Safety Analysis and Evaluation of Current Conditions and Future Expansion of US 395 in Lassen County

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for

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1. INTRODUCTION

1.1. Background

The Lassen County Transportation Commission (LCTC) is conducting a study to evaluate improvements to the United States Route 395 within Lassen County to enhance mobility, safety, and promote economic activity in the adjoining areas. The US 395 Strategic Corridor Investment Analysis Project aims to develop detailed plans for corridor improvement and quantify the economic benefits for the region. US 395 is the primary North-South corridor in eastern California travelling through multiple Caltrans districts and rural communities. The highway serves as an interstate connection between Nevada and Oregon through Caltrans District 2 and as an alternative freight route during adverse weather closures of Interstate 5 and 80. Additionally, the highway serves as a commuter route for several communities including between Susanville in Lassen County, CA and Reno, Nevada.

1.2. Study Objectives

Given the strategic importance of US 395 and with a view to improve safety, Lassen County is considering the expansion of a section of the highway from two-lanes to four-lane divided expressway, from Hallelujah Junction (interchange with State Route (SR) 70) to the State Route (SR) 36 intersection near Susanville. The main objective of the study is to conduct a detailed safety analysis of the US 395 corridor from Hallelujah Junction (Post Mile R4.6) to the State Route 36 intersection near Susanville (Post Mile R61.1) and evaluate the safety impact of the expansion of the corridor from two-lane conventional highway to a four-lane expressway in the future.

1.3. Existing Facility

US 395 within Lassen County is generally a rural two-lane highway with a few multilane segments. The section of highway analyzed in this report, henceforth known as the study area or study corridor, is located in northeast of California from Hallelujah Junction (interchange with State Route (SR) 70) to the State Route (SR) 36 intersection near Susanville in Lassen County as shown in Figure 1. The following considerations are presented in the United States Route 395 Transportation Concept Report for the study area on US 395 ("Caltrans", 2017):

- The differential speed limit of 55 mph for trucks and 65 miles per hour for passenger cars result in backups behind trucks and increases the demand for passing. Drivers sometimes do not follow passing laws.
- There is heavy truck, military, and commute traffic to and from Garnier Road especially during the morning and afternoon peaks. Queues formed in the afternoon along Garnier Road due to high traffic flows onto southbound United States Route 395.
- Numerous vehicles exceed the posted speed limit.
- There is heavy truck and commute traffic to and from Herlong Access Road leading especially during the morning and afternoon peaks.

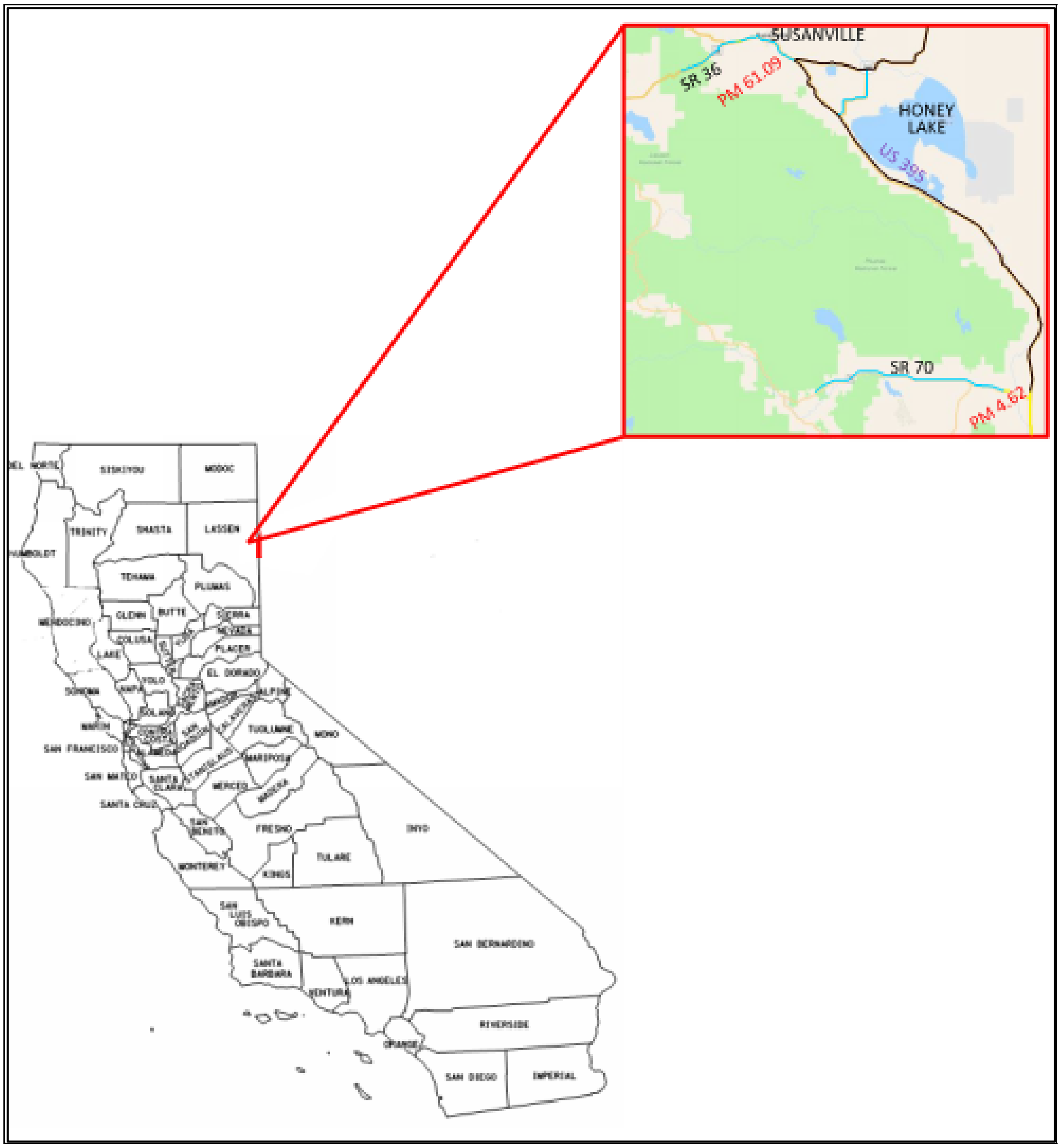


Figure 1: US 395 Study Area Location Map in Lassen County, CA

2. DATA COLLECTION

2.1. Data Sources

To complete the objectives of this study, detailed data were collected from various sources for the study area which included:

- Historical crash data from various sources for the six years from 2013 to 2018;
- Historical traffic volume data including heavy vehicle traffic data and trends;
- Highway inventory data with geometric characteristics for various segments.

The following resources were used to obtain the data:

- University of California, Berkley Transportation Injury Mapping System database ("TIMS", 2020) which provided Statewide Integrated Traffic Records System (SWITRS) data
- Highway Safety Information System ("HSIS", 2020) which provided Caltrans Traffic Accident Surveillance and Analysis (TASAS) dataset
- US 395 Transportation Concept Report ("Caltrans", 2017)
- California Department of Transportation Traffic Counts Report ("Caltrans", 2020)
- Google Earth Pro Web Base Application

The Highway Safety Information System (HSIS) data is a comprehensive database maintained by the Federal Highway Administration (FHWA), which includes collision data, traffic volume data, and some highway geometrics data. Data from abovementioned sources were collected and assembled in a Geographic Information System (GIS) environment for subsequent processing for use in safety analysis in this report.

2.2. Route Segmentation

The study area on US 395 from Hallelujah Junction (interchange with State Route 70) to the State Route 36 near Susanville is approximately 56.5 miles starting at Post Mile R4.6 and ending at Post Mile R61.1. For the purpose of safety analysis, the study area was divided into four segments based on the differences in Annual Average Daily Traffic (AADT) in each segment as reported by the California Department of Transportation (Caltrans) Traffic Census Program Traffic Count database. Table 1 shows the limits of the four segments in the study area and Figure 2 illustrates the four segments of US 395 in the study area.

Table 1: US 395 Segmentation within the Study Area

Segment No.	Location Description	County	Begin Post Mile	End Post Mile	Segment Length (Miles)
1	Junction SR 70 to Garnier Road	Lassen	R4.6	29.8	25.2
2	Garnier Road to Standish Road	Lassen	29.8	51.9	22.0

3	Standish Road to Janesville Road	Lassen	51.9	55.2	3.3
4	Janesville Road to Junction State Route 36	Lassen	55.2	R61.1	5.9

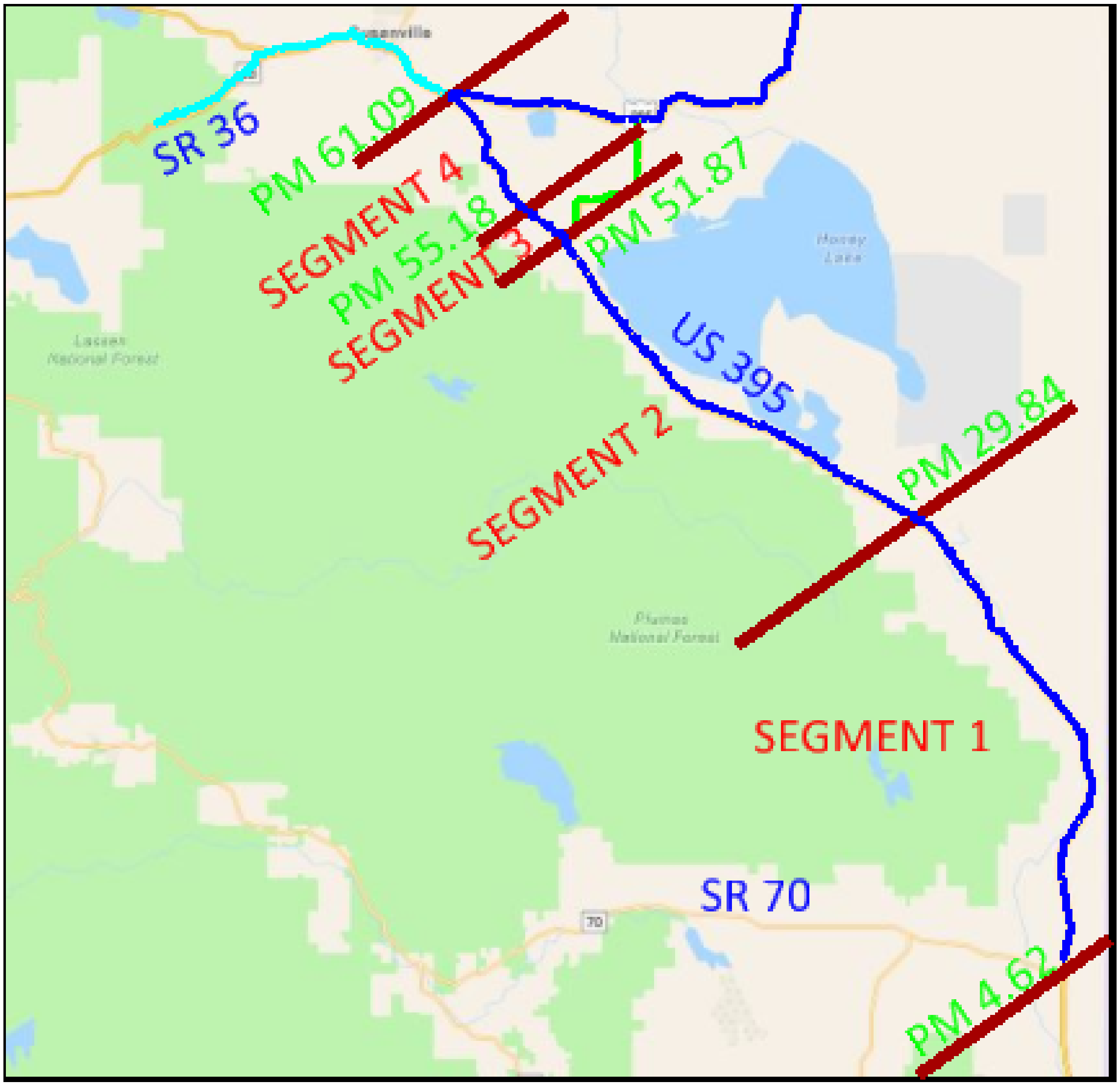


Figure 2: United States Route 395 Segmentation Within Study Limits

2.3. Historical Crash Data

Historical crash data for the study area were obtained from the University of California, Berkeley Transportation Injury Mapping System (TIMS) and the California Statewide Integrated Traffic Records System (SWITRS). Crash data were collected for a six-year period from 2013 to 2018. Although preliminary crash data for 2019 was available at the onset of this study, the data were not included in the analysis due to the uncertainty surrounding data accuracy. Furthermore, geographic location information for the preliminary crash data were not available, which hindered the use of the data in the GIS environment. A detailed review of the six-year crash data was performed to ensure only crashes relevant to the study corridor were used in the final analysis. A total of 312 crashes were identified in the study area in the six-year period.

2.4. Traffic Volume Data

Historical traffic volume data including heavy vehicle traffic data were collected from Caltrans Traffic Census Program website ("Caltrans", 2013-2018). The Total Annual Average Daily Traffic (AADT) and Annual Average Daily Truck Traffic (AADTT) were collected for the study area from 2013 through 2018. Data from 2019 were not collected since they were not finalized at the onset of this study and are subject to change.

Table 2 and Table 3 present the AADT and AADTT values and annual percent change, respectively, for each of the four segments in the project area.

Table 2: Total Annual Average Daily Traffic

Segment No.	2013 AADT	2014 AADT	2015 AADT	2016 AADT	2017 AADT	2018 AADT
1	5350	5300	5800	6300	6550	6800
2	4725	4725	5200	5350	5500	5450
3	5000	5000	5500	5900	6100	6050
4	7300	7300	7300	7900	8550	8450

Table 3: Total Annual Average Daily Traffic Annual Change

Segment No.	Percent Change 2013 to 2014	Percent Change 2014 to 2015	Percent Change 2015 to 2016	Percent Change 2016 to 2017	Percent Change 2017 to 2018
1	-0.9%	9.4%	8.6%	4.0%	3.8%
2	0%	10.1%	2.9%	2.8%	-0.9%
3	0%	10.0%	7.3%	3.4%	-0.8%
4	0%	0%	8.2%	8.2%	-1.2%

Table 4 and Table 5 present the Total Annual Average Daily Truck Traffic and Total Annual Average Daily Truck Traffic annual percent change, respectively, for each of the four segments in the project area.

Table 4: Total Annual Average Daily Truck Traffic

Segment No.	2013 AADTT	2014 AADTT	2015 AADTT	2016 AADTT	2017 AADTT	2018 AADTT
1	980	980	1072	923	986	1001
2	617	701	703	864	895	839
3	648	648	713	792	819	818
4	689	689	689	842	912	901

Table 5: Total Annual Average Daily Truck Traffic Annual Change

Segment No.	Percent Change 2013 to 2014	Percent Change 2014 to 2015	Percent Change 2015 to 2016	Percent Change 2016 to 2017	Percent Change 2017 to 2018
1	0%	9.4%	-13.9%	6.8%	1.5%
2	13.7%	0.2%	23.0%	3.5%	-6.2%
3	0%	10.0%	11.1%	3.4%	-0.1%
4	0%	0%	22.2%	8.3%	-1.3%

2.5. Highway Geometrics Data

Highway geometrics data were collected for various segments within the study area using the following three sources:

- Highway Safety Information System (HSIS)
- US 395 Transportation Concept Report
- Google Earth Pro computer application

The highway geometrics data elements obtained from the sources for the study area are listed below:

- Lane Width
- Shoulder Width
- Shoulder Type (Paved/Unpaved)
- Terrain
- Approximate Horizontal Curve Characteristics
- Driveway Density
- Presence or absence of centerline rumble strips

Table 6 shows the highway geometrics data for each segment of the highway within study limits.

Table 6: Highway Geometrics Data in Each Segment

Segment	Lane Width (Feet)	Shoulder Width (Feet)	Shoulder Type	Terrain	Driveway Density Per Mile	Presence of Centerline Rumble Strips
1	12	4-10	Paved	Rolling /Level	<5	Present
2	12	4-8	Paved	Rolling /Level	<5	Present
3	12	4-8	Paved	Rolling /Level	<5	Present
4	12	4-8	Paved	Rolling	<5	Present

3. DATA ANALYSIS AND RESULTS – CURRENT CONDITIONS

The historical crash, traffic volume, and geometric data were used in conjunction to evaluate the current safety performance of the study area to identify safety issues and concerns, details of which are presented in this section.

3.1. Crash Rate Analysis and Comparison

A comparative analysis of crash rates was conducted in the study corridor on US 395 using statewide and countywide (Lassen County) crash rates as reported by Caltrans. Additionally, the study corridor crash rates were compared with a crash rate prediction based on Caltrans method which uses crash rates of existing road segments to predict the average rates on similar types of roads for comparison purposes. The crash rates calculated in the comparative analysis were:

- Total crashes per MVM (million vehicle miles) travelled
- Fatal and injury crashes per MVM travelled
- Fatal crashes per 100 MVM travelled

Table 7 shows the 2018 California statewide and Caltrans District 2 average crash rates for 2-3 lanes highways. Table 8 shows the average crash rates for 2-3 lane highways in Lassen County from 2013 to 2018. Although both Table 7 and Table 8 show a total crash rate per MVM value, Caltrans allows for a more robust method of calculating a projected crash rate for a facility based on safety performance of similar sites across the state using additional variables (AADT, speed limit). The projected total crash rate per MVM (*what would be expected for the study area based on the performance of other similar sites across the state*) for the study area was calculated as shown in Table 9. The red highlighted values in Table 8 and Table 9 were used to compare with observed crashes rates in the study area.

Table 10 shows the crash rates in the study area calculated based on the observed crashes between 2013 and 2018 for the different segments. The red highlighted numbers in Table 10 are observed crash rates that are greater than the average crash rates in Lassen County or projected crash rates based on similar sites statewide in CA as presented in Table 8 and Table 9. The results in Table 10 show several segments in the study area displaying a higher than average crash rates in various years between 2013 to 2018. In particular, segment 3 shows a higher total crash rate consistently and segment 1 shows a higher crash rate for fatal crashes over the years highlighting safety issues at those locations. Additionally, the average crash rate calculated for each segment between 2013 to 2018 shows segments 3 exceeding the Lassen County averages in all three crash rates and segment 1 exceeding in fatal crash rates. It should be noted that segment 3 is the smallest in length, which may have an impact on the high crash rate observed. Nevertheless, the data clearly shows a potential safety issue in the study area.

Table 7: Statewide and Caltrans District 2 Average Crash Rates for 2-3 Lane Highways

	2018				
Statewide - 2 and 3 Lanes	**Road Miles**	**Travel (MVM)**	**Total Crashes per MVM**	**Fatal + Injury per MVM**	**Fatal per 100 MVM**
Rural (inside and outside city)	7081.8	10363	1.04	0.46	3.45
Rural (outside city)	7017.9	10162.6	1.04	0.46	3.47
Total (Statewide)	8000	14002	1.11	0.48	3.04
Caltrans District 2 - 2 and 3 Lanes					
Rural	1280.7	902.3	1.01	0.43	3.88
Total (District wide)	1315.3	942.8	1.00	0.43	3.82

Table 8: Lassen County Average Crash Rates for 2-3 Lane Highways from 2013 - 2018

Lassen County - 2 and 3 Lane	**Road Miles**	**Travel (MVM)**	**Total Crashes per MVM**	**Fatal + Injury per MVM**	**Fatal per 100 MVM**
Rural - 2013	232.4	143.6	0.75	0.22	0.70
Total (County wide) - 2013	244.9	149.6	0.80	0.23	1.34
Rural - 2014	246.4	151	0.81	0.34	1.99
Total (County wide) - 2014	249.5	156.2	0.83	0.34	1.92
Rural - 2015	236.4	150.3	0.83	0.35	3.33
Total (County wide) - 2015	244.9	156.4	0.90	0.39	3.20
Rural - 2016	236.4	158.4	1.09	0.39	4.42
Total (County wide) - 2016	244.9	164.5	1.10	0.38	4.26
Rural - 2017	242	167.3	0.99	0.36	2.99
Total (County wide) - 2017	244.9	172.5	0.96	0.35	2.90
Rural - 2018	242	166.1	0.88	0.34	3.01
Total (County wide) - 2018	244.9	171.3	0.85	0.33	2.92
			Avg. (Rural)	0.33	2.74
			Avg. (Countywide)	0.34	2.75

Table 9: Predicted Average Total Crash Rate for US 395 based on Caltrans Similar Road Facilities in CA

USH 395 Project Crash Rate Prediction (based on Caltrans similar facilities)	**AADT (2013 - 2018 average)**	**USH 395 Average Crash Rate Projection (> 55 mph)**
Segment 1	6017	0.70
Segment 2	5158	0.70
Segment 3	5592	0.70
Segment 4	7800	0.70

Table 10: Observed and Average Crash Rates for US 395 Study Area Segments, 2013 - 2018

USH 395 Observed Crash Rates	**Total Crashes per MVM**	**Fatal + Injury per MVM**	**Fatal per 100 MVM**
2013			
Segment 1	0.43	0.16	4.06
Segment 2	0.68	0.21	0.00
Segment 3	1.49	0.66	0.00
Segment 4	0.57	0.25	12.69
2014			
Segment 1	0.20	0.10	0.00
Segment 2	0.63	0.11	0.00
Segment 3	1.82	1.16	0.00
Segment 4	0.76	0.32	0.00
2015			
Segment 1	0.36	0.15	1.87
Segment 2	0.36	0.19	0.00
Segment 3	0.75	0.15	0.00
Segment 4	0.19	0.06	0.00
2016			
Segment 1	0.24	0.09	8.62
Segment 2	0.28	0.07	2.32
Segment 3	0.28	0.14	0.00
Segment 4	0.29	0.12	0.00
2017			
Segment 1	0.25	0.10	1.66
Segment 2	0.47	0.23	0.00
Segment 3	0.95	0.68	0.00
Segment 4	0.49	0.11	0.00
2018			
Segment 1	0.46	0.24	3.19
Segment 2	0.41	0.11	0.00
Segment 3	1.23	0.68	54.72
Segment 4	0.38	0.11	0.00
2013 – 2018 Average			
Segment 1	0.32	0.14	3.31
Segment 2	0.47	0.15	0.40
Segment 3	1.06	0.57	9.87
Segment 4	0.45	0.16	1.98
Combined Study Area Crash Rates	**0.43**	**0.17**	**2.49**

3.2. Crash Trend Analysis

In order to further explore the safety performance of segments in the study area, historical crash data for the period between January 01, 2013 to December 30, 2018 were analyzed to identify patterns and trends that may indicate potential safety concerns. The crash data were analyzed for each segment and year separately and analysis by various categories are listed below and discussed in detail in subsequent sections:

- Crash Severity Analysis
- Crashes by Day of Week
- Crash Analysis by Primary Collision Factor
- Crash Analysis by Type of Collision

Crash trends are impacted by the different lengths of the segments as defined in this study and the different traffic volumes observed. Table 11 shows the segments lengths, average total traffic volume and truck volumes, and total number of crashes by severity for reference.

Table 11: Segment Length, Average AADT, and Crash Severity (2013-2018) in the Study Corridor on Hwy 395

Segment No.	**Segment Length (Miles)**	**Average AADT**	**Average Truck AADT**	**Total No. of Crashes**	**Fatal**	**Severe Injury**	**Injury (Other Visible)**	**Injury (Complaint of Pain)**	**PDO**
1	25.5	5129	990	108	7	8	15	17	61
2	22	4375	770	116	1	9	4	22	80
3	3.3	4759	740	43	2	5	9	7	20
4	5.9	6584	787	45	1	2	5	8	29

3.2.1. Crash Severity Analysis

A comparison of crash severity in the study area by segments is presented in Figure 3. As shown in Table 11, majority of the crashes were Property Damage Only (PDO) crashes. The lengths of the segments vary affecting the number of crashes observed in each segment. However, segment 2 stands out with a higher number of some injury and PDO crashes even though it is the second longest in length and has less average traffic than segment 1. Segment 1 has the highest number of fatal crashes observed which is a possible indication of a safety concern in this area.

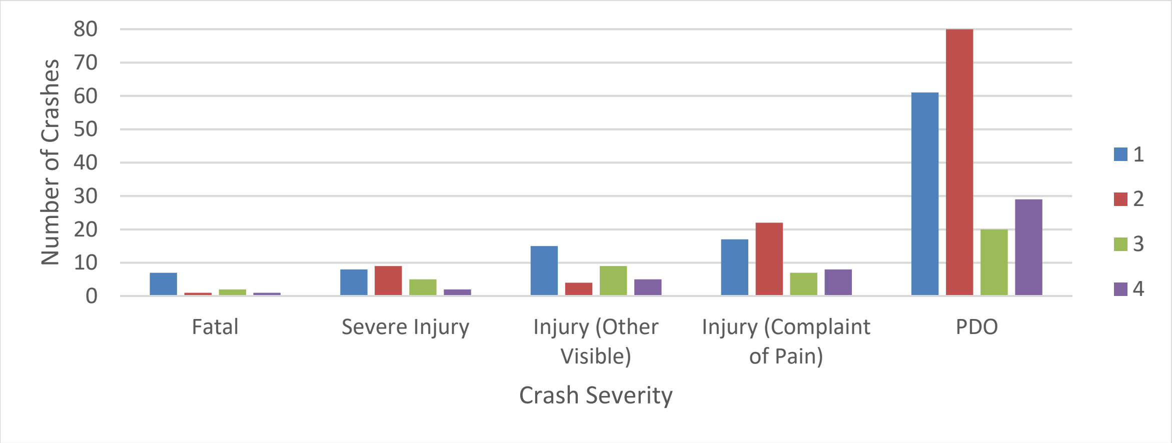
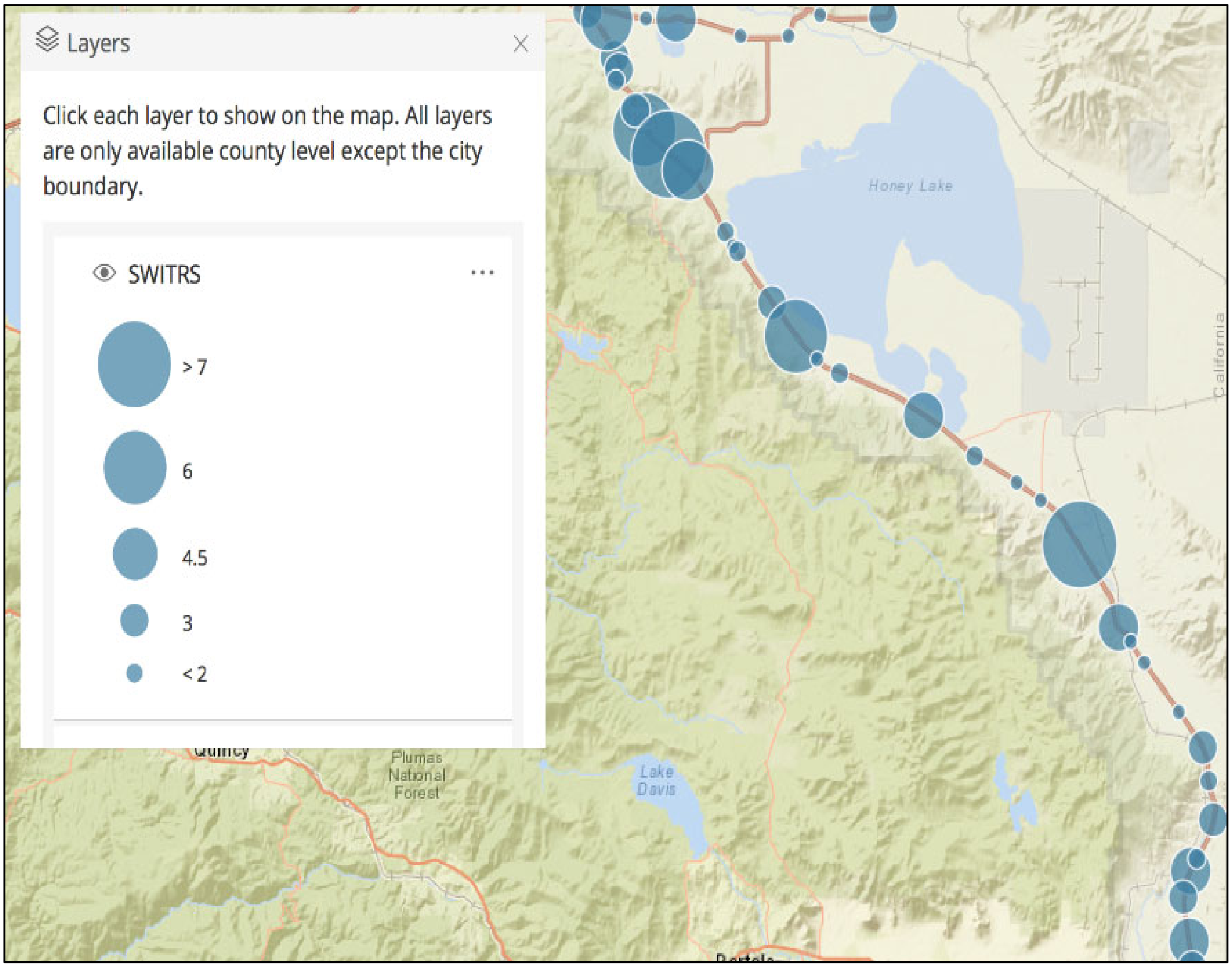


Figure 3: Crash Severity by Segments in US 395 Study Area



Click each layer to show on the map. All layers are only available county level except the city boundary.

Figure 4: Fatal and Injury Crash Concentration in US 395 Study Area [Source: TIMS]

Figure 4 shows the concentration of the 122 total fatal and injury crashes in the study area. The collision data show 47 crashes in segment 1 out of which seven were fatal, which are highest compared with other three segments. One reason for the higher crash frequency is the length of the segment being the longest. Furthermore, although segment 1 does not have the highest AADT of all segments, it has the highest truck traffic volume. The high posted speed limit of 65 mph along with the higher truck traffic volume encourages drivers to pass slow truck possibly contributing to a higher number of head-on and sideswipe crashes within segment 1.

Segment 2 has the lowest AADT and is the second longest in length of all the segments with a high number of crashes. Segment 3 is the shortest segment and has the lowest truck volume and AADT, however it has certain sections of high crash concentration. Further analysis in subsequent sections should reveal possible crash types and factors contributing to the crashes in this segment. Segment 4 is another short segment with relatively high number of recorded collisions. This segment has the highest AADT and is closer to more populated areas and the city of Susanville.

3.2.2. Crash Analysis by Day of Week

Figure 5 shows an analysis of crashes in each segment by the day of week in which the crashes occurred. The trends show a higher number of crashes observed on a weekend in segments 1 and 2 indicating the presence of recreational or other non-commuter type traffic in these segments contributing to the trend. Given the potential economic activity expected in the region, this trend may increase with increasing traffic volumes and patterns. Segments 3 and 4 being closer to Susanville and more populated areas display typical trends observed in similar locations where more crashes are observed in the first few workdays compared to the rest of the week.

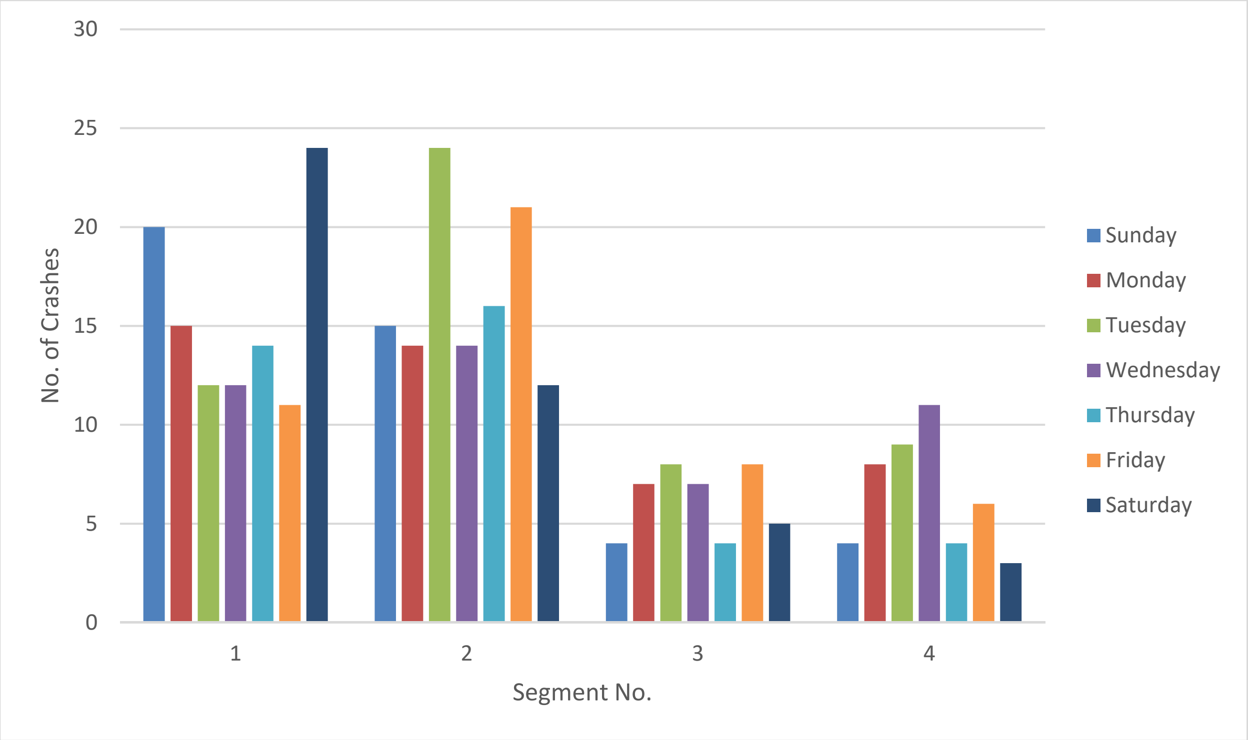


Figure 5: Crashes by Day of Week in US 395 Study Area

3.2.3. Crash Analysis by Primary Collision Factor

The SWITRS crash data provides an indicated of the primacy collision factor (PCF) that the reporting officer believed was mainly responsible for the occurrence of the crash. Figure 6 shows an analysis of crashes in each segment by the PCF. Although the data field on PCF contains 22 different types of factors that are primarily considered responsible for a crash, Figure 6 shows six of these factors which were represented predominantly and were of greatest interest from the perspective of the safety evaluation in this study.

The “other than drive or pedestrian” collision factor is general indicative of a crash involving an animal or other object that the driver did not foresee. The “improper turn” factor is indicative of the following driver or vehicle actions:

- Making a left turn at a “no left turn” intersection
- Turning at a “no turn on red” sign
- Illegal U-turn
- Turning from the wrong lane
- Turning into a lane of incoming traffic
- Turning without right-of-way
- Failure to use a turn signal

Figure 6 shows that all segments have a high number of crashes involving an animal or some other object represented by the “other than driver” factor (as discussed earlier). The data shows a higher number of speed related crashes in segments 1 and 2 although given the length of segment 3, it is also highly represented in speeding related crashes. A similar trend can be seen for improper turn crashes. There is also a number of “Wrong Side of Road” crashes. These factors are indicative of the general concern in the study area of the impact of heavy vehicle traffic on driver behavior and safety. US 395 has different speed limits for passenger cars and heavy vehicles and with most of the highway being a two-lane road, drivers may get frustrated with following a slower heavy vehicle or take additional risks of speeding or moving in the opposite lane to pass heavy vehicles, thereby potentially creating safety issues.

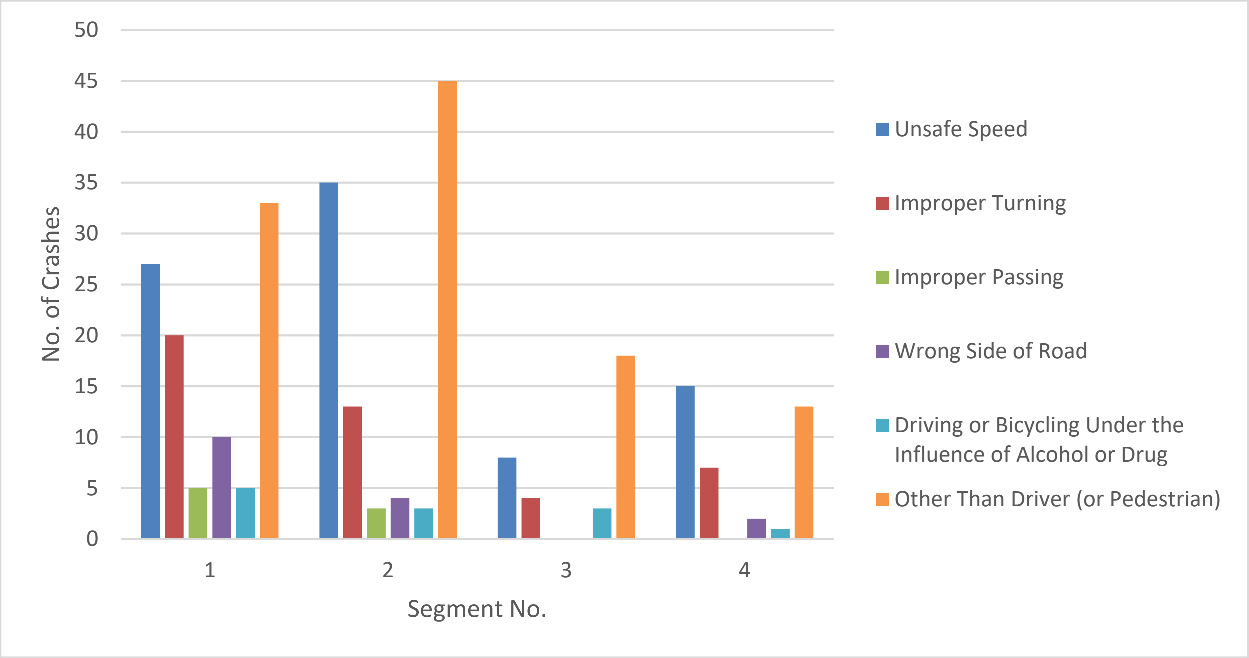


Figure 6: Crashes by Primary Collision Factor in US 395 Study Area

3.2.4. Crash Analysis by Type of Collision

The crash data in each segment was analyzed for the type of crashes occurring to identify trends indicative of safety concerns in each segment of the study area. The SWITRS “type of collision” data includes various types of crashes as listed below:

- A - Head-On
- B - Sideswipe
- C - Rear End
- D - Broadside
- E - Hit Object
- F - Overturned
- G - Vehicle/Pedestrian
- H – Other
- Not Stated

A preliminary review of the data indicated that most crashes classified as "H-Other" or "E-Hit-Object" are crashes involving animals, single vehicle run-off-the-road crashes, or single vehicle crashes hitting a fixed object on the side of the road. Therefore, as a first step, these crash types were set aside to be analyzed separately. Additionally, the different passing conditions on various section of US 395 were identified both in the Northbound (NB) and Southbound (SB) directions as:

- No passing allowed sections (approx. 24 miles NB and 30 miles in SB directions)
- Passing allowed section (approx. 28 miles NB and 25 miles in SB directions)
- Presence of a passing lane sections (approx. 8 miles NB and 4 miles in SB directions)

The passing conditions data were used in conjunction with the type of crashes to analyze crash trends in the vicinity of passing zones, no passing zones, and passing lanes. It should be noted that crashes were analyzed in the vicinity of different passing conditions both in the NB and SB directions, irrespective of the direction in which the vehicles were moving considering the involvement of multiple vehicles which may not always be moving in the same direction. Figure 7 (NB passing conditions) and Figure 8 (SB passing conditions) show analysis of crash types (multiple vehicle crashes) in each segment of the study area in the vicinity of different passing conditions where crashes occurred.

The general expectation is that the crash types shown in Figure 7 and 8 would be less prevalent in no passing zones as compared with passing zones and in the vicinity of passing lanes. However, the results indicate that in segments 1 and 2, the number of crashes is similar in both passing and no passing zones even though the number is slightly higher for certain crash types in passing zones. This trend is an indication of a possible safety issue with passing maneuvers in these segments especially considering the previous discussion about differential speed limits for passenger cars and heavy vehicles. Segments 3 and 4 show a high number of "broadside" crashes possibly due to the presence of more intersections being closer to Susanville and more built-up areas. This trend is further explored in crashes by intersection location. It should also be noted that the length of passing and no passing zones is relatively similar in the study area. The length of passing lane sections is relatively small, hence the smaller number of crashes observed.

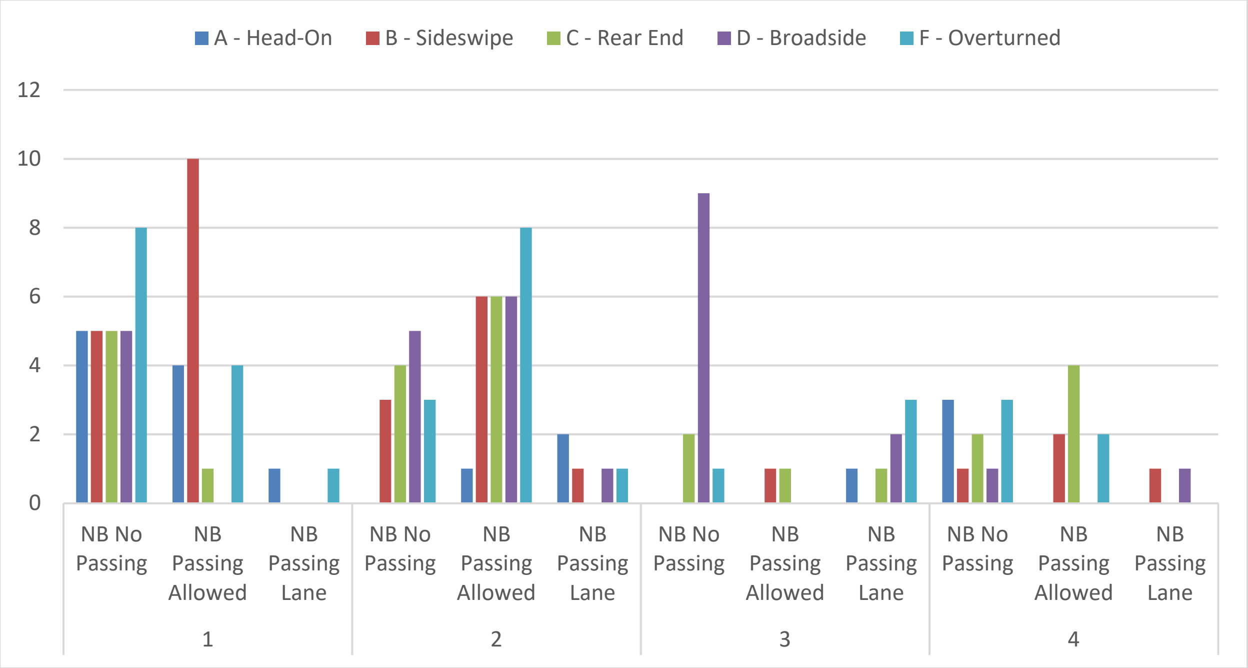


Figure 7: Crash Types in Vicinity of Different NB Passing Conditions in US 395 Study Area

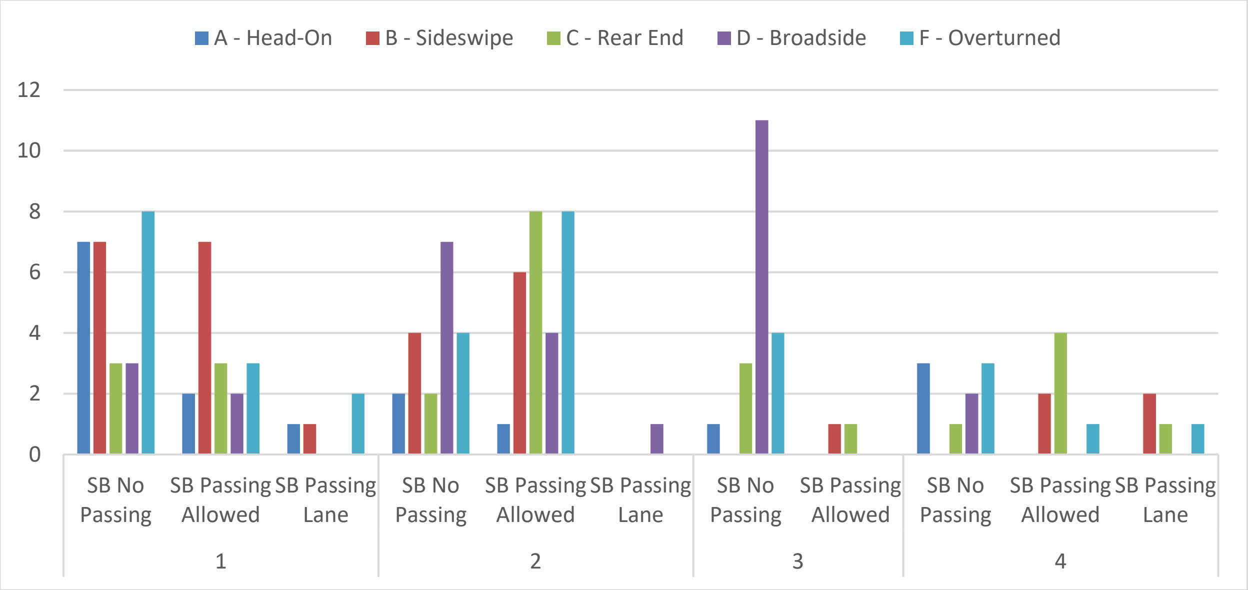


Figure 8: Crash Types in Vicinity of Different SB Passing Conditions in US 395 Study Area

3.2.5. Single Vehicle and Animal Related Crashes

As previously mentioned, crashes classified as “H-Other” or “E-Hit-Object” are generally considered to be single vehicle crashes involving animals or objects other than another vehicle. Such crashes are the predominant type of crashes on rural roads similar to US 395. Another possible indicator of single vehicle crashes in SWITRS data is the “motor vehicle involved with” field, which includes the following crash types that are indicative of single vehicle crashes:

- A - Non-Collision
- H - Animal
- I - Fixed Object
- J - Other Object

Table 12 shows a breakdown of possible single vehicle crashes involving animals and other types of objects in the study area by lighting conditions. As expected, these crashes represent approximately 64 percent of all the crashes with animal related crashes being the highest in number. Figure 9 shows a further breakdown of these crashes located in each of the four segments in the study area. Although there appears to be a similar distribution of single vehicle crashes during daytime and nighttime conditions, Figure 9 shows a very high number of animal crashes occurring in segment 2 especially during nighttime conditions, which should be the focus of targeted safety improvements in that segment to mitigate the overrepresented crashes. Figure 10 shows a map of crashes involving animals indicating the presence of most of the crashes in segment 2 and cluster of crashes in various section of the study area.

Table 12: Segment Length and Average AADT (2013-2018) in the Study Corridor on Hwy 395

Lighting Conditions at the time of Crash	**A - Non-Collision**	**H - Animal**	**I - Fixed Object**	**J - Other Object**	**Grand Total**
A - Daylight	23	25	30	3	81
B - Dusk - Dawn	2	14	1		17
C - Dark - Street Lights			1		1
D - Dark - No Street Lights	12	64	21	6	103
Grand Total	**37**	**103**	**53**	**9**	**202**

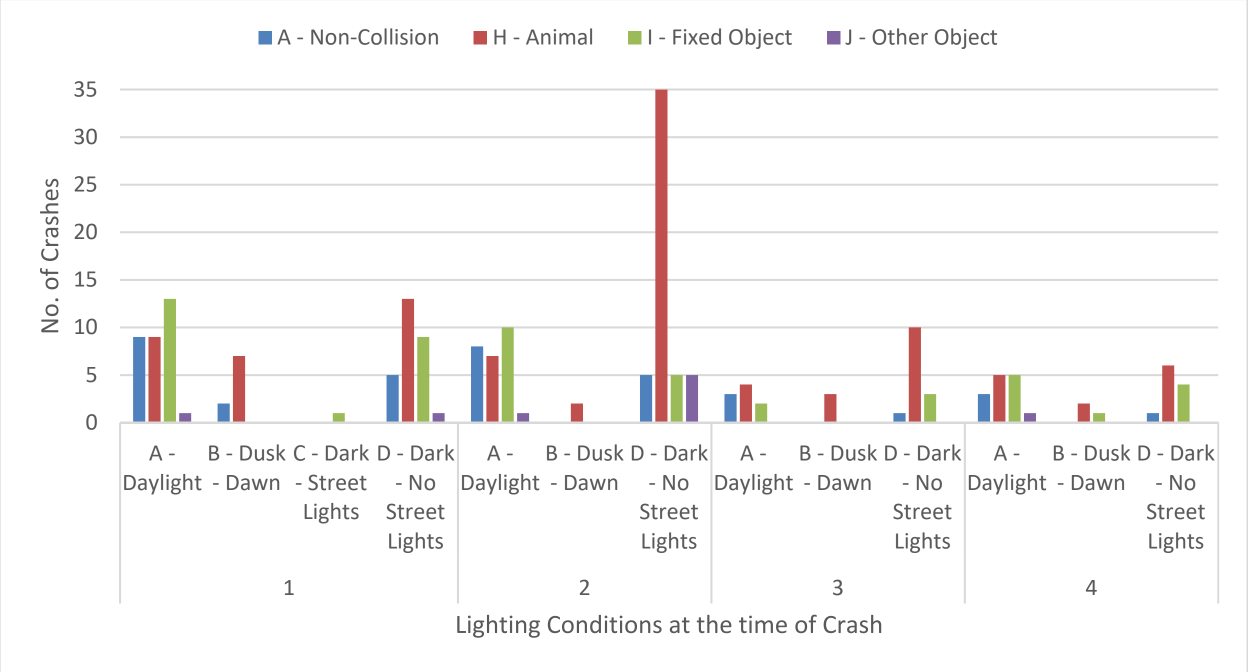


Figure 9: Single Vehicle Crashes by Lighting Conditions in Segments in US 395 Study Area

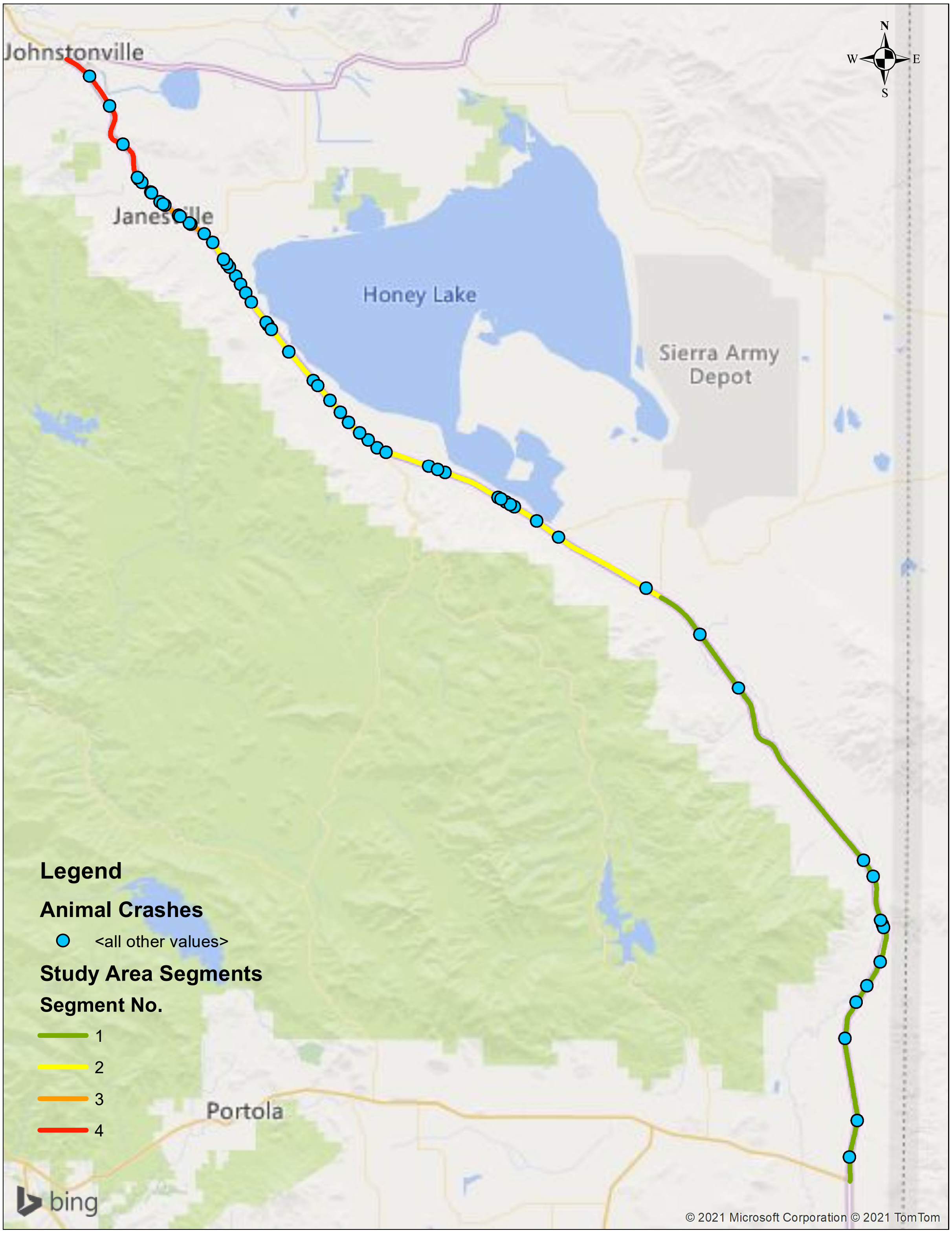


Figure 10: Clusters of Crashes Involving Animals on US 395 Study Area

3.2.6. Analysis of Truck Crashes

One of the concerns raised in various discussions and reports is the presence of heavy vehicle traffic on the two-lane US 395 and its potential impact on safety. Therefore, crashes involving trucks were analyzed separately. Table 13 shows that of the 312 total crashes in the six-year period, 41 crashes were identified as involving trucks or the presence of trucks, which represents approximately 13% of the total crashes. However, segments 3 and 4 show none to very few truck crashes, which can be of interest in developing plans for future new passing lanes and other types of safety improvements to address heavy-vehicle relates safety concerns.

Table 13: Truck and Non-Truck Crashes by Segments in Study Area on US 395

Segment No.	Truck Crashes	Non-Truck Crashes	Total	% of Truck Crashes
Segment 1	18	90	108	17%
Segment 2	19	97	116	16%
Segment 3	0	43	43	0%
Segment 4	4	41	45	9%
Total Crashes	**41**	**271**	**312**	**13%**

Truck and non-truck crashes were further analyzed using specific primary collision factor (PCF) which are of relevance to heavy-vehicle type crashes. Figure 11 shows the percentage within each category of truck and non-truck crashes by different PCF. Although truck crashes are only 13% of the total crashes, Figure 11 shows that a higher percentage of truck crashes are involved in crashes due to improper turning and on wrong side of the road and relatively comparable number of unsafe speeding crashes, possibly indicating safety issues related to heavy vehicle presence, especially in segments 1 and 2. Furthermore, Figure 12 shows clusters of truck crashes only in the study area clearly indicating specific sections of segments 1 and 2 where these crashes are clustering as possible target areas for future targeted safety improvements.

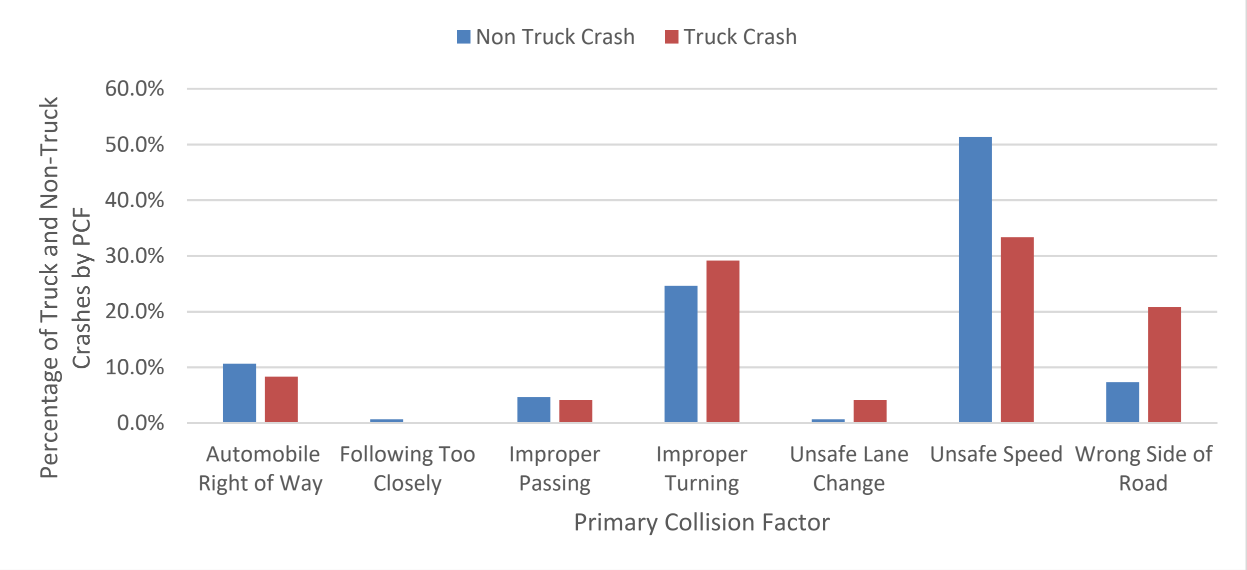


Figure 11: Percentage of Truck and Non-Truck Crashes by PCF on US 395 Study Area

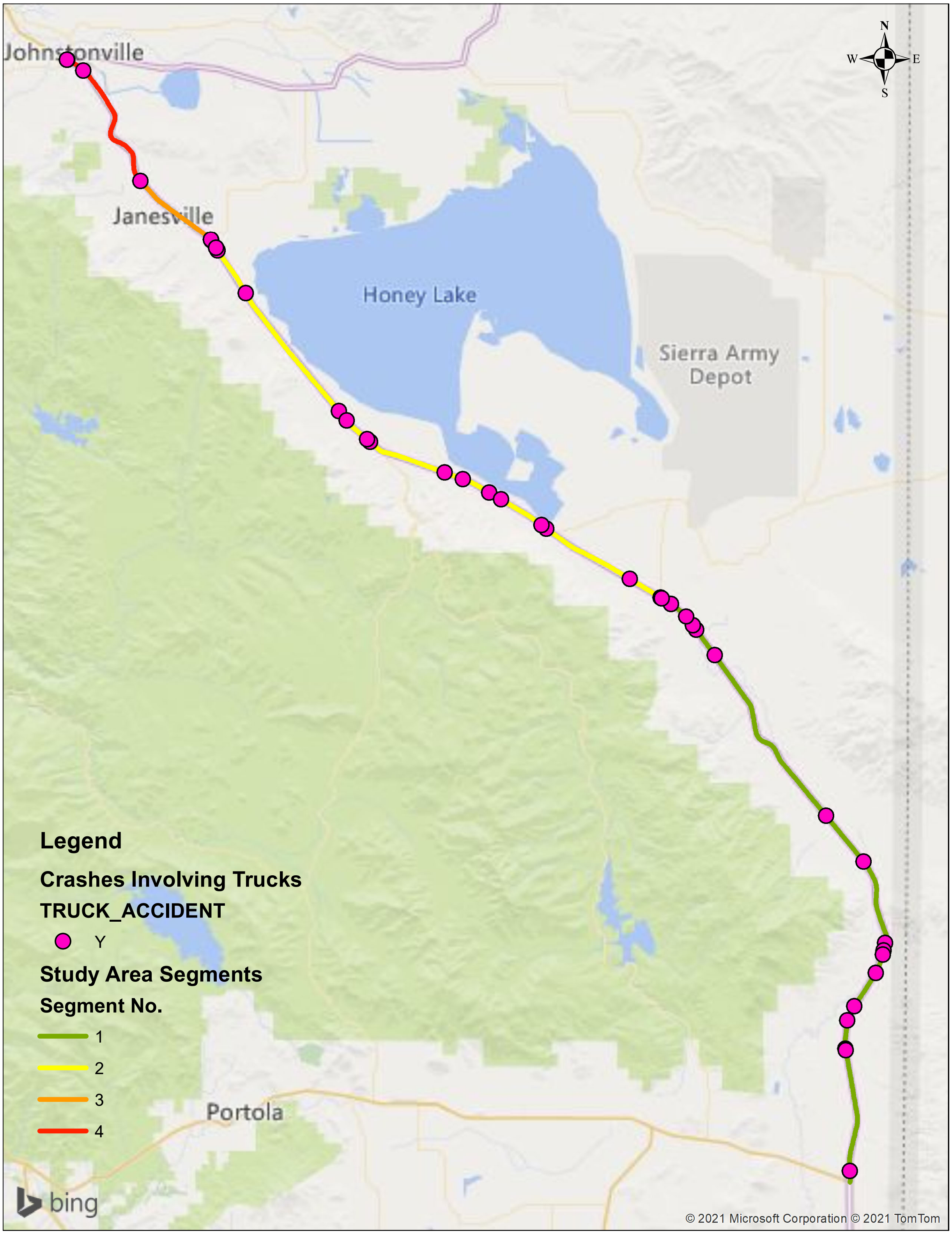


Figure 12: Clusters of Crashes Involving Trucks on US 395 Study Area

3.3. Comparison of US 395 with SR 70 Improvements Project in Butte County

One of the objectives of this study was to compare the proposed expansion of US 395 in Lassen County with a similar project that previously went through an expansion project to observe similarity in issues and safety concerns, which could inform safety engineers of possible improvements in the study area. One such project identified was the expansion of a two-lane section of State Route (SR) 70 in Butte County, CA between Postmile 5.6 to Postmile 12.1 (SR 70 Improvements Report, 2018). The section of SR 70 is very similar in characteristics and traffic conditions to US 395 study area and experienced similar safety and mobility concerns as observed on US 395 in Lassen County. A number of safety issues related to unavailable of passing opportunities and the occurrence of fatal crashes were pointed out as reasons for improvements. The SR 70 improvement project proposed an expansion from two to four lanes in order to address safety issues and in anticipation of future economic activity and growth in the area.

The SR 70 improvement project was divided into two segments from PM 5.6 – 8.8 and PM 8.8 – 12.1. Table 14 shows a comparison of crash rates calculated for the SR 70 project location using three years of crash data from 2012 – 2015 with crash rates from US 395 study area using six years of crash data from 2013 – 2018. The segments of US 395 which show a higher crash rate than SR 70 segments are underlined in Table 14. Although the section of SR 70 is similar in characteristics and some of the issues observed, one of the major differences between the two locations is the length of the study area, which is 6.5 miles for SR 70 as compared to 56.5 miles of US 395. It is generally accepted that crash rates can become higher with a smaller segment size. The one segment of US 395 similar in length to the segments on SR 70 is segment 3, which is shown to experience a higher crash rate than both segments of SR 70 for all crash rates. This indicates that a more targeted evaluation of crash rates on US 395 using smaller segment sizes in specific areas as highlighted in this study with specific safety concerns may yield segments that experience a much higher crash rate to allow for targeted safety improvements.

Table 14: Comparison of Crash Rates between US 395 and SR 70 Project Areas

Segment ID	**Total per MVM**	**Fatal + Injury per MVM**	**Fatal per 100 MVM**
US 395 Segment 1	0.32	0.14	3.31
US 395 Segment 2	0.47	0.15	0.40
US 395 Segment 3	**<u>1.06</u>**	**<u>0.57</u>**	**<u>9.87</u>**
US 395 Segment 4	0.45	0.16	1.98
US 395 Entire Study Area	0.43	0.17	2.49
SR 70 Segment 1	0.56	0.29	5.3
SR 70 Segment 2	0.71	0.27	4.9

The report on SR 70 project does not provide a breakdown of crashes by segments. However, the project report indicates the occurrence of 35 fatal crashes between 2010 – 2018 time period (approx. 4.4 fatal crashes per year) compared with 11 fatal crashes on US 395 in the six-year period from 2013 – 2018 (approx. 1.9 crashes per year). 13 of the 35 fatal crashes occurred on SR 70 in 2017 alone. This type of significant crash number can generally raise alarms and provide impetus to safety improvement projects, especially when such a large number of fatal crashes are observed in a short period of time. Furthermore, the SR 70 project location experiences a significantly large traffic volume (10,000 – 11,200 AADT), almost double the traffic volume on segments of US 395, which would explain the large number of fatal crashes observed. Conversely, the crash rates (normalizing for AADT) on the shorter segment 3 on US 395 with less AADT indicates the presence of safety concerns that could be worst than what is experienced on SR 70. Further breakdown of the longer segments 1 and 2 could unearth specific segments that are experiencing safety issues, some of which were highlighted in this report in the analysis of crash trends, to be addressed by future improvements. Such measures would require coordination with local agencies to identify and prioritize sections of US 395 that may offer the best investment going in to the future.

3.4. Summary of Current Safety Evaluation of US 395 Study Area

The analysis of historical crash data to evaluate the current safety performance of the study area on US 395 revealed a number of trends and safety issues which are summarized below:

- An analysis and comparison of crash rates on US 395 with CA statewide, Lassen County, and average crash rates for similar sites in CA shows that several segments in the study area have a higher than average crash rates in various years between 2013 to 2018. In particular, segment 3 and segment 1 standout with higher crash rates highlighting potential safety issues at those locations.
- Although the longest segment in the study area, Segment 1 has the highest number of fatal crashes observed and the highest of Truck AADT volumes, which is a possible indication of a safety concern in this area.
- The difference in the posted speed limit for passenger cars and heavy vehicles could be forcing drivers in sections with higher truck volumes to take additional risks to pass slow truck possibly contributing to a higher number of head-on and sideswipe crashes within segment 1.
- Segment 2 has the lowest AADT and is the second longest in length of all the segments with a high number of crashes.
- Segment 3 is the shortest segment and has the lowest truck volume and AADT, however it has certain sections of high crash concentration.
- Segments 1 and 2 show higher number of crashes observed on a weekend indicating the presence of recreational or other non-commuter type traffic, which may be exacerbated in the future by economic growth in the region.
- The primary collision factor is most crashes in segments 1 and 2 and to a certain extent in segment 3 is unsafe speed, improper turning, and driving on the wrong side of the road. These factors are indicative of a general issue of not having enough passing opportunities possibly exacerbated by the presence of slow-moving heavy vehicles impacting driver behavior and safety. The difference in speed limits as mentioned before contributes to this concern. These types of concerns may be resolved by new passing lanes at strategic locations.

- Analysis of crash types in vicinity of different passing conditions (passing zones, no passing zones etc.) indicate that in segments 1 and 2, the number of crashes is similar in both passing and no passing zones with slightly higher number of crashes in passing zones. This trend is an indication of a possible safety issue with passing maneuvers in these segments especially considering the previous discussion about differential speed limits for passenger cars and heavy vehicles. Segments 3 and 4 show a high number of "broadside" crashes possibly due to the presence of more intersections being closer to Susanville and more built-up areas. It should also be noted that the length of passing and no passing zones is relatively similar in the study area. The length of passing lane sections is relatively small, hence the smaller number of crashes observed.
- Approximately 64 percent of all the crashes in the study area are single vehicle crashes, a large number of which are animal related crashes. Overall, single vehicle crashes are equally distributed during daytime and nighttime, a very high number of animal crashes occur in segment 2 especially during nighttime conditions, which should be the focus of targeted safety improvements in that segment.
- Clusters of collisions involving animals occur along the route near Honey Lake. The area around the lake may attract more wildlife and lead to higher animal activity relative to other areas on US 395. Solutions such as warning signs, fencing, maintenance of tall vegetation, or widening the shoulders to allow more visibility would be beneficial. Lighting, where appropriate, may be another solution. Mitigation efforts can be focused on small sections such as areas around Honey Lake, areas near Long Valley Creek (south of Doyle), and areas around Janesville.
- 41 of the 312 crashes in the study area were truck related representing approximately 13% of the total crashes that mostly occurred in segments 1 and 2. Segments 3 and 4 show none to very few truck crashes. A high percentage of truck crashes are due to improper turning or wrong side of the road indicating passing related safety issues due to high heavy vehicle traffic in segments 1 and 2.
- A comparison of safety evaluation of US 395 study area with a similar project on SR 70 in Butte County showed mixed results. Although the SR 70 study area is similar in characteristics to US 395, one of the major differences between the two locations is the length of the study area, which is 6.5 miles for SR 70 as compared to 56.5 miles of US 395. Thus, the smaller segments on SR 70 and US 395 (segment 3) show high crash rates compared with the longer segments on US 395. Segment 3 experienced a higher crash rates than SR 70 segments. SR 70 did experience a higher number of fatal crashes and has a significantly higher AADT. These trends indicate the need for targeted evaluation of crash rates on US 395 using smaller segment sizes in specific areas as highlighted in this study with specific safety concerns. Analyzing smaller segments could identify opportunities for targeted safety improvements which would require coordination with local agencies to identify and prioritize sections of US 395 that may offer the best investment going in to the future.

4. DATA ANALYSIS AND RESULT – FUTURE CONDITOINS

In addition to analyzing the current safety trends on US 395 study corridor, this study utilized state-of-the-art methods from the AASHTO Highway Safety Manual to compare the safety performance of a "no build" scenario versus expansion of the US 395 corridor from two lanes to four lanes. The idea was to statistically estimate how many crashes may be observed in the on US 395 study area as a two-lane highway if no changes are made compared with an estimate of number of crashes if a four-lane highway is built.

The analysis of comparing two-lane versus four-lane highway safety performance was conducted by calculating the "expected crash frequency" (*crashes expected in the future as a function of observed crashes in the past in the study area and crash trends experienced by similar sites across the country*) of the two-lane US 395 corridor and comparing it with the "predicted crash frequency" of the proposed four-lane divided expressway in the future.

4.1. Expected and Predicted Crash Frequency

Expected crash frequency is a weighted average of Observed crashes and Predicted number of crashes using Safety Performance Functions (SPF), which are statistical models. Hence Expected crash frequency can only be calculated for an existing roadway as it requires the use of historical crash date. For a new proposed roadway, e.g. a four-lane highway in this study, only Predicted crash frequency can be calculated because historical crash data would not be available for a new roadway that is being proposed.

The Empirical Bayes (EB) analysis method as described by the AASHTO Highway Safety Manual utilizes Expected and Predicted crash frequencies to provide a more reliable basis for estimating an existing or proposed facility's safety performance, instead of only relying on historical crash data. The EB method is considered the most statistically reliable method because it takes advantage of both information about observed crashes at the location in question and information on predicted crashes based upon the crash experience at other similar sites. Applying the EB method ensures that any random temporal variations and the "regression to the mean effect" in the study area is accounted for.

Details of the step-by-step process implementing the Empirical Bayes analysis is presented in Appendix A.

4.2. Results of Comparison of Safety Performance of Two-Lane vs. Four-Lane Highway in US 395 Study Area

Using Empirical Bayes method, the safety performance of the study area in the case of a "no-build" (two-lane highway) scenario was compared with the proposed expansion to a four-lane divided expressway. Table 15 shows the results of "Expected" number of crashes in the study area by segments for each year 2013 - 2018. The results in Table 15 show how many crashes should generally be expected at each segment based on observed data and data from similar sites.

Using data from similar sites accounts for any random variations that may have been experienced in the past.

Table 15: Expected Number of Crashes for Each Segment and Year in the Study Period

Segment No.	2013 $N_{expected}$	2014 $N_{expected}$	2015 $N_{expected}$	2016 $N_{expected}$	2017 $N_{expected}$	2018 $N_{expected}$
1	27	19	26	24	25	36
2	28	27	21	20	26	24
3	8	9	5	3	7	8
4	10	12	5	7	11	9

As the final step, the predicted number of crashes for the proposed four-lane highway was determined using a Crash Modification Factor (CMF), which represents the anticipated change in safety performance due to change in the roadway type. A CMF of 0.712 was used in this study to represent the change from a two-lane to four-lane roadway in a rural area. The CMF was obtained from the Crash Modification Factors Clearinghouse website which is a database maintained by the Federal Highway Administration and contains thousands of CMFs for various safety modifications and changes.

Table 16 shows the "total expected average crash frequency per year" estimated to occur within each segment for the period between January 01, 2013 to December 30, 2018 as well as the "predicted crash frequency" upon conversion to a four-lane divided expressway for each segment.

Table 16: Total Expected Average Crash Frequency for Two-Lane US 395 and Predicted Crash Frequency for Proposed Four-Lane Roadway

Segment No.	Crashes Expected on a Two-Lane US 395 Study Area	Crashes Predicted to Occur on the Proposed Four-Lane Divided Road	Percentage Decrease in No. of Crashes due to Four-Lane Divided Road
1	26	19	-27
2	24	17	-29
3	7	5	-29
4	9	6	-33

The results in Table 16 show that converting the existing two-lane conventional highway to a four-lane expressway is anticipated to reduce the total number of collisions within each segment by approx. 27% to 33%. The reduction in total crashes is more noticeable in segment 1 and segment 2 due to high number of crashes experienced due to longer segment lengths. The results show a substantial improvement in safety given the percentage decrease in total number of crashes given a four-lane highway. Whether such improvements are economically feasible would require a comprehensive cost-benefit analysis utilizing these estimated safety improvements.

5. SUMMARY AND CONCLUSIONS

This study conducted a wide-ranging analysis of the safety performance of a section of US 395 in Lassen County, which is proposed to be expanded from a conventional two-lane to a four-lane highway. The main objective of the study was to conduct safety analyses using historical crash data, traffic volume, and roadway geometric data to identify safety trends and issues determining segments and sections with higher safety risks. Furthermore, the objective was to estimate the safety benefits that might be gained by converting the two-lane highway to a four-lane road. The results of this study are intended to inform safety practitioners and engineers on identifying specific targeted safety improvements and countermeasures that may be implemented to improve safety on US 395 in Lassen County. Furthermore, the results of the predictive methods (Empirical Bayes analysis) provides a comparison of the safety performance of a no-build scenario versus the proposed four-lane highway. The outcomes of this study also underline a pro-active approach to safety by analyzing various safety issues and concerns in the study area to take effective safety measures within the corridor.

A summary of the results and main outcomes of the safety analysis of current conditions is presented in section 3. The results from estimating the safety benefits gained from the proposed four-lane highway are presented in section 4.

1- By comparing the crash rate for various segments within the study limits, it can be proposed that segment 3 should receive the highest priority when considering new safety improvements on the existing roadway. Segment 3 is the shortest segment among other segments evaluated in this study but has both the highest total crash rate and fatal crash rate. The expected crash rate is lower than other sections and the proposed alternative to convert this segment to a four-lane expressway is not expected to significantly reduce the number of crashes due to the short length. Hence, other more cost-effective countermeasure should be considered. Segment 1 and 2 will benefit the most from the new expansion of roadway to a four-lane expressway.

2- The truck traffic volume has increased over past years and is anticipated to increase in the future. Several safety issues were identified in this research that could be attributed to the presence of heavy vehicles and heavy vehicle traffic. An increase in heavy vehicle traffic, especially considering new economic activity proposed in the region would result in increased frequency and severity of crashes. Therefore, the future improvement alternatives should put a special emphasis on this issue.

3- Given the outcomes of safety evaluation of the study area in this study, one effective approach would be to identify targeted sub sections of segment 1 and 2 for specific safety countermeasures, such as new passing lanes, intersection treatments, roadside improvements, etc. Such countermeasures may provide short-term and quick cost-effective safety improvements benefiting the region as a whole.

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Appendix A

Details of Empirical Bayes Analysis to Calculate Predicted and Expected Crash Frequencies

The Empirical Bayes analysis was performed as described below.

First, the “predicted” number of crashes for each segment and for every year in the study period (2013-2018) was calculated using Safety Performance Functions (SPF) (equation A-2) with Crash Modification Factor (CMF) adjustments (equation A-3).

$$N_{spf} = AADT \times L \times 365 \times 10^{-6} \times e^{(-0.312)} \qquad \text{A-2 [HSM 10-6]}$$

Where:
N_{spf} = Predicted total crash frequency for roadway segment’s base conditions;
AADT= Average Annual Daily Traffic Volume (vehicles per day);
L = Length of roadway segment (miles).

The N_{spf} assumes some base conditions, so it needed to be adjusted to reflect the real conditions using Crash Modification Factors (CMF). A Crash Modification Factor is the ratio of expected average crash frequency with modified site to the expected average crash frequency with base site. It is used to adjust crash frequency if a safety countermeasure is added or eliminated to or from the roadway while other conditions stay the same. The Crash Modification Factors for the features specific to this site that differ from base conditions are included in Table below.

Table: Site Specific Crash Modification Factors

Feature	Base Condition	Real Condition	CMF[1]
Shoulder Width	6 feet	4-10 feet	1.15
Centerline Rumble Strip	None	Present	0.94
Grade Level	0%	3% to 6%[2]	1.10

1-The Crash Modification Factors are obtained from applicable HSM tables.
2-The grade was selected by judgment as an average grade for the Rolling terrain.

A more detailed discussion of the base conditions associated with the above Safety Performance Function is included in Chapter 10 of the Highway Safety Manual. The section of highway within the study limit has occasional passing lanes, vertical curves, and horizontal curves, but they are considered negligible when compared to the total length of each segment. Hence, the Crash Modification Factor for those sections could be considered equal to 1.0.

The approximate locations of horizontal curves within each segment of the study limits are shown in Appendix B. As it can be seen from the figure in Appendix B, a majority of this section of highway is on tangent and the combined length of horizontal curves in the study area compared with the length of the tangent sections is negligible. Hence, the CMF associated with horizontal curve does not need to be incorporated into the Safety Performance Function to adjust the base conditions.

The "Predicted" number of crashes for each segment and for every year in the study period (2013-2018) was calculated using Equation A-3.

$$N_{predicted} = N_{spf} \times C_r \times (CMF_1 \times CMF_2 \times \dots CMF_i) \quad \text{A-3 [HSM 10-2]}$$

Where:

$N_{predicted}$ = Predicted average crash frequency for an individual roadway segment for a specific year;

N_{spf} = Predicted average crash frequency for base conditions for an individual roadway segment;

C_r = Calibration factor for roadway segments for a specific type developed for a particular jurisdiction or geographical area;

CMF_i= Crash Modification Factors for rural two-lane, two-way roadway segments.

The predicted number of crashes for each segment and for every year in the study period (2013-2018) are shown in Table below.

Table 12: Predicted Number of Crashes for Each Segment and Year in the Study Period

Segment	2013 $N_{predicted}$	2014 $N_{predicted}$	2015 $N_{predicted}$	2016 $N_{predicted}$	2017 $N_{predicted}$	2018 $N_{predicted}$
1	43	42	46	50	52	54
2	33	33	36	37	38	38
3	5	5	6	6	6	6
4	14	14	14	15	16	16

Next, the "Predicted" number of crashes were weighted with "Observed" (historical) crashes to provide a more statistically reliable method for estimating the "Expected" crashes at a particular location. The historical collision data were combined with the Empirical Bayes predictive model through equations A-3 and A-4.

$$N_{expected} = w \times N_{predicted} + (1.00-w) \times N_{observed} \quad \text{A-3 [HSM C-8]}$$

$$w = \frac{1}{1+k\ (\sum NPredicted)} \quad \text{A-4 [HSM C-9]}$$

$$k = \frac{0.236}{L} \quad \text{A-5 [HSM 10-7]}$$

Where:

$N_{expected}$ = estimate of expected average crash frequency for the study period;

$N_{predicted}$ = predictive model estimate of predicted average crash frequency for the study period;

$N_{observed}$ = observed crash frequency at the site over the study period;

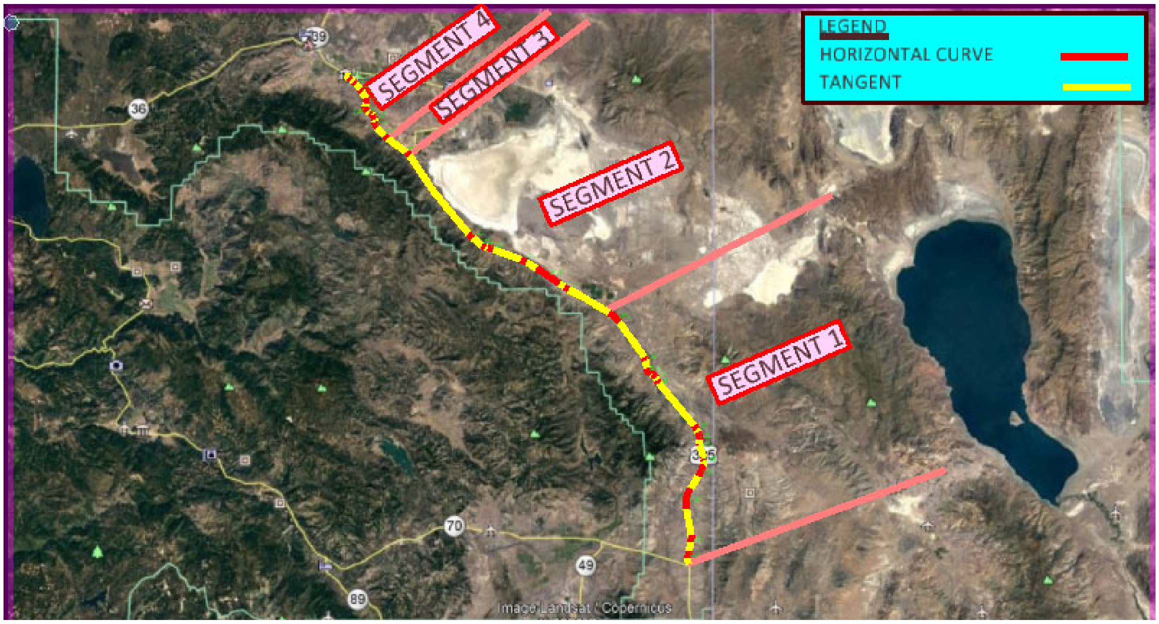
w = weighted adjustment to be placed on the SPF prediction and is calculated using the following equation; and

k = overdispersion parameter from the associated SPF;

L= Length of roadway segment (miles).

Appendix B

Location of Horizontal Curves Within Study Limits



Horizontal Curves Within Study Limits