APPENDIX B. MODIFICATIONS TO RSAPV3

The following appendix includes recommendations for potential modifications to the RSAPv3 model to coordinate and implement the results of this research in a future update to RSAPv3.

INTRODUCTION

A detailed review of the first edition of the Highway Safety Manual (HSMv1) and third version of the Roadside Safety Analysis Program (RSAPv3) was conducted as part of this research. Differences in methodology and application of the approaches were observed. RSAPv3, for example, differentiates between highway type (i.e., divided, undivided, or one way) while the HSMv1 differentiates between highway type, functional classification and area type (i.e., urban and rural).

These observations are reinforced by the differences in initial assumptions and input variables between the HSM and RSAPv3. One objective of this research was to allow for improved coordination of these two approaches (i.e., HSM and RSAPv3). This appendix summarizes the discontinuities between the two approaches and point out where these gaps have been bridged by the ROR predictive method proposed herein for the HSM. This appendix summarizes the changes recommended for implementation to the RSAPv3 encroachment probability model to bridge the gap between these two approaches.

CRASH TYPE COORDINATION

RSAPv3 explicitly predicts ROR crashes, where the HSMv1 models generally consider single vehicle crashes and do not always distinguish between the types of single vehicle crashes (i.e., on-road or off-road). For example, the rural two-lane road chapter models single-vehicle ROR crashes whereas the rural multi-lane road chapter models single-vehicle crashes which mixes ROR crashes with other events (e.g., pedestrian crashes, animal crashes).

The proposed HSM ROR predictive method has been coordinated with RSAPv3 to predict ROR crashes by roadway edge and direction of travel. The traffic volume, percent of trucks, and highway type (i.e., divided, undivided, or one-way) are the input variables for the proposed SPF while the output is now ROR crash frequency by edge and direction of travel. No further coordination is recommended for crash type.

AREA TYPE COORDINATION

The HSM ROR predictive method distinguishes between urban and rural area types where RSAPv3 does not. It is recommended that the SPFs developed under this research be used to create an RSAPv3 adjustment factor to allow for adjusting the rural encroachment data to consider urban areas. The need for this modifier may be otherwise addressed if the pending encroachment data collection research considers both urban and rural area types.

MODEL CAPABILITY COORDINATION

Table 102 is a summary of the base conditions from the HSMv1 SPFs and for the RSAPv3 model. The blank cells in this table represent situations which were not considered by the model heading the column. A review of the table reveals that not only do the models have base conditions which are different, but when the models do consider the same elements, the base values are often different. The proposed HSM ROR predicative method and RSAPv3 encroachment probability model base conditions are shown in Table 103. As can be seen, the base conditions and the modeling capabilities were aligned by the changes proposed to the HSM predictive methods. No changes are recommended to the RSAPv3 model to coordinate model capability.

Table 1. Summary of Base Conditions Across the HSM SPFs and RSAPv3.

Data Element	RSAPv3	Rural two-lane Road	Rural Multi-lane Road (U)	Rural Multi-lane Road (D)	Urban and Suburban Arterial
Number of Lanes	2 lanes (U) 4 lane (D)				
Posted Speed Limit	65 mph				
Access Density	0 points/mile	5 points/mile			
Terrain	Flat				
Vertical Grade	-2%≥ Segment ≤2%	0%			
Vertical Curve		None			
Horizontal Curve	-1910≥ Radius (ft) ≤1910	None			
Lane width	12 feet	12 feet	12 feet	12 feet	
Right shoulder width	*	6 feet	6 feet	8 feet	
Shoulder type		Paved	Paved		
Sideslopes	*		1V:7H or flatter		
Roadside fixed objects	*				0 pnts/mile
Median width	*			30 feet	30 feet
Lighting		None	None	None	
Automatic Speed Enforcement		None	None	None	
Roadside Hazard Rating	*	3			
Centerline Rumble Strip		None			
Passing lanes		None			
Two-way left turn lanes		None			

*The items marked with an asterisk are handled explicitly through the RSAP model.

Table 2. Summary of Coordinated Base Conditions Across the Proposed HSM ROR Predicted Method and RSAPv3.

Data Element	RSAPv3	HSM
Number of Lanes	2 lanes (U) 4 lane (D)	
Lane width	12 feet	
Posted Speed Limit	65 mph	
Vertical Grade	-3%≥Segment≤3%	
Horizontal Curve	-580≥Radius (ft)≤580	
Lane width	12 feet	
Right shoulder width	8 feet	
Sideslopes	Traversable	
Roadside fixed objects	Density and offset explicitly modeled	
Longitudinal barrier	Type and offset explicitly modeled	
Median width	explicitly modeled	Not recommended

ON-ROAD ADJUSTMENT FACTOR COORDINATION

It is recommended that the on-road CMFs from this research effort be incorporated into the encroachment probability model of RSAPv3. Integrating the on-road CMFs used in the proposed HSM ROR predictive method as RSAPv3 encroachment adjustment factors (EAF) will further coordinate the two models and provide consistency. These on-road CMFs are recommended for implementation in RSAPv3:

- CMF for average lane width (CMF_{LW}) as shown in Table 48,
- CMF for right shoulder width (CMF_{SW}) as shown in Table 50,
- CMF for posted speed limit (CMF_{PSL}) as shown in Table 54 and Table 55,
- CMF for number of lanes (CMF_{NL}) as shown in Table 57 and Table 58,
- CMF by direction of travel for percent grade (CMF_{PG}) as shown in Table 64 and Table 65, and
- CMF by direction and edge for horizontal curvature (CMF_{DOC}) as outline below.

The CMF developed for horizontal curvature should not be used within RSAPv3 because crashes from different encroachment directions are combined to edges. While conducting the modeling for the CMFs, however, EAF modeling was also done with directional and crash edge specific models. These models are documented within the body of the report, however, were not used for CMF development. These directionally and edge dependent models were developed solely for the coordination of the RSAPv3 and the proposed HSM ROR crash predictive method. Using the same technics discussed with the body of the report and the same base conditions, an EAF for horizontal curvature is recommended for RSAPv3, as outlined in Table 104 and Table 105. This EAF is shown graphically in Figure 40.

Table 3. Horizontal Curve EAF for Undivided Roadways.

$$CMF_i = e^{\beta_i x_i}$$

CMF$_i$	Alignment change	Rural Undivided Right edge in direction under evaluation			Urban Undivided Right edge in direction under evaluation		
		ß$_i$	95% Confidence		ß$_i$	95% Confidence	
CMF$_{DOC}$	Curve L	0.0756	0.0692	0.0818	0.0486	0.0354	0.0610
	Curve R	0.0204	0.0118	0.0287	0.0064	-0.0159	0.0259
Where x_i is the degree of curvature.							

Table 4. Horizontal Curve EAF for Divided Roadways.

$$CMF_i = e^{\beta_i x_i}$$

CMF$_i$	Alignment change	Rural Divided Right edge in direction under evaluation			Urban Divided Right edge in direction under evaluation		
		ß$_i$	95% Confidence		ß$_i$	95% Confidence	
CMF$_{DOC}$	Curve L	0.0083	-0.0010	0.0191	0.0032	-0.0044	0.0086
	Curve R	0.0112	0.0031	0.0225	0.0064	0.0010	0.0109
Where x_i is the degree of curvature.							

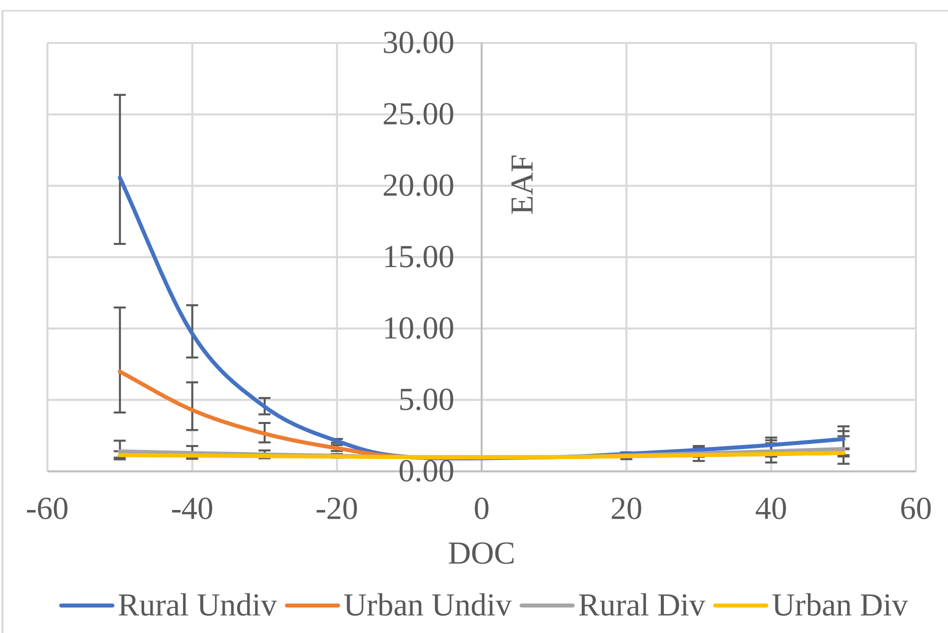

Figure 1. Horizontal Curve EAF Recommended for Implementation in RSAPv3.

APPENDIX C. DATABASES DOCUMENTATION

This appendix documents the data sources and the compilation of the data to create the datasets used for modeling in this research.

INTRODUCTION

The Ohio and Washington State run-off-road crash databases were derived from data requested from the Federal Highway Administration's (FHWA) Highway Safety Information System (HSIS) [HSIS01] for the states of Ohio and Washington referenced herein as OHHSIS and WSHSIS respectively, and longitudinal barrier inventories provided by the Ohio and Washington State Departments of Transportation (DOTs) [ODOT01][WSDOT01] referenced herein as OHLBI and WSRFIP, respectively. OHHSIS Roadlog, Curve, Grade, Accident, and Vehicle datasets were requested for 2002-2010, and WSHSIS Roadlog, Curve, Grade, Accident, and Vehicle datasets were requested for 2002-2007 for rural roadways and 2002-2011 for urban roadways.

The OHHSIS and WSHSIS Roadlog, Curve, and Grade datasets were merged to develop homogenous roadway segments for each year of data. The OHHSIS and WSHSIS Accident and Vehicle datasets were overlaid on the homogenous segments to determine the count of crashes by segment. A full description and definition of the variables used to merge all files for both the OHHSIS and WSHSIS datasets are available in the online HSIS guidebooks [HSISOH16] [HSISWS16] and are referred to by variable name herein to document the database development and variable definitions.

HOMOGENOUS SEGMENTS

The variables "CNTY_RTE" and "BEGMP" of the OHHSIS Roadlog, Curve, and Grade datasets were concatenated. The same was done to the "CNTY_RTE" and "ENDMP" variables of the same datasets. These new concatenated variables were copied from all three OHHSIS datasets and pasted into a new dataset. Duplicate values were removed, then the "VLOOKUP" function in Microsoft Excel *(6)* and some visual basic programming was used to fill in the geometric, horizontal curve, and vertical grade data from the OHHSIS Roadlog, Curve, and Grade datasets, respectively, for each new homogenized segment.

This same process was completed to the WSHSIS Roadlog, Curve, and Grade datasets, using "ROAD_INV", "BEGMP, and "ENDMP" in the WSHSIS Roadlog dataset, and "RTE_NBR", "BEGMP", and "ENDMP" in the WSHSIS Curve and Grade datasets.

The new homogenized roadway segment data were separated into divided and undivided databases. Any segment with a median width greater than zero was considered to be a divided roadway. Any segment with a median width equal to zero was considered to be an undivided roadway. In the OHHSIS Roadlog dataset, this variable is called "MED_WID", in the WSHSIS Roadlog dataset this variable is called "MEDWID".

CRASH DATA

The OHHSIS "CASENO" variable found in the Accident and Vehicle datasets was used to merge each year of these datasets using Microsoft Access [MSFT01]. ROR crashes were isolated using the criteria outlined below.

The following section describes ROR crashes. ROR crashes were determined using the sequence of event fields ("EVENT1", "EVENT2", "EVENT3", and "EVENT4") in both the OHHSIS and WSHSIS Vehicle datasets.

Ohio

A crash was considered to be a ROR crash in Ohio if any of these codes were present in any of the OHHSIS Vehicle dataset sequence of events fields:
01 = 'OVERTURN/ROLLOVER'

03 = 'IMMERSION'
08 = 'RAN OFF ROAD RIGHT'
09 = 'RAN OFF ROAD LEFT'
10 = 'CROSS MEDIAN/CENTERLINE' *[for divided roadways only]*
21 = 'PARKED MOTOR VEHICLE'
22 = 'WORK ZONE MAINTENANCE EQUIPMENT'
25 = 'IMPACT ATTENUATOR/CRASH CUSHION'
26 = 'BRIDGE OVERHEAD STRUCTURE'
27 = 'BRIDGE PIER OR ABUTMENT'
28 = 'BRIDGE PARAPET'
29 = 'BRIDGE RAIL'
30 = 'GUARDRAIL FACE'
31 = 'GUARDRAIL END'
32 = 'MEDIAN BARRIER'
33 = 'HIGHWAY TRAFFIC SIGN POST'
34 = 'OVERHEAD SIGN POST'
35 = 'LIGHT/LUMINARIES SUPPORT'
36 = 'UTILITY POLE'
37 = 'OTHER POST, POLE OR SUPPORT'
38 = 'CULVERT'
39 = 'CURB'
40 = 'DITCH'
41 = 'EMBANKMENT'
42 = 'FENCE'
43 = 'MAILBOX'
44 = 'TREE'
45 = 'OTHER FIXED OBJECT'
46 = 'WORK ZONE MAINTENANCE EUIPMENT'
47 = 'UNKNOWN FIXED OBJECT'
48 = 'OTHER'
49 = 'UNKNOWN'

Washington State

A crash was considered to be a ROR crash in Washington State if any of the following codes were present in any of the WSHSIS Vehicle dataset sequence of events:
'02' = 'COLLISION INVOLVING FIXED OBJECT'
'04' = 'COLLISION INVOLVING PARKED VEHICLE'
'09' = 'RAN OFF THE ROAD'
'11' = 'OVERTURN (ROLLOVER)'

Roadside departure determination was performed on the OHHSIS Crash dataset by first determining the direction the vehicle was traveling just prior to the crash. Using the fields “VEH_N_FROM” and “VEH_N_TO” in the OHHSIS Crash dataset, the following rules were applied:

If “VEH_N_FROM” = 2, 4, or 8, and “VEH_N_TO” = 1, 3, or 5, the vehicle was traveling in the increasing milepost direction. If “VEH_N_FROM” = 1, 3, or 5, and

"VEH_N_TO" = 2, 4, or 8, the vehicle was traveling in the decreasing milepost direction. If the vehicle crash record did not meet either of these criteria, the vehicle travel direction was listed as unknown.

After determining vehicle travel direction, this variable was used in conjunction with the sequence of events codes to determine ROR side using the following rules:

If the vehicle was traveling in the increasing milepost direction and had an event code of 8, the crash was coded as PR_ROR. If the vehicle was traveling in the increasing milepost direction and had an event code of 9 or 10, the crash was coded as PL_ROR. If the vehicle was traveling in the decreasing milepost direction and had an event code of 8, the crash was coded as OR_ROR. If the vehicle was traveling in the decreasing milepost direction and had an event code of 9 or 10, the crash was coded as OL_ROR. This criteria were checked starting with the "EVENT1" field and progressed through the remaining event fields if a ROR side could not be determined from the previous event field. If after cycling through all the event fields and codes 8, 9, or 10 were not present, or if the vehicle direction of travel could not be determined, the ROR side was coded as unknown (Unk_ROR).

In the WSHSIS Crash dataset, the variables "V1DIRCDE" and "V2DIRCDE" were used to first determine vehicle direction of travel. If the vehicle involved was vehicle 1 and the value for "V1DIRCDE" was "A", the vehicle was traveling in the increasing milepost direction. If the vehicle involved was vehicle 1 and the value for "V1DIRCDE" was "B", the vehicle was traveling in the decreasing milepost direction. Similarly, if the vehicle involved was vehicle 2 and the value for "V2DIRCDE" was "A", the vehicle was traveling in the increasing milepost direction, and if the vehicle involved was vehicle 2 and the value for "V2DIRCDE" was "B", the vehicle was traveling in the decreasing milepost direction. Any other value in "V1DIRCDE" or "V2DIRCDE" resulted in the vehicle being marked as a direction of travel as unknown.

After determining vehicle travel direction, this variable was used in conjunction with the "IMPACT" variable to determine ROR side using the following rules:

If the vehicle was traveling in the increasing milepost direction and had an "IMPACT" code of A0 or A7, the crash was coded as PR_ROR. If the vehicle was traveling in the increasing milepost direction and had an "IMPACT" code of A8, A9, D8, D9, D0 or D7, the crash was coded as PL_ROR. If the vehicle was traveling in the decreasing milepost direction and had an "IMPACT" code of A0 or A7, the crash was coded as OR_ROR. If the vehicle was traveling in the decreasing milepost direction and had an "IMPACT" code of A8, A9, D8, D9, D0 or D7, the crash was coded as OL_ROR. If the value for "IMPACT" was not one of the above codes, or if the vehicle direction of travel could not be determined, the ROR side was coded as unknown (Unk_ROR).

The new combined OHHSIS "ROR Crash" datasets were then overlaid on the homogenized roadway segments using "CNTYRTE" and "MILEPOST" in the OHHSIS Accident dataset and "CNTY_RTE", "BEGMP", and "ENDMP" in the OHHSIS Roadlog dataset.

The same process was performed on the WSHSIS Accident and Vehicle datasets using the "CASENO" variable present in both datasets. The new WSHSIS Crash dataset was then filtered for ROR crashes. The new combined WSHSIS "ROR Crash" datasets were then attached to the homogenized roadway segments using "RD_INV" and "MILEPOST" from the WSHSIS Accident dataset and ""ROAD_INV", "BEGMP", and "ENDMP" in the WSHSIS Roadlog dataset.

ROR crashes that had a crash milepost greater than a segment's beginning milepost and less than or equal to a segment's ending milepost were considered to have occurred on that segment.

OHLBI and WSRFIP were attached to the homogenized roadway segments to provide a length of longitudinal barrier coverage for the outside shoulders of each roadway segment. Table 106 shows the equivalent variables in each dataset for Ohio that were used to determine barrier lengths present on each homogenized roadway segment.

Table 5. Variables used to add OHLBI barrier lengths to Ohio homogenized roadway segments.

	OHLBI variable name	OHHSIS variable name
Route	RoadName	CNTY_RTE
Beginning Milepost	FromMilePoint	BEGMP
Ending Milepost	ToMilePoint	ENDMP

WSRFIP was created based on data requested from WSDOT from the Roadside Features Inventory Program (RFIP) [WSRFIP]. The following features were considered to be longitudinal barriers: bridge rails, cable barriers, concrete barriers, and guardrails. The RFIP data for these longitudinal barriers is stored in separate files. These files were merged into a single file and the overlapping milepost values were removed to avoid double-counting the length.

The WSRFIP database was created and populated using State Route Milepost (SRMP) values, instead of the Accumulated Route Milepost (ARM) values the WSHSIS Roadlog, Curve and Grade databases use. Washington State publishes highway logs annually [WSLOG01] that include information on the ARM and SRMP relationship. These logs were used to generate equivalencies between the ARM and SR milepost values for each year of WSHSIS ROR Crash data. The ARM values in the WSHSIS ROR Crash data were converted to SRMP values, and the longitudinal barrier values were added to the WSHSIS ROR Crash database.

OHIO AND WASHINGTON STATE RUN-OFF-ROAD DATABASES

The following is a description of how the OHHSIS and WSHSIS dataset variables were used to create each field in the Ohio and Washington State Run-Off-Road Databases. The fields in Table 107 are present in both the divided and undivided databases. Fields that are in **bold** are "binary fields", meaning the values in those fields will be either a "1", which indicates the record meets that particular criteria, or a "0", which means the record does not meet that particular criteria. A detailed description for each variable follows.

Table 6. Field names in OH and WA ROR databases.

SegL	**SW.PLE.2**	**PSL.60**	BarL_ORE
aadt	**SW.PLE.3**	**PSL.65**	PR_LB
LW.MORE15	**SW.PLE.4**	**PSL.70**	PL_LB
SW.PRE.0	**SW.PLE.5**	medwid	OR_LB
SW.PRE.1	**SW.PLE.6**	func_cls	OL_LB
SW.PRE.2	**SW.PLE.7**	**NL.2**	Unk_LB
SW.PRE.3	**SW.PLE.8**	**NL.4**	PR_ROR
SW.PRE.4	**SW.PLE.9**	**NL.6**	PL_ROR
SW.PRE.5	**SW.PLE.10**	**NL.8**	OR_ROR
SW.PRE.6	**PSL.25**	STATE	OL_ROR
SW.PRE.7	**PSL.30**	DOC_L	Unk_ROR
SW.PRE.8	**PSL.35**	DOC_R	lanewid
SW.PRE.9	**PSL.40**	PG_U	SHLDR_PRE
SW.PRE.10	**PSL.45**	PG_D	SHLDR_PLE
SW.PLE.0	**PSL.50**	PT	spd_limt
SW.PLE.1	**PSL.55**	BarL_PRE	no_lanes

SegL – Segment Length
Calculated for Ohio and Washington State by subtracting the OHHSIS and WSHSIS Roadlog beginning milepost values (BEGMP) from the OHHSIS and WSHSIS Roadlog ending milepost values (ENDMP).

aadt – Annual Average Daily Traffic
Variable taken directly from OHHSIS and WSHSIS Roadlog datasets from the variable "AADT".

The following SW fields describe shoulder width. In the Ohio OHHSIS Roadlog dataset, the primary right edge (PRE) shoulder width comes from the OHHSIS Roadlog variable "SHWD_RIGHT_OUTSIDE", and the primary left edge (PLE) shoulder width comes from the OHHSIS Roadlog variable "SHWD_RIGHT_INSIDE" for both divided and undivided roadways. In the Washington State WSHSIS Roadlog dataset, the PRE shoulder width comes from the WSHSIS Roadlog variable "RSHLDWID" for both divided and undivided roadways. However, PLE shoulder width comes from the WSHSIS Roadlog variable "LSHLDWID" on divided highways only. On undivided highways, the "LSHLDWID" variable in the Washington WSHSIS Roadlog dataset refers to the outside shoulder in the direction of decreasing inventory. These are "binary fields", meaning a value of 1=yes and a value of 0=no.

SW.PRE.0 – Right shoulder width is < 1 foot wide

SW.PRE.1 – Right shoulder width is ≥ to 1 foot wide and < 2 feet wide

SW.PRE.2 – Right shoulder width is ≥ to 2 feet wide and < 3 feet wide

SW.PRE.3 – Right shoulder width is ≥ to 3 feet wide and < 4 feet wide

SW.PRE.4 – Right shoulder width is ≥ to 4 feet wide and < 5 feet wide

SW.PRE.5 – Right shoulder width is ≥ to 5 feet wide and < 6 feet wide

SW.PRE.6 – Right shoulder width is ≥ to 6 feet wide and < 7 feet wide

SW.PRE.7 – Right shoulder width is ≥ to 7 feet wide and < 8 feet wide

SW.PRE.8 – Right shoulder width is ≥ to 8 feet wide and < 9 feet wide

SW.PRE.9 – Right shoulder width is ≥ to 9 feet wide and < 10 feet wide

SW.PRE.10 – Right shoulder width is ≥ 10 feet wide

SW.PLE.0 – Left shoulder width is < 1 foot wide

SW.PLE.1 – Left shoulder width is ≥ 1 foot wide and < 2 feet wide

SW.PLE.2 – Left shoulder width is ≥ 2 feet wide and < 3 feet wide

SW.PLE.3 – Left shoulder width is ≥ 3 feet wide and < 4 feet wide

SW.PLE.4 – Left shoulder width is ≥ 4 feet wide and < 5 feet wide

SW.PLE.5 – Left shoulder width is ≥ 5 feet wide and < 6 feet wide

SW.PLE.6 – Left shoulder width is ≥ 6 feet wide and < 7 feet wide

SW.PLE.7 – Left shoulder width is ≥ 7 feet wide and < 8 feet wide

SW.PLE.8 – Left shoulder width is ≥ 8 feet wide and < 9 feet wide

SW.PLE.9 – Left shoulder width is ≥ 9 feet wide and < 10 feet wide

SW.PLE.10 – Left shoulder width is ≥ 10 feet wide

The following "PSL" variables describe posted speed limit. For both Ohio and Washington State, the posted speed limit was provided on both the OHHSIS and WSHSIS Accident datasets and the OHHSIS and WSHSIS Roadlog datasets. However, this field was oftentimes incomplete on the Accident datasets, so only the posted speed limit on the OHHSIS and WSHSIS Roadlog datasets were used. In both datasets, the variable name is "SPD_LIMT". These are "binary fields", meaning a value of 1=yes and a value of 0=no.

PSL.25 – Posted speed limit is ≥ 25 mph and < 30 mph

PSL.30 – Posted speed limit is ≥ 30 mph and < 35 mph

PSL.35 – Posted speed limit is ≥ 35 mph and < 40 mph

PSL.40 – Posted speed limit is ≥ 40 mph and < 45 mph

PSL.45 – Posted speed limit is ≥ 45 mph and < 50 mph

PSL.50 – Posted speed limit is ≥ 50 mph and < 55 mph

PSL.55 – Posted speed limit is ≥ 55 mph and < 60 mph

PSL.60 – Posted speed limit is ≥ 60 mph and < 65 mph

PSL.65 – Posted speed limit is ≥ 65 mph and < 70 mph

PSL.70 – Posted speed limit is ≥ 70 mph

medwid – Median Width
This field was taken from the “MED_WID” variable in the OHHSIS dataset, and from the “MEDWID” variable in the WSHSIS dataset.

func_cls – Functional Class
The definitions for the OHHSIS functional class variable are as follows:
'01' = 'PRINICIPAL ARTERIAL (RURAL INTERSTATE)'
'02' = 'PRINICIPAL ARTERIAL (RURAL OTHERS)'
'06' = 'MINOR ARTERIAL (RURAL)'
'07' = 'MAJOR COLLECTOR (RURAL)'
'08' = 'MINOR COLLECTOR (RURAL)'
'09' = 'LOCAL (RURAL)'
'11' = 'PRINCIPAL ARTERIAL (URBAN INTERSTATE)'
'12' = 'PRINCIPAL ARTERIAL (URBAN-FREEWAY & EXPRESSWAY'
'14' = 'PRINCIPAL ARTERIAL (URBAN-OTHER)'
'16' = 'MINOR ARTERIAL (URBAN)'
'17' = 'COLLECTOR (URBAN)'
'19' = 'LOCAL (URBAN)'
' ' = 'NOT CODED'

For the WSHSIS Roadlog dataset, the codes are different for 2002-2007 than they are for 2008-2011. For 2002-2007, the codes are as follows:
'01' = 'RURAL-INTERSTATE'
'02' = 'RURAL-PRINCIPAL-ARTERIAL'

'06' = 'RURAL-MINOR-ARTERIAL'
'07' = 'RURAL-COLLECTOR'
'09' = 'RURAL-UNCLASSIFIED'
'11' = 'URBAN-INTERSTATE'
'12' = 'URBAN-PRINCIPAL-ARTERIAL (FREEWAYS & EXPRESSWAYS)'
'14' = 'URBAN-OTHER-PRINCIPAL-ARTERIAL'
'16' = 'URBAN-MINOR-ARTERIAL'
'17' = 'URBAN-COLLECTOR'
'19' = 'URBAN-UNCLASSIFIED'

For the WSHSIS Roadlog datasets for 2008-2011, the functional class codes are as follows:
'41' = 'RURAL-INTERSTATE'
'42' = 'RURAL-PRINCIPAL-ARTERIAL (FREEWAYS & EXPRESSWAYS)'
'43' = 'RURAL-OTHER-PRINCIPAL-ARTERIAL'
'44' = 'RURAL-MINOR-ARTERIAL'
'45' = 'RURAL-MAJOR-COLLECTOR'
'46' = 'RURAL-MINOR-COLLECTOR'
'47' = 'RURAL-LOCAL-ACCESS'
'51' = 'URBAN-INTERSTATE'
'52' = 'URBAN-PRINCIPAL-ARTERIAL (FREEWAYS & EXPRESSWAYS)'
'53' = 'URBAN-OTHER-PRINCIPAL-ARTERIAL'
'54' = 'URBAN-MINOR-ARTERIAL'
'55' = 'URBAN-MAJOR-COLLECTOR'
'56' = 'URBAN-MINOR-COLLECTOR'
'57' = 'URBAN-LOCAL-ACCESS';
For both the OHHSIS and WSHSIS Roadlog datasets, the variable name is “FUNC_CLS”.
The following “NL” variables indicate the number of lanes for each record. In both the OHHSIS and WSHSIS Roadlog datasets, the variable used for this was called “no_lanes”. This variable represents the total number of lanes in both directions for both divided and undivided roadways. As an example, a divided highway that has two lanes in each direction would have a “1” indicator in the NL.4 column. These are “binary fields”, meaning a value of 1=yes and a value of 0=no.

NL.2 – 2 lanes

NL.4 – 4 lanes

NL.6 – 6 lanes

NL.8 – 8 lanes

STATE – The state the record is associated with.
All Ohio records will have “OH” in this field and all Washington State records will have “WA” in this field.

DOC_L – Degree of horizontal curvature to the left
For both Ohio and Washington State, this variable was created by combining the OHHSIS and WSHSIS Curve dataset fields “DEG_CURV” and “DIR_CURV”. For OHHSIS, if the homogenized roadway file has a “LT” in the “DIR_CURV” field, the value in the “DEG_CURV” field was placed in this variable. If the value for “DIR_CURV” was either “RT” or blank, a zero was entered. For WSHSIS, if the homogenized roadway file has an “L” in the “DIR_CURV” field, the value in the “DEG_CURV” field was placed in this variable. If the value for “DIR_CURV” was either “R” or blank, a zero was entered.

DOC_R – Degree of horizontal curvature to the right
For both Ohio and Washington State, this variable was created by combining the OHHSIS and WSHSIS Curve dataset fields “DEG_CURV” and “DIR_CURV”. For OHHSIS, if the homogenized roadway file has a “RT” in the “DIR_CURV” field, the value in the “DEG_CURV” field was placed in this variable. If the value for “DIR_CURV” was either “LT” or blank, a zero was entered. For WSHSIS, if the homogenized roadway file has a “R” in the “DIR_CURV” field, the value in the “DEG_CURV” field was placed in this variable. If the value for “DIR_CURV” was either “L” or blank, a zero was entered.

PG_U – Percent grade up
For both Ohio and Washington State, this variable was created by combining the OHHSIS and WSHSIS Grade dataset fields “PCT_GRAD” and “DIR_GRAD”. If the “DIR_GRAD” field contained a “+”, the value for “PCT_GRAD” was entered in this field. If the “DIR_GRAD” field contained a “-“ or a blank, a zero was entered.

PG_D – Percent grade down
For both Ohio and Washington State, this variable was created by combining the OHHSIS and WSHSIS Grade dataset fields “PCT_GRAD” and “DIR_GRAD”. If the “DIR_GRAD” field contained a “-”, the value for “PCT_GRAD” was entered in this field. If the “DIR_GRAD” field contained a “+“ or a blank, a zero was entered.

PT – Percent Trucks
The OHHSIS Roadlog dataset does not contain a field for percent trucks. Instead, a separate field called “AADT_BC”, which is the AADT for types B and C trucks is present. For Ohio, PT was calculated by dividing this “AADT_BC” variable by the “AADT” variable and multiplying by 100. The WSHSIS Roadlog dataset contains a field called “TRKPCTS” which was used directly as PT.

BarL_PRE – The length in hundredths of miles of longitudinal barrier present on the primary right edge of the roadway segment. This value represents the total length of barrier, meaning it can be multiple discontinuous sections of barrier or a single length of continuous barrier. This information came from the longitudinal databases provided by the Ohio and Washington State Departments of Transportation (DOTs), OHLBI and WSRFIP.

BarL_ORE – The length in hundredths of miles of longitudinal barrier present on the opposing right edge of the roadway segment. This value represents the total length of barrier, meaning it can be multiple discontinuous sections of barrier or a single length of continuous barrier. This information came from the longitudinal databases provided by the Ohio and Washington State Departments of Transportation (DOTs), OHLBI and WSRFIP.

PR_ROR – Number of ROR crashes where the vehicle exited the primary right side of the roadway (includes all crash severities).

PL_ROR – Number of ROR crashes where the vehicle exited the primary left side of the roadway (includes all crash severities).

OR_ROR – Number of ROR crashes where the vehicle exited the opposing right side of the roadway (includes all crash severities).

OL_ROR – Number of ROR crashes where the vehicle exited the opposing left side of the roadway (includes all crash severities).

Unk_ROR – Number of ROR crashes where it is unknown which side of the road the vehicle exited (includes all crash severities).

The following section describes longitudinal barrier crashes. Longitudinal barrier crashes are a subset of ROR crashes. A ROR crash was determined to be a longitudinal barrier crash if a longitudinal barrier was the first fixed object struck after a vehicle left the roadway. The OHHSIS sequence of events ("EVENT1", "EVENT2", "EVENT3", and "EVENT4") variables were used in Ohio and the WSHSIS fixed object struck variables ("OBJECT1" and "OBJECT2") were used in Washington State to determine if a ROR crash was a longitudinal barrier crash.

Ohio

A ROR crash was considered an LB crash if any one of these codes were present in the "EVENT1" field of the OHHSIS Vehicle dataset:
25 = 'IMPACT ATTENUATOR/CRASH CUSHION'
26 = 'BRIDGE OVERHEAD STRUCTURE'
27 = 'BRIDGE PIER OR ABUTMENT'
28 = 'BRIDGE PARAPET'
29 = 'BRIDGE RAIL'
30 = 'GUARDRAIL FACE'
31 = 'GUARDRAIL END'
32 = 'MEDIAN BARRIER'

If one of these events were in an event just preceding an event containing any of the above codes, it was also considered an LB crash:
08 = 'RAN OFF ROAD RIGHT'
09 = 'RAN OFF ROAD LEFT'
10 = 'CROSS MEDIAN/CENTERLINE' [for divided only]

Washington State

As opposed to the OHHSIS Vehicle dataset using event codes, the WSHSIS Accident database uses “OBJECT1” and “OBJECT2” fields. If any of the following codes was present in the “OBJECT1” field, it was considered to be an LB crash:

'01' = 'BEAM GUARDRAIL, LEADING END'
'02' = 'BEAM GUARDRAIL, FACE OF (DID NOT GO THRU, OVER, OR UNDER)'
'03' = 'BEAM GUARDRAIL, FACE OF (DID GO THRU, OVER, OR UNDER'
'07' = 'CONCRETE MEDIAN BARRIER WALL'
'08' = 'RETAINING WALL (CONCRETE, ROCK, BRICK, ETC.)'
'O9' = 'CURB OR RAISED TRAFFIC ISLAND, RAISED MEDIAN CURB'
'30' = 'CRASH CUSHION OR DRUMS'
'31' = 'GUARDRAIL, LEADING END'
'32' = 'GUARDRAIL, FACE OF (DID NOT GO THRU, OVER, OR UNDER)'
'33' = 'GUARDRAIL, FACE OF (DID GO THRU, OVER, OR UNDER)'
'34' = 'CONCRETE BARRIER, LEADING END'
'35' = 'CONCRETE BARRIER, FACE OF (DID NOT GO THRU, OVER, OR UNDER)'
'36' = 'CONCRETE BARRIER, FACE OF (DID GO THRU, OVER, OR UNDER)'
'37' = 'BRIDGE RAIL, LEADING END'
'38' = 'BRIDGE RAIL, FACE OF (DID NOT GO THRU, OVER, OR UNDER)'
'39' = 'BRIDGE RAIL, FACE OF (DID GO THRU, OVER, OR UNDER)'

If one of the above fields was present in the “OBJECT2” field, AND one of the following codes was in the “OBJECT1” field, it was also considered an LB crash:

'23' = 'TOLL BOOTH'
'24' = 'TOLL BOOTH ISLAND'
'25' = 'CLOSED TOLL GATE'
'26' = 'RAILWAY CROSSING'
'27' = 'REVERSIBLE LANE CONTROL GATE'
'49' = 'MANHOLE COVER'
'50' = 'TEMPORARY TRAFFIC SIGN OR BARRICADE'
'51' = 'ROAD OR CONSTRUCTION MACHINERY'
'52' = 'CONSTRUCTION MATERIALS'
'53' = 'MISCELLANEOUS OBJECT OR DEBRIS ON ROAD SURFACE'
'54' = 'FALLING ROCK OR TREE FELL ON VEHICLE'
'55' = 'FALLEN ROCK OR TREE'
'60' = 'MUD OR LAND SLIDE'
'61' = 'SNOW BANK'
'62' = 'SNOW SLIDE'
'67' = 'DOMESTIC ANIMAL (RIDDEN)'
'68' = 'ANIMAL DRAWN VEHICLE'
'75' = 'STATE ROAD OR CONSTRUCTION MACHINERY'
'76' = 'COUNTY ROAD OR CONSTRUCTION MACHINERY'
'77' = 'CITY ROAD OR CONSTRUCTION MACHINERY'
'78' = 'OTHER ROAD OR CONSTRUCTION MACHINERY'

PR_LB – Number of ROR crashes where a vehicle struck a longitudinal barrier on the primary right side of the roadway.

PL_LB – Number of ROR crashes where a vehicle struck a longitudinal barrier on the primary left side of the roadway.

OR_LB – Number of ROR crashes where a vehicle struck a longitudinal barrier on the opposing right side of the roadway.

OL_LB – Number of ROR crashes where a vehicle struck a longitudinal barrier on the opposing left side of the roadway.

Unk_LB – Number of ROR crashes where a vehicle struck a longitudinal barrier and it is unknown which side of the roadway the crash occurred.

lanewid – In Ohio, lane width was calculated by taking the OHHSIS Roadlog variable "surf_wid" and dividing it by the OHHSIS Roadlog variable "no_lanes". The WSHSIS Roadlog dataset included a "lanewid" variable that was used directly for lane width.

SHLDR_PRE – In the Ohio OHHSIS Roadlog dataset, the primary right edge (PRE) shoulder width comes from the OHHSIS Roadlog variable "SHWD_RIGHT_OUTSIDE", and the primary left edge (PLE) comes from the OHHSIS Roadlog variable "SHWD_RIGHT_INSIDE" for both divided and undivided roadways. In the Washington State WSHSIS Roadlog dataset, the PRE comes from the WSHSIS Roadlog variable "RSHLDWID" for both divided and undivided roadways. However, PLE comes from the WSHSIS Roadlog variable "LSHLDWID" on divided highways only. On undivided highways, the "LSHLDWID" variable in the Washington WSHSIS Roadlog dataset refers to the outside shoulder in the direction of decreasing inventory.

SHLDR_PLE – The shoulder width of the primary left edge of the roadway, taken from the OHHSIS and WSHSIS Roadlog datasets (see SHLDR_PRE explanation above).

spd_limt – The posted speed limit, taken from the OHHSIS and WSHSIS Roadlog datasets. In both datasets, the variable name is "SPD_LIMT".

no_lanes – Number of lanes in both directions of travel, taken from the OHHSIS and WSHSIS Roadlog datasets; the variable used for this was called "no_lanes".

The following fields are currently only in the rural ROR databases:

KABC.PR_LB– Number of ROR crashes where a vehicle struck a longitudinal barrier on the primary right side of the roadway with a OHHSIS "SEVERITY" code = 1, 2, 3, or 4; or a WSHSIS "SEVERITY"code = 2, 3, 4, 5, 6, or 7.

KABC.PL_LB – Number of ROR crashes where a vehicle struck a longitudinal barrier on the primary left side of the roadway with a OHHSIS "SEVERITY" code = 1, 2, 3, or 4; or a WSHSIS "SEVERITY"code = 2, 3, 4, 5, 6, or 7.

KABC.OR_LB – Number of ROR crashes where a vehicle struck a longitudinal barrier on the opposing right side of the roadway with a OHHSIS "SEVERITY" code = 1, 2, 3, or 4; or a WSHSIS "SEVERITY"code = 2, 3, 4, 5, 6, or 7.

KABC.OL_LB – Number of ROR crashes where a vehicle struck a longitudinal barrier on the opposing left side of the roadway with a OHHSIS "SEVERITY" code = 1, 2, 3, or 4; or a WSHSIS "SEVERITY"code = 2, 3, 4, 5, 6, or 7.

KABC.Unk_LB – Number of ROR crashes where a vehicle struck a longitudinal barrier and it is unknown which side of the roadway the crash occurred with a OHHSIS "SEVERITY" code = 1, 2, 3, or 4; or a WSHSIS "SEVERITY"code = 2, 3, 4, 5, 6, or 7.

KABC.PR_ROR – Number of ROR crashes where the vehicle exited the primary right side of the roadway with a OHHSIS "SEVERITY" code = 1, 2, 3, or 4; or a WSHSIS "SEVERITY"code = 2, 3, 4, 5, 6, or 7.

KABC.PL_ROR – Number of ROR crashes where the vehicle exited the primary left side of the roadway with a OHHSIS "SEVERITY" code = 1, 2, 3, or 4; or a WSHSIS "SEVERITY"code = 2, 3, 4, 5, 6, or 7.

KABC.OR_ROR – Number of ROR crashes where the vehicle exited the opposing right side of the roadway with a OHHSIS "SEVERITY" code = 1, 2, 3, or 4; or a WSHSIS "SEVERITY"code = 2, 3, 4, 5, 6, or 7.

KABC.OL_ROR – Number of ROR crashes where the vehicle exited the opposing left side of the roadway with a OHHSIS "SEVERITY" code = 1, 2, 3, or 4; or a WSHSIS "SEVERITY"code = 2, 3, 4, 5, 6, or 7.

KABC.Unk_ROR – Number of ROR crashes where it is unknown which side of the road the vehicle exited with a OHHSIS "SEVERITY" code = 1, 2, 3, or 4; or a WSHSIS "SEVERITY"code = 2, 3, 4, 5, 6, or 7.

KAB.PR_LB– Number of ROR crashes where a vehicle struck a longitudinal barrier on the primary right side of the roadway with a OHHSIS "SEVERITY" code = 1, 2, or 3; or a WSHSIS "SEVERITY"code = 2, 3, 4, 5, or 6.

KAB.PL_LB – Number of ROR crashes where a vehicle struck a longitudinal barrier on the primary left side of the roadway with a OHHSIS "SEVERITY" code = 1, 2, or 3; or a WSHSIS "SEVERITY"code = 2, 3, 4, 5, or 6.

KAB.OR_LB – Number of ROR crashes where a vehicle struck a longitudinal barrier on the opposing right side of the roadway with a OHHSIS "SEVERITY" code = 1, 2, or 3; or a WSHSIS "SEVERITY"code = 2, 3, 4, 5, or 6.

KAB.OL_LB – Number of ROR crashes where a vehicle struck a longitudinal barrier on the opposing left side of the roadway with a OHHSIS “SEVERITY” code = 1, 2, or 3; or a WSHSIS “SEVERITY”code = 2, 3, 4, 5, or 6.

KAB.Unk_LB – Number of ROR crashes where a vehicle struck a longitudinal barrier and it is unknown which side of the roadway the crash occurred with a OHHSIS “SEVERITY” code = 1, 2, or 3; or a WSHSIS “SEVERITY”code = 2, 3, 4, 5, or 6.

KAB.PR_ROR – Number of ROR crashes where the vehicle exited the primary right side of the roadway with a OHHSIS “SEVERITY” code = 1, 2, or 3; or a WSHSIS “SEVERITY”code = 2, 3, 4, 5, or 6.

KAB.PL_ROR – Number of ROR crashes where the vehicle exited the primary left side of the roadway with a OHHSIS “SEVERITY” code = 1, 2, or 3; or a WSHSIS “SEVERITY”code = 2, 3, 4, 5, or 6.

KAB.OR_ROR – Number of ROR crashes where the vehicle exited the opposing right side of the roadway with a OHHSIS “SEVERITY” code = 1, 2, or 3; or a WSHSIS “SEVERITY”code = 2, 3, 4, 5, or 6.

KAB.OL_ROR – Number of ROR crashes where the vehicle exited the opposing left side of the roadway with a OHHSIS “SEVERITY” code = 1, 2, or 3; or a WSHSIS “SEVERITY”code = 2, 3, 4, 5, or 6.

KAB.Unk_ROR – Number of ROR crashes where it is unknown which side of the road the vehicle exited with a OHHSIS “SEVERITY” code = 1, 2, or 3; or a WSHSIS “SEVERITY”code = 2, 3, 4, 5, or 6.

KA.PR_LB– Number of ROR crashes where a vehicle struck a longitudinal barrier on the primary right side of the roadway with a OHHSIS “SEVERITY” code = 1, or 2; or a WSHSIS “SEVERITY”code = 2, 3, 4, or 5.

KA.PL_LB – Number of ROR crashes where a vehicle struck a longitudinal barrier on the primary left side of the roadway with a OHHSIS “SEVERITY” code = 1, or 2; or a WSHSIS “SEVERITY”code = 2, 3, 4, or 5.

KA.OR_LB – Number of ROR crashes where a vehicle struck a longitudinal barrier on the opposing right side of the roadway with a OHHSIS “SEVERITY” code = 1, or 2; or a WSHSIS “SEVERITY”code = 2, 3, 4, or 5.

KA.OL_LB – Number of ROR crashes where a vehicle struck a longitudinal barrier on the opposing left side of the roadway with a OHHSIS “SEVERITY” code = 1, or 2; or a WSHSIS “SEVERITY”code = 2, 3, 4, or 5.

KA.Unk_LB – Number of ROR crashes where a vehicle struck a longitudinal barrier and it is unknown which side of the roadway the crash occurred with a OHHSIS “SEVERITY” code = 1, or 2; or a WSHSIS “SEVERITY”code = 2, 3, 4, or 5.

KA.PR_ROR – Number of ROR crashes where the vehicle exited the primary right side of the roadway with a OHHSIS “SEVERITY” code = 1, or 2; or a WSHSIS “SEVERITY”code = 2, 3, 4, or 5.

KA.PL_ROR – Number of ROR crashes where the vehicle exited the primary left side of the roadway with a OHHSIS “SEVERITY” code = 1, or 2; or a WSHSIS “SEVERITY”code = 2, 3, 4, or 5.

KA.OR_ROR – Number of ROR crashes where the vehicle exited the opposing right side of the roadway with a OHHSIS “SEVERITY” code = 1, or 2; or a WSHSIS “SEVERITY”code = 2, 3, 4, or 5.

KA.OL_ROR – Number of ROR crashes where the vehicle exited the opposing left side of the roadway with a OHHSIS “SEVERITY” code = 1, or 2; or a WSHSIS “SEVERITY”code = 2, 3, 4, or 5.

KA.Unk_ROR – Number of ROR crashes where it is unknown which side of the road the vehicle exited with a OHHSIS “SEVERITY” code = 1, or 2; or a WSHSIS “SEVERITY”code = 2, 3, 4, or 5.

K.PR_LB– Number of ROR crashes where a vehicle struck a longitudinal barrier on the primary right side of the roadway with a OHHSIS “SEVERITY” code = 1; or a WSHSIS “SEVERITY”code = 2, 3, or 4.

K.PL_LB – Number of ROR crashes where a vehicle struck a longitudinal barrier on the primary left side of the roadway with a OHHSIS “SEVERITY” code = 1; or a WSHSIS “SEVERITY”code = 2, 3, or 4.

K.OR_LB – Number of ROR crashes where a vehicle struck a longitudinal barrier on the opposing right side of the roadway with a OHHSIS “SEVERITY” code = 1; or a WSHSIS “SEVERITY”code = 2, 3, or 4.

K.OL_LB – Number of ROR crashes where a vehicle struck a longitudinal barrier on the opposing left side of the roadway with a OHHSIS “SEVERITY” code = 1; or a WSHSIS “SEVERITY”code = 2, 3, or 4.

K.Unk_LB – Number of ROR crashes where a vehicle struck a longitudinal barrier and it is unknown which side of the roadway the crash occurred with a OHHSIS “SEVERITY” code = 1; or a WSHSIS “SEVERITY”code = 2, 3, or 4.

K.PR_ROR – Number of ROR crashes where the vehicle exited the primary right side of the roadway with a OHHSIS “SEVERITY” code = 1; or a WSHSIS “SEVERITY”code = 2, 3, or 4.

K.PL_ROR – Number of ROR crashes where the vehicle exited the primary left side of the roadway with a OHHSIS “SEVERITY” code = 1; or a WSHSIS “SEVERITY”code = 2, 3, or 4.

K.OR_ROR – Number of ROR crashes where the vehicle exited the opposing right side of the roadway with a OHHSIS “SEVERITY” code = 1; or a WSHSIS “SEVERITY”code = 2, 3, or 4.

K.OL_ROR – Number of ROR crashes where the vehicle exited the opposing left side of the roadway with a OHHSIS “SEVERITY” code = 1; or a WSHSIS “SEVERITY”code = 2, 3, or 4.

K.Unk_ROR – Number of ROR crashes where it is unknown which side of the road the vehicle exited with a OHHSIS “SEVERITY” code = 1; or a WSHSIS “SEVERITY”code = 2, 3, or 4.

APPENDIX C REFERENCES

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APPENDIX D. RSAPV3 SIMULATIONS

This appendix documents the RSAPv3 modeling to simulate the data necessary to develop CMF_J and CMF_K, the components of $CMF_{ROADSIDE}$ which account for modifications to roadside features.

SIMULATED ENCROACHMENT TRAJECTORY DATA

RSAPv3 release 16909BP [Ray16c] was used to simulate vehicle encroachment trajectories. Objects were simulated offset from the right edge of a 0.1 mile segment with a 12 foot wide right travel lane. Primary right encroachments initiating and crashes occurring at the right edge of travel were recorded. This approach allows for the resulting CMFs to be applicable to both divided and undivided roadways.

Trajectories were permitted to encroach toward the roadside objects from a point 300 feet upstream of the objects until the end of the 0.1 mile segment. This ensures that each simulated trajectory has an opportunity to intersect with each object. An arbitrary traffic volume of 10,000 vpd was chosen to allow for the simulation to take place, however, this value does not influence the outcome. A value of zero percent trucks was used to ensure that the more robust passenger vehicle trajectories were used in the simulations rather than the assumed heavy vehicle trajectories. The default analysis settings were used.

CMF_K

The simulated data used to develop crash modification factors associated with roadside feature *k* that modify the ROR crashes for unshielded roadsides is documented here. Fixed objects and miscellaneous obstacles were simulated at discrete offsets. The offsets studied (i.e., 4, 6, 8, 10, 15, 20, 25, 30, 35, 40, 45, 50 feet) were considered across a range of the narrow fixed objects and miscellaneous obstacle densities.

Narrow fixed object (NFO) density was varied on the segment (i.e., 1, 2, 3, 5, 7, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 200, 250, 300, 400, 500 average count per mile). The simulations were conducted for each density at each offset. For example, simulations were conducted for a density of 10 NFO per mile at offsets of 4, 6, 8, 10, 15, 20, 25, 30, 35, 40, 45, 50 feet. Therefore 228 simulations were conducted for NFOs (i.e., 19*12= 228). The offset was measured from the edge of travel to the close edge of a generic 14-inch narrow fixed object. The encroachment trajectory study "population" is tabulated for each offset and density of NFOs in Table 108.

The length of miscellaneous obstacles was varied on the segment (i.e., 50, 100, 200, 300, 400, 450, 500, 600, 700, 800, 1000, 2000, 3000, 4000, 5000 feet per mile) for each offset. A total of 180 simulations (i.e., 15*12=180) were conducted to study the effect of miscellaneous obstacles on crash frequency. The encroachment trajectory study "population" is tabulated for each offset and length of miscellaneous objects in Table 109.

Table 7. Crash Outcome Per Edge for NFOs Only.

Density (#/mile)	Outcome	Offset (feet)											
		4	6	8	10	15	20	25	30	35	40	45	50
1*	Crash	1444	1453	1384	1277	1040	879	869	693	637	524	449	411
	No Crash	253232	253223	253292	253399	253636	253797	253807	253983	254039	254152	254227	254265
2*	Crash	2888	2906	2768	2554	2080	1758	1738	1386	1274	1048	898	822
	No Crash	251788	251770	251908	252122	252596	252918	252938	253290	253402	253628	253778	253854
5*	Crash	7279	7284	6882	6419	5200	4382	4359	3497	3196	2624	2240	2074
	No Crash	247397	247392	247794	248257	249476	250294	250317	251179	251480	252052	252436	252602
7*	Crash	10142	10192	9640	8995	7281	6138	6111	4898	4476	3679	3145	2899
	No Crash	244534	244484	245036	245681	247395	248538	248565	249778	250200	250997	251531	251777
10	Crash	1444	1453	1384	1277	1040	879	869	693	637	524	449	411
	No Crash	36404	36395	36464	36571	36808	36969	36979	37155	37211	37324	37399	37437
20	Crash	2873	2903	2764	2555	2082	1760	1742	1393	1278	1037	903	825
	No Crash	34975	34945	35084	35293	35766	36088	36106	36455	36570	36811	36945	37023
30	Crash	4267	4245	4056	3822	3122	2630	2603	2098	1915	1587	1340	1241
	No Crash	33581	33603	33792	34026	34726	35218	35245	35750	35933	36261	36508	36607
40	Crash	5530	5582	5282	4960	4119	3511	3468	2798	2556	2100	1794	1655
	No Crash	32318	32266	32566	32888	33729	34337	34380	35050	35292	35748	36054	36193
50	Crash	6733	6800	6511	6062	5092	4387	4282	3499	3202	2656	2239	2072
	No Crash	31115	31048	31337	31786	32756	33461	33566	34349	34646	35192	35609	35776
60	Crash	7840	7921	7613	7062	6016	5229	5073	4190	3833	3148	2689	2485
	No Crash	30008	29927	30235	30786	31832	32619	32775	33658	34015	34700	35159	35363
70	Crash	8799	8968	8670	8005	6908	6087	5825	4845	4453	3668	3143	2877
	No Crash	29049	28880	29178	29843	30940	31761	32023	33003	33395	34180	34705	34971
80	Crash	9912	10050	9608	9041	7795	6892	6587	5560	5080	4211	3580	3315
	No Crash	27936	27798	28240	28807	30053	30956	31261	32288	32768	33637	34268	34533
90	Crash	10807	11001	10535	9923	8642	7694	7299	6185	5676	4718	4040	3724
	No Crash	27041	26847	27313	27925	29206	30154	30549	31663	32172	33130	33808	34124

*Densities of 1, 2, 5 and 7 were calculated on a 1 mile segment rather than a 0.1 mile segment.

Table 108. Crash Outcome Per Edge for NFOs Only. CONT'D

Density (#/mile)	Outcome	Offset (feet)											
		4	6	8	10	15	20	25	30	35	40	45	50
100	Crash	11776	11971	11419	10820	9471	8457	8001	6798	6267	5237	4467	4141
	No Crash	26072	25877	26429	27028	28377	29391	29847	31050	31581	32611	33381	33707
200	Crash	18377	18824	18280	17664	15837	14231	13490	12037	11197	9521	8210	7648
	No Crash	19471	19024	19568	20184	22011	23617	24358	25811	26651	28327	29638	30200
250	Crash	20520	20945	20510	19872	17916	16225	15417	13951	13013	11142	9625	8979
	No Crash	17328	16903	17338	17976	19932	21623	22431	23897	24835	26706	28223	28869
300	Crash	21524	21877	21490	20999	19017	17347	16539	15109	14131	12105	10455	9850
	No Crash	16324	15971	16358	16849	18831	20501	21309	22739	23717	25743	27393	27998
400	Crash	23389	23575	23218	22787	20853	19235	18403	16787	15940	13700	11856	11201
	No Crash	14459	14273	14630	15061	16995	18613	19445	21061	21908	24148	25992	26647
500	Crash	23222	23140	23031	22616	20787	19254	18362	16569	15974	13852	12062	11338
	No Crash	14626	14708	14817	15232	17061	18594	19486	21279	21874	23996	25786	26510

Table 8. Crash Outcome Per Edge for Miscellaneous Obstacles Only.

Misc. (ft/ mile)	Outcome	Offset (feet)											
		4	6	8	10	15	20	25	30	35	40	45	50
5	Crash	78	96	86	86	80	84	66	84	58	48	54	52
	No Crash	37770	37752	37762	37762	37768	37764	37782	37764	37790	37800	37794	37796
10	Crash	122	138	138	126	122	118	102	102	92	76	66	74
	No Crash	37726	37710	37710	37722	37726	37730	37746	37746	37756	37772	37782	37774
20	Crash	150	182	174	170	162	158	146	134	124	110	92	96
	No Crash	37698	37666	37674	37678	37686	37690	37702	37714	37724	37738	37756	37752
30	Crash	224	222	220	218	202	188	180	162	152	130	120	112
	No Crash	37624	37626	37628	37630	37646	37660	37668	37686	37696	37718	37728	37736
40	Crash	266	266	274	256	244	226	210	200	180	158	148	140
	No Crash	37582	37582	37574	37592	37604	37622	37638	37648	37668	37690	37700	37708
50	Crash	302	318	306	304	282	272	246	246	210	178	174	164
	No Crash	37546	37530	37542	37544	37566	37576	37602	37602	37638	37670	37674	37684
100	Crash	526	540	526	522	484	460	426	408	362	308	294	276
	No Crash	37322	37308	37322	37326	37364	37388	37422	37440	37486	37540	37554	37572
200	Crash	974	984	966	958	888	836	786	732	666	568	534	500
	No Crash	36874	36864	36882	36890	36960	37012	37062	37116	37182	37280	37314	37348
300	Crash	1422	1428	1406	1394	1292	1212	1146	1056	970	828	774	724
	No Crash	36426	36420	36442	36454	36556	36636	36702	36792	36878	37020	37074	37124
400	Crash	1870	1872	1846	1830	1696	1588	1506	1380	1274	1088	1014	948
	No Crash	35978	35976	36002	36018	36152	36260	36342	36468	36574	36760	36834	36900
450	Crash	2094	2094	2066	2048	1898	1776	1686	1542	1426	1218	1134	1060
	No Crash	35754	35754	35782	35800	35950	36072	36162	36306	36422	36630	36714	36788
500	Crash	2318	2316	2286	2266	2100	1964	1866	1704	1578	1348	1254	1172
	No Crash	35530	35532	35562	35582	35748	35884	35982	36144	36270	36500	36594	36676
600	Crash	2766	2760	2726	2702	2504	2340	2226	2028	1882	1608	1494	1396
	No Crash	35082	35088	35122	35146	35344	35508	35622	35820	35966	36240	36354	36452
700	Crash	3214	3204	3166	3138	2908	2716	2586	2352	2186	1868	1734	1620
	No Crash	34634	34644	34682	34710	34940	35132	35262	35496	35662	35980	36114	36228
800	Crash	3662	3648	3606	3574	3312	3092	2946	2676	2490	2128	1974	1844
	No Crash	34186	34200	34242	34274	34536	34756	34902	35172	35358	35720	35874	36004

Table 109. Crash Outcome Per Edge for Miscellaneous Obstacles Only. CONT'D

Misc. (ft/ mile)	Outcome	Offset (feet)											
		4	6	8	10	15	20	25	30	35	40	45	50
1000	Crash	4558	4536	4486	4446	4120	3844	3666	3324	3098	2648	2454	2292
	No Crash	33290	33312	33362	33402	33728	34004	34182	34524	34750	35200	35394	35556
2000	Crash	9038	8976	8886	8806	8160	7604	7266	6564	6138	5248	4854	4532
	No Crash	28810	28872	28962	29042	29688	30244	30582	31284	31710	32600	32994	33316
3000	Crash	13518	13416	13286	13166	12200	11364	10866	9804	9178	7848	7254	6772
	No Crash	24330	24432	24562	24682	25648	26484	26982	28044	28670	30000	30594	31076
4000	Crash	17998	17856	17686	17526	16240	15124	14466	13044	12218	10448	9654	9012
	No Crash	19850	19992	20162	20322	21608	22724	23382	24804	25630	27400	28194	28836
5000	Crash	22478	22296	22086	21886	20280	18884	18066	16284	15258	13048	12054	11252
	No Crash	15370	15552	15762	15962	17568	18964	19782	21564	22590	24800	25794	26596

RSAPv3 simulations were conducted in the same manner for the NFO and miscellaneous obstacle base conditions as outlined in Table 119.

Table 9. Base Conditions.

Area Type	Highway Type	NFO Density (#/mile)	NFO Offset (feet)	Misc (feet/ mile)	Mics Offset (feet)
Rural	Undivided	33	38	450	45
	Divided	33	30	600	45
Urban	Undivided	44	17	500	15
	Divided	28	7	300	7

CMF$_J$

The simulated data used to develop crash modification factors associated with roadside feature *j* that modify the ROR crashes for shielded roadsides is documented here. The offset of a generic roadside barrier was studied (i.e., 4, 6, 8, 10, 15, 20, 25, 30, 35, 40, 45, 50 feet). RSAPv3 simulations were conducted in the same manner for the base conditions as outlined in Table 111.

Table 10. Base Conditions.

Area Type	Highway Type	LB (feet/mile)	LB Offset (feet)
Rural	Undivided	558	8.34
	Divided	1,645	10.23
Urban	Undivided	760	3.89
	Divided	630	12.53

The encroachment trajectory study "population" used to develop crash modification factors accounting for offset associated with roadside feature *j* is tabulated in Table 112. Table 112 also includes the barrier offsets at base conditions. Irrespective of offset, there were zero rollovers observed in these data simulations.

Table 11. Crash Outcome Per Edge for Offset of Barrier CMF$_j$.

Barrier Offset (feet)	Crash	No Crash
3.89	29892	636
4	29892	636
6	29680	848
8	28832	1696
8.34	28832	1696
10	28620	1908
10.23	28408	2120
12.53	27348	3180

15	26924	3604
20	25440	5088
25	24168	6360
30	21624	8904
35	20140	10388
40	16960	13568
45	15688	14840
50	14628	15900

APPENDIX D REFERENCES

Ray16c M. H. Ray, C. A. Plaxico and C.E. Carrigan, RSAPv3, release 160909BP: Originally documented in "Roadside Safety Analysis Program (RSAP) Engineer's Manual," Roadsafe LLC, rsap.roadsafellc.com, October 25, 2012.

APPENDIX E. CHARACTERIZATION OF THE ROADSIDES EDGES

This appendix documents that collection and analysis of roadside features to characterize the right edge of base segment for both divided and undivided highways in Ohio and Washington State. The mean conditions for each state by highway and area type are calculated and values documented were used in the development of CMF_J and CMF_K.

ROADSIDE CHARACTERIZATION

Defining Roadside Features

The roadside features were classified into three categories: Longitudinal Barriers, Narrow Fixed Objects (NFOs), and “Other” obstacles.

Longitudinal barriers include all traffic barriers that are placed on the roadside to redirect encroaching vehicles and provide shielding from NFOs and other obstacles. These barriers include rigid (e.g., concrete safety and F-shape barriers), semi-rigid (e.g., w-beam and thrie-beam guardrails), and flexible (e.g., cable) barriers.

NFOs are considered “point” obstacles that occur on the roadside. These obstacles have a single milepost value to describe their location in the datasets. A fixed object may vary in diameter or width, but was considered an NFO if the dimension along the roadside was 1.5 feet or less.

“Other” obstacles were considered to have a measurable length along the roadside with beginning and ending milepost values. Only obstacles on the Primary Right Edge (PRE) and Opposing Right Edge (ORE) were considered. Recall the PRE and ORE encompasses both edges of an undivided highway, but only the outside edges of a divided highway. Unfortunately, the data available for medians was inconsistent. The lack of median feature data is not believed to present a problem because the model already deciphers between the frequency of crashes on divided and undivided highways and the frequency of left and right edge crashes. This data were used for adjust the crash severity, not frequency part of the model which should not be impacted by placement of the feature on the roadside or median.

The following section describes the steps taken for each state to collect the roadside feature data and merge the data with the HSIS database. A discussion on the characterization of the roadside characteristics for the base segment edges follows.

Identifying Segments

The State of Ohio maintains a longitudinal barrier database but does not maintain a database of all roadside features. Data on roadside features was therefore collected for base segments to conduct this analysis. To minimize collection efforts and ensure accuracy across the study period, the base segments which did not change during the study period were considered in this effort. This resulted in 132 divided and 159 undivided rural base segments and 282 divided and 92 undivided urban base segments from 2002 to 2010. Each of the 92 undivided urban base segments were examined. A subset of the 282 divided urban base segments. One-third of these base segments were randomly identified as a representative sample of the 282 consistent OH urban divided base segments.

Washington maintains the Roadside Features Inventory Program (RFIP) which is a dataset of roadside features cataloged by route, milepost, and year. The RFIP data was merged with the base segment edges used in the development of the SPF resulting in 26 divided and 5,840 undivided rural roadway segments. These base segments were not consistent between 2002 and 2007. Unfortunately, it is unclear whether the roadside features varied from year to year or data collection practices varied. For example, a roadway segment which did not have a sign for three years then had a sign could indicate that the sign was a new installation or it could indicate that the sign was not flagged during previous data collection efforts in that area.

For the urban Washington analysis, four more years of segment data were made available. Base segments were identified for the years 2002-2011, which resulted in 2,946 divided and 756 undivided urban roadway base segments.

Ohio

Longitudinal Barriers

The Ohio Department of Transportation (ODOT) longitudinal barrier database is the result of the collection of data for internal purposes, which characterized barriers into three groups: Rigid, Semi-Rigid, and Flexible barriers. The specific barriers listed were “Guardrail”, “Jersey Slope: Short”, “Jersey Slope: Tall”, “Nucor”, “Single Slope”, and “Other”.

When characterizing the base segment roadside characteristics, the assumptions made in the development of $CMF_{ROADSIDE}$ must be kept in mind. When developing $CMF_{ROADSIDE}$, the amount of longitudinal barrier was considered, not the type. Therefore, when characterizing the roadside it is important to know the amount of longitudinal barriers. As such, the database was simplified to a single spreadsheet consisting of longitudinal barrier lengths and locations. This spreadsheet was then associated with the HSIS data to determine the portion of base segment edges which are shielded.

Narrow Fixed Objects and Other Obstacles

The Ohio Department of Transportation (ODOT) has an online photolog database of a portion of their State highways. [OHIO01] This online photolog database was accessed to supplement the longitudinal barrier data and record NFOs and “Other” objects within 50 feet of the travel way. The milepost locations and offset distances for NFO and Other objects that were not shielded by a longitudinal barrier were recorded for each edge of the study segments discussed above. Any object located behind another object that is closer to the road was not recorded. These objects are considered protected by the object that is closer to the road.

Offset values were estimated from the photologs. The distances were estimated from the edge of the travel way to the face of the object. Examples of NFOs recorded for Ohio segments include:

- Small Sign,
- Mailbox post,
- Single tree,
- Large shrub,
- Utility pole,
- Underground utility marker,
- Fire hydrant,
- Posts for large sign (see example in Figure 41), and
- Warning light assemblies and gates for RR crossing.

An example of “Posts for large sign” can be seen in Figure 41. In this scenario, both of the sign posts would be recorded, as well as the shortened utility pole just to the left side of it. The large tree just off to the right side of the picture would be recorded as well.

Figure 2. Example of "Posts for Large Sign" NFO in Ohio. [OHIO01]

Examples of "Other" objects recorded for Ohio segments include:

- Fence of any type,
- Building,
- Tree line,
- Rock outcropping,
- Water body,
- Boulder,
- Large sign at ground level (see example in Figure 42),
- Cabinet,
- Statue, and
- Silo.

An example of an "Other" object is shown in Figure 42. This large sign at ground level has length, which was measured along the road. Had this particular example been raised up on posts, the posts would have been recorded as a NFO instead of an "Other" object.

Figure 3. Example of an "Other" Object in Ohio. [OHIO01]

Washington State

The Roadside Features Inventory Program (RFIP) database is a database of roadside features (including obstacles and barriers) collected from 2006-2011 using GPS technology. The RFIP database was created and populated using State Route Milepost (SRMP) values, instead of the Accumulated Route Milepost (ARM) values the HSIS database uses. HSIS base segments ARM values were converted to SRMP values to facilitate merging of the two databases.

Washington State publishes highway logs [WSDOT1] annually. These highway logs include information on the ARM and SRMP. These logs were used to generate equivalencies between the ARM And SRMP values and allowed the HSIS data and RFIP data to be merged. The RFIP features of interest were then added to the base segment edges using the State Route numbers and the SRMP. Unfortunately, the RFIP database did not include offset values for any of the obstacles, so obstacle offset values are limited to the data collected for Ohio.

Longitudinal Barriers

The following features were considered to be longitudinal barriers:

- Bridge Rail,
- Cable Barrier,
- Concrete Barrier,
- Guardrail,
- Impact Attenuator, and
- Special Use Barrier.

The RFIP data is stored in separate files. The files were merged into a single file and the duplicate and overlapping milepost values were removed. This was necessary because each feature was captured using GPS technology separately, even if the features were overlapped at the connection. As an example, when the crew captured a w-beam guardrail attached to a bridge rail, they would capture the beginning and ending mileposts for the w-beam, including the section overlapping to the concrete bridge rail. The crew would also record the starting and ending mileposts of the bridge rail. In order to capture the entire w-beam as well as the entire bridge rail, the area where these two features are connected to each other was captured twice.

As it was desired to know the proportion of the segment edge that is shielded and not a linear measurement of each type of shielding, all instances of overlapping mileposts were to be removed. Identification of the particular type of longitudinal barrier was not important, only if some type of longitudinal barrier was present or not. Visual Basic code within Microsoft Excel was used to accomplish this and create a single longitudinal barrier spreadsheet. The single new generalized longitudinal barrier dataset was then attached to the segments.

Narrow Fixed Objects (NFOs)

Each NFO was first considered against the longitudinal barrier database discussed above. NFOs that were located between the beginning and ending mileposts of a longitudinal barrier were removed because it is assumed they were located behind a longitudinal barrier and therefore shielded. The remaining non-shielded NFOs were then added to the base segment edges.

The RFIP features that the research team considered to be NFOs are as follows:

- Down Guy Anchor;
- Hydrant;
- Mailbox;
- Miscellaneous Fixed Object;
- Pedestal;
- Pipe End;
- Support – includes "Wood Sign Post", "Metal Sign Post", "Luminaire Pole or Base", "Utility Pole", and "Other";
- Tree; and
- Tree Group (please see discussion below).

All of these features were point objects – that is, they had only a single milepost for a location – except for the "Tree Group" obstacle, which had beginning and ending milepost values.

Work by Hummer was used to convert the tree groups to individual trees. Hummer concluded "[a] group of trees was considered as one continuous object rather than a [sic] several point objects when there were eight or more trees within 150 ft." [HUMM86] There is a lot of variability when dealing with trees. Trees not only range in diameter, but also in placement, therefore, no single conversion will work in all instances. This approximation, however, is considered appropriate. Using the approximation (150 ft. = 8 trees), the Tree Group obstacle was converted into single trees merged with the base segments.

"Other" Obstacles

The RFIP features that the research team considered to be "Other" obstacles are as follows:

- Cabinet,
- Culvert End,
- Down Guy,
- Fence,
- Guy Wire,
- Rock Outcropping, and
- Wall.

Both "Culvert End" and "Cabinet" had only a single milepost location value, but these objects are believed to be too large to be considered "narrow" fixed objects. Since the diameters of these objects were not known, the upper-bound criteria of a "narrow" fixed object (1.5 feet) was added to the milepost to give the object an assumed length. The original milepost was then renamed the beginning milepost and the new value added to it was named the ending milepost.

In some instances, these objects occupied the same mile posts. Recall the offsets of these features are unknown. It appeared, therefore, that these objects occupy the same space. The "Other" obstacles were combined into a single dataset to remove redundancies. As was done with the NFOs, the new consolidated "Other" dataset was then merged with the Longitudinal Barrier dataset to remove those obstacles that were shielded before adding the " Other" obstacles to the base segment edges.

Summary

The unshielded NFOs and "Other" obstacles as well as the longitudinal barriers were merged with the primary right edge and opposing right edge for each base segment in Washington and Ohio to represent the roadside characteristics of these edges. The NFOs were added as point objects while the "Other" obstacles and longitudinal barrier were added with lengths along the roadway. These roadside characteristics were then summarized for use in the development of CMF_j and CMF_k. The summarizing of the roadside characteristics are described in the next section.

CHARACTERIZATION OF THE ROADSIDE

The mean densities and offsets were calculated for divided and undivided primary right base segment edge and opposing right base segment edge, for each state and then combined values were derived.

Longitudinal Barriers

When determining the mean proportion of roadside edge shielded by a longitudinal barrier, the total length of longitudinal barriers present on that edge in feet was divided by the length of the base segment edge in miles. All of these calculated proportions were then summed and divided by the total number of base segment edges to determine the mean proportion of longitudinal barrier in feet per mile of segment edge, as shown here:

$$Mean\ LB = \frac{\sum \frac{L_{LBi}}{L_{EDGEi}}}{\#\ of\ edges}$$

Where: L_{LBi} = Total length of longitudinal barriers located on edge i (feet),
L_{EDGEi} = Length of edge i (miles),
\# of edges = Total number of primary right and opposing right base segment edges.
LB = proportion of roadside edge shielded by longitudinal barriers (feet/mile).

Offsets distances to features is not available in the RFIP data. The offset values collected for Ohio were measured from the edge of travelway to each object in feet. A mean offset distance was then calculated for each right edge of each base segment. The overall mean was then calculated for longitudinal barriers, NFOs and "Other" obstacles using the following equation:

$$Mean\ Offset\ Distance = \frac{\sum Offset_i}{\#\ of\ edges}$$

Where: $Offset_i$ = Mean offset distance for edge i (feet),
\# of edges = Total number of primary right and opposing right base segment edges.

The mean proportion of shielded edge and offset to the shielding are shown in Table 113.

Table 12. Mean Proportion of Shielded Edge and Offset to Longitudinal Barrier for Rural Roadways.

Highway Type	State	LB Proportion of Shielded Edge (ft/ mile)	LB Offset (ft)	Total # Right Edges	Total Right Edge Miles
Undivided	OH	810	8.34	318	127.5
	WA	551		11,680	2,912.2
	Combined	558		11,998	3,039.7
Divided	OH	1,669	10.23	264	132.4
	WA	1,523		52	8.2
	Combined	1,645		316	140.6

The mean proportion of shielded edge and offset to the shielding for urban roadways are shown in Table 114.

Table 13. Mean Proportion of Shielded Edge and Offset to Longitudinal Barrier for Urban Roadways.

Highway Type	State	LB Proportion of Shielded Edge (ft/ mile)	LB Offset (ft)	Total # Right Edges	Total Right Edge Miles
Undivided	OH	801	3.89	184	66.3
	WA	758		3,024	650.0
	Combined	760		3,208	716.3
Divided	OH	2,222	12.53	200	114.9
	WA	576		5,892	1,357.1
	Combined	630		6,092	1,472.0

Narrow Fixed Objects (NFOs)

It was desired to learn the mean density of the NFOs for each base primary right edge and opposing right edge. The number of NFOs on a particular right edge was divided by the length (miles) of that edge. All of these values were then summed and divided by the total number of base right edges. The governing equation is shown below:

$$Mean\ NFO\ Density\ (\#/edge\ mile) = \frac{\sum \frac{\#NFO_i}{L_{EDGEi}}}{\#\ of\ edges}$$

Where: #NFO*i* = number of Narrow Fixed Objects located on edge *i*,
L_{EDGE} = length of edge *i* (miles),

# of edges = total number of primary right and opposing right base segment edges.

The mean offset distance was calculated using the same equation above that was used to calculate the offset distances of the longitudinal barriers. Again, the offset distances were collected for Ohio. No offset values were present in the RFIP database for Washington State. The mean NFO density and offsets are shown in Table 115, and the mean NFO densities and offsets for urban roadways are shown in
Table 116.

Table 14. Mean NFO Density and Offsets for Rural Roadways.

Highway Type	State	NFO Density (#/mile)	NFO Offset (feet)	Total # Right Edges	Total Right Edge Miles
Undivided	OH	53	37.56	318	127.5
	WA	32		11,680	2,912.2
	Combined	33		11,998	3,039.7
Divided	OH	28	31.34	264	132.4
	WA	57		52	8.2
	Combined	33		316	140.6

Table 15. Mean NFO Density and Offsets for Urban Roadways.

Highway Type	State	NFO Density (#/mile)	NFO Offset (feet)	Total # Right Edges	Total Right Edge Miles
Undivided	OH	103	16.83	184	66.3
	WA	41		3,024	650.0
	Combined	44		3,208	716.3
Divided	OH	82	6.98	200	114.9
	WA	26		5,892	1,357.1
	Combined	28		6,092	1,472.0

Other Obstacles

While the mean proportion of shielded roadside edges and the mean density of unshielded NFOs has been determined, there are obstacles which do not fit in either of those two groups which also need to be characterized. The “other” obstacles group is the third and last group of roadside features. This group includes all unshielded obstacles not in the longitudinal barrier group or NFO group. Obstacles in this group have a length. The total length of “Other” obstacles (feet) present on each base segment edge *i* was divided by the length of the base segment edge *i* (miles) to determine the proportion of primary right and opposing right base segment edges where other obstacles are present (i.e., feet/miles). These proportions were then summed and divided by the total number of base segment right edges to determine the mean proportion of the roadside edges where unshielded "Other" obstacles are present as shown here:

$$Mean\ PO\ =\ \frac{\sum \frac{L_{OTHERi}}{L_{EDGEi}}}{\#\ of\ edges}$$

Where: L_{OTHERi} = total length of Other obstacles located on that edge of that segment (feet),
L_{EDGEi} = length of that edge of that segment (miles),
# of edges = total number of primary right and opposing right base segment edges.
PO = Proportion of edge where "Other" obstacles are present (feet/mile).

The mean offset distance for the PO was calculated as shown above for longitudinal barriers. As with the longitudinal barriers and NFOs, the offset distances were collected for Ohio and not available in the Washington RFIP dataset. The mean PO and offset value results are shown in Table 117, and the mean PO and offset value results for urban roadways are shown in Table 118.

Table 16. Mean Proportion and Offsets of "Other" Obstacles for Rural Roadways.

Highway Type	State	PO (feet/ mile)	Offset (feet)	Total # Right Edges	Total Right Edge Miles
Undivided	OH	519	42.25	318	127.5
	WA	463		11,680	2,912.2
	Combined	465		11,998	3,039.7
Divided	OH	482	43.99	264	132.4
	WA	1,228		52	8.2
	Combined	605		316	140.6

Table 17. Mean Proportion and Offsets of "Other" Obstacles for Urban Roadways.

Highway Type	State	PO (feet/ mile)	Offset (feet)	Total # Right Edges	Total Right Edge Miles
Undivided	OH	742	15.73	184	66.3
	WA	494		3,024	650.0
	Combined	508		3,208	716.3
Divided	OH	297	6.76	200	114.9
	WA	312		5,892	1,357.1
	Combined	311		6,092	1,472.0

Summary

The Ohio online Pathweb photolog database was used to collect the longitudinal barrier, NFO, and “Other” obstacle data presented for Ohio and used to characterized the Ohio base segment edges. Washington State provided the Roadside Features Inventory Program (RFIP) database, which was used to characterize the Washington base segment edges. The values discussed above are shown as combined datasets for rural roadways in Table 119 and urban roadways in Table 120. These data were used to develop CMF_j and CMF_k.

Table 18. Mean Proportions, Densities, and Offsets for Roadside Features for Rural Roadways.

Highway Type	State	NFO Density (#/mile)	NFO Offset (feet)	PO (feet/ mile)	PO Offset (feet)	LB (feet/mile)	LB Offset (feet)	Total # Right Edges	Total Right Edge Miles
Undivided	OH	53	37.56	519	42.25	810	8.34	318	127.5
	WA	32		463		551		11,680	2,912.2
	Combined	33		465		558		11,998	3,039.7
Divided	OH	28	31.34	482	43.99	1,669	10.23	264	132.4
	WA	57		1,228		1,523		52	8.2
	Combined	33		605		1,645		316	140.6

Table 19. Mean Proportions, Densities, and Offsets for Roadside Features for Urban Roadways.

Highway Type	State	NFO Density (#/mile)	NFO Offset (feet)	PO (feet/ mile)	PO Offset (feet)	LB (feet/mile)	LB Offset (feet)	Total # Right Edges	Total Right Edge Miles
Undivided	OH	103	16.83	742	15.73	801	3.89	184	66.3
	WA	41		494		758		3,024	650.0
	Combined	44		508		760		3,208	716.3
Divided	OH	82	6.98	297	6.76	2,222	12.53	200	114.9
	WA	26		312		576		5,892	1,357.1
	Combined	28		311		630		6,092	1,472.0

ROADSIDE SLOPE

Google Earth Pro was used to determine the slope for each crash in the identified population. The decision to use Google Earth Pro was made after first conducting a study of slope measurements in both the field and using Google Earth Pro. This study was conducted on Route 108 in Canton, Maine in September of 2014. The field elevation was determined at five offsets in 120 locations using a tape and level method. The slope was determined using Google Earth Pro for the same section of road. The results were indistinguishable, therefore, it was concluded that Google Earth Pro was acceptable for use in the surveying of roadside slopes for this effort.

The crash data did not originally contain the latitude and longitude; which are ideal for navigation using Google Earth Pro. These data were found using the route and milepost available in the crash database in conjunction with an online photo log of Ohio roadways called PathWeb. The route and milepost were entered into PathWeb for each case to obtain the corresponding latitude and longitude.

Using the latitude and longitude, each crash location was viewed on Google Earth Pro. The measuring tool was used to collect five data points that make up the slope data. These five data points are defined here:

- Edge line elevation (ELE) is the elevation at the edge line. It is the painted line at the edge of the travel way the vehicle exited.
- Break point elevation (BPE) is the elevation at the break point. It is defined as the first point from the edge line where the elevation has a measurable change.
- End of slope elevation (ESE) is the elevation at the end of the slope. It is defined as the point where the elevation change can be observed (visually on the elevation graph) changing direction from that indicated by the break point elevation or at a maximum of 60 feet.
- Edge to end distance (EED) is defined as the horizontal distance between the edge line and the end of the slope.
- Break point distance (BPD) is defined as the horizontal distance between the edge line and the break point.

It was not the objective to collect detailed data for complex slopes (e.g., grading around culverts, bridges, intersections, etc.) because this type of detailed slope data would not be applicable to long roadway stretches. Complex slopes, however, were captured in the data collection effort as "complex slopes." A complex slope is defined as any slope which is 400 ft in advance of an intersection, bridge, or a culvert as well as a slope at a location that is within the limits of an on/off ramp. It is possible, with enough data points, that the effect of complex slopes can be compared to traversable slopes through a CMF.

While data collection was limited to OC (i.e., non-longitudinal barrier crashes) to provide events where only unprotected roadside slopes were present, some locations were found to have longitudinal barriers. When the presence of longitudinal barrier was recorded at a location, this location was removed from the data population. The mean roadside unprotected roadside slope was found to be -10H:1V using this data.

APPENDIX E REFERENCES

HUMM86 "Safety Effects of Cross-Section Design for Two-Lane Roads – Data Base User's Guide", pg. 35, Federal Highway Administration, Office of Safety and Traffic Operations Research and Development, Washington, D.C. 20590, December, 1986.

OHIO01 ODOT Pathweb online photolog database: http://pathweb.pathwayservices.com/ohiopublic/, accessed 24 February, 2015.

WSDOT1 Washington State Department of Transportation State Highway Log Online Database: http://www.wsdot.wa.gov/mapsdata/roadway/statehighwaylog.htm, Accessed 24 February, 2015.

APPENDIX F. RESULTS OF SURVEY OF PRACTICE

INTRODUCTION

The survey was distributed via e-mail to more than 2,100 highway safety researchers, roadside safety researchers, DOT engineers, and highway design consultants. This survey was conducted to assess current crash modeling uses and needs as they relate to roadside safety during both planning and design. Specific roadside concerns and areas of need were also solicited. The distribution list was compiled from the TRB AFB20 and its subcommittees mailing lists, the ITE database, AASHTO-ARTBA-AGC TF13 mailing list, ATSSA training course participants, and from a list of people who have purchased the Roadside Design Guide from AASHTO. The survey was also forwarded to the AASHTO Joint Task Force on the HSM. A complete copy of the questionnaire can be found at the end of this report.

The survey was assembled and made available using the on-line tool surveymonkey.com (i.e., www.surveymonkey.com). The survey had several purposes. First, it was important to identify the user communities of the existing programs including the RSAP, IHSDM, and Safety Analysis programs and determine how each user analyzes roadside safety as a result of the various methods available. Similarly, it was important to get information about the implementation and use of the new HSM. Feedback was also gathered from respondents on their needs for new roadside CMFs.

Approximately 114 people started the survey and 95 people completed it after starting resulting in a completion rate of 83 percent. The partially completed surveys were also used in the analysis of results. Approximately five percent of the recipients responded, the remaining recipients who did not respond in any way are presumed to not be active in the roadside safety or crash modeling aspects of highway design. The survey asked a variety of questions about roadside safety and crash modeling. The following sections discuss each question and describe the research team's assessment of the responses.

Question 1: Please provide the following optional information about yourself.

Respondents were asked to provide contact information. All respondents provided their company name (i.e., State DOT, private companies, etc.). Respondents were primarily from the United States, with some from Canada and one from Argentina. Respondents represented thirty-seven states, including State DOTs, municipal and county engineering offices, consulting firms and research agencies. This variety of respondents provided a wide geographic cross-section regarding the CMF needs and the analysis methods currently in place.

Question 2: What types of work do you do (check all that apply)?

Respondents were asked the type of work they perform and instructed to check all that apply; therefore, respondents may have checked more than one field. The results are shown in Figure 43. One interesting observation is that most respondents engage in some type of design work with over 60 percent identifying themselves as working as highway and/or roadside designers. Policy work was identified by about 30 percent of respondents while highway and/or roadside planning work was identified approximately 25-30 percent of the time. The respondents who describe themselves as doing "other" work are engaged in activities including:

- Work Zone Safety,
- Traffic engineering,
- Traffic Control,

- Crash testing,
- Accident investigation/reconstruction,
- Applications engineers and suppliers of roadside safety products,
- Management of road and bridge construction projects,
- Road system maintenance,
- Multi-modal transportation planning,
- Accessibility in the public right of way,
- Value Engineering, and
- Public Involvement.

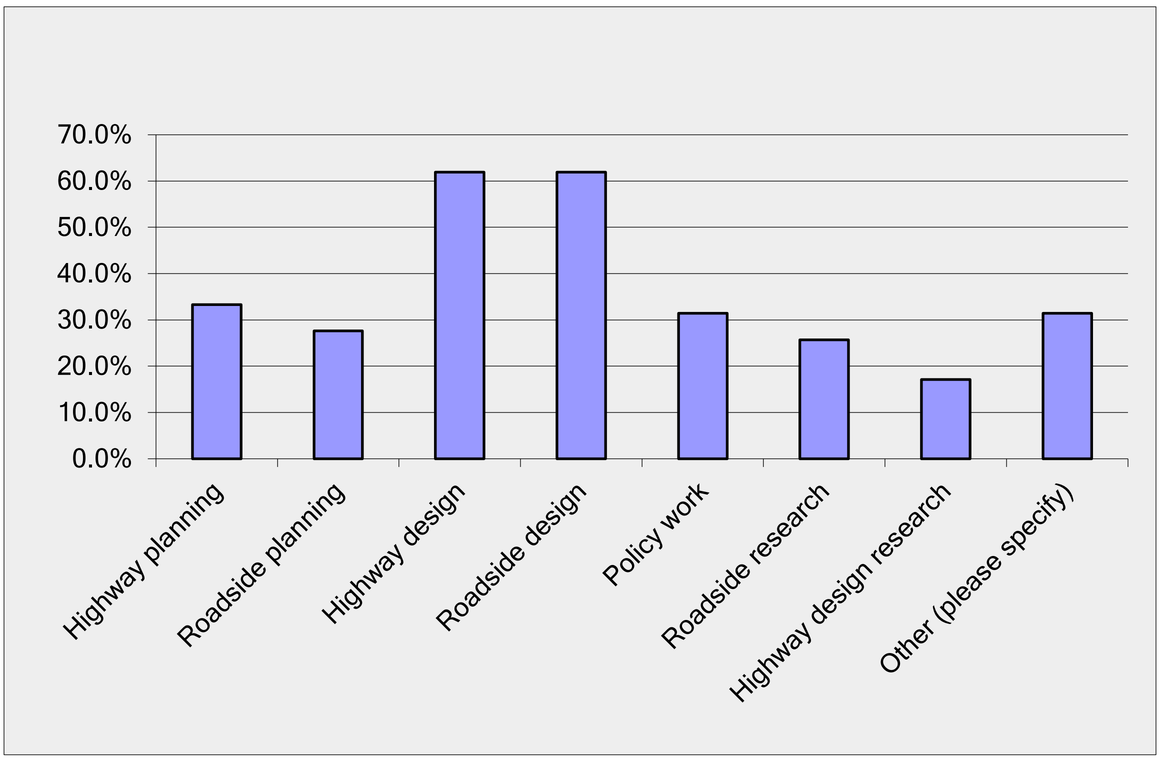

Figure 4. Distribution of Responses to Survey Question Two.

Question 3: Which software do you use to analyze highway safety (check all that apply)?
As shown in Figure 44, a large percentage of the people surveyed (i.e., 63 percent) do not use software tools of any kind to analyze highway safety. The remaining respondents appear to use a variety of tools including IHSDM and RSAP.

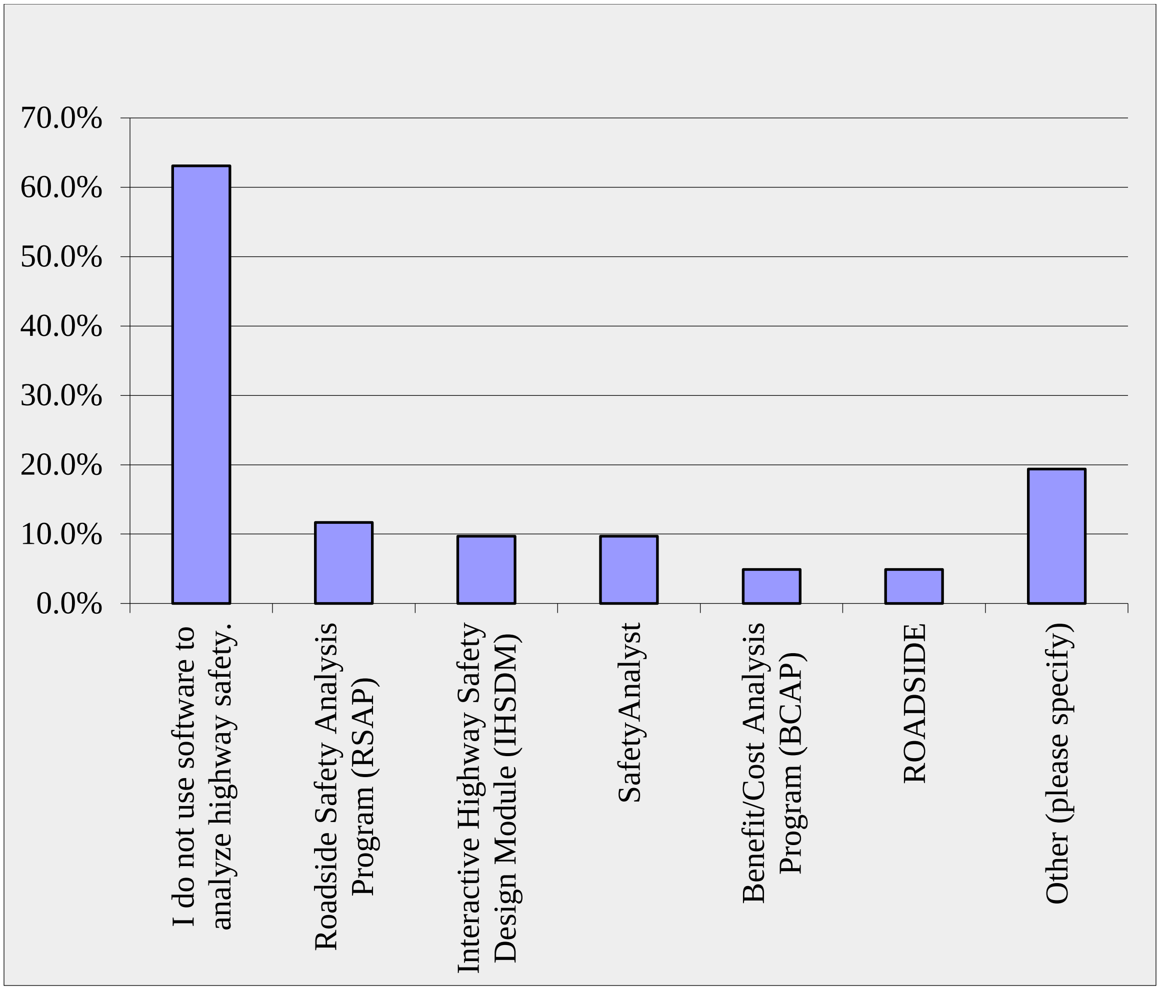

Figure 5. Distribution of Responses to Survey Question Three.

Surprisingly, some respondents are still using BCAP and ROADSIDE, two programs which have been replaced by RSAP for over a decade. This indicates the slow rate at which transportation professionals change from one tool to another or, possibility, that there is a need to better communicate to professionals that other tools are available. Conversely, approximately 20 percent of the respondents indicated that they are using tools other than those listed, including:

- Spreadsheet tools implementing the HSM and local SPFs and CMFs
- Locally developed safety analysis software (i.e., SAMS, RIMS, etc.)
- MicroBenCost
- Rapidplan
- "EICVVC" and "Assessing Available Sight Distance: An Indirect Tool to Evaluate Geometric Design Consistency". 4th International Symposium on Highway Geometric Design, 2010, 23p
- CMAT
- Diadem

Question 4: What have your experiences been using multiple approaches to roadside design? Have you found conflicts and/or similarities?

The responses to this question where quite varied, ranging from "yes, I have found the existing flexibility in roadside design can cause conflict" to "the approaches that we use typically don't conflict with each other …." Other respondents noted that they "…do not use multiple approaches to complete roadside design." This variety does not allow a conclusion to be made.

More specifically, some respondents addressed the use of RSAP and the HSM or the IHSDM for the analysis of roadside design. A sample of these comments is provided here:

- "Sometimes have found conflicts; never get the same exact answer, but majority of the time the information is at least consistent (i.e. RSAP agrees with HSM in terms of net positive/negative)"
- "Historically we have used RSAP to complete our more complex roadside design analyses. This software has generally served us well and we are happy with the improvements they are making. We are just starting to use the IHSDM but given its relatively simple metrics for roadside safety it is unlikely we will use it for anything more than very simple analyses."
- "IHSDM and Safety Analyst have not been integrated due to incomplete roadside characteristic data collection."

It appears that the survey respondents have many different experiences using or not using different approaches to roadside design. RSAP is, however, consistently being used to analyze complex roadside design situations, while the HSM, IHSDM, and SafetyAnalyst are not, likely due to the simplicity and/or lack of the roadside options within the HSM, IHSDM, and SafetyAnalyst.

Question 5: The Highway Safety Manual was published by AASHTO in 2010. Have you had an opportunity to use the manual yet?

The respondents were given the opportunity to answer Yes or No to this question then, using internal logic, were directed to the next question depending on the provided answer. If the respondent answered yes, information was solicited regarding how the respondent had used the HSM (i.e., questions six then seven). If the respondent answers No, then the respondent was directed to question seven. Forty-one percent of the respondents indicated that they have used the HSM.

Question 6: Have you used the HSM to analyze any of the follow scenarios?

This question asked participants if they had used the HSM to analyze these scenarios:

- Alternatives for horizontal curves and vertical curves?
- Alternatives for lane widths?
- Alternatives to limit run-off-road crashes?
- Alternatives for roadside designs?
- Combinations of different highway components to improve highway safety?
- Other (please explain)?

Again, respondents could check all the fields that applied, therefore, some respondents checked multiple fields. Surprisingly, the largest number of respondents (i.e., 38 percent) have used the

HSM for the analysis of ROR frequency followed closely by lane width and combinations of different components. The other design options analyzed using the HSM include the analysis of "shoulder widths" and "… choosing to construct a divided multilane highway vs. one with a (Two-way Left-Turn Lane)." These surprising results are likely related to the heavy roadside design background of the survey respondents.

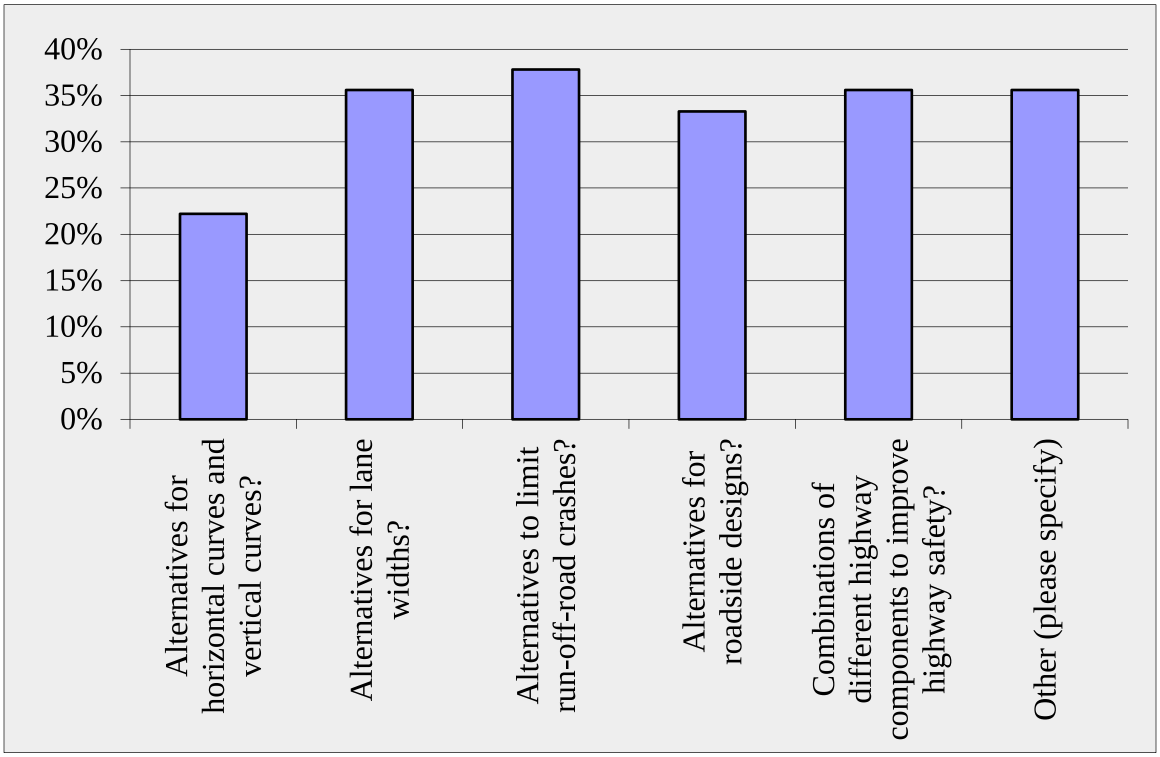

Figure 6. **Distribution of Responses to Survey Question Six.**

Respondents again expressed concerns with the use of the HSM for roadside design analysis, stating "some analysis was done to determine if narrowing the shoulder verses steepening the side slopes. However, HSM (is) not a very good method for evaluating roadside. RSAP is better for roadside."

Question 7: This research project will develop Crash Modification Factors (CMFs) to help explain which roadside treatments are most effective at reducing roadside crash potential and crash severity. Please check those that most interest you and will help with your work (check all that apply).

This question listed the following options for respondents to choose from:

1. Trees
2. Poles
3. Breakaway and non-breakaway signs
4. Breakaway and non-breakaway Luminaire supports

5. Roadside and Median ditch configurations
6. Roadside Slopes
7. Clear zone widths
8. Guardrail terminals
9. Culvert headwalls and drainage inlets
10. Various bridge rails
11. Various longitudinal barriers
12. Other (please specify)

Respondents were able to rank choice by priority of high (3), medium (2), or low (1). A summary of the results are presented in Table 121. Clear zone widths appeared to have generated the most interest. All other roadside features generated similar amounts of interest, indicating a need for CMFs to be developed in all of these areas.

Table 20. Ranking of Results from Question Seven.

Roadside Feature	Ranking
Clear zone widths	233
Poles	218
Roadside Slopes	218
Roadside and Median ditch configurations	216
Guardrail terminals	209
Trees	206
Culvert headwalls and drainage inlets	193
Various longitudinal barriers	189
Breakaway and non-breakaway signs	179
Breakaway and non-breakaway Luminaire supports	172
Various bridge rails	168
Other (please specify below)	24

The other areas of need that were identified by respondents included the effects of speed curb design and barrier transitions on ROR crash frequency.

Question 8: Please rate this large photograph using the RHR scale.

Respondents were asked to use the roadside hazard rating (RHR) to characterize the roadsides of the given photograph. Sample RHR photographs and text from the HSM were provided. The photograph in question is shown in Figure 46.

Figure 7. Sample Rural, Two-Lane Road.

The RHR scale ranges from one to seven, with an RHR of one representing wide clear zones and recoverable side slopes and an RHR of seven representing narrow clear zones, no guardrail, and non-recoverable side slopes. The respondents' ratings are shown in Table 122.

Table 21. Distribution of Responses to Question Eight.

RHR	Response	
	Number	Percent
1	0	0.0%
2	10	10.4%
3	26	27.1%
4	15	15.6%
5	40	41.7%
6	4	4.2%
7	1	1.0%

The largest percentage of respondents identified the photograph in Figure 46 as having an RHR equal to 5, however, respondents identified this photograph as having an RHR ranging from two through seven. The wide variability of the responses to this question demonstrate the inaccurate results which can be expected from the roadside design CMF which uses RHR to account for the effects of roadside design.

Question 9: Please provide any additional comments here. If you would like the research team to contact you directly to discuss the research, please provide the best way to contact you. Thank you.

Some respondents did provide contact information which will be used by the research team to contact those respondents. Additional comments included:

- “In general the RHR is too general and the guidance for rating a section has too many independent variables to provide a single rating. Elements including the height and type of guardrail can impact safety as much as the presence of any other roadside obstacle."
- “You need to be extremely careful with categorizing roadside conditions as stated in picture 8. The results of this research should indicate that even though there are trees, poles, etc. relatively close to the roadway that removal or shielding of these objects is appropriate. There needs to be flexibility to categorize based on the engineering judgment as well as the context of the surroundings leading up to the studied section of road as well as the section following the study section.”
- "I believe that the HSM methodology for clear zone is too subjective and does not allow for detail analysis or interaction of different variables. For example a slope could be 3:1 (i.e. “safe” slope), but if it has fixed objects on the slope or the 3:1 lacks a flat spot at the bottom of the ditch the 3:1 is a hazard.”
- “I also believe that some research into 3R clear zone criteria may be warranted."

In summary, some respondents reiterated their concerns with the RHR and the HSM methodology in general, as it pertains to roadside design considerations. Respondents also offered additional areas to focus development efforts.