated width, right side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	157	165.93	0.084	0.054	55%
1--2	69	79.27	0.037	0.026	42%
3--4	50	113.08	0.027	0.037	-38%
5--6	38	81.92	0.020	0.027	-32%
7--8	814	1003.06	0.434	0.327	33%
9--10	691	1443.58	0.368	0.470	-28%
11+	57	184.34	0.030	0.060	-98%
Blank		44.14			NA
Total	**1876**	**3115.33**	**1.000**	**1.000**	**0%**

Crashes by travel way width, left side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0--12	72	293.19	0.038	0.095	-154%
13--24	583	913.97	0.305	0.298	2%
25--36	547	689.81	0.286	0.225	27%
37--48	383	666.64	0.200	0.217	-8%
49+	327	506.70	0.171	0.165	4%
Blank		45.03			NA
Total	**1912**	**3115.33**	**1.000**	**1.000**	**0%**

Crashes by travel way width, right side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0--12	74	296.74	0.039	0.097	-145%
13--24	564	914.53	0.301	0.298	1%
25--36	533	676.79	0.284	0.220	29%
37--48	370	644.67	0.197	0.210	-6%
49+	335	538.46	0.179	0.175	2%
Blank		44.14			NA
Total	**1876**	**3115.33**	**1.000**	**1.000**	**0%**

Crashes by inside shoulder total width, left side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	948	890.18	0.496	0.290	71%
1--2	191	273.10	0.100	0.089	12%
3--4	86	128.20	0.045	0.042	8%
5--6	211	718.02	0.110	0.234	-112%
7--8	272	549.30	0.142	0.179	-26%
9--10	151	343.47	0.079	0.112	-42%
11+	53	168.04	0.028	0.055	-97%
Blank		45.03			NA
Total	**1912**	**3115.33**	**1.000**	**1.000**	**0%**

Crashes by inside shoulder total width, right side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	909	886.43	0.485	0.289	68%
1--2	198	278.29	0.106	0.091	16%
3--4	71	127.78	0.038	0.042	-10%
5--6	214	720.17	0.114	0.234	-106%
7--8	291	555.44	0.155	0.181	-17%
9--10	125	337.34	0.067	0.110	-65%
11+	68	165.73	0.036	0.054	-49%
Blank		44.14			NA
Total	**1876**	**3115.33**	**1.000**	**1.000**	**0%**

Crashes by inside shoulder treated width, left side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	948	890.48	0.496	0.290	71%
1--2	254	480.69	0.133	0.157	-18%
3--4	83	128.20	0.043	0.042	4%
5--6	156	532.80	0.082	0.174	-113%
7--8	272	536.53	0.142	0.175	-23%
9--10	146	339.31	0.076	0.111	-45%
11+	53	162.29	0.028	0.053	-91%
Blank		45.03			NA
Total	**1912**	**3115.33**	**1.000**	**1.000**	**0%**

Crashes by inside shoulder treated width, right side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	909	886.94	0.485	0.289	68%
1--2	271	486.27	0.144	0.158	-10%
3--4	72	125.21	0.038	0.041	-6%
5--6	146	539.73	0.078	0.176	-126%
7--8	292	541.30	0.156	0.176	-13%
9--10	121	332.93	0.064	0.108	-68%
11+	65	158.80	0.035	0.052	-49%
Blank		44.14			NA
Total	**1876**	**3115.33**	**1.000**	**1.000**	**0%**

Crashes by median type

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
Not Striped or Separated	0	1.21	0.000	0.000	NA
Striped	372	354.30	0.098	0.114	-16%
Reversible Peak Hour Lane(s) - Undivided	0	6.92	0.000	0.002	NA
Reversible Peak Hour Lane(s) - Divided	0	1.78	0.000	0.001	NA
Two-Way Left Turn Lane	315	114.29	0.083	0.037	127%
Continuous Left Turn Lane	578	115.17	0.153	0.037	313%
Paved Median	1518	1205.07	0.401	0.387	4%
Unpaved Median	776	1014.62	0.205	0.326	-59%
Separate Grades	52	99.59	0.014	0.032	-133%
Separate Grades w/ Retaining Wall	5	2.87	0.001	0.001	NA
Sawtooth - Unpaved	0	2.41	0.000	0.001	NA
Sawtooth - Paved	0	5.73	0.000	0.002	NA
Ditch	0	2.01	0.000	0.001	NA
Separate Structure	60	86.84	0.016	0.028	-76%
Railroad	53	56.79	0.014	0.018	-30%
Bus Lanes	3	1.53	0.001	0.000	NA
Paved Area Occasional Traffic Lane	0	0.00	0.000	0.000	NA
Railroad & Bus Lanes	0	0.22	0.000	0.000	NA
Contains Reversible Pk Hr Ln(s)	12	7.96	0.003	0.003	NA
Other	44	36.04	0.012	0.012	0%
Blank		0.00			NA
Total	**3788**	**3115.33**	**1.000**	**1.000**	**0%**

Crashes by median curb and landscape

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
Curbed Median	563	245.67	0.149	0.079	88%
Curbed Median with Trees	299	56.45	0.079	0.018	336%
Curbed Median with Shrubs	144	41.79	0.038	0.013	183%
Raised Traffic Bars	10	3.17	0.003	0.001	NA
Median with Trees	17	24.92	0.004	0.008	NA
Median with Shrubs	250	354.07	0.066	0.114	-72%
No Curbs or Shrubs/No Median	2505	2389.27	0.661	0.767	-16%
Blank		0.00			NA
Total	**3788**	**3115.33**	**1.000**	**1.000**	**0%**

Crashes by type of median barrier

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
Cable Barrier	19	44.70	0.005	0.014	NA
Cable Barrier w/ Glare Screen	10	13.24	0.003	0.004	NA
Metal Beam Barrier	104	96.98	0.027	0.031	-13%
Metal Beam Barrier w/ Glare Screen	136	83.73	0.036	0.027	34%
Concrete Barrier	610	684.79	0.161	0.220	-37%
Concrete Barrier w/ Glare Screen	402	313.73	0.106	0.101	5%
Bridge Barrier Railing	67	100.24	0.018	0.032	-82%
Chain Link Fence	10	10.54	0.003	0.003	NA
Guardrail in Median Both Roadway	6	16.01	0.002	0.005	NA
Guardrail in Median Left Roadway	14	29.88	0.004	0.010	NA
Guardrail in Median Right Roadway	5	11.98	0.001	0.004	NA
Two-Way, One Lane Road	0	0.00	0.000	0.000	NA
Thrie Beam Barrier	126	239.82	0.033	0.077	-131%
Thrie Beam Barrier w/ Glare Screen	1	0.55	0.000	0.000	NA
Conc. Barrier, Both Ways Inside Both Sh.	71	70.23	0.019	0.023	-20%
Conc. Barrier, Left Rdwy Median Sh. Area	13	16.18	0.003	0.005	NA
Conc. Barrier, Right Rdwy Median Sh. Area	3	9.67	0.001	0.003	NA
External Barriers on Median Type = C or E	0	7.00	0.000	0.002	NA
Other Not Included Above	1	1.83	0.000	0.001	NA
No Barriers	2190	1364.24	0.578	0.438	32%
Blank		0.00			NA
Total	**3788**	**3115.33**	**1.000**	**1.000**	**0%**

Crashes by median width (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	372	362.56	0.098	0.116	-19%
1--4	101	62.44	0.027	0.020	33%
5--8	332	221.33	0.088	0.071	23%
9--12	826	307.42	0.218	0.099	121%
13--16	616	245.01	0.163	0.079	107%
17--20	211	132.65	0.056	0.043	31%
21--24	456	449.00	0.120	0.144	-20%
25--36	285	380.80	0.075	0.122	-62%
37+	494	795.41	0.130	0.255	-96%
99 (no data)	95	158.71	0.025		NA
Blank		0.00			NA
Total	**3788**	**3115.33**	**1.000**	**1.000**	**0%**

Crashes by median width variance

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
Variable	548	138.97	0.145	0.045	224%
No Variance	3161	377.28	0.834	0.121	589%
Over 100' Median & No Var.	79	2599.08	0.021	0.834	-3900%
Blank		0.00			NA
Total	**3788**	**3115.33**	**1.000**	**1.000**	**0%**

Crashes by highway group

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
Independent Alignment - Right	42	2663.60	0.011	0.855	-7611%
Independent Alignment - Left	26	44.14	0.007	0.014	NA
Divided Highway	3348	45.03	0.884	0.014	6015%
Undivided Highway	372	362.56	0.098	0.116	-19%
Blank		0.00			NA
Total	**3788**	**3115.33**	**1.000**	**1.000**	**0%**

Crashes by access code

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
Conventional	1972	891.85	0.521	0.286	82%
Expressway	38	86.83	0.010	0.028	-178%
Freeway	1757	2118.13	0.464	0.680	-47%
One-Way City Street	21	18.52	0.006	0.006	NA
Blank		0.00			NA
Total	**3788**	**3115.33**	**1.000**	**1.000**	**0%**

Crashes by design speed

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
25	27	6.69	0.007	0.002	NA
30	57	15.62	0.015	0.005	200%
35	206	46.10	0.054	0.015	268%
40	191	87.46	0.050	0.028	80%
45	345	165.64	0.091	0.053	71%
50	555	240.00	0.147	0.077	90%
55	109	69.25	0.029	0.022	29%
60	401	231.78	0.106	0.074	42%
65	202	216.01	0.053	0.069	-30%
70	1695	2036.79	0.447	0.654	-46%
Blank		0.00			NA
Total	**3788**	**3115.33**	**1.000**	**1.000**	**0%**

Crashes by functional class

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
None	4	8.13	0.001	0.003	NA
Principal Arterial w/ C/L Prin Arterial	1675	1833.10	0.442	0.588	-33%
Principal Arterial w/ C/L Minor Arterial	653	442.43	0.172	0.142	21%
Principal Arterial Non-Connecting Link	1347	635.64	0.356	0.204	74%
Minor Arterial	108	178.37	0.029	0.057	-101%
Major Collector	1	15.58	0.000	0.005	NA
Minor Collector	0	0.00	0.000	0.000	NA
Local	0	2.08	0.000	0.001	NA
Blank		0.00			NA
Total	**3788**	**3115.33**	**1.000**	**1.000**	**0%**

Crashes by ADT amount

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
<10,000	40	118.21	0.011	0.038	-259%
10,000 to 20,000	218	278.58	0.058	0.089	-55%
20,000 to 30,000	540	273.82	0.143	0.088	62%
30,000+	2990	2444.73	0.789	0.785	1%
(blank)		0.00			NA
Total	**3788**	**3115.33**	**1.000**	**1.000**	**0%**

Crashes by surface type, left side

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
PCC - Bridge Deck	53	172.79	0.028	0.056	-103%
PCC - Concrete	673	1364.78	0.352	0.445	-26%
Earth	0	0.00	0.000	0.000	NA
Undetermined	5	1.48	0.003	0.000	NA
AC - Base & Surface >= 7" Thick	1176	1498.99	0.615	0.488	26%
AC - Base & Surface <7" Thick	5	30.05	0.003	0.010	NA
AC - Oiled Earth -- Gravel	0	0.02	0.000	0.000	NA
AC - Bridge Deck	0	2.20	0.000	0.001	NA
Blank		45.03			NA
Total	**1912**	**3115.33**	**1.000**	**1.000**	**0%**

Crashes by surface type, right side

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
PCC - Bridge Deck	59	173.02	0.031	0.056	-79%
PCC - Concrete	673	1363.05	0.359	0.444	-24%
Earth	0	0.00	0.000	0.000	NA
Undetermined	6	1.30	0.003	0.000	NA
AC - Base & Surface >= 7" Thick	1130	1501.54	0.602	0.489	23%
AC - Base & Surface <7" Thick	7	30.05	0.004	0.010	NA
AC - Oiled Earth -- Gravel	0	0.13	0.000	0.000	NA
AC - Bridge Deck	1	2.09	0.001	0.001	NA
Blank		44.14			NA
Total	**1876**	**3115.33**	**1.000**	**1.000**	**0%**

Appendix 5-C: Highways – Urbanized

Crashes by number of lanes, left side

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
1	97	266.18	0.339	0.373	-10%
2	165	375.42	0.577	0.526	10%
3	14	52.10	0.049	0.073	NA
4	5	17.90	0.017	0.025	NA
5	4	1.24	0.014	0.002	NA
6+	1	0.44	0.003	0.001	NA
zero, blank		2.70			NA
Total	**286**	**716.40**	**1.000**	**1.000**	**0%**

Crashes by number of lanes, right side

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
1	99	266.99	0.341	0.374	-10%
2	169	370.94	0.583	0.520	12%
3	17	55.20	0.059	0.077	NA
4	3	18.09	0.010	0.025	NA
5	1	1.62	0.003	0.002	NA
6+	1	0.76	0.003	0.001	NA
zero, blank		2.79			NA
Total	**290**	**716.40**	**1.000**	**1.000**	**0%**

Crashes by lanes on side of crash

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
1	196	266.59	0.340	0.374	-10%
2	334	373.18	0.580	0.523	11%
3	31	53.65	0.054	0.075	-40%
4	8	17.99	0.014	0.025	NA
5	5	1.43	0.009	0.002	NA
6+	2	0.60	0.003	0.001	NA
zero, blank		2.75			NA
Total	**576**	**716.40**	**1.000**	**1.000**	**0%**

Crashes by outside shoulder total width, left side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	30	37.20	0.103	0.052	98%
1--2	13	37.49	0.045	0.053	NA
3--4	45	62.88	0.155	0.088	76%
5--6	11	38.85	0.038	0.054	NA
7--8	109	285.85	0.376	0.401	-7%
9--10	50	202.88	0.172	0.284	-65%
11+	28	48.54	0.097	0.068	NA
Blank		2.70			NA
Total	**286**	**716.40**	**1.000**	**1.000**	**0%**

Crashes by outside shoulder total width, right side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	44	39.50	0.152	0.055	174%
1--2	14	34.39	0.048	0.048	NA
3--4	31	68.83	0.107	0.096	11%
5--6	25	40.46	0.086	0.057	NA
7--8	101	283.49	0.348	0.397	-14%
9--10	45	198.74	0.155	0.278	-79%
11+	30	48.20	0.103	0.068	53%
Blank		2.79			NA
Total	**290**	**716.40**	**1.000**	**1.000**	**0%**

Crashes by outside shoulder treated width, left side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	40	96.05	0.140	0.135	4%
1--2	18	37.37	0.063	0.052	NA
3--4	49	65.77	0.171	0.092	86%
5--6	4	21.91	0.014	0.031	NA
7--8	98	259.30	0.343	0.363	-6%
9--10	55	207.16	0.192	0.290	-51%
11+	22	26.14	0.077	0.037	NA
Blank		2.70			0%
Total	**286**	**716.40**	**1.000**	**1.000**	**0%**

Crashes by outside shoulder treated width, right side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	57	39.50	0.197	0.055	255%
1--2	18	34.39	0.062	0.048	NA
3--4	31	68.83	0.107	0.096	11%
5--6	17	40.46	0.059	0.057	NA
7--8	96	283.49	0.331	0.397	-20%
9--10	47	198.74	0.162	0.278	-72%
11+	24	48.20	0.083	0.068	NA
Blank		2.79			NA
Total	**290**	**716.40**	**1.000**	**1.000**	**0%**

Crashes by travel way width, left side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0--12	89	241.03	0.311	0.338	-9%
13--24	152	385.33	0.531	0.540	-2%
25--36	33	63.95	0.115	0.090	29%
37--48	7	20.92	0.024	0.029	NA
49+	5	2.48	0.017	0.003	NA
Blank		2.70			NA
Total	**286**	**716.40**	**1.000**	**1.000**	**0%**

Crashes by travel way width, right side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0--12	85	239.82	0.293	0.336	-15%
13--24	143	377.60	0.493	0.529	-7%
25--36	55	72.83	0.190	0.102	86%
37--48	4	20.17	0.014	0.028	NA
49+	3	3.19	0.010	0.004	NA
Blank		2.79			NA
Total	**290**	**716.40**	**1.000**	**1.000**	**0%**

Crashes by inside shoulder total width, left side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	218	358.01	0.762	0.502	52%
1--2	4	16.37	0.014	0.023	NA
3--4	0	1.79	0.000	0.003	NA
5--6	38	255.68	0.133	0.358	-170%
7--8	22	62.00	0.077	0.087	NA
9--10	3	11.60	0.010	0.016	NA
11+	1	8.24	0.003	0.012	NA
Blank		2.70			NA
Total	**286**	**716.39**	**1.000**	**1.000**	**0%**

Crashes by inside shoulder total width, right side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	225	359.01	0.776	0.503	54%
1--2	3	16.49	0.010	0.023	NA
3--4	0	3.33	0.000	0.005	NA
5--6	37	249.82	0.128	0.350	-174%
7--8	17	60.41	0.059	0.085	NA
9--10	2	12.22	0.007	0.017	NA
11+	6	12.33	0.021	0.017	NA
Blank		2.79			NA
Total	**290**	**716.39**	**1.000**	**1.000**	**0%**

Crashes by inside shoulder treated width, left side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	218	359.49	0.762	0.504	51%
1--2	20	99.43	0.070	0.139	NA
3--4	0	2.13	0.000	0.003	NA
5--6	24	182.45	0.084	0.256	NA
7--8	22	53.47	0.077	0.075	NA
9--10	2	14.07	0.007	0.020	NA
11+	0	2.66	0.000	0.004	NA
Blank		2.70			NA
Total	**286**	**716.39**	**1.000**	**1.000**	**0%**

Crashes by inside shoulder treated width, right side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	225	361.29	0.776	0.506	53%
1--2	15	102.65	0.052	0.144	NA
3--4	0	3.78	0.000	0.005	NA
5--6	25	172.85	0.086	0.242	NA
7--8	17	52.56	0.059	0.074	NA
9--10	5	14.50	0.017	0.020	NA
11+	3	5.97	0.010	0.008	NA
Blank		2.79			NA
Total	**290**	**716.39**	**1.000**	**1.000**	**0%**

Crashes by median type

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
Not Striped or Separated	0	0.00	0.000	0.000	NA
Striped	229	272.60	0.398	0.381	4%
Reversible Peak Hour Lane(s) - Undivided	0	0.00	0.000	0.000	NA
Reversible Peak Hour Lane(s) - Divided	0	0.00	0.000	0.000	NA
Two-Way Left Turn Lane	157	61.77	0.273	0.086	216%
Continuous Left Turn Lane	27	12.25	0.047	0.017	NA
Paved Median	44	40.49	0.076	0.057	35%
Unpaved Median	93	309.36	0.161	0.432	-167%
Separate Grades	9	5.89	0.016	0.008	90%
Separate Grades w/ Retaining Wall	0	0.00	0.000	0.000	NA
Sawtooth - Unpaved	0	0.00	0.000	0.000	NA
Sawtooth - Paved	0	0.00	0.000	0.000	NA
Ditch	0	0.00	0.000	0.000	NA
Separate Structure	1	8.33	0.002	0.012	NA
Railroad	2	0.09	0.003	0.000	NA
Bus Lanes	0	0.00	0.000	0.000	NA
Paved Area Occasional Traffic Lane	0	0.00	0.000	0.000	NA
Railroad & Bus Lanes	0	0.00	0.000	0.000	NA
Contains Reversible Pk Hr Ln(s)	0	0.00	0.000	0.000	NA
Other	14	5.62	0.024	0.008	NA
Blank		0.00			NA
Total	**576**	**716.40**	**1.000**	**1.000**	**0%**

Crashes by median curb and landscape

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
Curbed Median	12	8.11	0.021	0.011	NA
Curbed Median with Trees	1	1.80	0.002	0.003	NA
Curbed Median with Shrubs	2	1.80	0.003	0.003	NA
Raised Traffic Bars	0	0.00	0.000	0.000	NA
Median with Trees	1	1.20	0.002	0.002	NA
Median with Shrubs	23	49.86	0.040	0.070	NA
No Curbs or Shrubs/No Median	537	653.63	0.932	0.912	2%
Blank		0.00			NA
Total	**576**	**716.40**	**1.000**	**1.000**	**0%**

Crashes by type of median barrier

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
Cable Barrier	1	2.14	0.002	0.003	NA
Cable Barrier w/ Glare Screen	0	0.00	0.000	0.000	NA
Metal Beam Barrier	5	8.36	0.009	0.012	NA
Metal Beam Barrier w/ Glare Screen	1	1.75	0.002	0.002	NA
Concrete Barrier	12	28.97	0.021	0.040	NA
Concrete Barrier w/ Glare Screen	0	1.62	0.000	0.002	NA
Bridge Barrier Railing	2	8.00	0.003	0.011	NA
Chain Link Fence	4	0.80	0.007	0.001	NA
Guardrail in Median Both Roadway	1	4.91	0.002	0.007	NA
Guardrail in Median Left Roadway	0	0.77	0.000	0.001	NA
Guardrail in Median Right Roadway	0	0.33	0.000	0.000	NA
Two-Way, One Lane Road	0	0.00	0.000	0.000	NA
Thrie Beam Barrier	9	33.76	0.016	0.047	NA
Thrie Beam Barrier w/ Glare Screen	0	0.00	0.000	0.000	NA
Conc. Barrier, Both Ways Inside Both Sh.	0	0.00	0.000	0.000	NA
Conc. Barrier, Left Rdwy Median Sh. Area	0	0.00	0.000	0.000	NA
Conc. Barrier, Right Rdwy Median Sh. Area	0	0.00	0.000	0.000	NA
External Barriers on Median Type = C or E	0	0.00	0.000	0.000	NA
Other Not Included Above	0	0.00	0.000	0.000	NA
No Barriers	541	624.98	0.939	0.872	8%
Blank		0.00			NA
Total	**576**	**716.40**	**1.000**	**1.000**	**0%**

Crashes by median width (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	229	272.60	0.398	0.381	4%
1--4	10	4.26	0.017	0.006	NA
5--8	1	1.78	0.002	0.002	NA
9--12	185	77.28	0.321	0.108	198%
13--16	14	9.89	0.024	0.014	NA
17--20	3	4.44	0.005	0.006	NA
21--24	27	53.69	0.047	0.075	NA
25--36	10	19.56	0.017	0.027	NA
37+	78	259.27	0.135	0.362	-167%
99 (no data)	19	13.63	0.033		NA
Blank		0.00			NA
Total	**576**	**716.40**	**1.000**	**1.000**	**0%**

Crashes by median width variance

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
Variable	11	11.17	0.019	0.016	NA
No Variance	545	43.35	0.946	0.061	1464%
Over 100' Median & No Var.	20	661.87	0.035	0.924	NA
Blank		0.00			NA
Total	**576**	**716.40**	**1.000**	**1.000**	**0%**

Crashes by highway group

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
Independent Alignment - Right	11	438.30	0.019	0.612	NA
Independent Alignment - Left	8	2.79	0.014	0.004	NA
Divided Highway	328	2.70	0.569	0.004	14992%
Undivided Highway	229	272.60	0.398	0.381	4%
Blank		0.00			NA
Total	**576**	**716.40**	**1.000**	**1.000**	**0%**

Crashes by access code

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
Conventional	448	346.04	0.778	0.483	61%
Expressway	19	70.35	0.033	0.098	NA
Freeway	95	296.58	0.165	0.414	-151%
One-Way City Street	14	3.44	0.024	0.005	NA
Blank		0.00			NA
Total	**576**	**716.39**	**1.000**	**1.000**	**0%**

Crashes by design speed

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
25	31	11.02	0.054	0.015	250%
30	29	10.14	0.050	0.014	NA
35	87	29.15	0.151	0.041	271%
40	65	42.68	0.113	0.060	89%
45	63	55.10	0.109	0.077	42%
50	45	39.53	0.078	0.055	42%
55	24	27.55	0.042	0.038	NA
60	103	99.39	0.179	0.139	29%
65	38	99.40	0.066	0.139	-110%
70	91	302.43	0.158	0.422	-167%
Blank		0.00			NA
Total	**576**	**716.40**	**1.000**	**1.000**	**0%**

Crashes by functional class

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
None	0	1.07	0.000	0.001	NA
Principal Arterial w/ C/L Prin Arterial	193	375.07	0.335	0.524	-56%
Principal Arterial w/ C/L Minor Arterial	244	183.71	0.424	0.256	65%
Principal Arterial Non-Connecting Link	37	13.81	0.064	0.019	233%
Minor Arterial	82	113.65	0.142	0.159	-11%
Major Collector	20	29.09	0.035	0.041	NA
Minor Collector	0	0.00	0.000	0.000	NA
Local	0	0.00	0.000	0.000	NA
Blank		0.00			NA
Total	**576**	**716.40**	**1.000**	**1.000**	**0%**

Crashes by ADT

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
<10,000	74	157.62	0.128	0.220	-71%
10,000 to 20,000	184	192.69	0.319	0.269	19%
20,000 to 30,000	130	108.81	0.226	0.152	49%
30,000+	188	257.28	0.326	0.359	-10%
(blank)		0.00			NA
Total	**576**	**716.40**	**1.000**	**1.000**	**0%**

Crashes by surface type, left side

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
PCC - Bridge Deck	3	13.79	0.010	0.019	NA
PCC - Concrete	23	158.11	0.080	0.222	-175%
Earth	0	0.00	0.000	0.000	NA
Undetermined	0	0.00	0.000	0.000	NA
AC - Base & Surface >= 7" Thick	245	481.87	0.857	0.675	27%
AC - Base & Surface <7" Thick	14	56.29	0.049	0.079	-61%
AC - Oiled Earth -- Gravel	1	3.63	0.003	0.005	NA
AC - Bridge Deck	0	0.00	0.000	0.000	NA
Blank		2.70			NA
Total	**286**	**716.40**	**1.000**	**1.000**	**0%**

Crashes by surface type, right side

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
PCC - Bridge Deck	4	13.68	0.014	0.019	-39%
PCC - Concrete	20	170.46	0.069	0.239	-246%
Earth	0	0.00	0.000	0.000	NA
Undetermined	0	0.00	0.000	0.000	NA
AC - Base & Surface >= 7" Thick	247	469.63	0.852	0.658	29%
AC - Base & Surface <7" Thick	19	56.19	0.066	0.079	-20%
AC - Oiled Earth -- Gravel	0	3.63	0.000	0.005	NA
AC - Bridge Deck	0	0.00	0.000	0.000	NA
Blank		2.79			NA
Total	**290**	**716.40**	**1.000**	**1.000**	**0%**

Appendix 5-D: Highways – Rural

Crashes by number of lanes, left side

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
1	278	8533.608	0.523	0.745	-43%
2	201	2540.583	0.378	0.222	70%
3	23	211.2	0.043	0.018	NA
4	28	151.601	0.053	0.013	NA
5	2	8.987	0.004	0.001	NA
6+	0	0.932	0.000	0.000	NA
zero, blank		147.227			NA
Total	**532**	**11594.14**	**1.000**	**1.000**	**0%**

Crashes by number of lanes, right side

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
1	299	8492.30	0.515	0.742	-44%
2	201	2553.21	0.346	0.223	55%
3	30	235.59	0.052	0.021	151%
4	46	156.00	0.079	0.014	481%
5	4	7.91	0.007	0.001	NA
6+	1	1.41	0.002	0.000	NA
zero, blank		147.72			NA
Total	**581**	**11594.14**	**1.000**	**1.000**	**0%**

Crashes by lanes on side of crash

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
1	577	8512.96	0.518	0.744	-43%
2	402	2546.90	0.361	0.223	62%
3	53	223.40	0.048	0.020	144%
4	74	153.80	0.066	0.013	395%
5	6	8.45	0.005	0.001	NA
6+	1	1.17	0.001	0.000	NA
zero, blank		147.47			NA
Total	**1113**	**11594.14**	**1.000**	**1.000**	**0%**

Crashes by outside shoulder total width, left side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	22	763.98	0.038	0.067	NA
1--2	59	2043.71	0.102	0.179	-76%
3--4	78	2169.29	0.134	0.189	-41%
5--6	36	988.39	0.062	0.086	-39%
7--8	162	3112.49	0.279	0.272	3%
9--10	141	1853.73	0.243	0.162	50%
11+	34	516.47	0.059	0.045	30%
Blank		146.08			NA
Total	**532**	**11594.14**	**1.000**	**1.000**	**0%**

Crashes by outside shoulder total width, right side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	31	738.45	0.053	0.065	-21%
1--2	67	1934.84	0.115	0.169	-47%
3--4	86	2241.88	0.148	0.196	-32%
5--6	35	1025.57	0.060	0.090	-49%
7--8	157	3152.16	0.270	0.275	-2%
9--10	166	1859.44	0.286	0.162	76%
11+	39	494.68	0.067	0.043	55%
Blank		147.13			NA
Total	**581**	**11594.14**	**1.000**	**1.000**	**0%**

Crashes by outside shoulder treated width, left side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	100	4047.42	0.188	0.354	-88%
1--2	46	1484.30	0.086	0.130	-50%
3--4	80	1675.69	0.150	0.146	3%
5--6	13	371.81	0.024	0.032	NA
7--8	132	1931.37	0.248	0.169	47%
9--10	153	1886.30	0.288	0.165	75%
11+	8	51.17	0.015	0.004	NA
Blank		146.08			NA
Total	**532**	**11594.14**	**1.000**	**1.000**	**0%**

Crashes by outside shoulder treated width, right side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	106	738.45	0.182	0.065	183%
1--2	59	1934.84	0.102	0.169	-66%
3--4	78	2241.88	0.134	0.196	-46%
5--6	17	1025.57	0.029	0.090	NA
7--8	132	3152.16	0.227	0.275	-21%
9--10	175	1859.44	0.301	0.162	85%
11+	14	494.68	0.024	0.043	NA
Blank		147.13			NA
Total	**581**	**11594.14**	**1.000**	**1.000**	**0%**

Crashes by travel way width, left side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0--12	253	7946.87	0.476	0.694	-46%
13--24	221	3089.22	0.415	0.270	54%
25--36	25	233.81	0.047	0.020	NA
37--48	31	165.84	0.058	0.014	302%
49+	2	12.32	0.004	0.001	NA
Blank		146.08			NA
Total	**532**	**11594.14**	**1.000**	**1.000**	**0%**

Crashes by travel way width, right side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0--12	272	7902.29	0.468	0.690	-47%
13--24	223	3096.66	0.384	0.271	42%
25--36	34	271.67	0.059	0.024	147%
37--48	46	160.93	0.079	0.014	463%
49+	6	15.46	0.010	0.001	NA
Blank		147.13			NA
Total	**581**	**11594.14**	**1.000**	**1.000**	**0%**

Crashes by inside shoulder total width, left side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	340	8933.86	0.639	0.780	-22%
1--2	6	100.41	0.011	0.009	NA
3--4	4	48.04	0.008	0.004	NA
5--6	107	1698.75	0.201	0.148	36%
7--8	53	529.33	0.100	0.046	115%
9--10	14	97.39	0.026	0.009	NA
11+	8	40.28	0.015	0.004	NA
Blank		146.08			NA
Total	**532**	**11594.14**	**1.000**	**1.000**	**0%**

Crashes by inside shoulder total width, right side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	357	8940.80	0.614	0.781	-27%
1--2	10	91.50	0.017	0.008	NA
3--4	2	60.35	0.003	0.005	NA
5--6	116	1651.34	0.200	0.144	38%
7--8	73	555.99	0.126	0.049	159%
9--10	13	102.98	0.022	0.009	NA
11+	10	44.05	0.017	0.004	NA
Blank		147.13			NA
Total	**581**	**11594.14**	**1.000**	**1.000**	**0%**

Crashes by inside shoulder treated width, left side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	340	8944.51	0.639	0.781	-22%
1--2	43	623.71	0.081	0.054	48%
3--4	3	45.70	0.006	0.004	NA
5--6	80	1471.09	0.150	0.129	17%
7--8	44	242.67	0.083	0.021	290%
9--10	14	92.89	0.026	0.008	NA
11+	8	27.49	0.015	0.002	NA
Blank		146.08			NA
Total	**532**	**11594.14**	**1.000**	**1.000**	**0%**

Crashes by inside shoulder treated width, right side (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	357	8959.25	0.614	0.783	-27%
1--2	51	602.38	0.088	0.053	67%
3--4	2	68.13	0.003	0.006	NA
5--6	93	1453.07	0.160	0.127	26%
7--8	56	245.66	0.096	0.021	349%
9--10	12	85.03	0.021	0.007	NA
11+	10	33.50	0.017	0.003	NA
Blank		147.13			NA
Total	**581**	**11594.14**	**1.000**	**1.000**	**0%**

Crashes by median type

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
Not Striped or Separated	1	50.01	0.001	0.004	NA
Striped	550	8529.71	0.494	0.736	-49%
Reversible Peak Hour Lane(s) - Undivided	0	0.00	0.000	0.000	NA
Reversible Peak Hour Lane(s) - Divided	0	0.00	0.000	0.000	NA
Two-Way Left Turn Lane	109	119.74	0.098	0.010	848%
Continuous Left Turn Lane	7	13.35	0.006	0.001	NA
Paved Median	96	458.41	0.086	0.040	118%
Unpaved Median	304	2046.13	0.273	0.176	55%
Separate Grades	30	232.95	0.027	0.020	34%
Separate Grades w/ Retaining Wall	0	0.00	0.000	0.000	NA
Sawtooth - Unpaved	0	1.12	0.000	0.000	NA
Sawtooth - Paved	0	6.42	0.000	0.001	NA
Ditch	0	2.20	0.000	0.000	NA
Separate Structure	7	37.30	0.006	0.003	NA
Railroad	0	0.34	0.000	0.000	NA
Bus Lanes	0	2.90	0.000	0.000	NA
Paved Area Occasional Traffic Lane	0	0.00	0.000	0.000	NA
Railroad & Bus Lanes	0	0.00	0.000	0.000	NA
Contains Reversible Pk Hr Ln(s)	0	0.00	0.000	0.000	NA
Other	9	93.57	0.008	0.008	NA
Blank		0.00			NA
Total	**1113**	**11594.14**	**1.000**	**1.000**	**0%**

Crashes by median curb and landscape

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
Curbed Median	1	9.82	0.001	0.001	NA
Curbed Median with Trees	1	1.93	0.001	0.000	NA
Curbed Median with Shrubs	0	0.00	0.000	0.000	NA
Raised Traffic Bars	0	1.54	0.000	0.000	NA
Median with Trees	18	77.43	0.016	0.007	NA
Median with Shrubs	51	189.65	0.046	0.016	180%
No Curbs or Shrubs/No Median	1042	11313.77	0.936	0.976	-4%
Blank		0.00			NA
Total	**1113**	**11594.14**	**1.000**	**1.000**	**0%**

Crashes by type of median barrier

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
Cable Barrier	7	9.71	0.006	0.001	NA
Cable Barrier w/ Glare Screen	0	0.00	0.000	0.000	NA
Metal Beam Barrier	2	13.19	0.002	0.001	NA
Metal Beam Barrier w/ Glare Screen	4	4.73	0.004	0.000	NA
Concrete Barrier	73	207.54	0.066	0.018	266%
Concrete Barrier w/ Glare Screen	9	25.81	0.008	0.002	NA
Bridge Barrier Railing	7	37.90	0.006	0.003	NA
Chain Link Fence	0	2.96	0.000	0.000	NA
Guardrail in Median Both Roadway	1	4.81	0.001	0.000	NA
Guardrail in Median Left Roadway	3	13.40	0.003	0.001	NA
Guardrail in Median Right Roadway	1	10.55	0.001	0.001	NA
Two-Way, One Lane Road	0	0.00	0.000	0.000	NA
Thrie Beam Barrier	53	138.53	0.048	0.012	299%
Thrie Beam Barrier w/ Glare Screen	0	0.00	0.000	0.000	NA
Conc. Barrier, Both Ways Inside Both Sh.	0	0.08	0.000	0.000	NA
Conc. Barrier, Left Rdwy Median Sh. Area	0	2.05	0.000	0.000	NA
Conc. Barrier, Right Rdwy Median Sh. Area	0	0.82	0.000	0.000	NA
External Barriers on Median Type = C or E	0	0.00	0.000	0.000	NA
Other Not Included Above	0	0.00	0.000	0.000	NA
No Barriers	953	11122.06	0.856	0.959	-12%
Blank		0.00			NA
Total	**1113**	**11594.14**	**1.000**	**1.000**	**0%**

Crashes by median width (feet)

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
0	551	8583.93	0.495	0.740	-50%
1--4	25	213.21	0.022	0.018	NA
5--8	9	42.55	0.008	0.004	NA
9--12	103	145.54	0.093	0.013	637%
13--16	33	91.49	0.030	0.008	276%
17--20	3	16.47	0.003	0.001	NA
21--24	44	215.15	0.040	0.019	113%
25--36	58	178.30	0.052	0.015	239%
37+	190	1381.02	0.171	0.119	43%
99 (no data)	97	726.49	0.087		NA
Blank		0.00			NA
Total	**1113**	**11594.14**	**1.000**	**1.000**	**0%**

Crashes by median width variance

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
Variable	81	498.86	0.073	0.043	69%
No Variance	968	443.33	0.870	0.038	2175%
Over 100' Median & No Var.	64	10651.95	0.058	0.919	-1498%
Blank		0.00			NA
Total	**1113**	**11594.14**	**1.000**	**1.000**	**0%**

Crashes by highway group

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
Independent Alignment - Right	13	2716.33	0.012	0.234	NA
Independent Alignment - Left	11	147.13	0.010	0.013	NA
Divided Highway	538	146.75	0.483	0.013	3719%
Undivided Highway	551	8583.93	0.495	0.740	-50%
Blank		0.00			NA
Total	**1113**	**11594.14**	**1.000**	**1.000**	**0%**

Crashes by access code

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
Conventional	647	8061.51	0.581	0.695	-20%
Expressway	104	1457.38	0.093	0.126	-35%
Freeway	361	2072.81	0.324	0.179	81%
One-Way City Street	1	2.44	0.001	0.000	NA
Blank		0.00			NA
Total	**1113**	**11594.14**	**1.000**	**1.000**	**0%**

Crashes by design speed

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
25	35	43.36	0.031	0.004	741%
30	11	48.84	0.010	0.004	NA
35	62	318.31	0.056	0.027	103%
40	50	579.38	0.045	0.050	-11%
45	88	1033.71	0.079	0.089	-13%
50	89	1151.08	0.080	0.099	-24%
55	83	1123.12	0.075	0.097	-30%
60	159	2165.00	0.143	0.187	-31%
65	185	3129.60	0.166	0.270	-62%
70	351	2001.74	0.315	0.173	83%
Blank		0.00			NA
Total	**1113**	**11594.14**	**1.000**	**1.000**	**0%**

Crashes by functional class

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
None	2	5.76	0.002	0.000	NA
Principal Arterial w/ C/L Prin Arterial	556	4303.91	0.500	0.371	35%
Principal Arterial w/ C/L Minor Arterial	0	0.35	0.000	0.000	NA
Principal Arterial Non-Connecting Link	0	0.00	0.000	0.000	NA
Minor Arterial	500	6265.06	0.449	0.540	-20%
Major Collector	53	915.18	0.048	0.079	-66%
Minor Collector	2	103.44	0.002	0.009	NA
Local	0	0.43	0.000	0.000	NA
Blank		0.00			NA
Total	**1113**	**11594.14**	**1.000**	**1.000**	**0%**

Crashes by ADT amount

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
<10,000	386	8007.11	0.347	0.691	-99%
10,000 to 20,000	308	1739.63	0.277	0.150	84%
20,000 to 30,000	142	658.48	0.128	0.057	125%
30,000+	277	1188.92	0.249	0.103	143%
(blank)		0.00			NA
Total	**1113**	**11594.14**	**1.000**	**1.000**	**0%**

Crashes by surface type, left side

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
PCC - Bridge Deck	6	105.92	0.011	0.009	NA
PCC - Concrete	98	1187.79	0.184	0.104	78%
Earth	0	6.86	0.000	0.001	NA
Undetermined	0	0.82	0.000	0.000	NA
AC - Base & Surface >= 7" Thick	387	7946.92	0.727	0.694	5%
AC - Base & Surface <7" Thick	37	1928.87	0.070	0.168	-142%
AC - Oiled Earth -- Gravel	4	270.03	0.008	0.024	NA
AC - Bridge Deck	0	0.86	0.000	0.000	NA
Blank		146.08			NA
Total	**532**	**11594.14**	**1.000**	**1.000**	**0%**

Crashes by surface type, right side

	Total crashes on state highway system	State highway system miles	A. Proportion of crashes	B. Proportion of state highway miles	Relationship between A and B
PCC - Bridge Deck	10	109.055	0.017	0.010	NA
PCC - Concrete	128	1190.312	0.220	0.104	112%
Earth	1	6.864	0.002	0.001	NA
Undetermined	0	0.818	0.000	0.000	NA
AC - Base & Surface >= 7" Thick	387	7926.237	0.666	0.692	-4%
AC - Base & Surface <7" Thick	49	1926.778	0.084	0.168	-100%
AC - Oiled Earth -- Gravel	6	286.096	0.010	0.025	NA
AC - Bridge Deck	0	0.848	0.000	0.000	NA
Blank		147.13			NA
Total	**581**	**11594.14**	**1.000**	**1.000**	**0%**

Appendix 5-E: Intersections – All

Crashes by design code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Four-Legged	620	5703	0.649	0.313	108%
Multi-Legged	14	165	0.015	0.009	NA
Offset	66	647	0.069	0.035	95%
Tee	229	10489	0.240	0.575	-140%
WYE	15	1056	0.016	0.058	NA
Other	11	184	0.012	0.010	NA
Total	**955**	**18244**	**1.000**	**1.000**	**0%**

Crashes by presence of lighting

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Yes	876	8743	0.917	0.479	91%
No	79	9501	0.083	0.521	-530%
Total	**955**	**18244**	**1.000**	**1.000**	**0%**

Crashes by main signal mast arm

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Yes	479	2271	0.502	0.124	303%
No	476	15973	0.498	0.876	-76%
Total	**955**	**18244**	**1.000**	**1.000**	**0%**

Crashes by main left channel code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
No Left Turn Channelization	282	11373	0.295	0.623	-111%
Painted Left Turn Channelization	364	5096	0.381	0.279	36%
Curbed Median Left Turn Channelization	308	1747	0.323	0.096	237%
Raised Bars - Left Turn Channelization	0	17	0.000	0.001	NA
Yes	1	11	0.001	0.001	NA
Total	**955**	**18244**	**1.000**	**1.000**	**0%**

Crashes by main right channel code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Yes	134	1802	0.140	0.099	42%
No	817	16419	0.855	0.900	-5%
Partial	4	23	0.004	0.001	NA
Total	**955**	**18244**	**1.000**	**1.000**	**0%**

Crashes by main flow code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Two-Way Traffic - No Left Turns Permitted	38	746	0.040	0.041	-3%
Two-Way Traffic - Left Turns Permitted	860	17057	0.901	0.935	-4%
Two-Way Traffic - Left Turns Peak Hr Rest.	13	33	0.014	0.002	NA
One-Way Traffic	44	382	0.046	0.021	120%
Other	0	26	0.000	0.001	NA
Total	**955**	**18244**	**1.000**	**1.000**	**0%**

Crashes by crossing signal mast arm

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Yes	320	1497	0.335	0.082	308%
No	635	16747	0.665	0.918	-38%
Total	**955**	**18244**	**1.000**	**1.000**	**0%**

Crashes by left crossing channel code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
No Left Turn Channelization	669	16867	0.701	0.925	-32%
Painted Left Turn Channelization	199	1023	0.208	0.056	272%
Curbed Median Left Turn Channelization	84	338	0.088	0.019	375%
Raised Bars - Left Turn Channelization	2	7	0.002	0.000	NA
Yes	1	9	0.001	0.000	NA
Total	**955**	**18244**	**1.000**	**1.000**	**0%**

Crashes by right crossing channel code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Yes	165	1300	0.173	0.071	142%
No	788	16916	0.825	0.927	-12%
Partial	2	28	0.002	0.002	NA
Total	**955**	**18244**	**1.000**	**1.000**	**0%**

Crashes by crossing flow channel code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Two-Way Traffic - No Left Turns Permitted	32	659	0.034	0.036	-8%
Two-Way Traffic - Left Turns Permitted	890	17104	0.932	0.938	-1%
Two-Way Traffic - Left Turns Peak Hr Rest.	3	9	0.003	0.000	NA
One-Way Traffic	28	437	0.029	0.024	NA
Other	2	35	0.002	0.002	NA
Total	**955**	**18244**	**1.000**	**1.000**	**0%**

Crashes by control code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
No Control	4	1931	0.004	0.106	NA
Stop Signs on Cross Street Only	404	13500	0.423	0.740	-75%
Stop Signs on Mainline Only	2	112	0.002	0.006	NA
Four-Way Stop Signs	6	89	0.006	0.005	NA
Four-Way Flasher (Red on Cross Street)	1	50	0.001	0.003	NA
Four-Way Flasher (Red on Mainline)	0	9	0.000	0.000	NA
Four-Way Flasher (Red on All)	1	41	0.001	0.002	NA
Yield Signs (On Cross Street Only)	1	23	0.001	0.001	NA
Yield Signs (On Mainline Only)	0	5	0.000	0.000	NA
Signals Pretimed - 2 Phase	89	325	0.093	0.018	423%
Signals Pretimed - Multi-Phase	18	58	0.019	0.003	NA
Signals Semi-Traffic Actuated - 2 Phase	26	136	0.027	0.007	NA
Signals Semi-Traffic Actuated - Multi Phase	14	97	0.015	0.005	NA
Singals Full-Traffic Actuated - 2 Phase	72	260	0.075	0.014	429%
Singals Full-Traffic Actuated - Multi Phase	315	1576	0.330	0.086	282%
Other	2	32	0.002	0.002	NA
Signalized	534	2452	0.559	0.134	316%
Four-Way Flasher	2	91	0.002	0.005	NA
Total	**955**	**18244**	**1.000**	**1.000**	**0%**

Crashes by number of lanes on main street

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
1	0	1	0.000	0.000	NA
2	203	11260	0.213	0.617	-190%
3	32	525	0.034	0.029	16%
4	493	5225	0.516	0.286	80%
5	20	156	0.021	0.009	NA
6	182	975	0.191	0.053	257%
7	0	11	0.000	0.001	NA
8	25	90	0.026	0.005	NA
12	0	1	0.000	0.000	NA
blank			0.000		NA
Total	**955**	**18244**	**1.000**	**1.000**	**0%**

Crashes by number of lanes on crossing street

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
0	0	4	0.000	0.000	NA
1	6	760	0.006	0.042	NA
2	698	16517	0.731	0.905	-24%
3	31	168	0.032	0.009	253%
4	198	708	0.207	0.039	434%
5	8	19	0.008	0.001	NA
6	11	52	0.012	0.003	NA
7	0	1	0.000	0.000	NA
8	0	3	0.000	0.000	NA
Null	3	0	0.003	0.000	NA
blank	0	12	0.000	0.001	NA
Total	**955**	**18244**	**1.000**	**1.000**	**0%**

Crashes by highway group

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Undivided Highway	408	11700	0.427	0.641	-50%
Independent Alignment - Left	23	187	0.024	0.010	NA
Divided Highway	504	6182	0.528	0.339	56%
Independent Alignment - Right	18	175	0.019	0.010	NA
Null or blank	2	0	0.002	0.000	NA
Total	**955**	**18244**	**1.000**	**1.000**	**0%**

Crashes by mainline ADT

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
<10,000	75	8552	0.079	0.469	-497%
10,000 to 20,000	202	4099	0.212	0.225	-6%
20,000 to 30,000	229	2443	0.240	0.134	79%
30,000+	449	3150	0.470	0.173	172%
(blank)			0.000		NA
Total	**955**	**18244**	**1.000**	**1.000**	**0%**

Crashes by crossing ADT

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
<10,000	798	17415	0.836	0.966	-14%
10,000 to 20,000	104	428	0.109	0.024	364%
20,000 to 30,000	43	116	0.045	0.006	608%
30,000+	10	60	0.010	0.003	NA
(blank)		225			NA
Total	**955**	**18244**	**1.000**	**1.000**	**0%**

Appendix 5-F: Intersections – Urban

Crashes by design code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Four-Legged	460	2411	0.672	0.409	64%
Multi-Legged	12	77	0.018	0.013	NA
Offset	46	315	0.067	0.053	26%
Tee	149	2860	0.218	0.485	-123%
WYE	8	164	0.012	0.028	NA
Other	10	67	0.015	0.011	NA
Total	**685**	**5894**	**1.000**	**1.000**	**0%**

Crashes by presence of lighting

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Yes	659	4919	0.962	0.835	15%
No	26	975	0.038	0.165	NA
Total	**685**	**5894**	**1.000**	**1.000**	**0%**

Crashes by main signal mast arm

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Yes	407	1786	0.594	0.303	96%
No	278	4108	0.406	0.697	-72%
Total	**685**	**5894**	**1.000**	**1.000**	**0%**

Crashes by main left channel code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
No Left Turn Channelization	160	2309	0.234	0.392	-68%
Painted Left Turn Channelization	232	2096	0.339	0.356	-5%
Curbed Median Left Turn Channelization	293	1475	0.428	0.250	71%
Raised Bars - Left Turn Channelization	0	12	0.000	0.002	NA
Yes	0	2	0.000	0.000	NA
Total	**685**	**5894**	**1.000**	**1.000**	**0%**

Crashes by main right channel code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Yes	96	703	0.140	0.119	17%
No	586	5180	0.855	0.879	-3%
Partial	3	11	0.004	0.002	NA
Total	**685**	**5894**	**1.000**	**1.000**	**0%**

Crashes by main flow code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Two-Way Traffic - No Left Turns Permitted	36	637	0.053	0.108	-106%
Two-Way Traffic - Left Turns Permitted	609	4949	0.889	0.840	6%
Two-Way Traffic - Left Turns Peak Hr Rest.	13	31	0.019	0.005	NA
One-Way Traffic	27	261	0.039	0.044	NA
Other	0	16	0.000	0.003	NA
Total	**685**	**5894**	**1.000**	**1.000**	**0%**

Crashes by crossing signal mast arm

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Yes	267	1140	0.390	0.193	102%
No	418	4754	0.610	0.807	-32%
Total	**685**	**5894**	**1.000**	**1.000**	**0%**

Crashes by left crossing channel code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
No Left Turn Channelization	441	4899	0.644	0.831	-29%
Painted Left Turn Channelization	159	693	0.232	0.118	97%
Curbed Median Left Turn Channelization	83	295	0.121	0.050	142%
Raised Bars - Left Turn Channelization	2	6	0.003	0.001	NA
Yes	0	1	0.000	0.000	NA
Total	**685**	**5894**	**1.000**	**1.000**	**0%**

Crashes by right crossing channel code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Yes	133	754	0.194	0.128	52%
No	551	5121	0.804	0.869	-8%
Partial	1	19	0.001	0.003	NA
Total	**685**	**5894**	**1.000**	**1.000**	**0%**

Crashes by crossing flow channel code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Two-Way Traffic - No Left Turns Permitted	30	581	0.044	0.099	-125%
Two-Way Traffic - Left Turns Permitted	627	5030	0.915	0.853	7%
Two-Way Traffic - Left Turns Peak Hr Rest.	3	8	0.004	0.001	NA
One-Way Traffic	23	243	0.034	0.041	NA
Other	2	32	0.003	0.005	NA
Total	**685**	**5894**	**1.000**	**1.000**	**0%**

Crashes by control code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
No Control	2	238	0.003	0.040	NA
Stop Signs on Cross Street Only	223	3637	0.326	0.617	-90%
Stop Signs on Mainline Only	1	14	0.001	0.002	NA
Four-Way Stop Signs	2	25	0.003	0.004	NA
Four-Way Flasher (Red on Cross Street)	0	7	0.000	0.001	NA
Four-Way Flasher (Red on Mainline)	0	0	0.000	0.000	NA
Four-Way Flasher (Red on All)	0	5	0.000	0.001	NA
Yield Signs (On Cross Street Only)	0	4	0.000	0.001	NA
Yield Signs (On Mainline Only)	0	2	0.000	0.000	NA
Signals Pretimed - 2 Phase	85	302	0.124	0.051	142%
Signals Pretimed - Multi-Phase	17	49	0.025	0.008	NA
Signals Semi-Traffic Actuated - 2 Phase	25	123	0.036	0.021	NA
Signals Semi-Traffic Actuated - Multi Phase	13	85	0.019	0.014	NA
Singals Full-Traffic Actuated - 2 Phase	58	196	0.085	0.033	155%
Singals Full-Traffic Actuated - Multi Phase	257	1197	0.375	0.203	85%
Other	2	10	0.003	0.002	NA
Signalized	455	1952	0.664	0.331	101%
Four-Way Flasher	0	12	0.000	0.002	NA
Total	**685**	**5894**	**1.000**	**1.000**	**0%**

Crashes by number of lanes on main street

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
1	0	1	0.000	0.000	NA
2	56	1217	0.082	0.206	-153%
3	22	236	0.032	0.040	NA
4	381	3228	0.556	0.548	2%
5	19	140	0.028	0.024	NA
6	182	970	0.266	0.165	61%
7	0	11	0.000	0.002	NA
8	25	90	0.036	0.015	NA
12	0	1	0.000	0.000	NA
blank		0			NA
Total	**685**	**5894**	**1.000**	**1.000**	**0%**

Crashes by number of lanes on crossing street

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
1	1	161	0.001	0.027	NA
2	452	4894	0.660	0.832	-26%
3	27	139	0.039	0.024	NA
4	185	615	0.270	0.105	158%
5	8	19	0.012	0.003	NA
6	11	50	0.016	0.009	NA
7	0	1	0.000	0.000	NA
8	0	3	0.000	0.001	NA
Null	1	0	0.001	0.000	NA
blank		12			NA
Total	**685**	**5894**	**1.000**	**1.000**	**0%**

Crashes by highway group

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Undivided Highway	210	1697	0.307	0.288	7%
Independent Alignment - Left	18	127	0.026	0.022	NA
Divided Highway	450	3956	0.658	0.671	-2%
Independent Alignment - Right	6	114	0.009	0.019	NA
Null or blank	1	0			NA
Total	**685**	**5894**	**1.000**	**1.000**	**0%**

Crashes by mainline ADT

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
<10,000	13	423	0.019	0.072	NA
10,000 to 20,000	82	1258	0.120	0.213	-78%
20,000 to 30,000	165	1478	0.241	0.251	-4%
30,000+	425	2735	0.620	0.464	34%
(blank)		0			NA
Total	**685**	**5894**	**1.000**	**1.000**	**0%**

Crashes by crossing ADT

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
<10,000	538	5351	0.785	0.908	-16%
10,000 to 20,000	95	344	0.139	0.058	138%
20,000 to 30,000	42	103	0.061	0.017	251%
30,000+	10	52	0.015	0.009	NA
(blank)		0			NA
Total	**685**	**5894**	**1.000**	**1.000**	**0%**

Appendix 5-G: Intersections – Urbanized

Crashes by design code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Four-Legged	110	901	0.636	0.393	62%
Multi-Legged	2	26	0.012	0.011	NA
Offset	19	119	0.110	0.052	NA
Tee	41	1136	0.237	0.495	-109%
WYE	1	91	0.006	0.040	NA
Other	0	21	0.000	0.009	NA
Total	**173**	**2294**	**1.000**	**1.000**	**0%**

Crashes by presence of lighting

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Yes	160	1646	0.925	0.718	29%
No	13	648	0.075	0.282	NA
Total	**173**	**2294**	**1.000**	**1.000**	**0%**

Crashes by main signal mast arm

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Yes	55	294	0.318	0.128	148%
No	118	2000	0.682	0.872	-28%
Total	**173**	**2294**	**1.000**	**1.000**	**0%**

Crashes by main left channel code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
No Left Turn Channelization	69	1251	0.399	0.545	-37%
Painted Left Turn Channelization	92	916	0.532	0.399	33%
Curbed Median Left Turn Channelization	12	121	0.069	0.053	NA
Raised Bars - Left Turn Channelization	0	1	0.000	0.000	NA
Yes	0	5	0.000	0.002	NA
Total	**173**	**2294**	**1.000**	**1.000**	**0%**

Crashes by main right channel code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Yes	24	215	0.139	0.094	NA
No	149	2074	0.861	0.904	-5%
Partial	0	5	0.000	0.002	NA
Total	**173**	**2294**	**1.000**	**1.000**	**0%**

Crashes by main flow code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Two-Way Traffic - No Left Turns Permitted	2	37	0.012	0.016	NA
Two-Way Traffic - Left Turns Permitted	155	2181	0.896	0.951	-6%
Two-Way Traffic - Left Turns Peak Hr Rest.	0	0	0.000	0.000	NA
One-Way Traffic	16	71	0.092	0.031	NA
Other	0	5	0.000	0.002	NA
Total	**173**	**2294**	**1.000**	**1.000**	**0%**

Crashes by crossing signal mast arm

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Yes	40	208	0.231	0.091	155%
No	133	2086	0.769	0.909	-18%
Total	**173**	**2294**	**1.000**	**1.000**	**0%**

Crashes by left crossing channel code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
No Left Turn Channelization	143	2124	0.827	0.926	-12%
Painted Left Turn Channelization	30	145	0.173	0.063	174%
Curbed Median Left Turn Channelization	0	21	0.000	0.009	NA
Raised Bars - Left Turn Channelization	0	0	0.000	0.000	NA
Yes	0	4	0.000	0.002	NA
Total	**173**	**2294**	**1.000**	**1.000**	**0%**

Crashes by right crossing channel code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Yes	21	158	0.121	0.069	NA
No	152	2136	0.879	0.931	-6%
Partial	0	0	0.000	0.000	NA
Total	**173**	**2294**	**1.000**	**1.000**	**0%**

Crashes by crossing flow channel code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Two-Way Traffic - No Left Turns Permitted	2	26	0.012	0.011	NA
Two-Way Traffic - Left Turns Permitted	166	2194	0.960	0.956	0%
Two-Way Traffic - Left Turns Peak Hr Rest.	0	0	0.000	0.000	NA
One-Way Traffic	5	72	0.029	0.031	NA
Other	0	2	0.000	0.001	NA
Total	**173**	**2294**	**1.000**	**1.000**	**0%**

Crashes by control code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
No Control	1	100	0.006	0.044	NA
Stop Signs on Cross Street Only	105	1811	0.607	0.789	-30%
Stop Signs on Mainline Only	1	13	0.006	0.006	NA
Four-Way Stop Signs	4	32	0.023	0.014	NA
Four-Way Flasher (Red on Cross Street)	0	3	0.000	0.001	NA
Four-Way Flasher (Red on Mainline)	0	1	0.000	0.000	NA
Four-Way Flasher (Red on All)	1	9	0.006	0.004	NA
Yield Signs (On Cross Street Only)	0	7	0.000	0.003	NA
Yield Signs (On Mainline Only)	0	1	0.000	0.000	NA
Signals Pretimed - 2 Phase	4	23	0.023	0.010	NA
Signals Pretimed - Multi-Phase	0	6	0.000	0.003	NA
Signals Semi-Traffic Actuated - 2 Phase	1	13	0.006	0.006	NA
Signals Semi-Traffic Actuated - Multi Phase	1	4	0.006	0.002	NA
Singals Full-Traffic Actuated - 2 Phase	12	44	0.069	0.019	NA
Singals Full-Traffic Actuated - Multi Phase	43	221	0.249	0.096	158%
Other	0	6	0.000	0.003	NA
Total	**173**	**2294**	**1.000**	**1.000**	**0%**

Crashes by number of lanes on main street

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
1	0	0	0.000	0.000	NA
2	78	1309	0.451	0.571	-27%
3	9	81	0.052	0.035	NA
4	86	900	0.497	0.392	27%
5	0	4	0.000	0.002	NA
6	0	0	0.000	0.000	NA
7	0	0	0.000	0.000	NA
8	0	0	0.000	0.000	NA
12	0	0	0.000	0.000	NA
blank		0			NA
Total	**173**	**2294**	**1.000**	**1.000**	**0%**

Crashes by number of lanes on crossing street

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
0	0	0	0.000	0.000	NA
1	4	50	0.023	0.022	NA
2	154	2176	0.890	0.949	-7%
3	3	16	0.017	0.007	NA
4	10	49	0.058	0.021	NA
5	0	0	0.000	0.000	NA
6	0	1	0.000	0.000	NA
7	0	0	0.000	0.000	NA
8	0	0	0.000	0.000	NA
<Null>	2	0	0.012	0.000	NA
blank		2			NA
Total	**173**	**2294**	**1.000**	**1.000**	**0%**

Crashes by highway group

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Undivided Highway	117	1382	0.676	0.602	12%
Independent Alignment - Left	5	32	0.029	0.014	NA
Divided Highway	40	843	0.231	0.367	-59%
Independent Alignment - Right	11	37	0.064	0.016	NA
Null or blank		0			NA
Total	**173**	**2294**	**1.000**	**1.000**	**0%**

Crashes by mainline ADT

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
<10,000	23	715	0.133	0.312	NA
10,000 to 20,000	77	904	0.445	0.394	13%
20,000 to 30,000	52	453	0.301	0.197	52%
30,000+	21	222	0.121	0.097	NA
(blank)		0			NA
Total	**173**	**2294**	**1.000**	**1.000**	**0%**

Crashes by crossing ADT

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
<10,000	166	715	0.045	0.312	-134%
10,000 to 20,000	6	904	0.591	0.394	NA
20,000 to 30,000	1	453	0.273	0.197	NA
30,000+	0	222	0.091	0.097	NA
(blank)		0			NA
Total	**173**	**2294**	**1.000**	**1.000**	**0%**

Appendix 5-H: Intersections – Rural

Crashes by design code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Four-Legged	50	2391	0.515	0.238	117%
Multi-Legged	0	62	0.000	0.006	NA
Offset	1	213	0.010	0.021	NA
Tee	39	6493	0.402	0.646	-61%
WYE	6	801	0.062	0.080	NA
Other	1	96	0.010	0.010	NA
Total	**97**	**10056**	**1.000**	**1.000**	**0%**

Crashes by presence of lighting

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Yes	57	2178	0.588	0.217	171%
No	40	7878	0.412	0.783	-90%
Total	**97**	**10056**	**1.000**	**1.000**	**0%**

Crashes by main signal mast arm

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Yes	17	191	0.175	0.019	NA
No	80	9865	0.825	0.981	-19%
Total	**97**	**10056**	**1.000**	**1.000**	**0%**

Crashes by main left channel code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
No Left Turn Channelization	53	7813	0.546	0.777	-42%
Painted Left Turn Channelization	40	2084	0.412	0.207	99%
Curbed Median Left Turn Channelization	3	151	0.031	0.015	NA
Raised Bars - Left Turn Channelization	0	4	0.000	0.000	NA
Yes	1	4	0.010	0.000	NA
Total	**97**	**10056**	**1.000**	**1.000**	**0%**

Crashes by main right channel code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Yes	14	884	0.144	0.088	NA
No	82	9165	0.845	0.911	-8%
Partial	1	7	0.010	0.001	NA
Total	**97**	**10056**	**1.000**	**1.000**	**0%**

Crashes by main flow code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Two-Way Traffic - No Left Turns Permitted	0	72	0.000	0.007	NA
Two-Way Traffic - Left Turns Permitted	96	9927	0.990	0.987	0%
Two-Way Traffic - Left Turns Peak Hr Rest.	0	2	0.000	0.000	NA
One-Way Traffic	1	50	0.010	0.005	NA
Other	0	5	0.000	0.000	NA
Total	**97**	**10056**	**1.000**	**1.000**	**0%**

Crashes by crossing signal mast arm

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Yes	13	149	0.134	0.015	NA
No	84	9907	0.866	0.985	-14%
Total	**97**	**10056**	**1.000**	**1.000**	**0%**

Crashes by left crossing channel code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
No Left Turn Channelization	85	9844	0.876	0.979	-12%
Painted Left Turn Channelization	10	185	0.103	0.018	NA
Curbed Median Left Turn Channelization	1	22	0.010	0.002	NA
Raised Bars - Left Turn Channelization	0	1	0.000	0.000	NA
Yes	1	4	0.010	0.000	NA
Total	**97**	**10056**	**1.000**	**1.000**	**0%**

Crashes by right crossing channel code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Yes	11	388	0.113	0.039	NA
No	85	9659	0.876	0.961	-10%
Partial	1	9	0.010	0.001	NA
Total	**97**	**10056**	**1.000**	**1.000**	**0%**

Crashes by crossing flow channel code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Two-Way Traffic - No Left Turns Permitted	0	52	0.000	0.005	NA
Two-Way Traffic - Left Turns Permitted	97	9880	1.000	0.982	2%
Two-Way Traffic - Left Turns Peak Hr Rest.	0	1	0.000	0.000	NA
One-Way Traffic	0	122	0.000	0.012	NA
Other	0	1	0.000	0.000	NA
Total	**97**	**10056**	**1.000**	**1.000**	**0%**

Crashes by control code

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
No Control	1	1593	0.010	0.158	NA
Stop Signs on Cross Street Only	76	8052	0.784	0.801	-2%
Stop Signs on Mainline Only	0	85	0.000	0.008	NA
Four-Way Stop Signs	0	32	0.000	0.003	NA
Four-Way Flasher (Red on Cross Street)	1	40	0.010	0.004	NA
Four-Way Flasher (Red on Mainline)	0	8	0.000	0.001	NA
Four-Way Flasher (Red on All)	0	27	0.000	0.003	NA
Yield Signs (On Cross Street Only)	1	12	0.010	0.001	NA
Yield Signs (On Mainline Only)	0	2	0.000	0.000	NA
Signals Pretimed - 2 Phase	0	0	0.000	0.000	NA
Signals Pretimed - Multi-Phase	1	3	0.010	0.000	NA
Signals Semi-Traffic Actuated - 2 Phase	0	0	0.000	0.000	NA
Signals Semi-Traffic Actuated - Multi Phase	0	8	0.000	0.001	NA
Singals Full-Traffic Actuated - 2 Phase	2	20	0.021	0.002	NA
Singals Full-Traffic Actuated - Multi Phase	15	158	0.155	0.016	NA
Other	0	16	0.000	0.002	NA
Total	**97**	**10056**	**1.000**	**1.000**	**0%**

Crashes by number of lanes on main street

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
1	0	0	0.000	0.000	NA
2	69	8734	0.711	0.869	-22%
3	1	208	0.010	0.021	NA
4	26	1097	0.268	0.109	NA
5	1	12	0.010	0.001	NA
6	0	5	0.000	0.000	NA
7	0	0	0.000	0.000	NA
8	0	0	0.000	0.000	NA
12	0	0	0.000	0.000	NA
blank		0			NA
Total	**97**	**10056**	**1.000**	**1.000**	**0%**

Crashes by number of lanes on crossing street

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
0	0	2	0.000	0.000	NA
1	1	549	0.010	0.055	NA
2	92	9447	0.948	0.939	1%
3	1	13	0.010	0.001	NA
4	3	44	0.031	0.004	NA
5	0	0	0.000	0.000	NA
6	0	1	0.000	0.000	NA
7	0	0	0.000	0.000	NA
8	0	0	0.000	0.000	NA
blank		0			NA
Total	**97**	**10056**	**1.000**	**1.000**	**0%**

Crashes by highway group

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
Undivided Highway	81	8621	0.835	0.857	-3%
Independent Alignment - Left	0	28	0.000	0.003	NA
Divided Highway	14	1383	0.144	0.138	5%
Independent Alignment - Right	1	24	0.010	0.002	NA
Null or blank	1	0	0.010	0.000	NA
Total	**97**	**10056**	**1.000**	**1.000**	**0%**

Crashes by mainline ADT

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
<10,000	39	7414	0.402	0.737	-83%
10,000 to 20,000	43	1937	0.443	0.193	130%
20,000 to 30,000	12	512	0.124	0.051	NA
30,000+	3	193	0.031	0.019	NA
(blank)		0			NA
Total	**97**	**10056**	**1.000**	**1.000**	**0%**

Crashes by crossing ADT

	Total crashes on state highway system	Number of intersections in state highway system	A. Proportion of crashes	B. Proportion of state highway intersections	Relationship between A and B
<10,000	94	9833	0.969	0.978	-1%
10,000 to 20,000	3	42	0.031	0.004	NA
20,000 to 30,000	0	6	0.000	0.001	NA
30,000+	0	4	0.000	0.000	NA
(blank)		171			NA
Total	**97**	**10056**	**1.000**	**1.000**	**0%**

Appendix 5-I: Ramps – All

Crashes by ramp type

	Total crashes on state highway system	Number of ramps in state highway system	A. Proportion of crashes	B. Proportion of state highway ramps	Relationship between A and B
Frontage Road	2	30	0.002	0.002	NA
Collector Road	4	137	0.004	0.009	NA
Direct or Semi-Direct Connector (Left)	43	544	0.038	0.037	2%
Diamond Type Ramp	723	6412	0.641	0.440	46%
Slip Ramp	9	333	0.008	0.023	NA
Direct or Semi-Direct Connector (Right)	143	2045	0.127	0.140	-11%
Loop-w/Left Turn	32	603	0.028	0.041	-46%
Buttonhook Ramp	46	1187	0.041	0.082	-100%
Scissors Ramp	17	330	0.015	0.023	NA
Split Ramp	47	926	0.042	0.064	-53%
Loop-w/o Left Turn	49	1237	0.043	0.085	-96%
Two-Way Ramp Segment	2	34	0.002	0.002	NA
Rest Area, Vista Point, Truck Scale	5	336	0.004	0.023	NA
Other	6	168	0.005	0.012	NA
Dummy-Paired	0	138	0.000	0.009	NA
Dummy-Volume Only	0	97	0.000	0.007	NA
Total	**1128**	**14557**	**1.000**	**1.000**	**0%**

Crashes by on/off indicator

	Total crashes on state highway system	Number of ramps in state highway system	A. Proportion of crashes	B. Proportion of state highway ramps	Relationship between A and B
On	386	7282	0.342	0.500	-46%
Off	734	7090	0.651	0.487	34%
Other	8	185	0.007	0.013	NA
Total	**1128**	**14557**	**1.000**	**1.000**	**0%**

Crashes by Area 4

	Total crashes on state highway system	Number of ramps in state highway system	A. Proportion of crashes	B. Proportion of state highway ramps	Relationship between A and B
No	93	2159	0.082	0.148	-80%
Yes	1035	12398	0.918	0.852	8%
Total	**1128**	**14557**	**1.000**	**1.000**	**0%**

Crashes by ADT

	Total crashes on state highway system	Number of ramps in state highway system	A. Proportion of crashes	B. Proportion of state highway ramps	Relationship between A and B
<10,000	647	10813	0.581	0.758	-30%
10,000 to 20,000	355	2378	0.319	0.167	91%
20,000 to 30,000	77	573	0.069	0.040	72%
30,000 +	34	501	0.031	0.035	-15%
Blank	15	292			NA
Total	**1128**	**14557**	**1.000**	**1.000**	**0%**

Appendix 5-J: Ramps – Urban

Crashes by design code

	Total crashes on state highway system	Number of ramps in state highway system	A. Proportion of crashes	B. Proportion of state highway ramps	Relationship between A and B
Frontage Road	1	23	0.001	0.002	NA
Collector Road	4	137	0.004	0.013	NA
Direct or Semi-Direct Connector (Left)	41	483	0.039	0.045	-15%
Diamond Type Ramp	661	3960	0.634	0.370	71%
Slip Ramp	9	323	0.009	0.030	NA
Direct or Semi-Direct Connector (Right)	140	1775	0.134	0.166	-23%
Loop-w/Left Turn	28	437	0.027	0.041	NA
Buttonhook Ramp	41	849	0.039	0.079	-102%
Scissors Ramp	12	228	0.012	0.021	NA
Split Ramp	47	909	0.045	0.085	-88%
Loop-w/o Left Turn	49	1123	0.047	0.105	-123%
Two-Way Ramp Segment	2	18	0.002	0.002	NA
Rest Area, Vista Point, Truck Scale	2	90	0.002	0.008	NA
Other	6	142	0.006	0.013	NA
Dummy-Paired	0	135	0.000	0.013	NA
Dummy-Volume Only	0	81	0.000	0.008	NA
Total	**1043**	**10713**	**1.000**	**1.000**	**0%**

Crashes by on/off

	Total crashes on state highway system	Number of ramps in state highway system	A. Proportion of crashes	B. Proportion of state highway ramps	Relationship between A and B
On	350	5361	0.336	0.500	-49%
Off	686	5193	0.658	0.485	36%
Other	7	159	0.007	0.015	NA
Total	**1043**	**10713**	**1.000**	**1.000**	**0%**

Crashes by Area 4 code

	Total crashes on state highway system	Number of ramps in state highway system	A. Proportion of crashes	B. Proportion of state highway ramps	Relationship between A and B
No	81	1665	0.078	0.155	-100%
Yes	962	9048	0.922	0.845	9%
Total	**1043**	**10713**	**1.000**	**1.000**	**0%**

Crashes by ADT

	Total crashes on state highway system	Number of ramps in state highway system	A. Proportion of crashes	B. Proportion of state highway ramps	Relationship between A and B
<10,000	571	7105	0.555	0.679	-22%
10,000 to 20,000	348	2298	0.339	0.220	54%
20,000 to 30,000	75	567	0.073	0.054	35%
30,000 +	34	496	0.033	0.047	-43%
Blank	15	247			NA
Total	**1043**	**10713**	**1.000**	**1.000**	**0%**

Appendix 5-K: Ramps – Urbanized

Crashes by design code

	Total crashes on state highway system	Number of ramps in state highway system	A. Proportion of crashes	B. Proportion of state highway ramps	Relationship between A and B
Frontage Road	1	6	0.017	0.006	NA
Collector Road	0	0	0.000	0.000	NA
Direct or Semi-Direct Connector (Left)	1	19	0.017	0.019	NA
Diamond Type Ramp	46	622	0.767	0.632	21%
Slip Ramp	0	8	0.000	0.008	NA
Direct or Semi-Direct Connector (Right)	1	71	0.017	0.072	NA
Loop-w/Left Turn	3	55	0.050	0.056	NA
Buttonhook Ramp	2	118	0.033	0.120	NA
Scissors Ramp	5	30	0.083	0.030	NA
Split Ramp	0	10	0.000	0.010	NA
Loop-w/o Left Turn	0	30	0.000	0.030	NA
Two-Way Ramp Segment	0	3	0.000	0.003	NA
Rest Area, Vista Point, Truck Scale	1	8	0.017	0.008	NA
Other	0	2	0.000	0.002	NA
Dummy-Paired	0	0	0.000	0.000	NA
Dummy-Volume Only	0	2	0.000	0.002	NA
Total	**60**	**984**	**1.000**	**1.000**	**0%**

Crashes by on/off

	Total crashes on state highway system	Number of ramps in state highway system	A. Proportion of crashes	B. Proportion of state highway ramps	Relationship between A and B
On	28	497	0.467	0.505	NA
Off	31	478	0.517	0.486	6%
Other	1	9	0.017	0.009	NA
Total	**60**	**984**	**1.000**	**1.000**	**0%**

Crashes by Area 4 code

	Total crashes on state highway system	Number of ramps in state highway system	A. Proportion of crashes	B. Proportion of state highway ramps	Relationship between A and B
No	9	143	0.150	0.145	NA
Yes	51	841	0.850	0.855	-1%
Total	**60**	**984**	**1.000**	**1.000**	**0%**

Crashes by ADT

	Total crashes on state highway system	Number of ramps in state highway system	A. Proportion of crashes	B. Proportion of state highway ramps	Relationship between A and B
<10,000	52	920	0.867	0.947	-9%
10,000 to 20,000	6	45	0.100	0.046	NA
20,000 to 30,000	2	5	0.033	0.005	NA
30,000 +	0	2	0.000	0.002	NA
Blank	0	12			NA
Total	**60**	**984**	**1.000**	**1.000**	**0%**

Appendix 5-L: Ramps – Rural

Crashes by design code

	Total crashes on state highway system	Number of ramps in state highway system	A. Proportion of crashes	B. Proportion of state highway ramps	Relationship between A and B
Frontage Road	0	1	0.000	0.000	NA
Collector Road	0	0	0.000	0.000	NA
Direct or Semi-Direct Connector (Left)	1	42	0.040	0.015	NA
Diamond Type Ramp	16	1830	0.640	0.640	NA
Slip Ramp	0	2	0.000	0.001	NA
Direct or Semi-Direct Connector (Right)	2	199	0.080	0.070	NA
Loop-w/Left Turn	1	111	0.040	0.039	NA
Buttonhook Ramp	3	220	0.120	0.077	NA
Scissors Ramp	0	72	0.000	0.025	NA
Split Ramp	0	7	0.000	0.002	NA
Loop-w/o Left Turn	0	84	0.000	0.029	NA
Two-Way Ramp Segment	0	13	0.000	0.005	NA
Rest Area, Vista Point, Truck Scale	2	238	0.080	0.083	NA
Other	0	24	0.000	0.008	NA
Dummy-Paired	0	3	0.000	0.001	NA
Dummy-Volume Only	0	14	0.000	0.005	NA
Total	**25**	**2860**	**1.000**	**1.000**	**NA**

Crashes by on/off

	Total crashes on state highway system	Number of ramps in state highway system	A. Proportion of crashes	B. Proportion of state highway ramps	Relationship between A and B
On	8	1424	0.320	0.498	NA
Off	17	1419	0.680	0.496	NA
Other	0	17	0.000	0.006	NA
Total	**25**	**2860**	**1.000**	**1.000**	**NA**

Crashes by Area 4 code

	Total crashes on state highway system	Number of ramps in state highway system	A. Proportion of crashes	B. Proportion of state highway ramps	Relationship between A and B
No	3	351	0.120	0.123	NA
Yes	22	2509	0.880	0.877	NA
Total	**25**	**2860**	**1.000**	**1.000**	**NA**

Crashes by ADT

	Total crashes on state highway system	Number of ramps in state highway system	A. Proportion of crashes	B. Proportion of state highway ramps	Relationship between A and B
<10,000	24	2788	0.960	0.986	NA
10,000 to 20,000	1	35	0.040	0.012	NA
20,000 to 30,000	0	1	0.000	0.000	NA
30,000 +	0	3	0.000	0.001	NA
Blank		33			NA
Total	**25**	**2860**	**1.000**	**1.000**	**NA**

Appendix 5-M: Fatality Index of Highways – All

Crashes by number of lanes, left side

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
1	464	72%	13%	-27%
2	1026	75%	13%	-18%
3	538	72%	12%	-28%
4	390	56%	24%	53%
5	234	47%	26%	61%
6+	78	65%	21%	29%
zero, blank				NA
Total	**2730**	**69%**	**16%**	**0%**

Crashes by number of lanes, right side

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
1	483	67%	12%	-35%
2	993	75%	14%	-17%
3	570	73%	16%	-1%
4	393	59%	21%	28%
5	210	50%	24%	47%
6+	98	53%	29%	73%
zero, blank				NA
Total	**2747**	**68%**	**17%**	**0%**

Crashes by lanes on side of crash

	Total crashes on state highway system			Relationship between fatalities and total crashes
1	947	69%	12%	-31%
2	2019	75%	14%	-18%
3	1108	73%	14%	-12%
4	783	57%	23%	40%
5	444	49%	25%	54%
6+	176	59%	25%	54%
zero, blank				NA
Total	**5477**	**68%**	**16%**	**0%**

Crashes by outside shoulder total width, left side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	212	80%	7%	-141%
1--2	141	67%	11%	-49%
3--4	184	76%	10%	-63%
5--6	113	72%	13%	-20%
7--8	1052	73%	14%	-11%
9--10	863	58%	23%	43%
11+	165	76%	16%	-1%
Blank				NA
Total	**2730**	**69%**	**16%**	**0%**

Crashes by outside shoulder total width, right side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	223	76%	11%	-54%
1--2	144	72%	9%	-83%
3--4	164	71%	9%	-81%
5--6	101	71%	16%	-4%
7--8	1064	73%	16%	-1%
9--10	882	61%	20%	23%
11+	169	62%	20%	18%
Blank				NA
Total	**2747**	**68%**	**17%**	**0%**

Crashes by outside shoulder treated width, left side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	308	73%	8%	-96%
1--2	138	70%	14%	-10%
3--4	198	77%	11%	-50%
5--6	74	77%	9%	-68%
7--8	1023	72%	15%	-6%
9--10	900	59%	22%	40%
11+	89	84%	8%	-102%
Blank				NA
Total	**2730**	**69%**	**16%**	**0%**

Crashes by outside shoulder treated width, right side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	320	70%	12%	-39%
1--2	146	73%	12%	-34%
3--4	159	72%	12%	-38%
5--6	72	81%	11%	-49%
7--8	1042	72%	16%	-2%
9--10	913	60%	21%	25%
11+	95	73%	14%	-21%
Blank				NA
Total	**2747**	**68%**	**17%**	**0%**

Crashes by travel way width, left side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0--12	414	71%	13%	-24%
13--24	956	75%	14%	-13%
25--36	605	74%	12%	-34%
37--48	421	58%	23%	42%
49+	334	52%	24%	51%
Blank				NA
Total	**2730**	**69%**	**16%**	**0%**

Crashes by travel way width, right side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0--12	431	67%	12%	-37%
13--24	930	74%	15%	-11%
25--36	622	74%	15%	-9%
37--48	420	62%	20%	21%
49+	344	52%	25%	50%
Blank				NA
Total	**2747**	**68%**	**17%**	**0%**

Crashes by inside shoulder total width, left side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	1506	78%	10%	-60%
1--2	201	62%	17%	6%
3--4	90	48%	20%	26%
5--6	356	56%	26%	61%
7--8	347	56%	25%	60%
9--10	168	58%	23%	42%
11+	62	58%	24%	52%
Blank				NA
Total	**2730**	**69%**	**16%**	**0%**

Crashes by inside shoulder total width, right side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	1491	76%	12%	-42%
1--2	211	68%	16%	-6%
3--4	73	63%	18%	8%
5--6	367	57%	25%	48%
7--8	381	56%	24%	48%
9--10	140	56%	25%	51%
11+	84	61%	20%	22%
Blank				NA
Total	**2747**	**68%**	**17%**	**0%**

Crashes by inside shoulder treated width, left side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	1506	78%	10%	-60%
1--2	317	59%	21%	31%
3--4	86	48%	20%	24%
5--6	260	58%	23%	48%
7--8	338	55%	26%	66%
9--10	162	59%	22%	40%
11+	61	57%	25%	55%
Blank				NA
Total	**2730**	**69%**	**16%**	**0%**

Crashes by inside shoulder treated width, right side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	1491	76%	12%	-42%
1--2	337	64%	20%	18%
3--4	74	62%	19%	14%
5--6	264	57%	25%	49%
7--8	365	56%	24%	44%
9--10	138	57%	25%	49%
11+	78	63%	19%	16%
Blank				NA
Total	**2747**	**68%**	**17%**	**0%**

Crashes by median type

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Not Striped or Separated	1	100%	NA	NA
Striped	1151	73%	11%	-47%
Reversible Peak Hour Lane(s) - Undivided	0	NA	NA	NA
Reversible Peak Hour Lane(s) - Divided	0	NA	NA	NA
Two-Way Left Turn Lane	581	79%	12%	-41%
Continuous Left Turn Lane	612	81%	10%	-65%
Paved Median	1658	63%	19%	18%
Unpaved Median	1173	63%	23%	39%
Separate Grades	91	63%	18%	8%
Separate Grades w/ Retaining Wall	5	20%	40%	NA
Sawtooth - Unpaved	0	NA	NA	NA
Sawtooth - Paved	0	NA	NA	NA
Ditch	0	NA	NA	NA
Separate Structure	68	53%	19%	18%
Railroad	55	58%	18%	12%
Bus Lanes	3	33%	67%	NA
Paved Area Occasional Traffic Lane	0	NA	NA	NA
Railroad & Bus Lanes	0	NA	NA	NA
Contains Reversible Pk Hr Ln(s)	12	58%	17%	NA
Other	67	79%	13%	-21%
Blank				NA
Total	**5477**	**68%**	**16%**	**0%**

Crashes by median curb and landscape

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Curbed Median	576	77%	13%	-28%
Curbed Median with Trees	301	82%	9%	-81%
Curbed Median with Shrubs	146	84%	8%	-97%
Raised Traffic Bars	10	80%	10%	NA
Median with Trees	36	61%	22%	37%
Median with Shrubs	324	50%	33%	102%
No Curbs or Shrubs/No Median	4084	67%	16%	0%
Blank				NA
Total	**5477**	**68%**	**16%**	**0%**

Crashes by type of median barrier

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Cable Barrier	27	26%	44%	NA
Cable Barrier w/ Glare Screen	10	60%	NA	NA
Metal Beam Barrier	111	59%	19%	17%
Metal Beam Barrier w/ Glare Screen	141	52%	26%	62%
Concrete Barrier	695	55%	24%	50%
Concrete Barrier w/ Glare Screen	411	54%	21%	32%
Bridge Barrier Railing	76	49%	20%	22%
Chain Link Fence	14	57%	29%	NA
Guardrail in Median Both Roadway	8	50%	25%	NA
Guardrail in Median Left Roadway	17	47%	35%	NA
Guardrail in Median Right Roadway	6	33%	67%	NA
Two-Way, One Lane Road	0	NA	NA	NA
Thrie Beam Barrier	188	55%	27%	67%
Thrie Beam Barrier w/ Glare Screen	1	100%	NA	NA
Conc. Barrier, Both Ways Inside Both Sh.	71	62%	24%	48%
Conc. Barrier, Left Rdwy Median Sh. Area	13	62%	8%	NA
Conc. Barrier, Right Rdwy Median Sh. Area	3	100%	NA	NA
External Barriers on Median Type = C or E	0	NA	NA	NA
Other Not Included Above	1	NA	NA	NA
No Barriers	3684	75%	13%	-30%
Blank				NA
Total	**5477**	**68%**	**16%**	**0%**

Crashes by median width (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	1152	73%	11%	-47%
1--4	136	88%	4%	-268%
5--8	342	62%	15%	-11%
9--12	1114	75%	14%	-16%
13--16	663	75%	12%	-33%
17--20	217	68%	17%	5%
21--24	527	61%	21%	31%
25--36	353	59%	24%	50%
37+	762	57%	26%	60%
99 (no data)	211	63%	17%	2%
Blank				NA
Total	**5477**	**68%**	**16%**	**0%**

Crashes by median width variance

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Variable	640	69%	16%	1%
No Variance	4674	68%	16%	0%
Over 100' Median & No Var.	163	65%	15%	-10%
Blank				NA
Total	**5477**	**68%**	**16%**	**0%**

Crashes by highway group

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Independent Alignment - Right	66	67%	11%	-53%
Independent Alignment - Left	45	73%	9%	-82%
Divided Highway	4214	67%	18%	10%
Undivided Highway	1152	73%	11%	-47%
Blank				NA
Total	**5477**	**68%**	**16%**	**0%**

Crashes by access code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Conventional	3067	78%	11%	-54%
Expressway	161	66%	20%	26%
Freeway	2213	55%	24%	47%
One-Way City Street	36	86%	8%	-95%
Blank				NA
Total	**5477**	**68%**	**16%**	**0%**

Crashes by design speed

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
25	93	83%	5%	-202%
30	97	91%	4%	-293%
35	355	82%	7%	-121%
40	306	83%	8%	-116%
45	496	80%	8%	-101%
50	689	79%	11%	-51%
55	216	72%	15%	-9%
60	663	74%	14%	-17%
65	425	67%	17%	4%
70	2137	55%	24%	50%
Blank				NA
Total	**5477**	**68%**	**16%**	**0%**

Crashes by functional class

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
None	6	67%	17%	NA
Principal Arterial w/ C/L Prin Arterial	2424	57%	23%	42%
Principal Arterial w/ C/L Minor Arterial	897	78%	11%	-45%
Principal Arterial Non-Connecting Link	1384	82%	9%	-80%
Minor Arterial	690	68%	14%	-18%
Major Collector	74	66%	9%	-71%
Minor Collector	2	50%	NA	NA
Local	0	NA	NA	NA
Blank				NA
Total	**5477**	**68%**	**16%**	**0%**

Crashes by ADT amount

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
<10,000	500	67%	11%	-45%
10,000 to 20,000	710	75%	14%	-20%
20,000 to 30,000	812	79%	10%	-61%
30,000	3455	65%	19%	17%
Blank				NA
Total	**5477**	**68%**	**16%**	**0%**

Crashes by surface type, left side

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
PCC - Bridge Deck	62	52%	16%	1%
PCC - Concrete	794	56%	22%	41%
Earth	0	NA	NA	NA
Undetermined	5	100%	NA	NA
AC - Base & Surface >= 7" Thick	1808	75%	13%	-21%
AC - Base & Surface <7" Thick	56	70%	14%	-11%
AC - Oiled Earth -- Gravel	5	20%	NA	NA
AC - Bridge Deck	0	NA	NA	NA
Blank				NA
Total	**2730**	**69%**	**16%**	**0%**

Crashes by surface type, right side

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
PCC - Bridge Deck	73	49%	22%	33%
PCC - Concrete	821	58%	22%	36%
Earth	1	100%	NA	NA
Undetermined	6	100%	NA	NA
AC - Base & Surface >= 7" Thick	1764	74%	14%	-21%
AC - Base & Surface <7" Thick	75	59%	16%	-3%
AC - Oiled Earth -- Gravel	6	50%	33%	NA
AC - Bridge Deck	1	100%	NA	NA
Blank				NA
Total	**2747**	**68%**	**17%**	**0%**

Appendix 5-N: Fatality Index of Highways – Urban

Crashes by number of lanes, left side

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
1	89	84%	7%	-132%
2	660	79%	11%	-45%
3	501	73%	12%	-33%
4	357	54%	25%	61%
5	228	47%	25%	63%
6+	77	66%	19%	25%
zero, blank				NA
Total	**1912**	**69%**	**16%**	**0%**

Crashes by number of lanes, right side

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
1	85	72%	15%	-8%
2	623	80%	11%	-45%
3	523	74%	14%	-15%
4	344	58%	21%	29%
5	205	51%	24%	45%
6+	96	52%	29%	77%
zero, blank				NA
Total	**1876**	**69%**	**16%**	**0%**

Crashes by lanes on side of crash

	Total crashes on state highway system			Relationship between fatalities and total crashes
1	174	78%	11%	-47%
2	1283	80%	11%	-45%
3	1024	74%	13%	-23%
4	701	56%	23%	45%
5	433	49%	25%	54%
6+	173	58%	25%	55%
zero, blank				NA
Total	**3788**	**69%**	**16%**	**0%**

Crashes by outside shoulder total width, left side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	160	79%	7%	-127%
1--2	69	70%	14%	-8%
3--4	61	82%	8%	-91%
5--6	66	88%	5%	-244%
7--8	781	75%	12%	-30%
9--10	672	56%	23%	49%
11+	103	73%	18%	18%
Blank				NA
Total	**1912**	**69%**	**16%**	**0%**

Crashes by outside shoulder total width, right side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	148	76%	14%	-16%
1--2	63	79%	13%	-30%
3--4	47	77%	11%	-55%
5--6	41	80%	12%	-35%
7--8	806	76%	14%	-17%
9--10	671	59%	21%	26%
11+	100	63%	18%	9%
Blank				NA
Total	**1876**	**69%**	**16%**	**0%**

Crashes by outside shoulder treated width, left side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	168	78%	8%	-102%
1--2	74	73%	12%	-29%
3--4	69	84%	6%	-170%
5--6	57	86%	5%	-197%
7--8	793	73%	13%	-18%
9--10	692	57%	23%	48%
11+	59	85%	8%	-85%
Blank				NA
Total	**1912**	**69%**	**16%**	**0%**

Crashes by outside shoulder treated width, right side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	157	75%	15%	-12%
1--2	69	77%	13%	-26%
3--4	50	78%	12%	-37%
5--6	38	89%	11%	-56%
7--8	814	74%	14%	-16%
9--10	691	59%	21%	25%
11+	57	74%	16%	-4%
Blank				NA
Total	**1876**	**69%**	**16%**	**0%**

Crashes by travel way width, left side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0--12	72	83%	6%	-181%
13--24	583	79%	11%	-40%
25--36	547	74%	12%	-36%
37--48	383	57%	23%	50%
49+	327	53%	24%	51%
Blank				NA
Total	**1912**	**69%**	**16%**	**0%**

Crashes by travel way width, right side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0--12	74	72%	14%	-22%
13--24	564	81%	12%	-37%
25--36	533	74%	14%	-19%
37--48	370	61%	20%	21%
49+	335	52%	25%	50%
Blank				NA
Total	**1876**	**69%**	**16%**	**0%**

Crashes by inside shoulder total width, left side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	948	83%	8%	-100%
1--2	191	62%	17%	7%
3--4	86	48%	21%	34%
5--6	211	54%	25%	61%
7--8	272	53%	27%	72%
9--10	151	56%	25%	57%
11+	53	57%	23%	45%
Blank				NA
Total	**1912**	**69%**	**16%**	**0%**

Crashes by inside shoulder total width, right side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	909	80%	11%	-45%
1--2	198	69%	15%	-9%
3--4	71	62%	18%	11%
5--6	214	59%	23%	42%
7--8	291	54%	23%	40%
9--10	125	54%	26%	55%
11+	68	57%	21%	25%
Blank				NA
Total	**1876**	**69%**	**16%**	**0%**

Crashes by inside shoulder treated width, left side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	948	83%	8%	-100%
1--2	254	60%	19%	21%
3--4	83	47%	20%	31%
5--6	156	56%	25%	60%
7--8	272	52%	27%	74%
9--10	146	57%	24%	53%
11+	53	57%	23%	45%
Blank				NA
Total	**1912**	**69%**	**16%**	**0%**

Crashes by inside shoulder treated width, right side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	909	80%	11%	-45%
1--2	271	66%	18%	8%
3--4	72	61%	19%	18%
5--6	146	60%	21%	29%
7--8	292	53%	24%	43%
9--10	121	55%	25%	51%
11+	65	58%	22%	31%
Blank				NA
Total	**1876**	**69%**	**16%**	**0%**

Crashes by median type

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Not Striped or Separated	0	-	-	NA
Striped	372	84%	7%	-121%
Reversible Peak Hour Lane(s) - Undivided	0	-	-	NA
Reversible Peak Hour Lane(s) - Divided	0	-	-	NA
Two-Way Left Turn Lane	315	82%	10%	-69%
Continuous Left Turn Lane	578	82%	10%	-69%
Paved Median	1518	62%	19%	21%
Unpaved Median	776	65%	20%	23%
Separate Grades	52	50%	27%	68%
Separate Grades w/ Retaining Wall	5	20%	40%	NA
Sawtooth - Unpaved	0	-	-	NA
Sawtooth - Paved	0	-	-	NA
Ditch	0	-	-	NA
Separate Structure	60	50%	22%	35%
Railroad	53	57%	19%	18%
Bus Lanes	3	33%	67%	NA
Paved Area Occasional Traffic Lane	0	-	-	NA
Railroad & Bus Lanes	0	-	-	NA
Contains Reversible Pk Hr Ln(s)	12	58%	17%	NA
Other	44	80%	11%	-41%
Blank				NA
Total	**3788**	**69%**	**16%**	**0%**

Crashes by median curb and landscape

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Curbed Median	563	77%	13%	-26%
Curbed Median with Trees	299	83%	9%	-85%
Curbed Median with Shrubs	144	85%	8%	-110%
Raised Traffic Bars	10	80%	10%	NA
Median with Trees	17	41%	29%	NA
Median with Shrubs	250	51%	28%	77%
No Curbs or Shrubs/No Median	2505	67%	17%	5%
Blank				NA
Total	**3788**	**69%**	**16%**	**0%**

Crashes by type of median barrier

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Cable Barrier	19	11%	47%	NA
Cable Barrier w/ Glare Screen	10	60%	-	NA
Metal Beam Barrier	104	60%	17%	8%
Metal Beam Barrier w/ Glare Screen	136	50%	27%	69%
Concrete Barrier	610	54%	24%	50%
Concrete Barrier w/ Glare Screen	402	53%	22%	35%
Bridge Barrier Railing	67	48%	21%	30%
Chain Link Fence	10	80%	10%	NA
Guardrail in Median Both Roadway	6	67%	17%	NA
Guardrail in Median Left Roadway	14	50%	36%	NA
Guardrail in Median Right Roadway	5	40%	60%	NA
Two-Way, One Lane Road	0	-	-	NA
Thrie Beam Barrier	126	53%	30%	88%
Thrie Beam Barrier w/ Glare Screen	1	100%	-	NA
Conc. Barrier, Both Ways Inside Both Sh.	71	62%	24%	49%
Conc. Barrier, Left Rdwy Median Sh. Area	13	62%	8%	NA
Conc. Barrier, Right Rdwy Median Sh. Area	3	100%	-	NA
External Barriers on Median Type = C or E	0	-	-	NA
Other Not Included Above	1	-	-	NA
No Barriers	2190	80%	11%	-53%
Blank				NA
Total	**3788**	**69%**	**16%**	**0%**

Crashes by median width (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	372	84%	7%	-121%
1--4	101	92%	4%	-305%
5--8	332	62%	15%	-9%
9--12	826	75%	14%	-13%
13--16	616	75%	12%	-39%
17--20	211	68%	17%	3%
21--24	456	60%	22%	38%
25--36	285	56%	25%	57%
37+	494	59%	23%	46%
99 (no data)	95	58%	17%	5%
Blank				NA
Total	**3788**	**69%**	**16%**	**0%**

Crashes by median width variance

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Variable	548	70%	16%	2%
No Variance	3161	69%	16%	0%
Over 100' Median & No Var.	79	58%	16%	3%
Blank				NA
Total	**3788**	**69%**	**16%**	**0%**

Crashes by highway group

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Independent Alignment - Right	42	57%	12%	-35%
Independent Alignment - Left	26	65%	12%	NA
Divided Highway	3348	68%	17%	7%
Undivided Highway	372	84%	7%	-121%
Blank				NA
Total	**3788**	**69%**	**16%**	**0%**

Crashes by access code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Conventional	1972	83%	9%	-76%
Expressway	38	74%	16%	-2%
Freeway	1757	54%	24%	49%
One-Way City Street	21	90%	5%	NA
Blank				NA
Total	**3788**	**69%**	**16%**	**0%**

Crashes by design speed

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
25	27	74%	11%	NA
30	57	93%	2%	-815%
35	206	85%	7%	-136%
40	191	86%	7%	-119%
45	345	86%	7%	-141%
50	555	82%	10%	-59%
55	109	79%	13%	-25%
60	401	78%	11%	-43%
65	202	73%	13%	-25%
70	1695	54%	24%	51%
Blank				NA
Total	**3788**	**69%**	**16%**	**0%**

Crashes by functional class

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
None	4	50%	25%	NA
Principal Arterial w/ C/L Prin Arterial	1675	54%	24%	51%
Principal Arterial w/ C/L Minor Arterial	653	79%	10%	-56%
Principal Arterial Non-Connecting Link	1347	81%	9%	-74%
Minor Arterial	108	81%	10%	-58%
Major Collector	1	100%	-	NA
Minor Collector	0	-	-	NA
Local	0	-	-	NA
Blank				NA
Total	**3788**	**69%**	**16%**	**0%**

Crashes by ADT amount

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
<10,000	40	78%	10%	-61%
10,000 to 20,000	218	86%	10%	-67%
20,000 to 30,000	540	83%	7%	-117%
30,000+	2990	65%	18%	13%
(blank)				NA
Total	**3788**	**69%**	**16%**	**0%**

Crashes by surface type, left side

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
PCC - Bridge Deck	53	53%	19%	21%
PCC - Concrete	673	55%	23%	47%
Earth	0	-	-	NA
Undetermined	5	100%	-	NA
AC - Base & Surface >= 7" Thick	1176	78%	11%	-37%
AC - Base & Surface <7" Thick	5	80%	-	NA
AC - Oiled Earth -- Gravel	0	-	-	NA
AC - Bridge Deck	0	-	-	NA
Blank				NA
Total	**1912**	**69%**	**16%**	**0%**

Crashes by surface type, right side

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
PCC - Bridge Deck	59	46%	22%	34%
PCC - Concrete	673	57%	22%	33%
Earth	0	-	-	NA
Undetermined	6	100%	-	NA
AC - Base & Surface >= 7" Thick	1130	78%	13%	-27%
AC - Base & Surface <7" Thick	7	71%	29%	NA
AC - Oiled Earth -- Gravel	0	-	-	NA
AC - Bridge Deck	1	100%	-	NA
Blank				NA
Total	**1876**	**69%**	**16%**	**0%**

Appendix 5-O: Fatality Index of Highways – Urbanized

Crashes by number of lanes, left side

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
1	97	80%	10%	-76%
2	165	72%	20%	10%
3	14	64%	21%	NA
4	5	40%	60%	NA
5	4	50%	50%	NA
6+	1	-	100%	NA
zero, blank				NA
Total	**286**	**73%**	**18%**	**0%**

Crashes by number of lanes, right side

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
1	99	75%	9%	-67%
2	169	70%	15%	1%
3	17	59%	41%	NA
4	3	67%	33%	NA
5	1	-	100%	NA
6+	1	100%	-	NA
zero, blank				NA
Total	**290**	**71%**	**15%**	**0%**

Crashes by lanes on side of crash

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
1	196	78%	10%	-72%
2	334	71%	18%	6%
3	31	61%	32%	94%
4	8	50%	50%	NA
5	5	40%	60%	NA
6+	2	50%	50%	NA
zero, blank				NA
Total	**576**	**72%**	**17%**	**0%**

Crashes by outside shoulder total width, left side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	30	87%	10%	-82%
1--2	13	85%	-	NA
3--4	45	78%	11%	-64%
5--6	11	36%	36%	NA
7--8	109	75%	18%	1%
9--10	50	58%	32%	76%
11+	28	79%	14%	NA
Blank				NA
Total	**286**	**73%**	**18%**	**0%**

Crashes by outside shoulder total width, right side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	44	82%	5%	-234%
1--2	14	79%	14%	NA
3--4	31	77%	6%	-135%
5--6	25	72%	12%	NA
7--8	101	70%	22%	44%
9--10	45	58%	22%	46%
11+	30	67%	10%	-52%
Blank				NA
Total	**290**	**71%**	**15%**	**0%**

Crashes by outside shoulder treated width, left side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	40	85%	10%	-82%
1--2	18	72%	17%	NA
3--4	49	78%	10%	-78%
5--6	4	50%	25%	NA
7--8	98	73%	19%	7%
9--10	55	58%	33%	80%
11+	22	82%	9%	NA
Blank				NA
Total	**286**	**73%**	**18%**	**0%**

Crashes by outside shoulder treated width, right side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	57	81%	5%	-188%
1--2	18	83%	11%	NA
3--4	31	71%	16%	6%
5--6	17	65%	12%	NA
7--8	96	72%	21%	37%
9--10	47	57%	23%	54%
11+	24	67%	4%	NA
Blank				NA
Total	**290**	**71%**	**15%**	**0%**

Crashes by travel way width, left side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0--12	89	82%	9%	-102%
13--24	152	70%	22%	23%
25--36	33	70%	12%	-50%
37--48	7	57%	43%	NA
49+	5	40%	60%	NA
Blank				NA
Total	**286**	**73%**	**18%**	**0%**

Crashes by travel way width, right side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0--12	85	76%	8%	-84%
13--24	143	66%	18%	20%
25--36	55	78%	16%	8%
37--48	4	50%	25%	NA
49+	3	67%	33%	NA
Blank				NA
Total	**290**	**71%**	**15%**	**0%**

Crashes by inside shoulder total width, left side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	218	79%	11%	-59%
1--2	4	75%	25%	NA
3--4	0	-	-	NA
5--6	38	45%	45%	146%
7--8	22	59%	41%	NA
9--10	3	67%	-	NA
11+	1	100%	-	NA
Blank				NA
Total	**286**	**73%**	**18%**	**0%**

Crashes by inside shoulder total width, right side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	225	78%	9%	-63%
1--2	3	33%	33%	NA
3--4	0	-	-	NA
5--6	37	35%	41%	167%
7--8	17	71%	29%	NA
9--10	2	100%	-	NA
11+	6	50%	33%	NA
Blank				NA
Total	**290**	**71%**	**15%**	**0%**

Crashes by inside shoulder treated width, left side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	218	79%	11%	-59%
1--2	20	55%	35%	NA
3--4	0	-	-	NA
5--6	24	42%	46%	NA
7--8	22	59%	41%	NA
9--10	2	100%	-	NA
11+	0	-	-	NA
Blank				NA
Total	**286**	**73%**	**18%**	**0%**

Crashes by inside shoulder treated width, right side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	225	78%	9%	-63%
1--2	15	27%	47%	NA
3--4	0	-	-	NA
5--6	25	40%	36%	NA
7--8	17	71%	29%	NA
9--10	5	60%	40%	NA
11+	3	67%	-	NA
Blank				NA
Total	**290**	**71%**	**15%**	**0%**

Crashes by median type

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Not Striped or Separated	0	-	-	NA
Striped	229	77%	12%	-41%
Reversible Peak Hour Lane(s) - Undivided	0	-	-	NA
Reversible Peak Hour Lane(s) - Divided	0	-	-	NA
Two-Way Left Turn Lane	157	80%	9%	-87%
Continuous Left Turn Lane	27	67%	15%	NA
Paved Median	44	80%	14%	-22%
Unpaved Median	93	40%	45%	171%
Separate Grades	9	78%	11%	-50%
Separate Grades w/ Retaining Wall	0	-	-	NA
Sawtooth - Unpaved	0	-	-	NA
Sawtooth - Paved	0	-	-	NA
Ditch	0	-	-	NA
Separate Structure	1	100%	-	NA
Railroad	2	100%	-	NA
Bus Lanes	0	-	-	NA
Paved Area Occasional Traffic Lane	0	-	-	NA
Railroad & Bus Lanes	0	-	-	NA
Contains Reversible Pk Hr Ln(s)	0	-	-	NA
Other	14	86%	14%	NA
Blank				NA
Total	**576**	**72%**	**17%**	**0%**

Crashes by median curb and landscape

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Curbed Median	12	92%	8%	NA
Curbed Median with Trees	1	-	100%	NA
Curbed Median with Shrubs	2	50%	50%	NA
Raised Traffic Bars	0	-	-	NA
Median with Trees	1	100%	-	NA
Median with Shrubs	23	30%	52%	NA
No Curbs or Shrubs/No Median	537	74%	15%	-10%
Blank				NA
Total	**576**	**72%**	**17%**	**0%**

Crashes by type of median barrier

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Cable Barrier	1	-	100%	NA
Cable Barrier w/ Glare Screen	0	-	-	NA
Metal Beam Barrier	5	40%	60%	NA
Metal Beam Barrier w/ Glare Screen	1	100%	-	NA
Concrete Barrier	12	50%	42%	NA
Concrete Barrier w/ Glare Screen	0	-	-	NA
Bridge Barrier Railing	2	50%	-	NA
Chain Link Fence	4	-	75%	NA
Guardrail in Median Both Roadway	1	-	100%	NA
Guardrail in Median Left Roadway	0	-	-	NA
Guardrail in Median Right Roadway	0	-	-	NA
Two-Way, One Lane Road	0	-	-	NA
Thrie Beam Barrier	9	44%	22%	NA
Thrie Beam Barrier w/ Glare Screen	0	-	-	NA
Conc. Barrier, Both Ways Inside Both Sh.	0	-	-	NA
Conc. Barrier, Left Rdwy Median Sh. Area	0	-	-	NA
Conc. Barrier, Right Rdwy Median Sh. Area	0	-	-	NA
External Barriers on Median Type = C or E	0	-	-	NA
Other Not Included Above	0	-	-	NA
No Barriers	541	74%	15%	-11%
Blank				NA
Total	**576**	**72%**	**17%**	**0%**

Crashes by median width (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	229	77%	12%	-41%
1--4	10	90%	-	NA
5--8	1	100%	-	NA
9--12	185	78%	10%	-62%
13--16	14	71%	14%	NA
17--20	3	100%	-	NA
21--24	27	70%	26%	NA
25--36	10	70%	30%	NA
37+	78	37%	46%	177%
99 (no data)	19	84%	11%	NA
Blank				NA
Total	**576**	**72%**	**17%**	**0%**

Crashes by median width variance

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Variable	11	64%	9%	NA
No Variance	545	72%	17%	2%
Over 100' Median & No Var.	20	85%	10%	NA
Blank				NA
Total	**576**	**72%**	**17%**	**0%**

Crashes by highway group

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Independent Alignment - Right	11	82%	9%	NA
Independent Alignment - Left	8	88%	13%	NA
Divided Highway	328	68%	20%	23%
Undivided Highway	229	77%	12%	-41%
Blank				NA
Total	**576**	**72%**	**17%**	**0%**

Crashes by access code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Conventional	448	78%	11%	-56%
Expressway	19	63%	26%	NA
Freeway	95	42%	43%	159%
One-Way City Street	14	86%	14%	NA
Blank				NA
Total	**576**	**72%**	**17%**	**0%**

Crashes by design speed

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
25	31	84%	3%	-417%
30	29	90%	7%	NA
35	87	83%	6%	-190%
40	65	80%	11%	-55%
45	63	83%	6%	-163%
50	45	73%	18%	7%
55	24	71%	13%	NA
60	103	74%	17%	5%
65	38	61%	18%	11%
70	91	42%	45%	170%
Blank				NA
Total	**576**	**72%**	**17%**	**0%**

Crashes by functional class

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
None	0	-	-	NA
Principal Arterial w/ C/L Prin Arterial	193	64%	24%	46%
Principal Arterial w/ C/L Minor Arterial	244	75%	14%	-23%
Principal Arterial Non-Connecting Link	37	89%	3%	-517%
Minor Arterial	82	73%	16%	-5%
Major Collector	20	70%	10%	NA
Minor Collector	0	-	-	NA
Local	0	-	-	NA
Blank				NA
Total	**576**	**72%**	**17%**	**0%**

Crashes by ADT

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
<10,000	74	80%	11%	-54%
10,000 to 20,000	184	75%	15%	-14%
20,000 to 30,000	130	77%	12%	-35%
30,000+	188	63%	24%	44%
(blank)				NA
Total	**576**	**72%**	**17%**	**0%**

Crashes by surface type, left side

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
PCC - Bridge Deck	3	33%	-	NA
PCC - Concrete	23	43%	48%	163%
Earth	0	-	-	NA
Undetermined	0	-	-	NA
AC - Base & Surface >= 7" Thick	245	76%	16%	-11%
AC - Base & Surface <7" Thick	14	86%	7%	-155%
AC - Oiled Earth -- Gravel	1	100%	-	NA
AC - Bridge Deck	0	-	-	NA
Blank				NA
Total	**286**	**73%**	**18%**	**0%**

Crashes by surface type, right side

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
PCC - Bridge Deck	4	25%	25%	65%
PCC - Concrete	20	30%	45%	197%
Earth	0	-	-	NA
Undetermined	0	-	-	NA
AC - Base & Surface >= 7" Thick	247	75%	11%	-34%
AC - Base & Surface <7" Thick	19	68%	32%	108%
AC - Oiled Earth -- Gravel	0	-	-	NA
AC - Bridge Deck	0	-	-	NA
Blank				NA
Total	**290**	**71%**	**15%**	**0%**

Appendix P: Fatality Index of Highways – Rural

Crashes by number of lanes, left side

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
1	278	65%	15%	-3%
2	201	66%	17%	8%
3	23	61%	22%	NA
4	28	75%	7%	NA
5	2	-	-	NA
6+	0	-	-	NA
zero, blank				NA
Total	**532**	**66%**	**16%**	**0%**

Crashes by number of lanes, right side

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
1	299	63%	12%	-40%
2	201	63%	21%	23%
3	30	63%	37%	111%
4	46	72%	20%	13%
5	4	50%	25%	NA
6+	1	100%	-	NA
zero, blank				NA
Total	**581**	**64%**	**17%**	**0%**

Crashes by lanes on side of crash

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
1	577	64%	14%	-21%
2	402	64%	19%	16%
3	53	62%	30%	83%
4	74	73%	15%	-11%
5	6	33%	17%	NA
6+	1	100%	-	NA
zero, blank				NA
Total	**1113**	**65%**	**17%**	**0%**

Crashes by outside shoulder total width, left side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	22	73%	-	NA
1--2	59	59%	8%	-84%
3--4	78	69%	10%	-52%
5--6	36	53%	22%	42%
7--8	162	64%	22%	42%
9--10	141	66%	16%	5%
11+	34	82%	9%	-77%
Blank				NA
Total	**532**	**66%**	**16%**	**0%**

Crashes by outside shoulder total width, right side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	31	68%	3%	-439%
1--2	67	63%	4%	-288%
3--4	86	66%	9%	-87%
5--6	35	60%	23%	31%
7--8	157	59%	25%	43%
9--10	166	69%	18%	4%
11+	39	54%	31%	77%
Blank				NA
Total	**581**	**64%**	**17%**	**0%**

Crashes by outside shoulder treated width, left side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	100	60%	8%	-95%
1--2	46	65%	17%	11%
3--4	80	70%	15%	-4%
5--6	13	46%	23%	NA
7--8	132	65%	22%	41%
9--10	153	68%	15%	-4%
11+	8	88%	-	NA
Blank				NA
Total	**532**	**66%**	**16%**	**0%**

Crashes by outside shoulder treated width, right side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	106	58%	11%	-54%
1--2	59	64%	12%	-47%
3--4	78	68%	10%	-69%
5--6	17	76%	12%	NA
7--8	132	59%	25%	44%
9--10	175	66%	21%	18%
11+	14	79%	21%	NA
Blank				NA
Total	**581**	**64%**	**17%**	**0%**

Crashes by travel way width, left side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0--12	253	64%	16%	4%
13--24	221	67%	16%	2%
25--36	25	64%	20%	NA
37--48	31	74%	6%	-142%
49+	2	-	-	NA
Blank				NA
Total	**532**	**66%**	**16%**	**0%**

Crashes by travel way width, right side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0--12	272	62%	13%	-35%
13--24	223	63%	20%	16%
25--36	34	68%	32%	86%
37--48	46	72%	20%	13%
49+	6	67%	17%	NA
Blank				NA
Total	**581**	**64%**	**17%**	**0%**

Crashes by inside shoulder total width, left side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	340	66%	15%	-4%
1--2	6	50%	17%	NA
3--4	4	50%	-	NA
5--6	107	64%	20%	26%
7--8	53	70%	11%	-38%
9--10	14	79%	7%	NA
11+	8	63%	38%	NA
Blank				NA
Total	**532**	**66%**	**16%**	**0%**

Crashes by inside shoulder total width, right side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	357	63%	14%	-27%
1--2	10	70%	20%	NA
3--4	2	100%	-	NA
5--6	116	61%	22%	24%
7--8	73	62%	29%	65%
9--10	13	69%	23%	NA
11+	10	90%	10%	NA
Blank				NA
Total	**581**	**64%**	**17%**	**0%**

Crashes by inside shoulder treated width, left side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	340	66%	15%	-4%
1--2	43	58%	26%	64%
3--4	3	67%	-	NA
5--6	80	66%	14%	-13%
7--8	44	68%	14%	-14%
9--10	14	79%	7%	NA
11+	8	63%	38%	NA
Blank				NA
Total	**532**	**66%**	**16%**	**0%**

Crashes by inside shoulder treated width, right side (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	357	63%	14%	-27%
1--2	51	61%	22%	24%
3--4	2	100%	-	NA
5--6	93	58%	27%	55%
7--8	56	68%	23%	34%
9--10	12	75%	17%	NA
11+	10	90%	10%	NA
Blank				NA
Total	**581**	**64%**	**17%**	**0%**

Crashes by median type

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Not Striped or Separated	1	100%	-	NA
Striped	550	63%	13%	-25%
Reversible Peak Hour Lane(s) - Undivided	0	-	-	NA
Reversible Peak Hour Lane(s) - Divided	0	-	-	NA
Two-Way Left Turn Lane	109	69%	21%	28%
Continuous Left Turn Lane	7	57%	14%	NA
Paved Median	96	68%	16%	-6%
Unpaved Median	304	62%	23%	37%
Separate Grades	30	80%	3%	-396%
Separate Grades w/ Retaining Wall	0	-	-	NA
Sawtooth - Unpaved	0	-	-	NA
Sawtooth - Paved	0	-	-	NA
Ditch	0	-	-	NA
Separate Structure	7	71%	-	NA
Railroad	0	-	-	NA
Bus Lanes	0	-	-	NA
Paved Area Occasional Traffic Lane	0	-	-	NA
Railroad & Bus Lanes	0	-	-	NA
Contains Reversible Pk Hr Ln(s)	0	-	-	NA
Other	9	67%	22%	NA
Blank				NA
Total	**1113**	**65%**	**17%**	**0%**

Crashes by median curb and landscape

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Curbed Median	1	100%	-	NA
Curbed Median with Trees	1	100%	-	NA
Curbed Median with Shrubs	0	-	-	NA
Raised Traffic Bars	0	-	-	NA
Median with Trees	18	78%	17%	NA
Median with Shrubs	51	51%	45%	173%
No Curbs or Shrubs/No Median	1042	65%	15%	-9%
Blank				NA
Total	**1113**	**65%**	**17%**	**0%**

Crashes by type of median barrier

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Cable Barrier	7	71%	29%	NA
Cable Barrier w/ Glare Screen	0	-	-	NA
Metal Beam Barrier	2	100%	-	NA
Metal Beam Barrier w/ Glare Screen	4	100%	-	NA
Concrete Barrier	73	63%	23%	41%
Concrete Barrier w/ Glare Screen	9	78%	11%	NA
Bridge Barrier Railing	7	57%	14%	NA
Chain Link Fence	0	-	-	NA
Guardrail in Median Both Roadway	1	-	-	NA
Guardrail in Median Left Roadway	3	33%	33%	NA
Guardrail in Median Right Roadway	1	-	100%	NA
Two-Way, One Lane Road	0	-	-	NA
Thrie Beam Barrier	53	62%	21%	26%
Thrie Beam Barrier w/ Glare Screen	0	-	-	NA
Conc. Barrier, Both Ways Inside Both Sh.	0	-	-	NA
Conc. Barrier, Left Rdwy Median Sh. Area	0	-	-	NA
Conc. Barrier, Right Rdwy Median Sh. Area	0	-	-	NA
External Barriers on Median Type = C or E	0	-	-	NA
Other Not Included Above	0	-	-	NA
No Barriers	953	65%	16%	-5%
Blank				NA
Total	**1113**	**65%**	**17%**	**0%**

Crashes by median width (feet)

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	551	64%	13%	-25%
1--4	25	68%	8%	NA
5--8	9	67%	11%	NA
9--12	103	71%	19%	17%
13--16	33	61%	24%	47%
17--20	3	33%	67%	NA
21--24	44	70%	9%	-82%
25--36	58	72%	19%	15%
37+	190	61%	24%	46%
99 (no data)	97	64%	18%	6%
Blank				NA
Total	**1113**	**65%**	**17%**	**0%**

Crashes by median width variance

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Variable	81	63%	17%	5%
No Variance	968	64%	17%	1%
Over 100' Median & No Var.	64	67%	14%	-18%
Blank				NA
Total	**1113**	**65%**	**17%**	**0%**

Crashes by highway group

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Independent Alignment - Right	13	85%	8%	NA
Independent Alignment - Left	11	82%	-	NA
Divided Highway	538	65%	20%	24%
Undivided Highway	551	64%	13%	-25%
Blank				NA
Total	**1113**	**65%**	**17%**	**0%**

Crashes by access code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Conventional	647	64%	15%	-13%
Expressway	104	63%	21%	28%
Freeway	361	66%	19%	12%
One-Way City Street	1	-	-	NA
Blank				NA
Total	**1113**	**65%**	**17%**	**0%**

Crashes by design speed

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
25	35	89%	3%	-479%
30	11	82%	9%	NA
35	62	69%	11%	-46%
40	50	72%	4%	-313%
45	88	53%	15%	-12%
50	89	64%	11%	-47%
55	83	64%	18%	9%
60	159	63%	18%	10%
65	185	62%	21%	28%
70	351	65%	19%	15%
Blank				NA
Total	**1113**	**65%**	**17%**	**0%**

Crashes by functional class

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
None	2	100%	-	NA
Principal Arterial w/ C/L Prin Arterial	556	64%	19%	17%
Principal Arterial w/ C/L Minor Arterial	0	-	-	NA
Principal Arterial Non-Connecting Link	0	-	-	NA
Minor Arterial	500	65%	14%	-16%
Major Collector	53	64%	9%	-75%
Minor Collector	2	50%	-	NA
Local	0	-	-	NA
Blank				NA
Total	**1113**	**65%**	**17%**	**0%**

Crashes by ADT amount

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
<10,000	386	63%	11%	-45%
10,000 to 20,000	308	69%	16%	-6%
20,000 to 30,000	142	64%	18%	11%
30,000+	277	62%	24%	44%
(blank)				NA
Total	**1113**	**65%**	**17%**	**0%**

Crashes by surface type, left side

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
PCC - Bridge Deck	6	50%	-	NA
PCC - Concrete	98	67%	12%	-27%
Earth	0	-	-	NA
Undetermined	0	-	-	NA
AC - Base & Surface >= 7" Thick	387	66%	17%	6%
AC - Base & Surface <7" Thick	37	62%	19%	21%
AC - Oiled Earth -- Gravel	4	-	-	NA
AC - Bridge Deck	0	-	-	NA
Blank				NA
Total	**532**	**66%**	**16%**	**0%**

Crashes by surface type, right side

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
PCC - Bridge Deck	10	80%	20%	NA
PCC - Concrete	128	66%	22%	26%
Earth	1	100%	-	NA
Undetermined	0	-	-	NA
AC - Base & Surface >= 7" Thick	387	64%	17%	-4%
AC - Base & Surface <7" Thick	49	53%	8%	-113%
AC - Oiled Earth -- Gravel	6	50%	33%	NA
AC - Bridge Deck	0	-	-	NA
Blank				NA
Total	**581**	**64%**	**17%**	**0%**

Appendix 5-Q: Fatality Index of Intersections – All

Crashes by design code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Four-Legged	620	86%	4%	-24%
Multi-Legged	14	86%	NA	NA
Offset	66	86%	5%	3%
Tee	229	82%	7%	59%
WYE	15	73%	7%	NA
Other	11	91%	NA	NA
Total	**955**	**85%**	**4%**	**0%**

Crashes by presence of lighting

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Yes	876	87%	4%	-17%
No	79	67%	11%	159%
Total	**955**	**85%**	**4%**	**0%**

Crashes by main signal mast arm

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Yes	479	88%	2%	-92%
No	476	82%	7%	48%
Total	**955**	**85%**	**4%**	**0%**

Crashes by main left channel code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
No Left Turn Channelization	282	84%	6%	37%
Painted Left Turn Channelization	364	85%	4%	-14%
Curbed Median Left Turn Channelization	308	86%	4%	-23%
Raised Bars - Left Turn Channelization	0	NA	NA	NA
Yes	1	100%	NA	NA
Total	**955**	**85%**	**4%**	**0%**

Crashes by main right channel code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Yes	134	84%	4%	-18%
No	817	85%	5%	3%
Partial	4	75%	NA	NA
Total	**955**	**85%**	**4%**	**0%**

Crashes by main flow code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Two-Way Traffic - No Left Turns Permitted	38	92%	NA	NA
Two-Way Traffic - Left Turns Permitted	860	84%	5%	11%
Two-Way Traffic - Left Turns Peak Hr Rest.	13	69%	NA	NA
One-Way Traffic	44	98%	NA	NA
Other	0	NA	NA	NA
Total	**955**	**85%**	**4%**	**0%**

Crashes by crossing signal mast arm

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Yes	320	86%	3%	-28%
No	635	85%	5%	11%
Total	**955**	**85%**	**4%**	**0%**

Crashes by left crossing channel code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
No Left Turn Channelization	669	84%	5%	19%
Painted Left Turn Channelization	199	88%	2%	-192%
Curbed Median Left Turn Channelization	84	80%	5%	8%
Raised Bars - Left Turn Channelization	2	100%	NA	NA
Yes	1	100%	NA	NA
Total	**955**	**85%**	**4%**	**0%**

Crashes by right crossing channel code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Yes	165	89%	3%	-45%
No	788	84%	5%	7%
Partial	2	50%	NA	NA
Total	**955**	**85%**	**4%**	**0%**

Crashes by crossing flow channel code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Two-Way Traffic - No Left Turns Permitted	32	94%	NA	NA
Two-Way Traffic - Left Turns Permitted	890	84%	5%	5%
Two-Way Traffic - Left Turns Peak Hr Rest.	3	100%	NA	NA
One-Way Traffic	28	89%	4%	NA
Other	2	50%	NA	NA
Total	**955**	**85%**	**4%**	**0%**

Crashes by control code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
No Control	4	75%	NA	NA
Stop Signs on Cross Street Only	404	80%	7%	69%
Stop Signs on Mainline Only	2	100%	NA	NA
Four-Way Stop Signs	6	100%	NA	NA
Four-Way Flasher (Red on Cross Street)	1	100%	NA	NA
Four-Way Flasher (Red on Mainline)	0	NA	NA	NA
Four-Way Flasher (Red on All)	1	100%	NA	NA
Yield Signs (On Cross Street Only)	1	100%	NA	NA
Yield Signs (On Mainline Only)	0	NA	NA	NA
Signals Pretimed - 2 Phase	89	93%	NA	NA
Signals Pretimed - Multi-Phase	18	78%	11%	NA
Signals Semi-Traffic Actuated - 2 Phase	26	88%	4%	NA
Signals Semi-Traffic Actuated - Multi Phase	14	93%	NA	NA
Singals Full-Traffic Actuated - 2 Phase	72	93%	1%	-217%
Singals Full-Traffic Actuated - Multi Phase	315	86%	3%	-73%
Other	2	100%	NA	NA
Signalized	534	88%	2%	-96%
Four-Way Flasher	2	100%	NA	NA
Total	**955**	**85%**	**4%**	**0%**

Crashes by number of lanes on main street

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
1	0	NA	NA	NA
2	203	82%	7%	68%
3	32	91%	3%	-41%
4	493	85%	4%	1%
5	20	95%	NA	NA
6	182	86%	2%	-100%
7	0	NA	NA	NA
8	25	80%	NA	NA
12	0	NA	NA	NA
blank				NA
Total	**955**	**85%**	**4%**	**0%**

Crashes by number of lanes on crossing street

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	0	NA	NA	NA
1	6	83%	NA	NA
2	698	85%	5%	17%
3	31	87%	3%	-36%
4	198	87%	1%	-335%
5	8	63%	13%	NA
6	11	55%	18%	NA
7	0	NA	NA	NA
8	0	NA	NA	NA
Null	3	100%	NA	NA
blank	0	NA	NA	NA
Total	**955**	**85%**	**4%**	**0%**

Crashes by highway group

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Undivided Highway	408	83%	6%	34%
Independent Alignment - Left	23	100%	NA	NA
Divided Highway	504	85%	4%	-23%
Independent Alignment - Right	18	100%	NA	NA
Null or blank	2	50%	NA	NA
Total	**955**	**85%**	**4%**	**0%**

Crashes by mainline ADT

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
<10,000	75	79%	11%	143%
10,000 to 20,000	202	81%	7%	69%
20,000 to 30,000	229	87%	4%	-12%
30,000+	449	87%	2%	-97%
(blank)				NA
Total	**955**	**85%**	**4%**	**0%**

Crashes by crossing ADT

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
<10,000	798	85%	5%	5%
10,000 to 20,000	104	82%	3%	-52%
20,000 to 30,000	43	91%	2%	-89%
30,000+	10	90%	10%	NA
(blank)				NA
Total	**955**	**85%**	**4%**	**0%**

Appendix 5-R: Fatality Index of Intersections – Urban

Crashes by design code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Four-Legged	460	88%	2%	-21%
Multi-Legged	12	83%	-	NA
Offset	46	93%	2%	-21%
Tee	149	86%	5%	79%
WYE	8	88%	-	NA
Other	10	90%	-	NA
Total	**685**	**88%**	**3%**	**0%**

Crashes by presence of lighting

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Yes	659	88%	2%	-8%
No	26	81%	8%	NA
Total	**685**	**88%**	**3%**	**0%**

Crashes by main signal mast arm

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Yes	407	88%	2%	-34%
No	278	87%	4%	37%
Total	**685**	**88%**	**3%**	**0%**

Crashes by main left channel code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
No Left Turn Channelization	160	91%	3%	-5%
Painted Left Turn Channelization	232	89%	2%	-52%
Curbed Median Left Turn Channelization	293	85%	3%	30%
Raised Bars - Left Turn Channelization	0	-	-	NA
Yes	0	-	-	NA
Total	**685**	**88%**	**3%**	**0%**

Crashes by main right channel code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Yes	96	85%	2%	-26%
No	586	88%	3%	4%
Partial	3	67%	-	NA
Total	**685**	**88%**	**3%**	**0%**

Crashes by main flow code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Two-Way Traffic - No Left Turns Permitted	36	92%	-	NA
Two-Way Traffic - Left Turns Permitted	609	88%	3%	12%
Two-Way Traffic - Left Turns Peak Hr Rest.	13	69%	-	NA
One-Way Traffic	27	96%	-	NA
Other	0	-	-	NA
Total	**685**	**88%**	**3%**	**0%**

Crashes by crossing signal mast arm

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Yes	267	86%	3%	14%
No	418	89%	2%	-10%
Total	**685**	**88%**	**3%**	**0%**

Crashes by left crossing channel code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
No Left Turn Channelization	441	89%	3%	12%
Painted Left Turn Channelization	159	89%	1%	-318%
Curbed Median Left Turn Channelization	83	80%	5%	83%
Raised Bars - Left Turn Channelization	2	100%	-	NA
Yes	0	-	-	NA
Total	**685**	**88%**	**3%**	**0%**

Crashes by right crossing channel code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Yes	133	90%	3%	14%
No	551	87%	3%	-3%
Partial	1	-	-	NA
Total	**685**	**88%**	**3%**	**0%**

Crashes by crossing flow channel code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Two-Way Traffic - No Left Turns Permitted	30	93%	-	NA
Two-Way Traffic - Left Turns Permitted	627	88%	3%	3%
Two-Way Traffic - Left Turns Peak Hr Rest.	3	100%	-	NA
One-Way Traffic	23	87%	4%	NA
Other	2	50%	-	NA
Total	**685**	**88%**	**3%**	**0%**

Crashes by control code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
No Control	2	100%	-	NA
Stop Signs on Cross Street Only	223	87%	4%	54%
Stop Signs on Mainline Only	1	100%	-	NA
Four-Way Stop Signs	2	100%	-	NA
Four-Way Flasher (Red on Cross Street)	0	-	-	NA
Four-Way Flasher (Red on Mainline)	0	-	-	NA
Four-Way Flasher (Red on All)	0	-	-	NA
Yield Signs (On Cross Street Only)	0	-	-	NA
Yield Signs (On Mainline Only)	0	-	-	NA
Signals Pretimed - 2 Phase	85	93%	-	NA
Signals Pretimed - Multi-Phase	17	76%	12%	NA
Signals Semi-Traffic Actuated - 2 Phase	25	88%	4%	NA
Signals Semi-Traffic Actuated - Multi Phase	13	92%	-	NA
Singals Full-Traffic Actuated - 2 Phase	58	91%	2%	-52%
Singals Full-Traffic Actuated - Multi Phase	257	87%	2%	-35%
Other	2	100%	-	NA
Signalized	455	88%	2%	-33%
Four-Way Flasher	0	-	-	NA
Total	**685**	**88%**	**3%**	**0%**

Crashes by number of lanes on main street

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
1	0	-	-	NA
2	56	89%	5%	104%
3	22	95%	5%	NA
4	381	88%	3%	0%
5	19	95%	-	NA
6	182	86%	2%	-20%
7	0	-	-	NA
8	25	80%	-	NA
12	0	-	-	NA
blank				NA
Total	**685**	**88%**	**3%**	**0%**

Crashes by number of lanes on crossing street

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
1	1	100%	-	NA
2	452	89%	3%	1%
3	27	89%	4%	NA
4	185	87%	1%	-143%
5	8	63%	13%	NA
6	11	55%	18%	NA
7	0	-	-	NA
8	0	-	-	NA
Null	1	100%	-	NA
blank		-	-	NA
Total	**685**	**88%**	**3%**	**0%**

Crashes by highway group

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Undivided Highway	210	90%	3%	27%
Independent Alignment - Left	18	100%	-	NA
Divided Highway	450	86%	2%	-7%
Independent Alignment - Right	6	100%	-	NA
Null or blank	1	-	-	NA
Total	**685**	**88%**	**3%**	**0%**

Crashes by mainline ADT

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
<10,000	13	77%	15%	NA
10,000 to 20,000	82	94%	2%	-8%
20,000 to 30,000	165	89%	2%	-8%
30,000+	425	87%	2%	-12%
(blank)				NA
Total	**685**	**88%**	**3%**	**0%**

Crashes by crossing ADT

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
<10,000	538	89%	2%	-9%
10,000 to 20,000	95	81%	3%	20%
20,000 to 30,000	42	90%	2%	-10%
30,000+	10	90%	10%	NA
(blank)				NA
Total	**685**	**88%**	**3%**	**0%**

Appendix 5-S: Fatality Index of Intersections –Urbanized

Crashes by design code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Four-Legged	110	82%	8%	-6%
Multi-Legged	2	100%	-	NA
Offset	19	74%	11%	NA
Tee	41	71%	10%	13%
WYE	1	100%	-	NA
Other	0	-	-	NA
Total	**173**	**79%**	**9%**	**0%**

Crashes by presence of lighting

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Yes	160	80%	9%	8%
No	13	62%	-	NA
Total	**173**	**79%**	**9%**	**0%**

Crashes by main signal mast arm

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Yes	55	91%	4%	-138%
No	118	73%	11%	27%
Total	**173**	**79%**	**9%**	**0%**

Crashes by main left channel code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
No Left Turn Channelization	69	74%	12%	34%
Painted Left Turn Channelization	92	80%	7%	-33%
Curbed Median Left Turn Channelization	12	92%	8%	NA
Raised Bars - Left Turn Channelization	0	-	-	NA
Yes	0	-	-	NA
Total	**173**	**79%**	**9%**	**0%**

Crashes by main right channel code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Yes	24	88%	13%	NA
No	149	77%	8%	-8%
Partial	0	-	-	NA
Total	**173**	**79%**	**9%**	**0%**

Crashes by main flow code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Two-Way Traffic - No Left Turns Permitted	2	100%	-	NA
Two-Way Traffic - Left Turns Permitted	155	76%	10%	12%
Two-Way Traffic - Left Turns Peak Hr Rest.	0	-	-	NA
One-Way Traffic	16	100%	-	NA
Other	0	-	-	NA
Total	**173**	**79%**	**9%**	**0%**

Crashes by crossing signal mast arm

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Yes	40	90%	5%	-73%
No	133	75%	10%	13%
Total	**173**	**79%**	**9%**	**0%**

Crashes by left crossing channel code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
No Left Turn Channelization	143	76%	10%	13%
Painted Left Turn Channelization	30	93%	3%	-160%
Curbed Median Left Turn Channelization	0	-	-	NA
Raised Bars - Left Turn Channelization	0	-	-	NA
Yes	0	-	-	NA
Total	**173**	**79%**	**9%**	**0%**

Crashes by right crossing channel code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Yes	21	86%	5%	NA
No	152	78%	9%	6%
Partial	0	-	-	NA
Total	**173**	**79%**	**9%**	**0%**

Crashes by crossing flow channel code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Two-Way Traffic - No Left Turns Permitted	2	100%	-	NA
Two-Way Traffic - Left Turns Permitted	166	78%	9%	4%
Two-Way Traffic - Left Turns Peak Hr Rest.	0	-	-	NA
One-Way Traffic	5	100%	-	NA
Other	0	-	-	NA
Total	**173**	**79%**	**9%**	**0%**

Crashes by control code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
No Control	1	100%	-	NA
Stop Signs on Cross Street Only	105	70%	12%	43%
Stop Signs on Mainline Only	1	100%	-	NA
Four-Way Stop Signs	4	100%	-	NA
Four-Way Flasher (Red on Cross Street)	0	-	-	NA
Four-Way Flasher (Red on Mainline)	0	-	-	NA
Four-Way Flasher (Red on All)	1	100%	-	NA
Yield Signs (On Cross Street Only)	0	-	-	NA
Yield Signs (On Mainline Only)	0	-	-	NA
Signals Pretimed - 2 Phase	4	100%	-	NA
Signals Pretimed - Multi-Phase	0	-	-	NA
Signals Semi-Traffic Actuated - 2 Phase	1	100%	-	NA
Signals Semi-Traffic Actuated - Multi Phase	1	100%	-	NA
Singals Full-Traffic Actuated - 2 Phase	12	100%	-	NA
Singals Full-Traffic Actuated - Multi Phase	43	88%	5%	-86%
Other	0	-	-	NA
Total	**173**	**79%**	**9%**	**0%**

Crashes by number of lanes on main street

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
1	0	-	-	NA
2	78	83%	9%	4%
3	9	89%	-	NA
4	86	73%	9%	7%
5	0	-	-	NA
6	0	-	-	NA
7	0	-	-	NA
8	0	-	-	NA
12	0	-	-	NA
blank				NA
Total	**173**	**79%**	**9%**	**0%**

Crashes by number of lanes on crossing street

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	0	-	-	NA
1	4	75%	-	NA
2	154	77%	10%	12%
3	3	100%	-	NA
4	10	100%	-	NA
5	0	-	-	NA
6	0	-	-	NA
7	0	-	-	NA
8	0	-	-	NA
<Null>	2	100%	-	NA
blank				NA
Total	**173**	**79%**	**9%**	**0%**

Crashes by highway group

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Undivided Highway	117	75%	9%	-1%
Independent Alignment - Left	5	100%	-	NA
Divided Highway	40	80%	13%	44%
Independent Alignment - Right	11	100%	-	NA
Null or blank				NA
Total	**173**	**79%**	**9%**	**0%**

Crashes by mainline ADT

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
<10,000	23	83%	13%	NA
10,000 to 20,000	77	71%	12%	35%
20,000 to 30,000	52	83%	6%	-50%
30,000+	21	90%	-	NA
(blank)				NA
Total	**173**	**79%**	**9%**	**0%**

Crashes by crossing ADT

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
<10,000	166	78%	9%	4%
10,000 to 20,000	6	100%	-	NA
20,000 to 30,000	1	100%	-	NA
30,000+	0	-	-	NA
(blank)				NA
Total	**173**	**79%**	**9%**	**0%**

Appendix 5-T: Fatality Index of Intersections – Rural

Crashes by design code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Four-Legged	50	78%	6%	-55%
Multi-Legged	0	-	-	NA
Offset	1	-	-	NA
Tee	39	77%	13%	38%
WYE	6	50%	17%	NA
Other	1	100%	-	NA
Total	**97**	**75%**	**9%**	**0%**

Crashes by presence of lighting

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Yes	57	86%	4%	-164%
No	40	60%	18%	89%
Total	**97**	**75%**	**9%**	**0%**

Crashes by main signal mast arm

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Yes	17	71%	6%	NA
No	80	76%	10%	8%
Total	**97**	**75%**	**9%**	**0%**

Crashes by main left channel code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
No Left Turn Channelization	53	79%	9%	2%
Painted Left Turn Channelization	40	68%	10%	8%
Curbed Median Left Turn Channelization	3	100%	-	NA
Raised Bars - Left Turn Channelization	0	-	-	NA
Yes	1	100%	-	NA
Total	**97**	**75%**	**9%**	**0%**

Crashes by main right channel code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Yes	14	71%	-	NA
No	82	76%	11%	18%
Partial	1	100%	-	NA
Total	**97**	**75%**	**9%**	**0%**

Crashes by main flow code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Two-Way Traffic - No Left Turns Permitted	0	-	-	NA
Two-Way Traffic - Left Turns Permitted	96	75%	9%	1%
Two-Way Traffic - Left Turns Peak Hr Rest.	0	-	-	NA
One-Way Traffic	1	100%	-	NA
Other	0	-	-	NA
Total	**97**	**75%**	**9%**	**0%**

Crashes by crossing signal mast arm

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Yes	13	62%	8%	NA
No	84	77%	10%	3%
Total	**97**	**75%**	**9%**	**0%**

Crashes by left crossing channel code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
No Left Turn Channelization	85	76%	9%	1%
Painted Left Turn Channelization	10	60%	10%	NA
Curbed Median Left Turn Channelization	1	100%	-	NA
Raised Bars - Left Turn Channelization	0	-	-	NA
Yes	1	100%	-	NA
Total	**97**	**75%**	**9%**	**0%**

Crashes by right crossing channel code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Yes	11	82%	-	NA
No	85	74%	11%	14%
Partial	1	100%	-	NA
Total	**97**	**75%**	**9%**	**0%**

Crashes by crossing flow channel code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Two-Way Traffic - No Left Turns Permitted	0	-	-	NA
Two-Way Traffic - Left Turns Permitted	97	75%	9%	0%
Two-Way Traffic - Left Turns Peak Hr Rest.	0	-	-	NA
One-Way Traffic	0	-	-	NA
Other	0	-	-	NA
Total	**97**	**75%**	**9%**	**0%**

Crashes by control code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
No Control	1	-	-	NA
Stop Signs on Cross Street Only	76	76%	11%	13%
Stop Signs on Mainline Only	0	-	-	NA
Four-Way Stop Signs	0	-	-	NA
Four-Way Flasher (Red on Cross Street)	1	100%	-	NA
Four-Way Flasher (Red on Mainline)	0	-	-	NA
Four-Way Flasher (Red on All)	0	-	-	NA
Yield Signs (On Cross Street Only)	1	100%	-	NA
Yield Signs (On Mainline Only)	0	-	-	NA
Signals Pretimed - 2 Phase	0	-	-	NA
Signals Pretimed - Multi-Phase	1	100%	-	NA
Signals Semi-Traffic Actuated - 2 Phase	0	-	-	NA
Signals Semi-Traffic Actuated - Multi Phase	0	-	-	NA
Singals Full-Traffic Actuated - 2 Phase	2	100%	-	NA
Singals Full-Traffic Actuated - Multi Phase	15	67%	7%	NA
Other	0	-	-	NA
Total	**97**	**75%**	**9%**	**0%**

Crashes by number of lanes on main street

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
1	0	-	-	NA
2	69	74%	7%	-28%
3	1	-	-	NA
4	26	81%	15%	NA
5	1	100%	-	NA
6	0	-	-	NA
7	0	-	-	NA
8	0	-	-	NA
12	0	-	-	NA
blank				NA
Total	**97**	**75%**	**9%**	**0%**

Crashes by number of lanes on crossing street

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
0	0	-	-	NA
1	1	100%	-	NA
2	92	76%	10%	5%
3	1	-	-	NA
4	3	67%	-	NA
5	0	-	-	NA
6	0	-	-	NA
7	0	-	-	NA
8	0	-	-	NA
blank				NA
Total	**97**	**75%**	**9%**	**0%**

Crashes by highway group

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Undivided Highway	81	75%	9%	-7%
Independent Alignment - Left	0	-	-	NA
Divided Highway	14	71%	14%	NA
Independent Alignment - Right	1	100%	-	NA
Null or blank	1	100%	-	NA
Total	**97**	**75%**	**9%**	**0%**

Crashes by mainline ADT

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
<10,000	39	77%	8%	-21%
10,000 to 20,000	43	74%	9%	0%
20,000 to 30,000	12	75%	17%	NA
30,000+	3	67%	-	NA
(blank)				NA
Total	**97**	**75%**	**9%**	**0%**

Crashes by crossing ADT

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
<10,000	94	76%	10%	3%
10,000 to 20,000	3	67%	-	NA
20,000 to 30,000	0	-	-	NA
30,000+	0	-	-	NA
(blank)				NA
Total	**97**	**75%**	**9%**	**0%**

Appendix 5-U: Fatality Index of Ramps – All

Crashes by ramp type

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Frontage Road	2	50%	0%	NA
Collector Road	4	50%	25%	NA
Direct or Semi-Direct Connector (Left)	43	70%	16%	162%
Diamond Type Ramp	723	88%	3%	-87%
Slip Ramp	9	89%	11%	NA
Direct or Semi-Direct Connector (Right)	143	78%	9%	46%
Loop-w/Left Turn	32	88%	0%	NA
Buttonhook Ramp	46	85%	9%	40%
Scissors Ramp	17	71%	0%	NA
Split Ramp	47	55%	23%	277%
Loop-w/o Left Turn	49	73%	16%	163%
Two-Way Ramp Segment	2	100%	0%	NA
Rest Area, Vista Point, Truck Scale	5	40%	20%	NA
Other	6	83%	0%	NA
Dummy-Paired	0	-	-	NA
Dummy-Volume Only	0	-	-	NA
Total	**1128**	**83%**	**6%**	**0%**

Crashes by on/off indicator

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
On	386	81%	8%	29%
Off	734	84%	5%	-20%
Other	8	63%	13%	NA
Total	**1128**	**83%**	**6%**	**0%**

Crashes by Area 4

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
No	93	77%	6%	4%
Yes	1035	83%	6%	0%
Total	**1128**	**83%**	**6%**	**0%**

Crashes by ADT

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
<10,000	647	84%	5%	-22%
10,000 to 20,000	355	84%	7%	9%
20,000 to 30,000	77	75%	9%	46%
30,000 +	34	65%	15%	137%
Blank	15			NA
Total	**1128**	**83%**	**6%**	**0%**

Appendix 5-V: Fatality Index of Ramps – Urban

Crashes by ramp type

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Frontage Road	1	100%	0%	NA
Collector Road	4	50%	25%	NA
Direct or Semi-Direct Connector (Left)	41	68%	17%	166%
Diamond Type Ramp	661	88%	3%	-93%
Slip Ramp	9	89%	11%	NA
Direct or Semi-Direct Connector (Right)	140	78%	9%	45%
Loop-w/Left Turn	28	86%	0%	NA
Buttonhook Ramp	41	83%	10%	52%
Scissors Ramp	12	92%	0%	NA
Split Ramp	47	55%	23%	264%
Loop-w/o Left Turn	49	73%	16%	154%
Two-Way Ramp Segment	2	100%	0%	NA
Rest Area, Vista Point, Truck Scale	2	50%	0%	NA
Other	6	83%	0%	NA
Dummy-Paired	0	-	-	NA
Dummy-Volume Only	0	-	-	NA
Total	**1043**	**83%**	**6%**	**0%**

Crashes by on/off

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
On	350	81%	9%	33%
Off	686	84%	5%	-22%
Other	7	71%	14%	NA
Total	**1043**	**83%**	**6%**	**0%**

Crashes by Area 4 code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
No	81	77%	7%	15%
Yes	962	84%	6%	-1%
Total	**1043**	**83%**	**6%**	**0%**

Crashes by ADT

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
<10,000	571	84%	5%	-26%
10,000 to 20,000	348	84%	7%	5%
20,000 to 30,000	75	75%	9%	42%
30,000 +	34	65%	15%	129%
Blank	15			NA
Total	**1043**	**83%**	**6%**	**0%**

Appendix 5-W: Fatality Index of Ramps – Urbanized

Crashes by ramp type

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Frontage Road	1	0%	0%	NA
Collector Road	0	NA	NA	NA
Direct or Semi-Direct Connector (Left)	1	100%	0%	NA
Diamond Type Ramp	46	85%	2%	30%
Slip Ramp	0	NA	NA	NA
Direct or Semi-Direct Connector (Right)	1	100%	0%	NA
Loop-w/Left Turn	3	100%	0%	NA
Buttonhook Ramp	2	100%	0%	NA
Scissors Ramp	5	20%	0%	NA
Split Ramp	0	NA	NA	NA
Loop-w/o Left Turn	0	NA	NA	NA
Two-Way Ramp Segment	0	NA	NA	NA
Rest Area, Vista Point, Truck Scale	1	100%	0%	NA
Other	0	NA	NA	NA
Dummy-Paired	0	NA	NA	NA
Dummy-Volume Only	0	NA	NA	NA
Total	**60**	**80%**	**2%**	**0%**

Crashes by on/off

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
On	28	75%	4%	NA
Off	31	87%	0%	NA
Other	1	0%	0%	NA
Total	**60**	**80%**	**2%**	**0%**

Crashes by Area 4 code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
No	9	89%	0%	NA
Yes	51	78%	2%	18%
Total	**60**	**80%**	**2%**	**0%**

Crashes by ADT

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
<10,000	52	85%	2%	15%
10,000 to 20,000	6	33%	0%	NA
20,000 to 30,000	2	100%	0%	NA
30,000 +	0	NA	NA	NA
Blank	0			NA
Total	**60**	**80%**	**2%**	**0%**

Appendix 5-X: Fatality Index of Ramps – Rural

Crashes by ramp type

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
Frontage Road	0	NA	NA	NA
Collector Road	0	NA	NA	NA
Direct or Semi-Direct Connector (Left)	1	100%	0%	NA
Diamond Type Ramp	16	88%	6%	NA
Slip Ramp	0	NA	NA	NA
Direct or Semi-Direct Connector (Right)	2	50%	0%	NA
Loop-w/Left Turn	1	100%	0%	NA
Buttonhook Ramp	3	100%	0%	NA
Scissors Ramp	0	NA	NA	NA
Split Ramp	0	NA	NA	NA
Loop-w/o Left Turn	0	NA	NA	NA
Two-Way Ramp Segment	0	NA	NA	NA
Rest Area, Vista Point, Truck Scale	2	0%	50%	NA
Other	0	NA	NA	NA
Dummy-Paired	0	NA	NA	NA
Dummy-Volume Only	0	NA	NA	NA
Total	**25**	**80%**	**8%**	**NA**

Crashes by on/off

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
On	8	88%	0%	NA
Off	17	76%	12%	NA
Other	0	NA	NA	NA
Total	**25**	**80%**	**8%**	**NA**

Crashes by Area 4 code

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
No	3	67%	0%	NA
Yes	22	82%	9%	NA
Total	**25**	**80%**	**8%**	**NA**

Crashes by ADT

	Total crashes on state highway system	Injured	Killed	Relationship between fatalities and total crashes
<10,000	24	79%	8%	NA
10,000 to 20,000	1	100%	0%	NA
20,000 to 30,000	0	NA	NA	NA
30,000 +	0	NA	NA	NA
Blank				NA
Total	**25**	**80%**	**8%**	**NA**

Appendix 7-A Training Materials Memorandum

MEMORANDUM

Date: March 18, 2014

To: Offer Grembek, SafeTREC

From: Nikki Foletta, Meghan Weir, and Meghan Mitman, Fehr & Peers

As part of UC Berkeley's Safe Transportation Research & Education Center (SafeTREC) development of a Pedestrian Safety Improvement Program (PSIP), Fehr & Peers has inventoried courses and tools related to pedestrian safety currently available to Caltrans staff. We have interviewed staff (Beth Thomas of District 4, Dario Senor of District 5 and Carolyn Dudley of Headquarters) about existing training programs and resources, and reviewed material shared by Caltrans staff.
This memo summarizes findings with a focus on:

- Inventory of courses and tools related to pedestrian safety currently available to Caltrans staff; summary of training content, intended and actual audience; and training target for each course and/or tool;
- Identification of gaps in training material targeted to engineers, designers and construction personnel;
- Recommended courses and programs to fill gaps;
- Recommended institutional changes to address ongoing training needs and support Caltrans' pedestrian safety and complete streets directive

INVENTORY

Pedestrian safety courses and tools currently available to Caltrans staff vary by district and include both internal and external training materials. Caltrans maintains a Learning Management System (LMS) with internal training courses available to Caltrans staff. Many Pedestrian coordinators also seek out training materials from external resources such as the Federal Highway Administration's (FHWA) training courses, which are available to the general public. Dario Senor and Carolyn Dudley shared sample pedestrian safety training materials (for District 5 and for Headquarters Landscape Architecture); both include materials sourced from Caltrans' LMS and from external sources.
Training subjects range from broad and introductory, to focused on specific facility types. Example training materials identified by Mr. Senor Ms. Dudley and Fehr & Peers are

summarized in the following table. Not all internal training courses and materials are available all the time.

Table 1: Summary of Pedestrian Safety Training Materials				
Course or Curriculum Title	**Source and format (internal/external; in-person/online)**	**Target Audience**	**Length**	**Subject**
Complete Streets Planning and Design	Caltrans, in partnership with UC Berkeley's Tech Transfer Program; in-person training (new training, offered to HQ and District 4 so far; current demand exceeds capacity)	Caltrans Complete Streets Coordinators at each district, and other Caltrans staff	2 days	How complete streets are planned, designed, operated and maintained to provide safe and comfortable travel for all users of all ages, including pedestrians, bicyclists, transit vehicles and motorists; with a focus on planning, design, history; policy and implementation of complete streets, intersections, crossings and interchanges
Introduction to Pedestrian Safety Design and Planning Principles	FHWA[1] and PBIC[2]; recorded webinar from July 2010	Designers	1 hour	Part of the *Designing for Pedestrian Safety* series
How to Develop a Pedestrian Safety Action Plan	FHWA and PBIC; report from February 2006	State and local agencies; engineers, planners, traffic safety and enforcement, public health and injury prevention, and decision makers	159 pages	Overview and framework for state and local agencies to develop and implement a Pedestrian Safety Plan tailored to specific needs: this guide is meant to help state and local officials know where to begin the process to address pedestrian safety issues, including big picture planning, involving stakeholders, collecting data, analyzing information, prioritizing, selecting solutions, funding and creating the Pedestrian Safety Action Plan

Table 1: Summary of Pedestrian Safety Training Materials				
Course or Curriculum Title	**Source and format (internal/external; in-person/online)**	**Target Audience**	**Length**	**Subject**
A Guide for Reducing Collisions Involving Pedestrians	NCHRP[3], TRB[4]; report from 2004	Transportation professionals, especially those responsible for implementing the AASHTO[5] Strategic Highway safety Plan	143 pages	Addressing pedestrian safety though speed reduction, visibility, exposure to traffic, access mobility, and safety awareness and behavior
The Highway Safety Improvement Program (HSIP), Pedestrian Focus States Webinar	FHWA and Caltrans internal presentation; in-person presentation from 2010	Caltrans (and local agency) staff	2 hours	HSIP background and eligibility
Pedestrian Road Safety Audits (RSAs), A Walk Through Tools, Techniques and Troubles for Pedestrians	In-person presentation by Dan Nabors from 2010	Those who will conduct RSAs and implement RSA programs	35 slides	Introduction to RSAs, how to use them for pedestrian safety issues, and program implementation strategies
Pedestrian Road Safety Audit Guidelines and Prompt Lists	FHWA; technical report from 2007	Transportation agencies and RSA teams	138 pages	How to address the needs of pedestrians of all abilities when conducting an RSA, a broad overview of the RSA process, and how to include pedestrians
Pedestrian Checklist and Considerations for Temporary Traffic Control Zones	US DOT[6]; checklist	Those who plan, design and construct temporary traffic control zones	2 pages	Checklist and overview of pedestrian-related considerations during planning, design and construction phases to enhance pedestrian safety, accessibility and ADA[7] compliance at each phase

Table 1: Summary of Pedestrian Safety Training Materials				
Course or Curriculum Title	**Source and format (internal/external; in-person/online)**	**Target Audience**	**Length**	**Subject**
Temporary Pedestrian Facilities Training	Caltrans; online training course	Construction resident engineers, inspectors, personnel responsible for developing, approving and implementing work zones, including temporary routes for use by the public; *required* for Caltrans staff who work in the field (mostly aimed at construction division, but open to others)	1 hour	Online training about accommodation of pedestrians, including persons with disabilities as defined by ADA, through and around work zones
Designing Pedestrian Facilities	Caltrans; online training course	Transportation planners and planning staff	Unknown	Principles and best practice for how to plan, design and operate a wide range of pedestrian-friendly facilities, including sidewalks, crosswalks and other public spaces adjoining or intersecting the road network
Designing for Pedestrian Safety	Caltrans and FHWA; in-person workshop	Planners, engineers and designers	2 days	Designing streets for pedestrian safety, engineering countermeasures, short- and long-term solutions to reduce pedestrian collisions and make communities safer and more walkable
Designing Pedestrian Safety Action Plans	Caltrans and FHWA; in-person workshop	Local agencies and Caltrans planning and engineering staff	3 days	How to develop effective pedestrian safety action plans, identify obstacles to walking, and present short- and long-term solutions

Table 1: Summary of Pedestrian Safety Training Materials				
Course or Curriculum Title	**Source and format (internal/external; in-person/online)**	**Target Audience**	**Length**	**Subject**
CA Ped Safety Assessment Handbook and Technical Assistance Program	UC Berkeley Technology Transfer Program; handbook technical guide, with context and additional information online	Local jurisdictions, with a focus on cities and counties, with content practical to Caltrans staff needs	63 page handbook and 2 page brochure	How-to guide for conducting pedestrian safety assessments (PSAs) with the objective of improving site specific and citywide pedestrian safety, creating safe and comfortable walking environments, and enhancing overall walkability
Community Pedestrian Safety Trainings	UC Berkeley SafeTREC; in-person workshops	Community members, city and county officials, local agencies and schools, with content practical to Caltrans staff needs	1 day	Focus on community skills and education about pedestrian safety best practices, walkability assessments and pedestrian safety action plans
Designing Safe, Accessible Pedestrian Facilities	UC Berkeley Technology Transfer; in-person training	Engineers, planners and consultants responsible for planning, designing or constructing pedestrian facilities	1 day	Principles and good practices for pedestrian safety, including planning, design, and operation of sidewalks, crosswalks, and other public spaces; application of current standards and guidelines
Various internal Academy programs, including Transportation Planning Academy, Project Engineer Academy, Traffic Safety Academy, Resident Engineer Certificate Program, Construction Academy	Internal training curricula organized around specific professional needs for divisions and programs	Defined for each academy	Varies and includes a variety of courses, checklists and training materials for each academy	Very broad, including some aspect of pedestrian safety related to the target audience

Table 1: Summary of Pedestrian Safety Training Materials				
Course or Curriculum Title	**Source and format (internal/external; in-person/online)**	**Target Audience**	**Length**	**Subject**
Curriculum Guide for Transportation Landscape Architecture	Internal training guide; internal website	Landscape Architecture	11 pages (references other training materials)	Guide with instructions and a curriculum to be used as a tool to assist Caltrans Landscape Architects, with an emphasis on how to fit training into all levels of professional development

Notes:

1. Federal Highway Administration
2. Pedestrian and Bicycle Information Center
3. National Cooperative Highway Research Program
4. Transportation Research Board
5. American Association of State Highway and Transportation Officials
6. U.S. Department of Transportation
7. Americans with Disabilities Act of 1990

Some of the Caltrans training course materials are listed within the online training program website, but are not available for download.

Outside of the internal Caltrans inventory, many organizations offer training opportunities. For example, many of the training materials for the courses listed above are provided by FHWA or UC Berkeley's Tech Transfer. The Institute of Transportation Engineers (ITE), Association of Pedestrian and Bicycle Professionals (APBP) and the Complete Streets Coalition also offer training materials and interactive webinars for members and members of the public.

Caltrans has identified pedestrian safety resource documents and provides links to several resources on the external website (http://www.dot.ca.gov/hq/traffops/survey/pedestrian/). These include the following guidance documents and manuals:

- Complete Intersections: A Guide to Reconstructing Intersections and Interchanges for Bicyclists and Pedestrians; 133 page document outlining intersection best practices for pedestrians and bicyclists, completed 2010
- Complete Intersection Brochure; 2 page summary of guide, completed 2010
- Deputy Directive 64-R1, October 2008; Complete Streets policy directive, signed 2008
- Pedestrian and Bicycle Facilities in California: A Technical Reference and Technology Transfer Synthesis for Caltrans Planners and Engineers; 164 page

reference guide outlining concepts and non-motorized best practices in response to Accommodating Non-Motorized Travel directive, 2005

- California Blueprint for Bicycling and Walking; 38 page report to California State Legislature addressing goals for increasing bicycling and reducing pedestrian and bicycle injuries across the state, 2002
- Highway Design Manual (HDM): Sections relating to pedestrians are Topics 105, 208, 302, 303, 305, 401, 403, 405
- California Manual on Uniform Traffic Control Devices (CA MUTCD): Sections relating to pedestrians are Parts 2B, 2C, 3B, and 4
- California Vehicle Code (CVC): Sections relating to pedestrian rights and duties are 21949-21979

IDENTIFICATION OF GAPS

The Caltrans pedestrian training program may be enhanced to support safety initiatives by addressing several specific issues:

- Structure and requirements are not clear
- Variation among districts leads to inconsistency
- Reaching targeted audiences can be a challenge
- Internal barriers limit staff access to and availability for optional training time
- Across department training may be necessary to address information gaps

STRUCTURE AND REQUIREMENTS

Caltrans does not currently provide a structured, funded training program for pedestrian safety, and has not outlined specific pedestrian safety training goals for different departments. This is an especially relevant gap among those staff responsible for the design and implementation of Caltrans facilities. The Design and Construction divisions receive no formal pedestrian safety training, though these divisions are responsible for accommodating pedestrians and bicyclists in the design and implementation of new facilities.

The Caltrans staff we interviewed noted that while manuals and reference guides include current standards and best practices for pedestrian safety, many Design and Construction staff are not aware of these standards and resources. For example, the latest Manual on Uniform Traffic Control Devices (MUTCD) includes a section on bicycles in construction zones, but this resource is not widely known to staff. The necessary tools are in place, and must be consistently integrated on projects.

Headquarters has presented the new Complete Streets initiative as a mandate, accompanied by a new Complete Streets Planning and Design course, which focuses on

the planning and design of Complete Streets. This course covers how to design streets, intersections, crossings, and interchanges consistent with the Complete Streets approach. Each district Complete Streets Coordinator will be required to attend, and other staff and non-Caltrans participants are also welcome, but there is currently more demand than capacity so attendance may be limited. The training has been delivered to staff at Headquarters and District 4, and will be delivered to all Caltrans Districts by the end of the 2014 calendar year. This training course provides a first step toward a structured pedestrian safety training program, but does not go into detail on this topic.
Trainings for Caltrans staff are generally either mandatory (federally mandated, such as civil and workplace rights training), job-required training (courses associated with specific job duties), or job-related training (supportive training programs for professional growth). Most pedestrian safety training currently falls into the job-related category, and is not required for any groups.

VARIATION AMONG DISTRICTS

Because the pedestrian safety training program is undefined and not structured around specific requirements from Headquarters, training courses and materials are hosted and shared internally at the District level. According to Mr. Senor, courses and training materials are provided by Caltrans District Pedestrian Coordinators or other interested staff. Training content depends largely on the training resources the Pedestrian Coordinators choose to use; participation is optional and can vary among districts.

REACHING TARGETED AUDIENCES

Caltrans has not defined a target audience for training programs, thus the same select group of interested staff members typically participates in optional training sessions, and no mechanism is in place to ensure that the sessions reach a broad cross section of staff. Training for Design and Construction divisions is particularly important, as these divisions are responsible for implementing plans. Because training is not always structured to support and implement policy, some Caltrans staff may be unaware of various policy directives and relevant vehicle codes relating to pedestrian safety, despite these being official Caltrans policies. Crosswalk enhancement policies outlined in the Departments Complete Intersections Guide, for example, may not be widely known by long-term Caltrans staff who have not received training on recent policy updates and internal design guides.

INTERNAL BARRIERS

Training opportunities are optional for most staff and many course materials are provided by outside organizations. Therefore, staff may only be available to participate on their own time, and webinars must be arranged through outside organizations. Short lunch breaks and limited workday flexibility for non-Caltrans training limit staff availability. Many outside organizations require paid memberships or fees for each training session, presenting financial barriers to participation, even among interested staff.

ACROSS DEPARTMENT TRAINING

The Planning division may be more focused on pedestrian safety and related training than the Design and Construction divisions. Nearly all District bicycle and pedestrian coordinators work within the Planning division. However, this division is not responsible for implementing capital projects. Courses with cross-disciplinary participants would present opportunities for different departments to better understand each other's constraints and opportunities to support the development of a relevant and practical training program for a wide variety of participants.

RECOMMENDATIONS

Fehr & Peers recommends the following steps to implement an effective training program that will support the PSIP program:

- Define a targeted training program built around existing and new training resources as part of the implementation of the new Pedestrian Monitoring Report program. This way, the training can be institutionalized and will reach staff that may otherwise not participate in optional training programs. This may be achieved with more job-required training sessions.

- Develop targeted safety training goals and objectives with specific pedestrian safety countermeasures in mind to support implementation of treatments that are necessary to address hotspots in each district. This is partially supported by the new Complete Streets course (described in Table 1), which covers the planning and design of Complete Streets for all modes, including pedestrians. Defined safety training goals and objectives will help to define other training needs and to integrate pedestrian training courses on a regular basis.

- Target certain training sessions towards managers in order to establish support for pedestrian safety best practices among leadership and those responsible for reviewing plans and construction documents, and to reach more junior staff directly through their immediate supervisors.

- Provide training for Caltrans design and engineering staff on recently adopted design guides, especially new pedestrian safety content in the CAMUTCD. Include these pedestrian safety standards in new hire training.

- Initiate policy at Headquarters which support the appropriate training and implementation of programs at the district level, including funding for both training resources, and staff time. (Legal trainings, such as sexual harassment and violence, are required, but there are no other agency-wide safety training programs, even outside of the pedestrian safety focus area.) Unfunded mandates are difficult to successfully implement – for example, complete streets are a mandate, but may not be uniformly treated as a priority. Providing supportive policy and funding can help improve the success of training programs.

- When a training program is developed, identify a champion at the District level who is responsible for training District employees.

- Include a multimodal or pedestrian and bicycle safety segment in all new curriculum programs or academy trainings developed for any topic to integrate pedestrian safety topics in all Caltrans divisions

- Work from headquarters to develop a Caltrans train-the-trainer program that targets District representatives. These District representatives would then present training programs locally, and targeted divisions or employee groups would participate.

- Develop and implement on-the-job-training (OJT) programs as a way to stretch training resources and provide concrete examples to those staff working in the field. Training structured around real world examples, practical tasks and field work needs will create training opportunities for staff that may otherwise not be present at classroom training sessions. OJT programs could be structured around a series of targeted safety audits, project checklists, and small-team training about CAMUTCD-approved pedestrian safety tools.

- Develop more online trainings. Several recently developed training programs do address pedestrian safety, but are not widely available to staff throughout the state. For example, the Complete Streets training is very relevant and directly addresses pedestrian safety training needs, but the classroom format limits participation from staff across the state, so it has not yet reached most districts. The Complete Streets and other similar trainings could be converted into an online training format (this has been done successfully with visual impact training and context sensitive design training in partnership with Sacramento State).

CONCLUSIONS

The recommendations outlined above are consistent with recent internal and external reviews of Caltrans programs. The January 2014 *Caltrans Program Review* and *State Smart Transportation Initiative Assessment and Recommendations* (SSTI Report) provide recommendations aimed at modernizing Caltrans and changing culture to meet new demands. The Program Review refers to the Departments Strategic 2014-18 Strategic Management Plan goals related to safety, mobility and sustainability, which would be supported by a greater emphasis on pedestrian safety.

The SSTI Report outlines specific recommendations aimed at modernizing Caltrans and changing its culture to meet new demands. The following specific recommendations related to pedestrian safety and training are included in the SSTI Report:

- Reform critical guidance documents and standard operating procedures; update design and traffic control device manuals and other guidance documents as necessary…
- Foster innovative and continuing evolution; Caltrans should improve staff training and workforce development.

As outlined above, several important guidance documents including the CAMUTCD and the Complete Intersections Guide have been recently reformed to address pedestrian safety, though many Caltrans staff are not aware of updates. Likewise, many pedestrian safety training opportunities exist, but reach only a narrow audience. Training programs built around the recommendations outlined above would build awareness of existing resources, support efforts to update and reform manuals and guidance, and foster innovations and workforce development.

Appendix 7-B Implementation Protocol

MEMORANDUM

Date: March 21, 2014

To: Offer Grembek, SafeTREC

From: Nikki Foletta, Meghan Weir, and Meghan Mitman, Fehr & Peers

In an effort to identify successful strategies to institutionalize UC Berkeley's Safe Transportation Research and Education Center (SafeTREC) tools for a Pedestrian Safety Improvement Program (PSIP), Fehr & Peers has outlined important implementation steps and organizational considerations. We have interviewed staff (Beth Thomas of District 4, Dario Senor of District 5, Romeo Estrella of District 12, and Carolyn Dudley of Headquarters) about best practices for sharing tools and PSIP materials internally among Caltrans staff and possible implementation approaches.

This memo summarizes recommendations for where to store PSIP materials and first steps for how SafeTREC's tools could be used at Headquarters and within each District in order to initiate the PSIP program across the state.

PSIP MATERIALS

SafeTREC has developed a number of tools to analyze pedestrian collision, volume and infrastructure data; perform both "hotspot" and systematic hazard assessment to identify improvement locations in each district; and guide the selection of appropriate pedestrian safety countermeasures for capital investments. Figure 1 provides a summary of how Task 1 – Task 7 of the PSIP project relate to each other and the inputs and outputs of each task. These tools and materials developed through these tasks should be made available to all Caltrans staff working on pedestrian safety efforts. Therefore, an appropriate home for the materials should facilitate easy access and tool application. Most of the PSIP materials have been designed for use by Caltrans staff, and should only be available internally. Fehr & Peers only has access to the external Caltrans website, but we understand from conversations with staff that the Caltrans intranet closely mirrors the external website. The following potential storage locations on the Caltrans intranet are likely to meet the needs of staff using PSIP tools and materials:

Table 1: Possible Storage for PSIP Tools and Materials		
Caltrans Intranet Locations	**Strengths**	**Challenges**
Complete Streets Program, managed by the Planning Division (http://www.dot.ca.gov/hq/tpp/offices/ocp/complete_streets.html on the external website)	• Caltrans has compiled an online overview of the Complete Streets Program, which includes links to the Complete Streets Implementation Action Plan, Complete Streets Resources, related Caltrans References, additional information and Headquarters contacts. • Because the Complete Streets Program focuses on planning for active transportation and includes guidance for pedestrian safety, this webpage may be a logical location for PSIP materials. • Many of the Complete Streets Program materials will also support PSIP efforts and this webpage already includes links to a Pedestrian Safety Resource Page and Complete Intersections: A Guide to Reconstructing Intersections and Interchanges for Bicyclists and Pedestrians, both of which are key resources for PSIP efforts	• The Complete Streets Program is managed through the Planning Division, so this location may not be readily accessible to other divisions.
Caltrans Office of Traffic Safety Program Pedestrian Safety Branch, managed by the Traffic Operations Division, (http://www.dot.ca.gov/hq/traffops/saferesr/ped.htm on the external website)	• The Pedestrian Safety Branch includes a simple introduction with pedestrian safety goals that are consistent with PSIP efforts. • The webpage includes links to Pedestrian Safety Resources and District Bicycle and Pedestrian Coordinators. PSIP tools could be added to these links, or could be included as part of the Pedestrian Safety Resources links. • The Pedestrian Safety Resources linked through this webpage were outlined in the training memo, and include several documents also linked through the Complete Streets Program webpage. • The internal/intranet version of this webpage could be readily accessible to multiple divisions and presents a logical location for staff looking for pedestrian resources; this page does not currently include many program links, which might allow the PSIP materials to stand out in a short list of tools and resources.	• There is a great deal of overlap between PSIP goals and the existing Complete Streets Program; this location would present the PSIP program as a separate effort, and may not emphasize the consistency with existing Complete Streets resources.

As mentioned, most of the PSIP materials should only be stored on the internal Caltrans website, with one exception, the Pedestrian Safety Report Card, which should also be made available on the external Caltrans website. The Pedestrian Safety Report Card (from SafeTREC's Task 3), to be produced annually, monitors progress towards California's Strategic Highway Safety Plan Challenge Area 8 (SHSP CA8), Making Walking and Street Crossing Safer, goals and is intended to be a public facing document. This document has the potential to highlight the steps Caltrans is taking to monitor and address pedestrian safety issues across the state. The external Caltrans website for either the Complete Streets Program or the Office of Traffic Safety, both mentioned in Table 1, are two potential locations for this resource. The Traffic Operations Division, which manages the Office of Traffic Safety Program, is responsible for evaluation of the SHSP pedestrian fatality and injury data, and provides an SHSP Performance Tracking Details Report on the external SHSP website (http://www.dot.ca.gov/hq/traffops/shsp/). Therefore, the Office of Traffic Safety may be most appropriate, as Traffic Operations already provides this role for current SHSP efforts.

Wherever the PSIP tools are stored, a dashboard style interface could provide an easy-to-navigate access point for all the tools and reports. Figure 1 presents a one-page format to organize the tools and clearly define their relationships. The tools and related supporting documentation could be linked to the headings in this flow chart, which includes very brief descriptions of each tool and how it may be used by Caltrans staff.

In addition to the PSIP tools, a toolbox of references to existing, relevant Caltrans manuals would be helpful so Caltrans staff in different divisions can communicate in terms that have already been official approved.

IMPLEMENTATION STEPS

The below sections outline a simple list of steps for using the PSIP tools and implementing the program across the state assuming that the effort will be led by the Headquarters Pedestrian Program, which will provide each district with specific directions.

HEADQUARTERS FIRST STEPS

The Headquarters Pedestrian Program Coordinator would use the tools developed under PSIP to create a list of 10 pedestrian safety target locations in each district. These locations will be distributed to each district in the form of a list or a Pedestrian Monitoring Report, which could include five urban and five rural locations in each district. This entails the following steps:

1. Introduce the District Pedestrian Coordinators to the PSIP program and the accompanying Pedestrian Monitoring Reports, so each district anticipates the implementation of the new program and list of hotspots.
2. Actively define roles for implementing the PSIP program at the district level, across different divisions, to improve communication and transparency.

3. Run the PSIP Data Access Tool (from SafeTREC Task 1) to create a database of collision records with infrastructure data from Caltrans' Traffic Accident Surveillance and Analysis System (TASAS) and severity/fatality details from the California Statewide Integrated Traffic Records System (SWITRS); this output provides more detail about collision records than previously used databases and formats the data in Excel.
4. Identify important criteria for prioritizing collision hotspots with input from each of the districts.
5. Run the PSIP Hazard Assessment Tool (from SafeTREC Task 4) to sort data records according to the specified criteria and to create the lists of pedestrian collision hotspots in each district.
6. Use this tool output to draft a Pedestrian Monitoring Report for each Caltrans District, which may include five urban and five rural locations identified as high priority based on collision records. The tool output also provides information about collision type and location type.
7. As with other monitoring report-related implementations, funding for implementation in each district may fall under Caltrans' 010 Reactive Funding category because it comes from headquarters and relates to collision records.
8. Distribute the Pedestrian Monitoring Reports to each district and work with districts to address hotspots.
9. If the Pedestrian Monitoring Report is approved/adopted then it will be included in the Highway Safety Improvement Program (HSIP) manual, along with Table C (which is a report that comes from headquarters that defines how Caltrans performs investigations). This would be the first version of Table C for pedestrian or bicycle safety.
10. Continue to coordinate with the Complete Streets Program planning effort to address pedestrian safety challenges and institutionalize the PSIP program across multiple divisions.
11. As an ongoing, parallel process, coordinate with District Pedestrian Coordinators to develop a uniform statewide data collection approach to build an inventory of pedestrian facilities. This may entail defining relevant facility types or a uniform checklist that can be distributed to the various Caltrans staff who may be making field visits in each district, and then managing a central database of the information collected in these field visits. This inventory will serve as a reference for future pedestrian facility retrofits and project planning.

DISTRICT STEPS

Upon receiving the Pedestrian Monitoring Reports from Headquarters, each district should coordinate with the Headquarters Pedestrian Program Coordinator to address pedestrian safety challenges at the ten identified locations. This will entail the following steps:

1. Identify the collision type and location type for each of the ten locations within the district.
2. Use the PSIP Causal Analysis and Countermeasure Selection Matrix (from SafeTREC's Task 5) to identify countermeasures appropriate for specific collision and intersection types, which can be matched to each hotspot location. Refer also to the Caltrans *Complete Intersections: A Guide to Reconstructing Intersections and Interchanges for Bicyclists and Pedestrians* [1] (2010) for design guidelines. Coordinate with local jurisdictions if applicable, as they may be able to share local priorities for pedestrian facilities.
3. Visit each site and collect information to refine countermeasure selection for each location. Refer to UC Berkeley Tech Transfer's *A Technical Guide for Conducting Pedestrian Safety Assessments* [2] (2008) and the Federal Highway Administrations *Pedestrian Road Safety Audit Guidelines and Prompt Lists*[3] (2007) for site visit guidance. Coordinate with local jurisdictions if applicable, as they may be able to share an inventory of pedestrian facilities and local knowledge about safety challenges.
4. Use the PSIP Cost Benefit Calculation tool (from SafeTREC Task 6) to compare costs of collisions at hotspot locations and benefits of location specific countermeasures.
5. Identify relevant local jurisdictions for each hotspot location, especially for urban locations which are likely to overlap with city and county jurisdictions. Coordinate with local jurisdictions to confirm that safety improvements identified through the PSIP process are consistent with local plans and priorities. In some cases, local plans may have already identified these locations for pedestrian safety improvements.
6. Use the PSIP Funding Sources and Strategies tool (from SafeTREC Task 7) to identify additional funds available to coordinate infrastructure improvements with local plans and at edges of Caltrans corridors. In locations that have also been identified as local priorities, use this tool and coordinate directly with local jurisdictions to identify opportunities to maximize non-Caltrans funds. For example, local agencies may be eligible for grant funds that are not available for Caltrans. This will help with limited funding, as the 010 funds described above are often oversubscribed and may not be sufficient for all PSIP identified locations.
7. As an ongoing, parallel process, coordinate with Headquarters to collect information about the pedestrian facilities at each hotspot location, which will be used to populate a statewide inventory of pedestrian facilities on Caltrans roadways. As the PSIP program continues and the pedestrian facilities inventory grows, District Pedestrian Coordinators

[1] Available on the Caltrans Pedestrian Safety Resources webpage: http://www.dot.ca.gov/hq/traffops/survey/pedestrian/
[2] http://www.techtransfer.berkeley.edu/pedsafety/
[3] http://www.pedbikeinfo.org/data/library/details.cfm?id=3955

will be able to check with Headquarters for available data at the outset of each PSIP effort, and provide new data with each project completion. District ADA coordinators may be appropriate for this effort, as they can provide institutional knowledge about pedestrian facilities.

CONCLUSIONS

The timing of the PSIP project is particularly relevant given recent internal and external reviews of Caltrans programs. The January 2014 *Caltrans Program Review* and *State Smart Transportation Initiative Assessment and Recommendations* (SSTI Report) provide recommendations aimed at modernizing Caltrans and changing culture to meet new demands. Both reports support a greater focus on pedestrian safety and monitoring. In order to ensure successful implementation of the PSIP program, Fehr & Peers suggests the following:

- A clear directive and guidance from Headquarters will be key to program success to ensure consistent application of the program across districts. Roles and responsibilities should be clearly defined.
- Funding is limited so emphasis should be placed on coordination with local jurisdictions. Creating a funding stream within Caltrans exclusively for pedestrian safety improvements may be an important goal for future phases of the project.
- Implementing the PSIP program may require a significant shift for Caltrans staff and may be adopted at different rates across different districts. Headquarters should collect feedback from each district on program implementation and incorporate lessons learned into future phases of the program.
- To ensure consistency, Headquarters intends to initially use the PSIP tools to select the 10 locations per district. To provide more flexibility and get buy-in for this new approach, district leaders could be given access to the full suite of tools provided by the PSIP program. In this way they can also perform additional hot spot or pedestrian safety monitoring analysis beyond the ten locations each year.

Appendix 7-B PSIP Flowchart