Using Complementary Intersection and Segment Analyses to Identify Crash Hot Spots

Grant G. Schultz, Ph.D., P.E., PTOE

Camille C. Lunt, EIT

Timo Pew

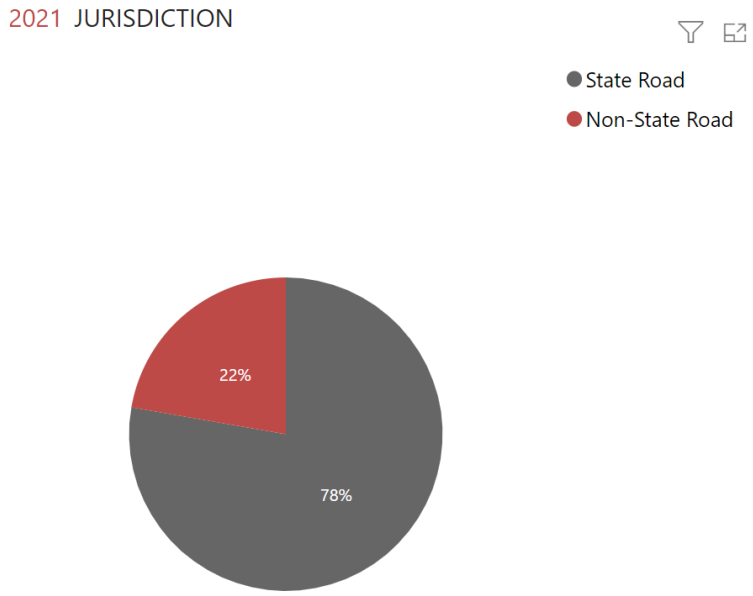
Richard L. Warr, Ph.D.

Outline

- Introduction
- Methodology
- Results
- Conclusions

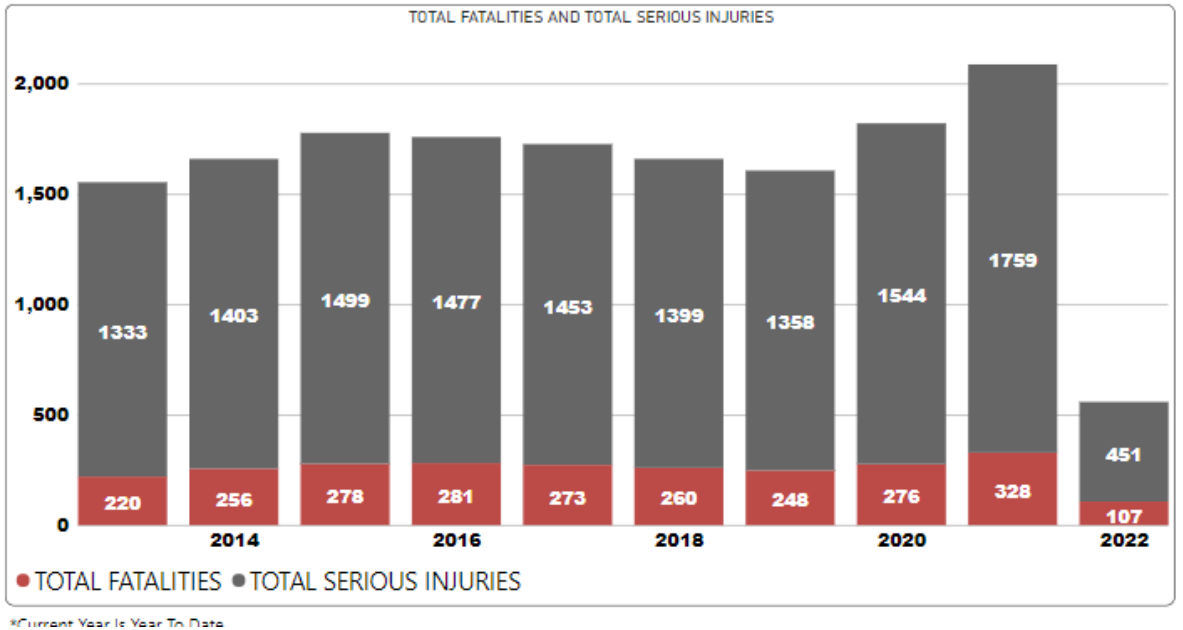
Introduction

- The primary objectives of the effort include:
  - Create a methodology that identifies crash hot spots on Utah highways
  - Separate intersection crashes from non-intersection (segment) crashes in the analyses
  - Identify and rank the hotspots
  - Analyze the top-ranking hotspots



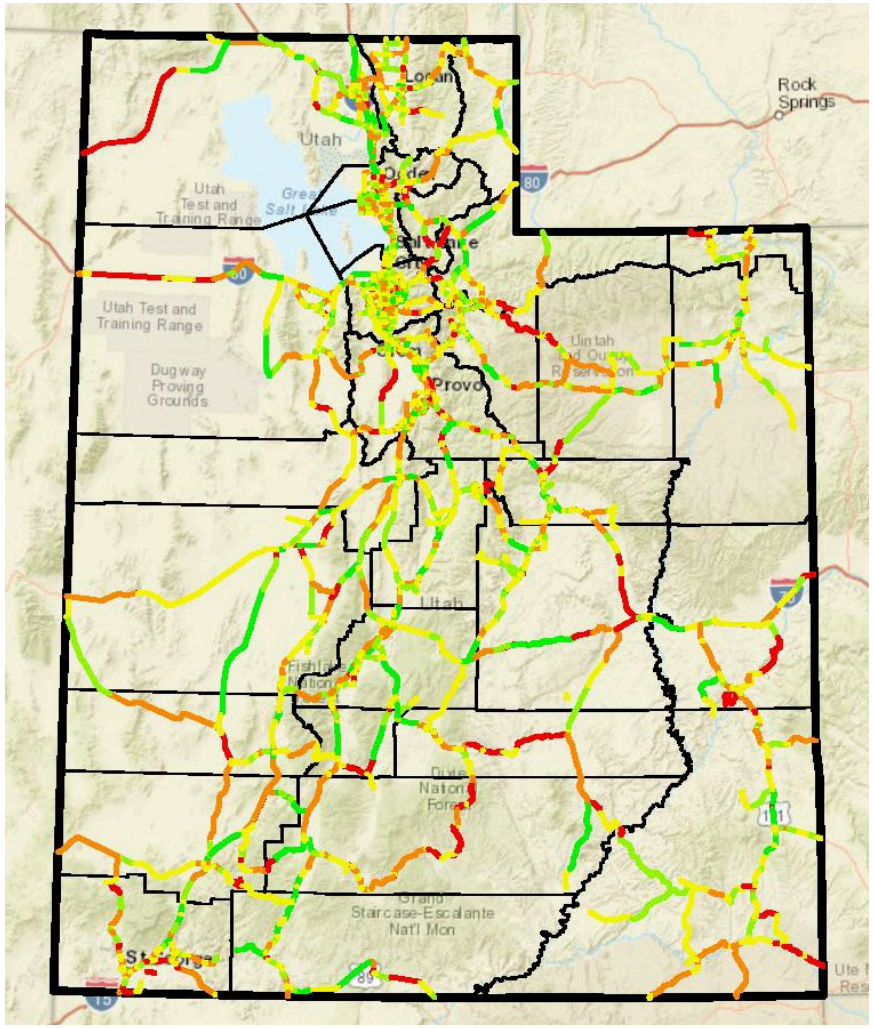
(zerofatalities.com)

TOTAL FATALITIES AND SERIOUS INJURIES



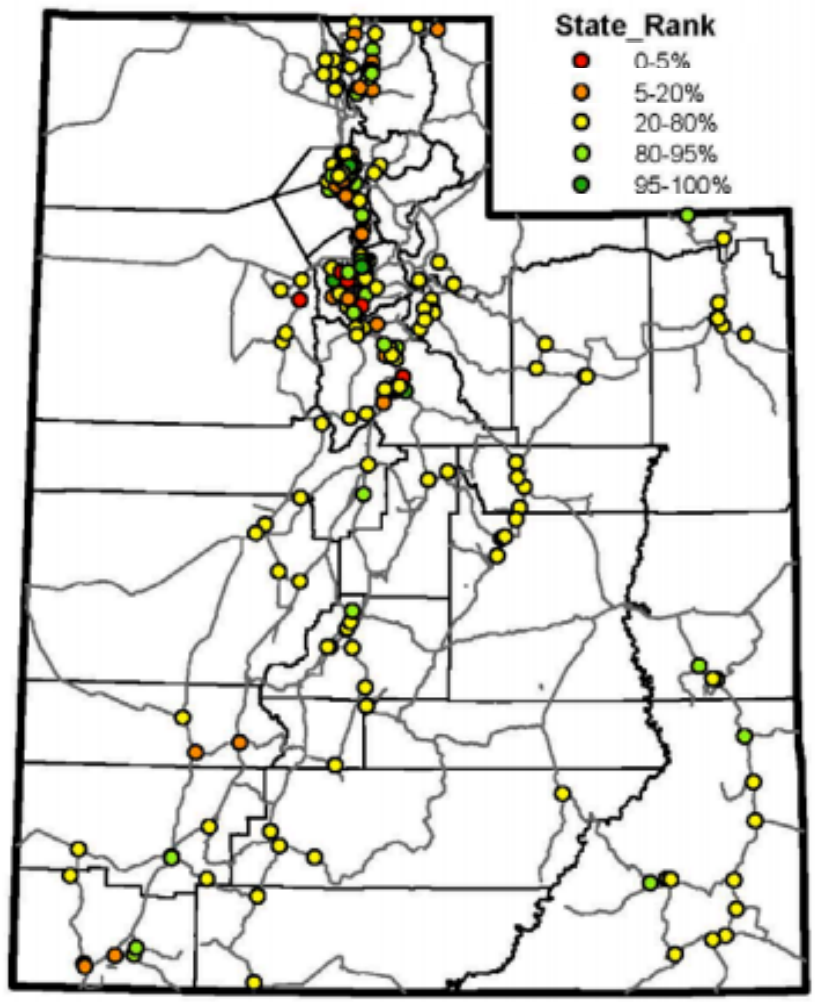
Methodology: Crash Analysis Methodology for Segments (CAMS)

- The Roadway Safety Analysis Methodology (RSAM) is used to evaluate segments of Utah state routes:
  - Forms the foundation of the Crash Analysis Methodology for Segments (CAMS)
- Two statistical models applied:
  - Utah Crash Prediction Model (UCPM)
  - Utah Crash Severity Model (UCSM)
- Homogenous segmentation based on:
  - AADT
  - Functional Class
  - Number of Lanes
  - Speed Limit
  - Urban Code

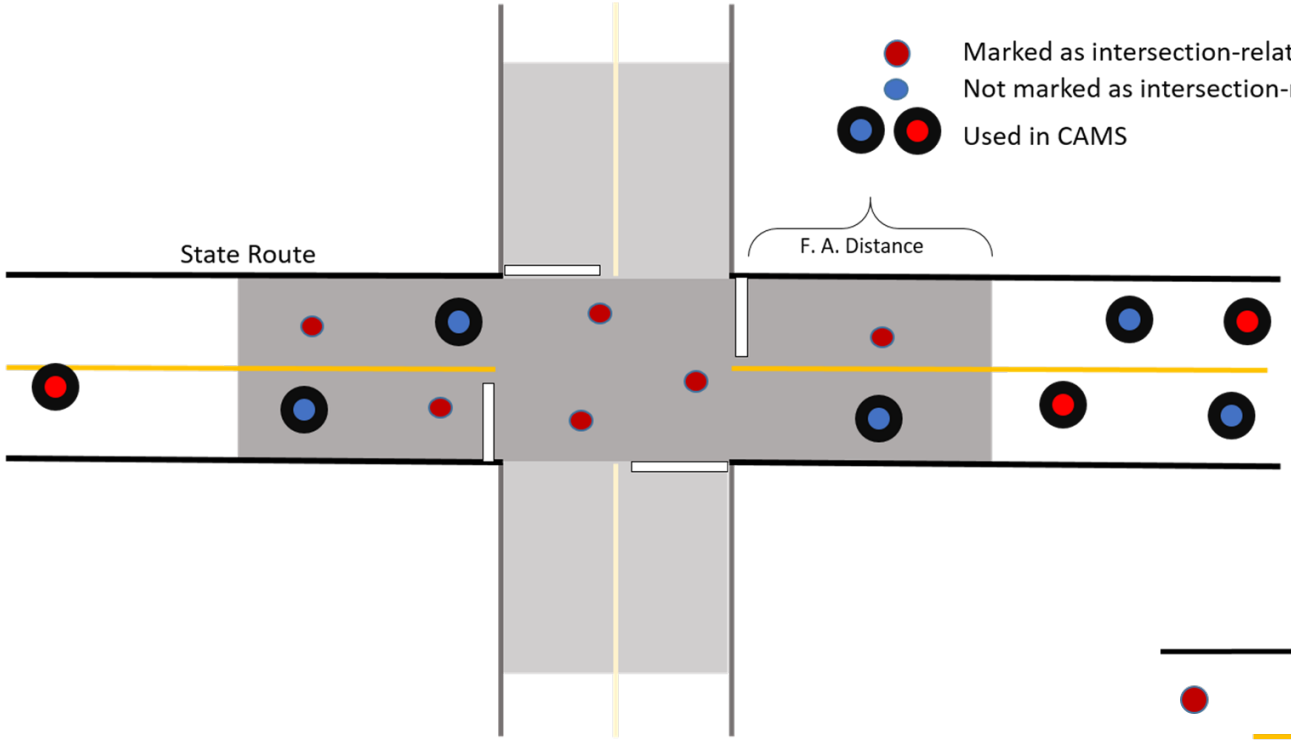


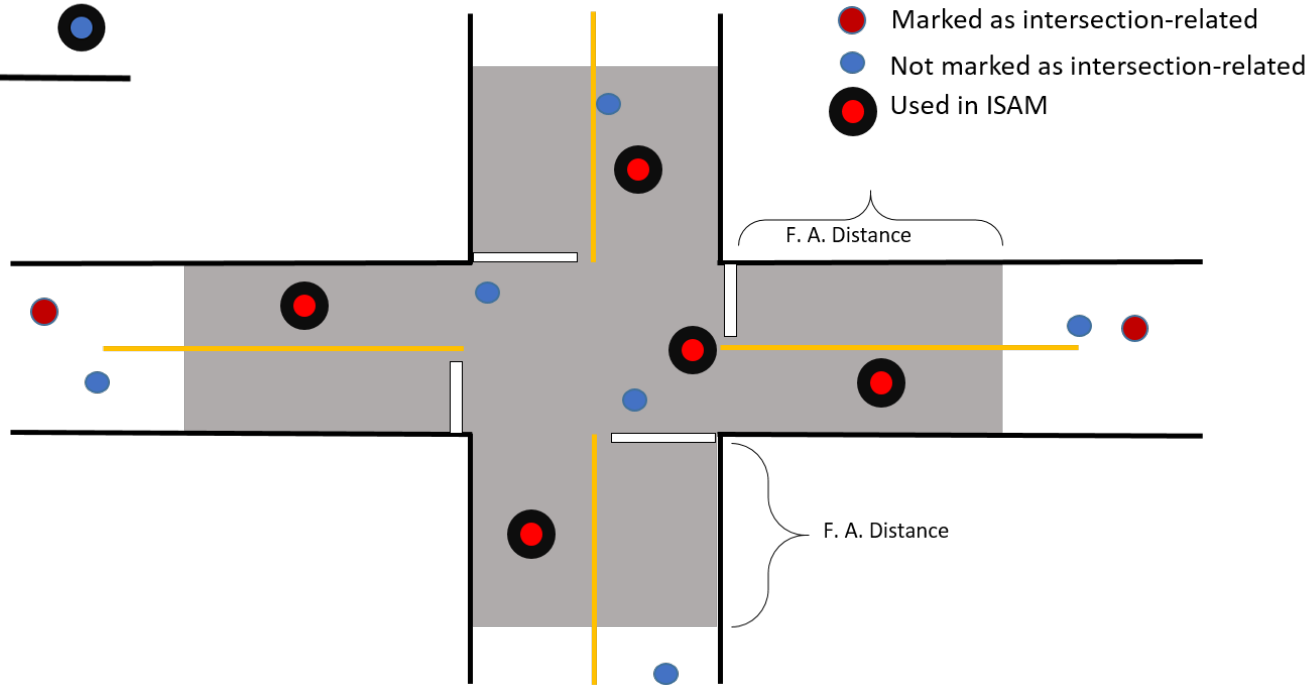
Methodology: Intersection Safety Analysis Methodology (ISAM)

- The ISAM identifies intersection crash hot spots:
  - Intersections with two or more state routes
  - Intersection crashes defined based on functional area and intersection-related criteria
- Two statistical models applied:
  - Utah Intersection Crash Prediction Model (UICPM)
  - Utah Intersection Crash Severity Model (UICSM)

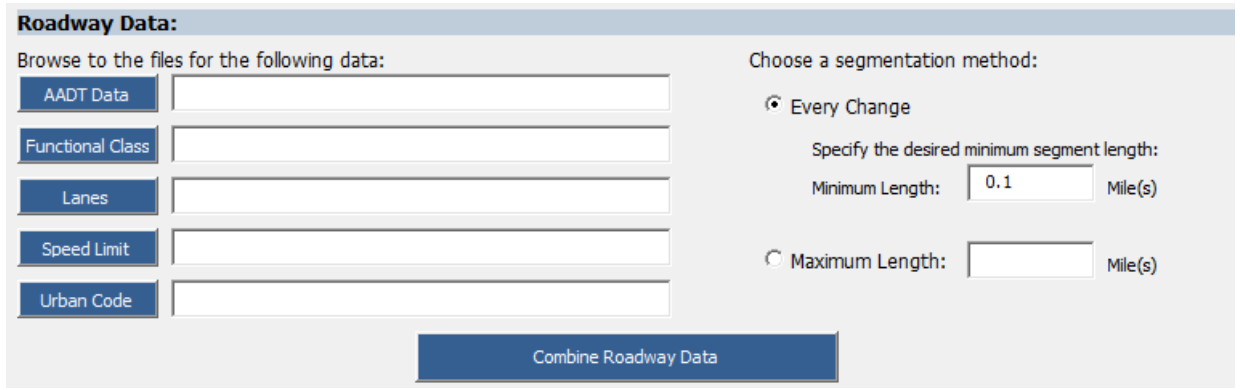


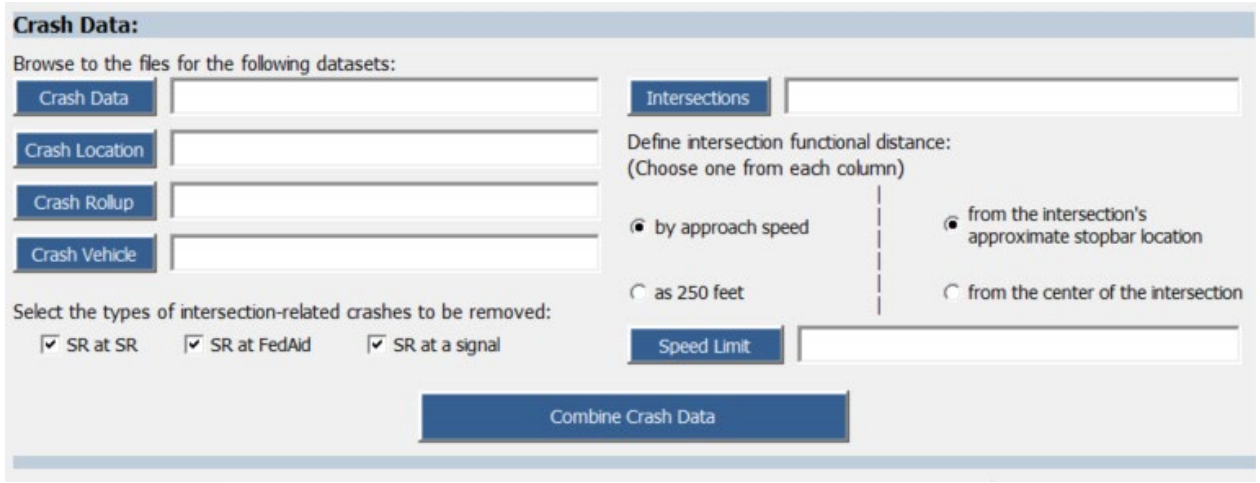
Methodology: Distinction between CAMS/ISAM





Methodology: CAMS Data Integration





Combining the Roadway Data

- Homogeneous segmentation with 5 variables:
  - AADT
  - Functional Class
  - Number of Through Lanes
  - Speed Limit
  - Urban Code

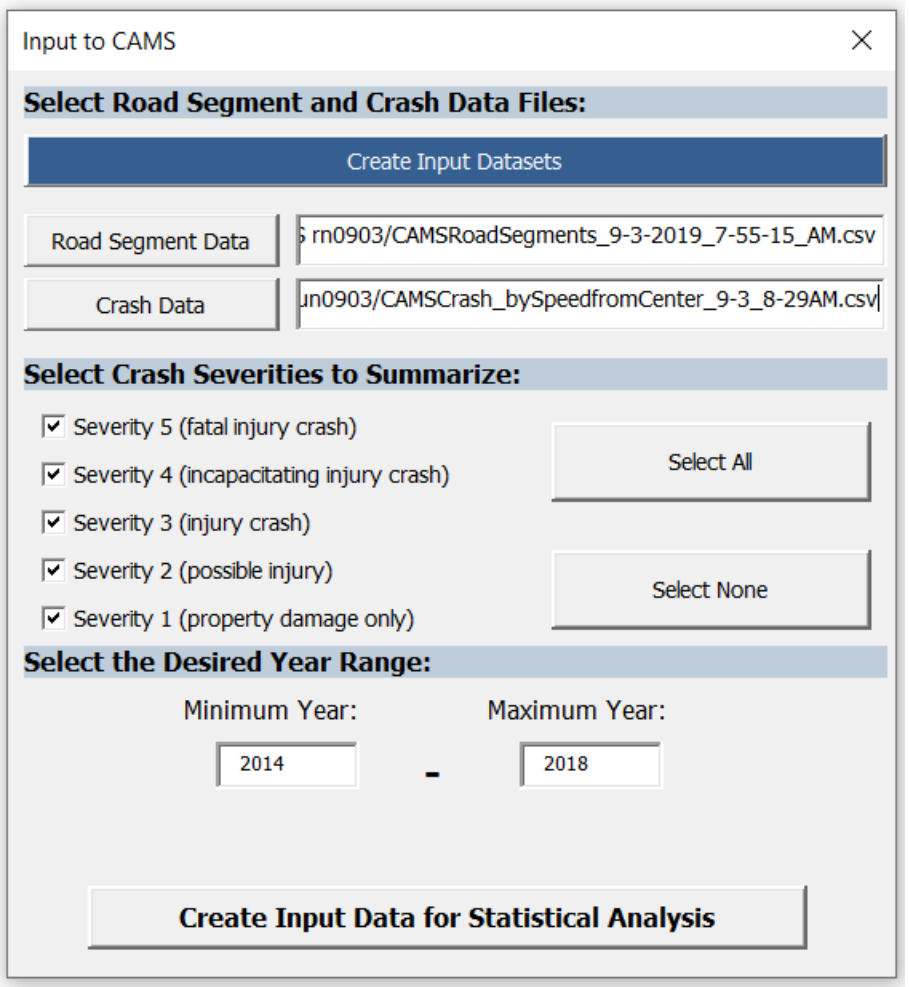
Combining the Crash Data

- Includes removing intersection-related crashes at selected intersection types:
  - Functional Area Distance
  - Physical Area Distance = 60’

Methodology: CAMS Data Integration

Combining Roadway and Crash Data Together

- Assigns crashes to segments



Methodology: CAMS Statistical Analysis

CAMS Prediction Model

- What segments have more crashes than expected?

CAMS Severity Model

- What segments have a higher proportion of injury crashes than expected?

Both models create distributions of predicted crashes for each segment

Prediction Model Variables	Severity Model Variables
Speed Limit	Speed Limit
Number of Lanes	Number of Lanes
Truck Percentage	Truck Percentage
ln(VMT)	VMT
Urban code	Urban code

Methodology: CAMS Statistical Analysis

Predicted Distributions

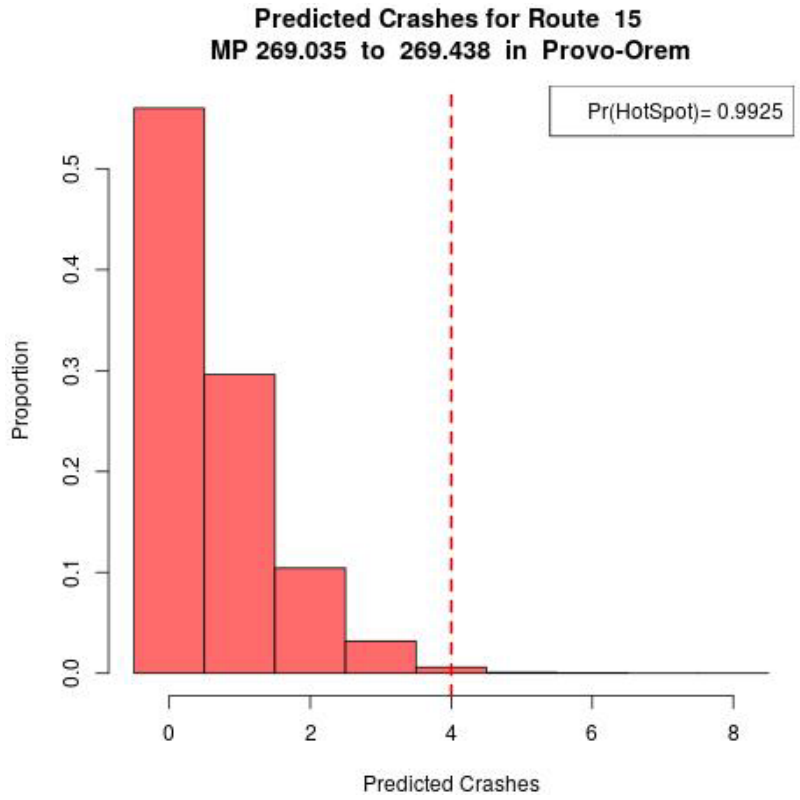
- Current model uses 4 years to build the model and 1 year to compare against the distribution
- Percentiles are used to rank the segments

$$P(Y_{ij} = y_{ij}|\pi, \lambda_{ij}) = \begin{cases} \pi + (1-\pi)e^{\lambda_{ij}} & y_{ij} = 0 \\ (1-\pi)\frac{e^{\lambda_{ij}}\lambda_{ij}^{y_{ij}}}{y_{ij}!} & y_{ij} = 1,2,\ldots \end{cases}$$

$$\ln(\lambda_{ij}) = \beta_0 + x'_{ij}\beta_k + \eta_{ij}$$

$$P(Y_{ij} = y_{ij}|\pi_{ij}) = \binom{n_{ij}}{y_{ij}}\pi_{ij}^{y_{ij}}(1-\pi_{ij})^{n_{ij}-y_{ij}} \quad y_{ij} = 0,1,\ldots,n_{ij}$$

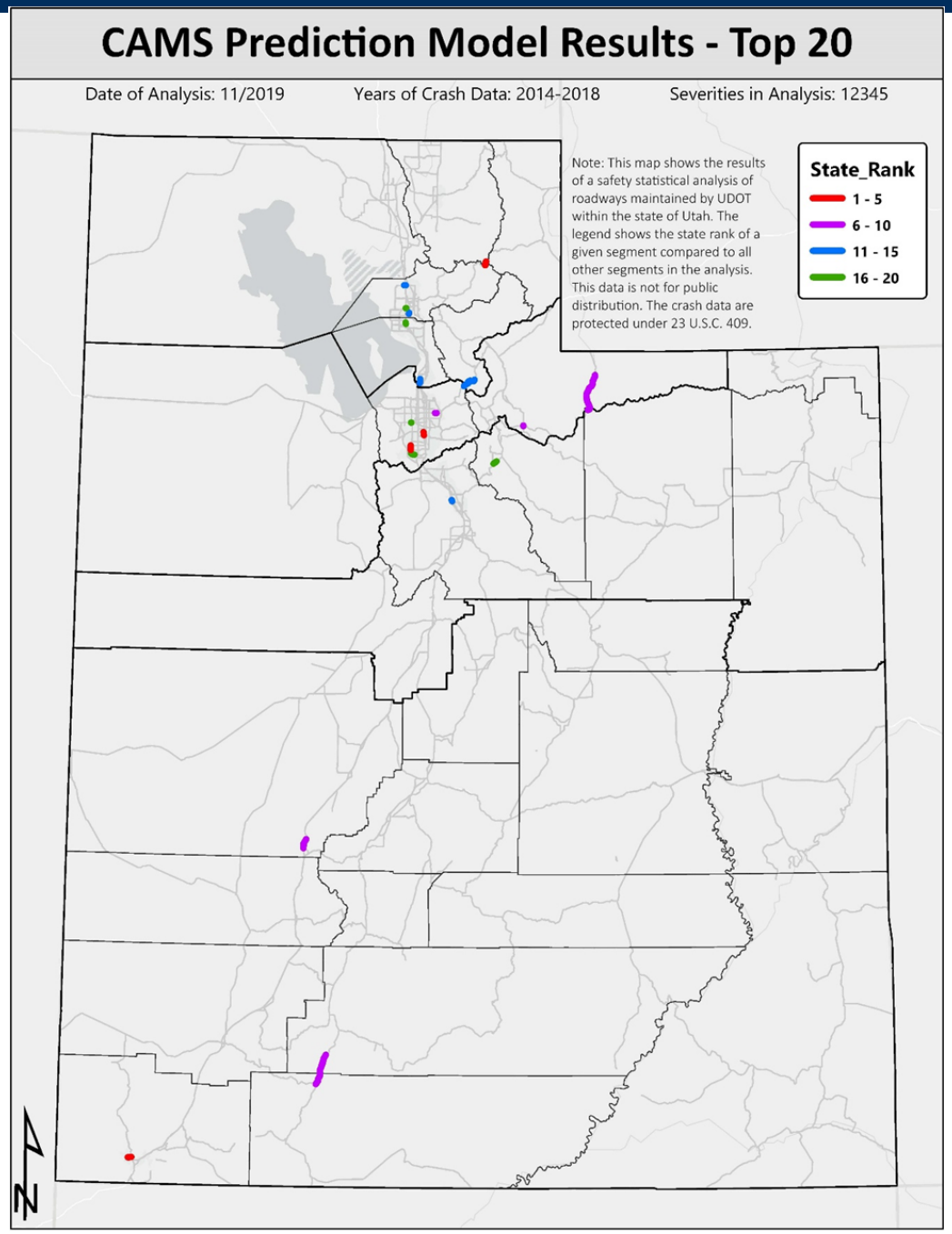
$$\log\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) = \beta_{0k} + x'_{ij}\beta$$



Results: CAMS Prediction Model

State Rank	*Segment Length (miles/km)*	*2018 Injury Crashes*	*Predicted 2018 Injury Crashes*	*Percentile*
1	1.5/2.4	4	0.07	1.0000
2	0.4/0.6	7	0.91	0.9998
3	13.2/21.2	5	0.42	0.9996
4	0.5/0.8	7	0.87	0.9994
5	10.5/16.9	8	1.44	0.9992
6	1.4/2.3	5	0.58	0.9990
7	5.7/9.2	6	0.99	0.9986
8	1.3/2.1	4	0.38	0.9985
9	1.1/1.8	13	3.87	0.9984
10	3.2/5.1	8	1.79	0.9983
11	0.1/0.2	5	0.69	0.9976
12	5.6/9.0	11	3.64	0.9972
13	0.4/0.6	6	0.94	0.9972
14	1.2/1.9	9	2.37	0.9971
15	1.5/2.4	10	3.03	0.9971
16	0.6/1.0	5	0.79	0.9959
17	0.5/0.8	7	1.70	0.9953
18	0.1/0.2	2	0.09	0.9946
19	15.3/24.6	7	1.81	0.9943
20	1.8/2.9	2	0.10	0.9943

Results: CAMS Maps



Results: CAMS Report

Segment Safety Analysis Report

Introduction

The purpose of this report is to summarize and present preliminary results from a safety-specific micro analysis on an identified segment of interest. This report includes identification of the roadway segment and sub-segments, micro-analysis of the crash data, site visit notes, and a list of possible countermeasures.

Segment Identification and Roadway Characteristics

Date: 7/17/2020

Street Name: *Ogden River Scenic Byway*

Table 1: Segment Metadata

Route Number:	39	UC Model Used:	CAMS-P
Road Direction:	P	State Rank:	1
Beginning, Ending MP:	42.67-44.13	Region, Rank:	1, 1
Length (miles):	1.46	County, Rank:	WEBER, 1
Data Source Years:	2014-2018		

Table 2: Segment Characteristics

Functional Class:	Major Collector	AADT:	510
Number of Thru Lanes:	2	Speed Limit (MPH):	45

Table 3: Roadway Characteristics

MPs	Median	Shoulder	Grade	Curve	Lanes	Wall/ Barrier	Rumble Strips
42.67 - 44.13	None	Paved - 3ft	Steep	4 sharp curves	2	None	No

Micro-Analysis of Crash Data

Crash Data Summary

Table 4: Crash Count and Severity

Crash Severities	Functional Area Method	Crashes During 2018		Total Crashes Between 2014-2018				
		Predicted	Actual	Sev. 5	Sev. 4	Sev. 3	Sev. 2	Sev. 1
345	by speed from stop bar	0.0716	4	0	3	1	0	2

Table 5: Top 7 Crash Factors

Crash ID	Latitude	Longitude	SINGLE VEHICLE	ROADWAY GEOMETRY RELATED	ROADWAY DEPARTURE	COLLISION WITH FIXED OBJECT	OVERTURN ROLLOVER	NIGHT DARK CONDITION	IMPROPER RESTRAINT
Injury Total			4/4	4/4	4/4	3/4	2/4	1/4	1/4
Segment Total			6/6	5/6	5/6	4/6	2/6	3/6	1/6

Table 6: Manner of Collision Data

	Manner 1	Manner 2	Manner 3	Manner 4	Manner 5	Manner 6	Manner 7	Manner 8	Manner 9
Name	Single Vehicle	Angle	Front to Rear	Head On	Sideswipe Same Direction	Sideswipe Opposite Direction	Parked Vehicle	Rear to Side	Rear to Rear
Injury Total	4/4	0/4	0/4	0/4	0/4	0/4	0/4	0/4	0/4
Segment Total	6/6	0/6	0/6	0/6	0/6	0/6	0/6	0/6	0/6

Historical Perspective, Current Conditions, Site Visit Notes

Date: 3/25/2020

This segment has not experienced significant changes since the beginning of the analysis period (2014).

This segment is a portion of SR 39 in Weber County. It is a two lane undivided highway. There is one northbound lane and one southbound lane. There are no rumble strips. The paved shoulder on both sides of the road is 3 ft. There are horizontal and vertical curves on this segment, one of which can be seen in Figure 1. There are no barriers on the curves.

Figure 1: A curve on this segment of the Ogden River Scenic Byway (SR 39) without delineation or barriers (Google).

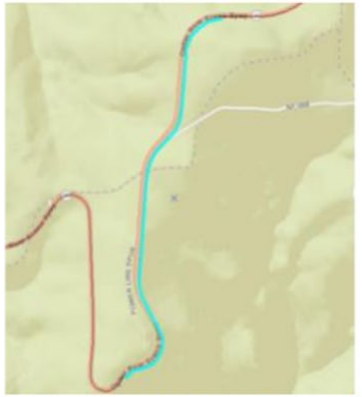


Figure 2: GIS map showing the location of the segment (ESRI).

Possible Countermeasures

The following is a list of possible countermeasures related to the top 8 crash factors listed in Table 5. The countermeasures listed were compiled from the NCHRP 500 Report volumes and Countermeasures That Work (CTW). (P) = Proven (T) = Tried (E) = Experimental (NA) = Data not available (X*) = Star rating, as designated by CTW. (If countermeasures were listed in both the NCHRP 500 Report and CTW, it is listed with both ratings. For instance, Proven and 4-star rating = (P,4*).)

Engineering Countermeasures

Change or mitigate the effects of identified elements in the environment (E)
Delineate roadside objects (E)
Provide adequate sight distance (T)
Provide advance warning of unexpected changes in horizontal alignments (T)
Remove/relocate objects in hazardous locations (P)
Widen the roadway (P)
Design safer slopes and ditches to prevent rollovers (P)

Policy Countermeasures

Encourage trucking companies and other fleet operators to implement fatigue management programs (T)

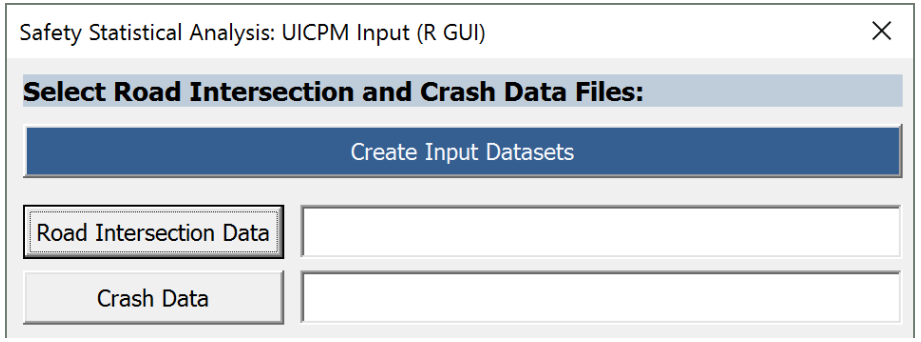
Results: CAMS Analysis

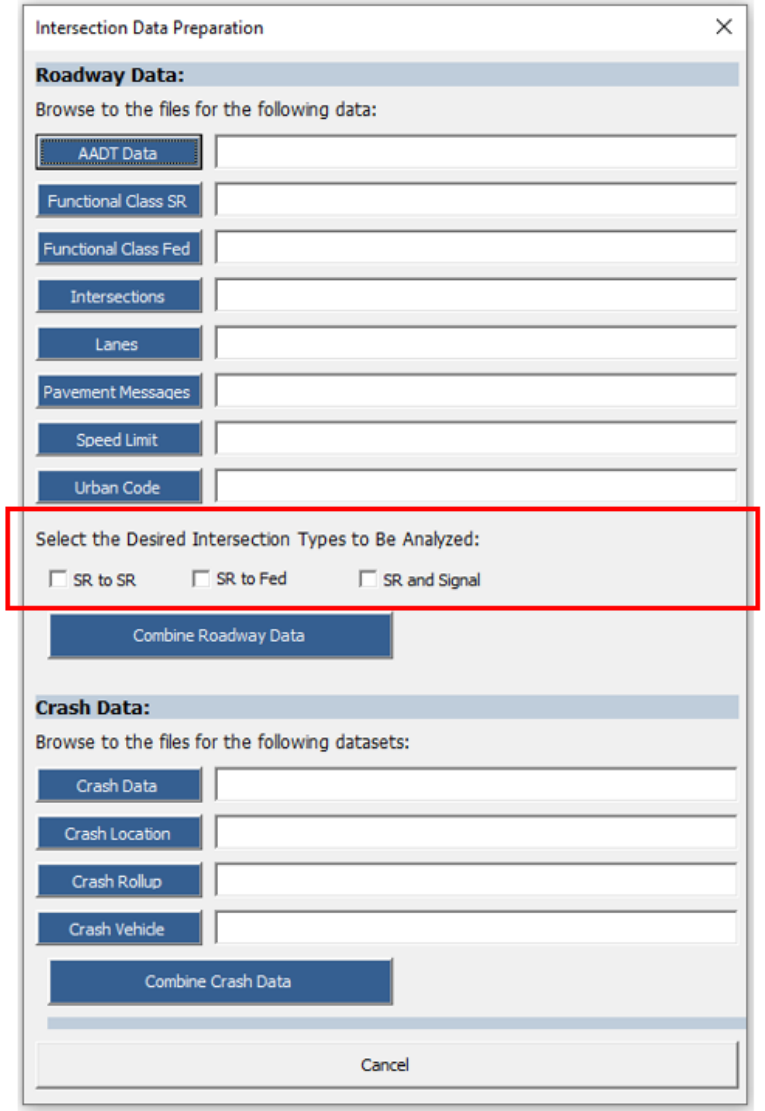
Manner of Collision	*Total Segment Crashes*	*Percent of Total Segment Crashes*	*Crashes in the Top 20 Segments*	*Percent of Crashes in the Top 20 Segments*	*Difference in Percent*
Single Vehicle	49,049	37.6%	680	37.4%	-0.2%
Front to Rear	46,301	35.5%	673	37.0%	1.5%
Sideswipe Same Direction	15,346	11.8%	191	10.5%	-1.3%
Angle	14,547	11.1%	211	11.6%	0.5%
Parked Vehicle	2,161	1.7%	15	0.8%	-0.8%
Head On	1,587	1.2%	25	1.4%	0.2%
Sideswipe Opposite Direction	1,291	1.0%	23	1.3%	0.3%
Rear to Side	148	0.1%	0	0.0%	-0.1%
Rear to Rear	64	0.0%	0	0.0%	0.0%
Total	*130,494*		*1,818*		

Methodology: ISAM Data Integration

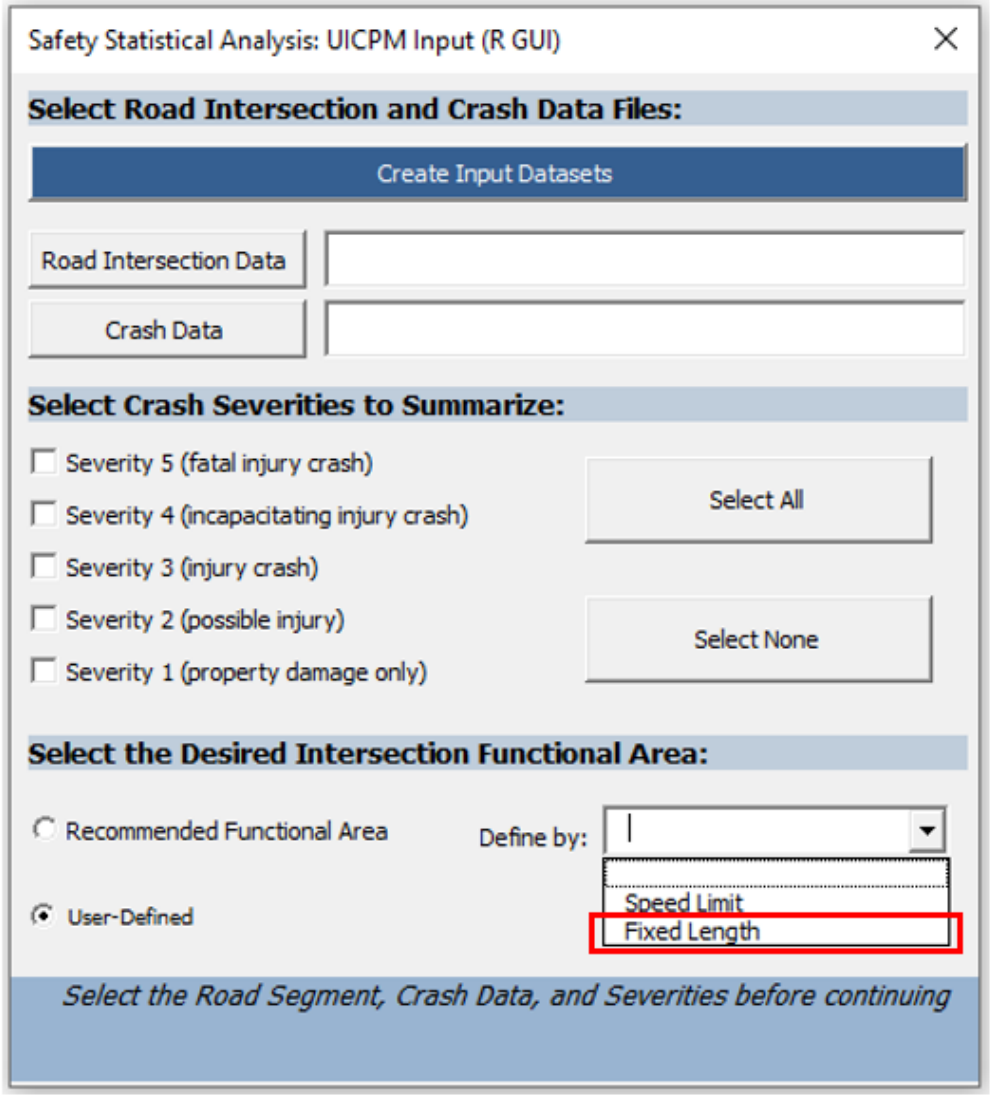
Preliminary Data Preparation:

- Import, format, and combine raw roadway and crash data
- Process transferred from Roadway and Crash Data Preparation tool to RGUI tool
- Creates the following datasets:
  - Combined intersection roadway data
  - Combined crash data





Methodology: ISAM Data Integration

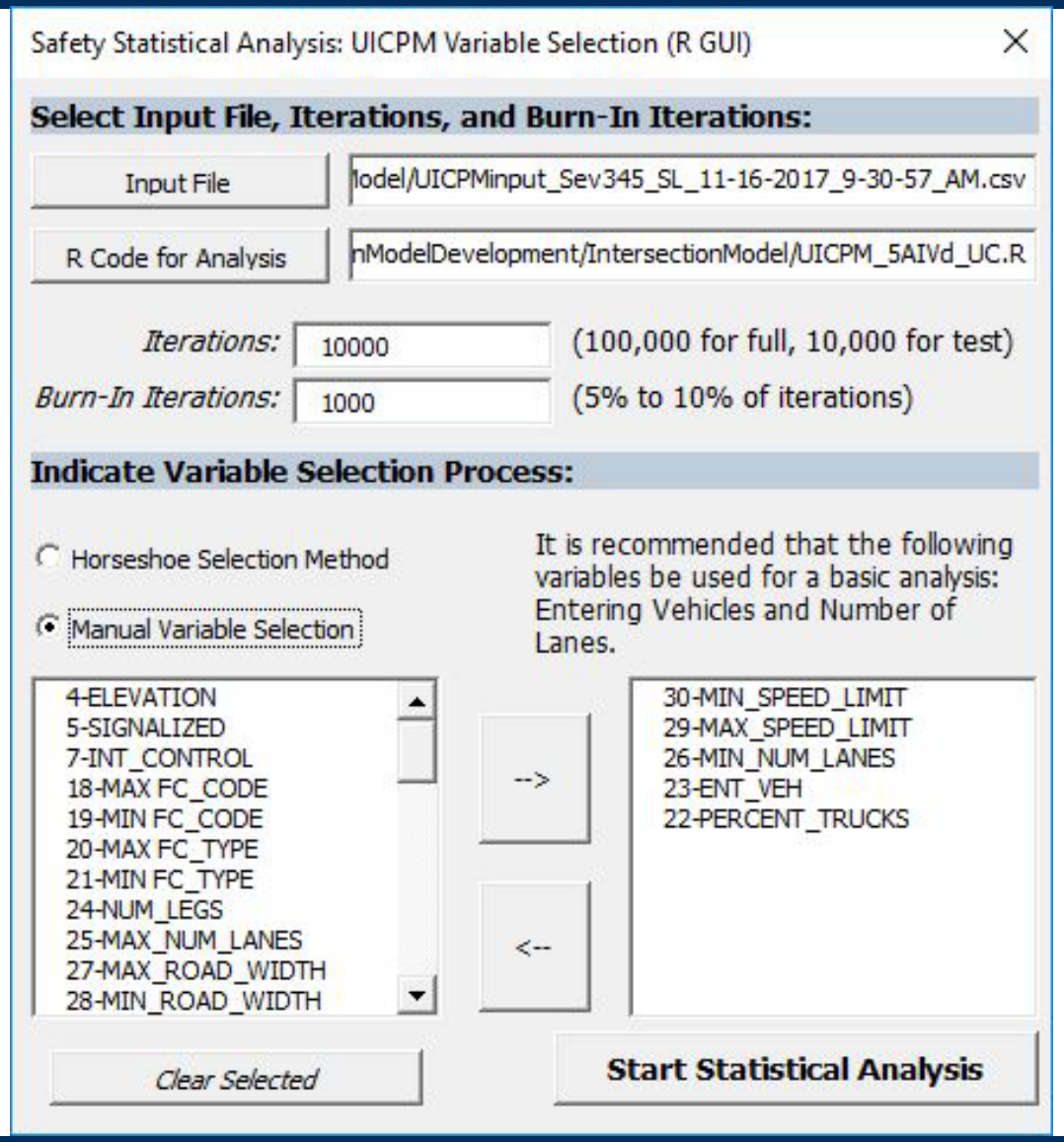


Model Input File Creation

- User selects:
  - Roadway and crash files
  - Crash severities
  - Intersection functional area

- Functional area can be defined by:
  - Speed limit (default) based on *Access Management Manual, 2nd Ed.*
  - Fixed length (e.g., 250 ft based on the *Highway Safety Manual*)

Methodology: ISAM Statistical Analysis



Model Execution & Variable Selection

- Select the UICPM input and R model files
- Select the number of iterations
- Select the variables to use in the model

Methodology: ISAM Statistical Analysis

Utah Intersection Crash Prediction Model (UICPM)

- A Bayesian generalized linear model
- Produces a distribution of the number of annual crashes that are expected at each intersection
- Distributions are based on intersection type (categorical variable) and intersection characteristics (explanatory variables)

Categorical Variable

Interaction Term of:

- UDOT Region
- Functional Class

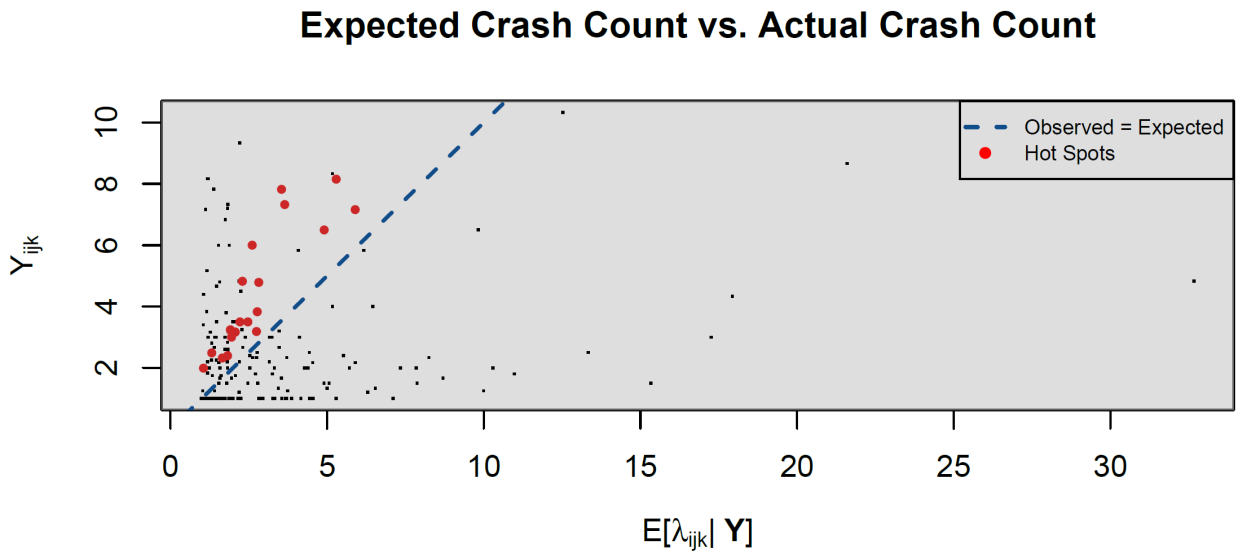
Explanatory Variables

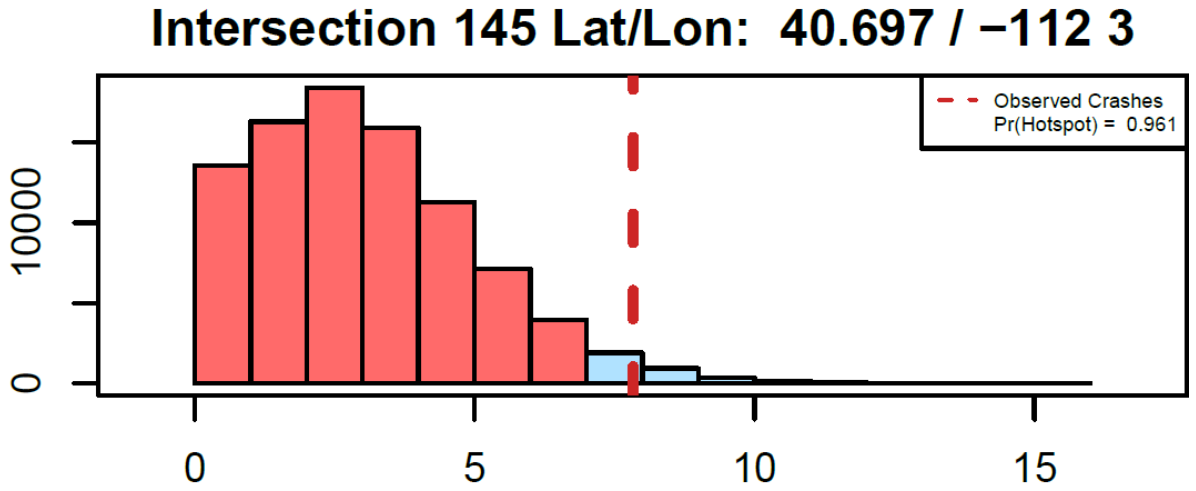
- Entering Vehicles
- Number of Intersection Legs
- Minimum Number of Lanes
- Maximum Roadway Width
- Maximum Speed Limit

Methodology: ISAM Statistical Analysis

Two models:

- Utah Intersection Crash Prediction Model (UICPM):
  - Similar to CAMS Prediction model
- Utah Intersection Crash Severity Model (UICSM):
  - Similar to CAMS Severity model

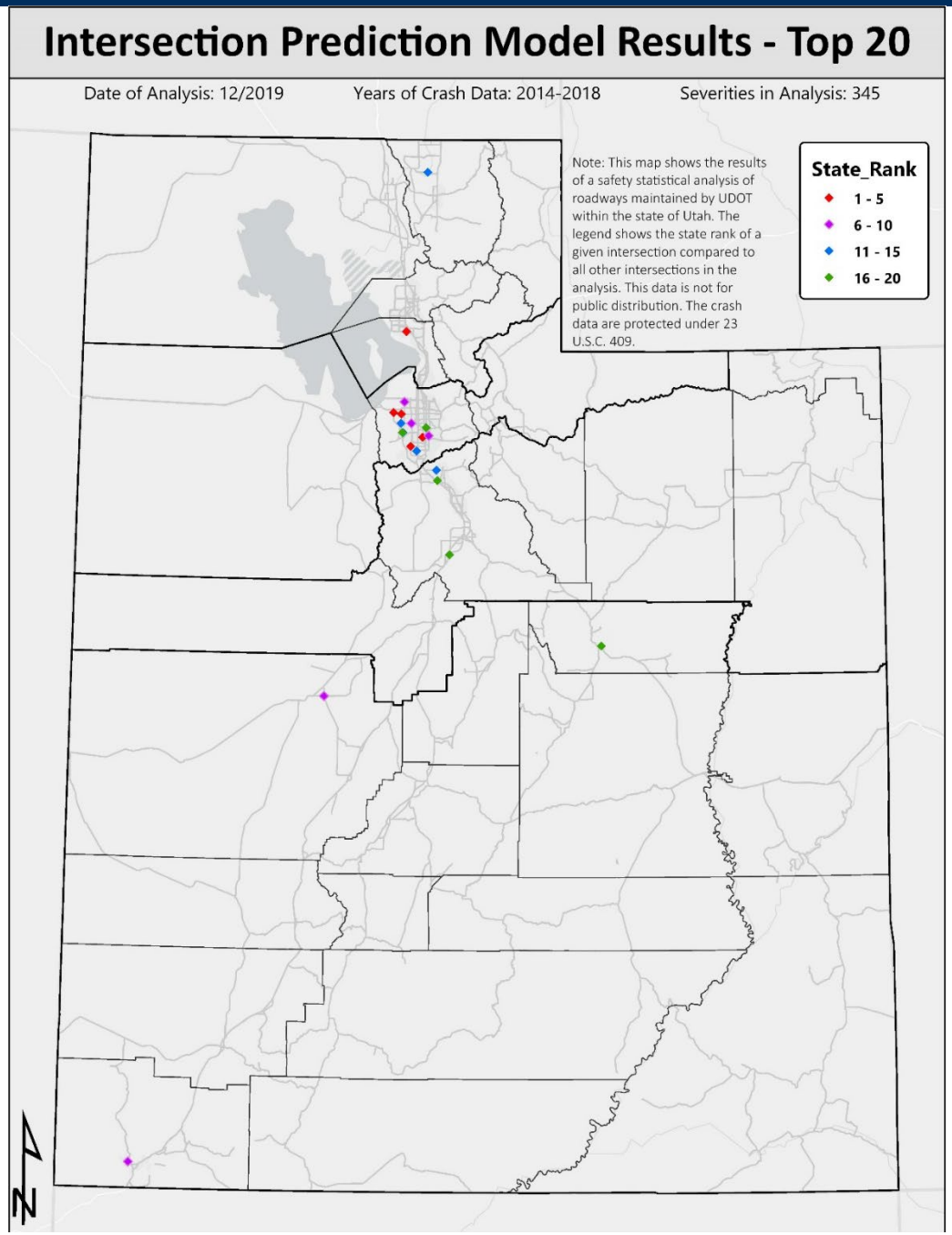




Results: ISAM Prediction Model

State Rank	*Intersection Type*	*Traffic Control Device*	*2018 Injury Crashes*	*Predicted 2018 Injury Crashes*	*Percentile*
1	State Route & Federal Aid	Stop Sign	4	0.22	0.9997
2	State Route & Local Road	Signal	8	1.34	0.9993
3	State Route & State Route	Signal	8	1.72	0.9986
4	State Route & Federal Aid	Signal	5	0.55	0.9985
5	State Route & Federal Aid	Stop Sign	9	2.08	0.9984
6	State Route & State Route	Stop Sign	2	0.07	0.9971
7	State Route & Federal Aid	Signal	5	0.74	0.9967
8	State Route & Federal Aid	Stop Sign	3	0.20	0.9965
9	State Route & State Route	Signal	9	2.58	0.9953
10	State Route & Federal Aid	Signal	6	1.26	0.9944
11	State Route & Federal Aid	Stop Sign	2	0.09	0.9938
12	State Route & Federal Aid	Signal	5	0.87	0.9935
13	State Route & Local Road	Signal	3	0.27	0.9924
14	State Route & Local Road	Signal	4	0.73	0.9869
15	State Route & Federal Aid	Signal	13	5.88	0.9861
16	State Route & Federal Aid	Signal	5	1.21	0.9851
17	State Route & Federal Aid	Signal	5	1.22	0.9845
18	State Route & Federal Aid	Stop Sign	2	0.16	0.9815
19	State Route & Federal Aid	Signal	13	6.27	0.9788
20	State Route & State Route	Signal	3	0.49	0.9785

Results: ISAM Maps



Results: ISAM Report

Intersection Safety Analysis Reports (ISAR)

- Tables 1 and 2 describe the roadway and intersection characteristics
- Tables 3 and 4 describe the crash history
- Table 5 identifies manner of collision
- User identifies:
  - The safety problem
  - Historical & current conditions
  - Site visit notes
  - Potential countermeasures (Engineering and Policy/Enforcement)

Intersection Identification and Roadway Characteristics *Date: 12/10/2019*

Table 1: Intersection Metadata

Model Used:	UICPM	**Leg 0 Route & MP:**	108	1.57
State Rank:	1	**Leg 1 Route & MP:**	Local	-
Region & Rank:	1, 1	**Leg 2 Route & MP:**	108	1.57
County & Rank	DAVIS, 1	**Leg 3 Route & MP:**	Local	-
Years of Data:	2014-2018	**Leg 4 Route & MP:**	-	-
City/Area:	Hooper	**Latitude & Longitude**	41.089	-112.018

Table 2: Intersection Characteristics

Intersection Control:	SIGNAL	**Entering Vehicles in 2018:**	86,000
Max. Functional Class:	Other Principal Arterial	**# of Lanes on Route 0:**	5
Min. Functional Class:	Local	**Max & Min Speed Limit (mph):**	45 -

Table 3: Crash Count and Severity

Crash Severities Used	Functional Area Method Used	Number of Crashes						
		Predicted	Actual	Sev. 5	Sev. 4	Sev. 3	Sev. 2	Sev. 1
345	Speed Limit	22.0	47	1	4	42	87	263

Table 4: Crash Factors

Crash ID	Latitude	Longitude	NIGHT DARK CONDITION	TEENAGE DRIVER INVOLVED	SINGLE VEHICLE	HEADON COLLISION	ROADWAY GEOMETRY RELATED	OLDER DRIVER INVOLVED	DISTRACTED DRIVING
Intersection Total			13/47	10/47	10/47	8/47	7/47	6/47	5/47

Table 5: Manner of Collision Data

	Manner 1	Manner 2	Manner 3	Manner 4	Manner 5	Manner 6	Manner 7	Manner 8	Manner 9
Name	**Angle**	**Rear to Rear**	**Front to Rear**	**Rear to Side**	**Head On**	**Single Vehicle**	**Sideswipe Same Direction**	**Sideswipe Opposite Direction**	**Parked Vehicle**
Intersct'n Total	**4/12**	**3/12**	**2/12**	**2/12**	**1/12**	**0/12**	**0/12**	**0/12**	**0/12**

Conclusions

- The CAMS provides UDOT with useful tools that identify segments of particular concern
- The ISAM is used to analyze the majority of State Route intersections
- The CAMS and ISAM provide a complementary analysis of the State Route crash data
- UDOT uses these findings to prioritize the use of safety funds
- The two tools used together allow for an in-depth analysis of crashes and help to identify crash hot spots and safety concerns

Thank You!

Grant G. Schultz, Ph.D., P.E., PTOE
gschultz@byu.edu