Development of Speed Crash Modification Factors (CMFs) Using SHRP2 Roadway Information Database (RID), Volume II: Appendices

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FOREWORD

This research was conducted under Transportation Pooled Fund study TPF-5(361): *SHRP2 Naturalistic Driving Study Pooled Fund: Advancing Implementable Solutions* (NCHRP 2023), for which the goal is to develop novel, multidisciplinary solutions based on recorded natural behavior of vehicle operators interacting with infrastructure and other vehicles. Speed can have serious safety impacts, especially on the severity of crashes. However, these effects are complex and generally have not been captured in the *Highway Safety Manual* (HSM) (American Association of State Highway and Transportation Officials 2010). This project developed speed-related crash modification factors (CMFs) for the existing crash prediction models of the HSM.

The project used three databases from the States of Washington and North Carolina: roadway geometric and operational data from the Second Strategic Highway Research Program Roadway Information Database; operating speed data from the National Performance Management Research Dataset; and crash data from the Highway Safety Information System (Iowa State University of Science and Technology 2023; National Academies of Sciences 2023; RITIS 2023; FHWA n.d.). Speed-related CMFs for 12 different roadway facility types covering rural highways, urban and suburban arterials, and rural and urban freeways were developed. These CMFs were prepared to meet the quality standards for CMF Clearinghouse (Federal Highway Administration 2023a) submission. The research demonstrates that inclusion of speed CMFs can improve crash prediction precision for certain facility types. The speed CMF development approach used in this study can be used to develop speed CMFs at the jurisdiction level, if required data are available. This research will be of interest to roadway designers, safety professionals, and others with an interest in speed management. This volume is the second in a series. The other volume in the series is FHWA-HRT-24-129, *Development of Speed Crash Modification Factors (CMFs) Using SHRP2 Roadway Information Database (RID), Volume I: Final Report.*

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16. Abstract
Speed is widely recognized as having significant safety impacts, especially on the severity of crashes. However, these effects are complex and generally have not been captured in the *Highway Safety Manual* (HSM) (American Association of State Highway and Transportation Officials (AASHTO) 2010). The current Federal Highway Administration (FHWA) project developed speed-related crash modification factors (CMFs) for 12 different roadway facility types—rural highways, urban and suburban arterials, and rural and urban freeways—by using Washington and North Carolina data from three major databases: Second Strategic Highway Research Program Roadway Information Database, National Performance Management Research Dataset, and Highway Safety Information System (VTTI 2020; Iowa State University of Science and Technology 2023; National Academies of Sciences 2023; RITIS 2023; FHWA n.d.). The results show that speed variation (e.g., operating speed standard deviation) was the dominant speed measure for rural highways and rural and urban freeways, and speed differential (i.e., difference between the posted speed limit and average operating speed) was the dominant speed measure for urban and suburban arterials. In most cases, the association of speed variation/differential with crashes is positive. The researchers developed CMFs for 129 crash types and severity levels, and most obtained three-star CMF Clearinghouse ratings (AASHTO 2010; FHWA 2023a). These CMFs were developed through a data-driven safety analysis approach, and application of these CMFs (e.g., in HSM-related evaluation tools) requires careful interpretation. The findings show that inclusion of speed-related CMFs improves model precision. While this study focused on Washington and North Carolina data, other States can use the documented approach to develop speed-related CMFs for their own jurisdictions. This volume is the second in a series. The other volume in the series is FHWA-HRT-24-129, *Development of Speed Crash Modification Factors (CMFs) Using SHRP2 Roadway Information Database (RID): Volume I: Final Report*.

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SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1,000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or “metric ton”)	Mg (or “t”)
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or “t”)	megagrams (or “metric ton”)	1.103	short tons (2,000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	2.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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LIST OF ABBREVIATIONS

AADT	annual average daily traffic
AASHTO	American Association of State Highway and Transportation Officials
CF	calibration factor
CMF	crash modification factor
CPM	crash prediction module
csv	comma-separated values
CURE	cumulative residuals
DBF	database file
FHWA	Federal Highway Administration
FID	feature identification
GIS	geographic information system
HSM	*Highway Safety Manual*
ID	identification
IHSDM	Interactive Highway Safety Design Model
KABCO	KABCO crash severity scale (K = fatal, A = incapacitating injury, B = non-incapacitating injury, C = possible injury, and O = no injury, property damage only)
MAD	mean absolute deviation
MP	mile point
MV	multiple vehicle
MVFI	multiple vehicle fatal and injury
MVPDO	multiple vehicle property damage only
NPMRDS	National Performance Management Research Dataset
PDO	property damage only
PSL	posted speed limit
R2U	undivided rural two-lane, two-way roadway segments
R4D	rural four-lane divided segments
R4U	rural four-lane undivided segments
RID	Roadway Information Database
RMSE	root mean squared error
SHP file	shapefile
Spd85	85th percentile operating speed
SpdAve	average operating speed
$SpdAve_{Day}$	average operating speed during daytime
$SpdAve_{FSS}$	average operating speed during weekend
$SpdAve_{MTWT}$	average operating speed during weekdays
$SpdAve_{Night}$	average operating speed determined during nighttime
SpdFF85	85th percentile free-flow operating speed
SpdFFAve	average free-flow operating speed
SpdStd	standard deviation of average operating speed
$SpdStd_{Day}$	standard deviation of operating speed during daytime
$SpdStd_{FSS}$	standard deviation of operating speed during the weekend
$SpdStd_{MTWT}$	standard deviation of operating speed during weekdays
$SpdStd_{Night}$	standard deviation of operating speed during nighttime

SV	single vehicle
SVFI	single vehicle fatal and injury
SVPDO	single vehicle property damage only
TMC	traffic message channel
TWLTL	two-way, left-turn lane
U2U	two-lane undivided urban and suburban arterial segments
U3T	three-lane urban and suburban arterials including a center two-way, left-turn lane
U4D	four-lane divided urban and suburban arterials (including a raised or depressed median)
U4U	four-lane undivided urban and suburban arterial segments
U5T	five-lane urban and suburban arterials including a center two-way, left-turn lane
U6D	six-lane divided urban and suburban arterials (including a raised or depressed median)
U6U	six-lane undivided urban and suburban arterial segments
U7T	seven-lane urban and suburban arterials including a center two-way, left-turn lane
W_{hc}	clear zone width
$X_{b,ent}$	distance from begin point to upstream entrance ramp (mi)
$X_{b,ext}$	distance from begin point to downstream exit ramp (mi)
$X_{e,ent}$	distance from end point to upstream entrance ramp (mi)
$X_{e,ext}$	distance from end point to downstream exit ramp (mi)

APPENDIX A. DATA PREPARATION

This appendix provides a detailed description of the data preparation steps. This study developed databases by collecting data from two States: Washington and North Carolina. The conflation and data preparation procedures for Washington and North Carolina are similar. This appendix describes the data preparation work. The data preparation of this study consists of three major steps:

- Process 1: Conflate the Roadway Information Database (RID) network with the National Performance Management Research Dataset (NPMRDS) network (Iowa State University of Science and Technology (ISU) 2023; RITIS 2023).
- Process 2: Assign crashes on conflated networks.
- Process 3: Determine suitable speed measures.

PROCESS 1: CONFLATE RID NETWORK WITH NPMRDS NETWORK

Preparation of Homogeneous Roadway Segments

The project's part A efforts used a list of filters (table 1) to prepare the database with homogenous segments. The steps used in this task are described in the following subsections.

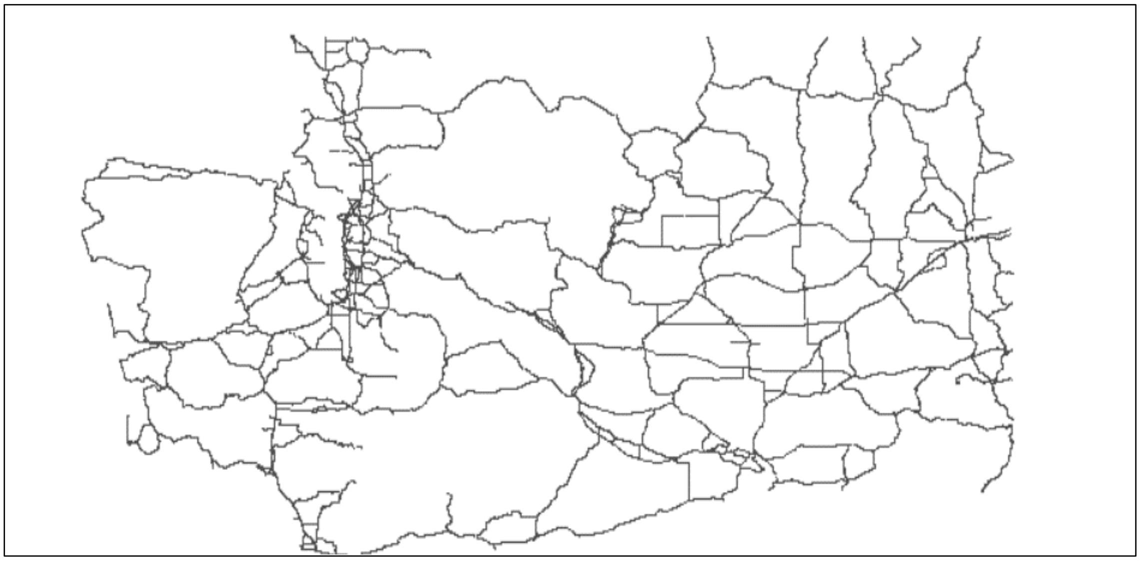
Table 1. Roadway features and layer names.

No.	Roadway Feature	RID Layer Name	Filter(s)
1	Functional class	FunctionalClass_SR	STATEFUNCT IN (R1, R2, R3); DIRECTION = B; RouteID > 0
2	Divided or not	RW_DividedHighway2010	RouteID > 0
3	Lane	RW_Lanes2010	DIR = B; RouteID > 0
4	Shoulder	RW_Shoulders2010	RouteID > 0
5	Median	RW_Median2010	RouteID > 0
6	PSL	RW_LegalSpeedLimits2010	RouteID > 0
7	Presence of rumble strips	RumbleStrip	RouteID > 0
8	Roadway lighting	Lighting	RouteID > 0
9*	Routes	Routes	—

—Not applicable.
PSL = posted speed limit.
*The layer "Routes" is used as the base map of the roadway network, rather than as a roadway feature.

Export Each Layer into a Database File (DBF) (ArcGIS®)

Using ArcMap of ArcGIS suite (Esri™ 2020), in this step, the project team excluded redundant fields from the original lane layer and only kept those needed for the project (i.e., number of lanes and lane width in each direction, route identification (ID), and from/to measures). The project team applied a few filters to the original layer to reduce nonexisting routes and eliminate duplicated polylines (figure 1).



A. Roadway network.

rdwywidthd	numinsdec	rdwywidthi	numinsinc	RouteID	ToMeasure	FrMeasure
12	1	12	1	46	1192.9	0
11	1	11	1	92	32595.7	0
13	1	13	1	92	32750.5	32595.7
11	1	11	1	92	33245.6	32750.5
22	2	22	2	92	33487.7	33245.6
28	2	28	2	92	37583.6	33487.7
12	1	24	2	92	41074.1	37583.6
12	1	12	1	92	52153	41074.1
18	1	18	1	92	52258.5	52153
12	1	12	1	92	53563.1	52258.5
18	1	18	1	92	53665	53563.1
12	1	12	1	92	79183.8	53665
19	1	19	1	92	80032	79183.8

B. Example of overlapping segments.

Figure 1. Screenshots. Roadway network and example of overlapping segments (Esri 2020).

Dissolve the Exported DBF Files (ArcGIS)

The main purpose of dissolving a DBF was to combine continuous segments with the same roadway features and on the same route into longer segments.

Adjust the Dissolved DBF Tables (Python®)

The main purpose of this step was to address the overlapping issue in the dissolved DBF tables. While processing the data, the project team realized that some polylines overlapped in the original layer data; this overlap caused the number of segments to increase exponentially, which brought challenges to the data preparation. The project team developed a Python-based program to eliminate the overlapping issue (Python 2023). The basic concept of the program is to identify overlapped segments and adjust the from/to measure of one segment (table 2).

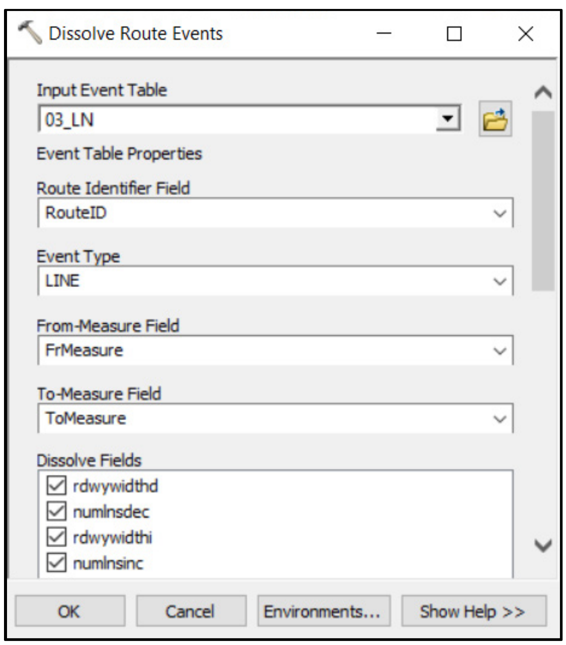
Table 2. Example illustrating segment adjustment.

Segment Type	RouteID	FrMeasure (mi)	ToMeasure (mi)	Feature 1	Feature 2
Original segments	2	0.0	6.0	A	W
Original segments	2	5.8	7.0	B	C
Adjusted segments	2	0.0	6.0	A	W
Adjusted segments	2	6.0	7.0	B	C

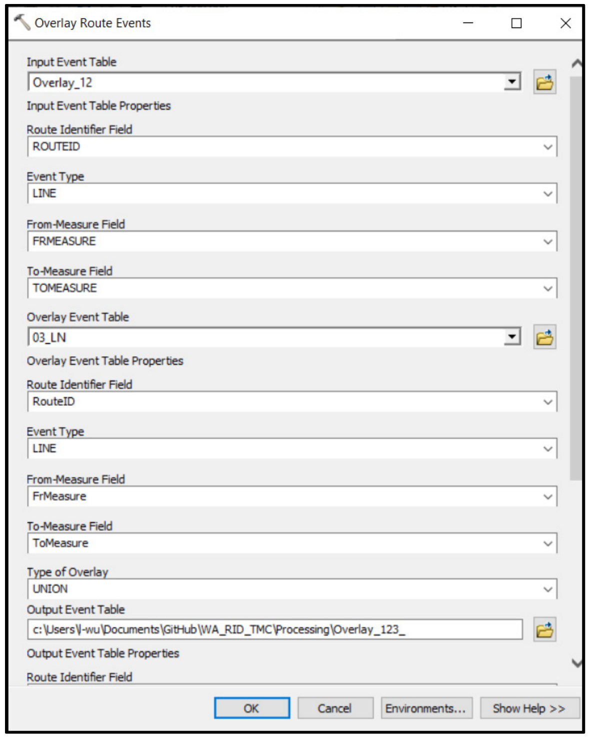
Fr = from; A = feature 1 attribute A (e.g., curve); B = feature 1 attribute B (e.g., straight); W = feature 2 attribute W (e.g., paved shoulder); C = feature 2 attribute C (e.g., unpaved shoulder).

Overlaying Tables (ArcGIS)

The objective of overlaying two DBF tables was to create an output DBF table (i.e., event table) that represents the union of the input. (This step is also known as dynamic segmentation.) The project team applied "union" in the overlaying process, such that all the segments (even some features missing in the original dataset) could be included in the final segment dataset (figure 2).



A. DBF table.



B. Overlaying DBF table.

Figure 2. Screenshot. Dissolve and overlay of route events (Esri 2020).

Export to Shapefile (ArcGIS)

Once all the features mentioned in table 1 were overlaid, the team developed the final DBF table based on the route layer (i.e., "Routes" in the RID) data and then exported the layer as a separate shapefile (ISU 2023). The SHP file includes homogenous roadway segments in Washington.

Conflation of Two Linear Networks

In this step, the project team integrated two linear systems (NPMRDS and segment polyline files) to enable segment-based analysis with speed measures (RITIS 2023). This study uses two formats of RID files: roadway line work without roadway characteristics (i.e., routes), and roadway line work with roadway characteristics (i.e., roadway segments created in the first step). In the former file, each route is a continuous polyline in the geographic information system (GIS) database and includes only the basic information for the route (e.g., route name, beginning and ending mileposts) (Esri 2020). In the latter file, routes were divided into various numbers of homogeneous segments with roadway assets or features (e.g., functional class, lane, shoulder, posted speed limit (PSL), presence of rumble strips, and lighting situation).

The conflation work considered the 2018 NPMRDS file in Washington and the homogeneous segment file created from the Washington RID data in the first step (RITIS 2023; ISU 2023). The project team used two software packages (ArcGIS and R) to conflate these databases. The researchers took the following steps in this task (Esri 2020; R Core Team 2023).

Step 1: Divide the NPMRDS File by Direction

In this step, the project team divided the NPMRDS file into two files: positive and negative (RITIS 2023). The direction of the NPMRDS segments is determined by the traffic message channel (TMC) name: “+” or “P” indicates positive, and “−” or “N” indicates negative (figure 3).

OBJECTID	RouteID	FrMeasure	ToMeasure	ROUTENAME	ROUTEBASE	LENGTH	ONEWAY	Shape_Leng
1154	1154	0.0000000…	41704.730…	3|SR00028…	WA-281	41704.730…	0	0.1143320…

Tmc	TmcType	RoadNumber	RoadName	IsPrimary	Miles
114+14219	P1	281	State Rout…	1	7.8971780…

Figure 3. Screenshot. Example of a route and an NPMRDS TMC segment (Esri 2020).

Step 2: Conflate NPMRDS Segments Along with Roadway Routes

In this step, the project team used one direction of NPMRDS and roadway route line work without roadway characteristics as the input route features (RITIS 2023). The event table generated from the conflating process was exported as a comma-separated values (csv) file. Each direction of NPMRDS was located separately (figure 4).

	Rowid	ROUTEID	FMEAS	TMEAS	TMC	TMCTYPE	ROADNUMBER	ROADNAME	ISPRIMARY	MILES	DIR_INDEX
▶	1	92	88489.474174	90387.835474	114+05416	P1	2	State Route 2	1	0.374631	1
	2	92	75890.161745	85470.689947	114+05418	P1	2	State Route 2	1	1.825103	1
	3	92	60654.582974	67163.147474	114+05420	P1	2	State Route 2	1	1.228053	1
	4	92	35079.103474	37922.257174	114+05422	P1	2	State Route 2	1	0.530471	1
	5	92	-0.000026	35079.103474	114+05423	P1	2	W Stevens Ave	1	7.413764	1
	6	92	85470.689947	88489.474174	114P05416	P1	2	State Route 2	1	0.531061	1
	7	92	37922.257174	38020.874874	114P05421	P1	2	State Route 2	1	0.025812	1
	8	92	90387.835474	91084.563974	114+05415	P1	2	State Route 2	1	0.124579	1
	9	92	67163.147474	71057.395074	114P05419	P1	2	State Route 2	1	0.751499	1
	10	92	38020.874874	60654.582974	114+05421	P1	2	State Route 2	1	4.279867	1
	11	92	71057.395074	75890.161745	114+05419	P1	2	State Route 2	1	0.92826	1
	12	92	91084.563974	93278.436674	114P05414	P1	2	State Route 2	1	0.703877	1
	13	93	-0.000026	606.905674	114+05423	P1	2	W Stevens Ave	1	7.413764	1
	14	94	-0.000026	42319.126274	114+06717	P1	2	US Highway 2	1	8.224268	1
	15	94	42319.126274	86259.603274	114+05429	P1	2	Stevens Pass Hwy	1	8.315106	1
	16	94	97443.025374	154552.159674	114+05427	P1	2	Stevens Pass Hwy	1	25.159741	1
	17	94	86259.603274	97443.025374	114+05428	P1	2	NE Stevens Pass Hwy	1	2.108455	1
	18	95	-0.000026	42492.592274	114+05427	P1	2	Stevens Pass Hwy	1	25.159741	1

Figure 4. Screenshot. Conflating NPMRDS segments along roadway routes (Esri 2020).

Step 3: Refine the Event Table

In step 2, the two files (i.e., NPMRDS and routes) were conflated based on spatial relationships. A few segments were mismatched in the process. This step eliminated the mismatched events based on the roadway information and spatial matching results. In the refined event table, each NPMRDS segment had a route name and beginning and ending mileposts relative to the roadway route line work (RITIS 2023).

Step 4: Create the Final Table

The project team refined the event table and roadway line work with roadway characteristics. In this step, the association between NPMRDS segments and roadway segments with roadway characteristics was created based on the route name and mileposts. For each roadway segment, the team collected data from NPMRDS segments (RITIS 2023). The information included the TMC name and the effective length ratio of the TMC matching with the roadway segment (table 3).

Table 3. Roadway segments with NPMRDS information.

RouteID	Unique ID	Begin MP	End MP	TMC	Effective Ratio
92	2	15,280.1	16,871.3	114+05423	0.041
92	3	16,871.3	18,564.8	114+05423	0.043
92	4	60,632.2	61,160.4	114+05420	0.078
92	4	60,632.2	61,160.4	114+05421	0.001
92	5	58,192.9	60,630.6	114+05421	0.108
92	6	67,278.1	67,471.1	114P05419	0.049
92	7	67,471.1	68,624.31	114P05419	0.291

MP = mile point.

The researchers took similar steps for the conflation of the roadway routes, segments, and NPMRDS in the negative direction. The current data conflation work is limited to the quality of the original RID data as well as the NPMRDS dataset (ISU 2023; RITIS 2023). For example, if a roadway feature is missing in the RID data, the feature will be shown as “NA” or “0” in the final conflated dataset.

PROCESS 2: ASSIGN CRASHES ON CONFLATED NETWORKS

The project team acquired 2017–18 Washington crash data from the HSIS (FHWA n.d.). The crash events SHP files contain information including crash data, crash severity, and the latitude and longitude of the crash events. The project team first applied the near feature tool in ArcMap® (Esri 2020) to assign crash events to roadway segments that were created in process 1. Each crash was assigned an attribute named Near_FID. Near_FID stands for the feature identification (FID) number (roadway segment corresponding row number starting from 0 in the crash characteristics file) of the roadway segment on which the crash event happened. The team considered a buffer of 30 ft as a threshold to determine if a crash event happened on a roadway segment. If a crash event cannot be assigned to any roadway segment, its Near_FID attribute will be equal to −1. The project team filtered out the crash events with Near_FID equals −1 because they cannot be connected with any roadway segments. After crash events were assigned to roadway segments for both 2017 and 2018, the project team summarized the total number of crashes that happened on each roadway segment based on crash severity.

PROCESS 3: DETERMINE SUITABLE SPEED MEASURES

This study acquired 3 yr of speed measure data (2017–19) from NPMRDS by using the TMC number from step 2 (RITIS 2023). First, the project team developed an R code (R Core Team 2023) to summarize the 3 yr of speed measures for each TMC name. The speed measures used in this study are listed in table 4.

Table 4. Definition of the selected speed measures.

Speed Measure	Definition
SpdAve	Average operating speed determined for year using all data
SpdStd	Standard deviation of operating speed determined for year using all data
Spd85	85th percentile operating speed determined for year using all data
PSL	Posted speed limit
$SpdAve_{Day}$	Average operating speed during daytime determined for year (>5 h and <18 h) using all data
$SpdStd_{Day}$	Standard deviation of operating speed during daytime determined for year (>5 h and <18 h) using all data
$SpdAve_{Night}$	Average operating speed during nighttime determined for year (>17 h and <24 h and > −1 h and <6 h) using all data
$SpdStd_{Night}$	Standard deviation of operating speed during nighttime determined for year (>17 h and <24 h and > −1 h and <6 h) using all data
$SpdAve_{MTWT}$	Average operating speed during weekdays determined for year (Monday, Tuesday, Wednesday, Thursday) using all data
$SpdStd_{MTWT}$	Standard deviation of operating speed during weekdays determined for year (Monday, Tuesday, Wednesday, Thursday) using all data
$SpdAve_{FSS}$	Average operating speed during weekend determined for year (Friday, Saturday, Sunday) using all data
$SpdStd_{FSS}$	Standard deviation of operating speed during weekend determined for year (Friday, Saturday, Sunday) using all data
SpdFFAve	Average free-flow operating speed determined for year using speed data (>0 h and <5 h)
SpdFF85	85th percentile free-flow operating speed determined for year using speed data (>0 h and <5 h)

Each roadway segment has both negative and positive TMC names. Additionally, some segments have more than one negative or positive TMC names. This situation leads to each roadway segment having more than one set of speed measure data. The project team developed an R code to calculate the weighted average of all the speed measure attributes for each unique roadway segment. The original speed measure file was merged with the roadway segments with the NPMRDS information file created in process 2 (RITIS 2023). Then, the speed measure data were grouped by unique ID, and the weighted average values of all the speed measure attributes in table 4 were calculated based on the effective ratio of each TMC. The weighted average calculation methods for standard deviation of operating speed (SpdStd), standard deviation of operating speed during the daytime ($SpdStd_{Day}$), standard deviation of operating speed during the nighttime ($SpdStd_{Night}$), standard deviation of operating speed during weekdays ($SpdStd_{MTWT}$), and standard deviation of operating speed during the weekend ($SpdStd_{FSS}$) are different from other speed measure attributes.

Figure 5 is applied to the following speed measurement variables: SpdStd, $SpdStd_{Day}$, $SpdStd_{Night}$, $SpdStd_{MTWT}$, and $SpdStd_{FSS}$.

$$S1 = \sqrt{\sum_{i=1}^{n} (w_i s_i)^2}$$

Figure 5. Equation. Aggregated speed standard deviation variable.

Where:

$S1$ = aggregated speed measurement variable.
n = number of unique TMC names of an RID segment.
w_i = normalized effective ratio of the ith TMC name of an RID segment.
s_i = speed measurement value of the ith TMC name an RID segment.

Figure 6 is applied to the following speed measurement variables: average operating speed (SpdAve), 85th percentile operating speed (Spd85), RefSpd, average operating speed during daytime ($SpdAve_{Day}$), average operating speed determined during nighttime ($SpdAve_{Night}$), average operating speed during weekdays ($SpdAve_{MTWT}$), average operating speed during weekend ($SpdAve_{FSS}$), average free-flow operating speed (SpdFFAve), and 85th percentile free-flow operating speed (SpdFF85).

$$S2 = \sum_{i=1}^{n} w_i s_i$$

Figure 6. Equation. Aggregated average speed variable.

Where $S2$ is the aggregated speed measurement variable.

WASHINGTON DATA

The work for Washington data with RID roadway characteristics, NPMRDS speed measure, and crash events count mainly includes six major parts:

1. Prepare a homogeneous roadway segment dataset with necessary roadway features from the RID (ISU 2023).
2. Conflate the segment dataset with the NPMRDS dataset (RITIS 2023).
3. Calculate the speed measure.
4. Assign the points events.
5. Process the final combination process.
6. Add the horizontal and vertical alignment information.

The team considered three types of roadways in this study: undivided roadways, divided freeways, and divided non-freeways. The team conducted the data preparation process on these three roadway types separately.

Part 1: Preparation of Homogeneous Roadway Segments

Two steps were involved in part 1. In the first step, a base layer was created to classify roadways into different facility types. A data conflation method was applied to prepare the base layers. For undivided roadways, the RID layer "Links" was used to develop the base layer for the undivided roadway (ISU 2023). All undivided roadways were selected by setting "to_lane" > 0 and "from_lane" > 0. The base layer of undivided roadways contains information for number of lanes, urban or rural location, and presence of a two-way, left-turn lane (TWLTL).

For divided roadways, the RID layer "RW_DividedHighway2010" was used to develop the base layer for the divided roadway. The base layer contains information for functional class, number of lanes, median width, and presence of TWLTL. All divided roadways can be separated into freeways and non-freeways based on their functional class.

In the second step, additional data can be conflated to the based layers prepared in the first step using the data conflation method. The data used for each roadway type and their corresponding source layer in the RID data warehouse are listed in table 5.

Table 5. Roadway features and layer names considered in the homogeneous segment data (Washington data).

Roadway Types	Data	RID Layers
Undivided	Lane width (RW_Lane)	RW_Lane
Undivided	Roadside fixed objects*	Signs
Undivided	Lighting/number of luminaires (lighting)	Lighting
Undivided	Horizontal curves#	RW_HorizontalAlignment2010
Undivided	Outside shoulder width	RW_Shoulder2010
Undivided	Posted speed/speed category	RW_Legalspeedlimit2010
Undivided	Highway rail grade crossings*	RW_RailCrossing2010
Undivided	Shoulder width and type	RW_Shoulder2010
Undivided	Centerline rumble strips	RumbleStrip
Undivided	Grades#	RW_VerticalAlignment2010
Undivided	Superelevation#	RW_HorizontalAlighment2010
Divided non-freeway	Lane width	RW_Lane
Divided non-freeway	Roadside fixed objects*	Signs ()
Divided non-freeway	Lighting/number of luminaires (lighting)	Lighting
Divided non-freeway	Median barrier	Barrier

Roadway Types	Data	RID Layers
Divided non-freeway	Outside shoulder width	RW_Shoulder2010
Divided non-freeway	Posted speed/speed category	RW-Legalspeedlimit2010
Divided non-freeway	Highway rail grade crossings*	RW_RailCrossing2010
Divided non-freeway	Shoulder width and type	RW-Shoulder2010
Divided freeway	Lane width	RW_Lane2010
Divided freeway	Horizontal curves#	RW_HorizontalAlignment2010
Divided freeway	Median barrier	Barrier
Divided freeway	Outside shoulder width	RW_Shoulder2010
Divided freeway	Inside shoulder width	RW_Shoulder2010
Divided freeway	Outside barrier	Barrier
Divided freeway	Shoulder rumble strips	RumbleStrip

*Points layers were added to the data in step 4.
#Horizontal and vertical alignment information were added in step 5.
RW = roadway.

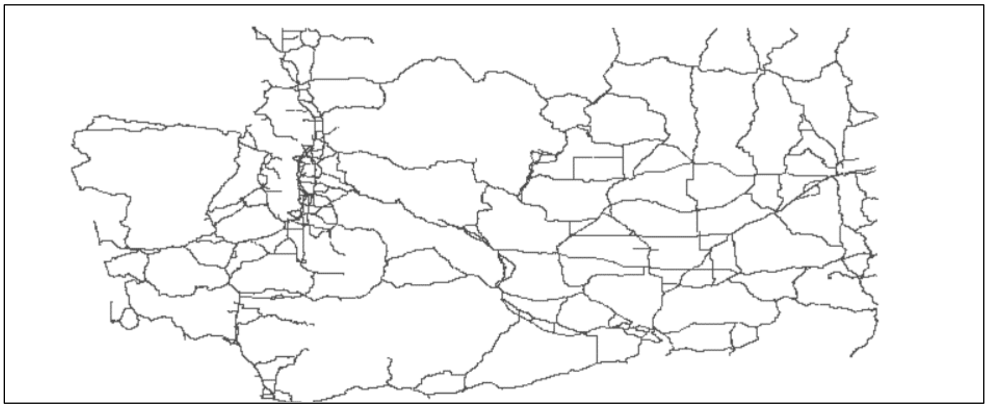
The data conflation method has the following five steps as discussed in detail:

1. Export each layer into a DBF (ArcGIS) (Esri 2020).
2. Dissolve the exported DBFs (ArcGIS).
3. Adjust the dissolved DBF tables (Python) (Python Software Foundation 2023).
4. Overlay the tables (ArcGIS).
5. Export to SHP file (ArcGIS).

Step 1: Export Each Layer into a DBF (ArcGIS)

Taking lane as an example (figure 7), in this step, the project team excluded unnecessary fields from the original lane layer and only kept those needed for the project (i.e., number of lanes and lane width in each direction, route ID, and from/to measures).

The project team has applied a few filters in the original layer to reduce nonexisting routes and eliminate duplicated polylines. The filters are illustrated in table 5 (last column).



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A. Polylines of lane layer.

RW_Lanes2010					
OBJECTID*	**Shape***	**ElementID***	**SourceID**	**DataSourceID**	**DataDate**
1	Polyline M	{F0C2F962-FE21-4E7E-8F51-3BA9AF4034B2}	<Null>	2	12:00:00 AM
2	Polyline M	{802D7217-C2A3-41C0-840C-AEDBF2B04A83}	<Null>	2	12:00:00 AM
3	Polyline M	{C4EC13F1-15F8-4212-AE82-8FF0CBBC9B2B}	<Null>	2	12:00:00 AM
4	Polyline M	{6097E95B -1E61-40B7-9300-5E6512BE6920}	<Null>	2	12:00:00 AM
5	Polyline M	{C0C018E5-63F0-472A-B8C3-D6303D3FB580}	<Null>	2	12:00:00 AM
6	Polyline M	{0F3FE962-2E95-4916-A757-9D90DC488B39}	<Null>	2	12:00:00 AM
7	Polyline M	{CC3A57E4-4091-4892-B7E5-D4A24D28C75A}	<Null>	2	12:00:00 AM
8	Polyline M	{E633E831-6CE6-475B-BAF8-801476003497}	<Null>	2	12:00:00 AM
9	Polyline M	{1349302B-E8BA-4494-B945-95048541F809}	<Null>	2	12:00:00 AM
10	Polyline M	{2CBA000F-CC50-409D-A305-2D82F982335B}	<Null>	2	12:00:00 AM
11	Polyline M	{0C4D366E-8A0B-455B-A9A3-9E4EAF2E3663}	<Null>	2	12:00:00 AM
12	Polyline M	{2BBDBF78-3B59-4512-9DDE-A9AC33856D74}	<Null>	2	12:00:00 AM

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B. Original attribute table for lane.

03_LN						
rdwywidthd	**numinsdec**	**rdwywidthi**	**numinsinc**	**RouteID**	**ToMeasure**	**FrMeasure**
12	1	12	1	46	1192.9	0
11	1	11	1	92	32595.7	0
13	1	13	1	92	32750.5	32595.7
11	1	11	1	92	33245.6	32750.5
22	2	22	2	92	33487.7	33245.6
28	2	28	2	92	37583.6	33487.7
12	1	24	2	92	41074.1	37583.6
12	1	12	1	92	52153	41074.1
18	1	18	1	92	52258.5	52153
12	1	12	1	92	53563.1	52258.5
18	1	18	1	92	53665	53563.1
12	1	12	1	92	79183.8	53665
19	1	19	1	92	80032	79183.8
12	1	12	1	92	82809.9	80032

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C. Exported DBF table with necessary fields.

Figure 7. Screenshot. Export RID layers to DBFs (Esri 2020).

Step 2: Dissolve the Exported DBFs (ArcGIS)

The main purpose of dissolving a DBF is to combine continuous segments with the same roadway feature on the same route into a longer segment. This practice will reduce the number of segments in the final database, making it easier and more accurate for the analyses. The dissolving function is illustrated in figure 8.

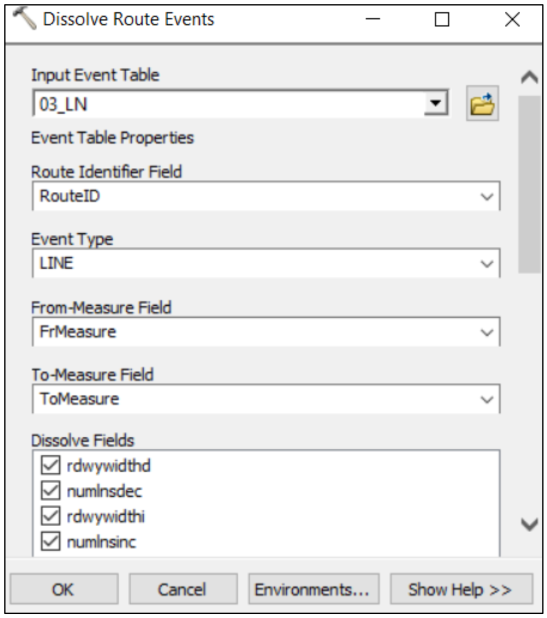

Figure 8. Screenshot. Dissolving a DBF table (Esri 2020).

Step 3: Adjust the Dissolved DBF Tables (Python)

The main purpose of this step is to address the overlapping issue in the dissolved DBF tables. While processing the data, the research team realized that some polylines overlapped in the original layer data, which made the number of segments increase exponentially and brought challenges to the segment data preparation.

The research team developed a Python-based program to eliminate the overlapping issue. The basic concept was to identify overlapped segments and adjust the from/to measure of one segment. An example is illustrated in table 2.

In table 2, the two segments are overlapping, i.e., both contain 5.8–6.0 on RouteID 2 (see original segments). The overlapping issue will make ArcGIS crash and increase the number of segments (in the next step) exponentially. With the Python-based program, the FrMeasure of the second segment is adjusted as 6.0 (see adjusted segments in table 2).

Step 4: Overlay the Tables (ArcGIS)

The objective of overlaying two DBF tables is to create an output DBF table (i.e., event table) that represents the union of the input. (This step is also known as dynamic segmentation.) The research team applied "union" in the overlaying process, such that all the segments (even some features missing in the original dataset) could be included in the final segment dataset. Figure 9 shows how the lane table is overlaid with other tables.

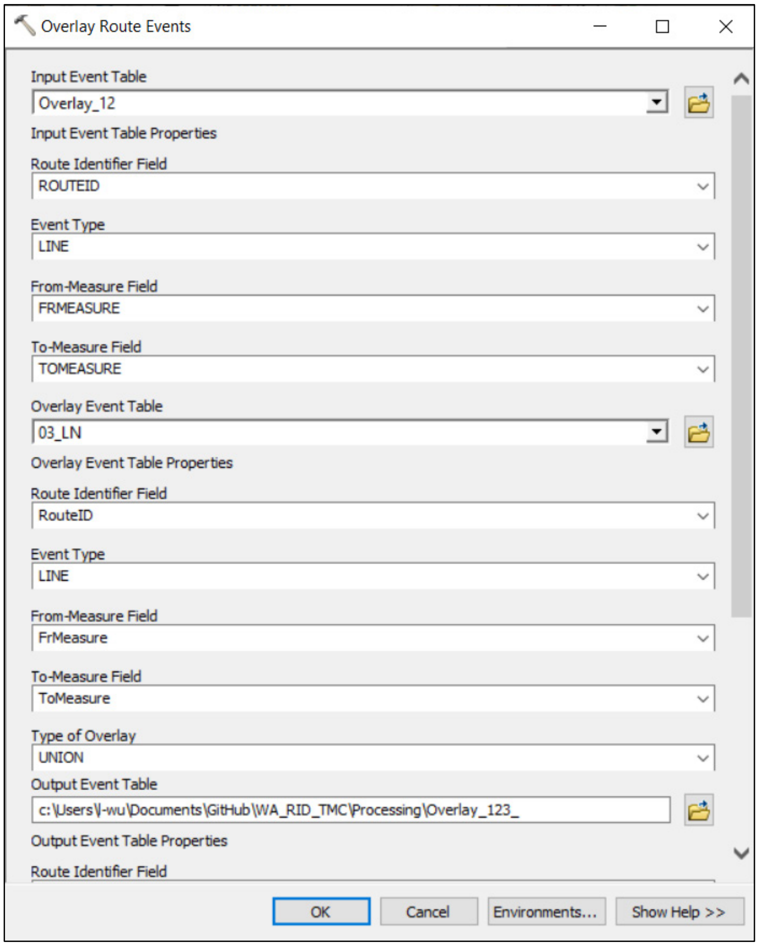

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Figure 9. Screenshot. Overlaying DBF tables (Esri 2020).

Step 5: Export to SHP File (ArcGIS)

Once all the features mentioned in table 5 are overlaid, the final DBF table can be displayed based on the route layer (i.e., "Routes" in the RID) data, and the layer is then exported as a separate SHP file (ISU 2023). The SHP file includes homogenous roadway segments in Washington (State-maintained highways). The roadway segments table is illustrated in table 6.

Table 6. Overlaid homogenous roadway segments (example).

Route ID	From	To	fun_cls	Divided	rd_wid_dec (ft)	num_lan_dec (No.)	rd_wid_inc (ft)	num_lan_inc (No.)	shd_wid (ft)	shd_typ	med_wid (ft)
92	15,280	16,871.3	R1	0	11	1	11	1	8	Paved	0
92	16,871	18,564.8	R1	0	11	1	11	1	8	Paved	0
92	60,632	61,160.4	R1	0	12	1	12	1	8	Paved	0
92	58,193	60,630.6	R1	0	12	1	12	1	8	Paved	0
92	67,278	67,471.1	R1	0	12	1	12	1	8	Paved	0
92	67,471	68,624.31	R1	0	12	1	12	1	8	Paved	0
92	24,064	24,275.4	R1	0	11	1	11	1	8	Paved	0
92	516	667.5	R1	0	11	1	11	1	8	Paved	0
92	416	515.7	R1	0	11	1	11	1	8	Paved	0
92	100	415.6	R1	0	11	1	11	1	0	NA	0
92	24,370	24,576.2	R1	0	11	1	11	1	8	Paved	0
92	61,160	67,278.1	R1	0	12	1	12	1	8	Paved	0

fun_cls = functional class; rd_wid_dec = roadway width (decreasing direction); num_lan_dec = number of lanes (decreasing direction); rd_wid_inc = roadway width (increasing direction); num_lan_inc = number of lanes (increasing direction); shd_wid = shoulder width; shd_typ = shoulder type; med_wid = median width; R1 = rural two lane; NA = not applicable.

Part 2: Segment and NPMPRD Datasets Conflations

Conflation of NPMRDS Networks

In this step, the research team integrated two linear systems (NPMRDS and segment polyline files) to enable segment-based analysis with speed measures (RITIS 2023). This study uses two formats of segment files: roadway line work without roadway characteristics (i.e., routes), and roadway line work with roadway characteristics (i.e., roadway segments created in the first step). In the former file, each route is a continuous polyline in the GIS database (Esri 2020), and the file includes only the basic information for the route (e.g., route name, beginning and ending mileposts). In the latter file, routes are split into various numbers of homogeneous segments with roadway assets or features (e.g., functional class, lane, shoulder, PSL, presence of rumble strips, and lighting situation).

The conflation work considered the 2018 NPMRDS file in Washington and the homogeneous segment file created from the Washington RID data in the first step (ISU 2023). The research team used two software packages (ArcGIS and R) to conflate these databases (Esri 2020; R Core Team 2023). The researchers took the following steps in this task.

Step 1: Divide the NPMRDS File by Direction

In this step, the research team divided the NPMRDS file into two files: positive and negative (RITIS 2023). The direction of the NPMRDS segments is determined by the TMC name: "+" or "P" indicates positive, and "−" or "N" indicates negative (figure 3).

Step 2: Locate NPMRDS Segments Along with Roadway Routes

In this step, the research team used one direction of NPMRDS files as the input feature and roadway route line work without roadway characteristics as the input route feature and then located the NPMRDS segments on the roadway routes (RITIS 2023). The event table generated from the locating process was exported as a csv file. Each direction of NPMRDS was located separately (figure 4).

Step 3: Refine the Event Table

In step 2, the two files (i.e., NPMRDS and Routes) were located based on spatial relationships (RITIS 2023). A few segments were mismatched in the process. Step 4 eliminated the mismatched events based on the roadway information and spatial matching results. In the refined event table, each NPMRDS segment had a route name and beginning and ending mileposts relative to the roadway route line work.

Step 4: Create the Final Table

The research team refined the event table and roadway line work with roadway characteristics. In this step, the association between NPMRDS segments and roadway segments with roadway characteristics was created based on the route name and mileposts (RITIS 2023). For each roadway segment, the data from NPMRDS segments were collected. The information included the TMC name and the effective length ratio of the TMC matching with the roadway segment (table 3).

The researchers took similar steps for the conflation of the roadway routes, segments, and NPMRDS in the negative direction. The current data conflation work is limited to the quality of the original RID data as well as the NPMRDS dataset (ISU 2023; RITIS 2023). For example, if a roadway feature is missing in the RID data, the feature will be shown as "NA" or "0" in the final conflated dataset. A few segments had two or more entries in the attribute table, and so the information contradicted with each other. Subsequently, the research team made some assumptions.

Part 3: Speed Measure Calculation

The research downloaded 3 yr of speed measure data (2017–19) from NPMRDS by using the TMC number from step 2 (RITIS 2023). First, the research team developed an R code to summarize the 3-yr speed measure for each TMC name. Speed measures used in this study are in table 4.

In part 2, each roadway segment has both negative and positive TMC names, and some roadway segments have more than one negative or positive TMC names. This situation leads to each roadway segment having more than one set of speed measure data. The research team developed another R code to calculate the weighted average of all the speed measure attributes for each unique roadway segment. The original speed measure file was merged with the roadway segments with NPMRDS information file created in part 2. Then, the speed measure data were grouped by unique ID, and the weighted average values of all speed measure attributes in table 4 were calculated based on the effective ratio of each TMC. The weighted average calculation methods for SpdStd, $SpdStd_{Day}$, $SpdStd_{Night}$, $SpdStd_{MTWT}$, and $SpdStd_{FSS}$ are different from other speed measure attributes.

Like Washington data, figure 5 is applied to the following speed measurement variables: SpdStd, $SpdStd_{Day}$, $SpdStd_{Night}$, $SpdStd_{MTWT}$, and $SpdStd_{FSS}$.

Figure 6 is applied to the following speed measurement variables: SpdAve, Spd85, RefSpd, $SpdAve_{Day}$, $SpdAve_{Night}$, $SpdAve_{MTWT}$, $SpdAve_{FSS}$, SpdFFAve, and SpdFF85.

Moreover, three new columns were added to the database, namely "num_tmc_n," "num_tmc_p," and "ratio_tmc_n_p." "num_tmc_n" indicates the number of negative TMCs for each unique ID, "num_tmc_p" indicates the number of positive TMC for each unique ID, and "ratio_tmc_n_p" indicates the ratio between the sum of negative TMCs' effective ratio and the sum of positive TMCs' effective ratio.

Part 4: Crash and Point Events Assignment

The research team downloaded Washington crash data from 2017 to 2018. The crash events SHP files contained information for crash date, crash severity, and the latitude and longitude of the crash events. The research team first applied the near feature tool in ArcMap (Esri 2020) (figure 10) to assign crash events to roadway segments that were created in part 1. Each crash was assigned an attribute named "Near_FID," which is the FID number (roadway segment corresponding row number starting from 0 in the crash characteristics file) of the roadway segment on which the crash event happened. For “Near_FID,” the research team chose 30 ft as the threshold to determine if a crash event happened on a roadway segment, meaning only if a crash event is within 30 ft of a roadway segment is this crash event assigned to this specific roadway segment. If a crash event cannot be assigned to any roadway segment, its “Near_FID” attribute would be equal to −1. The research team filtered out the crash events whose “Near_FID” equaled −1 because they cannot be connected with any roadway segments. This method may cause some inaccuracy, especially in urban areas where roadway segments are close to each other.

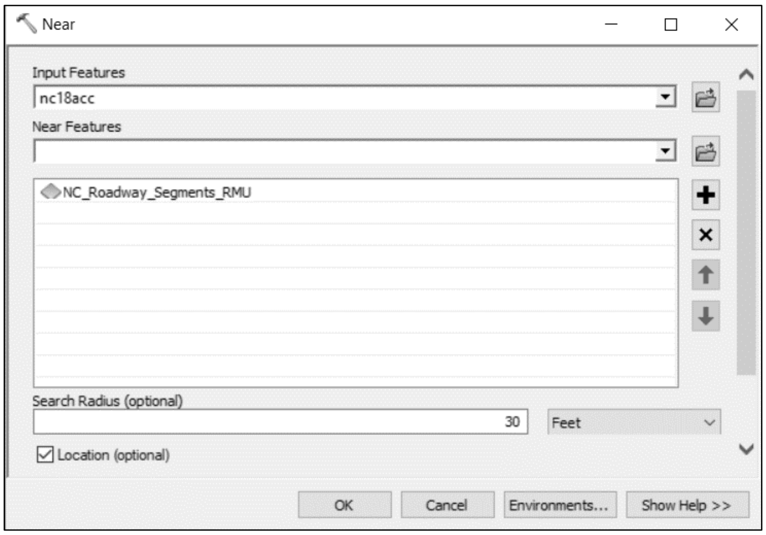

Figure 10. Screenshot. Near (analysis) tool (Esri 2020).

After crash events were assigned to roadway segments for both 2017 and 2018, the research team summarized the total number of crashes that happened on each roadway segment based on crash severity. The crash severity levels range from 0 to 7, and thus for each “Near_FID” number the research team summarized 14 new columns named “crash_17_0,” “crash_17_1,” … “crash_18_5 “crash_18_6,” and “crash_18_7” (table 7). For example, the column “crash_17_1” indicates the number of severity level 1 crash that happened during 2017.

Table 7. Crash summary for each "Near_FID" (partially displayed).

Near_FID	Crash_17_0	Crash_17_1	Crash_18_5	Crash_18_6	Crash_18_7
1	0	0	0	0	0
4	0	0	0	0	3
8	0	0	0	0	0
9	0	0	0	0	0
10	0	0	0	0	2
11	0	0	0	0	0
15	0	0	0	0	0
17	0	0	0	0	1
20	0	0	0	0	1
21	0	0	0	2	4
22	0	0	0	0	1
25	0	0	1	1	4

Note: the values represent number of crashes.

Part 5: Final Combination Process

In part 1, the research team created the file for roadway segments with roadway characteristics, and each unique roadway segment was assigned a unique ID. In part 3, the research team assigned crash events to each roadway segment. The number of crash events was summarized by crash severity level for each "Near_FID." In this case, "Near_FID" indicates the corresponding roadway segment's row number (starting from 0) in the roadway characteristics file from part 1. Thus, to connect the "unique_id" column with the "Near_FID" column, the research team added a new column "Near_FID" to the roadway characteristics file. Because in R the row number starts from 1, "Near_FID" equals "row number 1" in the calculation. Then, crash event files were joined to the roadway characteristics file by "Near_FID." In part 4, speed measures were calculated for each unique ID. Thus, the speed measure file was joined to the roadway characteristics file by unique ID.

Part 6: Horizontal and Vertical Alignment Information Assignment

The final step was to add horizontal and vertical information to the dataset prepared by the previous steps. Horizontal alignment information was selected from RID layer "RW_HorizontalAlignment2010," and vertical alignment information was selected from RID layer "RW_VerticalAlignment2010" (ISU 2023). These two tables were processed by an R code developed by the research team. The final output includes six additional columns (table 8).

Table 8. Horizontal and vertical alignment-related columns.

Column Names	Definition
Num_HC	Number of horizontal curves
MinR	Minimum radius
MaxR	Maximum radius
MeanR	Mean radius
StdR	Standard deviation of radius
Maxe	Maximum superelevation

NORTH CAROLINA DATA

The work for North Carolina data with RID roadway characteristics, NPMRDS speed measures, and crash event counts mainly includes six major parts (ISU 2023; RITIS 2023):

1. Prepare a homogeneous roadway segment dataset with necessary roadway features from the RID.
2. Conflate the segment dataset with the NPMRDS dataset.
3. Calculate the speed measure.
4. Assign the points events.
5. Process the final combination process.
6. Add the horizontal and vertical alignment information.

Three types of roadways were considered in this study: undivided roadways, divided freeway, and divided non-freeway. The team conducted the data preparation process on these three roadway types separately.

Part 1: Preparation of Homogeneous Roadway Segments

Two steps were involved in part 1. In the first step, a base layer was created to classify roadways into different facility types. A data conflation method was applied to prepare the base layers. For undivided roadways, RID layer "Links" was used to develop the base layer for undivided roadways (ISU 2023). All undivided roadways were selected by setting "to_lane" > 0 and "from_lane" > 0. The base layer of undivided roadways contains information for number of lanes, urban or rural location, and presence of TWLTL.

For divided roadways, the research team combined the information from the HSIS layer and RID layer to obtain as much information as possible (FHWA n.d.; ISU 2023). The RID layer "Route" was used to develop the base layer for the divided roadway. The base layer contains information for functional class, number of lanes, median width, shoulder width, and facility type. All divided roadways can be separated into freeways and non-freeways based on their facility type.

In the second step, additional data can be conflated to the based layers prepared in the first step using the data conflation method. The data used for each roadway type and their corresponding source layer in the RID data warehouse are partially listed in table 9.

Table 9. Roadway features and layer names considered in the homogeneous segment data (North Carolina data).

No.	Roadway Feature	RID Layer Name	Filter(s)
1	Functional class	Links and HSIS layer	"RouteID" > 0
2	Road location (urban or rural)	UrbanRural	"RouteID" > 0
3	Lane	Lane_ReducedDataset and HSIS layer	"RouteID" > 0
4	Shoulder	Rd_Char	"RouteID" > 0
5	Lighting	Mobile_HPMS_Presence_Reduced Dataset	"RouteID" > 0
6	Median	Mobile_HPMS_Presence_Reduced Dataset	"RouteID" > 0
7	Rumble strip	RumbleStrip	"RouteID" > 0
8	PSL	Rd_Char	"RouteID" > 0
9	Divided or undivided	Links and HSIS layer	Undivided: "to_lanes" and "from_lanes" > 0 Divided: Otherwise
10	Acceleration or deceleration	Lane	"RumbleStripLocation" = Centerline "RouteID" > 0
11	Facility type	Tops and HSIS layer	"RouteID" > 0
12#	Horizontal curve	Alignment	"RouteID" > 0
13*	Base roadway network	Links	—

—No data.
*Points layers were added to the data in step 4.
#Horizontal and vertical alignment information were added in step 5.

The data conflation method has the following five steps as discussed in detail:

1. Export each layer into a DBF (ArcGIS) (Esri 2020).
2. Dissolve the exported DBFs (ArcGIS).
3. Adjust the dissolved DBF tables (Python) (Python Software Foundation 2023).
4. Overlay the tables (ArcGIS).
5. Export to SHP file (ArcGIS).

Step 1: Export Each Layer into a DBF (ArcGIS)

Taking lane as an example (figure 7), in this step, the project team excluded unnecessary fields from the original lane layer and only kept those needed for the project (i.e., number of lanes and lane width in each direction, route ID, and from/to measures).

The project team has applied a few filters in the original layer to reduce nonexisting routes and eliminate duplicated polylines. The filters are illustrated in table 8 (last column).

Step 2: Dissolve the Exported DBFs (ArcGIS)

The main purpose of dissolving a DBF is to combine continuous segments with the same roadway features on the same route into a longer segment. This practice will reduce the number of segments in the final database, making it easier and more accurate for the analyses. The dissolving function is illustrated in figure 8.

Step 3: Adjust the Dissolved DBF Tables (Python)

The main purpose of this step is to address the overlapping issue in the dissolved DBF tables. While processing the data, the research team realized that some polylines overlapped in the original layer data, which made the number of segments increase exponentially and brought challenges to the segment data preparation.

The research team developed a Python-based program to eliminate the overlapping issue. The basic concept was to identify overlapped segments and adjust the from/to measure of one segment. An example is illustrated in table 2.

In table 2, the two segments are overlapping, i.e., both contain 5.8–6.0 on RouteID 2 (see original segments). The overlapping issue will make ArcGIS crash and increase the number of segments (in the next step) exponentially. With the Python-based program, the FrMeasure of the second segment is adjusted as 6.0 (see adjusted segments in table 2).

Step 4: Overlay the Tables (ArcGIS)

The objective of overlaying two DBF tables is to create an output DBF table (i.e., event table) that represents the union of the input. (This step is also known as dynamic segmentation.) The research team applied "union" in the overlaying process, such that all the segments (even some features missing in the original dataset) could be included in the final segment dataset. Figure 9 shows how the lane table is overlaid with other tables.

Step 5: Export to SHP File (ArcGIS)

Once all the features mentioned in table 5 are overlaid, the final DBF table can be displayed based on the route layer (i.e., "Routes" in the RID) data, and the layer is then exported as a separate SHP file (ISU 2023). The SHP file includes homogenous roadway segments in North Carolina (State-maintained highways). The roadway segments table is illustrated in table 6.

Part 2: Segment and NPMPRD Datasets Conflations

Conflation of NPMRDS Networks

In this step, the research team integrated two linear systems (NPMRDS and segment polyline files) to enable segment-based analysis with speed measures. This study uses two formats of segment files: roadway line work without roadway characteristics (i.e., routes), and roadway line work with roadway characteristics (i.e., roadway segments created in the first step). In the former file, each route is a continuous polyline in the GIS database (Esri 2020), and the file includes only the basic information for the route (e.g., route name, begin and end mileposts). In the latter file, routes are split into various numbers of homogeneous segments with roadway assets or features (e.g., functional class, lane, shoulder, PSL, presence of rumble strips, and lighting situation).

The conflation work considered the 2018 NPMRDS file in North Carolina and the homogeneous segment file created from the North Carolina RID data in the first step (ISU 2023; RITIS 2023). The research team used two software packages (ArcGIS and R) to conflate these databases (Esri 2020; R Core Team 2023). The following steps were taken in this task.

Step 1: Divide the NPMRDS File by Direction

In this step, the research team divided the NPMRDS file into two files: positive and negative (RITIS 2023). The direction of the NPMRDS segments is determined by the TMC name: "+" or "P" indicates positive, and "−" or "N" indicates negative (figure 3).

Step 2: Locate NPMRDS Segments Along with Roadway Routes

In this step, the research team used one direction of NPMRDS files as the input feature and roadway route line work without roadway characteristics as the input route feature and then located the NPMRDS segments on the roadway routes (RITIS 2023). The event table generated from the locating process was exported as a csv file. Each direction of NPMRDS was located separately (figure 4).

Step 3: Refine the Event Table

In step 2, the two files (i.e., NPMRDS and Routes) were located based on spatial relationships (RITIS 2023). A few segments were mismatched in the process. Step 4 eliminated mismatched events based on the roadway information and spatial matching results. In the refined event table, each NPMRDS segment had a route name and beginning and ending mileposts relative to the roadway route line work.

Step 4: Create the Final Table

The research team refined the event table and roadway line work with roadway characteristics. In this step, the association between NPMRDS segments and roadway segments with roadway characteristics was created based on the route name and mileposts (RITIS 2023). For each roadway segment, the data from NPMRDS segments were collected. The information included the TMC name and the effective length ratio of the TMC matching with the roadway segment (table 3).

The researchers took similar steps for the conflation of the roadway routes, segments, and NPMRDS in the negative direction. The current data conflation work is limited to the quality of the original RID data as well as the NPMRDS dataset (ISU 2023; RITIS 2023). For example, if a roadway feature is missing in the RID data, the feature will be shown as "NA" or "0" in the final conflated dataset. A few segments had two or more entries in the attribute table, and so the information contradicted with each other. Subsequently, the research team made some assumptions.

Part 3: Speed Measure Calculation

The research downloaded 3 yr of speed measure data (2017–19) from NPMRDS by using the TMC number from step 2 (RITIS 2023). First, the research team developed an R code to summarize the 3-yr speed measure for each TMC name. Speed measures used in this study are in table 4.

In part 2, each roadway segment has both negative and positive TMC names, and some roadway segments have more than one negative or positive TMC name. This situation leads to each roadway segment having more than one set of speed measure data. The research team developed another R code to calculate the weighted average of all the speed measure attributes for each unique roadway segment. The original speed measure file was merged with the roadway segments with the NPMRDS information file created in part 2. Then, the speed measure data were grouped by unique ID, and the weighted average values of all speed measure attributes in table 4 were calculated based on the effective ratio of each TMC. The weighted average calculation methods for SpdStd, $SpdStd_{Day}$, $SpdStd_{Night}$, $SpdStd_{MTWT}$, and $SpdStd_{FSS}$ are different from other speed measure attributes.

Like Washington data, figure 5 is applied to the following speed measurement variables: SpdStd, $SpdStd_{Day}$, $SpdStd_{Night}$, $SpdStd_{MTWT}$, and $SpdStd_{FSS}$.

Figure 6 is applied to the following speed measurement variables: SpdAve, Spd85, RefSpd, $SpdAve_{Day}$, $SpdAve_{Night}$, $SpdAve_{MTWT}$, $SpdAve_{FSS}$, SpdFFAve, and SpdFF85.

Moreover, three new columns were added, namely "num_tmc_n," "num_tmc_p," and "ratio_tmc_n_p." "num_tmc_n" indicates the number of negative TMC for each unique ID, "num_tmc_p" indicates the number of positive TMC for each unique ID, and "ratio_tmc_n_p" indicates the ratio between the sum of negative TMCs' effective ratio and the sum of positive TMCs' effective ratio.

Part 4: Crash and Point Events Assignment

The research team downloaded North Carolina crash data from 2017 to 2018. The crash events SHP files contained information for crash date, crash severity, and the latitude and longitude of the crash events. The research team first applied the near feature tool in ArcMap (Esri 2020) (figure 10) to assign crash events to roadway segments that were created in part 1. Each crash was assigned an attribute named "Near_FID," which is the FID number (roadway segment corresponding row number starting from 0 in the crash characteristics file) of the roadway segment on which the crash event happened. For "Near_FID," the research team chose 30 ft as the threshold to determine if a crash event happened on a roadway segment, meaning only if a crash event is within 30 ft of a roadway segment is this crash event assigned to this specific roadway segment. If a crash event cannot be assigned to any roadway segment, its "Near_FID" attribute would be equal to −1. The research team filtered out the crash events whose "Near_FID" equaled −1 because they cannot be connected with any roadway segments. Note that this method may cause some inaccuracy, especially in urban areas where roadway segments are close to each other.

After crash events were assigned to roadway segments for both 2017 and 2018, the research team summarized the total number of crashes that happened on each roadway segment based on crash severity. The crash severity levels range from 0 to 7, and crash types were categorized as single vehicle (SV), multiple vehicle (MV), and unknown (UO) (American Association of State Highway and Transportation Officials (AASHTO) 2010). Therefore, for each "Near_FID" number, the research team summarized 36 new columns named "SV_17_0," "SV_17_1," … "UO_18_5," "UO_18_6," and "UO_18_7" (table 7). For example, the column "SV_17_1" indicates the number of severity level 1 crashes that happened during 2017 with an SV crash type.

Part 5: Final Combination Process

In part 1, the research team created the file for roadway segments with roadway characteristics, and each unique roadway segment was assigned a unique ID. In part 3, the research team assigned crash events to each roadway segment. The number of crash events was summarized by crash severity level for each "Near_FID." In this case, "Near_FID" indicates the corresponding roadway segment's row number (starting from 0) in the roadway characteristics file from part 1. Thus, to connect the "unique_id" column with the "Near_FID" column the research team added a new column "Near_FID" to the roadway characteristics file. Because in R the row number starts from 1, "Near_FID" equals "row number 1" in calculations. Then, crash event files were joined to the roadway characteristics file by "Near_FID." In part 4, speed measures were calculated for each unique ID. Thus, the speed measure file was joined to the roadway characteristics file by unique ID.

Part 6: Horizontal and Vertical Alignment Information Assignment

The final step was to add horizontal and vertical information to the dataset prepared by the previous steps. Horizontal alignment information was selected from RID layer "Tops," and vertical alignment information was selected from RID layer "Tops" (ISU 2023). These two tables were processed by an R code developed by the research team. The final output includes six additional columns (table 8).

APPENDIX B. SUPPORTING TABLES

This appendix lists several supporting tables for chapter 1 through chapter 3 of the main report (Das et al. 2024). These tables offer a comprehensive overview of various studies and data analyses, illustrating key concepts and findings related to speed-crash associations, data needs for specific road types, and calibration factors for crash type and severity levels. Specifically:

- Table 10 presents various studies on the speed-crash association, detailing their findings and impacts on crashes.
- Table 11 to table 16 outline the data needs for different types of road segments, such as undivided, rural two-lane roads and urban arterials, detailing the base conditions and availability status of various data items.

Table 10. Studies on speed-crash association.

Study	Finding	Effect on Crashes
Hauer 1971; Nilsson 2004; Elvik, Christensen and Amundsen 2004	The average operating speed is positively correlated with the crash rate and more so with the crash severity.	↑
Solomon 1974	On rural highways, crash likelihood increases as the difference between an individual driver's speed and the SpdAve on the road increases.	↑
Lave 1985	The crash severity might increase because of the variance in the speed and not because of the higher speed.	↑
Baum, Lund, and Wells 1989	Fatalities on rural interstates with higher speed limits were 15 percent more than the expected value.	↑
Farmer, Retting, and Lund 1997	Increase in fatalities occurred due to speed limit increase from 70 to 75 mph (on freeway segments).	↑
Vernon et al. 2004	The crash rate for urban interstates and the fatality rate for non-freeway highways increased due to raised speed limits.	↑
Kweon and Kockelman 2005	A hypothetical 5 mph speed limit increase on the road with average characteristics would not have a statistically significant impact on the count of fatal crashes.	→
Kockelman et al. 2006	A 1-percent increase in the total crash numbers and a 13-percent increase in the fatal crash count were associated with the speed limit increase from 65 to 75 mph.	↑
Taylor, Lynam, and Baruya 2008	The mean speed measure was negatively related to crash frequency at the aggregate level.	↓

Study	Finding	Effect on Crashes
Malyshkina and Mannering 2008	The increased speed limits on rural interstates did not significantly affect crash severities.	→
Rosen and Sander 2009	Fatality risks are highly associated with impact speed.	↑
Bonneson, Pratt, and Miles 2009	The advisory speed limit should be based on the mean operating speed of the truck drivers.	—
Elvik 2010	Speed regulation measures are crucial in assisting for proper speed choices while driving.	—
Jaarsma et al. 2011	A statistically significant overall reduction in fatal and fatal plus injury crashes occurred due to lowering speed limits in the Netherlands.	↑
Pei, Wong, and Sze 2012	As speed measures increase, crashes decrease.	↓
Yu et al. 2013	A negative relationship exists between speed and crash occurrence.	↓
De Pauw et al. 2014	A nonsignificant reduction in injury and severe injury crashes occurred due to lower speed limits in Belgium.	→
Montella and Imbriani 2015	Speed variance should be considered in crash data analysis.	—
Gargoum and El-Basyouny 2016	SpdStd has a negative likelihood of crash occurrences.	↓
Sayed and Sacchi 2016	Speed limit increases are associated with a statistically significant 11-percent increase in fatal and injury crashes in Canada.	↑
Imprialou, Quddus, and Pitfield, 2016	SV crashes of all severities and fatal or severe injury crashes involving MVs increased due to speed limit increase in the United Kingdom.	↑
Imprialou et al. 2016	For the condition-based approach, speed measures are associated with crashes. For the segment-based approach, the speed-crash relationship is negative, regardless of crash severity.	↑↓
Wang et al. 2018	A 1.0-percent increase in SpdAve was associated with a 0.70-percent increase in total crashes.	↑
De Pauw et al. 2018	The number of injury crashes decreased significantly with the implementation of variable speed limits.	↑
Monsere, Kothuri, and Anderson 2018	Average operating speeds increased with the increase of PSL.	—
Vadeby and Forsman 2018	A speed limit decrease had mixed results.	↑↓
Yu et al. 2018	Crash and speed have a negative relationship.	↓

Study	Finding	Effect on Crashes
Dimaiuta et al. 2018; Banihashemi et al. 2019	The severity of crashes measured by the KABC/total crashes ratio increases by increasing the speed differential.	↓
Tarko, Pineda-Mendez, and Guo 2019	Speed limit was found to affect mobility and safety mostly in noncongested traffic conditions, whereas no significant effects were found in congested conditions.	↑→
Dutta and Fontaine 2019	Lower mean speed is associated with higher crash frequency.	↓
Hutton et al. 2020	On U2U and U4D urban and suburban arterials, no clear predictive relationship could be identified. Speed variance may play more of a role in crash likelihood than speed does.	→
Das and Geedipally 2020; Das et al. 2020	Rural facility types were examined, and increases in different speed measures were positively correlated with an increase in crash frequency on most facility types, except rural interstates.	↑

—No data.
↑ = positive association.
↓ = negative association.
→ = no association.
U2U = two-lane undivided urban and suburban arterial segments; U4D = four-lane divided urban and suburban arterials (including a raised or depressed median).

Table 11. Data needs for data analysis (undivided rural two-lane, two-way roadway segments (R2U) facility type).

Data Item	Base Condition	Availability Status	Note
Segment length	—	Available	—
AADT	—	Available	—
Lane width	12 ft	Available	—
Shoulder width	6 ft	Available	—
Shoulder type	Paved	Available	—
Curve radius	None	Available	The dataset includes HC_Num, MinR, MaxR, MeanR, and StdDevR.*
Curve length	None	Need to estimate/assume	The length of the segment encompassing curve(s) is known.
Horizontal curve: presence of spiral transitions	None	Not available (use base condition)	The RID horizontal curve layer does not include spiral information.

Data Item	Base Condition	Availability Status	Note
Horizontal curve: superelevation	None	Available	Maximum superelevation is available from the horizontal curve layer.
Grades	0 percent	Available	Maximum grade (absolute value) is available from a vertical curve.
Driveway density	5 drives/mi	Not available (use base condition)	No driveway information is in the RID data.
Centerline rumble strips	None	Available	Centerline rumble strip is available.
Passing lanes	None	Not available (use base condition)	No passing lane information is in the lane layer of RID data.
TWLTLs	None	Available	An example is three-lane cross section
Roadside design	3	Not available (use base condition)	An example is roadside hazard rating (1–7 scale). No roadside information is in the RID data.
Lighting	None	Available	—
Automated speed enforcement	None	Not available (use base condition)	No speed enforcement information is in the RID data.
Speed data	—	Available (partially)	Sites with speed data were selected.
Crash data	—	Available	—

—Not applicable.
AADT = annual average daily traffic.
*See table 8 for definition of abbreviations.
Data are from SHRP2 RID (ISU 2023), NPMRDS (RITIS 2023), HSIS (FHWA n.d.), and the *Highway Safety Manual* (HSM) (AASHTO 2010).

Table 12. Data needs for data analysis (rural four-lane undivided segments (R4U) facility type).

Data Item	Base Condition	Availability Status	Note
Segment length	—	Available	—
AADT	—	Available	—
Lane width	12 ft	Available	—
Shoulder width	6 ft	Available	—
Shoulder type	Paved	Available	—
Side slopes	1V:7H or flatter	Not available (use base condition)	Side slopes are 1:2 or steeper and 1:3, 1:4, 1:5, 1:6, and 1:7 or flatter. No side slope is present in the RID.
Lighting	None	Available	—
Automated speed enforcement	None	Not available (use base condition)	No speed enforcement information is in the RID data.
Speed data	—	Available	Sites with speed data were selected.
Crash data	—	Available	—

—Not applicable.
V = vertical; H = horizontal.
Data are from SHRP2 RID (ISU 2023), NPMRDS (RITIS 2023), HSIS (FHWA n.d.), and the HSM (AASHTO 2010).

Table 13. Data needs for data analysis (rural four-lane divided segments (R4D) facility type).

Data Item	Base Condition	Availability Status	Note
Segment length	—	Available	—
AADT	—	Available	—
Lane width	12 ft	Available	—
Shoulder width	6 ft	Available	—
Shoulder type	Paved	Available	—
Median width	30 ft	Available	—
Lighting	None	Available	—
Automated speed enforcement	None	Not available (use base condition)	No speed enforcement information is in the RID data.
Speed data	—	Available (partially)	Sites with speed data were selected.
Crash data	—	Available	—

—Not applicable.
Data are from SHRP2 RID (ISU 2023), NPMRDS (RITIS 2023), HSIS (FHWA n.d.), and the HSM (AASHTO 2010).

Table 14. Data needs for data analysis (undivided urban and suburban arterials facility type).

Data Item	Base Condition	Availability Status	Note
Segment length	—	Available	—
AADT	—	Available	—
Number of through lanes	None	Available	—
Lane width	12 ft	Available	Item is needed for six-plus-lane arterials.
Outside shoulder width	1.5 ft	Available	Item is needed for six-plus-lane arterials.
Lighting	None	Available	Item is needed for arterials with up to five lanes.
Automated speed enforcement	None	Not available (use base condition)	No speed enforcement information is in the RID data.
On-street parking	None	Not available (collect for sampled sites)	Item is needed for arterials with up to five lanes. No on-street parking information is in the RID data.
Highway-rail grade crossings	None	Available	Item is needed for six-plus-lane arterials.
Driveways by land use	None	Not available (collect for sampled sites)	Driveways are categorized by major and minor. No driveway information is in the RID data.
Roadside fixed objects	None	Available	—
Speed category	—	Available	—
Speed data	—	Available	Sites with speed data were selected.
Crash data	—	Available	—

—Not applicable.
Data are from SHRP2 RID (ISU 2023), NPMRDS (RITIS 2023), HSIS (FHWA n.d.), and the HSM (AASHTO 2010).

Table 15. Data needs for data analysis (divided urban and suburban arterials facility type).

Data Item	Base Condition	Availability Status	Note
Segment length	—	Available	—
AADT	—	Available	—
Number of through lanes	None	Available	—
Lane width	12 ft	Available	Item is needed for six-plus-lane arterials.
Outside shoulder width	1.5 ft	Available	Item is needed for six-plus-lane arterials.
Median width	30 ft	Available	—
Lighting	None	Available	Item is needed for arterials with up to five lanes.
Automated speed enforcement	None	Not available (use base condition)	No speed enforcement information is in the RID data.
On-street parking	None	Not available (collect for sampled sites)	Item is needed for arterials with up to five lanes. No on-street parking information is in the RID data.
Highway-rail grade crossings	None	Available	Needed for six-plus lanes arterials.
Driveways by land use	None	Not available (collect for sampled sites)	Driveways are categorized by major and minor. No driveway information is in the RID data.
Roadside fixed objects	None	Available	—
Speed category	None	Available	—
Speed data	—	Available	Sites with speed data were selected.
Crash data	—	Available	—

—Not applicable.
Data are from SHRP2 RID (ISU 2023), NPMRDS (RITIS 2023), HSIS (FHWA n.d.), and the HSM (AASHTO 2010).

Table 16. Data needs for data analysis (freeway segment facility type).

Data Item	Base Condition	Availability Status	Note
Segment length	—	Available	—
AADT	—	Available	—
Area type	None	Available	—
Number of through lanes	None	Available	—
Lane width	12 ft	Available	—
Inside shoulder width	6 ft	Available	—
Outside shoulder width	6 ft	Available	—
Median width	60 ft	Available	—
Horizontal curve	Not present	Available	—
Type B weaving	Not present	Not available	Sampled sites without weaving were selected.
Median barrier	Not present	Not available (collect for sampled sites)	—
Outside barrier	Not present	Not available (collect for sampled sites)	—
Outside clearance	30 ft	Not available (collect for sampled sites)	—
Inside shoulder rumble strips	Not present	Available	—
Outside shoulder rumble strips	Not present	Available	—
High volume	—	Not available	—
Lane change	Distance > 0.5 mi.	Not available (collect for sampled sites)	This adjustment factor requires eight data items: distances from beginning and end points of a freeway segment to downstream and upstream entrance and exit ramps and their AADTs. The base condition is more than 0.5 mi.
Speed data	—	Available	Sites with speed data were selected.
Crash data	—	Available	—

—Not applicable.
Data are from SHRP2 RID (ISU 2023), NPMRDS (RITIS 2023), HSIS (FHWA n.d.), and the HSM (AASHTO 2010).

Table 17 and table 18 summarize calibration factors (CFs) for different crash type/severity levels for all facility types considered in this study from Washington and North Carolina (AASHTO 2010, 2014). These CFs used in the crash modification factor (CMF) development process were defined based on the needs of this research study (they were calculated based on training datasets) and are not necessarily the same CF used in the evaluation processes.

Table 17. CFs for different crash type/severity levels in Washington.

Facility	KABCO	KABC	O	SVFI	SVPDO	MVFI	MVPDO
R2U	0.80	0.74	0.83	—	—	—	—
R4U	0.80	0.37	1.35	—	—	—	—
U2U	0.29	0.29	0.29	0.90	0.65	0.25	0.24
U3T	0.51	0.42	0.55	0.63	0.74	0.55	0.61
U4U	0.55	0.54	0.55	1.27	0.39	0.68	0.73
U4D	0.94	0.81	1.00	0.36	0.31	1.48	1.88
U5T	0.46	0.48	0.46	0.80	0.32	0.72	0.62
U6U	0.48	0.35	0.56	0.98	0.62	0.32	0.55
U7T	1.36	1.06	1.59	1.42	1.13	1.18	1.64
Rural freeway	1.15	0.80	1.34	0.67	1.25	1.14	1.54
Urban freeway	1.10	0.90	1.21	0.61	0.97	1.15	1.40

—Inapplicable crash type/severity level.
KABCO = crash severity scale (K = fatal, A = incapacitating injury, B = non-incapacitating injury, C = possible injury, and O = no injury, property damage only); SVFI = single vehicle fatal and injury; SVPDO = single vehicle property damage only; MVFI = multiple vehicle fatal and injury; MVPDO = multiple vehicle property damage only; U3T = three-lane urban and suburban arterials including a center two-way, left-turn lane; U4U = four-lane undivided urban and suburban arterial segments; U5T = five-lane urban and suburban arterials including a center two-way, left-turn lane; U6U = six-lane undivided urban and suburban arterial segments; U7T = seven-lane urban and suburban arterials including a center two-way, left-turn lane.
Note: These CFs were calculated based on training datasets.

Table 18. CFs for different crash type/severity levels in North Carolina.

Facility	KABCO	KABC	O	SVFI	SVPDO	MVFI	MVPDO
R2U	0.75	0.68	0.79	—	—	—	—
R4U	0.62	0.32	1.02	—	—	—	—
R4D	1.07	0.56	1.57	—	—	—	—
U2U	1.32	1.41	1.29	1.78	1.13	1.74	1.56
U3T	1.80	1.71	1.84	2.62	2.02	2.11	2.18
U4U	2.39	2.36	2.42	3.17	1.63	3.61	3.62
U4D	1.95	1.78	2.02	5.29	2.29	1.91	2.09
U5T	1.13	1.05	1.17	0.93	0.71	1.61	1.60
U6U	2.46	2.13	2.68	2.65	1.82	2.23	2.71
U6D	2.20	1.36	2.80	1.26	1.74	1.45	2.90
Rural freeway	1.31	1.08	1.41	0.84	1.10	1.39	1.80
Urban freeway	1.44	1.02	1.63	0.91	1.32	1.06	1.79

—Inapplicable crash type/severity level.
U6D = six-lane divided urban and suburban arterials (including a raised or depressed median).
Note: These CFs were calculated based on training datasets.

APPENDIX C. MANUAL DATA COLLECTION

This appendix provides a detailed description of the manual data collection efforts. The manual data conflation part aims to collect variables that cannot be automatically collected. The manually collected variables include facility type checking, driveways information, on-street parking, ramp entrance and exit, barrier offset, barrier length, and outside clearance. The collected variables for the undivided and divided facility types are slightly different. For undivided and divided non-freeway roadways, the research team manually collected the following information: facility type checking, driveways information, and on-street parking. For freeways, the manually collected information includes distances to upstream and downstream entrance and exit ramps, barrier offset, barrier length, and outside clearance. Google® Earth™ Pro was used for visualizing the roadway segment. The corresponding "kmz" files are generated based on the final SHP files after the automatic data conflation process. The manual data collection for Washington and North Carolina are similar. For demonstration purposes, only the Washington data are shown in the following sections. The detailed measurement for each type of roadway is introduced in the following sections.

MANUAL DATA COLLECTION FOR UNDIVIDED AND DIVIDED NON-FREEWAY ROADWAYS

The research team used the "unique_id" column to identify each roadway segment and further collect the needed information. The facility type was first manually checked, and then the number of driveways was manually counted. The driveway information was further categorized into major and minor driveways. Major driveways are those that serve sites with 50 or more parking spaces. Minor driveways are those that serve sites with less than 50 parking spaces. The researchers did not intend to make an exact count of the number of parking spaces for each site. Driveways can be readily classified as major or minor from a quick review of aerial photographs that show parking areas or through user judgment based on the character of the establishment served by the driveway. Also, the driveways are categorized as commercial, industrial/institutional, residential, and other driveways. Commercial driveways provide access to establishments that serve retail customers. Residential driveways serve single- and multiple-family dwellings. Industrial/institutional driveways serve factories, warehouses, schools, hospitals, churches, offices, public facilities, and other places of employment. Commercial sites with no restriction on access along an entire property frontage are generally counted as two driveways. The parking information was first divided into right-side parking and left-side parking. For each side of the parking, the parking type was further categorized as residential parallel parking, commercial/industrial/institutional parallel parking, residential angle parking, and commercial/industrial/institutional angle parking. For example, figure 11 shows an undivided roadway segment where unique ID equals 12659, and research team collects the aforementioned information based on figure 11. Table 19 shows the detailed form used for collecting the data for undivided and divided non-freeway roadways.

Figure 11. Screenshot. Undivided roadway segment in Washington (unique ID = 12659) (Google 2023).

Table 19. Data collection form for Washington undivided and divided non-freeway roadways (example).

Unique ID	FT	MaCD	MiCD	MaIID	MiIID	MaRD	MiRD	Other	Right	Left
24945	U5T	0	1	0	0	0	0	1	No parking	No parking
24977	U5T	2	1	0	0	0	0	0	No parking	No parking
25000	U5T	0	1	0	0	1	0	0	No parking	No parking
25002	U7T	0	4	0	0	0	0	0	No parking	No parking
25241	U5T	0	3	0	2	0	0	0	No parking	No parking
25281	U5T	0	0	1	1	2	0	2	No parking	No parking
25307	U5T	0	1	0	0	0	0	0	No parking	No Parking
25339	U2U	0	0	0	0	1	0	0	No parking	No parking
25352	U3T	0	0	0	4	0	0	0	No parking	No parking
25359	U3T	0	0	0	4	0	3	0	Parallel—residential/ other	Parallel—residential/ other
25363	U5T	0	1	0	0	0	3	0	No parking	No parking
25551	U2U	0	1	0	0	0	0	0	No parking	No parking

FT = facility type; MaCD = major commercial driveways; MiCD = minor commercial driveways; MaIID = major industrial/ institutional driveways; MiIID = minor industrial/ institutional driveways; MaRD = major residential driveways; MiRD = minor residential driveways; Other = other driveways; Right = type of parking and land use—right side; Left = type of parking and land use—left side.
Note: Values are the number of occurrences.

MANUAL DATA COLLECTION FOR FREEWAYS

Distances to Upstream and Downstream Entrance and Exit Ramps

The distances of beginning and end points of a freeway segment to the upstream and downstream entrance and exit ramps were manually measured using Google Earth Pro. Figure 12 shows the detailed measurement of four variables (i.e., distance from begin point to upstream entrance ramp ($X_{b,ent}$), distance from begin point to downstream exit ramp ($X_{b,ext}$), distance from end point to upstream entrance ramp ($X_{e,ent}$), and distance from end point to downstream exit ramp ($X_{e,ext}$)). Before the distances to the ramps can be measured, identifying the beginning and end points of the segments is necessary. The research team categorized all the segments into horizontal and vertical segments. First, the map view should be kept toward north in Google Earth Pro. If a segment is horizontal or closely horizontal, the left side of the segment is the beginning point and the right side of the segment is the end point (figure 13). If a segment is vertical or closely vertical, the top side of the segment is the end point and the bottom side of the segment is the beginning point (figure 14).

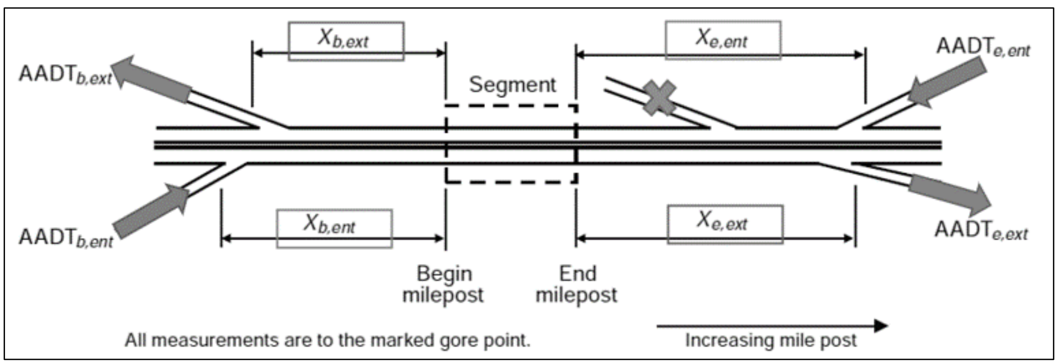

Figure 12. Illustration. Distances to upstream and downstream entrance and exit ramps measurement (AASHTO 2010).

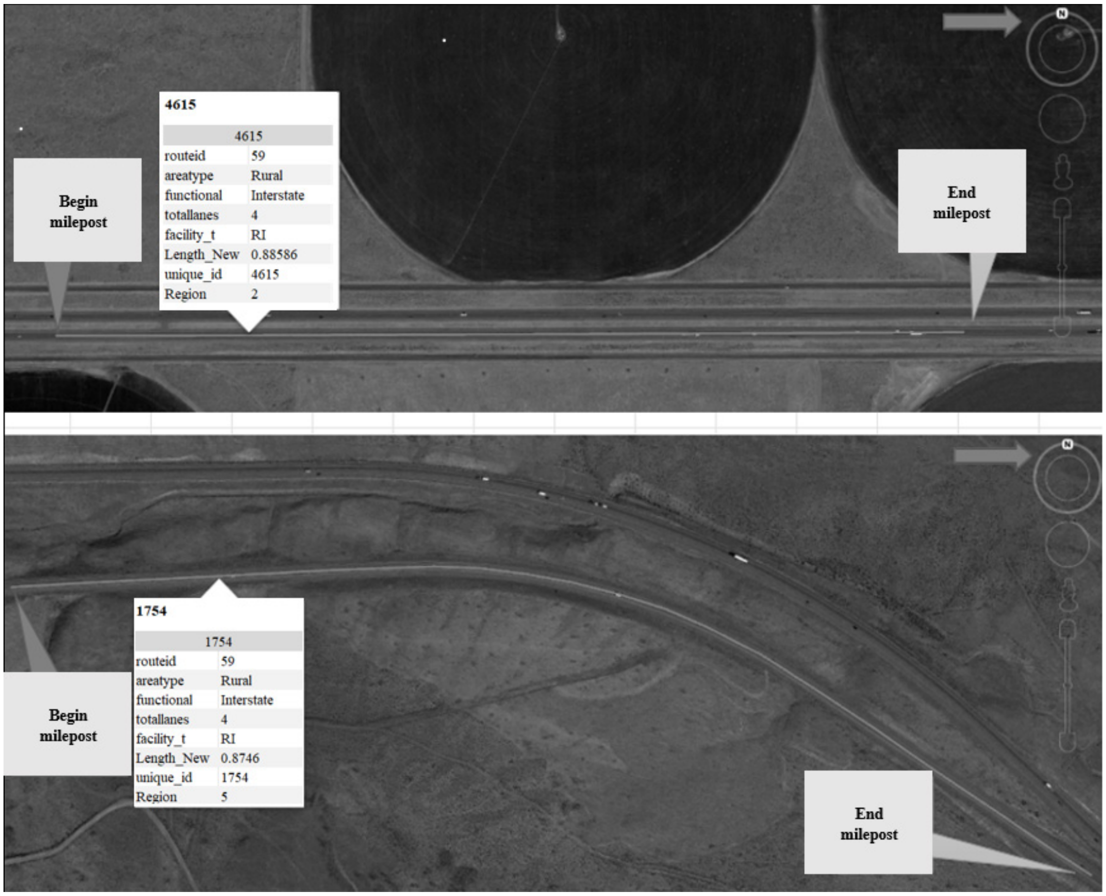

Figure 13. Screenshot. Examples of beginning and end points for horizontal segments (Google 2023).

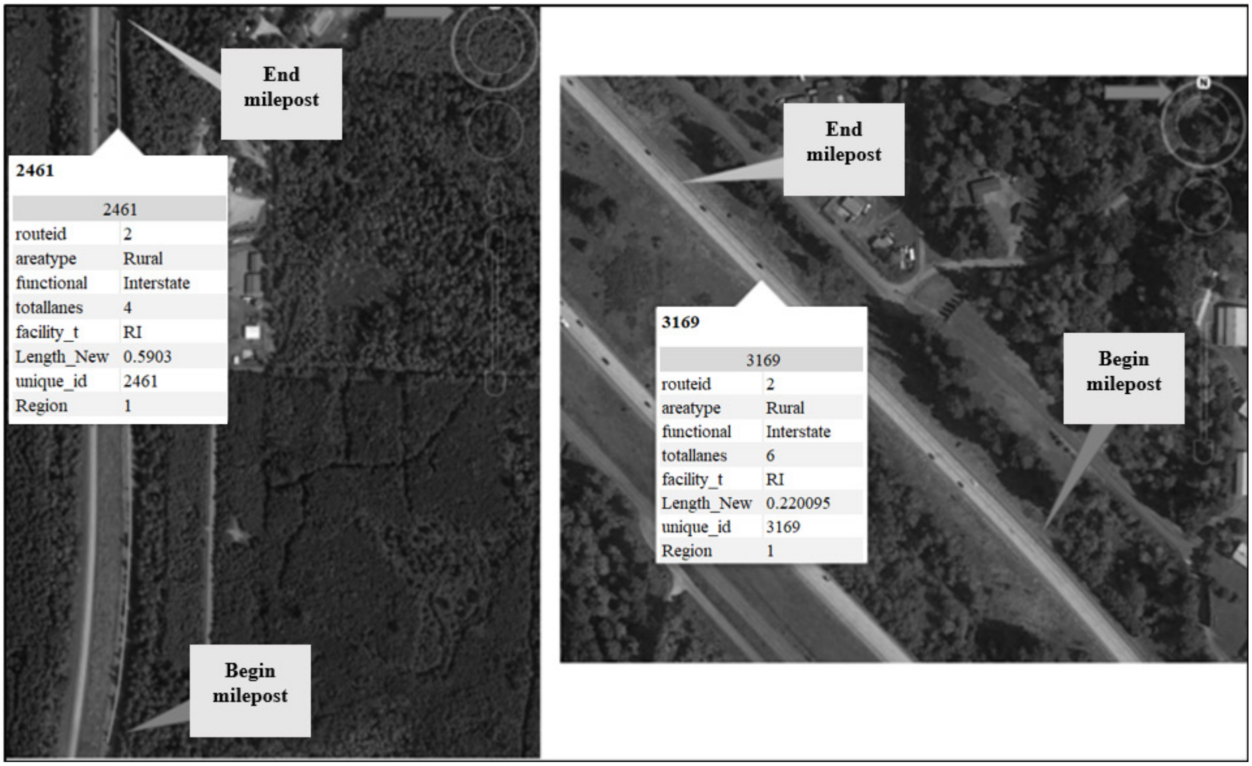

Figure 14. Screenshot. Examples of beginning and end points for vertical segments (Google 2023).

After identifying the beginning and end points of the segment, the team measured the distance to the nearest upstream entrance ramp in each travel direction. This distance is measured from the segment boundary to the ramp gore point, along the freeway's solid white pavement edge marking that intersects the gore point. The distance to the nearest upstream entrance ramp in each travel direction is shown in figure 12 using the two variables $X_{b,ent}$ and $X_{e,ent}$. If the ramp entrance is located in the segment, then the corresponding distance is equal to 0.0 mi. If the ramp does not exist or is located more than 0.5 mi from the segment, then this distance can be set to a large value (i.e., 999) in the predictive method to obtain the correct results. The gore point is located where the pair of solid white pavement edge markings that separate the ramp from the freeway main lanes are 2.0 ft apart. If the markings do not extend to a point where they are 2.0 ft apart, then the gore point is found by extrapolating both markings until the extrapolated portion is 2.0 ft apart. Upstream exit ramps are not of direct interest, and data are not needed for them if they exist in the vicinity of the segment. Figure 12 shows an upstream exit ramp serving travel in the decreasing milepost direction. This ramp is not of interest to the evaluation of the subject segment. The measurement technique for distance to the nearest downstream exit ramp in each travel direction is the same as for upstream entrance ramps. This distance is shown in figure 12 using the two variables $X_{b,ext}$ and $X_{e,ext}$. Downstream entrance ramps are not of direct interest, and their data are not needed. One example segment is given in figure 15 where the unique ID equals 715. The detailed measurements are shown in figure 16 to figure 19. Table 20 shows the form used for entrance and exit ramp distance measurements.

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Figure 15. Screenshot. Freeway segment in Washington (unique ID = 715).

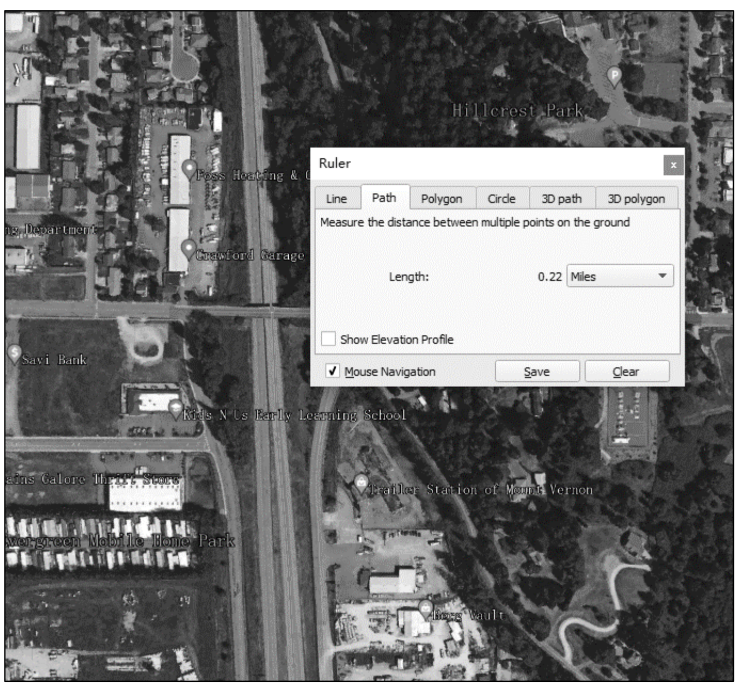

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Figure 16. Screenshot. Example of measurement of $X_{b,ent}$ (unique ID = 715) (Google 2023).

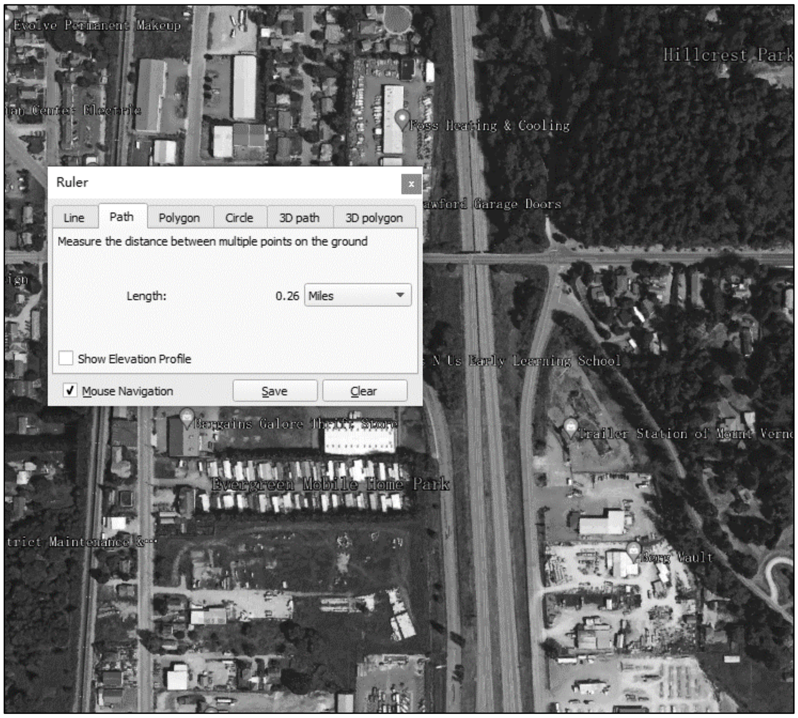

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Figure 17. Screenshot. Example of measurement of $X_{b,ext}$ (unique ID = 715) (Google 2023).

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Figure 18. Screenshot. Example of measurement of $X_{e,ext}$ (unique ID = 715) (Google 2023).

Figure 19. Screenshot. Example of measurement of $X_{e,ent}$ (unique ID = 715) (Google 2023).

Table 20. Entrance and exit ramps manual distance measurement form (example).

Unique ID	Valid (Yes/No)	Direction	$X_{b,ent}$ (mi)	$X_{b,ext}$ (mi)	$X_{e,ent}$ (mi)	$X_{e,ext}$ (mi)
425	Yes	Horizontal	0.21	0.04	0.08	0.1
432	Yes	Vertical	999	999	999	999
448	Yes	Vertical	999	999	0.03	0.11
450	Yes	Vertical	999	999	999	999
453	Yes	Vertical	0.29	0	0.45	0.49
455	Yes	Horizontal	999	999	999	999
463	Yes	Vertical	999	999	999	999

Barrier Offset Length Measurement

Barrier offset is measured for the barrier that continues for the length of the segment or speed-change lane (and beyond). Each piece is represented once for a site. Barrier length is measured along the reference line. Offset is measured from the nearest edge of the traveled way to the barrier face. Figure 20 illustrates these measurements for two barrier elements protecting sign support in a median with width W_m and adjacent to inside shoulders with width W_{is}. Each barrier element has a portion of its length that is parallel to the roadway and a portion of its length that is tapered from the roadway. One way to evaluate these elements is to separate them into four pieces, as shown in figure 20. Each piece is represented by its average offset $W_{off,in,i}$ ($W_{off,in,2}$ and $W_{off,in,3}$ for sections parallel to the roadway; $W_{off,in,1}$ and $W_{off,in,4}$ for sections tapered from the roadway) and $L_{ib,i}$, where W is width, L is length, *off* is offset, *in* is inside, and *ib* is inside barrier. Alternatively, the analyst may recognize that the offset is the same for piece 1 and piece 4 and for piece 2 and piece 3. In this case, each pair can be combined by adding the two lengths (e.g., $L_{ib,1}+L_{ib,4}$) and using the common offset. A barrier is associated with the freeway if the offset from the near edge of the traveled way is 30 ft or less. A barrier adjacent to a ramp but also within 30 ft of the freeway traveled way should also be associated with the freeway. The determination of whether a barrier is adjacent to a speed-change lane, or a ramp is based on the gore and taper points. When measuring the median barrier, if for segments with a barrier centered in the median (i.e., symmetric median barrier), measure for one travel direction. If for segments with a barrier adjacent to one roadbed (i.e., asymmetric median barrier), measure for both travel directions and use the smaller distance(s). Figure 21 show one example segment in Washington freeway data. The median outside barrier offset is shown in figure 21.

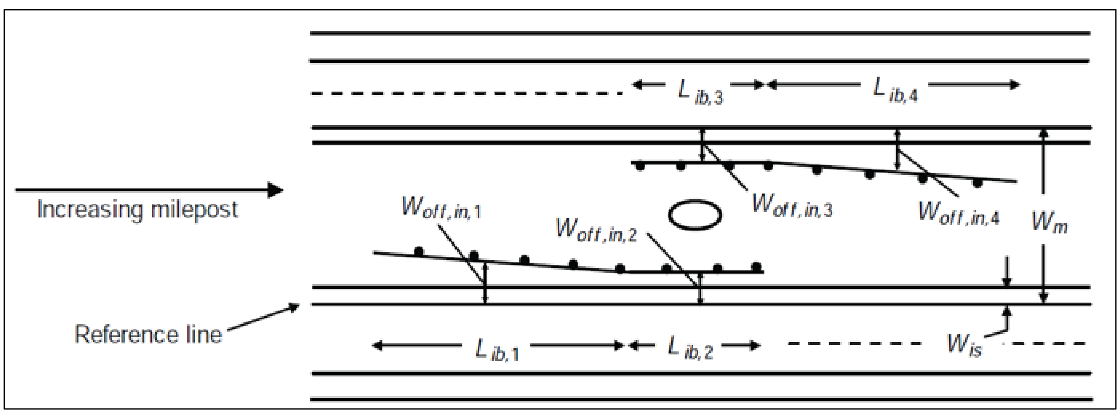

Figure 20. Illustration. Freeway segment barrier variables (AASHTO 2010).

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Figure 21. Screenshot. Example of freeway segment outside barrier offset measurement (Google 2023).

Clear Zone Width Measurement

The clear zone width (W_{hc}) includes the outside shoulder. The width is measured for both travel directions. If this width varies along the segment, then use the estimated length-weighted average W_{hc} (excluding the portion of the segment with a barrier). Do not consider roadside barriers when determining the W_{hc} for the predictive method. Barrier location and influence are addressed in other CMFs. If the segment has a roadside barrier on both sides for its entire length, then the W_{hc} will not influence the model prediction, and any value can be used as a model input (e.g., 30 ft). This guidance is illustrated in figure 22 where the clear zone is shown to be established by a fence line that varies in offset from the edge of the traveled way. A length-weighted width is appropriate for this situation. The lone tree and the guardrail are not considered in the determination of W_{hc}. Figure 23 shows an example case for W_{hc} measurement in Washington freeway data. Table 21 shows the form used for the manual collection of freeways.

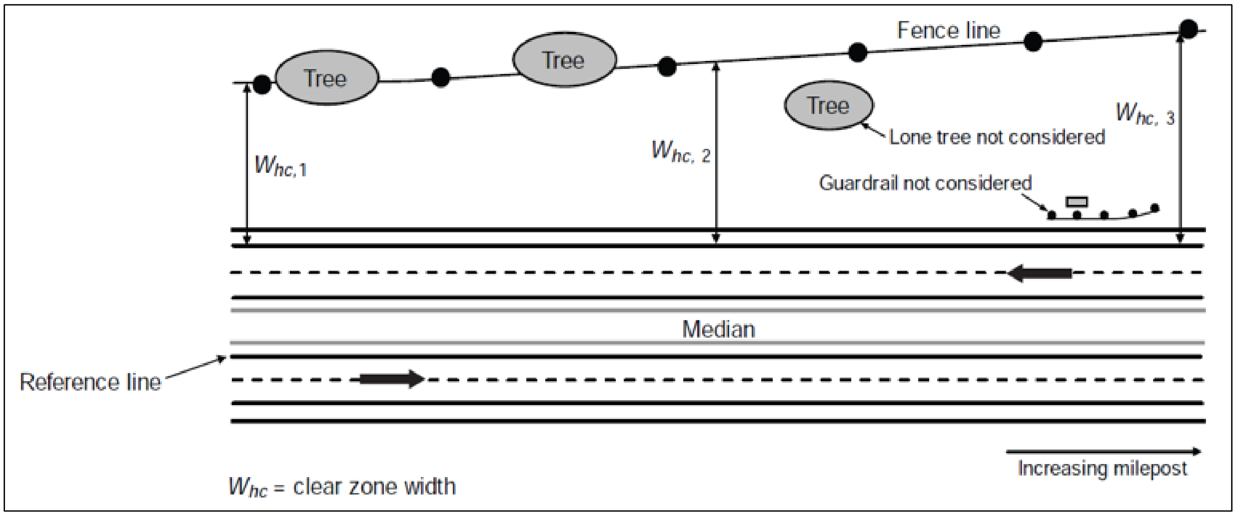


Figure 22. Illustration. Freeway W_{hc} consideration.

Figure 23. Screenshot. Example of freeway W_{hc} measurement (Google 2023).

Table 21. Data collection form for Washington freeway segments (example).

Unique ID	Length of Segment with Median Barrier (mi)	Offset from Traveled Way (Including Inside Shoulder) (ft)			Length of Segment with Outside Barrier (mi)	Offset from Traveled Way (Including Outside Shoulder) (ft)			Outside Clear Zone Width (ft)	
		Begin	Middle	End		Begin	Middle	End	Right Side	Left Side
544	0.12	2.7	2.17	3.02	0.00	—	—	—	30.00	28.43
556	0.54	13.15	13.03	9.23	0.00	—	—	—	30.00	30.00
564	0.40	9.11	10.07	7.84	0.29	13.36	9.775	17.22	30.00	30.00
583	0.73	8.7	10.1	9.66	0.33	10.54	10.635	9.995	30.00	30.00
602	0.49	9.42	10.4	11.71	0.21	11.835	12.34	11	30.00	26.41
612	0.97	8.44	10.9	10.9	0.55	9.605	9.78	9.69	30.00	30.00
632	0	—	—	—	0.00	—	—	—	30.00	30.00
651	0.24	6.09	5.66	10.33	0.23	6.62	11.995	11.925	30.00	30.00
656	0.16	10.74	10.95	9.14	0.05	—	11.54	10.5	30.00	30.00
660	0.18	11.73	10.06	9.07	0.10	—	11.25	10.175	30.00	30.00

—No data.

APPENDIX D. DETAILS OF RURAL HIGHWAYS SPEED CMFs

This appendix provides details of rural highway speed CMFs. For brevity, only the speed CMF plots of R2U are reported in appendix D.

R2U SPEED CMFs

Table 22 through table 25 show the R2U statistics.

Table 22. Summary descriptive statistics of R2U (Washington).

Dataset	Segments (No.)	Length (mi)	KABC (No.)	PDO (No.)	Total (No.)	SVFI (No.)	SVPDO (No.)	MVFI (No.)	MVPDO (No.)
Training	1,460	1,196.2	962	2,281	3,243	—	—	—	—
Test	486	373.1	309	687	996	—	—	—	—
All	1,946	1,569.3	1,271	2,968	4,239	—	—	—	—

—Not applicable.
PDO = property damage only.
Note: The values for KABC, PDO, Total, SVFI, SVPDO, MVFI, and MVPDO represent observed crashes from 2017–18.

Table 23. Summary descriptive statistics of R2U (North Carolina).

Dataset	Segments (No.)	Length (mile)	KABC (No.)	PDO (No.)	Total (No.)	SVFI (No.)	SVPDO (No.)	MVFI (No.)	MVPDO (No.)
Training	810	839.5	1,033	2,522	3,555	—	—	—	—
Test	270	272.1	343	837	1,180	—	—	—	—
All	1,080	1,111.6	1,376	3,359	4,735	—	—	—	—

—Not applicable.
Note: The values for KABC, PDO, Total, SVFI, SVPDO, MVFI, and MVPDO represent observed crashes from 2017–18.

Table 24. *R*-square values of speed CMF equations of R2U (Washington).

Speed Measure	KABCO (Linear)	KABCO (Power)	KABC (Linear)	KABC (Power)	O (Linear)	O (Power)
SpdStd	***0.07***	***0.17***	***0.41***	***0.54***	0.01	***0.08***
(SpdAve − PSL)	***0.09***	—	***0.25***	—	***0.04***	—
|SpdAve − PSL|	0.05	***0.19***	0.18	***0.35***	***0.02***	***0.12***
SpdStd/SpdAve	0.00	***0.07***	0.13	***0.28***	0.01	***0.02***

—Not applicable.
(SpdAve − PSL) = speed differential of SpdAve and PSL; |SpdAve − PSL| = absolute value of speed differential of SpdAve and PSL.
Note: Bold italic numbers indicate the top five potential speed CMFs for each crash type/severity level.

Table 25. *R*-square values of speed CMF equations of R2U (North Carolina).

Speed Measure	KABCO (Linear)	KABCO (Power)	KABC (Linear)	KABC (Power)	O (Linear)	O (Power)
SpdStd	***0.35***	***0.43***	***0.13***	***0.20***	***0.47***	***0.55***
(SpdAve − PSL)	***0.66***	—	***0.49***	—	***0.71***	—
|SpdAve − PSL|	***0.62***	***0.66***	***0.50***	***0.52***	***0.67***	***0.71***
SpdStd/SpdAve	0.14	0.29	0.03	0.13	0.21	0.36

—Not applicable.
Note: Bold italic numbers indicate the top five potential speed CMFs for each crash type/severity level.

R2U Speed CMF for KABCO Crashes

Table 26 to table 29 and figure 24 to figure 27 show the KABCO crash severity scale (K = fatal, A = incapacitating injury, B = non-incapacitating injury, C = possible injury, and O = no injury, property damage only) statistics for R2U (AASHTO 2010).

Table 26. Summary of R2U speed CMF development statistics for KABCO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.80	996	1,086.9	1.735	—	4.748	—
SpdStd	0.78	996	1,079.6	1.717	−1.0	4.543	−4.3
SpdStd	***0.80***	***996***	***1,063.4***	***1.680***	***−3.2***	***4.093***	***−13.8***
(SpdAve − PSL)	0.80	996	959.7	1.705	−1.7	4.441	−6.5
|SpdAve − PSL|	*0.82*	*996*	*1,059.6*	*1.690*	*−2.6*	*4.137*	*−12.9*
SpdStd/SpdAve	*0.82*	*996*	*1,075.3*	*1.706*	*−1.7*	*4.404*	*−7.2*

—Not applicable.
MAD = mean absolute deviation; RMSE = root mean squared error.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 27. Summary of R2U speed CMF development statistics for KABCO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.75	1,180	1,156.8	2.899	—	5.374	—
SpdStd	0.75	1,180	1,161.6	2.874	−0.9	5.028	−6.4
SpdStd	*0.76*	*1,180*	*1,161.3*	*2.847*	*−1.8*	*4.825*	*−10.2*
(SpdAve − PSL)	0.73	1,180	1,162.7	2.802	−3.4	4.732	−12.0
|SpdAve − PSL|	0.74	1,180	1,162.9	2.800	−3.4	4.717	−12.2
|SpdAve − PSL|	***0.75***	***1,180***	***1,165.1***	***2.766***	***−4.6***	***4.501***	***−16.3***

—Not applicable.

Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

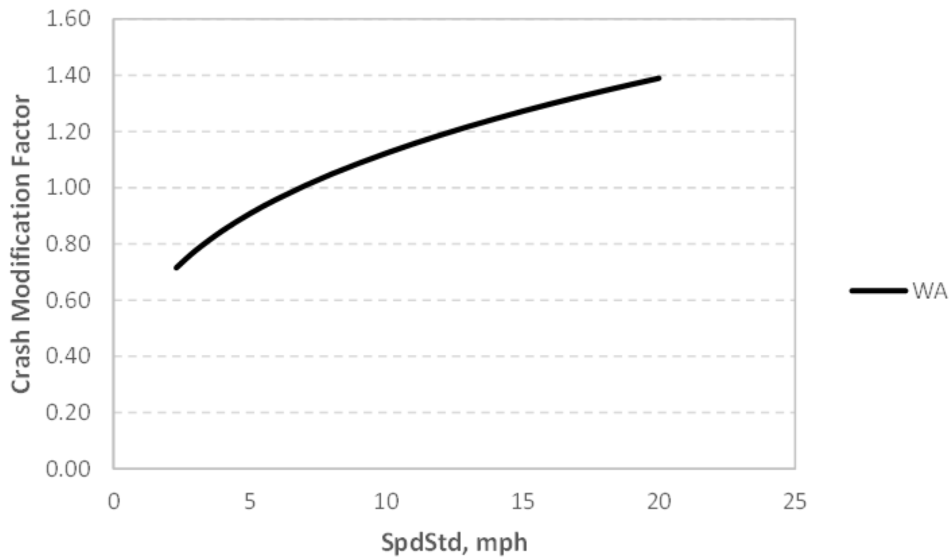
Table 28. Speed CMF of R2U for KABCO crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.5537 \times x^{0.3071}$
R-square	0.17
Speed measure boundaries	(2.30, 20.00)
Base condition	7
t-Test (*p*-value)	0.67
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.09

Note: See the "CMF Crash Modification Factors Clearinghouse" for a description of the star quality rating system (FHWA 2023a).

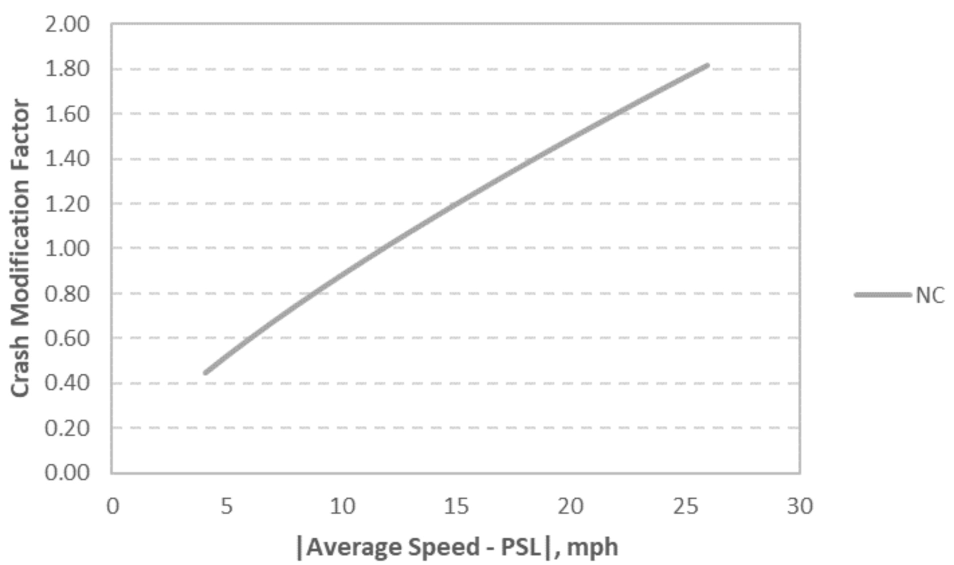
Table 29. Speed CMF of R2U for KABCO crashes (North Carolina).

Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 0.1533 \times x^{0.759}$
R-square	0.69
Speed measure boundaries	(4.10, 26.00)
Base condition	12
t-Test (*p*-value)	0.98
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.24



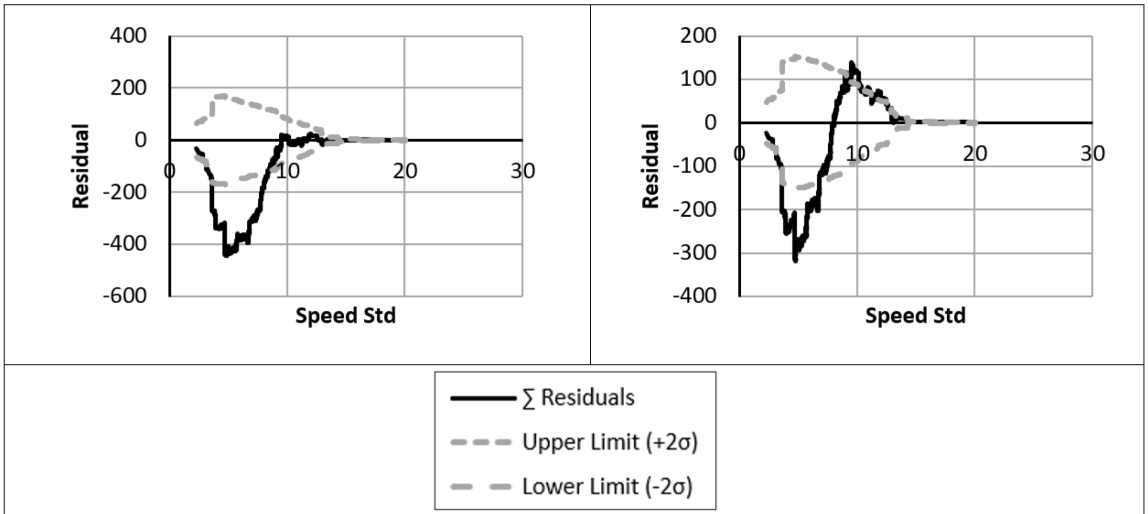
Source: FHWA.

Figure 24. Graph. Speed CMF of R2U for KABCO crashes (Washington).



Source: FHWA.

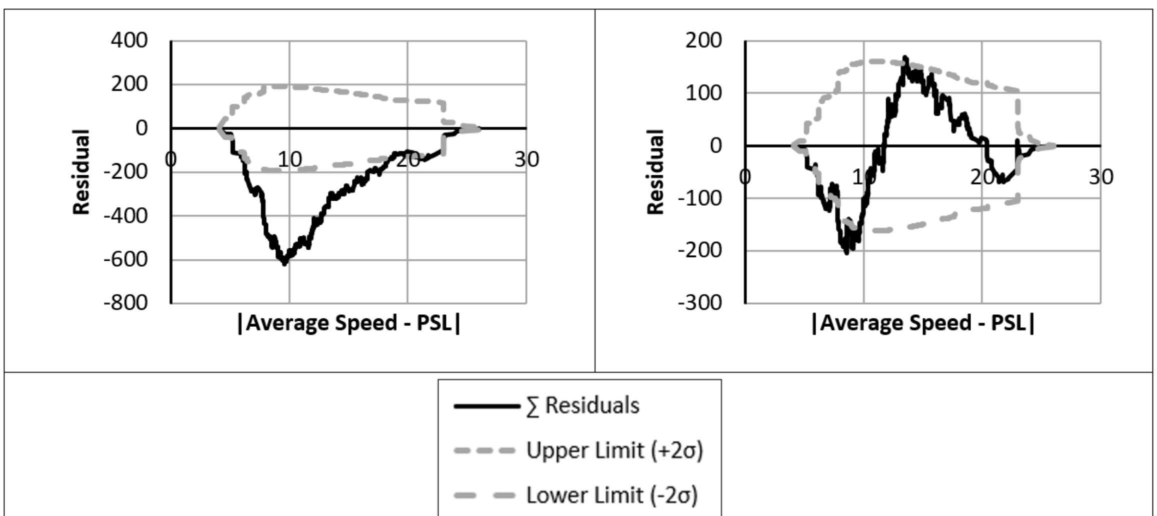
Figure 25. Graph. Speed CMF of R2U for KABCO crashes (North Carolina).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.
σ = standard deviation.

Figure 26. Graph. Cumulative residuals (CURE) plots of R2U speed CMF for KABCO crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 27. Graph. CURE plots of R2U speed CMF for KABCO crashes (North Carolina).

R2U Speed CMF for KABC Crashes

Table 30 to table 33 and figure 28 to figure 31 show the KABC crash severity scale statistics for R2U (AASHTO 2010).

Table 30. Summary of R2U speed CMF development statistics for KABC crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.74	309	322.1	0.733	—	1.599	—
SpdStd	0.74	309	317.0	0.719	−1.9	1.472	−7.9
SpdStd	***0.75***	***309***	***312.5***	***0.706***	***−3.7***	***1.366***	***−14.6***
(SpdAve − PSL)	0.75	309	254.1	0.699	−4.7	1.477	−7.6
|SpdAve − PSL|	*0.76*	*309*	*310.8*	*0.709*	*−3.3*	*1.382*	*−13.6*
SpdStd/SpdAve	*0.78*	*309*	*316.2*	*0.716*	*−2.3*	*1.447*	*−9.5*

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 31. Summary of R2U speed CMF development statistics for KABC crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.68	343	336.6	1.148	—	1.908	—
SpdStd	0.67	343	337.5	1.143	−0.5	1.851	−3.0
SpdStd	*0.69*	*343*	*337.6*	*1.134*	*−1.2*	*1.790*	*−6.2*
(SpdAve − PSL)	0.66	343	338.2	1.121	−2.3	1.759	−7.8
|SpdAve − PSL|	0.66	343	338.3	1.120	−2.5	1.751	−8.2
|SpdAve − PSL|	***0.68***	***343***	***339.3***	***1.105***	***−3.7***	***1.682***	***−11.9***

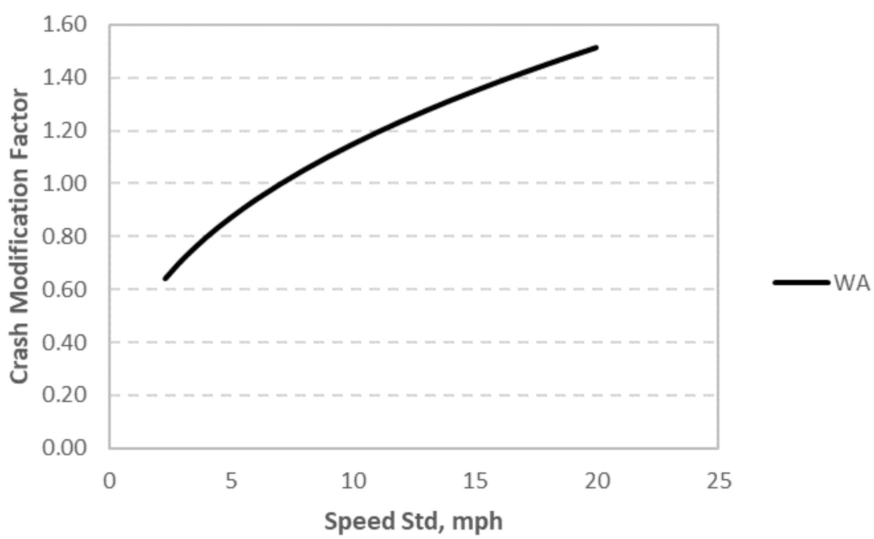
—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 32. Speed CMF of R2U for KABC crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.4588 \times x^{0.399}$
R-square	0.39
Speed measure boundaries	(2.30, 20.00)
Base condition	7
t-Test (p-value)	0.54
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.12

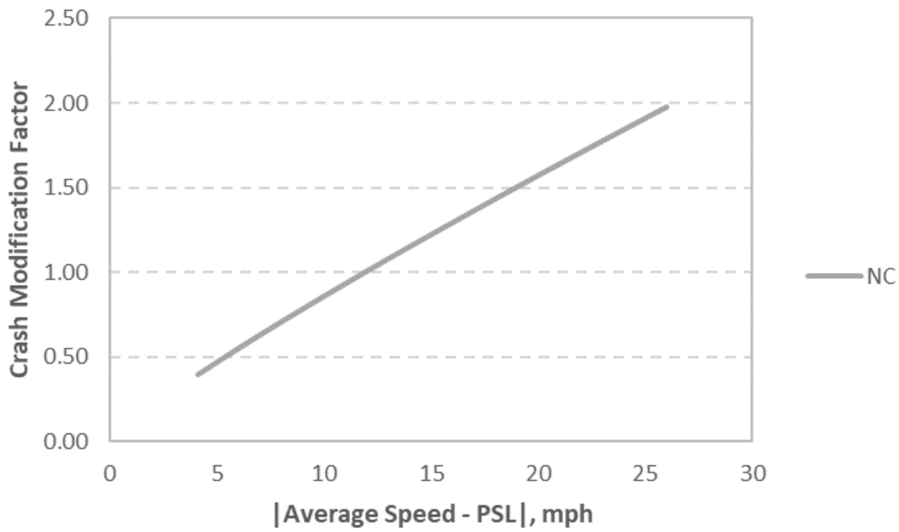
Table 33. Speed CMF of R2U for KABC crashes (North Carolina).

Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 0.1148 \times x^{0.8735}$
R-square	0.56
Speed measure boundaries	(4.10, 26.00)
Base condition	12
t-Test (p-value)	0.97
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.28



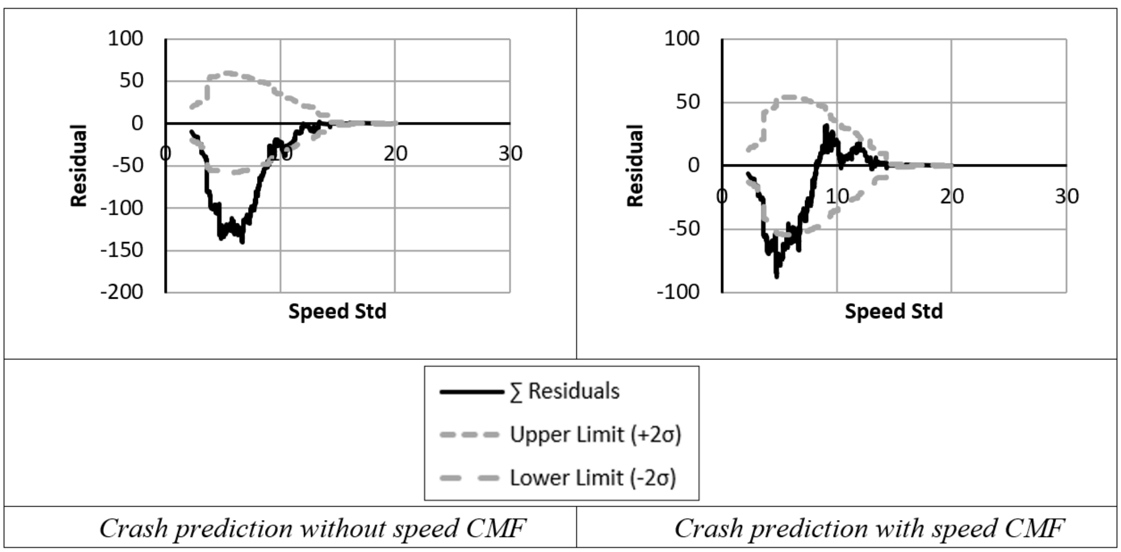
Source: FHWA.

Figure 28. Graph. Speed CMF of R2U for KABC crashes (Washington).



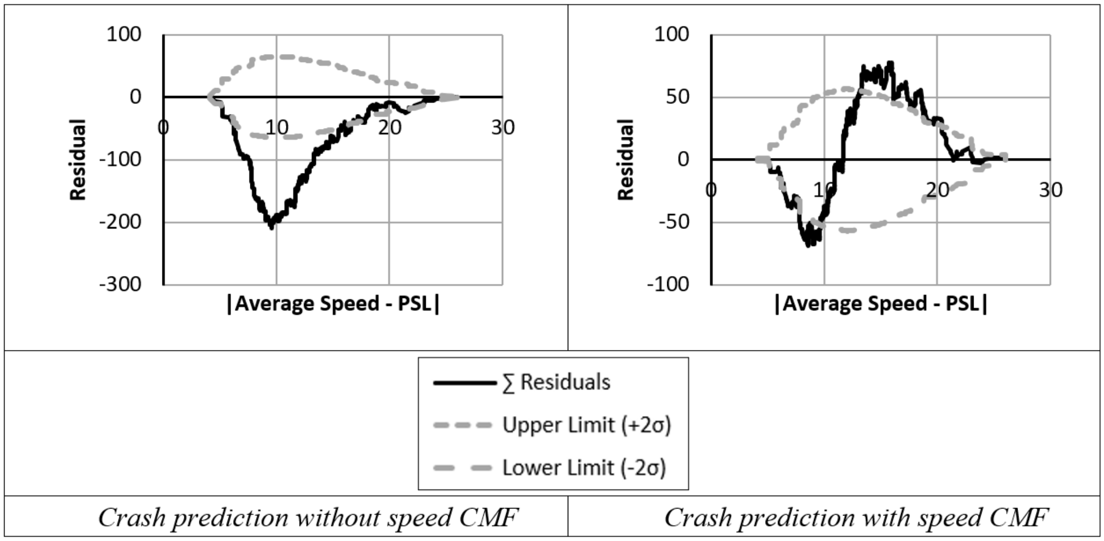
Source: FHWA.

Figure 29. Graph. Speed CMF of R2U for KABC crashes (North Carolina).



Source: FHWA.

Figure 30. Graph. CURE plots of R2U speed CMF for KABC crashes (Washington).



Source: FHWA.

Figure 31. Graph. CURE plots of R2U speed CMF for KABC crashes (North Carolina).

R2U Speed CMF for O Crashes

Table 34 to table 37 and figure 32 to figure 35 show the O crash severity scale statistics for R2U (AASHTO 2010).

Table 34. Summary of R2U speed CMF development statistics for O crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.83	687	763.1	1.315	—	3.375	—
SpdStd	***0.83***	***687***	***749.5***	***1.285***	***−2.3***	***3.003***	***−11.0***
(SpdAve − PSL)	0.83	687	706.2	1.284	−2.4	3.231	−4.3
|SpdAve − PSL|	0.84	687	759.9	1.310	−0.4	3.315	−1.8
|SpdAve − PSL|	*0.85*	*687*	*747.4*	*1.287*	*−2.1*	*3.029*	*−10.2*
SpdStd/SpdAve	*0.83*	*687*	*757.5*	*1.302*	*−1.0*	*3.212*	*−4.8*

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 35. Summary of R2U speed CMF development statistics for O crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.79	837	820.2	2.173	—	3.918	—
SpdStd	0.78	837	824.0	2.139	−1.6	3.652	−6.8
SpdStd	*0.79*	*837*	*823.6*	*2.122*	*−2.4*	*3.529*	*−9.9*
(SpdAve − PSL)	0.77	837	824.4	2.093	−3.7	3.475	−11.3
|SpdAve − PSL|	0.78	837	824.4	2.092	−3.7	3.470	−11.4
|SpdAve − PSL|	***0.78***	***837***	***825.6***	***2.072***	***−4.7***	***3.347***	***−14.6***

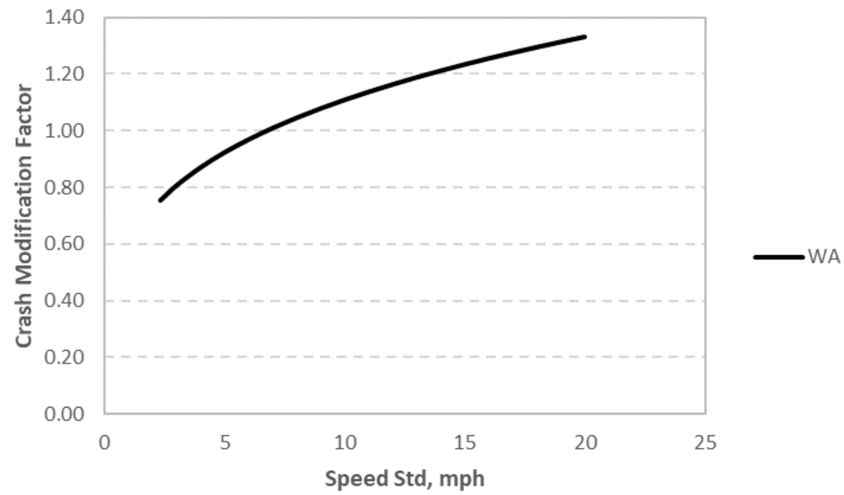
—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 36. Speed CMF of R2U for O crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.6035 \times x^{0.2643}$
R-square	0.1
Speed measure boundaries	(2.30, 20.00)
Base condition	7
t-Test (*p*-value)	0.33
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.08

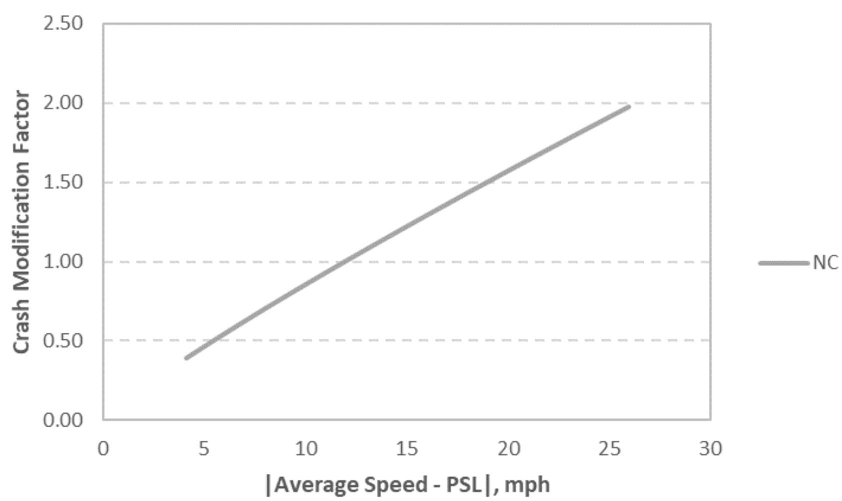
Table 37. Speed CMF of R2U for O crashes (North Carolina).

Speed CMF	Value
Speed measure	|Average Speed − PSL|
CMF equation	$y = 0.1704 \times x^{0.7166}$
R-square	0.8
Speed measure boundaries	(4.10, 26.00)
Base condition	12
t-Test (*p*-value)	0.93
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.23



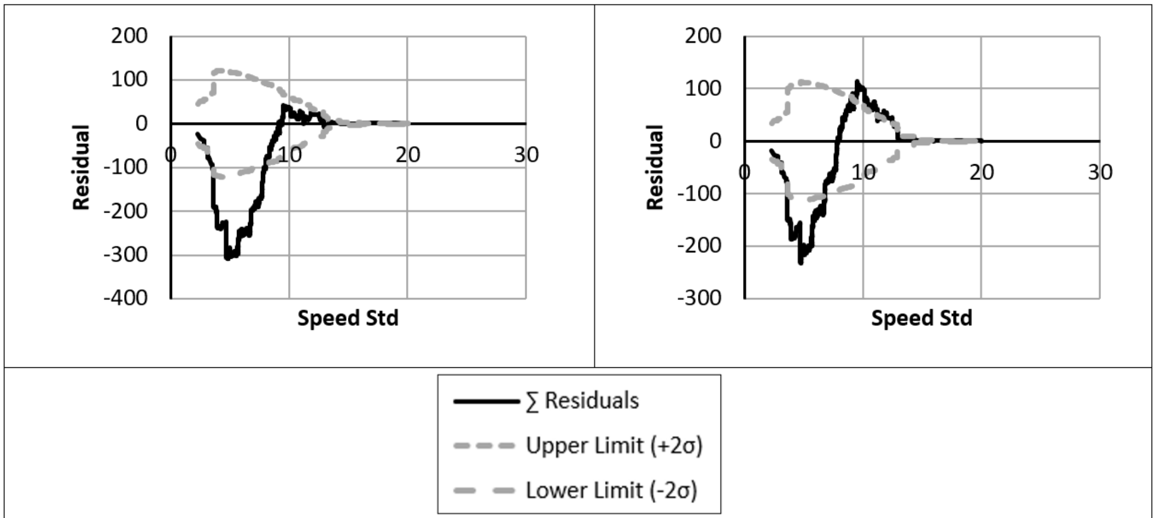
Source: FHWA.

Figure 32. Graph. Speed CMF of R2U for O crashes (Washington).



Source: FHWA.

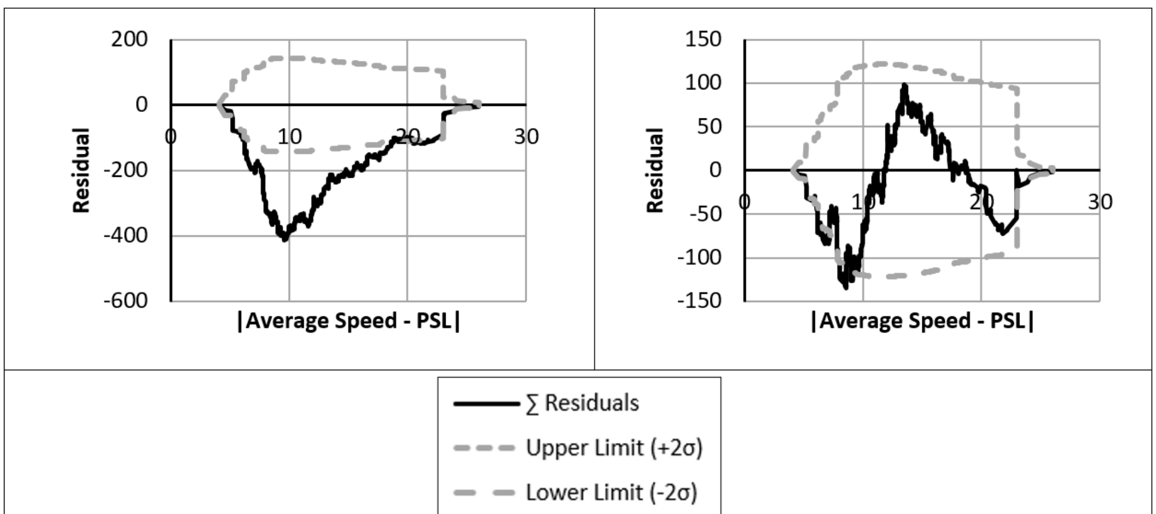
Figure 33. Graph. Speed CMF of R2U for O crashes (North Carolina).



Crash prediction without speed CMF	Crash prediction with speed CMF

Source: FHWA.

Figure 34. Graph. CURE plots of R2U speed CMF for O crashes (Washington).



Crash prediction without speed CMF	Crash prediction with speed CMF

Source: FHWA.

Figure 35. Graph. CURE plots of R2U speed CMF for O crashes (North Carolina).

Table 38 and table 39 show the R2U CURE plot summary for Washington and North Carolina, respectively.

Table 38. CURE plots summary of R2U (Washington).

Crash	Crash Prediction Method	Within CURE (%)	Change to HSM (%)	|Maximum CURE Deviation|	Change to HSM (%)
KABCO	HSM (without speed CMF)	36.84	—	282.68	—
KABCO	HSM × speed CMF	46.40	10	166.48	−41
KABC	HSM (without speed CMF)	29.39	—	84.11	—
KABC	HSM × speed CMF	73.12	44	35.01	−58
O	HSM (without speed CMF)	42.39	—	189.78	—
O	HSM × speed CMF	41.98	0	119.85	−37

—Not applicable.
|Maximum CURE Deviation| = absolute value of maximum CURE deviation.

Table 39. CURE plots summary of R2U (North Carolina).

Crash	Crash Prediction Method	Within CURE (%)	Change to HSM (%)	|Maximum CURE Deviation|	Change to HSM (%)
KABCO	HSM (without speed CMF)	5.46	—	429.83	—
KABCO	HSM × speed CMF	77.69	72	59.44	−86
KABC	HSM (without speed CMF)	16.39	—	144.97	—
KABC	HSM × speed CMF	42.04	26	31.08	−79
O	HSM (without speed CMF)	5.00	—	270.63	—
O	HSM × speed CMF	90.00	85	26.28	−90

—Not applicable.

R4U SPEED CMFs

Table 40 through table 43 show the R4U statistics.

Table 40. Summary descriptive statistics of R4U (Washington).

Dataset	Segments (No.)	Length (mile)	KABC (No.)	PDO (No.)	Total (No.)	SVFI (No.)	SVPDO (No.)	MVFI (No.)	MVPDO (No.)
Training	120	34.9	91	257	348	—	—	—	—
Test	40	14.2	33	72	105	—	—	—	—
All	160	49.1	124	329	453	—	—	—	—

—Not applicable.
Note: Values for KABC, PDO, Total, SVFI, SVPDO, MVFI, and MVPDO represent observed crashes from 2017-2018.

Table 41. Summary descriptive statistics of R4U (North Carolina).

Dataset	Segments (No.)	Length (mile)	KABC (No.)	PDO (No.)	Total (No.)	SVFI (No.)	SVPDO (No.)	MVFI (No.)	MVPDO (No.)
Training	280	155.1	439	1,055	1,494	—	—	—	—
Test	93	54.3	124	331	455	—	—	—	—
All	373	209.4	563	1,386	1,949	—	—	—	—

—Not applicable.
Note: Values for KABC, PDO, Total, SVFI, SVPDO, MVFI, and MVPDO represent observed crashes from 2017-2018.

Table 42. *R*-square values of speed CMF equations of R4U (Washington).

Speed Measure	KABCO (Linear)	KABCO (Power)	KABC (Linear)	KABC (Power)	O (Linear)	O (Power)
SpdStd	***0.28***	***0.29***	***0.03***	***0.05***	***0.37***	***0.37***
(SpdAve − PSL)	0.00	—	0.00	—	0.00	—
|SpdAve − PSL|	***0.05***	***0.09***	0.00	***0.00***	***0.05***	***0.07***
SpdStd/SpdAve	***0.04***	0.00	***0.07***	***0.00***	***0.03***	0.00

—Not applicable.
Note: Bold italic numbers indicate the top five potential speed CMFs for each crash type/severity level.

Table 43. *R*-square values of speed CMF equations of R4U (North Carolina).

Speed Measure	KABCO (Linear)	KABCO (Power)	KABC (Linear)	KABC (Power)	O (Linear)	O (Power)
SpdStd	***0.96***	***0.96***	***0.81***	***0.78***	***0.95***	***0.95***
(SpdAve − PSL)	***0.78***	—	***0.55***	—	0.83	—
|SpdAve − PSL|	***0.78***	0.77	0.53	0.52	***0.84***	***0.83***
SpdStd/SpdAve	0.78	***0.85***	***0.56***	***0.67***	0.83	***0.88***

—Not applicable.
Note: Bold italic numbers indicate the top five potential speed CMFs for each crash type/severity level.

R4U Speed CMF for KABCO Crashes

Table 44 to table 47 and figure 36 and figure 37 show the KABCO crash severity scale statistics for R4U (AASHTO 2010).

Table 44. Summary of R4U speed CMF development statistics for KABCO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.80	105	173.6	3.468	—	6.301	—
SpdStd	0.81	105	160.6	3.207	−7.5	5.641	−10.5
SpdStd	***0.84***	***105***	***157.9***	***3.156***	***−9.0***	***5.544***	***−12.0***
|SpdAve − PSL|	0.79	105	171.5	3.507	1.1	6.419	1.9
|SpdAve − PSL|	*0.81*	*105*	*169.2*	*3.530*	*1.8*	*6.518*	*3.4*
SpdStd/SpdAve	0.75	105	175.6	3.485	0.5	6.348	0.7

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 45. Summary of R4U speed CMF development statistics for KABCO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.62	455	533.6	0.636	—	2.129	—
SpdStd	**0.63**	**455**	**505.9**	**0.582**	**−8.5**	**1.923**	**−9.7**
SpdStd	*0.63*	*455*	*507.6*	*0.584*	*−8.1*	*1.934*	*−9.1*
(SpdAve − PSL)	0.64	455	510.8	0.599	−5.8	2.084	−2.1
|SpdAve − PSL|	0.65	455	510.9	0.599	−5.8	2.083	−2.1
SpdStd/SpdAve	*0.70*	*455*	*14.3*	*0.910*	*43.2*	*3.039*	*42.8*

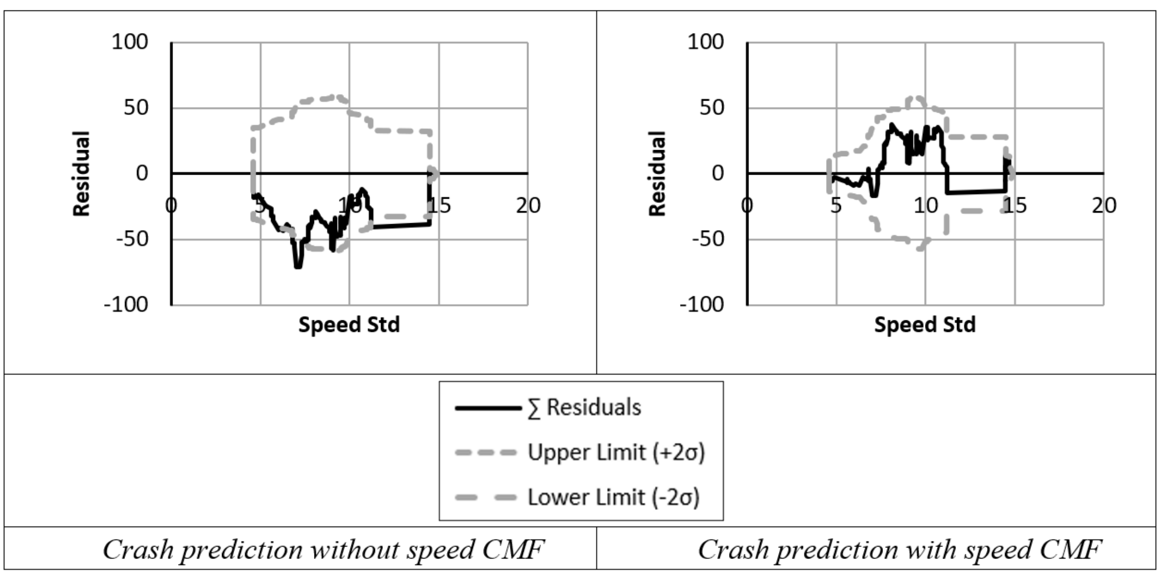
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 46. Speed CMF of R4U for KABCO crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.0343 \times x^{1.5408}$
R-square	0.8
Speed measure boundaries	(4.60, 14.90)
Base condition	9
t-Test (*p*-value)	0.59
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.48

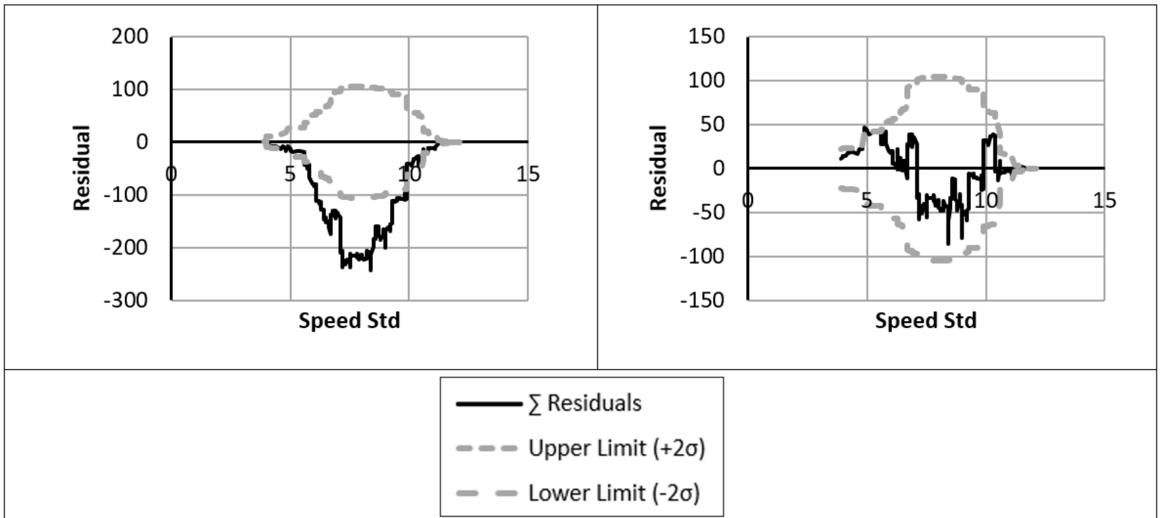
Table 47. Speed CMF of R4U for KABCO crashes (North Carolina).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.1358 \times x - 0.0401$
R-square	0.92
Speed measure boundaries	(3.90, 12.10)
Base condition	8
t-Test (*p*-value)	0.19
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.23



Source: FHWA.

Figure 36. Graph. CURE plots of R4U speed CMF for KABCO crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 37. Graph. CURE plots of R4U speed CMF for KABCO crashes (North Carolina).

R4U Speed CMF for KABC Crashes

Table 48 to table 51 and figure 38 and figure 39 show the KABC crash severity scale statistics for R4U (AASHTO 2010).

Table 48. Summary of R4U speed CMF development statistics for KABC crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.37	33	44.8	1.019	—	1.705	—
SpdStd	0.37	33	43.8	0.984	−3.4	1.644	−3.6
SpdStd	***0.39***	***33***	***42.7***	***0.950***	***−6.8***	***1.584***	***−7.1***
$\lvert SpdAve - PSL \rvert$	*0.37*	*33*	*44.5*	*1.009*	*−1.0*	*1.704*	*−0.1*
SpdStd/SpdAve	0.33	33	45.4	1.029	1.0	1.712	0.4
SpdStd/SpdAve	*0.36*	*33*	*45.4*	*1.034*	*1.4*	*1.718*	*0.7*

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 49. Summary of R4U speed CMF development statistics for KABC crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.32	124	156.9	0.230	—	0.752	—
SpdStd	**0.32**	**124**	**150.0**	**0.211**	**−8.3**	**0.693**	**−7.8**
SpdStd	*0.32*	*124*	*150.9*	*0.213*	*−7.5*	*0.700*	*−6.9*
(SpdAve − PSL)	0.33	124	151.6	0.213	−7.4	0.727	−3.3
SpdStd/SpdAve	0.35	124	155.3	0.224	−2.8	0.732	−2.6
SpdStd/SpdAve	*0.35*	*124*	*153.7*	*0.217*	*−5.7*	*0.714*	*−5.0*

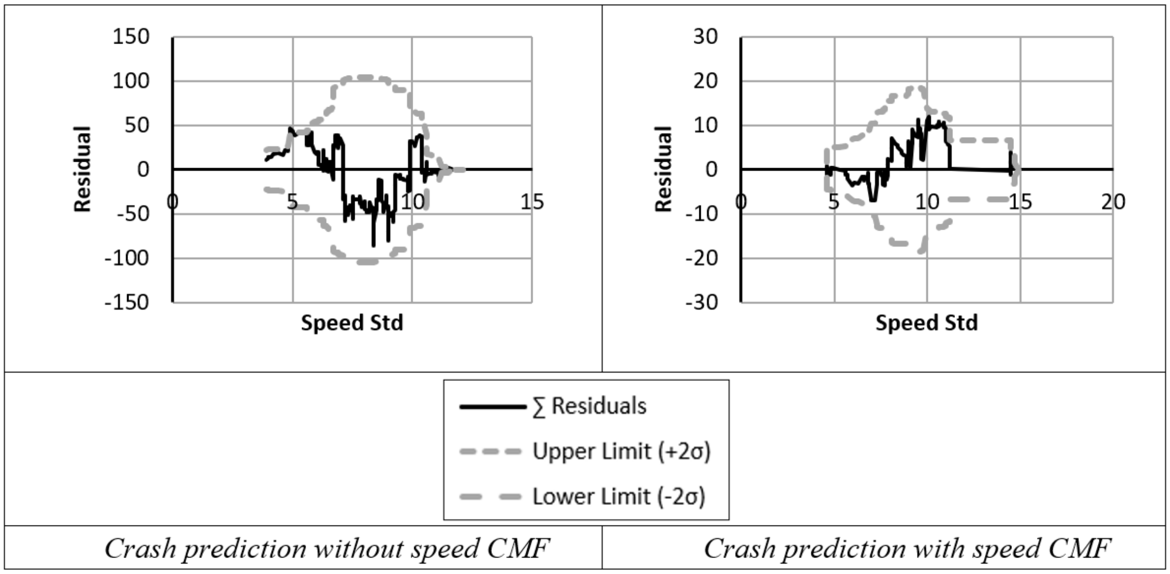
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 50. Speed CMF of R4U for KABC crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.0501 \times x^{1.3474}$
R-square	0.69
Speed measure boundaries	(4.60, 14.90)
Base condition	9
t-Test (p-value)	0.1
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.39

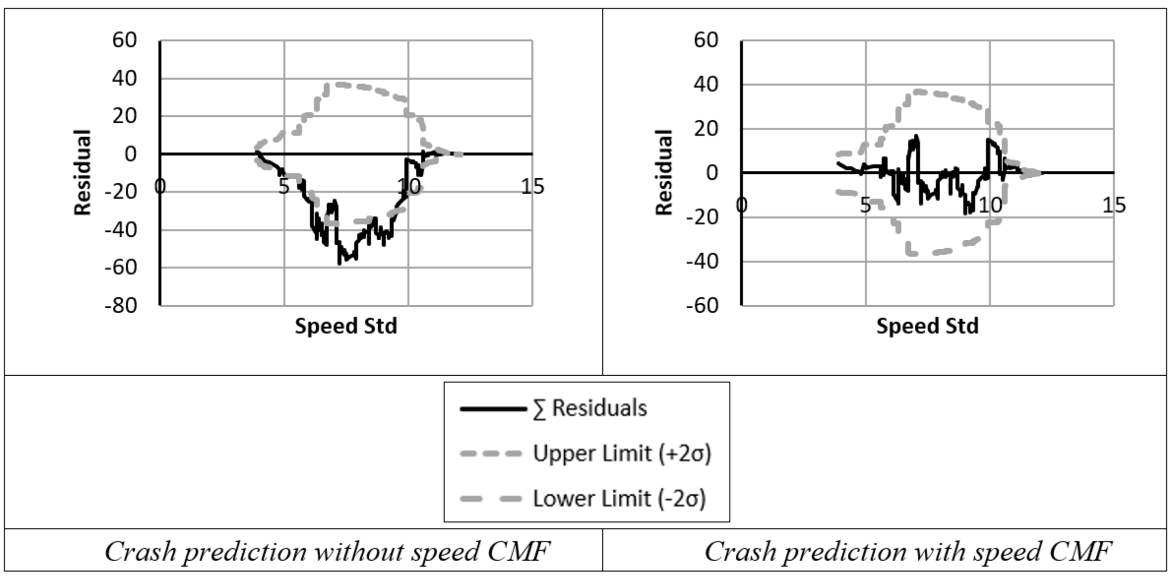
Table 51. Speed CMF of R4U for KABC crashes (North Carolina).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.1146 \times x + 0.1198$
R-square	0.91
Speed measure boundaries	(3.90, 12.10)
Base condition	8
t-Test (p-value)	0.13
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.20



Source: FHWA.

Figure 38. Graph. CURE plots of R4U speed CMF for KABC crashes (Washington).



Source: FHWA.

Figure 39. Graph. CURE plots of R4U speed CMF for KABC crashes (North Carolina).

R4U Speed CMF for O Crashes

Table 52 to table 55 and figure 40 and figure 41 show the O crash severity scale statistics for R4U (AASHTO 2010).

Table 52. Summary of R4U speed CMF development statistics for O crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.35	72	129.7	2.886	—	5.225	—
SpdStd	1.36	72	116.5	2.614	−9.5	4.721	−9.6
SpdStd	***1.44***	***72***	***115.7***	***2.597***	***−10.0***	***4.703***	***−10.0***
|SpdAve − PSL|	1.35	72	127.9	2.911	0.9	5.347	2.3
|SpdAve − PSL|	*1.39*	*72*	*125.5*	*2.931*	*1.6*	*5.495*	*5.2*
SpdStd/SpdAve	1.30	72	131.2	2.898	0.4	5.261	0.7

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 53. Summary of R4U speed CMF development statistics for O crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.02	331	377.0	0.459	—	1.557	—
SpdStd	**1.04**	**331**	**356.2**	**0.426**	**−7.1**	**1.432**	**−8.0**
SpdStd	*1.05*	*331*	*357.1*	*0.428*	*−6.8*	*1.437*	*−7.7*
|SpdAve − PSL|	1.08	331	359.9	0.436	−4.9	1.556	−0.1
|SpdAve − PSL|	*1.09*	*331*	*362.3*	*0.438*	*−4.6*	*1.545*	*−0.8*
SpdStd/SpdAve	*1.17*	*331*	*367.1*	*0.437*	*−4.9*	*1.462*	*−6.1*

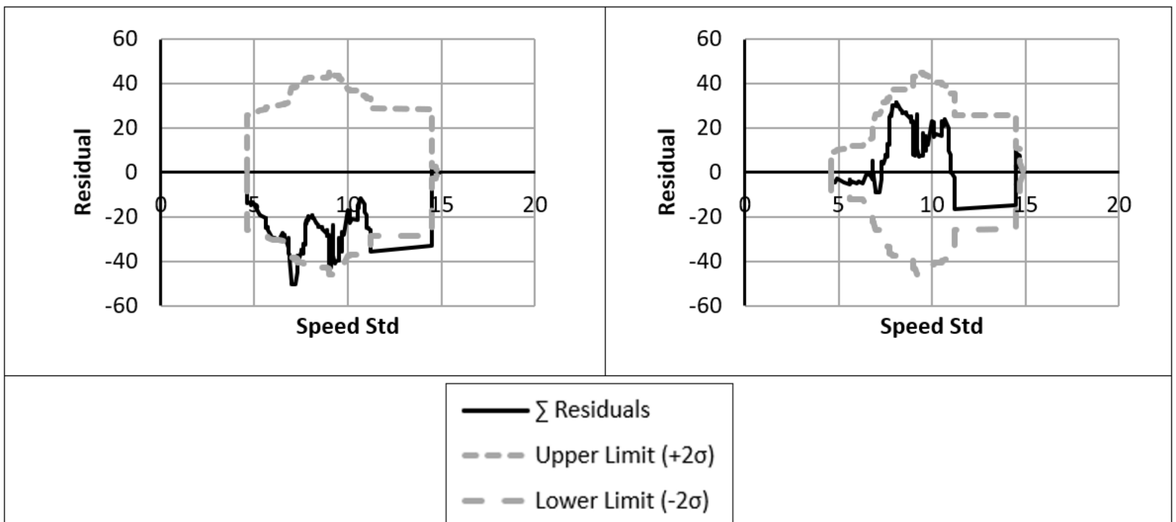
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 54. Speed CMF of R4U for O crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.0266 \times x^{1.6642}$
R-square	0.79
Speed measure boundaries	(4.60, 14.90)
Base condition	9
t-Test (*p*-value)	0.83
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.54

Table 55. Speed CMF of R4U for O crashes (North Carolina).

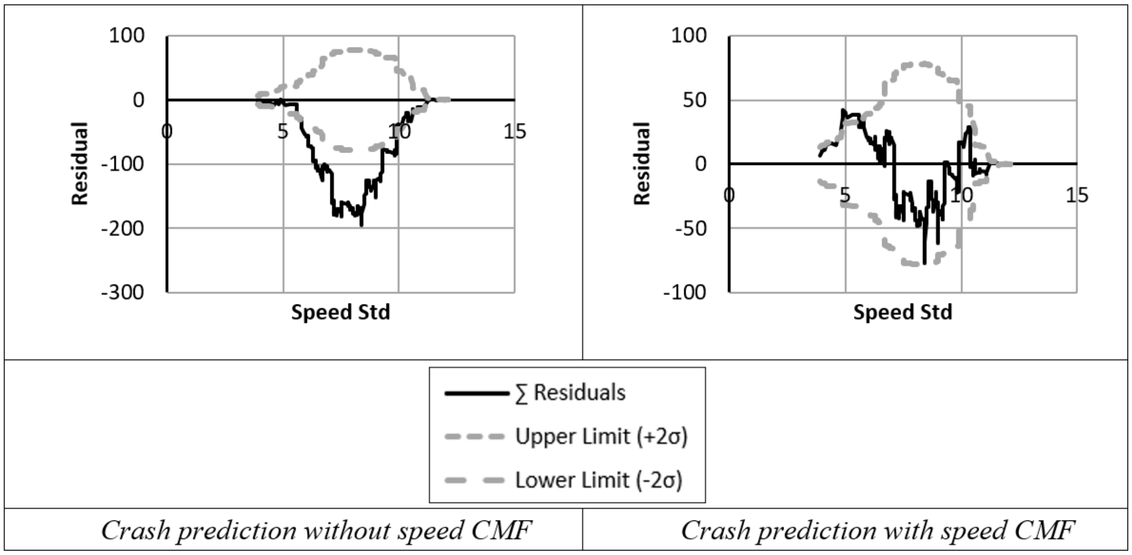
Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.145 \times x - 0.1081$
R-square	0.88
Speed measure boundaries	(3.90, 12.10)
Base condition	8
t-Test (*p*-value)	0.25
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.25



Crash prediction without speed CMF | *Crash prediction with speed CMF*

Source: FHWA.

Figure 40. Graph. CURE plots of R4U speed CMF for O crashes (Washington).



Source: FHWA.

Figure 41. Graph. CURE plots of R4U speed CMF for O crashes (North Carolina).

Table 56 and table 57 show the R4U CURE plot summary for Washington and North Carolina, respectively.

Table 56. CURE plots summary of R4U (Washington).

Crash	Crash Prediction Method	Within CURE (%)	Change to HSM (%)	|Maximum CURE Deviation|	Change to HSM (%)
KABCO	HSM (without speed CMF)	88.13	—	19.40	—
KABCO	HSM × speed CMF	99.38	11	0.00	−100
KABC	HSM (without speed CMF)	90.00	—	5.01	—
KABC	HSM × speed CMF	97.50	8	0.44	−91
O	HSM (without speed CMF)	88.75	—	12.27	—
O	HSM × speed CMF	99.38	11	0.00	−100

—Not applicable.

Table 57. CURE plots summary of R4U (North Carolina).

Crash	Crash Prediction Method	Within CURE (%)	Change to HSM (%)	|Maximum CURE Deviation|	Change to HSM (%)
KABCO	HSM (without speed CMF)	21.18	—	137.38	—
KABCO	HSM × speed CMF	98.93	78	4.85	−96
KABC	HSM (without speed CMF)	32.44	—	21.10	—
KABC	HSM × speed CMF	99.73	67	0.00	−100
O	HSM (without speed CMF)	23.06	—	116.94	—
O	HSM × speed CMF	95.71	73	10.41	−91

—Not applicable.

R4D SPEED CMFs

Table 58 and table 59 show the R4D statistics.

Table 58. Summary descriptive statistics of R4D (North Carolina).

Dataset	Segments (No.)	Length (mile)	KABC (No.)	PDO (No.)	Total (No.)	SVFI (No.)	SVPDO (No.)	MVFI (No.)	MVPDO (No.)
Training	1,346	360.9	672	1,968	2,640	—	—	—	—
Test	448	118.6	221	683	904	—	—	—	—
All	1,794	479.5	893	2,651	3,544	—	—	—	—

—Not applicable.
Note: The values for KABC, PDO, Total, SVFI, SVPDO, MVFI, and MVPDO represent observed crashes from 2017–18.

Table 59. *R*-square values of speed CMF equations of R4D (North Carolina).

Speed Measure	KABCO (Linear)	KABCO (Power)	KABC (Linear)	KABC (Power)	O (Linear)	O (Power)
SpdStd	0.38	0.41	0.42	0.45	***0.34***	***0.36***
(SpdAve − PSL)	***0.50***	—	***0.59***	—	***0.33***	—
|SpdAve − PSL|	***0.42***	***0.41***	***0.61***	***0.64***	0.22	0.19
SpdStd/SpdAve	***0.45***	***0.49***	***0.53***	***0.60***	***0.32***	***0.34***

—Not applicable.
Note: Bold italic numbers indicate the top five potential speed CMFs for each crash type/severity level.

R4D Speed CMF for KABCO Crashes

Table 60 and table 61 and figure 42 show the KABCO crash severity scale statistics for R4D (AASHTO 2010).

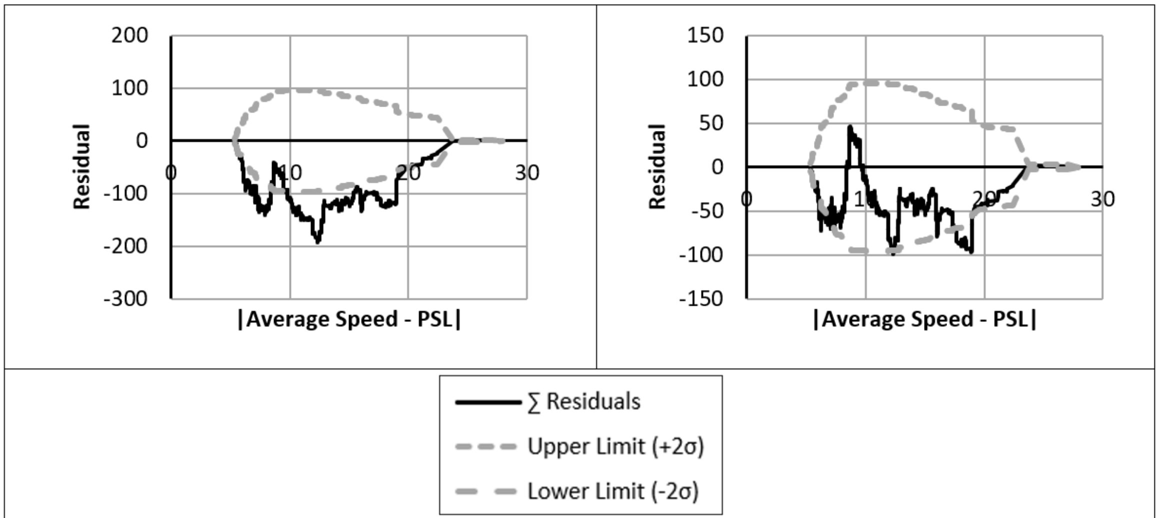
Table 60. Summary of R4D speed CMF development statistics for KABCO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.07	904	907.4	1.343	—	2.373	—
(SpdAve − PSL)	1.09	904	913.4	1.344	0.1	2.367	−0.3
|SpdAve − PSL|	**1.10**	**904**	**913.3**	**1.344**	**0.0**	**2.367**	**−0.3**
|SpdAve − PSL|	*1.10*	*904*	*913.1*	*1.344*	*0.1*	*2.366*	*−0.3*
SpdStd/SpdAve	1.12	904	909.1	1.342	−0.1	2.372	0.0
SpdStd/SpdAve	*1.12*	*904*	*911.0*	*1.343*	*−0.1*	*2.377*	*0.2*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 61. Speed CMF of R4D for KABCO crashes (North Carolina).

Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 0.016 \times x + 0.808$
R-square	0.32
Speed measure boundaries	(5.40, 27.90)
Base condition	12
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.06



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 42. Graph. CURE plots of R4D speed CMF for KABCO crashes (North Carolina).

R4D Speed CMF for KABC Crashes

Table 62 shows the KABC crash severity scale statistics for R4D (AASHTO 2010).

Table 62. Summary of R4D speed CMF development statistics for KABC crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	**0.56**	**221**	**230.3**	**0.563**	**—**	**0.867**	**—**
(SpdAve − PSL)	0.57	221	233.4	0.570	1.1	0.878	1.3
|SpdAve − PSL|	0.58	221	233.3	0.570	1.1	0.877	1.2
|SpdAve − PSL|	*0.58*	*221*	*233.7*	*0.571*	*1.4*	*0.881*	*1.6*
SpdStd/SpdAve	0.60	221	231.0	0.565	0.2	0.869	0.2
SpdStd/SpdAve	*0.60*	*221*	*231.8*	*0.567*	*0.6*	*0.874*	*0.8*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Speed CMF and associated CURE plot for R4D KABC in North Carolina are not included here as no effective speed CMF was found that could improve HSM default crash prediction for this facility type.

R4D Speed CMF for O Crashes

Table 63 and table 64 and figure 43 show the O crash severity scale statistics for R4D (AASHTO 2010).

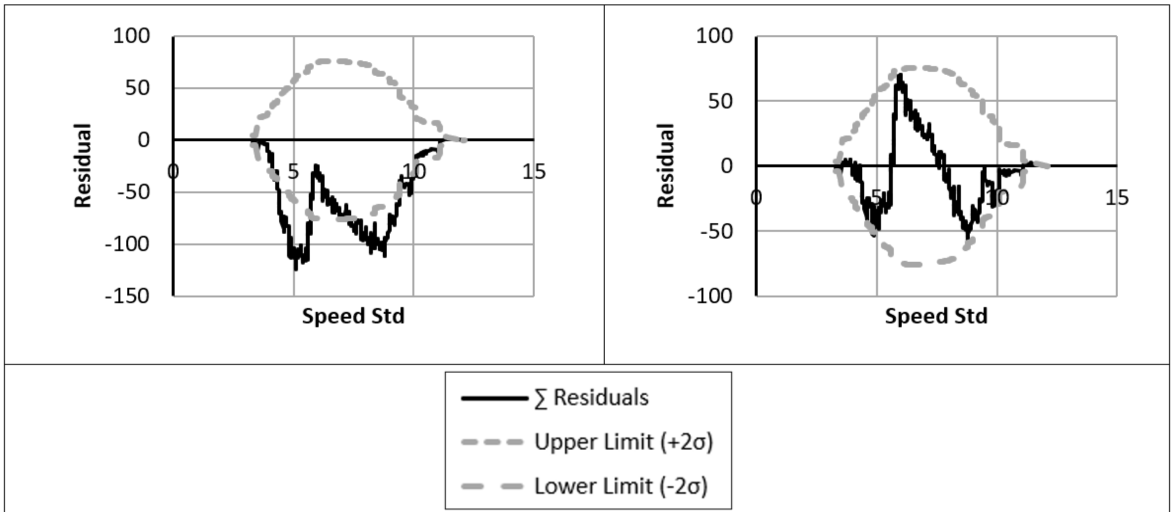
Table 63. Summary of R4D speed CMF development statistics for O crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.57	683	678.3	1.123	—	1.888	—
SpdStd	1.58	683	682.6	1.119	−0.4	1.880	−0.4
SpdStd	***1.58***	***683***	***682.7***	***1.118***	***−0.5***	***1.878***	***−0.5***
(SpdAve − PSL)	1.59	683	680.7	1.121	−0.2	1.880	−0.4
SpdStd/SpdAve	1.62	683	679.2	1.122	−0.1	1.886	−0.1
SpdStd/SpdAve	*1.62*	*683*	*680.2*	*1.121*	*−0.1*	*1.886*	*−0.1*

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 64. Speed CMF of R4D for O crashes (North Carolina).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.5567 \times x^{0.3076}$
R-square	0.44
Speed measure boundaries	(3.30, 12.10)
Base condition	7
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.08



Crash prediction without speed CMF | *Crash prediction with speed CMF*

Source: FHWA.

Figure 43. Graph. CURE plots of R4D speed CMF for O crashes (North Carolina).

Table 65 shows the R4D CURE plot summary for North Carolina.

Table 65. CURE plots summary of R4D (North Carolina).

Crash	Crash Prediction Method	Within CURE (%)	Change to HSM (%)	|Maximum CURE Deviation|	Change to HSM (%)
KABCO	HSM (without speed CMF)	15.27	—	96.75	—
KABCO	HSM × speed CMF	81.61	66	32.56	−66
KABC	HSM (without speed CMF)	44.15	—	45.90	—
KABC	HSM default	44.15	0	45.90	0
O	HSM (without speed CMF)	39.46	—	63.84	—
O	HSM × speed CMF	99.39	60	3.07	−95

—Not applicable.

APPENDIX E. DETAILS OF URBAN AND SUBURBAN ARTERIALS SPEED CMFs

This appendix provides details of speed CMFs of urban and suburban arterial roadways. Note that, for brevity, only the speed CMF plot of two-lane undivided urban and suburban arterial segments (U2U)-KABCO in Washington is reported in appendix E.

U2U SPEED CMFs

Table 66 through table 69 show the U2U statistics.

Table 66. Summary descriptive statistics of U2U (Washington).

Dataset	Segments (No.)	Length (mile)	KABC (No.)	PDO (No.)	Total (No.)	SVFI (No.)	SVPDO (No.)	MVFI (No.)	MVPDO (No.)
Training	335	132.7	111	277	388	40	108	71	169
Test	112	44.17	33	69	102	9	26	24	43
All	447	176.87	144	346	490	49	134	95	212

Note: Values for KABC, PDO, Total, SVFI, SVPDO, MVFI, and MVPDO represent observed crashes from 2017-2018.

Table 67. Summary descriptive statistics of U2U (North Carolina).

Dataset	Segments (No.)	Length (mile)	KABC (No.)	PDO (No.)	Total (No.)	SVFI (No.)	SVPDO (No.)	MVFI (No.)	MVPDO (No.)
Training	281	147.3	430	960	1,390	90	208	338	744
Test	93	49.8	117	310	427	28	79	87	229
All	374	197.1	547	1,270	1,817	118	287	425	973

Note: Values for KABC, PDO, Total, SVFI, SVPDO, MVFI, and MVPDO represent observed crashes from 2017-2018.

Table 68. *R*-square values of speed CMF equations of U2U (Washington).

Speed Measure	KABCO (L)	KABCO (P)	KABC (L)	KABC (P)	O (L)	O (P)	SVFI (L)	SVFI (P)	SVPDO (L)	SVPDO (P)	MVFI (L)	MVFI (P)	MVPDO (L)	MVPDO (P)
SpdStd	***0.58***	***0.52***	***0.60***	***0.55***	***0.55***	***0.49***	0.01	0.01	***0.55***	***0.56***	***0.85***	***0.81***	***0.42***	***0.37***
(SpdAve – PSL)	***0.30***	—	***0.11***	—	***0.39***	—	***0.12***	—	***0.12***	—	***0.73***	—	***0.72***	—
|SpdAve – PSL|	***0.27***	***0.27***	***0.05***	***0.05***	***0.43***	***0.43***	***0.12***	***0.09***	0.10	0.09	***0.56***	***0.49***	***0.77***	***0.68***
SpdStd/ SpdAve	0.00	0.00	0.00	0.00	0.00	0.00	***0.17***	***0.15***	***0.30***	***0.14***	0.33	0.36	0.30	0.32

—Not applicable.
L = linear; P = power.
Note: Bold italic numbers indicate the top five potential speed CMFs for each crash type/severity level.

Table 69. *R*-square values of speed CMF equations of U2U (North Carolina).

Speed Measure	KABCO (L)	KABCO (P)	KABC (L)	KABC (P)	O (L)	O (P)	SVFI (L)	SVFI (P)	SVPDO (L)	SVPDO (P)	MVFI (L)	MVFI (P)	MVPDO (L)	MVPDO (P)
SpdStd	***0.78***	***0.78***	***0.51***	***0.53***	***0.81***	***0.79***	***0.14***	***0.25***	0.00	0.00	***0.53***	***0.52***	***0.83***	***0.78***
(SpdAve – PSL)	***0.39***	—	***0.16***	—	***0.49***	—	***0.20***	—	***0.11***	—	***0.16***	—	***0.50***	—
|SpdAve – PSL|	0.33	0.27	0.13	0.14	0.43	0.34	***0.10***	*0.06*	***0.10***	***0.15***	0.14	0.11	0.42	0.28
SpdStd/ SpdAve	***0.68***	***0.78***	***0.47***	***0.63***	***0.75***	***0.82***	0.06	***0.21***	***0.10***	***0.08***	***0.47***	***0.56***	***0.81***	***0.83***

—Not applicable.
Note: Bold italic numbers indicate the top five potential speed CMFs for each crash type/severity level.

U2U Speed CMF for KABCO Crashes

Table 70 to table 73 and figure 44 to figure 46 show the KABCO crash severity scale statistics for U2U (AASHTO 2010).

Table 70. Summary of U2U speed CMF development statistics for KABCO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.29	102	376.4	1.656	—	13.552	—
SpdStd	*0.25*	*102*	*496.2*	*2.040*	*23.2*	*21.294*	*57.1*
SpdStd	0.27	102	592.2	2.365	42.8	27.257	101.1
(SpdAve − PSL)	0.24	102	369.0	1.595	−3.7	13.122	−3.2
|SpdAve − PSL|	0.25	102	368.9	1.594	−3.8	13.117	−3.2
|SpdAve − PSL|	***0.28***	***102***	***361.8***	***1.539***	***−7.1***	***12.721***	***−6.1***

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 71. Summary of U2U speed CMF development statistics for KABCO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.32	427	509.0	4.202	—	10.332	—
SpdStd	*1.36*	*427*	*542.1*	*4.597*	*9.4*	*13.244*	*28.2*
SpdStd	1.38	427	548.1	4.677	11.3	13.878	34.3
(SpdAve − PSL)	**1.22**	**427**	**491.0**	**3.933**	**−6.4**	**8.829**	**−14.6**
SpdStd/SpdAve	1.43	427	505.8	4.100	−2.4	10.018	−3.0
SpdStd/SpdAve	*1.51*	*427*	*508.1*	*4.024*	*−4.2*	*9.876*	*−4.4*

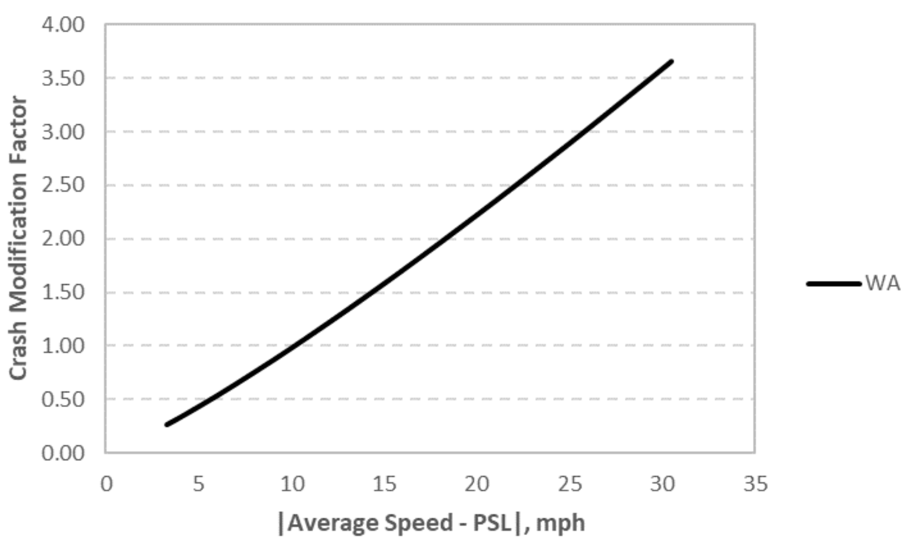
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 72. U2U speed CMF for KABCO crashes (Washington).

Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 0.0642 \times x^{1.1825}$
R-square	0.28
Speed measure boundaries	(3.30, 30.50)
Base condition	10
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.65

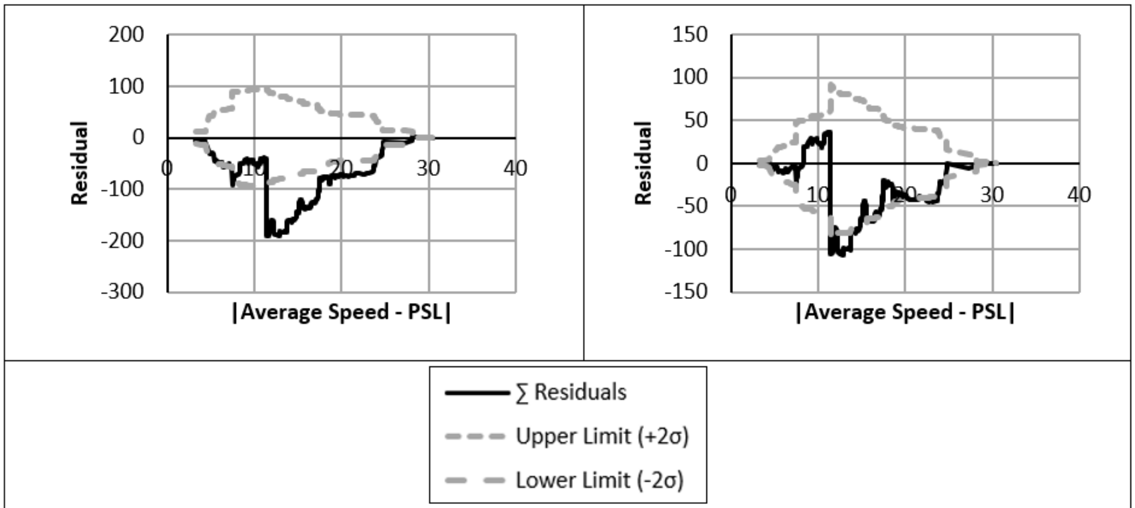
Table 73. U2U speed CMF for KABCO crashes (North Carolina).

Speed CMF	Value
Speed measure	(SpdAve − PSL)
CMF equation	$y = -0.0516 \times x + 0.3138$
R-square	0.37
Speed measure boundaries	(−31.10, −4.10)
Base condition	−13
t-Test (p-value)	0.25
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.20



Source: FHWA.

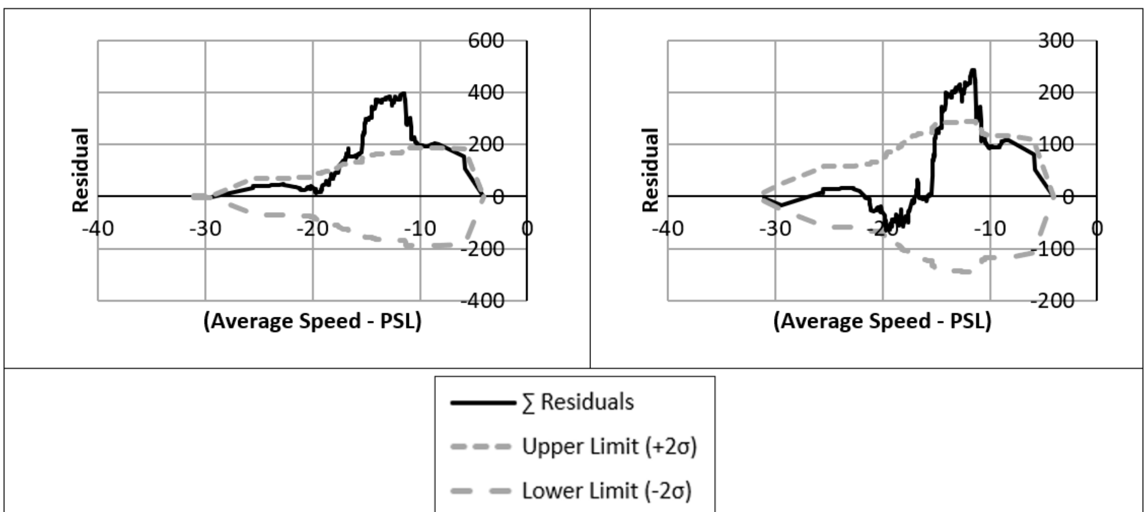
Figure 44. Graph. Speed CMF of U2U for KABCO crashes (Washington).



Crash prediction without speed CMF	Crash prediction with speed CMF

Source: FHWA.

Figure 45. Graph. CURE plots of U2U speed CMF for KABCO crashes (Washington).



Crash prediction without speed CMF	Crash prediction with speed CMF

Source: FHWA.

Figure 46. Graph. CURE plots of U2U speed CMF for KABCO crashes (North Carolina).

U2U Speed CMF for KABC Crashes

Table 74 to table 77 and figure 47 and figure 48 show the KABC crash severity scale statistics for U2U (AASHTO 2010).

Table 74. Summary of U2U speed CMF development statistics for KABC crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.29	33	106.6	0.504	—	3.795	—
SpdStd	0.25	33	140.4	0.621	23.2	5.973	57.4
SpdStd	*0.27*	*33*	*168.2*	*0.716*	*42.2*	*7.690*	*102.6*
(SpdAve − PSL)	0.23	33	105.2	0.496	−1.5	3.714	−2.1
|SpdAve − PSL|	0.23	33	105.4	0.497	−1.3	3.723	−1.9
|SpdAve − PSL|	***0.29***	***33***	***102.6***	***0.482***	***−4.4***	***3.563***	***−6.1***

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 75. Summary of U2U speed CMF development statistics for KABC crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.41	117	156.7	1.397	—	3.290	—
SpdStd	1.44	117	164.2	1.490	6.6	3.932	19.5
SpdStd	*1.40*	*117*	*157.6*	*1.460*	*4.5*	*3.823*	*16.2*
(SpdAve − PSL)	**1.29**	**117**	**153.4**	**1.351**	**−3.3**	**3.016**	**−8.3**
SpdStd/SpdAve	1.48	117	156.0	1.381	−1.1	3.230	−1.8
SpdStd/SpdAve	*1.55*	*117*	*156.9*	*1.369*	*−2.0*	*3.192*	*−3.0*

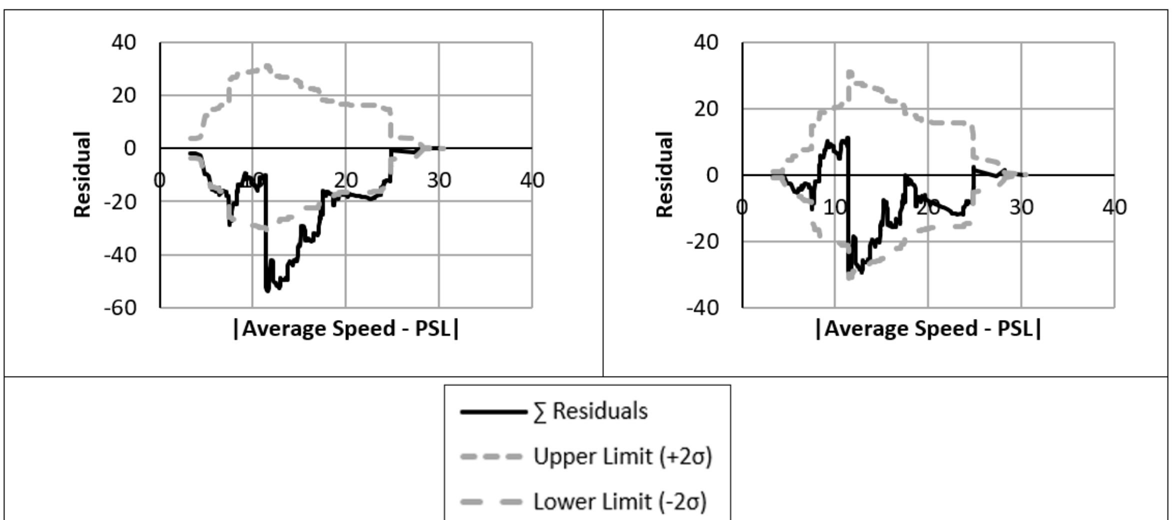
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 76. U2U speed CMF for KABC crashes (Washington).

Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 0.0778 \times x^{1.1051}$
R-square	0.14
Speed measure boundaries	(3.30, 30.50)
Base condition	10
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.60

Table 77. U2U speed CMF for KABC crashes (North Carolina).

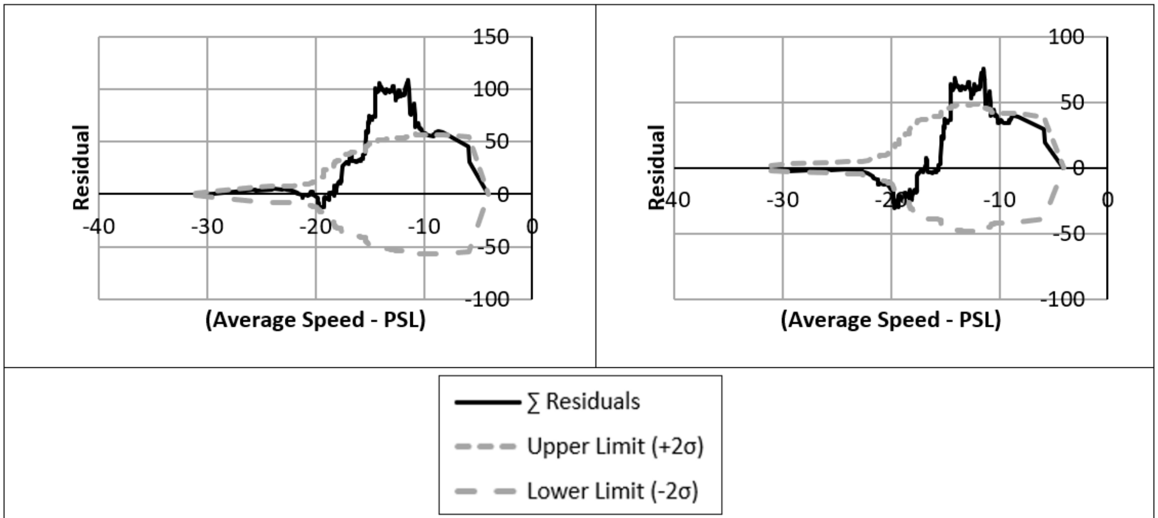
Speed CMF	Value
Speed measure	(SpdAve − PSL)
CMF equation	$y = -0.0377 \times x + 0.5184$
R-square	0.2
Speed measure boundaries	(−31.10, −4.10)
Base condition	−13
t-Test (*p*-value)	0.04
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.14



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 47. Graph. CURE plots of U2U speed CMF for KABC crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 48. Graph. CURE plots of U2U speed CMF for KABC crashes (North Carolina).

U2U Speed CMF for O Crashes

Table 78 to table 81 and figure 49 and figure 50 show the O crash severity scale statistics for U2U (AASHTO 2010).

Table 78. Summary of U2U speed CMF development statistics for O crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.29	69	269.7	1.183	—	9.762	—
SpdStd	0.24	69	354.9	1.460	23.4	15.280	56.5
SpdStd	*0.27*	*69*	*423.1*	*1.685*	*42.5*	*19.527*	*100.0*
(SpdAve − PSL)	0.25	69	263.5	1.133	−4.2	9.412	−3.6
|SpdAve − PSL|	0.25	69	263.2	1.131	−4.4	9.396	−3.7
|SpdAve − PSL|	***0.28***	***69***	***258.6***	***1.096***	***−7.3***	***9.143***	***−6.3***

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 79. Summary of U2U speed CMF development statistics for O crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.29	310	352.1	3.155	—	7.393	—
SpdStd	1.33	310	377.7	3.477	10.2	9.590	29.7
SpdStd	*1.35*	*310*	*383.1*	*3.563*	*12.9*	*10.263*	*38.8*
(SpdAve − PSL)	**1.20**	**310**	**337.7**	**2.965**	**−6.0**	**6.249**	**−15.5**
SpdStd/SpdAve	1.42	310	349.6	3.094	−1.9	7.147	−3.3
SpdStd/SpdAve	*1.50*	*310*	*350.9*	*3.055*	*−3.2*	*7.052*	*−4.6*

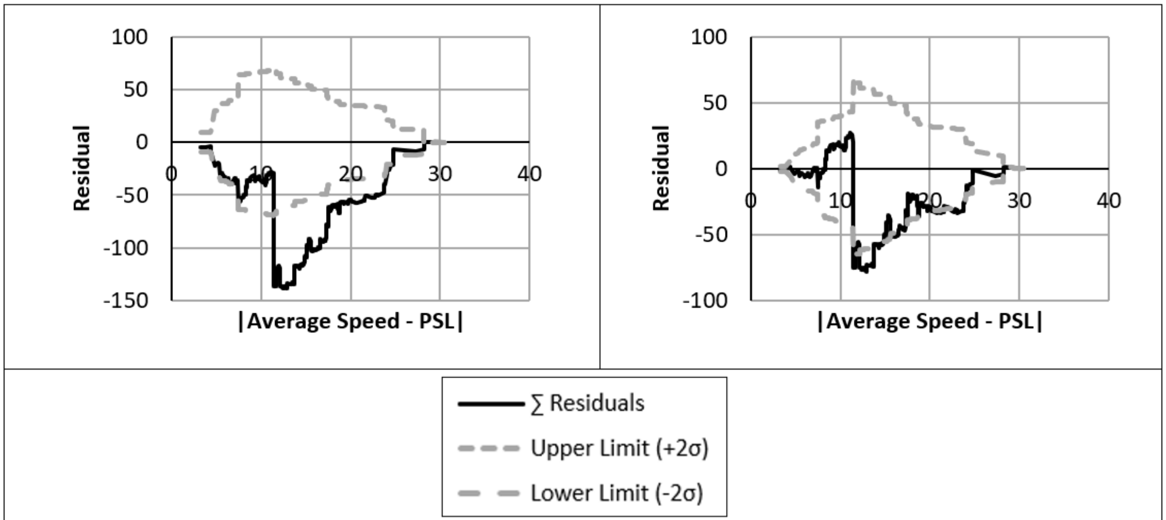
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 80. U2U speed CMF for O crashes (Washington).

Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 0.0597 \times x^{1.2103}$
R-square	0.34
Speed measure boundaries	(3.30, 30.50)
Base condition	10
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.67

Table 81. U2U speed CMF for O crashes (North Carolina).

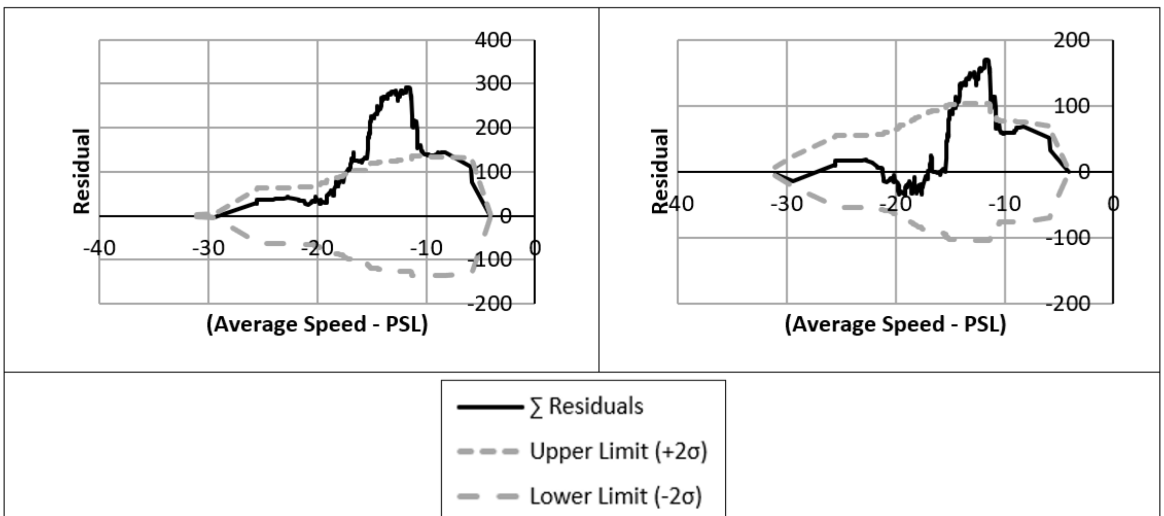
Speed CMF	Value
Speed measure	(SpdAve − PSL)
CMF equation	$y = -0.0578 \times x + 0.222$
R-square	0.44
Speed measure boundaries	(−31.10, −4.10)
Base condition	−13
t-Test (p-value)	0.37
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.22



Crash prediction without speed CMF	Crash prediction with speed CMF

Source: FHWA.

Figure 49. Graph. CURE plots of U2U speed CMF for O crashes (Washington).



Crash prediction without speed CMF	Crash prediction with speed CMF

Source: FHWA.

Figure 50. Graph. CURE plots of U2U speed CMF for O crashes (North Carolina).

U2U Speed CMF for SVFI Crashes

Table 82 to table 85 and figure 51 and figure 52 show the SVFI statistics for U2U.

Table 82. Summary of U2U speed CMF development statistics for SVFI crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.90	9	14.6	0.201	—	0.403	—
(SpdAve − PSL)	0.83	9	14.2	0.197	−1.8	0.405	0.4
|SpdAve − PSL|	0.84	9	14.2	0.197	−1.8	0.405	0.4
|SpdAve − PSL|	*0.98*	*9*	*14.3*	*0.199*	*−0.9*	*0.405*	*0.5*
SpdStd/SpdAve	**0.73**	**9**	**14.2**	**0.197**	**−1.8**	**0.401**	**−0.4**
SpdStd/SpdAve	*0.95*	*9*	*14.0*	*0.196*	*−2.5*	*0.406*	*0.6*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 83. Summary of U2U speed CMF development statistics for SVFI crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.78	28	29.9	0.425	—	0.627	—
SpdStd	1.75	28	30.5	0.427	0.4	0.630	0.4
SpdStd	***1.79***	***28***	***29.4***	***0.424***	***−0.4***	***0.629***	***0.3***
(SpdAve − PSL)	1.78	28	30.4	0.427	0.5	0.630	0.6
|SpdAve − PSL|	1.75	28	30.4	0.427	0.5	0.630	0.5
SpdStd/SpdAve	*1.79*	*28*	*30.1*	*0.426*	*0.2*	*0.627*	*0.1*

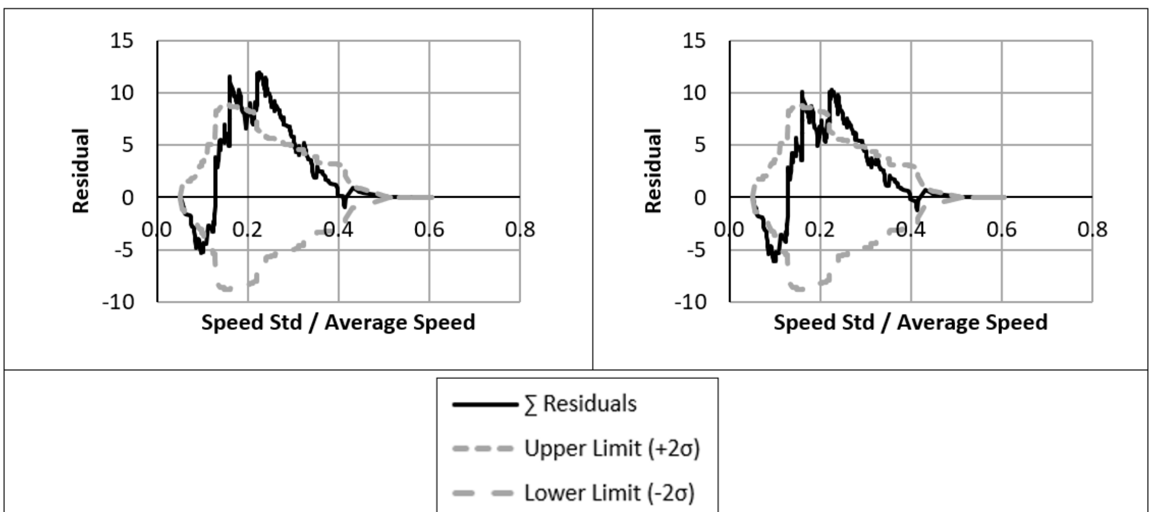
—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 84. U2U speed CMF for SVFI crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = -1.0591 \times x + 1.4384$
R-square	0.15
Speed measure boundaries	(0.05, 0.61)
Base condition	0.41
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.10

Table 85. U2U speed CMF for SVFI crashes (North Carolina).

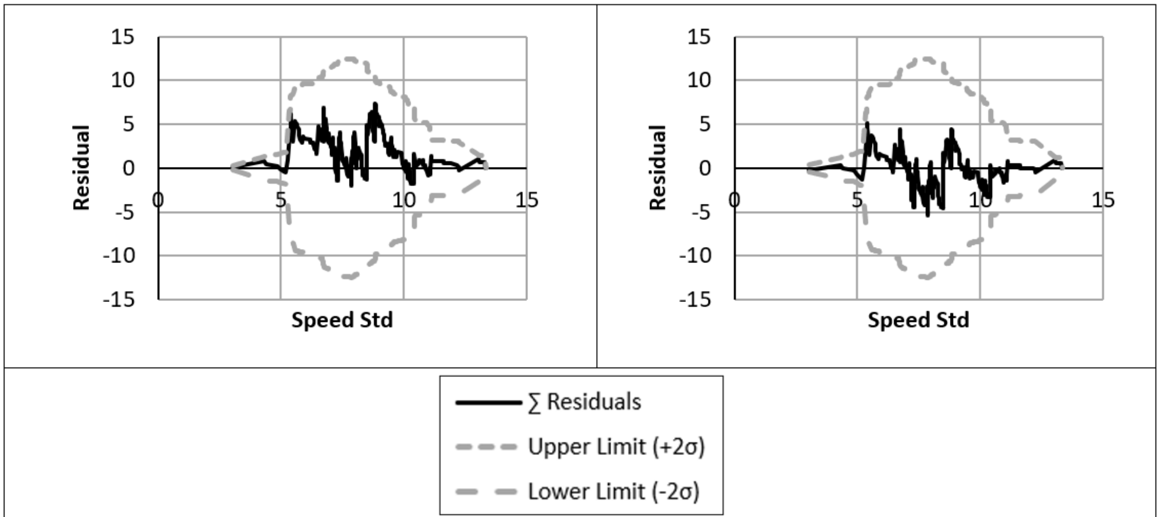
Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 1.9076 \times x^{-0.324}$
R-square	0.2
Speed measure boundaries	(3.00, 13.30)
Base condition	7
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.06



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 51. Graph. CURE plots of U2U speed CMF for SVFI crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 52. Graph. CURE plots of U2U speed CMF for SVFI crashes (North Carolina).

U2U Speed CMF for SVPDO Crashes

Table 86 to table 89 and figure 53 and figure 54 show the SVPDO statistics for U2U.

Table 86. Summary of U2U speed CMF development statistics for SVPDO crashes (Washington).

Speed CMF	CF	Observed crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.65	26	45.9	0.541	—	1.027	—
SpdStd	0.62	26	48.9	0.548	1.2	1.149	11.9
SpdStd	*0.63*	*26*	*49.9*	*0.551*	*1.7*	*1.203*	*17.1*
(SpdAve − PSL)	0.59	26	45.9	0.552	1.9	1.092	6.4
SpdStd/SpdAve	**0.48**	**26**	**44.9**	**0.539**	**−0.5**	**1.045**	**1.7**
SpdStd/SpdAve	*0.57*	*26*	*44.5*	*0.550*	*1.7*	*1.127*	*9.8*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 87. Summary of U2U speed CMF development statistics for SVPDO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.13	79	70.5	0.722	—	1.022	—
(SpdAve − PSL)	1.11	79	69.4	0.724	0.3	1.021	−0.1
|SpdAve − PSL|	1.11	79	69.5	0.724	0.3	1.021	−0.1
|SpdAve − PSL|	*1.14*	*79*	*68.6*	*0.727*	*0.6*	*1.021*	*−0.1*
SpdStd/SpdAve	1.10	79	70.7	0.720	−0.3	1.020	−0.2
SpdStd/SpdAve	***1.13***	***79***	***70.8***	***0.719***	***−0.4***	***1.018***	***−0.4***

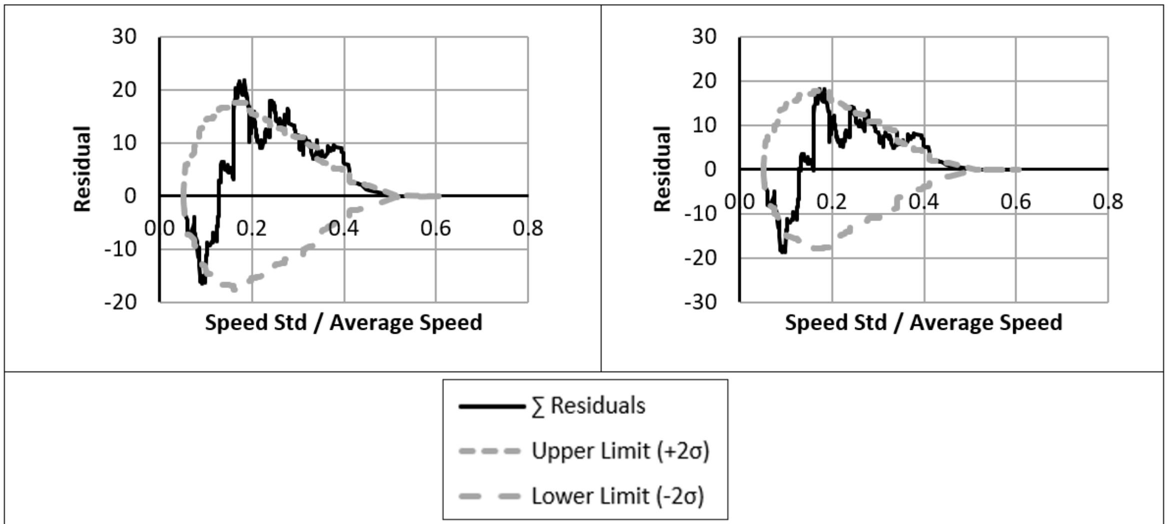
—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 88. U2U speed CMF for SVPDO crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = -0.844 \times x + 1.4073$
R-square	0.18
Speed measure boundaries	(0.05, 0.61)
Base condition	0.48
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.08

Table 89. U2U speed CMF for SVPDO crashes (North Carolina).

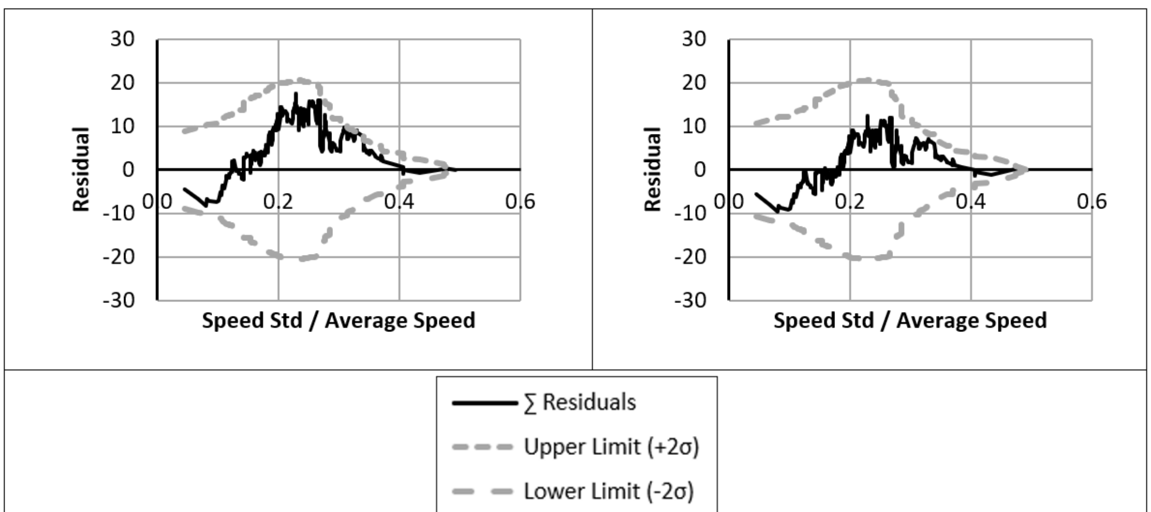
Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 0.8368 \times x^{-0.122}$
R-square	0.32
Speed measure boundaries	(0.05, 0.49)
Base condition	0.23
t-Test (*p*-value)	0.02
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.04



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 53. Graph. CURE plots of U2U speed CMF for SVPDO crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 54. Graph. CURE plots of U2U speed CMF for SVPDO crashes (North Carolina).

U2U Speed CMF for MVFI Crashes

Table 90 to table 93 and figure 55 and figure 56 show the MVFI statistics for U2U.

Table 90. Summary of U2U speed CMF development statistics for MVFI crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.25	24	76.0	0.864	—	4.560	—
SpdStd	0.23	24	125.0	1.280	48.2	9.479	107.9
SpdStd	*0.24*	*24*	*139.5*	*1.403*	*62.4*	*10.765*	*136.1*
(SpdAve − PSL)	0.21	24	74.4	0.841	−2.6	4.446	−2.5
|SpdAve − PSL|	0.21	24	74.5	0.843	−2.4	4.456	−2.3
|SpdAve − PSL|	***0.24***	***24***	***67.8***	***0.778***	***−10.0***	***3.835***	***−15.9***

—Not applicable.
Note:Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 91. Summary of U2U speed CMF development statistics for MVFI crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.74	87	121.8	1.296	—	2.883	—
SpdStd	1.79	87	130.9	1.375	6.1	3.375	17.1
SpdStd	*1.86*	*87*	*133.4*	*1.400*	*8.1*	*3.588*	*24.5*
(SpdAve − PSL)	**1.53**	**87**	**118.9**	**1.235**	**−4.6**	**2.563**	**−11.1**
SpdStd/SpdAve	1.82	87	121.3	1.272	−1.8	2.770	−3.9
SpdStd/SpdAve	*2.06*	*87*	*122.1*	*1.246*	*−3.8*	*2.651*	*−8.0*

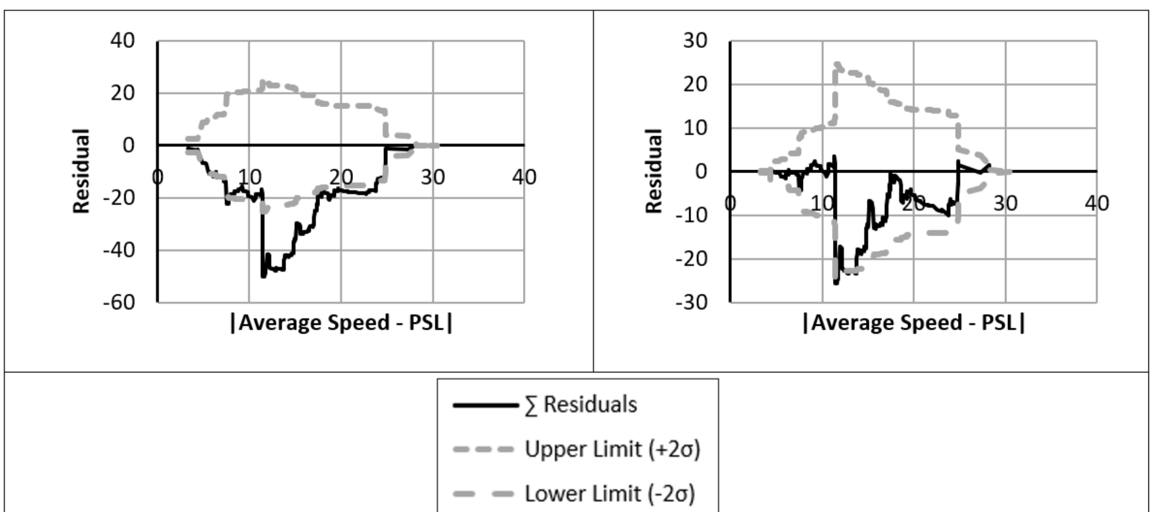
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 92. U2U speed CMF for MVFI crashes (Washington).

Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 0.0127 \times x^{1.813}$
R-square	0.31
Speed measure boundaries	(3.30, 30.50)
Base condition	11
t-Test (p-value)	0.02
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	1.11

Table 93. U2U speed CMF for MVFI crashes (North Carolina).

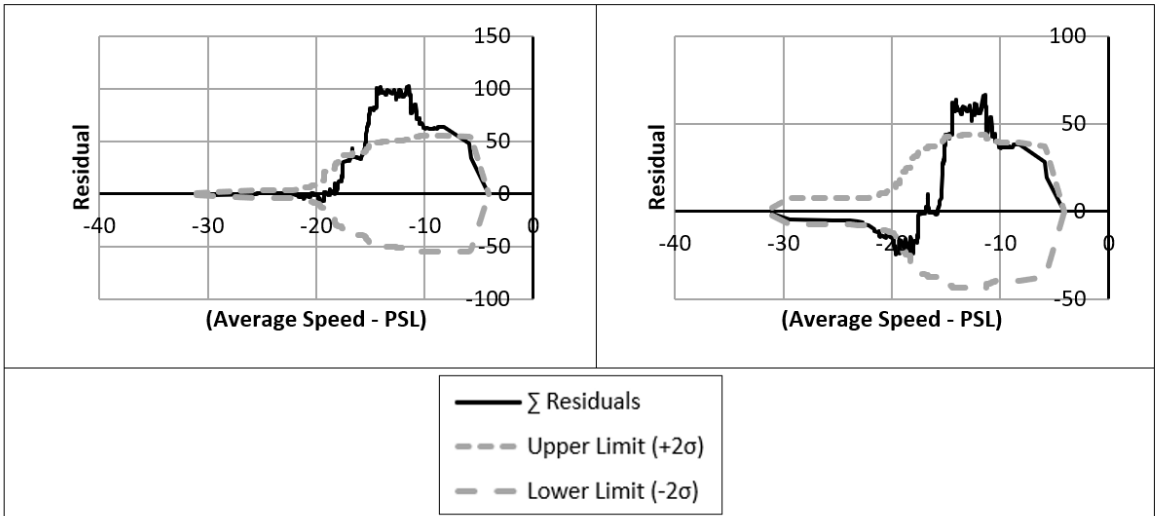
Speed CMF	Value
Speed measure	(SpdAve − PSL)
CMF equation	$y = -0.0476 \times x + 0.4197$
R-square	0.19
Speed measure boundaries	(−31.30, −4.10)
Base condition	−12
t-Test (p-value)	0.04
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.18



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 55. Graph. CURE plots of U2U speed CMF for MVFI crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 56. Graph. CURE plots of U2U speed CMF for MVFI crashes (North Carolina).

U2U Speed CMF for MVPDO Crashes

Table 94 to table 97 and figure 57 and figure 58 show the MVPDO statistics for U2U.

Table 94. Summary of U2U speed CMF development statistics for MVPDO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.24	43	186.3	1.950	—	11.303	—
SpdStd	0.19	43	268.7	2.639	35.4	19.538	72.9
SpdStd	*0.22*	*43*	*330.2*	*3.155*	*61.8*	*25.422*	*124.9*
(SpdAve − PSL)	0.20	43	182.1	1.863	−4.4	11.039	−2.3
|SpdAve − PSL|	0.21	43	182.1	1.863	−4.4	11.039	−2.3
|SpdAve − PSL|	***0.22***	***43***	***161.3***	***1.656***	***−15.0***	***9.045***	***−20.0***

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 95. Summary of U2U speed CMF development statistics for MVPDO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.56	229	270.0	2.928	—	6.701	—
SpdStd	1.64	229	301.8	3.213	9.7	8.616	28.6
SpdStd	*1.69*	*229*	*310.0*	*3.337*	*14.0*	*9.836*	*46.8*
(SpdAve − PSL)	**1.41**	**229**	**258.5**	**2.686**	**−8.3**	**5.464**	**−18.5**
SpdStd/SpdAve	1.77	229	268.5	2.791	−4.7	6.244	−6.8
SpdStd/SpdAve	*1.99*	*229*	*268.7*	*2.703*	*−7.7*	*6.008*	*−10.4*

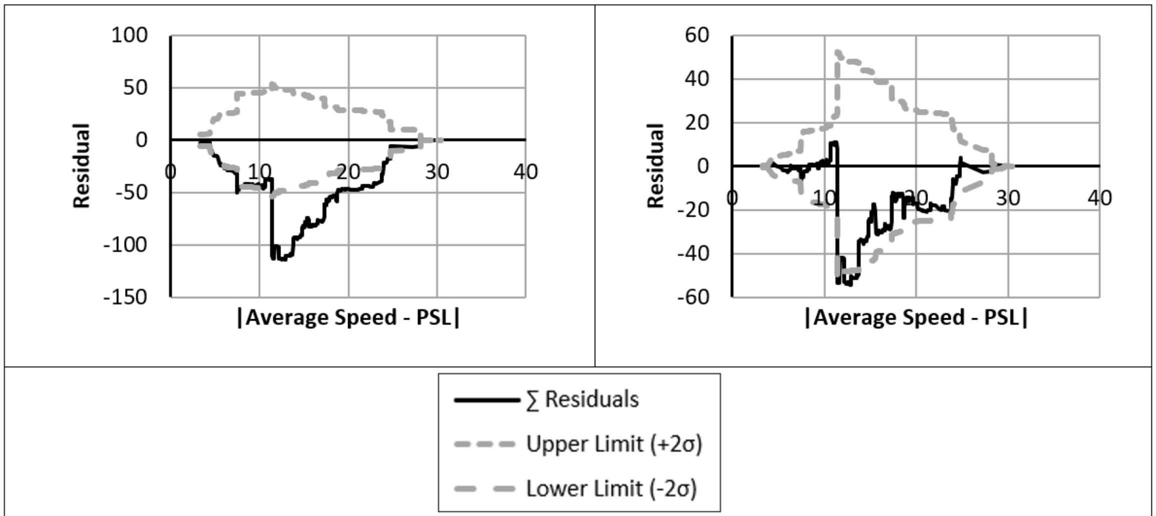
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 96. U2U speed CMF for MVPDO crashes (Washington).

Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 0.0076 \times x^{2.0095}$
R-square	0.39
Speed measure boundaries	(3.30, 30.50)
Base condition	11
t-Test (*p*-value)	0.03
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	1.28

Table 97. U2U speed CMF for MVPDO crashes (North Carolina).

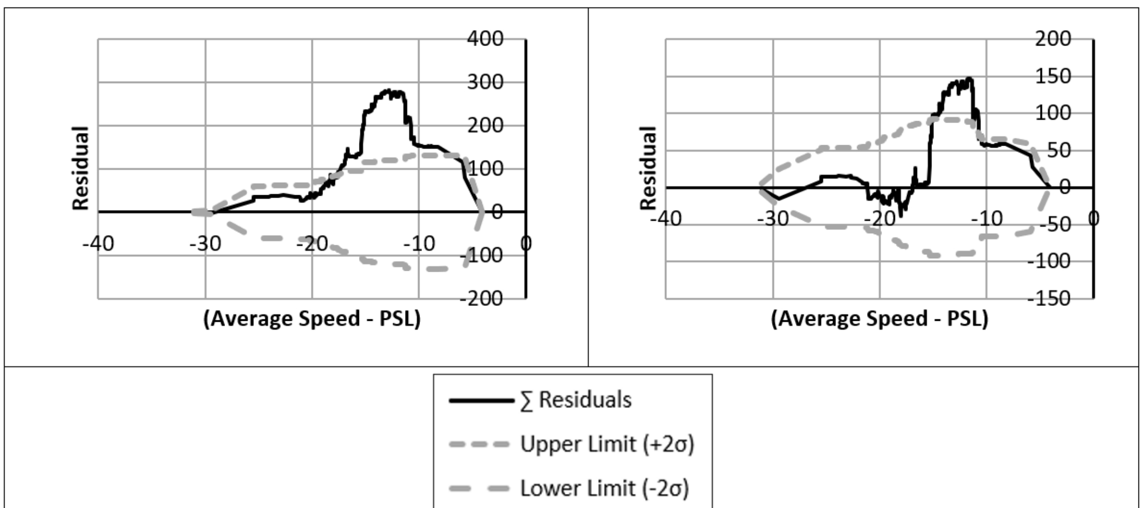
Speed CMF	Value
Speed measure	(SpdAve − PSL)
CMF equation	$y = -0.0726 \times x + 0.0642$
R-square	0.42
Speed measure boundaries	(−31.10, −4.10)
Base condition	−13
t-Test (*p*-value)	0.35
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.28



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 57. Graph. CURE plots of U2U speed CMF for MVPDO crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 58. Graph. CURE plots of U2U speed CMF for MVPDO crashes (North Carolina).

Table 98 and table 99 show the U2U CURE plot summary for Washington and North Carolina, respectively.

Table 98. CURE plots summary of U2U (Washington).

Crash	Crash Prediction Method	Within CURE (%)	Change to HSM (%)	|Maximum CURE Deviation|	Change to HSM (%)
KABCO	HSM (without speed CMF)	35.12	—	110.95	—
KABCO	HSM × speed CMF	72.71	38	26.10	−76
KABC	HSM (without speed CMF)	39.37	—	25.30	—
KABC	HSM × speed CMF	95.30	56	1.92	−92
O	HSM (without speed CMF)	36.69	—	77.86	—
O	HSM × speed CMF	72.48	36	16.87	−78
SVFI	HSM (without speed CMF)	42.51	—	5.73	—
SVFI	HSM × speed CMF	62.42	20	4.22	−26
SVPDO	HSM (without speed CMF)	52.13	—	4.95	—
SVPDO	HSM × speed CMF	77.40	25	5.02	1
MVFI	HSM (without speed CMF)	31.77	—	24.71	—
MVFI	HSM × speed CMF	95.08	63	0.86	−97
MVPDO	HSM (without speed CMF)	25.95	—	65.58	—
MVPDO	HSM × speed CMF	89.71	64	6.18	−91

—Not applicable.

Table 99. CURE plots summary of U2U (North Carolina).

Crash	Crash Prediction Method	Within CURE (%)	Change to HSM (%)	|Maximum CURE Deviation|	Change to HSM (%)
KABCO	HSM (without speed CMF)	28.61	—	227.21	—
KABCO	HSM × speed CMF	60.96	32	98.76	−57
KABC	HSM (without speed CMF)	40.91	—	54.25	—
KABC	HSM × speed CMF	50.53	10	26.85	−50
O	HSM (without speed CMF)	28.61	—	165.82	—
O	HSM × speed CMF	61.76	33	67.24	−59
SVFI	HSM (without speed CMF)	99.73	—	0.00	—
SVFI	HSM × speed CMF	99.73	0	0.00	−47
SVPDO	HSM (without speed CMF)	98.93	—	0.42	—
SVPDO	HSM × speed CMF	99.73	1	0.00	−100
MVFI	HSM (without speed CMF)	36.63	—	53.06	—
MVFI	HSM × speed CMF	43.85	7	23.09	−56
MVPDO	HSM (without speed CMF)	26.20	—	162.66	—
MVPDO	HSM × speed CMF	56.15	30	57.57	−65

—Not applicable.

U3T SPEED CMFs

Table 100 through table 103 show the three-lane urban and suburban arterials including a center two-way, left-turn lane (U3T) statistic.

Table 100. Summary descriptive statistics of U3T (Washington).

Dataset	Segments (No.)	Length (mile)	KABC (No.)	PDO (No.)	Total (No.)	SVFI (No.)	SVPDO (No.)	MVFI (No.)	MVPDO (No.)
Training	170	32.7	47	137	184	6	22	41	115
Test	56	9.1	7	15	22	0	1	7	14
All	226	41.8	54	152	206	6	23	48	129

Note: Values for KABC, PDO, Total, SVFI, SVPDO, MVFI, and MVPDO represent observed crashes from 2017-2018.

Table 101. Summary descriptive statistics of U3T (North Carolina).

Dataset	Segments (No.)	Length (mile)	KABC (No.)	PDO (No.)	Total (No.)	SVFI (No.)	SVPDO (No.)	MVFI (No.)	MVPDO (No.)
Training	72	21.7	84	220	304	16	33	65	184
Test	24	5.5	26	78	104	4	19	21	59
All	96	27.2	110	298	408	20	52	86	243

Note: Values for KABC, PDO, Total, SVFI, SVPDO, MVFI, and MVPDO represent observed crashes from 2017-2018.

Table 102. *R-s*quare values of speed CMF equations of U3T (Washington).

Speed Measure	KABCO (L)	KABCO (P)	KABC (L)	KABC (P)	O (L)	O (P)	SVFI (L)	SVFI (P)	SVPDO (L)	SVPDO (P)	MVFI (L)	MVFI (P)	MVPDO (L)	MVPDO (P)
SpdStd	***0.54***	***0.50***	0.07	0.06	***0.63***	***0.59***	***0.01***	—	***0.44***	***0.39***	***0.03***	0.01	***0.48***	***0.44***
(SpdAve – PSL)	***0.11***	—	***0.12***	—	***0.09***	—	***0.00***	—	***0.13***	—	***0.06***	—	***0.16***	—
|SpdAve – PSL|	0.06	0.02	***0.15***	***0.07***	0.03	0.01	***0.06***	—	0.01	—	***0.05***	0.01	0.04	0.02
SpdStd/ SpdAve	***0.20***	***0.11***	***0.20***	***0.10***	***0.30***	***0.16***	***0.09***	—	***0.23***	***0.59***	***0.15***	***0.06***	***0.67***	***0.62***

—Not applicable.

Note: Bold italic numbers indicate the top five potential speed CMFs for each crash type/severity level.

Table 103. *R*-square values of speed CMF equations of U3T (North Carolina).

Speed Measure	KABCO (L)	KABCO (P)	KABC (L)	KABC (P)	O (L)	O (P)	SVFI (L)	SVFI (P)	SVPDO (L)	SVPDO (P)	MVFI (L)	MVFI (P)	MVPDO (L)	MVPDO (P)
SpdStd	***0.06***	0.04	***0.06***	***0.05***	***0.09***	***0.07***	***0.27***	—	0.00	0.00	0.05	0.06	***0.13***	***0.12***
(SpdAve − PSL)	***0.09***	—	***0.05***	—	***0.20***	—	***0.24***	—	***0.42***	—	***0.06***	—	***0.59***	—
|SpdAve − PSL|	***0.29***	***0.31***	0.01	0.00	***0.34***	***0.34***	***0.67***	***0.46***	***0.39***	***0.23***	***0.45***	***0.47***	***0.56***	***0.50***
SpdStd/ SpdAve	0.03	***0.07***	***0.13***	***0.15***	0.01	0.04	***0.36***	—	***0.18***	***0.21***	***0.75***	***0.78***	0.07	0.11

—Not applicable.

Note: Bold italic numbers indicate the top five potential speed CMFs for each crash type/severity level.

U3T Speed CMF for KABCO Crashes

Table 104 to table 107 and figure 59 and figure 60 show the KABCO crash severity scale statistics for U3T (AASHTO 2010).

Table 104. Summary of U3T speed CMF development statistics for KABCO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.51	22	63.0	0.333	—	1.194	—
SpdStd	***0.52***	***22***	***63.1***	***0.325***	***−2.3***	***1.192***	***−0.2***
SpdStd	0.54	22	63.2	0.328	−1.5	1.196	0.2
(SpdAve − PSL)	0.50	22	63.7	0.334	0.5	1.216	1.9
SpdStd/SpdAve	0.52	22	63.8	0.336	1.0	1.217	1.9
SpdStd/SpdAve	*0.52*	*22*	*63.7*	*0.335*	*0.8*	*1.212*	*1.5*

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 105. Summary of U3T speed CMF development statistics for KABCO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.80	104	99.7	3.691	—	6.804	—
SpdStd	**1.87**	**104**	**103.0**	**3.773**	**2.2**	**6.783**	**−0.3**
(SpdAve − PSL)	1.78	104	102.3	3.790	2.7	6.760	−0.6
|SpdAve − PSL|	1.83	104	104.3	3.870	4.8	6.755	−0.7
|SpdAve − PSL|	*1.85*	*104*	*105.2*	*3.918*	*6.1*	*6.751*	*−0.8*
SpdStd/SpdAve	*2.06*	*104*	*103.2*	*3.770*	*2.1*	*6.816*	*0.2*

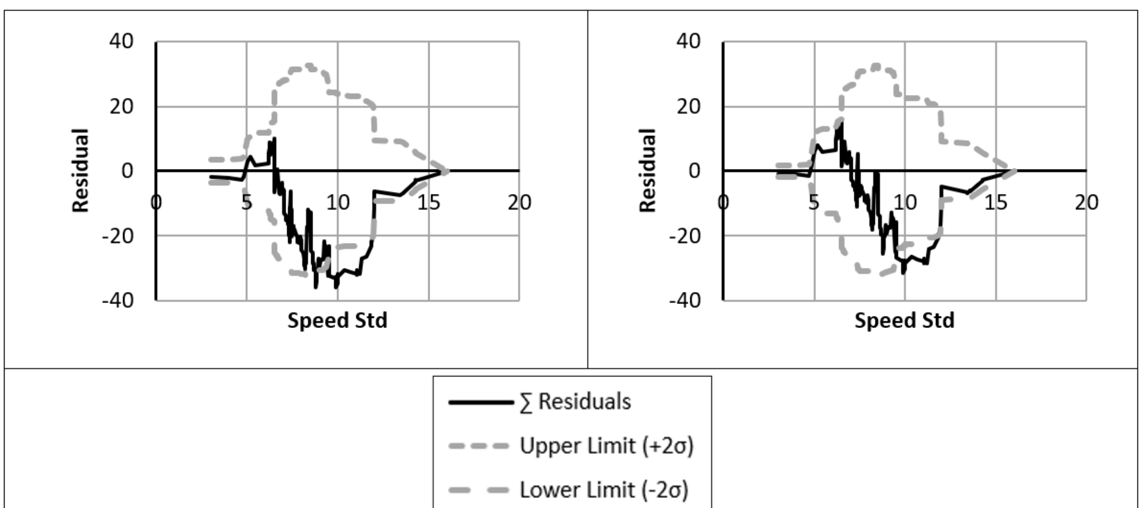
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 106. U3T speed CMF for KABCO crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.1705 \times x^{0.7853}$
R-square	0.43
Speed measure boundaries	(3.00, 16.00)
Base condition	10
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.15

Table 107. U3T speed CMF for KABCO crashes (North Carolina).

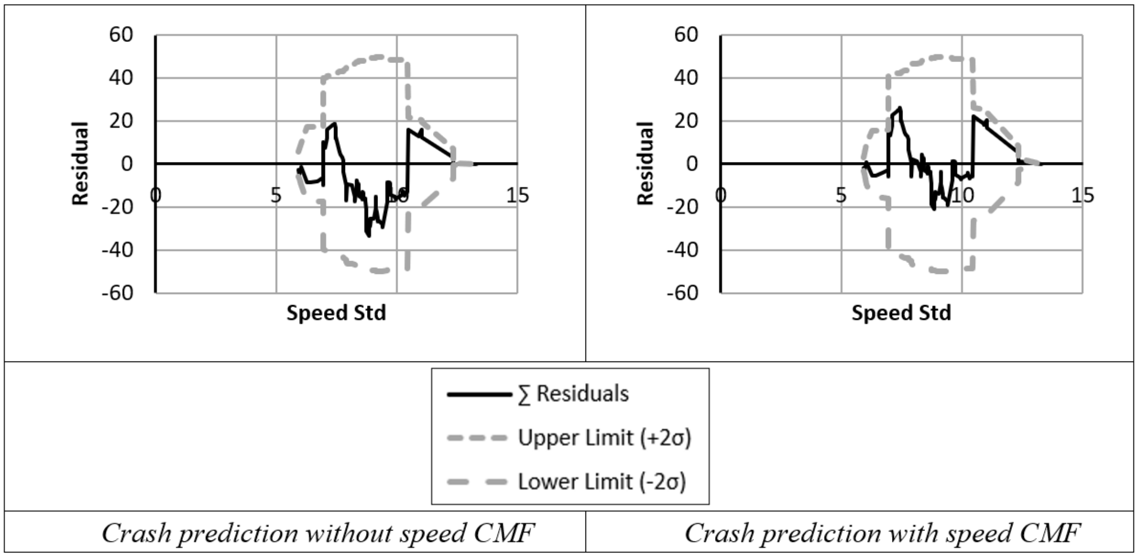
Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.053 \times x + 0.5086$
R-square	0.09
Speed measure boundaries	(5.90, 13.30)
Base condition	9
t-Test (*p*-value)	0.01
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.07



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 59. Graph. CURE plots of U3T speed CMF for KABCO crashes (Washington).



Source: FHWA.

Figure 60. Graph. CURE plots of U3T speed CMF for KABCO crashes (North Carolina).

U3T Speed CMF for KABC Crashes

Table 108 to table 111 and figure 61 and figure 62 show the KABC crash severity scale statistics for U3T (AASHTO 2010).

Table 108. Summary of U3T speed CMF development statistics for KABC crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.42	7	16.9	0.108	—	0.384	—
(SpdAve − PSL)	0.41	7	17.0	0.108	0.4	0.386	0.6
|SpdAve − PSL|	0.41	7	17.0	0.108	0.5	0.387	0.8
|SpdAve − PSL|	*0.44*	*7*	*17.0*	*0.108*	*0.4*	*0.386*	*0.5*
SpdStd/SpdAve	**0.40**	**7**	**16.6**	**0.106**	**−1.3**	**0.378**	**−1.6**
SpdStd/SpdAve	*0.42*	*7*	*16.6*	*0.106*	*−1.5*	*0.380*	*−0.9*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 109. Summary of U3T speed CMF development statistics for KABC crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.71	26	28.1	1.371	—	1.909	—
SpdStd	1.71	26	27.3	1.364	−0.5	1.909	0.0
SpdStd	*1.75*	*26*	*27.2*	*1.366*	*−0.3*	*1.914*	*0.3*
(SpdAve − PSL)	**1.68**	**26**	**27.4**	**1.345**	**−1.9**	**1.905**	**−0.2**
SpdStd/SpdAve	1.73	26	28.5	1.383	0.9	1.924	0.8
SpdStd/SpdAve	*1.79*	*26*	*28.8*	*1.386*	*1.1*	*1.923*	*0.7*

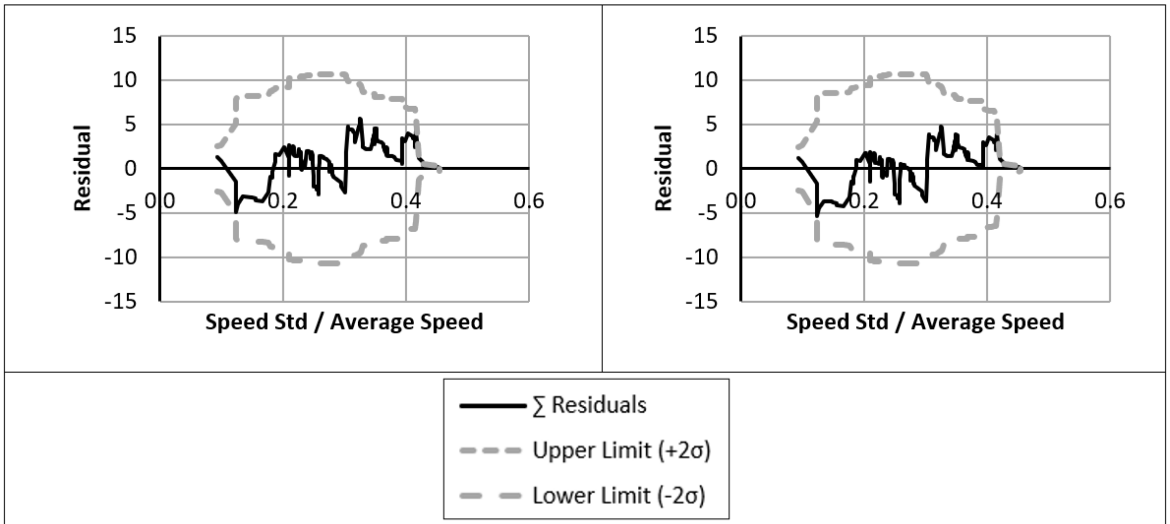
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 110. U3T speed CMF for KABC crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = -0.5055 \times x + 1.2285$
R-square	0.09
Speed measure boundaries	(0.09, 0.45)
Base condition	0.45
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.04

Table 111. U3T speed CMF for KABC crashes (North Carolina).

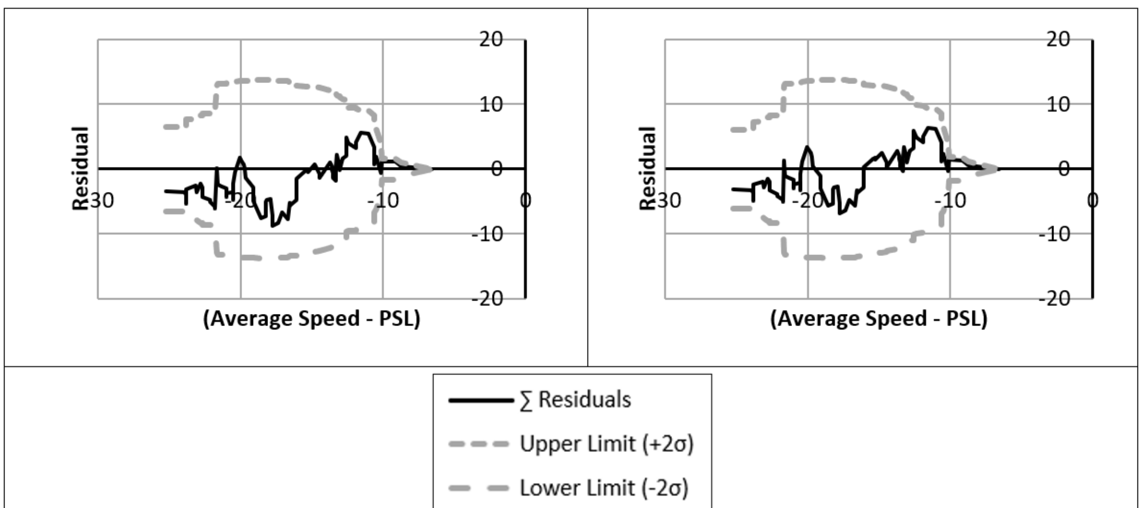
Speed CMF	Value
Speed measure	(SpdAve − PSL)
CMF equation	$y = 0.0101 \times x + 1.2106$
R-square	0.06
Speed measure boundaries	(−25.30, −6.60)
Base condition	−21
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.04



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 61. Graph. CURE plots of U3T speed CMF for KABC crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 62. Graph. CURE plots of U3T speed CMF for KABC crashes (North Carolina).

U3T Speed CMF for O Crashes

Table 112 to table 115 and figure 63 and figure 64 show the O crash severity scale statistics for U3T (AASHTO 2010).

Table 112. Summary of U3T speed CMF development statistics for O crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.55	15	45.6	0.239	—	0.835	—
SpdStd	**0.57**	**15**	**45.7**	**0.232**	**−2.8**	**0.840**	**0.7**
SpdStd	*0.59*	*15*	*45.8*	*0.235*	*−1.8*	*0.841*	*0.7*
(SpdAve − PSL)	0.54	15	46.2	0.241	0.6	0.855	2.5
SpdStd/SpdAve	0.57	15	46.7	0.244	1.9	0.870	4.2
SpdStd/SpdAve	*0.57*	*15*	*46.4*	*0.242*	*1.3*	*0.858*	*2.8*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 113. Summary of U3T speed CMF development statistics for O crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.84	78	70.8	2.728	—	5.219	—
SpdStd	1.93	78	74.8	2.840	4.1	5.183	−0.7
SpdStd	*2.10*	*78*	*73.6*	*2.805*	*2.8*	*5.185*	*−0.7*
(SpdAve − PSL)	**1.82**	**78**	**74.0**	**2.799**	**2.6**	**5.131**	**−1.7**
|SpdAve − PSL|	1.89	78	75.5	2.860	4.8	5.118	−1.9
|SpdAve − PSL|	*1.93*	*78*	*76.6*	*2.915*	*6.8*	*5.121*	*−1.9*

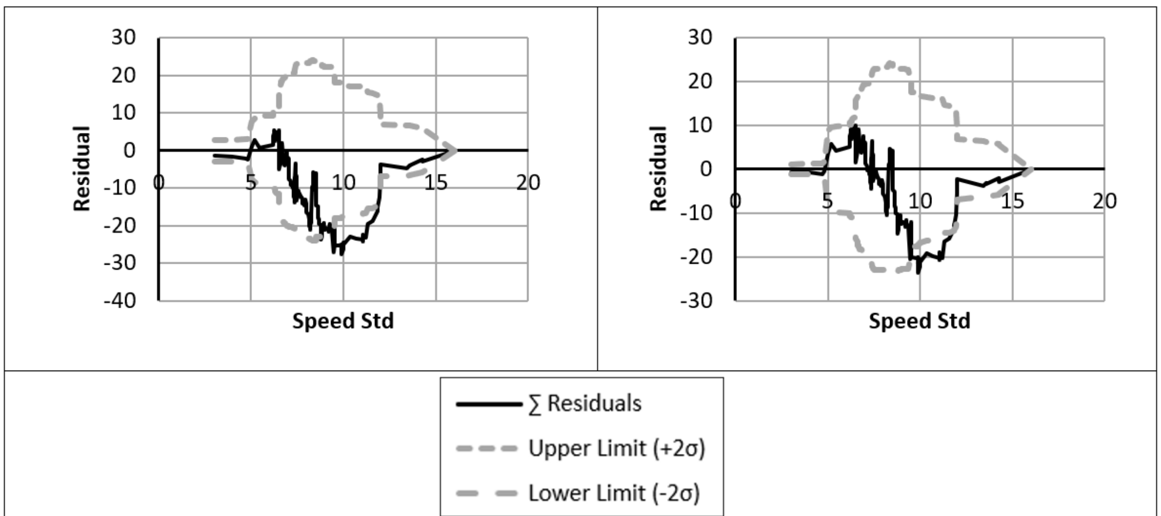
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 114. U3T speed CMF for O crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.1062 \times x + 0.0745$
R-square	0.42
Speed measure boundaries	(3.00, 16.00)
Base condition	9
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.19

Table 115. U3T speed CMF for O crashes (North Carolina).

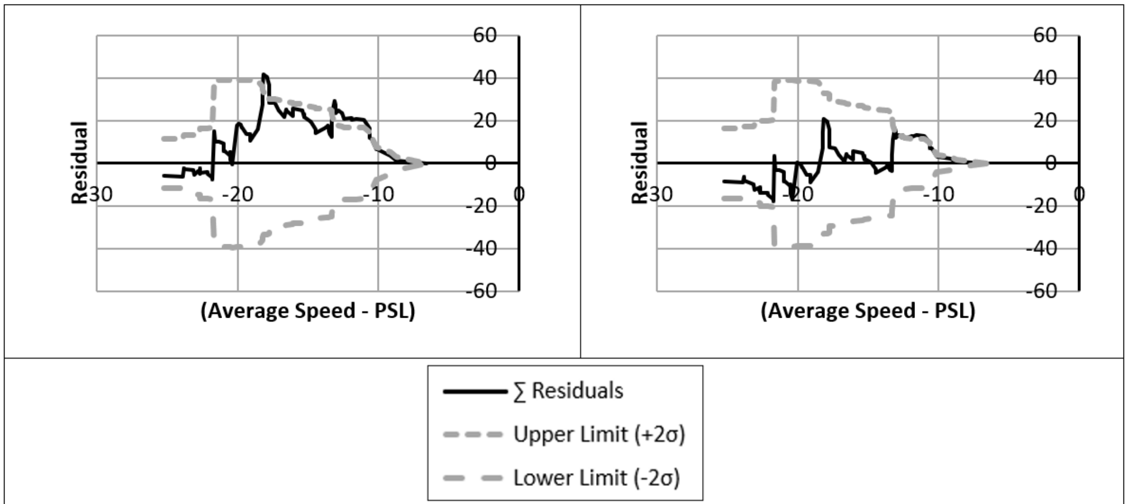
Speed CMF	Value
Speed measure	(SpdAve − PSL)
CMF equation	$y = -0.0403 \times x + 0.3419$
R-square	0.37
Speed measure boundaries	(−25.30, −6.60)
Base condition	−16
t-Test (*p*-value)	0.08
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.18



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 63. Graph. CURE plots of U3T speed CMF for O crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 64. Graph. CURE plots of U3T speed CMF for O crashes (North Carolina).

U3T Speed CMF for SVFI Crashes

Table 116 to table 119 and figure 65 and figure 66 show the SVFI statistics for U3T (AASHTO 2010).

Table 116. Summary of U3T speed CMF development statistics for SVFI crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	**0.63**	**0**	**1.7**	**0.030**	—	**0.065**	—
SpdStd	0.67	0	1.7	0.031	0.6	0.066	1.8
(SpdAve − PSL)	0.63	0	1.7	0.030	0.0	0.065	0.0
|SpdAve − PSL|	0.61	0	1.8	0.031	3.4	0.069	6.2
SpdStd/SpdAve	0.64	0	1.8	0.032	4.6	0.071	9.0
NA	—	0	—	—	—	—	—

—Not applicable.
Note: Bold row indicates the best speed CMF.

Table 117. Summary of U3T speed CMF development statistics for SVFI crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	2.62	4	4.5	0.265	—	0.430	—
SpdStd	2.41	4	3.6	0.252	−4.7	0.438	1.9
(SpdAve − PSL)	2.70	4	4.2	0.241	−9.0	0.395	−8.2
|SpdAve − PSL|	**2.56**	**4**	**4.2**	**0.240**	**−9.4**	**0.394**	**−8.3**
|SpdAve − PSL|	*2.75*	*4*	*4.2*	*0.249*	*−6.0*	*0.408*	*−5.2*
SpdStd/SpdAve	2.29	4	4.2	0.253	−4.5	0.417	−3.1

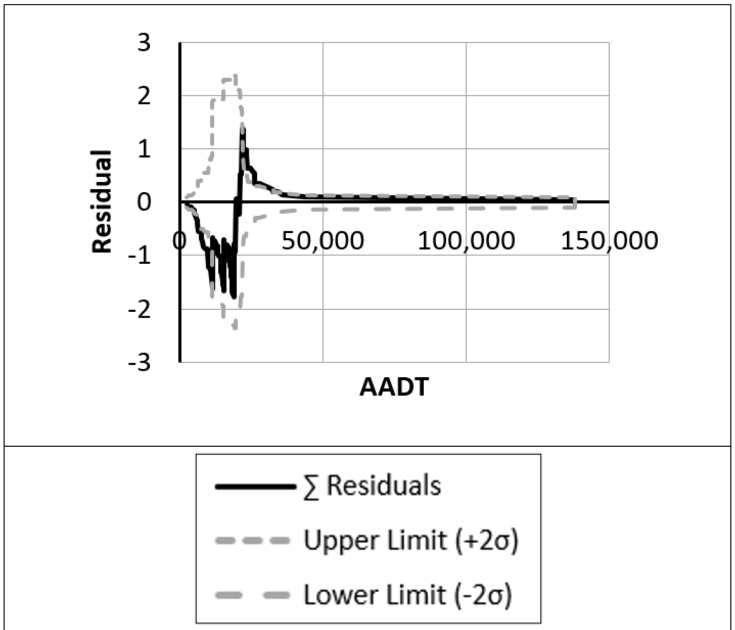
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 118. U3T speed CMF for SVFI crashes (Washington).

Speed CMF	Value
Speed measure	NA
CMF equation	NA
R-square	NA
Speed measure boundaries	NA
Base condition	NA
t-Test (*p*-value)	NA
Estimated CMF Clearinghouse star quality rating	NA
CMF standard error	NA

Table 119. U3T speed CMF for SVFI crashes (North Carolina).

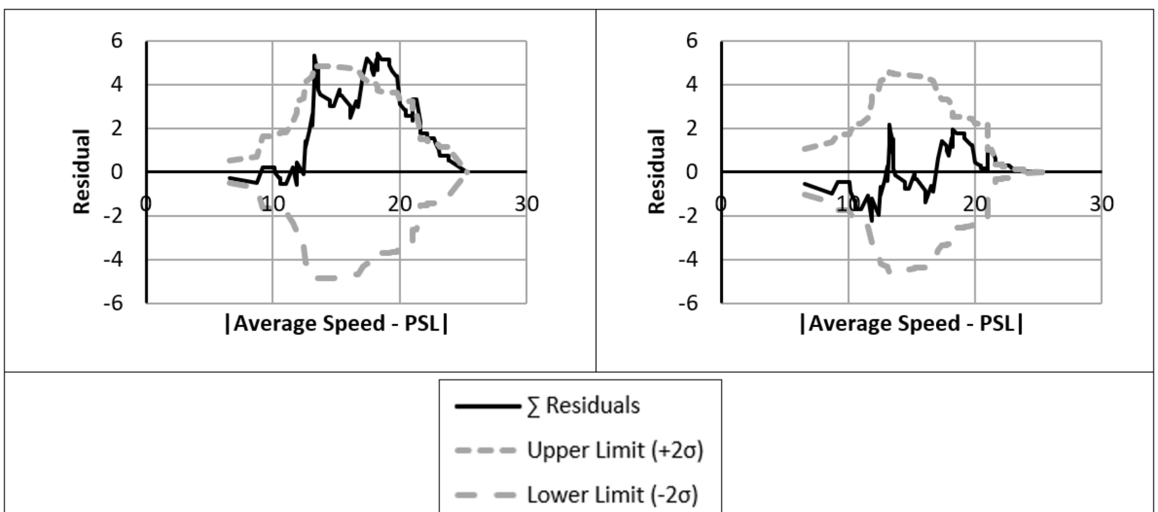
Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = -0.1018 \times x + 2.6094$
R-square	0.32
Speed measure boundaries	(6.60, 25.30)
Base condition	16
t-Test (*p*-value)	0.41
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.44



Crash prediction without speed CMF

Source: FHWA.

Figure 65. Graph. CURE plots of U3T speed CMF for SVFI crashes (Washington).



Crash prediction without speed CMF | *Crash prediction with speed CMF*

Source: FHWA.

Figure 66. Graph. CURE plots of U3T speed CMF for SVFI crashes (North Carolina).

U3T Speed CMF for SVPDO Crashes

Table 120 to table 123 and figure 67 and figure 68 show the SVPDO statistics for U3T.

Table 120. Summary of U3T speed CMF development statistics for SVPDO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.74	1	7.0	0.140	—	0.242	—
SpdStd	0.77	1	7.2	0.143	1.7	0.249	3.2
SpdStd	*0.82*	*1*	*7.2*	*0.143*	*2.2*	*0.253*	*4.7*
(SpdAve − PSL)	0.72	1	6.7	0.136	−2.9	0.232	−4.1
SpdStd/SpdAve	0.62	1	6.5	0.132	−6.0	0.219	−9.3
SpdStd/SpdAve	***0.84***	***1***	***5.9***	***0.121***	***−13.7***	***0.202***	***−16.3***

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 121. Summary of U3T speed CMF development statistics for SVPDO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	2.02	19	9.1	0.734	—	1.474	—
(SpdAve − PSL)	2.09	19	8.2	0.732	−0.2	1.422	−3.5
|SpdAve − PSL|	1.98	19	8.2	0.732	−0.2	1.422	−3.5
|SpdAve − PSL|	***2.27***	***19***	***8.5***	***0.723***	***−1.4***	***1.428***	***−3.1***
SpdStd/SpdAve	1.62	19	8.8	0.742	1.2	1.465	−0.6
SpdStd/SpdAve	*2.01*	*19*	*8.5*	*0.747*	*1.8*	*1.459*	*−1.0*

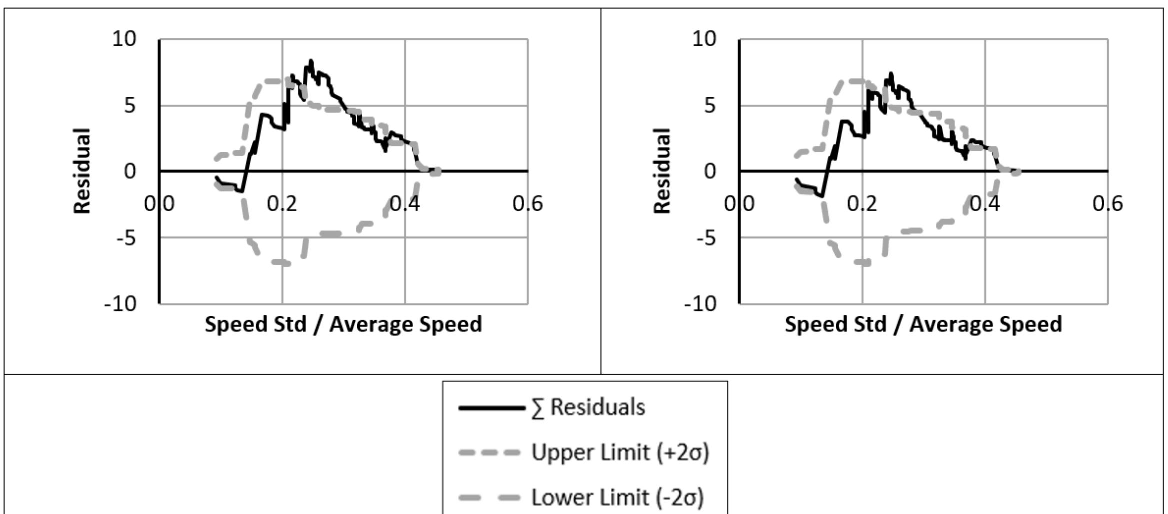
—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 122. U3T speed CMF for SVPDO crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = -1.4994 \times x + 1.5898$
R-square	0.26
Speed measure boundaries	(0.09, 0.45)
Base condition	0.39
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.11

Table 123. U3T speed CMF for SVPDO crashes (North Carolina).

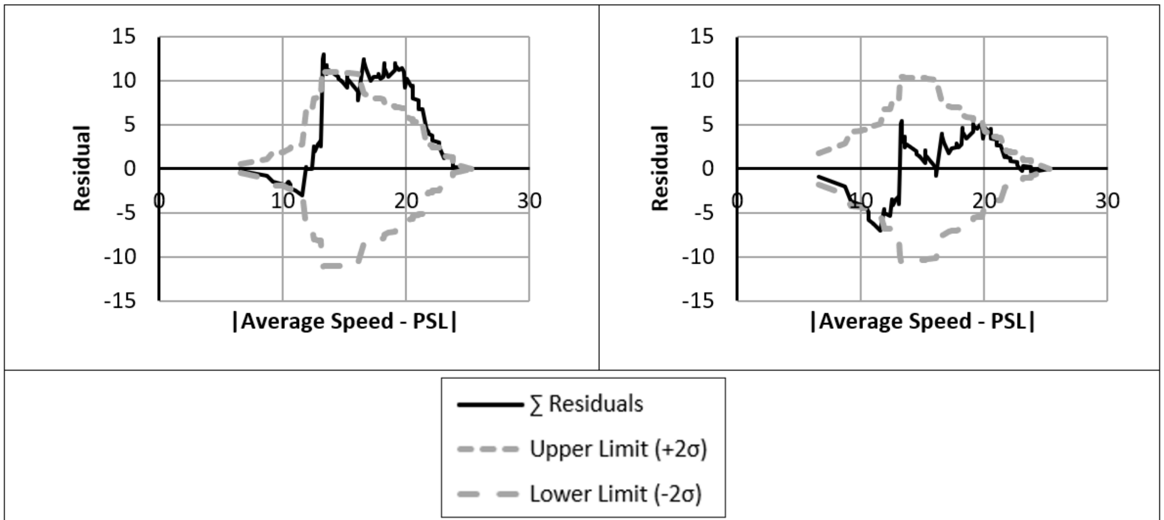
Speed measure	$\lvert \text{SpdAve} - \text{PSL} \rvert$
CMF equation	$y = 44.872 \times x^{-1.448}$
R-square	0.17
Speed measure boundaries	(6.60, 25.30)
Base condition	14
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.40



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 67. Graph. CURE plots of U3T speed CMF for SVPDO crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 68. Graph. CURE plots of U3T speed CMF for SVPDO crashes (North Carolina).

U3T Speed CMF for MVFI Crashes

Table 124 to table 127 and figure 69 and figure 70 show the MVFI statistics for U3T.

Table 124. Summary of U3T speed CMF development statistics for MVFI crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.55	7	15.1	0.374	—	0.724	—
SpdStd	**0.50**	**7**	**15.0**	**0.373**	**−0.4**	**0.717**	**−0.9**
(SpdAve − PSL)	0.49	7	15.1	0.375	0.3	0.721	−0.3
|SpdAve − PSL|	0.51	7	15.1	0.375	0.3	0.722	−0.3
SpdStd/SpdAve	0.53	7	14.8	0.370	−1.0	0.719	−0.7
SpdStd/SpdAve	*0.55*	*7*	*14.9*	*0.371*	*−1.0*	*0.725*	*0.2*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 125. Summary of U3T speed CMF development statistics for MVFI crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	2.11	21	22.6	1.104	—	1.780	—
(SpdAve − PSL)	2.06	21	23.1	1.119	1.4	1.759	−1.2
|SpdAve − PSL|	2.11	21	23.6	1.132	2.6	1.750	−1.7
|SpdAve − PSL|	***2.11***	***21***	***23.8***	***1.138***	***3.1***	***1.747***	***−1.9***
SpdStd/SpdAve	2.38	21	23.6	1.123	1.8	1.787	0.4
SpdStd/SpdAve	*2.40*	*21*	*24.0*	*1.123*	*1.7*	*1.778*	*−0.1*

—Not applicable.

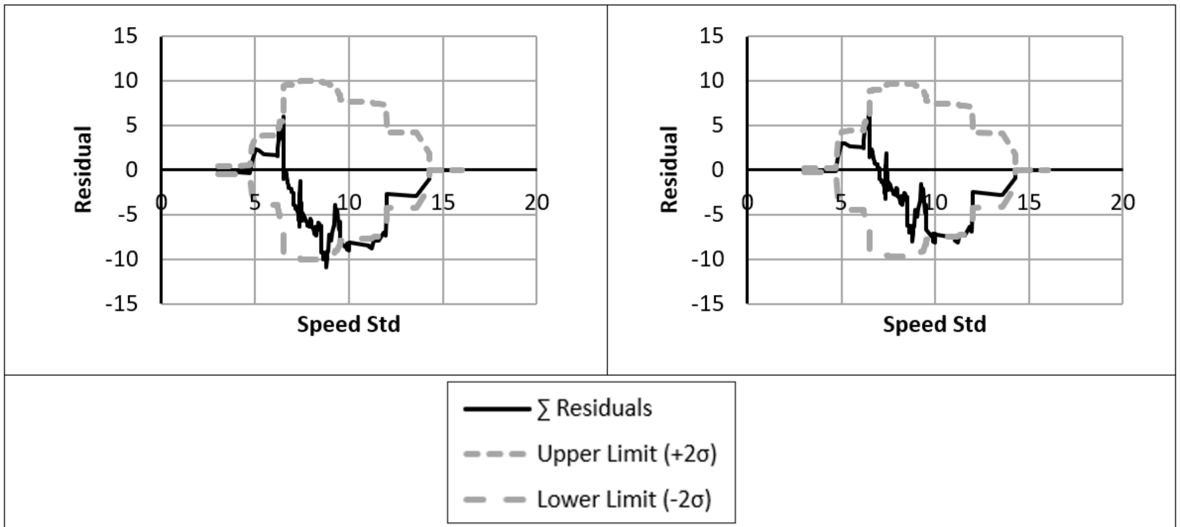
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 126. U3T speed CMF for MVFI crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.1195 \times x + 0.0208$
R-square	0.22
Speed measure boundaries	(3.00, 16.00)
Base condition	8
t-Test (*p*-value)	0.21
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.22

Table 127. U3T speed CMF for MVFI crashes (North Carolina).

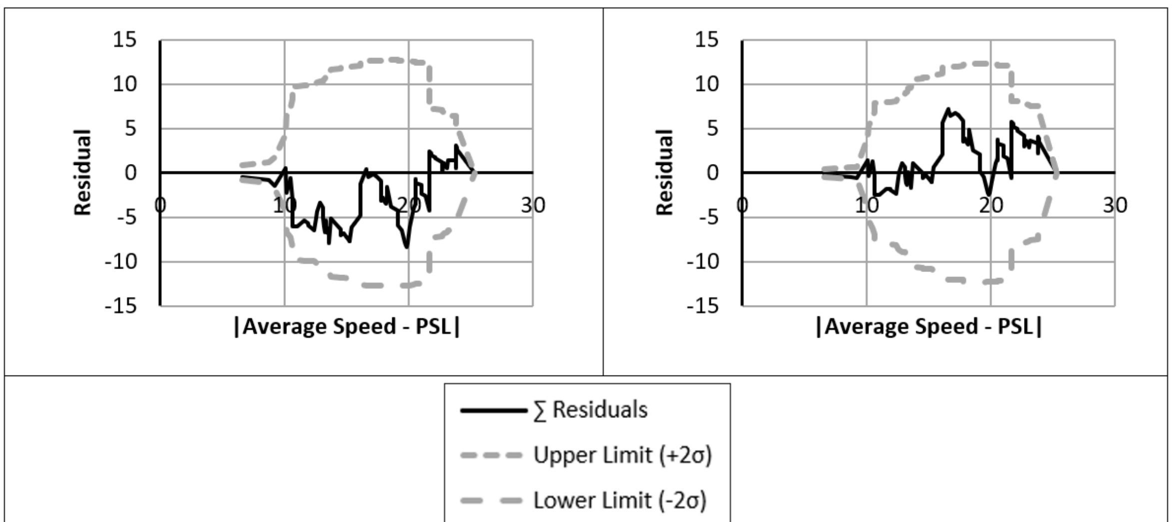
Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 0.1286 \times x^{0.7258}$
R-square	0.17
Speed measure boundaries	(6.60, 25.30)
Base condition	17
t-Test (*p*-value)	0.73
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.19



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 69. Graph. CURE plots of U3T speed CMF for MVFI crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 70. Graph. CURE plots of U3T speed CMF for MVFI crashes (North Carolina).

U3T Speed CMF for MVPDO Crashes

Table 128 to table 131 and figure 71 and figure 72 show the MVPDO statistics for U3T.

Table 128. Summary of U3T speed CMF development statistics for MVPDO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	**0.61**	**14**	**38.6**	**0.820**	**—**	**1.466**	**—**
SpdStd	*0.62*	*14*	*38.6*	*0.813*	*−0.9*	*1.485*	*1.3*
SpdStd	0.67	14	38.7	0.818	−0.3	1.481	1.0
(SpdAve − PSL)	0.59	14	39.3	0.836	1.9	1.522	3.8
SpdStd/SpdAve	0.67	14	40.6	0.854	4.1	1.604	9.4
SpdStd/SpdAve	*0.67*	*14*	*40.7*	*0.856*	*4.3*	*1.608*	*9.7*

Note: Bold row indicates the best speed CMF; italic row indicates power function.
—Not applicable.

Table 129. Summary of U3T speed CMF development statistics for MVPDO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	2.18	59	59.7	2.578	—	5.191	—
SpdStd	2.36	59	64.8	2.736	6.1	5.149	−0.8
SpdStd	*2.68*	*59*	*63.9*	*2.704*	*4.9*	*5.146*	*−0.9*
(SpdAve − PSL)	**2.13**	**59**	**64.2**	**2.547**	**−1.2**	**5.011**	**−3.5**
|SpdAve − PSL|	2.27	59	65.7	2.556	−0.9	5.004	−3.6
|SpdAve − PSL|	*2.30*	*59*	*69.2*	*2.595*	*0.7*	*5.121*	*−1.3*

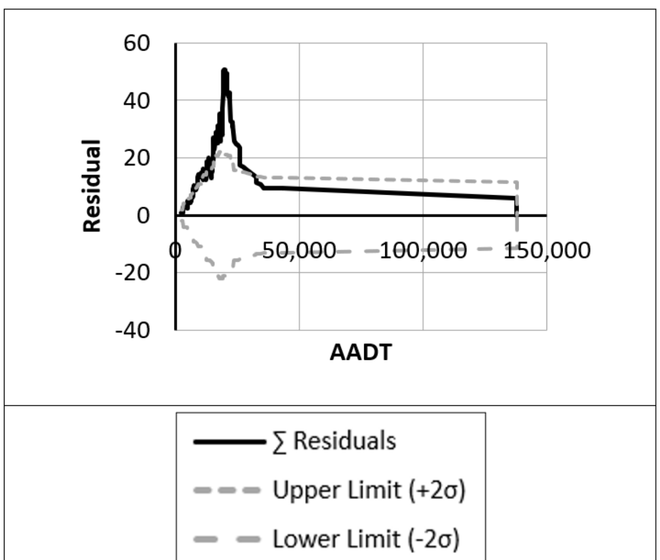
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 130. U3T speed CMF for MVPDO crashes (Washington).

Speed CMF	Value
Speed measure	NA
CMF equation	NA
R-square	NA
Speed measure boundaries	NA
Base condition	NA
t-Test (*p*-value)	NA
Estimated CMF Clearinghouse star quality rating	NA
CMF standard error	NA

Table 131. U3T speed CMF for MVPDO crashes (North Carolina).

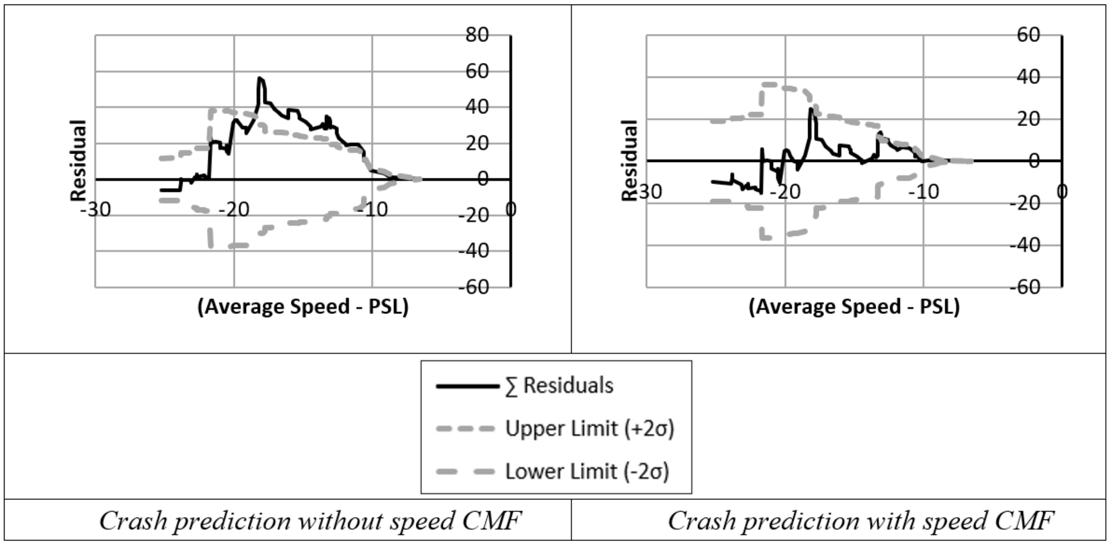
Speed CMF	Value
Speed measure	(SpdAve − PSL)
CMF equation	$y = -0.0763 \times x - 0.2554$
R-square	0.8
Speed measure boundaries	(−25.30, −6.60)
Base condition	−16
t-Test (*p*-value)	0.2
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.33



Crash prediction without speed CMF

Source: FHWA.

Figure 71. Graph. CURE plots of U3T speed CMF for MVPDO crashes (Washington).



Source: FHWA.

Figure 72. Graph. CURE plots of U3T speed CMF for MVPDO crashes (North Carolina).

Table 132 and table 133 show the U3T CURE plot summary for Washington and North Carolina, respectively.

Table 132. CURE plots summary of U3T (Washington).

Crash	Crash Prediction Method	Within CURE (%)	Change to HSM (%)	|Maximum CURE Deviation|	Change to HSM (%)
KABCO	HSM (without speed CMF)	83.19	—	11.93	—
KABCO	HSM × speed CMF	90.71	8	8.37	−30
KABC	HSM (without speed CMF)	99.56	—	0.00	—
KABC	HSM × speed CMF	99.56	0	0.00	8
O	HSM (without speed CMF)	84.51	—	9.93	—
O	HSM × speed CMF	91.59	7	6.47	−35
SVFI	HSM (without speed CMF)	65.04	—	0.68	—
SVFI	HSM default	65.04	0	0.68	0
SVPDO	HSM (without speed CMF)	57.52	—	3.38	—
SVPDO	HSM × speed CMF	69.91	12	2.53	−25
MVFI	HSM (without speed CMF)	84.07	—	1.23	—
MVFI	HSM × speed CMF	92.04	8	1.00	−18
MVPDO	HSM (without speed CMF)	25.22	—	29.67	—
MVPDO	HSM default	25.22	0	29.67	0

—Not applicable.

Table 133. CURE plots summary of U3T (North Carolina).

Crash	Crash Prediction Method	Within CURE (%)	Change to HSM (%)	|Maximum CURE Deviation|	Change to HSM (%)
KABCO	HSM (without speed CMF)	98.96	—	0.00	—
KABCO	HSM × speed CMF	98.96	0	0.00	0
KABC	HSM (without speed CMF)	98.96	—	0.00	—
KABC	HSM × speed CMF	98.96	0	0.00	0
O	HSM (without speed CMF)	80.21	—	9.64	—
O	HSM × speed CMF	90.63	10	1.69	−83
SVFI	HSM (without speed CMF)	66.67	—	1.68	—
SVFI	HSM × speed CMF	87.50	21	0.05	−97
SVPDO	HSM (without speed CMF)	39.58	—	4.97	—
SVPDO	HSM × speed CMF	84.38	45	1.90	−62
MVFI	HSM (without speed CMF)	98.96	—	0.00	—
MVFI	HSM × speed CMF	98.96	0	0.00	0
MVPDO	HSM (without speed CMF)	52.08	—	25.78	—
MVPDO	HSM × speed CMF	92.71	41	2.52	−90

—Not applicable.

U4U SPEED CMFs

Table 134 through table 137 show the four-lane undivided urban and suburban arterial segments (U4U) statistics.

Table 134. Summary descriptive statistics of U4U (Washington).

Dataset	Segments (No.)	Length (mile)	KABC (No.)	PDO (No.)	Total (No.)	SVFI (No.)	SVPDO (No.)	MVFI (No.)	MVPDO (No.)
Training	155	39.3	131	300	431	28	28	103	272
Test	51	10.1	57	107	164	9	16	48	91
All	206	49.4	188	407	595	37	44	151	363

Note: Values for KABC, PDO, Total, SVFI, SVPDO, MVFI, and MVPDO represent observed crashes from 2017-2018.

Table 135. Summary descriptive statistics of U4U (North Carolina).

Dataset	Segments (No.)	Length (mile)	KABC (No.)	PDO (No.)	Total (No.)	SVFI (No.)	SVPDO (No.)	MVFI (No.)	MVPDO (No.)
Training	89	28.3	269	583	852	39	60	228	522
Test	30	9.3	95	209	304	7	21	85	187
All	119	37.6	364	792	1,156	46	81	313	709

Note: Values for KABC, PDO, Total, SVFI, SVPDO, MVFI, and MVPDO represent observed crashes from 2017-2018.

Table 136. *R*-square values of speed CMF equations of U4U (Washington).

Speed Measure	KABCO (L)	KABCO (P)	KABC (L)	KABC (P)	O (L)	O (P)	SVFI (L)	SVFI (P)	SVPDO (L)	SVPDO (P)	MVFI (L)	MVFI (P)	MVPDO (L)	MVPDO (P)
SpdStd	***0.48***	***0.48***	***0.65***	***0.47***	***0.21***	***0.21***	***0.15***	—	***0.52***	***0.51***	***0.64***	***0.52***	0.08	0.07
(SpdAve − PSL)	***0.12***	—	***0.07***	—	***0.15***	—	***0.00***	—	***0.01***	—	0.09	—	***0.24***	—
|SpdAve − PSL|	0.09	0.09	0.06	0.06	0.10	0.10	***0.00***	—	***0.02***	—	***0.13***	0.12	***0.19***	***0.19***
SpdStd/ SpdAve	***0.45***	***0.55***	***0.26***	***0.34***	***0.50***	***0.59***	***0.30***	***0.28***	***0.01***	—	***0.60***	***0.65***	***0.67***	***0.69***

—Not applicable.

Note: Bold italic numbers indicate the top five potential speed CMFs for each crash type/severity level.

Table 137. *R*-square values of speed CMF equations of U4U (North Carolina).

Speed Measure	KABCO (L)	KABCO (P)	KABC (L)	KABC (P)	O (L)	O (P)	SVFI (L)	SVFI (P)	SVPDO (L)	SVPDO (P)	MVFI (L)	MVFI (P)	MVPDO (L)	MVPDO (P)
SpdStd	0.24	0.24	***0.07***	***0.08***	0.33	0.33	***0.01***	0.01	***0.15***	0.13	***0.13***	***0.13***	0.34	0.34
(SpdAve − PSL)	***0.40***	—	0.04	—	***0.65***	—	0.00	—	0.05	—	0.07	—	***0.63***	—
|SpdAve − PSL|	***0.51***	***0.51***	***0.08***	***0.11***	***0.62***	***0.61***	***0.44***	***0.46***	***0.57***	***0.54***	***0.13***	***0.15***	***0.64***	***0.62***
SpdStd/ SpdAve	***0.48***	***0.51***	0.04	***0.05***	***0.77***	***0.78***	***0.09***	***0.15***	***0.15***	***0.20***	0.08	***0.10***	***0.86***	***0.87***

—Not applicable.
Note: Bold italic numbers indicate the top five potential speed CMFs for each crash type/severity level.

U4U Speed CMF for KABCO Crashes

Table 138 to table 141 and figure 73 and figure 74 show the KABCO crash severity scale statistics for U4U (AASHTO 2010).

Table 138. Summary of U4U speed CMF development statistics for KABCO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.55	164	108.6	0.535	—	1.832	—
SpdStd	0.53	164	117.3	0.536	0.0	1.850	1.0
SpdStd	*0.56*	*164*	*118.5*	*0.536*	*0.1*	*1.857*	*1.3*
(SpdAve − PSL)	**0.53**	**164**	**114.1**	**0.528**	**−1.3**	**1.803**	**−1.6**
SpdStd/SpdAve	0.59	164	111.8	0.537	0.3	1.825	−0.4
SpdStd/SpdAve	*0.62*	*164*	*116.4*	*0.540*	*0.8*	*1.813*	*−1.1*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 139. Summary of U4U speed CMF development statistics for KABCO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	2.39	304	329.2	4.370	—	5.564	—
(SpdAve − PSL)	**2.36**	**304**	**346.8**	**4.204**	**−3.8**	**5.378**	**−3.3**
|SpdAve − PSL|	2.47	304	350.5	4.223	−3.4	5.445	−2.1
|SpdAve − PSL|	*2.51*	*304*	*358.1*	*4.492*	*2.8*	*5.695*	*2.3*
SpdStd/SpdAve	2.61	304	333.0	4.424	1.2	5.526	−0.7
SpdStd/SpdAve	*2.67*	*304*	*337.6*	*4.459*	*2.0*	*5.529*	*−0.6*

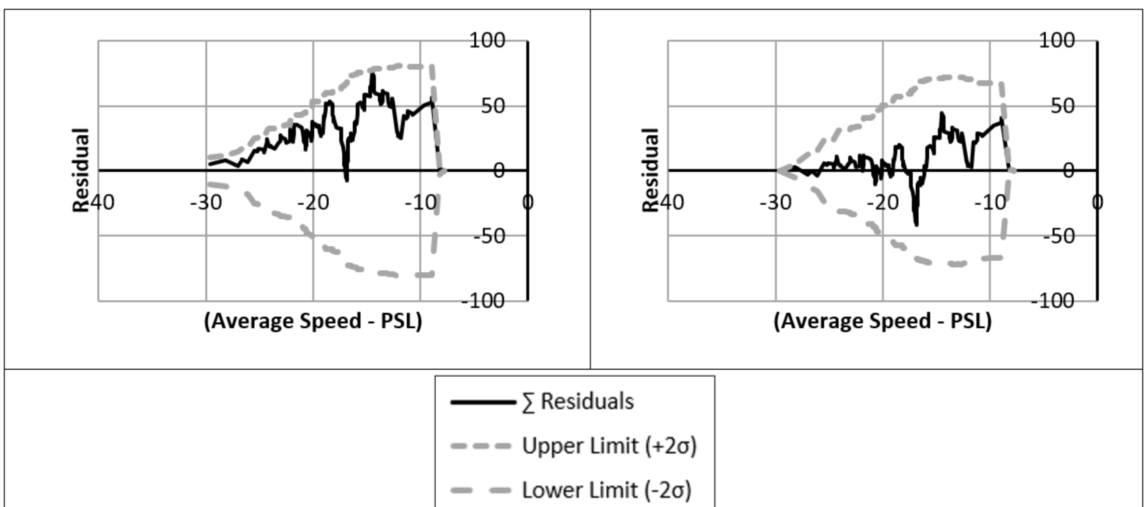
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 140. U4U speed CMF for KABCO crashes (Washington).

Speed CMF	Value
Speed measure	(SpdAve − PSL)
CMF equation	$y = -0.0287 \times x + 0.5283$
R-square	0.13
Speed measure boundaries	(−29.60, −7.80)
Base condition	−17
t-Test (*p*-value)	0.51
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.12

Table 141. U4U speed CMF for KABCO crashes (North Carolina).

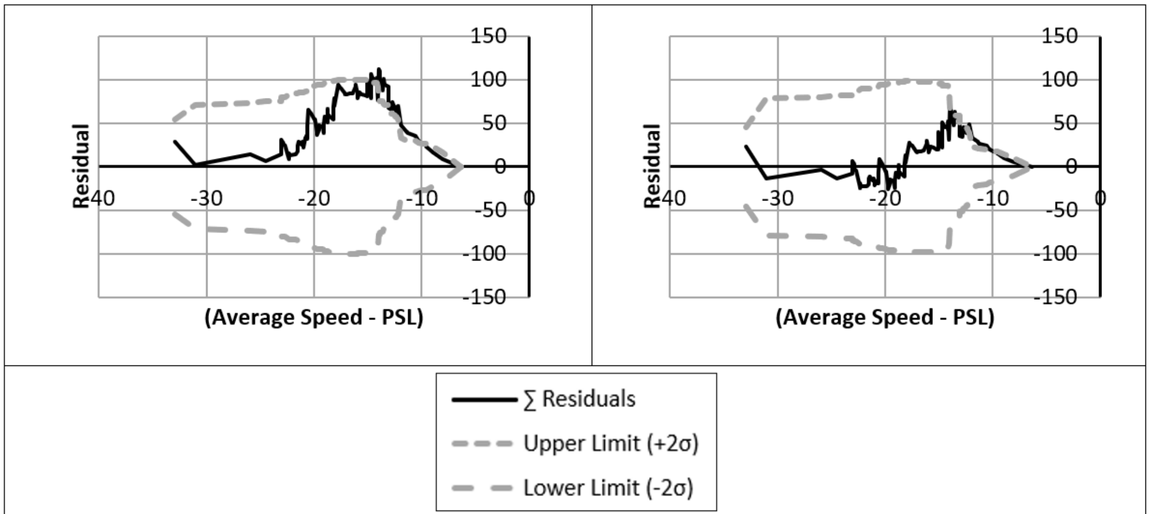
Speed CMF	Value
Speed measure	(SpdAve − PSL)
CMF equation	$y = -0.03 \times x + 0.4617$
R-square	0.58
Speed measure boundaries	(−32.90, −6.30)
Base condition	−18
t-Test (*p*-value)	0.45
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.13



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 73. Graph. CURE plots of U4U speed CMF for KABCO crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 74. Graph. CURE plots of U4U speed CMF for KABCO crashes (North Carolina).

U4U Speed CMF for KABC Crashes

Table 142 to table 145 and figure 75 and figure 76 show the KABC crash severity scale statistics for U4U (AASHTO 2010).

Table 142. Summary of U4U speed CMF development statistics for KABC crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.54	57	33.5	0.200	—	0.740	—
SpdStd	0.59	57	37.9	0.202	0.9	0.733	−0.9
SpdStd	*0.65*	*57*	*41.7*	*0.208*	*3.9*	*0.779*	*5.3*
(SpdAve − PSL)	**0.52**	**57**	**34.5**	**0.199**	**−0.8**	**0.731**	**−1.2**
SpdStd/SpdAve	0.58	57	34.1	0.200	0.1	0.739	−0.2
SpdStd/SpdAve	*0.61*	*57*	*35.2*	*0.201*	*0.3*	*0.735*	*−0.6*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 143. Summary of U4U speed CMF development statistics for KABC crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	2.36	95	104.7	1.720	—	2.232	—
SpdStd	2.37	95	105.7	1.763	2.5	2.299	3.0
SpdStd	*9.78*	*95*	*107.1*	*1.726*	*0.3*	*2.211*	*−0.9*
|SpdAve − PSL|	*2.37*	*95*	*107.4*	*1.677*	*−2.5*	*2.113*	*−5.3*
|SpdAve − PSL|	**2.43**	**95**	**111.0**	**1.622**	**−5.7**	**2.025**	**−9.3**
SpdStd/SpdAve	*2.63*	*95*	*106.6*	*1.724*	*0.2*	*2.211*	*−1.0*

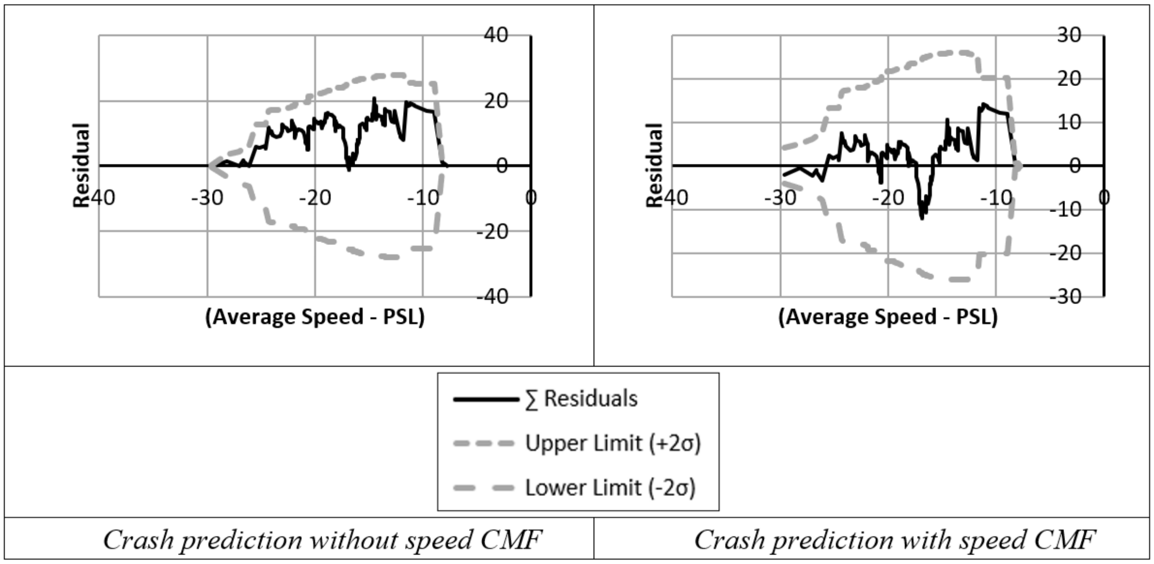
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 144. U4U speed CMF for KABC crashes (Washington).

Speed CMF	Value
Speed measure	(SpdAve − PSL)
CMF equation	$y = -0.0291 \times x + 0.5123$
R-square	0.18
Speed measure boundaries	(−29.60, −7.80)
Base condition	−17
t-Test (p-value)	0.64
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.12

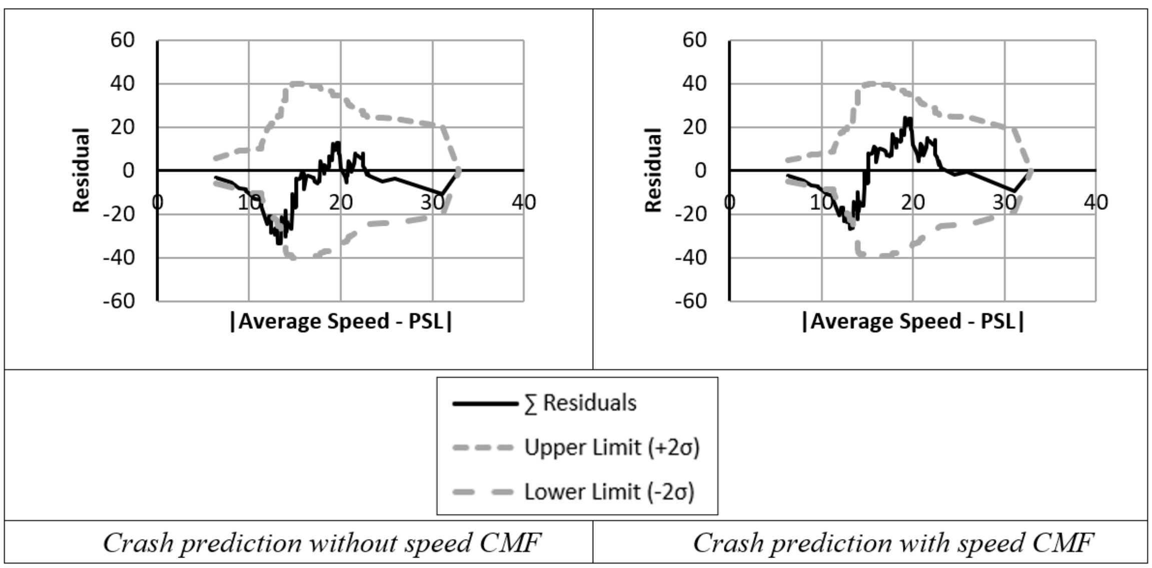
Table 145. U4U speed CMF for KABC crashes (North Carolina).

Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 0.0182 \times x + 0.6895$
R-square	0.11
Speed measure boundaries	(6.30, 32.90)
Base condition	17
t-Test (p-value)	0.45
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.08



Source: FHWA.

Figure 75. Graph. CURE plots of U4U speed CMF for KABC crashes (Washington).



Source: FHWA.

Figure 76. Graph. CURE plots of U4U speed CMF for KABC crashes (North Carolina).

U4U Speed CMF for O Crashes

Table 146 to table 149 and figure 77 and figure 78 show the O crash severity scale statistics for U4U (AASHTO 2010).

Table 146. Summary of U4U speed CMF development statistics for O crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.55	107	74.9	0.349	—	1.220	—
SpdStd	0.51	107	79.0	0.349	0.0	1.235	1.3
SpdStd	*0.55*	*107*	*80.0*	*0.350*	*0.1*	*1.240*	*1.6*
(SpdAve − PSL)	**0.53**	**107**	**79.5**	**0.343**	**−1.7**	**1.205**	**−1.2**
SpdStd/SpdAve	0.59	107	77.5	0.351	0.5	1.214	−0.4
SpdStd/SpdAve	*0.62*	*107*	*81.0*	*0.353*	*1.2*	*1.207*	*−1.0*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 147. Summary of U4U speed CMF development statistics for O crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	2.42	209	225.3	3.013	—	3.999	—
(SpdAve − PSL)	2.42	209	241.3	3.258	8.1	4.213	5.4
|SpdAve − PSL|	2.54	209	244.6	3.383	12.3	4.361	9.1
|SpdAve − PSL|	*2.61*	*209*	*248.1*	*3.539*	*17.5*	*4.580*	*14.5*
SpdStd/SpdAve	**2.77**	**209**	**229.0**	**3.022**	**0.3**	**3.978**	**−0.5**
SpdStd/SpdAve	*2.77*	*209*	*232.0*	*3.030*	*0.5*	*4.005*	*0.2*

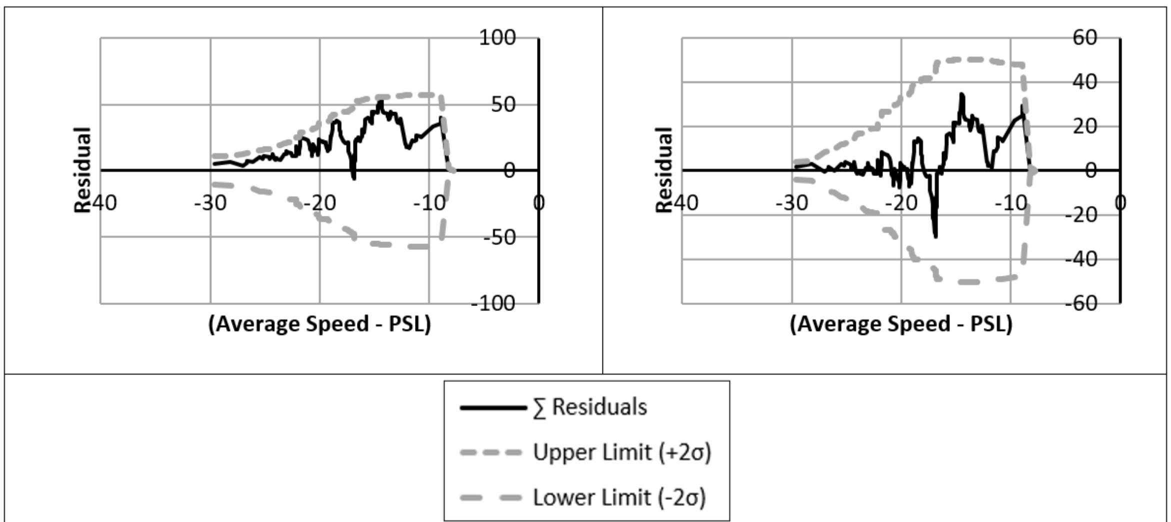
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 148. U4U speed CMF for O crashes (Washington).

Speed CMF	Value
Speed measure	(SpdAve − PSL)
CMF equation	$y = -0.0287 \times x + 0.5333$
R-square	0.11
Speed measure boundaries	(−29.60, −7.80)
Base condition	−16
t-Test (*p*-value)	0.44
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.12

Table 149. U4U speed CMF for O crashes (North Carolina).

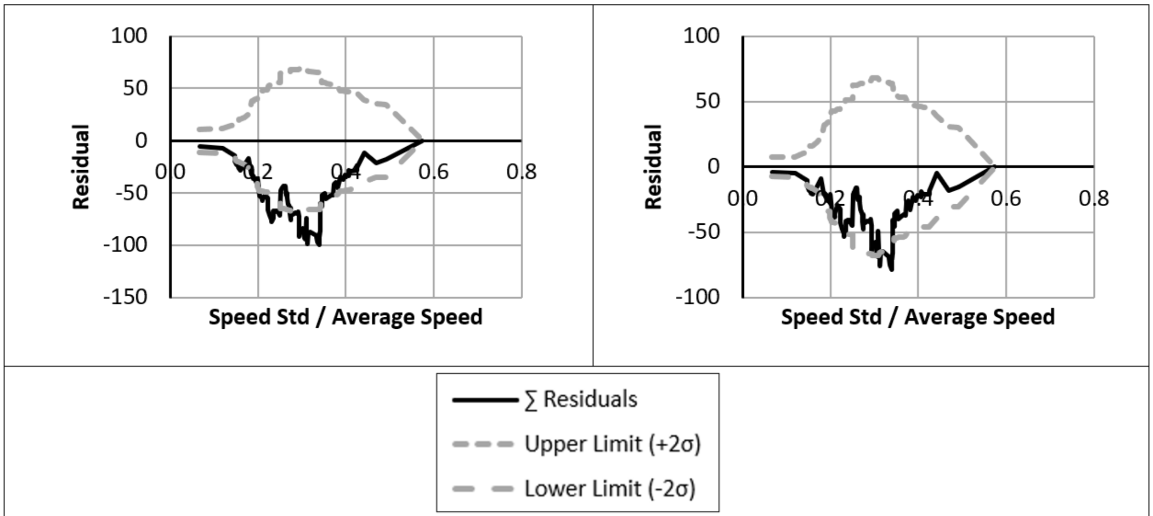
Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 1.0273 \times x + 0.6104$
R-square	0.8
Speed measure boundaries	(0.07, 0.57)
Base condition	0.38
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.09



Crash prediction without speed CMF | *Crash prediction with speed CMF*

Source: FHWA.

Figure 77. Graph. CURE plots of U4U speed CMF for O crashes (Washington).



Crash prediction without speed CMF | *Crash prediction with speed CMF*

Source: FHWA.

Figure 78. Graph. CURE plots of U4U speed CMF for O crashes (North Carolina).

U4U Speed CMF for SVFI Crashes

Table 150 to table 153 and figure 79 and figure 80 show the SVFI statistics for U4U.

Table 150. Summary of U4U speed CMF development statistics for SVFI crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.27	9	7.5	0.125	—	0.316	—
SpdStd	1.38	9	8.0	0.127	1.5	0.316	0.0
(SpdAve − PSL)	1.31	9	7.6	0.125	0.1	0.315	−0.1
|SpdAve − PSL|	1.28	9	7.5	0.125	0.0	0.316	0.0
SpdStd/SpdAve	1.48	9	7.8	0.125	0.6	0.313	−0.7
SpdStd/SpdAve	***1.73***	***9***	***8.0***	***0.126***	***1.3***	***0.312***	***−1.1***

—Not applicable.
Note: Rows that are both bold and italics indicate the best speed CMF with power function.

Table 151. Summary of U4U speed CMF development statistics for SVFI crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	**3.17**	**7**	**13.6**	**0.519**	**—**	**0.673**	**—**
SpdStd	3.09	7	13.8	0.523	0.8	0.676	0.5
|SpdAve − PSL|	3.16	7	14.2	0.529	1.9	0.709	5.3
|SpdAve − PSL|	*3.18*	*7*	*14.5*	*0.534*	*3.0*	*0.733*	*8.9*
SpdStd/SpdAve	3.27	7	13.7	0.523	0.8	0.678	0.8
SpdStd/SpdAve	*3.51*	*7*	*13.9*	*0.534*	*2.9*	*0.695*	*3.3*

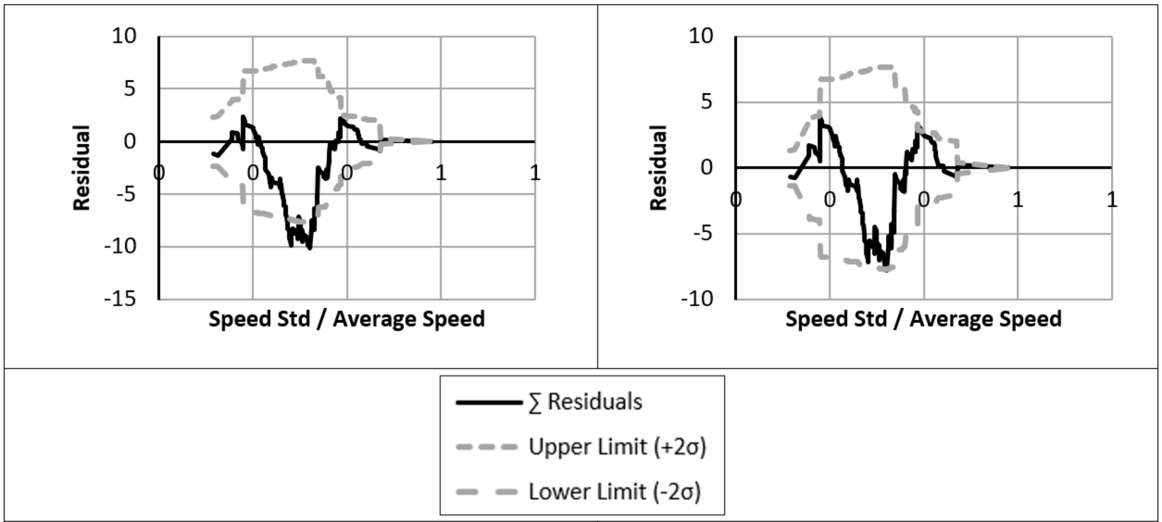
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 152. U4U speed CMF for SVFI crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 1.5787 \times x^{0.6484}$
R-square	0.27
Speed measure boundaries	(0.12, 0.58)
Base condition	0.49
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.12

Table 153. U4U speed CMF for SVFI crashes (North Carolina).

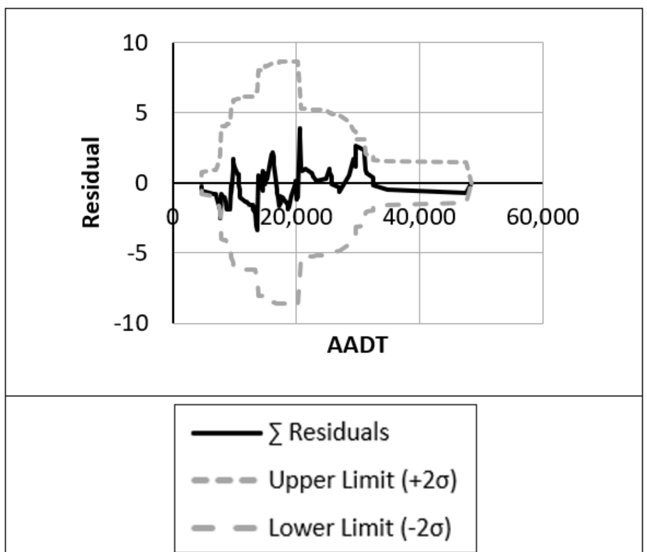
Speed CMF	Value
Speed measure	NA
CMF equation	NA
R-square	NA
Speed measure boundaries	NA
Base condition	NA
t-Test (p-value)	NA
Estimated CMF Clearinghouse star quality rating	NA
CMF standard error	NA



Crash prediction without speed CMF | *Crash prediction with speed CMF*

Source: FHWA.

Figure 79. Graph. CURE plots of U4U speed CMF for SVFI crashes (Washington).



Crash prediction without speed CMF

Source: FHWA.

Figure 80. Graph. CURE plots of U4U speed CMF for SVFI crashes (North Carolina).

U4U Speed CMF for SVPDO Crashes

Table 154 to table 157 and figure 81 and figure 82 show the SVPDO statistics for U4U.

Table 154. Summary of U4U speed CMF development statistics for SVPDO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.39	16	7.2	0.157	—	0.438	—
SpdStd	**0.39**	**16**	**7.8**	**0.153**	**−3.1**	**0.421**	**−3.8**
SpdStd	*0.40*	*16*	*7.8*	*0.153*	*−2.9*	*0.422*	*−3.6*
(SpdAve − PSL)	0.40	16	7.1	0.158	0.4	0.441	0.7
|SpdAve − PSL|	0.39	16	6.9	0.159	0.9	0.444	1.5
SpdStd/SpdAve	0.41	16	7.2	0.157	−0.2	0.438	0.1

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 155. Summary of U4U speed CMF development statistics for SVPDO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.63	21	21.3	0.656	—	0.752	—
SpdStd	1.65	21	21.8	0.666	1.5	0.755	0.4
|SpdAve − PSL|	1.67	21	22.6	0.616	−6.2	0.717	−4.7
|SpdAve − PSL|	***1.68***	***21***	***23.2***	***0.609***	***−7.3***	***0.716***	***−4.8***
SpdStd/SpdAve	1.72	21	21.4	0.654	−0.4	0.746	−0.8
SpdStd/SpdAve	*1.91*	*21*	*21.9*	*0.647*	*−1.4*	*0.735*	*−2.3*

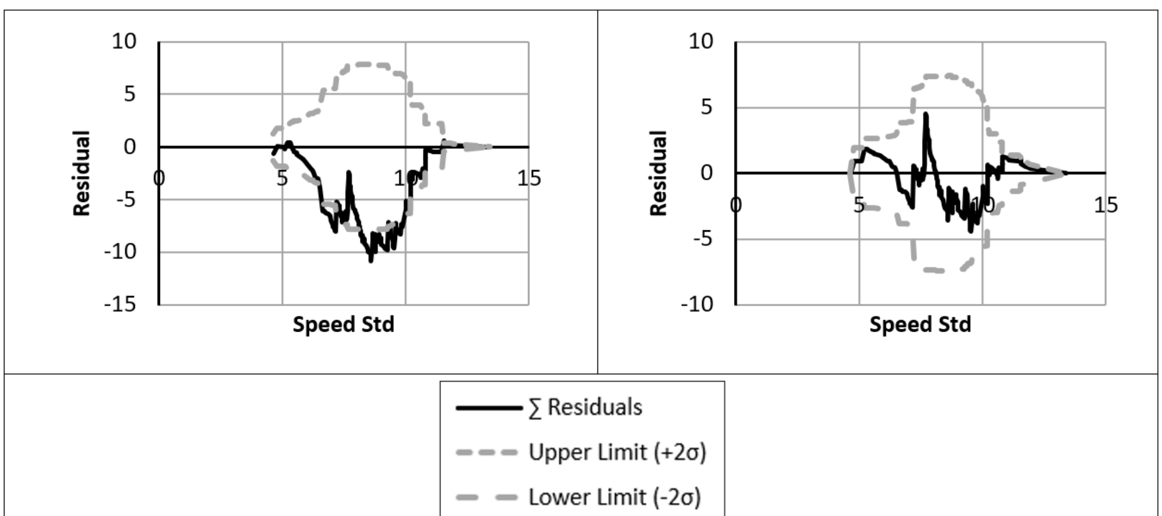
—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 156. U4U speed CMF for SVPDO crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.2598 \times x - 1.1636$
R-square	0.78
Speed measure boundaries	(4.60, 13.40)
Base condition	8
t-Test (p-value)	0.49
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.38

Table 157. U4U speed CMF for SVPDO crashes (North Carolina).

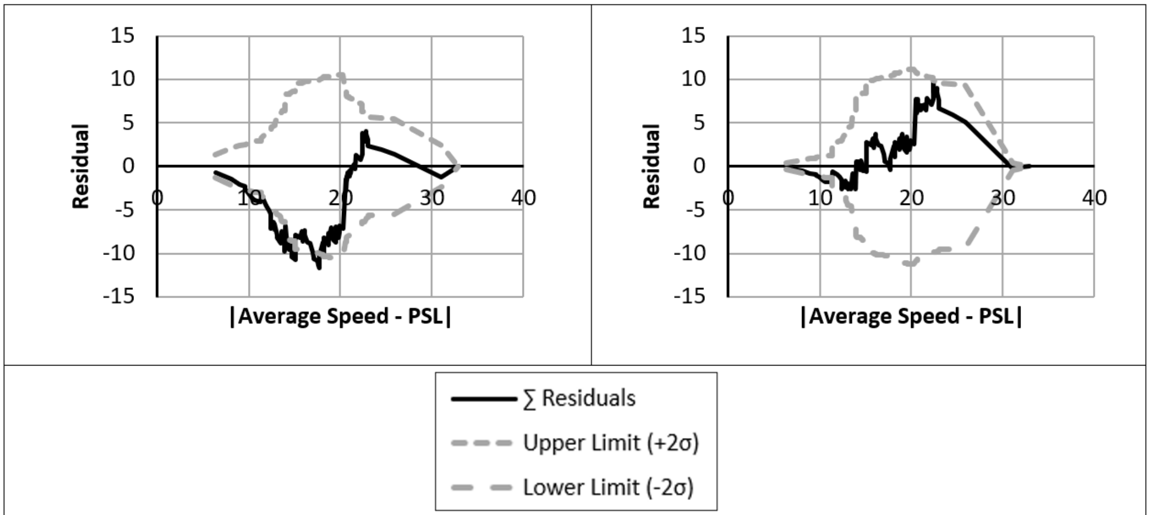
Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 0.0278 \times x^{1.2315}$
R-square	0.37
Speed measure boundaries	(6.30, 32.90)
Base condition	18
t-Test (p-value)	0.14
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.29



Crash prediction without speed CMF | *Crash prediction with speed CMF*

Source: FHWA.

Figure 81. Graph. CURE plots of U4U speed CMF for SVPDO crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 82. Graph. CURE plots of U4U speed CMF for SVPDO crashes (North Carolina).

U4U Speed CMF for MVFI Crashes

Table 158 to table 161 and figure 83 and figure 84 show the MVFI statistics for U4U.

Table 158. Summary of U4U speed CMF development statistics for MVFI crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.68	48	25.1	0.394	—	1.009	—
SpdStd	0.71	48	29.7	0.397	0.7	1.014	0.5
SpdStd	*0.78*	*48*	*32.8*	*0.405*	*2.7*	*1.081*	*7.2*
|SpdAve − PSL|	**0.68**	**48**	**27.1**	**0.390**	**−1.2**	**0.989**	**−2.0**
SpdStd/SpdAve	0.75	48	26.4	0.394	−0.1	1.003	−0.6
SpdStd/SpdAve	*0.81*	*48*	*27.9*	*0.394*	*−0.1*	*0.997*	*−1.2*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 159. Summary of U4U speed CMF development statistics for MVFI crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	3.61	85	83.3	1.714	—	2.537	—
SpdStd	3.60	85	85.7	1.818	6.0	2.636	3.9
SpdStd	*3.88*	*85*	*86.1*	*1.819*	*6.1*	*2.628*	*3.6*
|SpdAve − PSL|	3.67	85	86.2	1.636	−4.6	2.348	−7.5
|SpdAve − PSL|	***3.79***	***85***	***89.1***	***1.585***	***−7.5***	***2.201***	***−13.2***
SpdStd/SpdAve	3.70	85	84.0	1.708	−0.3	2.515	−0.9

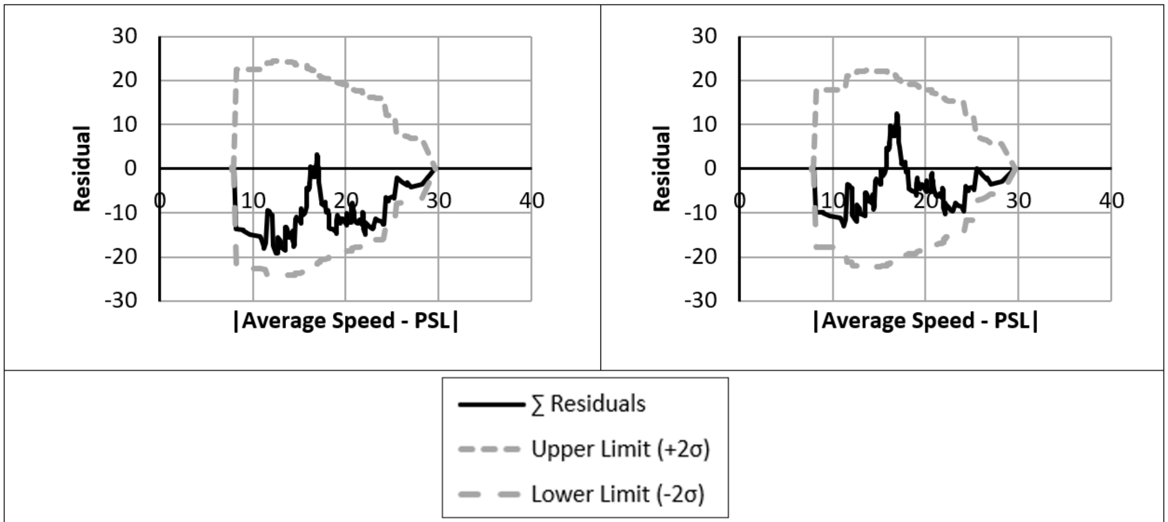
—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 160. U4U speed CMF for MVFI crashes (Washington).

Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 0.0318 \times x + 0.4933$
R-square	0.09
Speed measure boundaries	(7.80, 29.60)
Base condition	16
t-Test (*p*-value)	0.23
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.13

Table 161. U4U speed CMF for MVFI crashes (North Carolina).

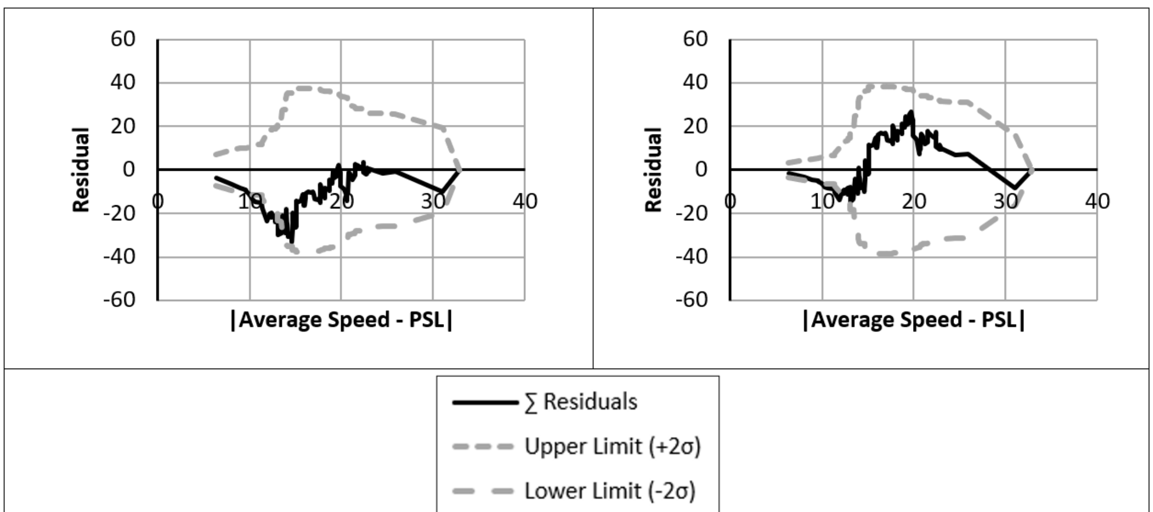
Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 0.1098 \times x^{0.7675}$
R-square	0.36
Speed measure boundaries	(6.30, 32.90)
Base condition	18
t-Test (*p*-value)	0.41
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.19



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 83. Graph. CURE plots of U4U speed CMF for MVFI crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 84. Graph. CURE plots of U4U speed CMF for MVFI crashes (North Carolina).

U4U Speed CMF for MVPDO Crashes

Table 162 to table 165 and figure 85 and figure 86 show the MVPDO statistics for U4U.

Table 162. Summary of U4U speed CMF development statistics for MVPDO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.73	91	64.8	0.751	—	1.896	—
(SpdAve − PSL)	0.69	91	71.9	0.757	0.9	1.922	1.4
|SpdAve − PSL|	0.72	91	72.5	0.759	1.1	1.925	1.5
|SpdAve − PSL|	*0.80*	*91*	*73.1*	*0.760*	*1.3*	*1.928*	*1.7*
SpdStd/SpdAve	**0.81**	**91**	**70.0**	**0.756**	**0.7**	**1.892**	**−0.2**
SpdStd/SpdAve	*0.89*	*91*	*74.4*	*0.767*	*2.2*	*1.894*	*−0.1*

—Not applicable.

Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 163. Summary of U4U speed CMF development statistics for MVPDO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	3.62	187	195.8	3.541	—	4.681	—
(SpdAve − PSL)	3.61	187	211.6	3.591	1.4	4.862	3.9
|SpdAve − PSL|	3.83	187	215.0	3.682	4.0	4.989	6.6
|SpdAve − PSL|	*4.02*	*187*	*216.9*	*3.749*	*5.9*	*5.106*	*9.1*
SpdStd/SpdAve	**4.24**	**187**	**201.0**	**3.434**	**−3.0**	**4.664**	**−0.4**
SpdStd/SpdAve	*4.23*	*187*	*203.9*	*3.424*	*−3.3*	*4.691*	*0.2*

—Not applicable.

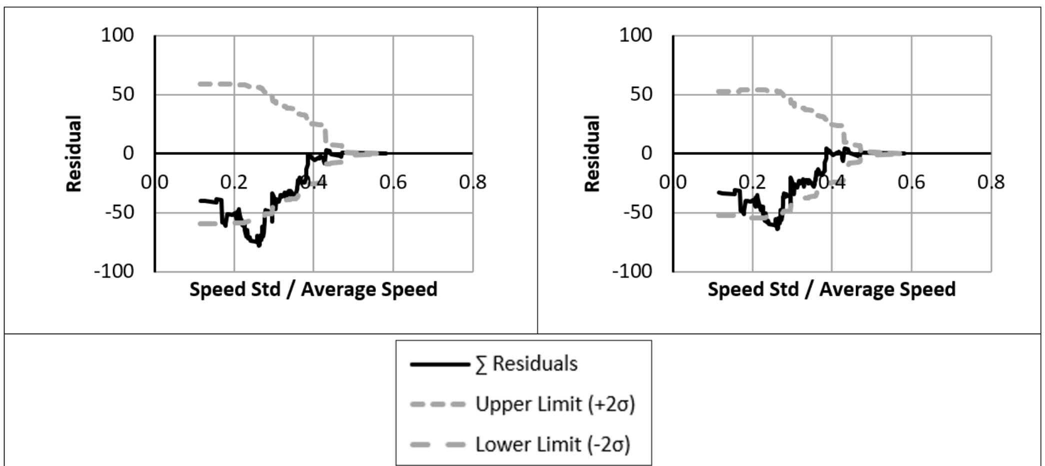
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 164. U4U speed CMF for MVPDO crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 1.0528 \times x + 0.6751$
R-square	0.44
Speed measure boundaries	(0.12, 0.58)
Base condition	0.31
t-Test (p-value)	0.06
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.08

Table 165. U4U speed CMF for MVPDO crashes (North Carolina).

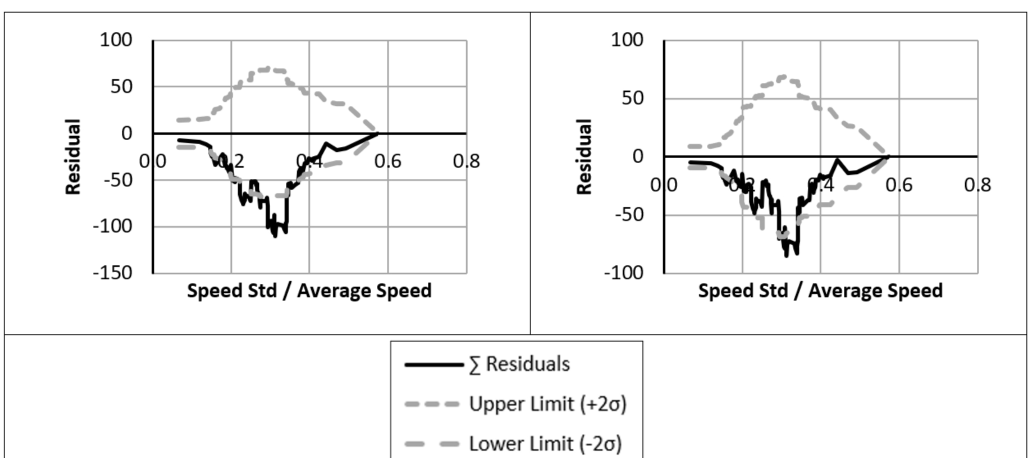
Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 1.2536 \times x + 0.5368$
R-square	0.87
Speed measure boundaries	(0.07, 0.57)
Base condition	0.37
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.11



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 85. Graph. CURE plots of U4U speed CMF for MVPDO crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 86. Graph. CURE plots of U4U speed CMF for MVPDO crashes (North Carolina).

Table 166 and table 167 show the U4U CURE plot summary for Washington and North Carolina, respectively.

Table 166. CURE plots summary of U4U (Washington).

Crash	Crash Prediction Method	Within CURE (%)	Change to HSM (%)	|Maximum CURE Deviation|	Change to HSM (%)
KABCO	HSM (without speed CMF)	99.51	—	0.00	—
KABCO	HSM × speed CMF	99.51	0	0.00	0
KABC	HSM (without speed CMF)	99.51	—	0.00	—
KABC	HSM × speed CMF	99.51	0	0.00	0
O	HSM (without speed CMF)	98.06	—	0.59	—
O	HSM × speed CMF	99.51	1	0.00	−100
SVFI	HSM (without speed CMF)	70.87	—	2.50	—
SVFI	HSM × speed CMF	97.09	26	0.39	−84
SVPDO	HSM (without speed CMF)	55.34	—	2.94	—
SVPDO	HSM × speed CMF	99.51	44	0.00	−100
MVFI	HSM (without speed CMF)	99.51	—	0.00	—
MVFI	HSM × speed CMF	99.51	0	0.00	0
MVPDO	HSM (without speed CMF)	70.87	—	21.91	—
MVPDO	HSM × speed CMF	83.98	13	10.63	−51

—Not applicable.

Table 167. CURE plots summary of U4U (North Carolina).

Crash	Crash Prediction Method	Within CURE (%)	Change to HSM (%)	|Maximum CURE Deviation|	Change to HSM (%)
KABCO	HSM (without speed CMF)	67.23	—	34.46	—
KABCO	HSM × speed CMF	90.76	24	10.39	−70
KABC	HSM (without speed CMF)	83.19	—	8.04	—
KABC	HSM × speed CMF	85.71	3	4.56	−43
O	HSM (without speed CMF)	42.02	—	34.15	—
O	HSM × speed CMF	80.67	39	14.26	−58
SVFI	HSM (without speed CMF)	97.48	—	0.23	—
SVFI	HSM default	97.48	0	0.23	0
SVPDO	HSM (without speed CMF)	58.82	—	3.21	—
SVPDO	HSM × speed CMF	94.96	36	0.52	−84
MVFI	HSM (without speed CMF)	81.51	—	6.43	—
MVFI	HSM × speed CMF	93.28	12	3.78	−41
MVPDO	HSM (without speed CMF)	42.02	—	42.09	—
MVPDO	HSM × speed CMF	78.99	37	19.05	−55

—Not applicable.

U4D SPEED CMFs

Table 168 through table 171 show the four-lane divided urban and suburban arterials (including a raised or depressed median) (U4D) statistics.

Table 168. Summary descriptive statistics of U4D (Washington).

Dataset	Segments (No.)	Length (mile)	KABC (No.)	PDO (No.)	Total (No.)	SVFI (No.)	SVPDO (No.)	MVFI (No.)	MVPDO (No.)
Training	174	34.7	268	614	882	71	106	197	508
Test	58	10	92	175	267	29	24	63	151
All	232	44.7	360	789	1,149	100	130	260	659

Note: Values for KABC, PDO, Total, SVFI, SVPDO, MVFI, and MVPDO represent observed crashes from 2017-2018.

Table 169. Summary descriptive statistics of U4D (North Carolina).

Dataset	Segments (No.)	Length (mile)	KABC (No.)	PDO (No.)	Total (No.)	SVFI (No.)	SVPDO (No.)	MVFI (No.)	MVPDO (No.)
Training	395	74	433	1,258	1,691	73	208	357	1,038
Test	131	25.4	168	482	650	37	92	130	386
All	526	99.4	601	1,740	2,341	110	300	487	1,424

Note: Values for KABC, PDO, Total, SVFI, SVPDO, MVFI, and MVPDO represent observed crashes from 2017-2018.

Table 170. *R*-square values of speed CMF equations of U4D (Washington).

Speed Measure	KABCO (L)	KABCO (P)	KABC (L)	KABC (P)	O (L)	O (P)	SVFI (L)	SVFI (P)	SVPDO (L)	SVPDO (P)	MVFI (L)	MVFI (P)	MVPDO (L)	MVPDO (P)
SpdStd	***0.35***	***0.36***	***0.24***	***0.24***	***0.38***	***0.39***	0.00	0.00	***0.14***	0.11	***0.64***	***0.64***	***0.56***	***0.58***
(SpdAve – PSL)	***0.30***	—	***0.20***	—	0.28	—	***0.10***	—	***0.20***	—	***0.34***	—	***0.55***	—
|SpdAve – PSL|	***0.54***	***0.56***	***0.28***	***0.32***	***0.59***	***0.60***	***0.14***	***0.03***	***0.18***	0.10	***0.45***	***0.44***	***0.65***	***0.61***
SpdStd/ SpdAve	0.21	0.26	0.13	0.17	0.24	***0.28***	***0.05***	***0.05***	***0.33***	***0.47***	0.12	0.20	0.37	0.45

—Not applicable.

Note: Bold italic numbers indicate the top five potential speed CMFs for each crash type/severity level.

Table 171. *R*-square values of speed CMF equations of U4D (North Carolina).

Speed Measure	KABCO (L)	KABCO (P)	KABC (L)	KABC (P)	O (L)	O (P)	SVFI (L)	SVFI (P)	SVPDO (L)	SVPDO (P)	MVFI (L)	MVFI (P)	MVPDO (L)	MVPDO (P)
SpdStd	0.84	0.82	0.40	0.39	***0.94***	***0.92***	***0.32***	***0.34***	***0.43***	***0.50***	0.50	0.43	***0.92***	0.82
(SpdAve – PSL)	***0.92***	—	***0.89***	—	***0.92***	—	***0.42***	—	0.17	—	***0.94***	—	***0.94***	—
|SpdAve – PSL|	***0.87***	***0.87***	***0.91***	***0.91***	0.85	0.85	***0.45***	***0.76***	***0.23***	***0.43***	***0.95***	***0.94***	***0.87***	0.82
SpdStd/ SpdAve	***0.90***	***0.94***	***0.88***	***0.91***	***0.91***	***0.95***	0.01	0.13	0.06	***0.20***	***0.89***	***0.91***	***0.85***	***0.86***

—Not applicable.

Note: Bold italic numbers indicate the top five potential speed CMFs for each crash type/severity level.

U4D Speed CMF for KABCO Crashes

Table 172 to table 175 and figure 87 and figure 88 show the KABCO crash severity scale statistics for U4D (AASHTO 2010).

Table 172. Summary of U4D speed CMF development statistics for KABCO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.94	267	267.2	1.467	—	3.886	—
SpdStd	0.87	267	273.3	1.458	−0.7	3.963	2.0
SpdStd	*0.91*	*267*	*273.3*	*1.458*	*−0.6*	*3.963*	*2.0*
(SpdAve − PSL)	0.93	267	268.5	1.452	−1.1	3.946	1.5
|SpdAve − PSL|	0.98	267	269.1	1.445	−1.5	3.984	2.5
|SpdAve − PSL|	***0.98***	***267***	***269.1***	***1.435***	***−2.2***	***4.029***	***3.7***

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 173. Summary of U4D speed CMF development statistics for KABCO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.95	650	632.9	3.697	—	6.219	—
(SpdAve − PSL)	2.07	650	631.0	3.607	−2.4	5.968	−4.0
|SpdAve − PSL|	2.12	650	631.0	3.606	−2.5	5.969	−4.0
|SpdAve − PSL|	*2.14*	*650*	*630.5*	*3.608*	*−2.4*	*5.975*	*−3.9*
SpdStd/SpdAve	2.38	650	632.6	3.561	−3.7	5.934	−4.6
SpdStd/SpdAve	***2.34***	***650***	***631.5***	***3.532***	***−4.5***	***5.856***	***−5.8***

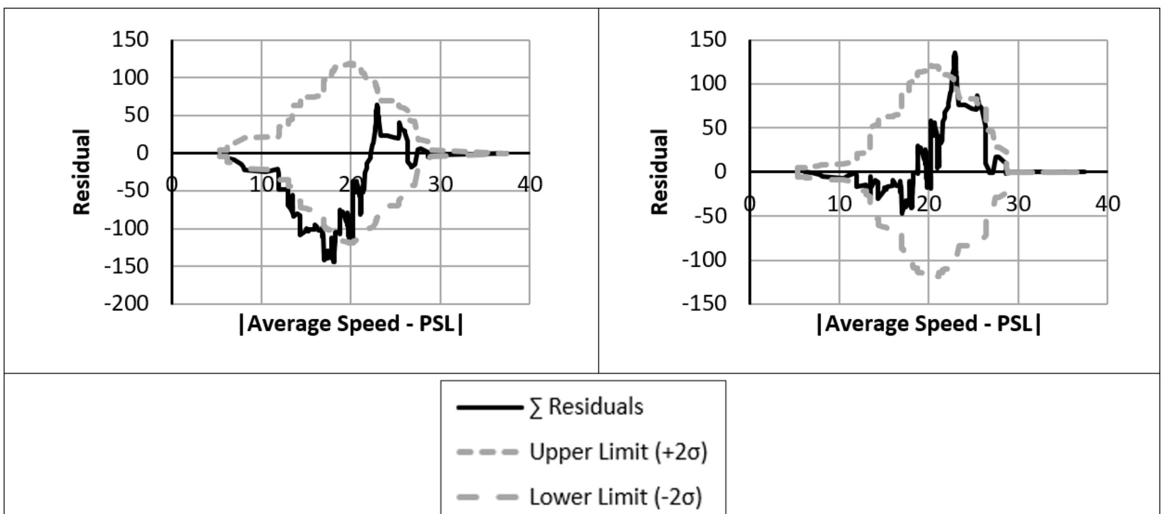
—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 174. U4D speed CMF for KABCO crashes (Washington).

Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 0.0503 \times x^{1.0057}$
R-square	0.49
Speed measure boundaries	(5.40, 37.40)
Base condition	20
t-Test (p-value)	0.16
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.24

Table 175. U4D speed CMF for KABCO crashes (North Carolina).

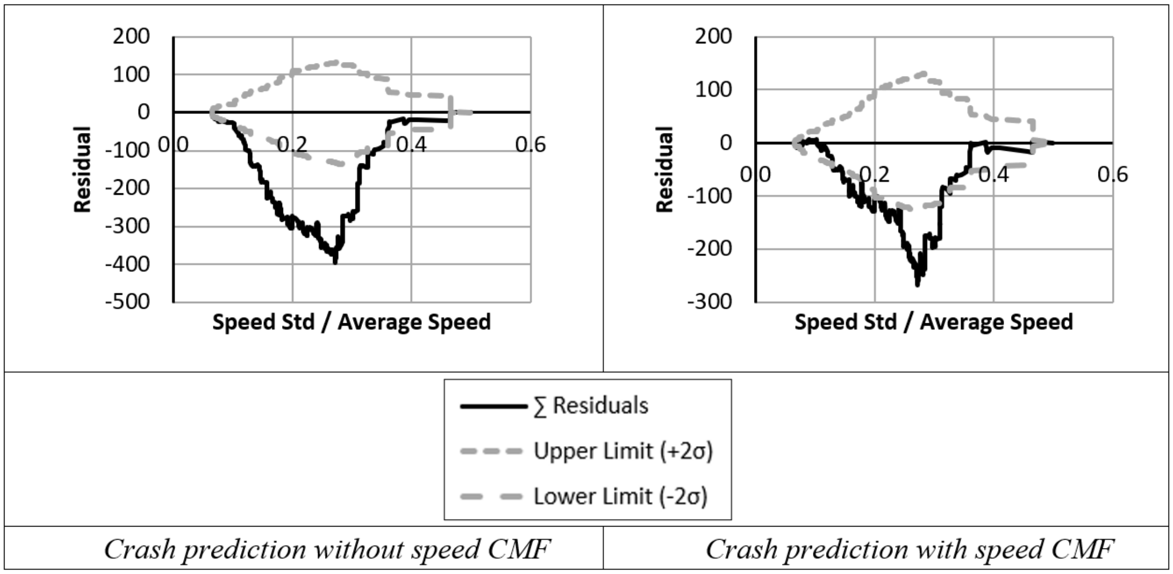
Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 1.9476 \times x^{0.5478}$
R-square	0.98
Speed measure boundaries	(0.07, 0.50)
Base condition	0.30
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.17



Crash prediction without speed CMF | *Crash prediction with speed CMF*

Source: FHWA.

Figure 87. Graph. CURE plots of U4D speed CMF for KABCO crashes (Washington).



Source: FHWA.

Figure 88. Graph. CURE plots of U4D speed CMF for KABCO crashes (North Carolina).

U4D Speed CMF for KABC Crashes

Table 176 to table 179 and figure 89 and figure 90 show the KABC crash severity scale statistics for U4D (AASHTO 2010).

Table 176. Summary of U4D speed CMF development statistics for KABC crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.81	92	81.7	0.491	—	1.421	—
SpdStd	0.78	92	83.1	0.490	−0.2	1.432	0.8
SpdStd	*0.83*	*92*	*83.3*	*0.490*	*−0.2*	*1.435*	*1.0*
(SpdAve − PSL)	0.83	92	81.9	0.486	−0.9	1.423	0.1
|SpdAve − PSL|	0.87	92	81.9	0.485	−1.1	1.425	0.3
|SpdAve − PSL|	***0.88***	***92***	***81.7***	***0.481***	***−1.9***	***1.427***	***0.4***

—Not applicable.

Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 177. Summary of U4D speed CMF development statistics for KABC crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.78	168	161.9	1.257	—	2.242	—
(SpdAve − PSL)	1.89	168	161.0	1.227	−2.4	2.178	−2.8
|SpdAve − PSL|	1.92	168	161.1	1.228	−2.3	2.180	−2.8
|SpdAve − PSL|	*1.92*	*168*	*160.4*	*1.228*	*−2.4*	*2.182*	*−2.7*
SpdStd/SpdAve	2.15	168	161.6	1.231	−2.1	2.176	−2.9
SpdStd/SpdAve	***2.11***	***168***	***161.2***	***1.223***	***−2.7***	***2.156***	***−3.8***

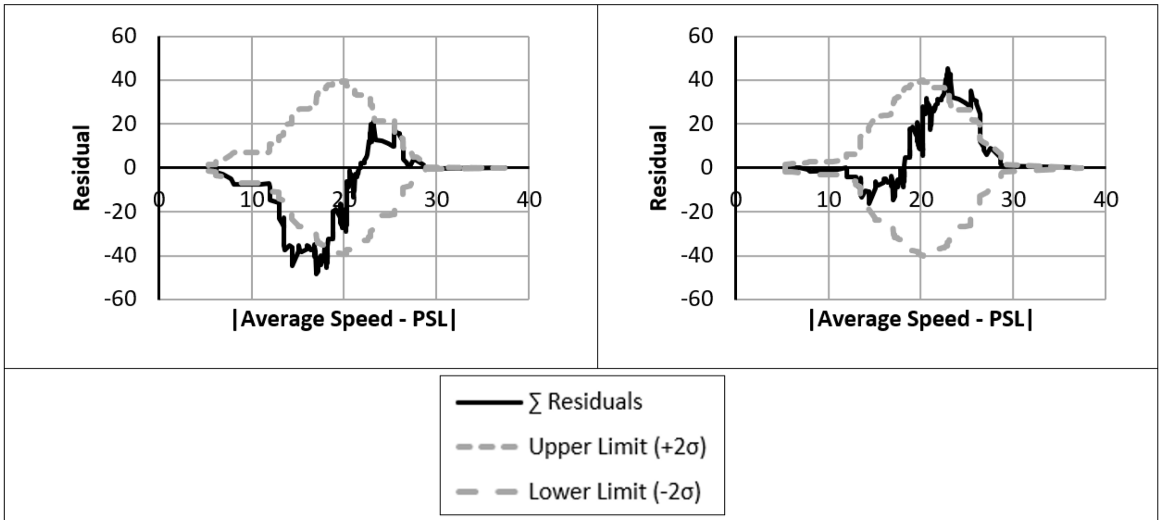
—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 178. U4D speed CMF for KABC crashes (Washington).

Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 0.0318 \times x^{1.1439}$
R-square	0.39
Speed measure boundaries	(5.40, 37.40)
Base condition	20
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.25

Table 179. U4D speed CMF for KABC crashes (North Carolina).

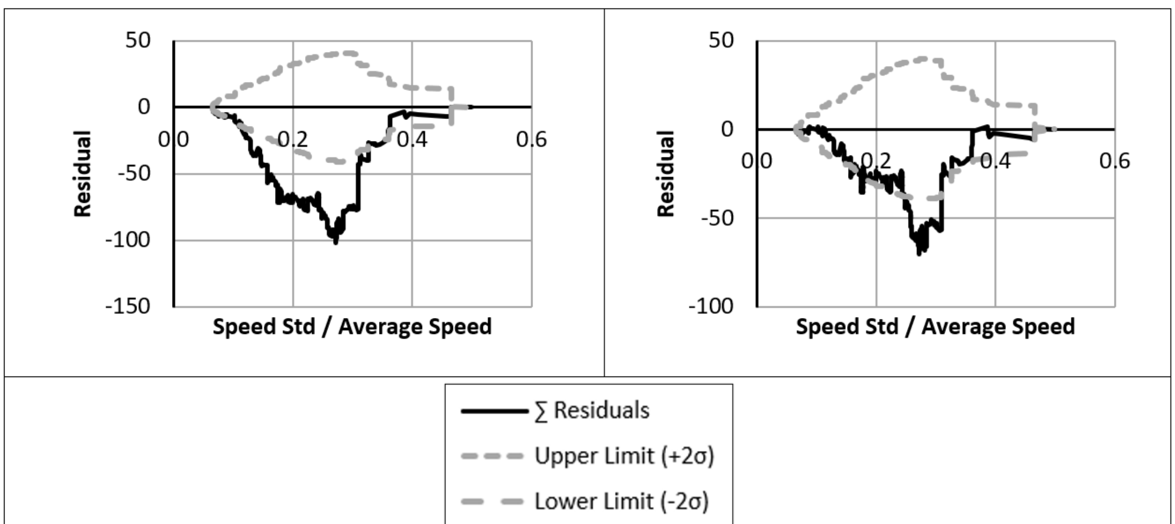
Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 1.8616 \times x^{0.5124}$
R-square	0.97
Speed measure boundaries	(0.07, 0.50)
Base condition	0.30
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.16



Crash prediction without speed CMF | *Crash prediction with speed CMF*

Source: FHWA.

Figure 89. Graph. CURE plots of U4D speed CMF for KABC crashes (Washington).



Crash prediction without speed CMF | *Crash prediction with speed CMF*

Source: FHWA.

Figure 90. Graph. CURE plots of U4D speed CMF for KABC crashes (North Carolina).

U4D Speed CMF for O Crashes

Table 180 to table 183 and figure 91 and figure 92 show the O crash severity scale statistics for U4D (AASHTO 2010).

Table 180. Summary of U4D speed CMF development statistics for O crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.00	175	185.3	1.051	—	2.742	—
SpdStd	0.91	175	190.0	1.052	0.0	2.809	2.5
SpdStd	*0.96*	*175*	*189.8*	*1.052*	*0.0*	*2.805*	*2.3*
|SpdAve − PSL|	1.05	175	187.1	1.045	−0.6	2.842	3.7
|SpdAve − PSL|	*1.04*	*175*	*187.4*	*1.042*	*−0.8*	*2.888*	*5.3*
SpdStd/SpdAve	***1.05***	***175***	***183.5***	***1.033***	***−1.8***	***2.726***	***−0.6***

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 181. Summary of U4D speed CMF development statistics for O crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	2.02	482	471.2	2.776	—	4.354	—
SpdStd	2.12	482	471.9	2.746	−1.1	4.320	−0.8
SpdStd	*2.13*	*482*	*472.4*	*2.745*	*−1.1*	*4.330*	*−0.6*
(SpdAve − PSL)	2.14	482	469.7	2.688	−3.2	4.179	−4.0
SpdStd/SpdAve	2.47	482	470.9	2.646	−4.7	4.149	−4.7
SpdStd/SpdAve	***2.43***	***482***	***470.0***	***2.621***	***−5.6***	***4.097***	***−5.9***

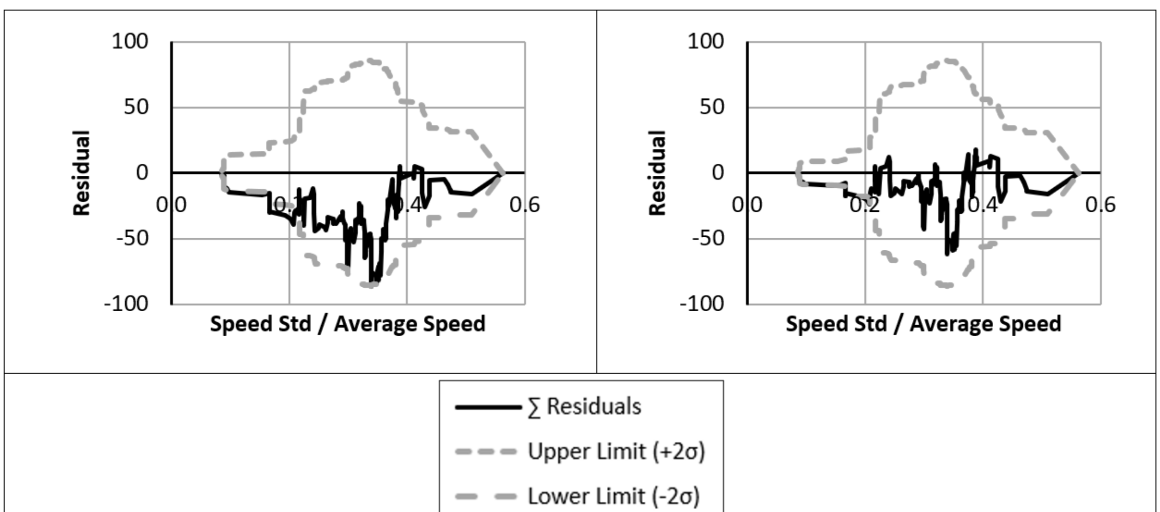
—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 182. U4D speed CMF for O crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 1.3939 \times x^{0.3538}$
R-square	0.17
Speed measure boundaries	(0.09, 0.56)
Base condition	0.39
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.10

Table 183. U4D speed CMF for O crashes (North Carolina).

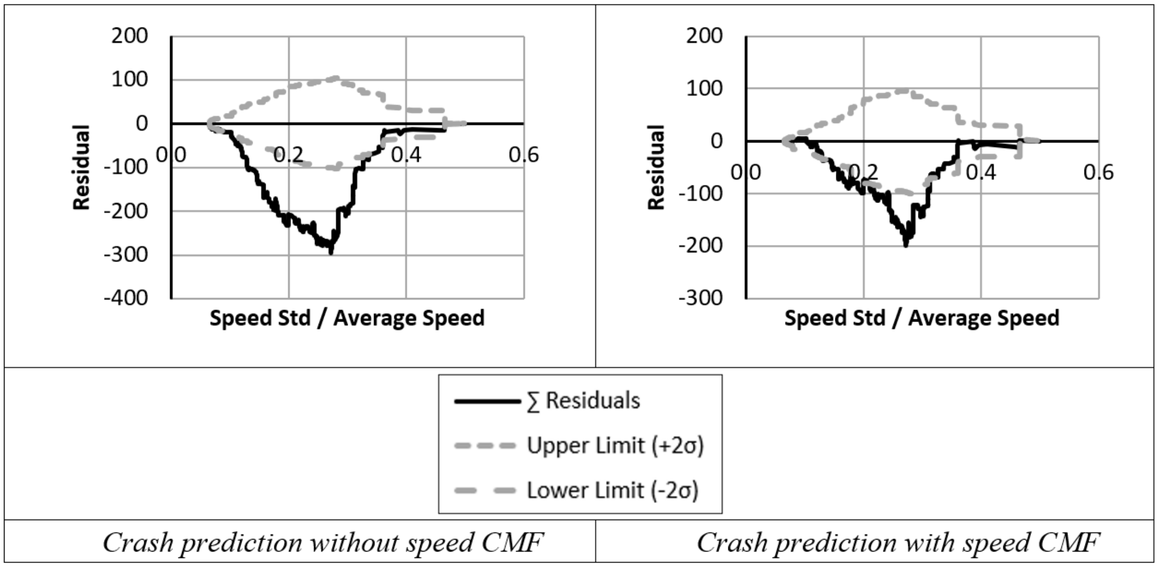
Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 1.9801 \times x^{0.5607}$
R-square	0.98
Speed measure boundaries	(0.07, 0.50)
Base condition	0.30
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.17



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 91. Graph. CURE plots of U4D speed CMF for O crashes (Washington).



Source: FHWA.

Figure 92. Graph. CURE plots of U4D speed CMF for O crashes (North Carolina).

U4D Speed CMF for SVFI Crashes

Table 184 to table 187 and figure 93 and figure 94 show the SVFI statistics for U4D.

Table 184. Summary of U4D speed CMF development statistics for SVFI crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.36	29	21.7	0.637	—	0.952	—
(SpdAve − PSL)	0.38	29	22.0	0.654	2.7	0.963	1.1
|SpdAve − PSL|	0.38	29	22.0	0.658	3.4	0.966	1.5
|SpdAve − PSL|	*0.43*	*29*	*22.4*	*0.666*	*4.7*	*0.973*	*2.2*
SpdStd/SpdAve	0.34	29	21.6	0.631	−0.9	0.947	−0.5
SpdStd/SpdAve	***0.41***	***29***	***21.2***	***0.610***	***−4.1***	***0.935***	***−1.8***

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 185. Summary of U4D speed CMF development statistics for SVFI crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	5.29	37	29.6	0.372	—	0.599	—
SpdStd	4.67	37	30.1	0.370	−0.6	0.600	0.2
SpdStd	*5.22*	*37*	*30.6*	*0.370*	*−0.6*	*0.603*	*0.7*
(SpdAve − PSL)	4.82	37	30.5	0.366	−1.5	0.596	−0.4
|SpdAve − PSL|	4.38	37	30.7	0.366	−1.8	0.597	−0.3
|SpdAve − PSL|	***5.17***	***37***	***32.1***	***0.364***	***−2.2***	***0.596***	***−0.5***

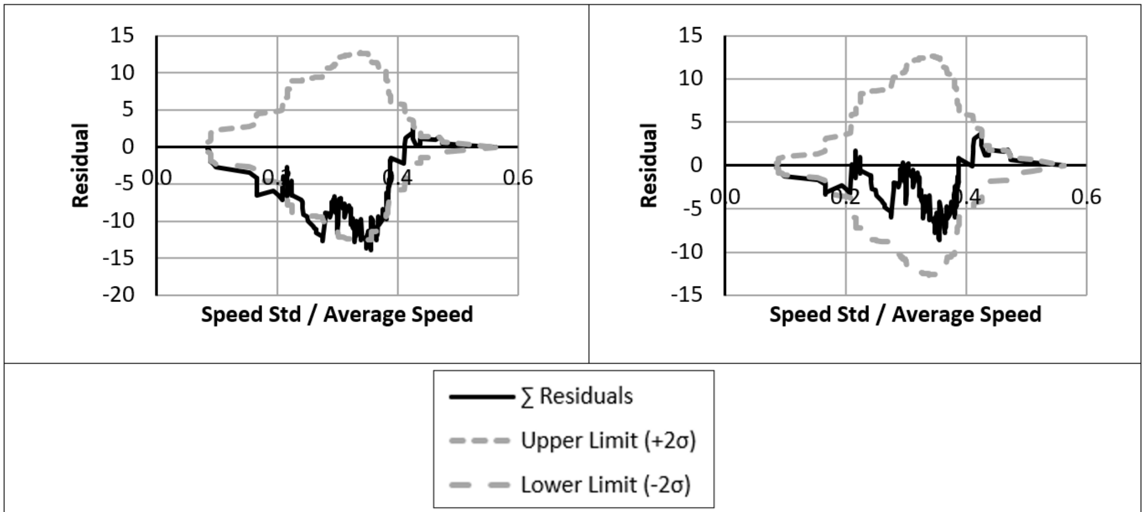
—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 186. U4D speed CMF for SVFI crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 1.8365 \times x^{0.6618}$
R-square	0.63
Speed measure boundaries	(0.09, 0.56)
Base condition	0.40
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.16

Table 187. U4D speed CMF for SVFI crashes (North Carolina).

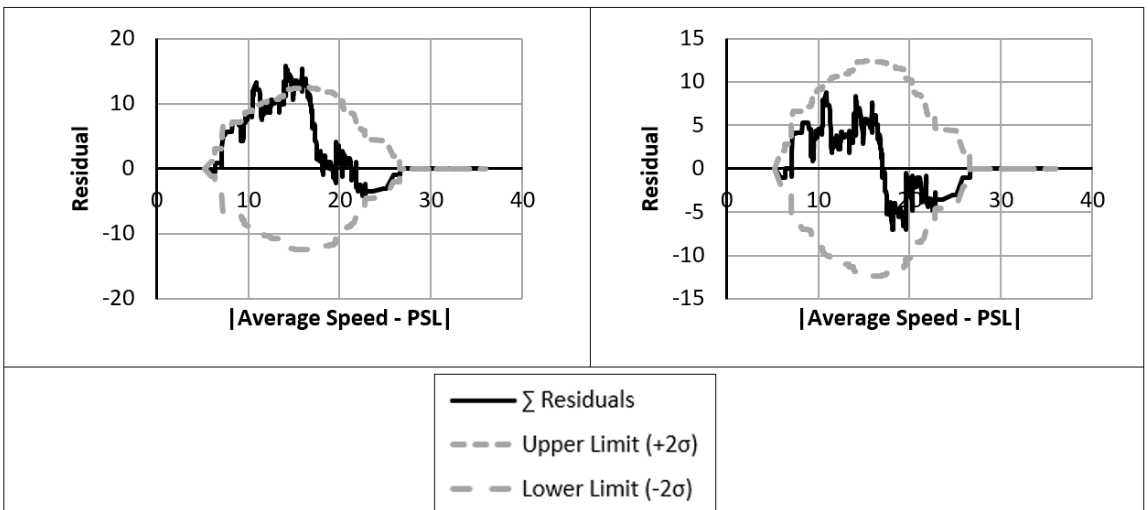
Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 5.3925 \times x^{-0.615}$
R-square	0.54
Speed measure boundaries	(5.30, 36.00)
Base condition	15
t-Test (p-value)	0.96
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.24



Crash prediction without speed CMF	Crash prediction with speed CMF

Source: FHWA.

Figure 93. Graph. CURE plots of U4D speed CMF for SVFI crashes (Washington).



Crash prediction without speed CMF	Crash prediction with speed CMF

Source: FHWA.

Figure 94. Graph. CURE plots of U4D speed CMF for SVFI crashes (North Carolina).

U4D Speed CMF for SVPDO Crashes

Table 188 to table 191 and figure 95 and figure 96 show the SVPDO statistics for U4D.

Table 188. Summary of U4D speed CMF development statistics for SVPDO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.31	24	32.7	0.740	—	1.254	—
SpdStd	0.29	24	32.8	0.740	0.0	1.253	−0.1
(SpdAve − PSL)	0.26	24	33.7	0.752	1.6	1.251	−0.2
|SpdAve − PSL|	**0.29**	**24**	**33.4**	**0.748**	**1.1**	**1.249**	**−0.4**
SpdStd/SpdAve	0.26	24	32.9	0.744	0.5	1.253	−0.1
SpdStd/SpdAve	*0.30*	*24*	*34.0*	*0.761*	*2.9*	*1.260*	*0.5*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 189. Summary of U4D speed CMF development statistics for SVPDO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	2.29	92	74.1	0.701	—	0.962	—
SpdStd	2.25	92	74.3	0.691	−1.3	0.953	−1.0
SpdStd	*2.28*	*92*	*74.5*	*0.689*	*−1.7*	*0.951*	*−1.2*
|SpdAve − PSL|	2.20	92	74.4	0.690	−1.5	0.947	−1.5
|SpdAve − PSL|	***2.30***	***92***	***75.0***	***0.686***	***−2.0***	***0.939***	***−2.4***
SpdStd/SpdAve	*2.27*	*92*	*74.3*	*0.694*	*−0.9*	*0.954*	*−0.8*

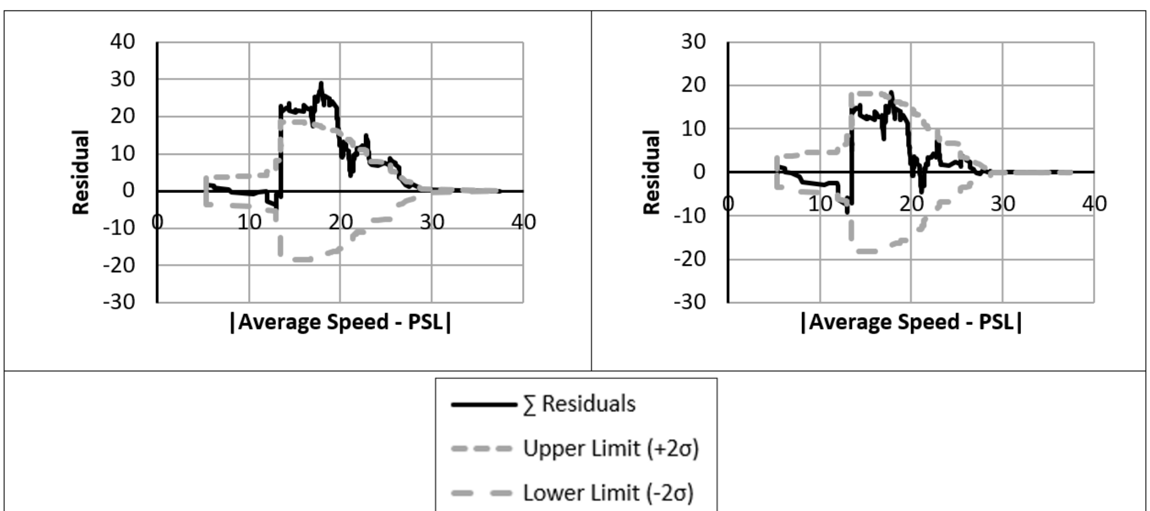
—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 190. U4D speed CMF for SVPDO crashes (Washington).

Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = -0.0574 \times x + 2.2864$
R-square	0.15
Speed measure boundaries	(5.40, 37.40)
Base condition	22
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.26

Table 191. U4D speed CMF for SVPDO crashes (North Carolina).

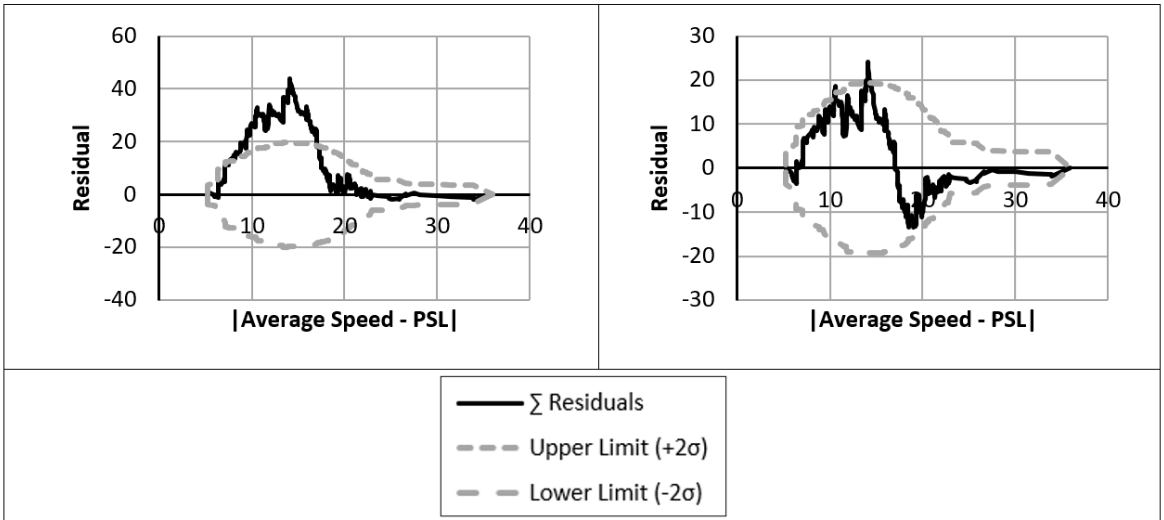
Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 3.8613 \times x^{-0.499}$
R-square	0.64
Speed measure boundaries	(5.30, 36.00)
Base condition	15
t-Test (p-value)	0.8
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.19



Crash prediction without speed CMF | *Crash prediction with speed CMF*

Source: FHWA.

Figure 95. Graph. CURE plots of U4D speed CMF for SVPDO crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 96. Graph. CURE plots of U4D speed CMF for SVPDO crashes (North Carolina).

U4D Speed CMF for MVFI Crashes

Table 192 to table 195 and figure 97 and figure 98 show the MVFI statistics for U4D.

Table 192. Summary of U4D speed CMF development statistics for MVFI crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	**1.48**	**63**	**59.3**	**1.452**	**—**	**2.219**	**—**
SpdStd	1.38	63	63.8	1.499	3.2	2.376	7.1
SpdStd	*1.47*	*63*	*64.2*	*1.508*	*3.9*	*2.384*	*7.5*
(SpdAve − PSL)	1.48	63	61.5	1.459	0.5	2.332	5.1
|SpdAve − PSL|	1.53	63	62.1	1.463	0.7	2.367	6.7
|SpdAve − PSL|	*1.57*	*63*	*63.1*	*1.472*	*1.4*	*2.431*	*9.6*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 193. Summary of U4D speed CMF development statistics for MVFI crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.91	130	135.6	1.128	—	2.103	—
(SpdAve − PSL)	2.07	130	135.8	1.070	−5.1	2.012	−4.3
|SpdAve − PSL|	2.13	130	135.8	1.071	−5.0	2.012	−4.3
|SpdAve − PSL|	*2.19*	*130*	*136.4*	*1.072*	*−4.9*	*2.008*	*−4.5*
SpdStd/SpdAve	2.49	130	136.0	1.084	−3.8	2.013	−4.3
SpdStd/SpdAve	***2.55***	***130***	***136.1***	***1.074***	***−4.8***	***1.981***	***−5.8***

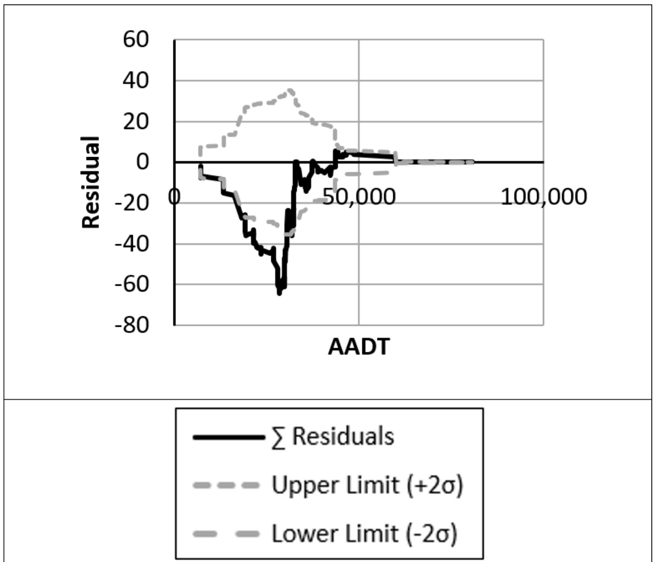
—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 194. U4D speed CMF for MVFI crashes (Washington).

Speed CMF	Value
Speed measure	NA
CMF equation	NA
R-square	NA
Speed measure boundaries	NA
Base condition	NA
t-Test (*p*-value)	NA
Estimated CMF Clearinghouse star quality rating	NA
CMF standard error	NA

Table 195. U4D speed CMF for MVFI crashes (North Carolina).

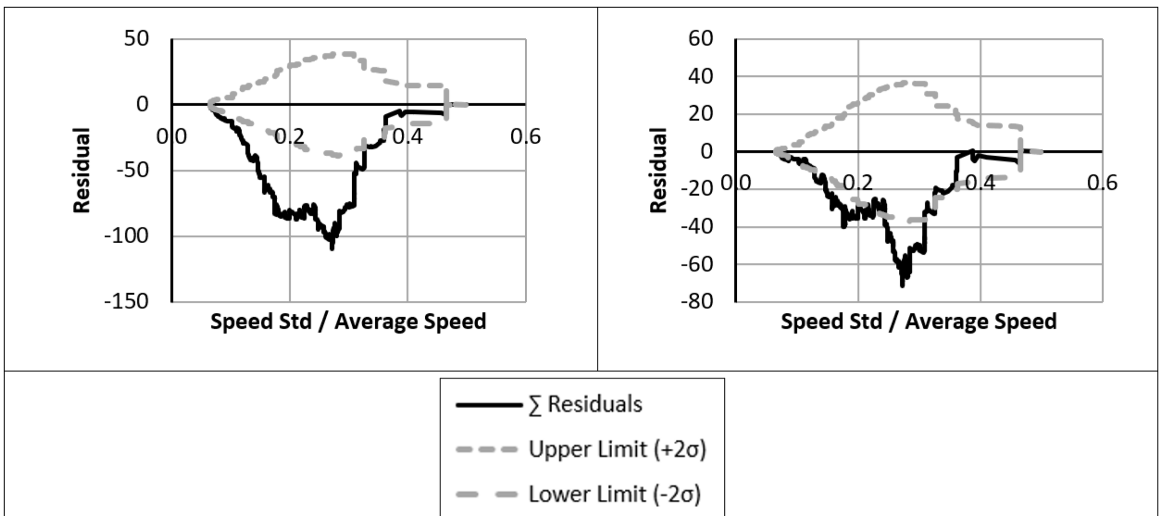
Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 2.491 \times x^{0.785}$
R-square	0.95
Speed measure boundaries	(0.07, 0.50)
Base condition	0.31
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.21



Crash prediction without speed CMF

Source: FHWA.

Figure 97. Graph. CURE plot of U4D speed CMF for MVFI crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 98. Graph. CURE plots of U4D speed CMF for MVFI crashes (North Carolina).

U4D Speed CMF for MVPDO Crashes

Table 196 to table 199 and figure 99 and figure 100 show the MVPDO statistics for U4D.

Table 196. Summary of U4D speed CMF development statistics for MVPDO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	**1.88**	**151**	**148.3**	**3.598**	**—**	**5.272**	**—**
SpdStd	1.65	151	160.5	3.728	3.6	5.747	9.0
SpdStd	*1.75*	*151*	*160.2*	*3.729*	*3.7*	*5.720*	*8.5*
(SpdAve − PSL)	1.87	151	157.4	3.705	3.0	5.846	10.9
|SpdAve − PSL|	1.96	151	159.1	3.727	3.6	5.980	13.4
|SpdAve − PSL|	*2.02*	*151*	*163.4*	*3.789*	*5.3*	*6.243*	*18.4*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 197. Summary of U4D speed CMF development statistics for MVPDO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	2.09	386	398.3	2.590	—	4.107	—
SpdStd	2.24	386	401.8	2.473	−4.5	4.048	−1.4
(SpdAve − PSL)	2.29	386	399.6	2.334	−9.9	3.854	−6.2
|SpdAve − PSL|	2.38	386	399.6	2.333	−9.9	3.854	−6.2
SpdStd/SpdAve	2.79	386	399.4	2.393	−7.6	3.828	−6.8
SpdStd/SpdAve	***2.96***	***386***	***399.9***	***2.301***	***−11.1***	***3.722***	***−9.4***

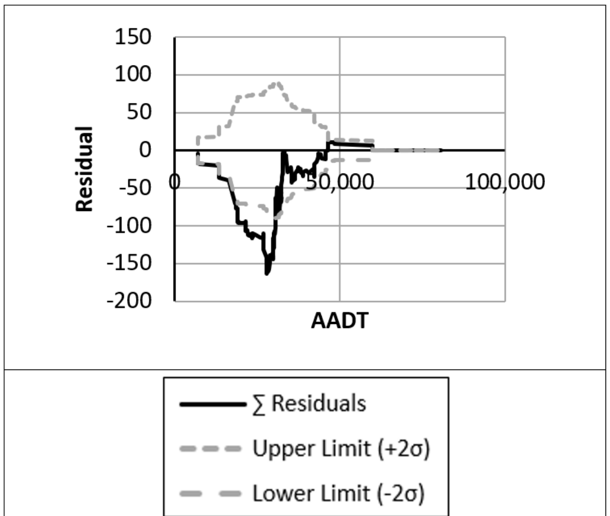
—Not applicable.
Note: Rows that are both bold and italics indicate the best speed CMF with power function.

Table 198. U4D speed CMF for MVPDO crashes (Washington).

Speed CMF	Value
Speed measure	NA
CMF equation	NA
R-square	NA
Speed measure boundaries	NA
Base condition	NA
t-Test (*p*-value)	NA
Estimated CMF Clearinghouse star quality rating	NA
CMF standard error	NA

Table 199. U4D speed CMF for MVPDO crashes (North Carolina).

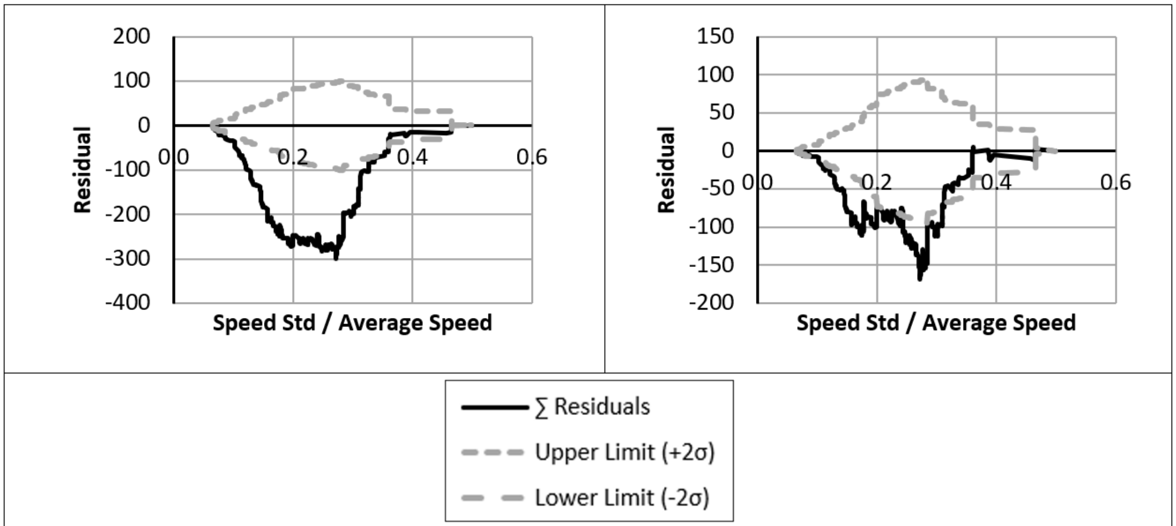
Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 2.8401 \times x^{0.9265}$
R-square	0.88
Speed measure boundaries	(0.07, 0.50)
Base condition	0.32
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.23



Crash prediction without speed CMF

Source: FHWA.

Figure 99. Graph. CURE plot of U4D speed CMF for MVPDO crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 100. Graph. CURE plots of U4D speed CMF for MVPDO crashes (North Carolina).

Table 200 and table 201 show the U4D CURE plot summary for Washington and North Carolina, respectively.

Table 200. CURE plots summary of U4D (Washington).

Crash	Crash Prediction Method	Within CURE (%)	Change to HSM (%)	|Maximum CURE Deviation|	Change to HSM (%)
KABCO	HSM (without speed CMF)	63.79	—	44.29	—
KABCO	HSM × speed CMF	88.79	25	34.32	−23
KABC	HSM (without speed CMF)	62.07	—	21.04	—
KABC	HSM × speed CMF	82.33	20	12.59	−40
O	HSM (without speed CMF)	93.10	—	13.18	—
O	HSM × speed CMF	95.69	3	4.36	−67
SVFI	HSM (without speed CMF)	77.16	—	3.30	—
SVFI	HSM × speed CMF	94.83	18	0.69	−79
SVPDO	HSM (without speed CMF)	46.98	—	11.58	—
SVPDO	HSM × speed CMF	95.69	49	2.40	−79
MVFI	HSM (without speed CMF)	55.17	—	32.22	—
MVFI	HSM default	55.17	0	32.22	0
MVPDO	HSM (without speed CMF)	55.60	—	80.86	—
MVPDO	HSM default	55.60	0	80.86	0

—Not applicable.

Table 201. CURE plots summary of U4D (North Carolina).

Crash	Crash Prediction Method	Within CURE (%)	Change to HSM (%)	|Maximum CURE Deviation|	Change to HSM (%)
KABCO	HSM (without speed CMF)	4.94	—	264.24	—
KABCO	HSM × speed CMF	24.90	20	141.81	−46
KABC	HSM (without speed CMF)	9.32	—	61.42	—
KABC	HSM × speed CMF	60.08	51	31.05	−49
O	HSM (without speed CMF)	6.08	—	194.49	—
O	HSM × speed CMF	26.62	21	102.51	−47
SVFI	HSM (without speed CMF)	76.81	—	3.67	—
SVFI	HSM × speed CMF	98.48	22	0.00	−100
SVPDO	HSM (without speed CMF)	47.53	—	24.44	—
SVPDO	HSM × speed CMF	94.30	47	4.70	−81
MVFI	HSM (without speed CMF)	3.99	—	71.98	—
MVFI	HSM × speed CMF	24.52	21	35.61	−51
MVPDO	HSM (without speed CMF)	4.37	—	201.55	—
MVPDO	HSM × speed CMF	16.54	12	77.32	−62

—Not applicable.

U5T SPEED CMFs

Table 202 through table 205 show the five-lane urban and suburban arterials including a center two-way, left-turn lane (U5T) statistic.

Table 202. Summary descriptive statistics of U5T (Washington).

Dataset	Segments (No.)	Length (mile)	KABC (No.)	PDO (No.)	Total (No.)	SVFI (No.)	SVPDO (No.)	MVFI (No.)	MVPDO (No.)
Training	537	99.7	420	925	1,345	71	94	349	831
Test	179	31.5	150	307	457	23	30	127	277
All	716	131.2	570	1,232	1,802	94	124	476	1,108

Note: Values for KABC, PDO, Total, SVFI, SVPDO, MVFI, and MVPDO represent observed crashes from 2017-2018.

Table 203. Summary descriptive statistics of U5T (North Carolina).

Dataset	Segments (No.)	Length (mile)	KABC (No.)	PDO (No.)	Total (No.)	SVFI (No.)	SVPDO (No.)	MVFI (No.)	MVPDO (No.)
Training	242	84	582	1,556	2,138	62	156	515	1,388
Test	80	22.3	173	472	645	15	41	155	427
All	322	106.3	755	2,028	2,783	77	197	670	1,815

Note: Values for KABC, PDO, Total, SVFI, SVPDO, MVFI, and MVPDO represent observed crashes from 2017-2018.

Table 204. *R*-square values of speed CMF equations of U5T (Washington).

Speed Measure	KABCO (L)	KABCO (P)	KABC (L)	KABC (P)	O (L)	O (P)	SVFI (L)	SVFI (P)	SVPDO (L)	SVPDO (P)	MVFI (L)	MVFI (P)	MVPDO (L)	MVPDO (P)
SpdStd	***0.87***	***0.80***	***0.78***	***0.74***	***0.89***	***0.81***	***0.75***	***0.71***	***0.70***	***0.69***	***0.65***	***0.61***	***0.84***	***0.75***
(SpdAve − PSL)	***0.83***	—	***0.45***	—	***0.91***	—	***0.22***	—	*0.03*	—	***0.55***	—	***0.92***	—
|SpdAve − PSL|	***0.84***	***0.84***	***0.47***	***0.48***	***0.91***	***0.91***	***0.24***	***0.24***	***0.04***	0.04	***0.56***	***0.57***	***0.93***	***0.91***
SpdStd/ SpdAve	0.09	0.17	0.00	0.03	0.15	0.23	0.12	0.01	***0.29***	***0.07***	0.13	0.23	0.28	0.34

—Not applicable.

Note: Bold italic numbers indicate the top five potential speed CMFs for each crash type/severity level.

Table 205. *R*-square values of speed CMF equations of U5T (North Carolina).

Speed Measure	KABCO (L)	KABCO (P)	KABC (L)	KABC (P)	O (L)	O (P)	SVFI (L)	SVFI (P)	SVPDO (L)	SVPDO (P)	MVFI (L)	MVFI (P)	MVPDO (L)	MVPDO (P)
SpdStd	0.48	0.49	0.31	0.34	0.44	0.44	***0.30***	***0.27***	0.11	0.07	0.53	0.54	0.52	0.51
(SpdAve − PSL)	***0.85***	—	***0.69***	—	***0.84***	—	***0.18***	—	***0.35***	—	***0.75***	—	***0.84***	—
|SpdAve − PSL|	***0.83***	***0.84***	***0.71***	***0.67***	***0.80***	***0.78***	0.16	0.09	***0.27***	***0.21***	***0.75***	***0.73***	***0.82***	***0.77***
SpdStd/ SpdAve	***0.86***	***0.91***	***0.93***	***0.93***	***0.79***	***0.85***	***0.31***	***0.21***	***0.11***	***0.21***	***0.95***	***0.96***	***0.79***	***0.83***

—Not applicable.
Note: Bold italic numbers indicate the top five potential speed CMFs for each crash type/severity level.

U5T Speed CMF for KABCO Crashes

Table 206 to table 209 and figure 101 and figure 102 show the KABCO crash severity scale statistics for U5T (AASHTO 2010).

Table 206. Summary of U5T speed CMF development statistics for KABCO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	**0.46**	**457**	**414.5**	**1.461**	**—**	**3.519**	**—**
SpdStd	0.48	457	440.1	1.466	0.4	3.535	0.5
SpdStd	*0.50*	*457*	*442.7*	*1.472*	*0.8*	*3.548*	*0.8*
(SpdAve − PSL)	0.48	457	439.0	1.487	1.8	3.786	7.6
|SpdAve − PSL|	0.49	457	438.5	1.485	1.7	3.780	7.4
|SpdAve − PSL|	*0.49*	*457*	*439.3*	*1.488*	*1.9*	*3.795*	*7.9*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 207. Summary of U5T speed CMF development statistics for KABCO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.13	645	634.1	5.570	—	10.889	—
(SpdAve − PSL)	1.18	645	639.3	5.350	−3.9	9.902	−9.1
|SpdAve − PSL|	1.21	645	639.0	5.359	−3.8	9.959	−8.5
|SpdAve − PSL|	***1.21***	***645***	***640.5***	***5.338***	***−4.2***	***9.823***	***−9.8***
SpdStd/SpdAve	1.30	645	646.6	5.420	−2.7	10.281	−5.6
SpdStd/SpdAve	*1.29*	*645*	*655.0*	*5.351*	*−3.9*	*9.981*	*−8.3*

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

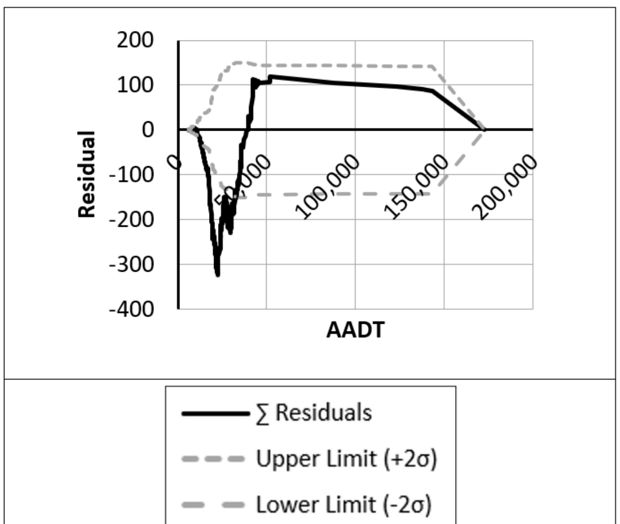
Table 208. U5T speed CMF for KABCO crashes (Washington).

Speed CMF	Value
Speed measure	NA
CMF equation	NA
R-square	NA
Speed measure boundaries	NA
Base condition	NA
t-Test (*p*-value)	NA
Estimated CMF Clearinghouse star quality rating	NA
CMF standard error	NA

—Not applicable.

Table 209. U5T speed CMF for KABCO crashes (North Carolina).

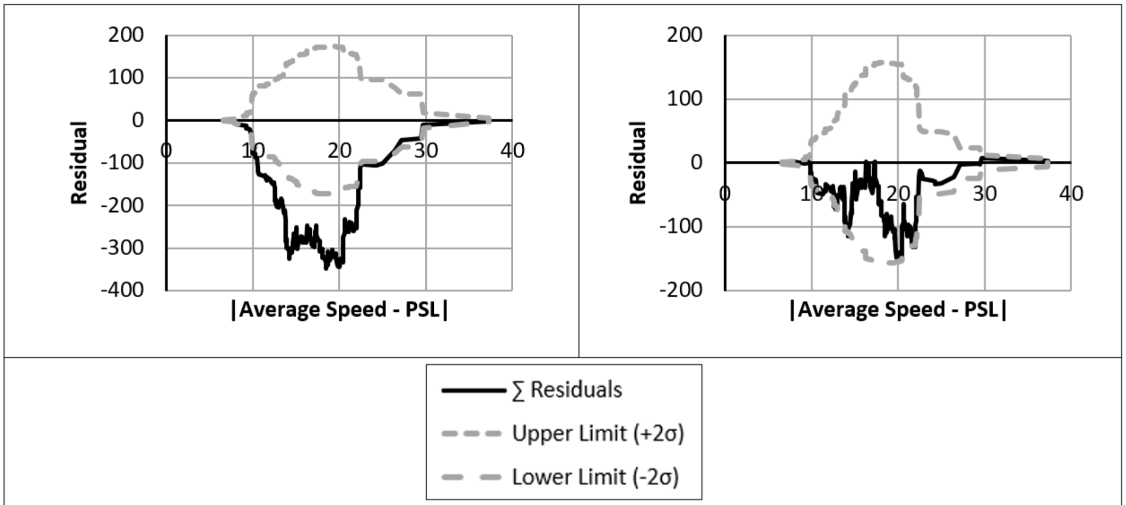
Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 0.0682 \times x^{0.9274}$
R-square	0.87
Speed measure boundaries	(6.60, 37.30)
Base condition	18
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.22



Crash prediction without speed CMF

Source: FHWA.

Figure 101. Graph. CURE plot of U5T speed CMF for KABCO crashes (Washington).



Crash prediction without speed CMF	Crash prediction with speed CMF

Source: FHWA.

Figure 102. Graph. CURE plots of U5T speed CMF for KABCO crashes (North Carolina).

U5T Speed CMF for KABC Crashes

Table 210 to table 213 and figure 103 and figure 104 show the KABC crash severity scale statistics for U5T (AASHTO 2010).

Table 210. Summary of U5T speed CMF development statistics for KABC crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.48	150	130.5	0.529	—	1.265	—
SpdStd	**0.49**	**150**	**136.8**	**0.531**	**0.4**	**1.259**	**−0.5**
SpdStd	*0.50*	*150*	*137.6*	*0.532*	*0.6*	*1.259*	*−0.5*
(SpdAve − PSL)	0.49	150	135.3	0.529	0.1	1.307	3.3
|SpdAve − PSL|	0.49	150	135.2	0.529	0.1	1.305	3.2
|SpdAve − PSL|	*0.51*	*150*	*136.1*	*0.530*	*0.1*	*1.307*	*3.3*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 211. Summary of U5T speed CMF development statistics for KABC crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.05	173	170.9	2.027	—	5.157	—
(SpdAve − PSL)	**1.07**	**173**	**171.8**	**2.004**	**−1.1**	**5.011**	**−2.8**
|SpdAve − PSL|	1.09	173	171.7	2.004	−1.1	5.027	−2.5
|SpdAve − PSL|	*1.10*	*173*	*172.1*	*2.012*	*−0.7*	*5.041*	*−2.2*
SpdStd/SpdAve	1.18	173	174.0	2.028	0.1	5.042	−2.2
SpdStd/SpdAve	*1.16*	*173*	*175.3*	*2.027*	*0.0*	*5.006*	*−2.9*

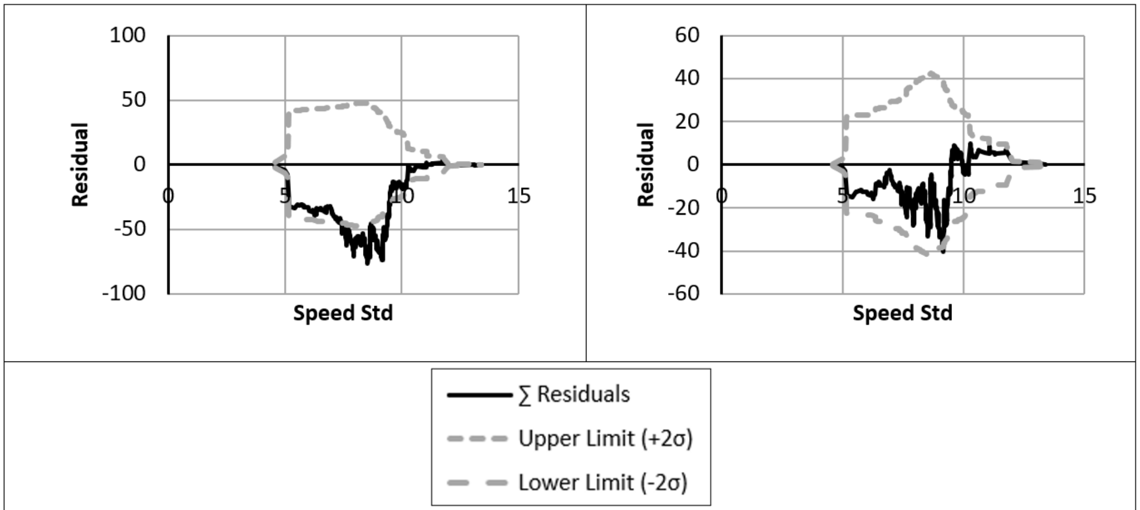
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 212. U5T speed CMF for KABC crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.1558 \times x - 0.3313$
R-square	0.87
Speed measure boundaries	(4.60, 13.40)
Base condition	9
t-Test (*p*-value)	0.16
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.17

Table 213. U5T speed CMF for KABC crashes (North Carolina).

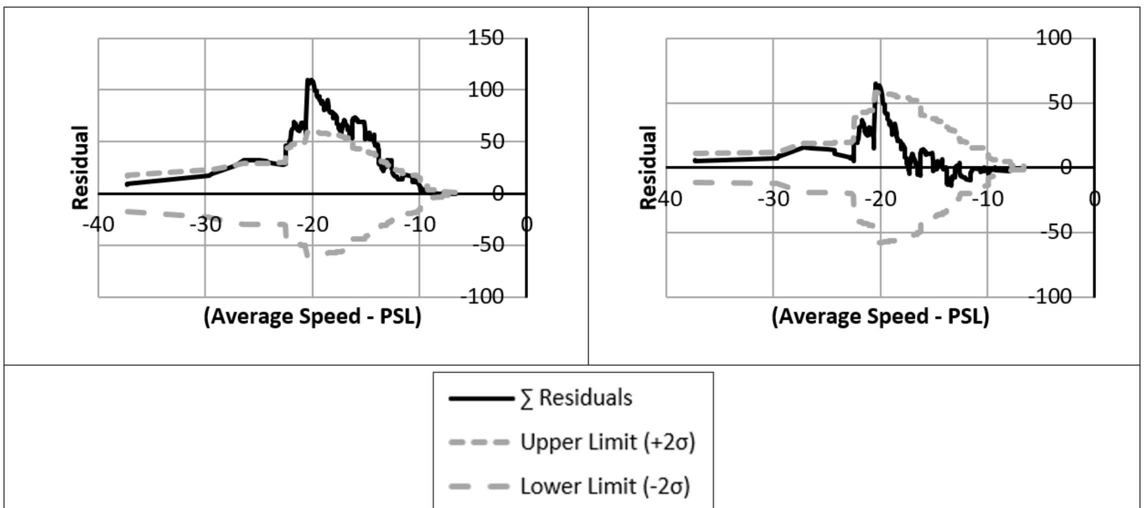
Speed CMF	Value
Speed measure	(SpdAve − PSL)
CMF equation	$y = -0.0462 \times x + 0.1775$
R-square	0.69
Speed measure boundaries	(−37.30, −6.60)
Base condition	−18
t-Test (*p*-value)	0.01
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.20



Crash prediction without speed CMF | *Crash prediction with speed CMF*

Source: FHWA.

Figure 103. Graph. CURE plots of U5T speed CMF for KABC crashes (Washington).



Crash prediction without speed CMF | *Crash prediction with speed CMF*

Source: FHWA.

Figure 104. Graph. CURE plots of U5T speed CMF for KABC crashes (North Carolina).

U5T Speed CMF for O Crashes

Table 214 to table 217 and figure 105 and figure 106 show the O crash severity scale statistics for U5T (AASHTO 2010).

Table 214. Summary of U5T speed CMF development statistics for O crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	**0.46**	**307**	**283.5**	**1.021**	**—**	**2.438**	**—**
SpdStd	0.48	307	302.8	1.027	0.6	2.467	1.2
SpdStd	*0.50*	*307*	*304.6*	*1.031*	*1.0*	*2.482*	*1.8*
(SpdAve − PSL)	0.47	307	303.3	1.053	3.2	2.661	9.1
|SpdAve − PSL|	0.48	307	303.1	1.052	3.1	2.657	9.0
|SpdAve − PSL|	*0.49*	*307*	*302.5*	*1.054*	*3.2*	*2.673*	*9.6*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 215. Summary of U5T speed CMF development statistics for O crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.17	472	462.7	4.137	—	7.166	—
(SpdAve − PSL)	1.22	472	467.3	3.896	−5.8	6.406	−10.6
|SpdAve − PSL|	1.26	472	467.1	3.904	−5.6	6.438	−10.2
|SpdAve − PSL|	***1.27***	***472***	***467.6***	***3.861***	***−6.7***	***6.255***	***−12.7***
SpdStd/SpdAve	1.35	472	472.2	3.971	−4.0	6.734	−6.0
SpdStd/SpdAve	*1.36*	*472*	*479.6*	*3.877*	*−6.3*	*6.493*	*−9.4*

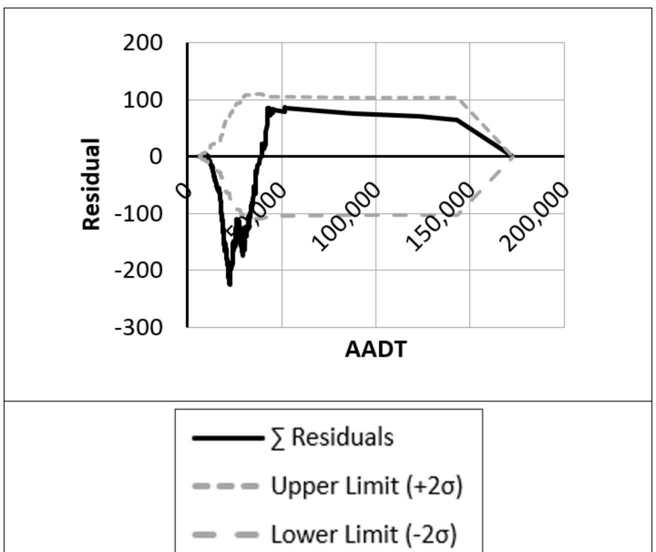
—Not applicable.
Note:Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 216. U5T speed CMF for O crashes (Washington).

Speed CMF	Value
Speed measure	NA
CMF equation	NA
R-square	NA
Speed measure boundaries	NA
Base condition	NA
t-Test (*p*-value)	NA
Estimated CMF Clearinghouse star quality rating	NA
CMF standard error	NA

Table 217. U5T speed CMF for O crashes (North Carolina).

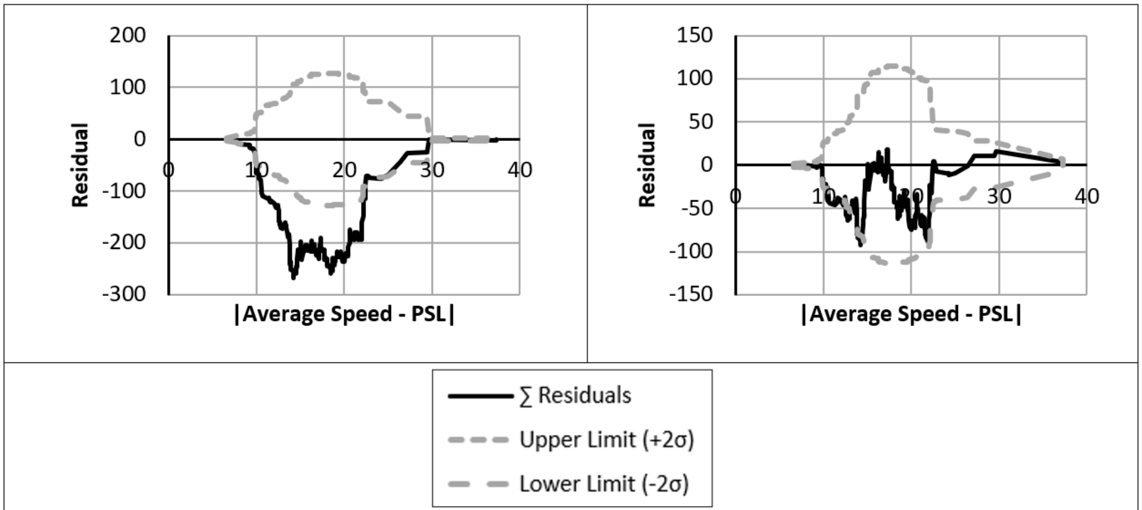
Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 0.0449 \times x^{1.0714}$
R-square	0.83
Speed measure boundaries	(6.60, 37.30)
Base condition	18
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.26



Crash prediction without speed CMF

Source: FHWA.

Figure 105. Graph. CURE plot of U5T speed CMF for O crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 106. Graph. CURE plots of U5T speed CMF for O crashes (North Carolina).

U5T Speed CMF for SVFI Crashes

Table 218 to table 221 and figure 107 and figure 108 show the SVFI statistics for U5T.

Table 218. Summary of U5T speed CMF development statistics for SVFI crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.80	23	22.7	0.202	—	0.364	—
SpdStd	**0.83**	**23**	**23.6**	**0.202**	**0.0**	**0.363**	**−0.1**
SpdStd	*0.86*	*23*	*23.7*	*0.201*	*−0.2*	*0.364*	*0.1*
(SpdAve − PSL)	0.80	23	23.2	0.203	0.9	0.370	1.6
|SpdAve − PSL|	0.81	23	23.2	0.203	0.9	0.369	1.5
|SpdAve − PSL|	*0.95*	*23*	*23.3*	*0.204*	*1.2*	*0.371*	*2.1*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 219. Summary of U5T speed CMF development statistics for SVFI crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.93	15	17.4	0.307	—	0.501	—
SpdStd	0.93	15	16.9	0.301	−2.0	0.505	0.7
SpdStd	***0.96***	***15***	***16.8***	***0.300***	***−2.4***	***0.503***	***0.4***
(SpdAve − PSL)	0.94	15	17.5	0.308	0.3	0.499	−0.5
SpdStd/SpdAve	0.95	15	17.5	0.308	0.2	0.500	−0.3
SpdStd/SpdAve	*0.95*	*15*	*17.5*	*0.308*	*0.3*	*0.500*	*−0.3*

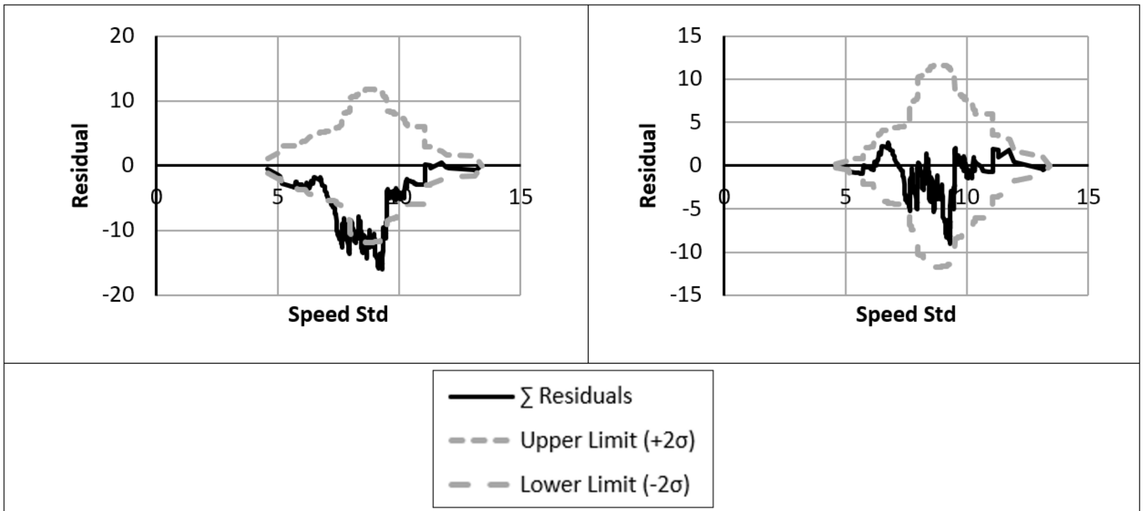
—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 220. U5T speed CMF for SVFI crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.2054 \times x - 0.7786$
R-square	0.95
Speed measure boundaries	(4.60, 13.40)
Base condition	9
t-Test (p-value)	0.01
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.22

Table 221. U5T speed CMF for SVFI crashes (North Carolina).

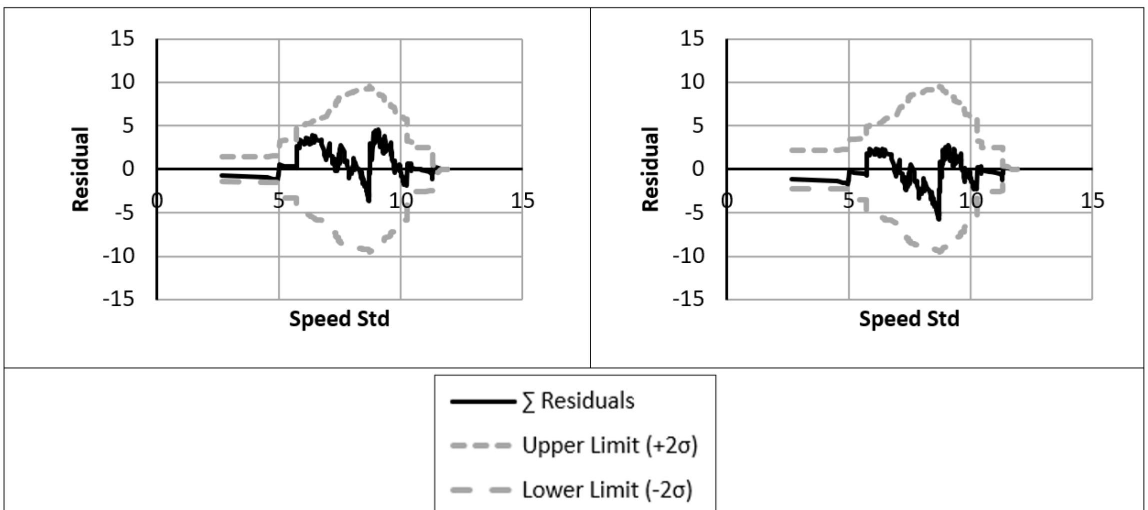
Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 2.1824 \times x^{-0.385}$
R-square	0.16
Speed measure boundaries	(2.70, 11.90)
Base condition	8
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.07



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 107. Graph. CURE plots of U5T speed CMF for SVFI crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 108. Graph. CURE plots of U5T speed CMF for SVFI crashes (North Carolina).

U5T Speed CMF for SVPDO Crashes

Table 222 to table 225 and figure 109 and figure 110 show the SVPDO statistics for U5T.

Table 222. Summary of U5T speed CMF development statistics for SVPDO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.32	30	30.0	0.266	—	0.504	—
SpdStd	0.33	30	30.9	0.269	1.1	0.508	0.7
SpdStd	*0.33*	*30*	*31.0*	*0.270*	*1.3*	*0.508*	*0.8*
|SpdAve − PSL|	**0.32**	**30**	**29.7**	**0.264**	**−0.9**	**0.500**	**−0.7**
SpdStd/SpdAve	0.29	30	29.9	0.265	−0.6	0.504	−0.1
SpdStd/SpdAve	*0.34*	*30*	*29.2*	*0.261*	*−1.9*	*0.503*	*−0.2*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 223. Summary of U5T speed CMF development statistics for SVPDO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	**0.71**	**41**	**43.2**	**0.528**	**—**	**0.710**	**—**
(SpdAve − PSL)	0.70	41	42.8	0.538	1.9	0.736	3.7
|SpdAve − PSL|	0.68	41	42.9	0.537	1.8	0.734	3.4
|SpdAve − PSL|	*0.71*	*41*	*42.5*	*0.537*	*1.7*	*0.733*	*3.4*
SpdStd/SpdAve	0.69	41	43.0	0.529	0.3	0.713	0.5
SpdStd/SpdAve	*0.71*	*41*	*42.7*	*0.530*	*0.5*	*0.717*	*1.1*

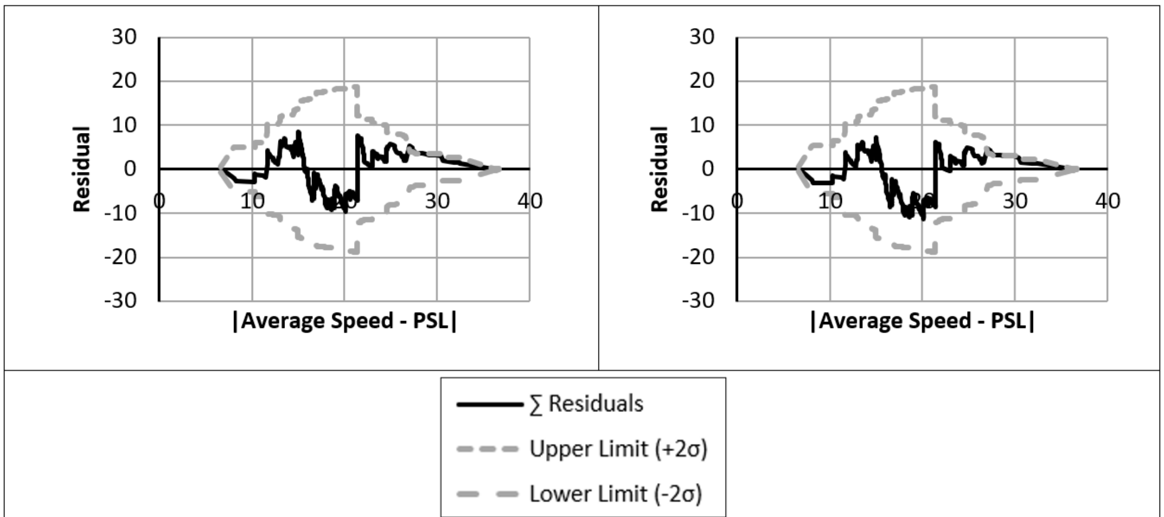
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 224. U5T speed CMF for SVPDO crashes (Washington).

Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = -0.0076 \times x + 1.1382$
R-square	0.02
Speed measure boundaries	(6.60, 36.60)
Base condition	18
t-Test (*p*-value)	0.71
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.03

Table 225. U5T speed CMF for SVPDO crashes (North Carolina).

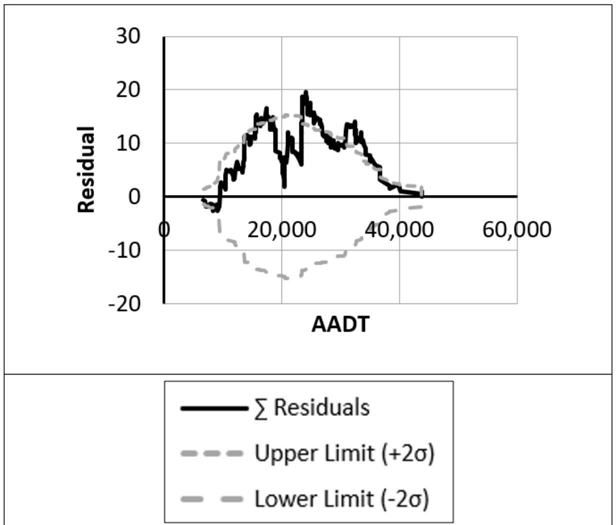
Speed CMF	Value
Speed measure	NA
CMF equation	NA
R-square	NA
Speed measure boundaries	NA
Base condition	NA
t-Test (*p*-value)	NA
Estimated CMF Clearinghouse star quality rating	NA
CMF standard error	NA



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 109. Graph. CURE plots of U5T speed CMF for SVPDO crashes (Washington).



Crash prediction without speed CMF

Source: FHWA.

Figure 110. Graph. CURE plot of U5T speed CMF for SVPDO crashes (North Carolina).

U5T Speed CMF for MVFI Crashes

Table 226 to table 229 and figure 111 and figure 112 show the MVFI statistics for U5T.

Table 226. Summary of U5T speed CMF development statistics for MVFI crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.72	127	105.5	0.854	—	1.547	—
SpdStd	**0.73**	**127**	**110.8**	**0.862**	**0.9**	**1.546**	**−0.1**
SpdStd	*0.76*	*127*	*112.2*	*0.867*	*1.5*	*1.548*	*0.1*
(SpdAve − PSL)	0.73	127	110.0	0.859	0.6	1.565	1.1
|SpdAve − PSL|	0.74	127	109.8	0.859	0.6	1.564	1.1
|SpdAve − PSL|	*0.76*	*127*	*110.7*	*0.861*	*0.8*	*1.565*	*1.2*

—Not applicable.

Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 227. Summary of U5T speed CMF development statistics for MVFI crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.61	155	148.1	1.884	—	5.003	—
(SpdAve − PSL)	**1.65**	**155**	**148.2**	**1.841**	**−2.3**	**4.829**	**−3.5**
|SpdAve − PSL|	1.70	155	148.2	1.845	−2.1	4.848	−3.1
|SpdAve − PSL|	*1.72*	*155*	*148.6*	*1.851*	*−1.7*	*4.862*	*−2.8*
SpdStd/SpdAve	1.89	155	151.6	1.884	0.0	4.856	−2.9
SpdStd/SpdAve	*1.86*	*155*	*153.0*	*1.886*	*0.1*	*4.816*	*−3.7*

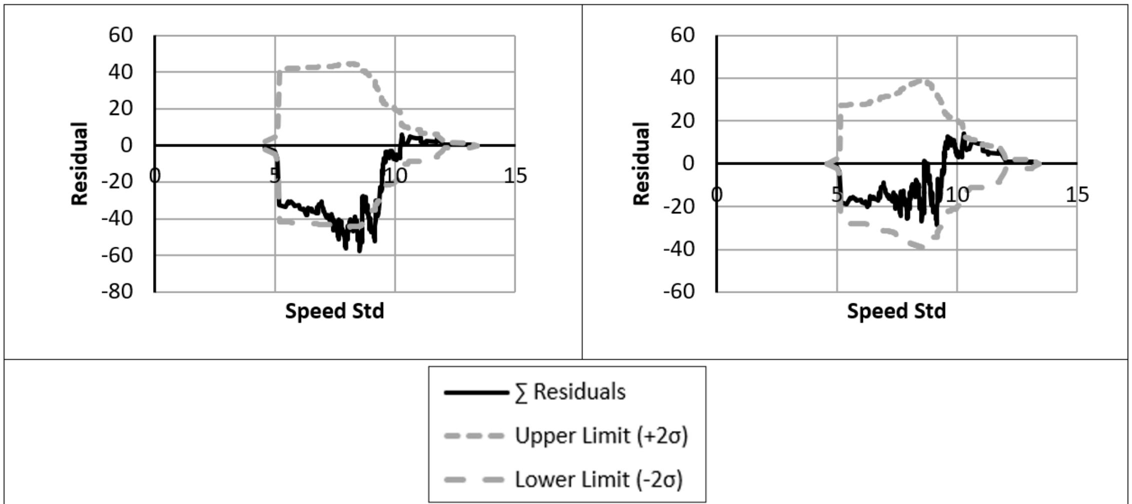
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 228. U5T speed CMF for MVFI crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.1258 \times x - 0.0719$
R-square	0.69
Speed measure boundaries	(4.60, 13.40)
Base condition	9
t-Test (p-value)	0.3
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.14

Table 229. U5T speed CMF for MVFI crashes (North Carolina).

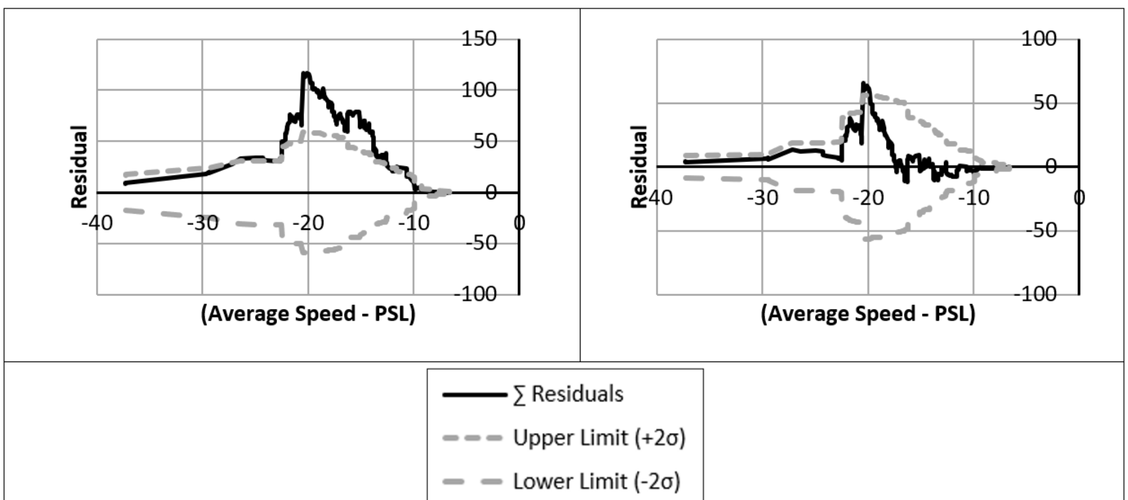
Speed CMF	Value
Speed measure	(SpdAve − PSL)
CMF equation	$y = -0.0624 \times x - 0.0893$
R-square	0.78
Speed measure boundaries	(−37.30, −6.60)
Base condition	−17
t-Test (p-value)	0.04
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.27



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 111. Graph. CURE plots of U5T speed CMF for MVFI crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 112. Graph. CURE plots of U5T speed CMF for MVFI crashes (North Carolina).

U5T Speed CMF for MVPDO Crashes

Table 230 to table 233 and figure 113 and figure 114 show the MVPDO statistics for U5T.

Table 230. Summary of U5T speed CMF development statistics for MVPDO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	**0.62**	**277**	**248.4**	**1.785**	**—**	**3.174**	**—**
SpdStd	0.65	277	267.7	1.797	0.7	3.228	1.7
SpdStd	*0.67*	*277*	*270.7*	*1.801*	*0.9*	*3.261*	*2.7*
(SpdAve − PSL)	0.64	277	267.3	1.811	1.5	3.342	5.3
|SpdAve − PSL|	0.65	277	267.1	1.811	1.4	3.340	5.2
|SpdAve − PSL|	*0.66*	*277*	*265.6*	*1.812*	*1.5*	*3.365*	*6.0*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 231. Summary of U5T speed CMF development statistics for MVPDO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.60	427	401.5	4.334	—	7.480	—
(SpdAve − PSL)	1.68	427	401.6	4.050	−6.6	6.630	−11.4
|SpdAve − PSL|	1.74	427	20.6	5.114	18.0	9.023	20.6
|SpdAve − PSL|	***1.77***	***427***	***397.9***	***3.987***	***−8.0***	***6.408***	***−14.3***
SpdStd/SpdAve	1.90	427	411.1	4.165	−3.9	6.986	−6.6
SpdStd/SpdAve	*1.98*	*427*	*419.0*	*4.067*	*−6.2*	*6.681*	*−10.7*

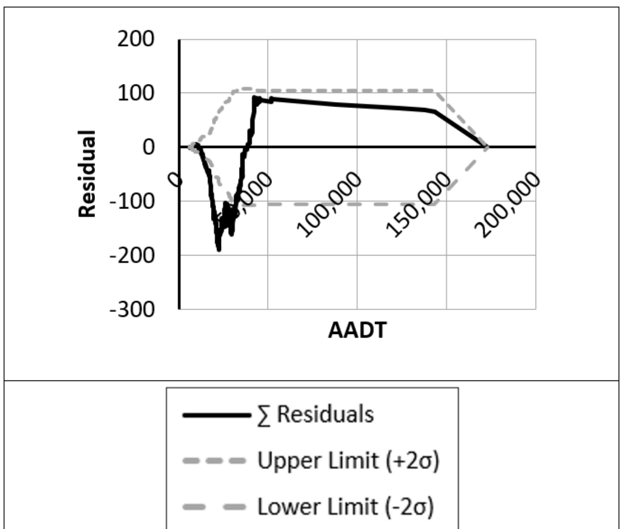
—Not applicable.
Note:Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 232. U5T speed CMF for MVPDO crashes (Washington).

Speed CMF	Value
Speed measure	NA
CMF equation	NA
R-square	NA
Speed measure boundaries	NA
Base condition	NA
t-Test (*p*-value)	NA
Estimated CMF Clearinghouse star quality rating	NA
CMF standard error	NA

Table 233. U5T speed CMF for MVPDO crashes (North Carolina).

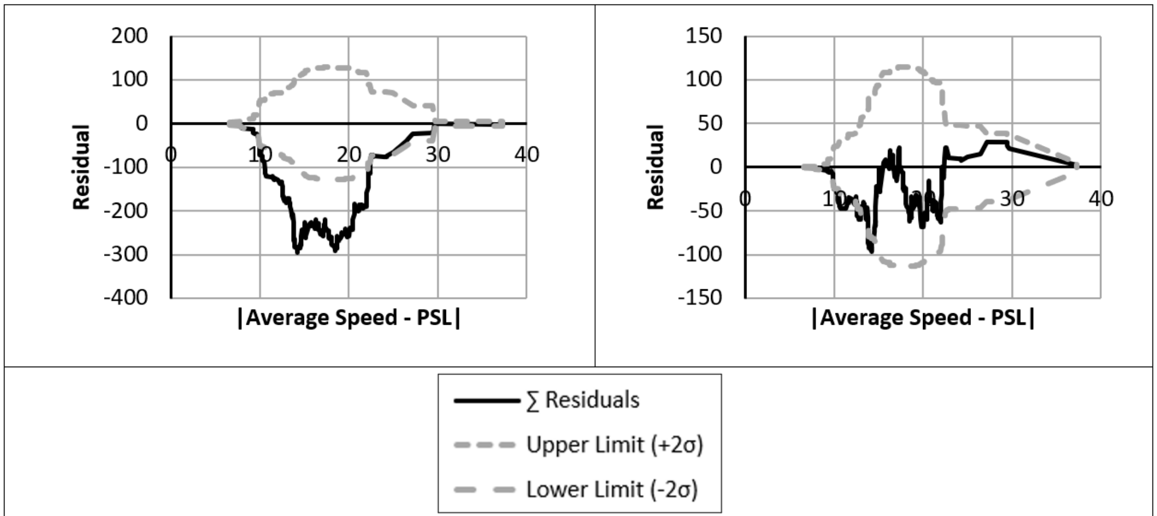
Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 0.0181 \times x^{1.3802}$
R-square	0.84
Speed measure boundaries	(6.60, 37.30)
Base condition	18
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.33



Crash prediction without speed CMF

Source: FHWA.

Figure 113. Graph. CURE plot of U5T speed CMF for MVPDO crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 114. Graph. CURE plots of U5T speed CMF for MVPDO crashes (North Carolina).

Table 234 and table 235 show the U5T CURE plot summary for Washington and North Carolina, respectively.

Table 234. CURE plots summary of U5T (Washington).

Crash	Crash Prediction Method	Within CURE (%)	Change to HSM (%)	|Maximum CURE Deviation|	Change to HSM (%)
KABCO	HSM (without speed CMF)	22.91	—	226.10	—
KABCO	HSM default	22.91	0	226.10	0
KABC	HSM (without speed CMF)	26.82	—	33.63	—
KABC	HSM × speed CMF	99.02	72	2.15	−94
O	HSM (without speed CMF)	22.21	—	159.44	—
O	HSM default	22.21	0	159.44	0
SVFI	HSM (without speed CMF)	50.56	—	6.30	—
SVFI	HSM × speed CMF	99.44	49	0.08	−99
SVPDO	HSM (without speed CMF)	99.16	—	1.18	—
SVPDO	HSM × speed CMF	99.02	0	1.09	−8
MVFI	HSM (without speed CMF)	57.26	—	16.90	—
MVFI	HSM × speed CMF	99.58	42	0.47	−97
MVPDO	HSM (without speed CMF)	25.84	—	132.69	—
MVPDO	HSM default	25.84	0	132.69	0

—Not applicable.

Table 235. CURE plots summary of U5T (North Carolina).

Crash	Crash Prediction Method	Within CURE (%)	Change to HSM (%)	|Maximum CURE Deviation|	Change to HSM (%)
KABCO	HSM (without speed CMF)	4.04	—	188.07	—
KABCO	HSM × speed CMF	95.03	91	5.81	−97
KABC	HSM (without speed CMF)	22.98	—	50.49	—
KABC	HSM × speed CMF	96.58	74	6.90	−86
O	HSM (without speed CMF)	5.90	—	163.01	—
O	HSM × speed CMF	87.27	81	14.26	−91
SVFI	HSM (without speed CMF)	99.38	—	0.00	—
SVFI	HSM × speed CMF	99.38	0	0.00	−57
SVPDO	HSM (without speed CMF)	65.53	—	6.06	—
SVPDO	HSM default	65.53	0	6.06	0
MVFI	HSM (without speed CMF)	12.42	—	58.30	—
MVFI	HSM × speed CMF	96.27	84	9.15	−84
MVPDO	HSM (without speed CMF)	4.97	—	187.21	—
MVPDO	HSM × speed CMF	83.54	79	17.43	−91

—Not applicable.

U6U SPEED CMFs

Table 236 through table 239 show the six-lane undivided urban and suburban arterial segments (U6U) statistics.

Table 236. Summary descriptive statistics of U6U (Washington).

Dataset	Segments (No.)	Length (mile)	KABC (No.)	PDO (No.)	Total (No.)	SVFI (No.)	SVPDO (No.)	MVFI (No.)	MVPDO (No.)
Training	75	14.4	71	165	236	17	13	54	152
Test	25	6.3	32	77	109	10	6	22	71
All	100	20.7	103	242	345	27	19	76	223

Note: Values for KABC, PDO, Total, SVFI, SVPDO, MVFI, and MVPDO represent observed crashes from 2017-2018.

Table 237. Summary descriptive statistics of U6U (North Carolina).

Dataset	Segments (No.)	Length (mile)	KABC (No.)	PDO (No.)	Total (No.)	SVFI (No.)	SVPDO (No.)	MVFI (No.)	MVPDO (No.)
Training	17	3.1	92	171	263	9	8	83	162
Test	6	1	14	42	56	0	1	14	41
All	23	4.1	106	213	319	9	9	97	203

Note: Values for KABC, PDO, Total, SVFI, SVPDO, MVFI, and MVPDO represent observed crashes from 2017-2018.

Table 238. *R*-square values of speed CMF equations of U6U (Washington).

Speed Measure	KABCO (L)	KABCO (P)	KABC (L)	KABC (P)	O (L)	O (P)	SVFI (L)	SVFI (P)	SVPDO (L)	SVPDO (P)	MVFI (L)	MVFI (P)	MVPDO (L)	MVPDO (P)
SpdStd	0.37	0.23	***0.72***	—	0.24	0.14	***0.71***	—	***0.08***	***0.06***	***0.64***	—	0.31	—
(SpdAve – PSL)	***0.48***	—	***0.45***	—	***0.48***	—	***0.31***	—	***0.33***	—	***0.43***	—	***0.50***	—
|SpdAve – PSL|	***0.51***	***0.58***	***0.57***	***0.61***	***0.48***	***0.54***	***0.64***	***0.66***	***0.30***	—	***0.52***	—	***0.49***	***0.57***
SpdStd/ SpdAve	***0.57***	***0.56***	0.20	***0.20***	***0.63***	***0.61***	***0.01***	0.00	***0.40***	—	***0.31***	—	***0.58***	***0.57***

—Not applicable.

Note: Bold italic numbers indicate the top five potential speed CMFs for each crash type/severity level.

Table 239. *R*-square values of speed CMF equations of U6U (North Carolina).

Speed Measure	KABCO (L)	KABCO (P)	KABC (L)	KABC (P)	O (L)	O (P)	SVFI (L)	SVFI (P)	SVPDO (L)	SVPDO (P)	MVFI (L)	MVFI (P)	MVPDO (L)	MVPDO (P)
SpdStd	0.01	0.02	0.00	—	***0.69***	***0.74***	***0.00***	—	***0.55***	—	0.01	—	***0.57***	***0.41***
(SpdAve – PSL)	***0.06***	—	***0.03***	—	***0.23***	—	***0.13***	—	***0.24***	—	***0.02***	—	***0.15***	—
|SpdAve – PSL|	***0.19***	***0.18***	***0.00***	***0.02***	0.01	0.01	***0.01***	—	***0.16***	—	***0.02***	***0.02***	0.00	0.01
SpdStd/ SpdAve	***0.42***	***0.35***	***0.13***	***0.14***	***0.42***	***0.41***	***0.18***	—	***0.30***	—	***0.19***	***0.19***	***0.40***	***0.41***

—Not applicable.
Note: Bold italic numbers indicate the top five potential speed CMFs for each crash type/severity level.

U6U Speed CMF for KABCO Crashes

Table 240 to table 243 and figure 115 and figure 116 show the KABCO crash severity scale statistics for U6U (AASHTO 2010).

Table 240. Summary of U6U speed CMF development statistics for KABCO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.48	109	94.3	0.759	—	2.649	—
(SpdAve − PSL)	**0.54**	**109**	**84.4**	**0.678**	**−10.7**	**2.440**	**−7.9**
|SpdAve − PSL|	0.52	109	86.0	0.681	−10.2	2.433	−8.1
|SpdAve − PSL|	*0.76*	*109*	*87.9*	*0.699*	*−7.9*	*2.461*	*−7.1*
SpdStd/SpdAve	0.61	109	96.3	0.752	−0.9	2.618	−1.2
SpdStd/SpdAve	*0.71*	*109*	*96.7*	*0.750*	*−1.1*	*2.614*	*−1.3*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 241. Summary of U6U speed CMF development statistics for KABCO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	**2.46**	**56**	**84.5**	**8.055**	**—**	**10.025**	**—**
(SpdAve − PSL)	2.45	56	90.6	9.338	15.9	12.232	22.0
|SpdAve − PSL|	*2.33*	*56*	*93.5*	*9.955*	*23.6*	*13.349*	*33.2*
|SpdAve − PSL|	*2.47*	*56*	*97.7*	*10.814*	*34.2*	*14.951*	*49.1*
SpdStd/SpdAve	*3.06*	*56*	*84.4*	*8.237*	*2.3*	*10.253*	*2.3*
SpdStd/SpdAve	*3.14*	*56*	*84.3*	*8.225*	*2.1*	*10.228*	*2.0*

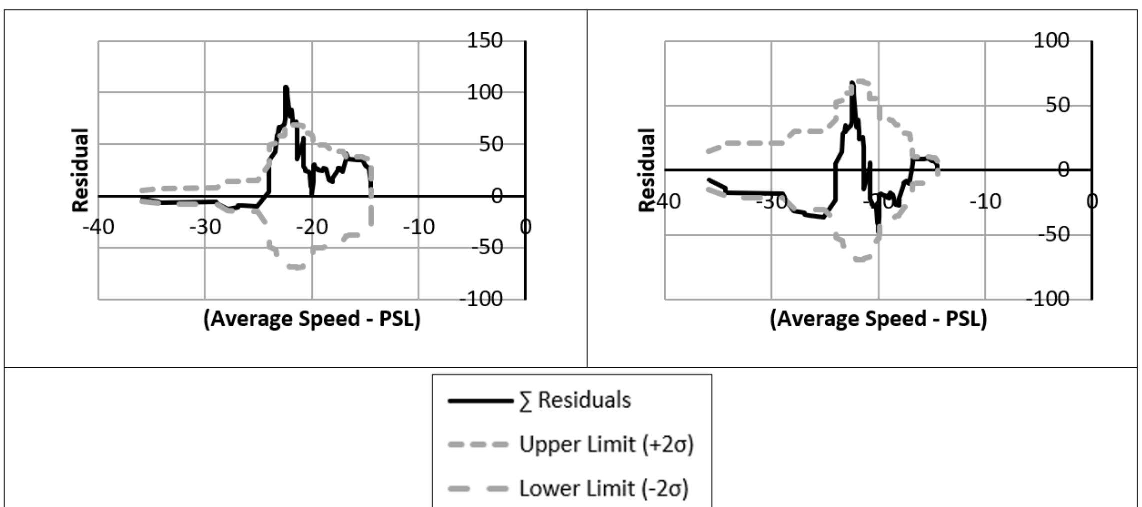
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 242. U6U speed CMF for KABCO crashes (Washington).

Speed CMF	Value
Speed measure	(SpdAve − PSL)
CMF equation	$y = -0.1097 \times x - 1.3651$
R-square	0.43
Speed measure boundaries	(−35.90, −14.00)
Base condition	−22
t-Test (*p*-value)	0.07
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.43

Table 243. U6U speed CMF for KABCO crashes (North Carolina).

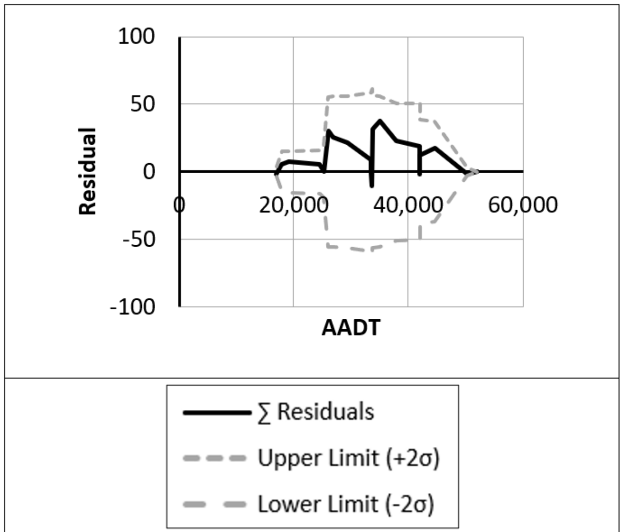
Speed CMF	Value
Speed measure	NA
CMF equation	NA
R-square	NA
Speed measure boundaries	NA
Base condition	NA
t-Test (*p*-value)	NA
Estimated CMF Clearinghouse star quality rating	NA
CMF standard error	NA



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 115. Graph. CURE plots of U6U speed CMF for KABCO crashes (Washington).



Crash prediction without speed CMF

Source: FHWA.

Figure 116. Graph. CURE plot of U6U speed CMF for KABCO crashes (North Carolina).

U6U Speed CMF for KABC Crashes

Table 246 and table 247 and figure 117 and figure 118 show the KABC crash severity scale statistics for U6U (AASHTO 2010).

Table 244. Summary of U6U speed CMF development statistics for KABC crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.35	32	28.3	0.227	—	0.808	—
SpdStd	0.40	32	34.4	0.228	0.4	0.818	1.3
(SpdAve − PSL)	**0.41**	**32**	**26.0**	**0.202**	**−11.0**	**0.746**	**−7.6**
|SpdAve − PSL|	0.41	32	26.2	0.204	−10.4	0.747	−7.5
|SpdAve − PSL|	*0.51*	*32*	*26.2*	*0.207*	*−9.1*	*0.750*	*−7.1*
SpdStd/SpdAve	0.42	32	28.6	0.226	−0.4	0.802	−0.6

—Not applicable.

Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 245. Summary of U6U speed CMF development statistics for KABC crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	2.13	14	29.7	3.118	—	4.095	—
(SpdAve − PSL)	**1.91**	**14**	**26.4**	**2.528**	**−18.9**	**3.367**	**−17.8**
|SpdAve − PSL|	1.74	14	30.7	3.339	7.1	4.399	7.4
|SpdAve − PSL|	*2.92*	*14*	*30.7*	*3.354*	*7.6*	*4.411*	*7.7*
SpdStd/SpdAve	2.18	14	29.6	3.193	2.4	4.128	0.8
SpdStd/SpdAve	*2.88*	*14*	*29.6*	*3.227*	*3.5*	*4.144*	*1.2*

—Not applicable.

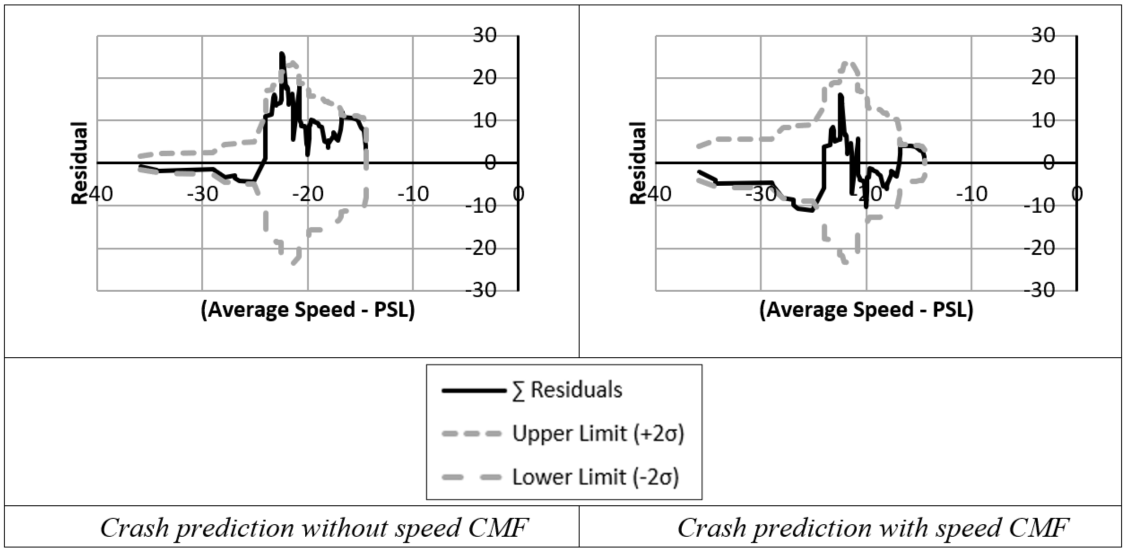
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 246. U6U speed CMF for KABC crashes (Washington).

Speed CMF	Value
Speed measure	(SpdAve − PSL)
CMF equation	$y = -0.0883 \times x - 0.9632$
R-square	0.38
Speed measure boundaries	(−35.90, −14.00)
Base condition	−22
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.34

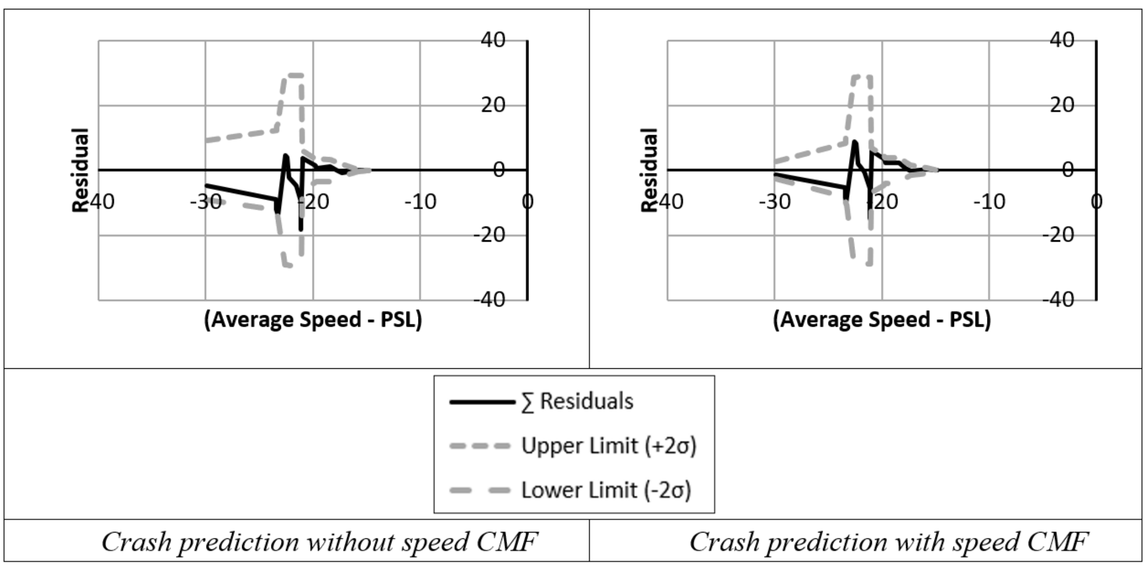
Table 247. U6U speed CMF for KABC crashes (North Carolina).

Speed CMF	Value
Speed measure	(SpdAve − PSL)
CMF equation	$y = 0.0497 \times x + 2.2585$
R-square	0.07
Speed measure boundaries	(−30.00, −14.80)
Base condition	−25
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.15



Source: FHWA.

Figure 117. Graph. CURE plots of U6U speed CMF for KABC crashes (Washington).



Source: FHWA.

Figure 118. Graph. CURE plots of U6U speed CMF for KABC crashes (North Carolina).

U6U Speed CMF for O Crashes

Table 248 to table 251 and figure 119 and figure 120 show the O crash severity scale statistics for U6U (AASHTO 2010).

Table 248. Summary of U6U speed CMF development statistics for O crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.56	77	65.6	0.534	—	1.868	—
(SpdAve − PSL)	0.64	77	58.1	0.489	−8.4	1.732	−7.3
|SpdAve − PSL|	**0.60**	**77**	**59.5**	**0.482**	**−9.8**	**1.719**	**−8.0**
|SpdAve − PSL|	*0.94*	*77*	*61.5*	*0.496*	*−7.0*	*1.741*	*−6.8*
SpdStd/SpdAve	0.74	77	67.3	0.529	−0.9	1.844	−1.3
SpdStd/SpdAve	*0.88*	*77*	*67.4*	*0.529*	*−1.0*	*1.842*	*−1.4*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 249. Summary of U6U speed CMF development statistics for O crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	2.68	42	54.9	4.890	—	6.575	—
SpdStd	2.17	42	72.2	7.792	59.3	12.144	84.7
SpdStd	*2.67*	*42*	*86.2*	*10.209*	*108.8*	*17.268*	*162.6*
(SpdAve − PSL)	**2.50**	**42**	**44.0**	**2.600**	**−46.8**	**3.843**	**−41.6**
SpdStd/SpdAve	3.15	42	54.8	5.250	7.4	6.950	5.7
SpdStd/SpdAve	*4.45*	*42*	*54.7*	*5.472*	*11.9*	*7.181*	*9.2*

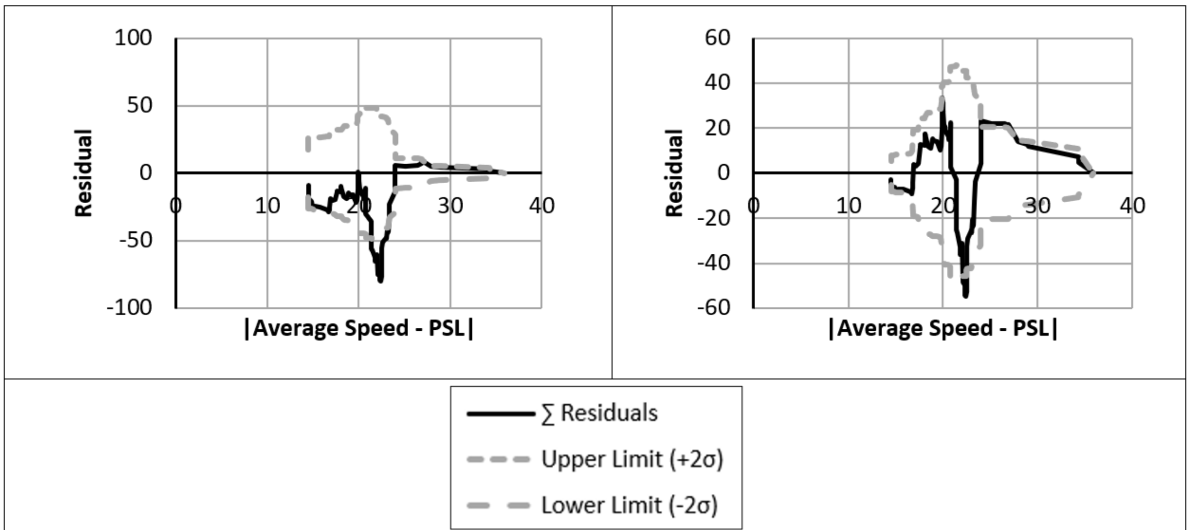
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 250. U6U speed CMF for O crashes (Washington).

Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 0.1114 \times x - 1.3275$
R-square	0.36
Speed measure boundaries	(14.00, 35.90)
Base condition	21
t-Test (p-value)	0.55
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.43

Table 251. U6U speed CMF for O crashes (North Carolina).

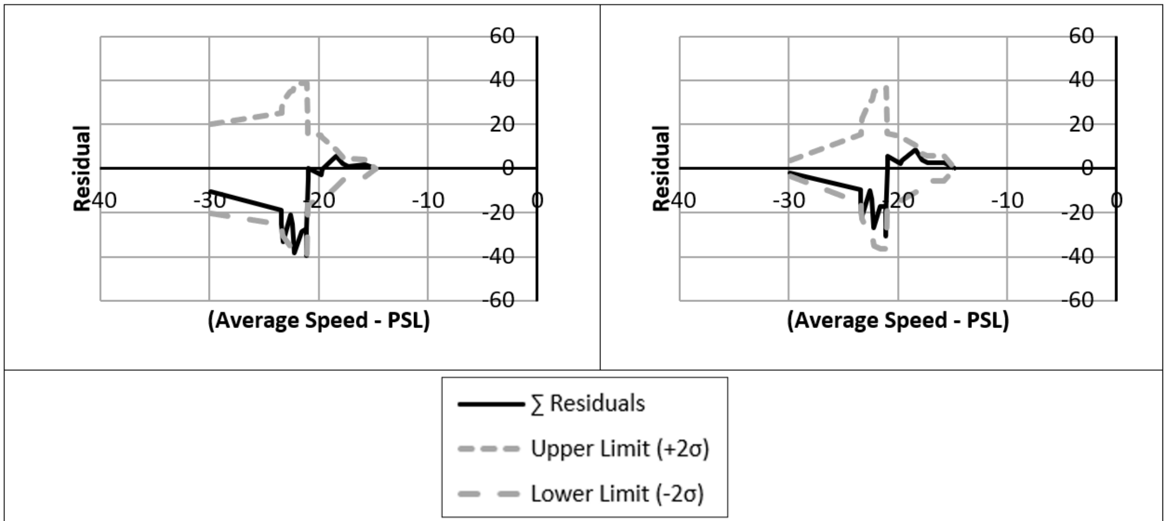
Speed CMF	Value
Speed measure	(SpdAve − PSL)
CMF equation	$y = 0.058 \times x + 2.2971$
R-square	0.15
Speed measure boundaries	(−30.00, −14.80)
Base condition	−22
t-Test (*p*-value)	0.69
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.18



Crash prediction without speed CMF | *Crash prediction with speed CMF*

Source: FHWA.

Figure 119. Graph. CURE plots of U6U speed CMF for O crashes (Washington).



Crash prediction without speed CMF | *Crash prediction with speed CMF*

Source: FHWA.

Figure 120. Graph. CURE plots of U6U speed CMF for O crashes (North Carolina).

U6U Speed CMF for SVFI Crashes

Table 252 to table 255 and figure 121 and figure 122 show the SVFI crash severity scale statistics for U6U (AASHTO 2010).

Table 252. Summary of U6U speed CMF development statistics for SVFI crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.98	10	6.9	0.549	—	0.865	—
SpdStd	1.19	10	9.7	0.587	6.8	0.873	0.9
(SpdAve − PSL)	**1.17**	**10**	**6.3**	**0.531**	**−3.3**	**0.879**	**1.6**
|SpdAve − PSL|	1.13	10	6.4	0.534	−2.7	0.876	1.2
|SpdAve − PSL|	*1.20*	*10*	*6.4*	*0.535*	*−2.6*	*0.873*	*0.9*
SpdStd/SpdAve	0.99	10	6.9	0.549	−0.1	0.865	−0.1

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 253. Summary of U6U speed CMF development statistics for SVFI crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	2.65	0	2.4	0.397	—	0.518	—
SpdStd	2.24	0	2.4	0.397	0.0	0.518	0.0
(SpdAve − PSL)	**2.08**	**0**	**1.8**	**0.298**	**−24.9**	**0.339**	**−34.5**
|SpdAve − PSL|	1.98	0	2.3	0.377	−5.2	0.472	−8.9
SpdStd/SpdAve	2.57	0	2.3	0.390	−1.8	0.508	−2.0
NA	NA	0	—	—	—	—	—

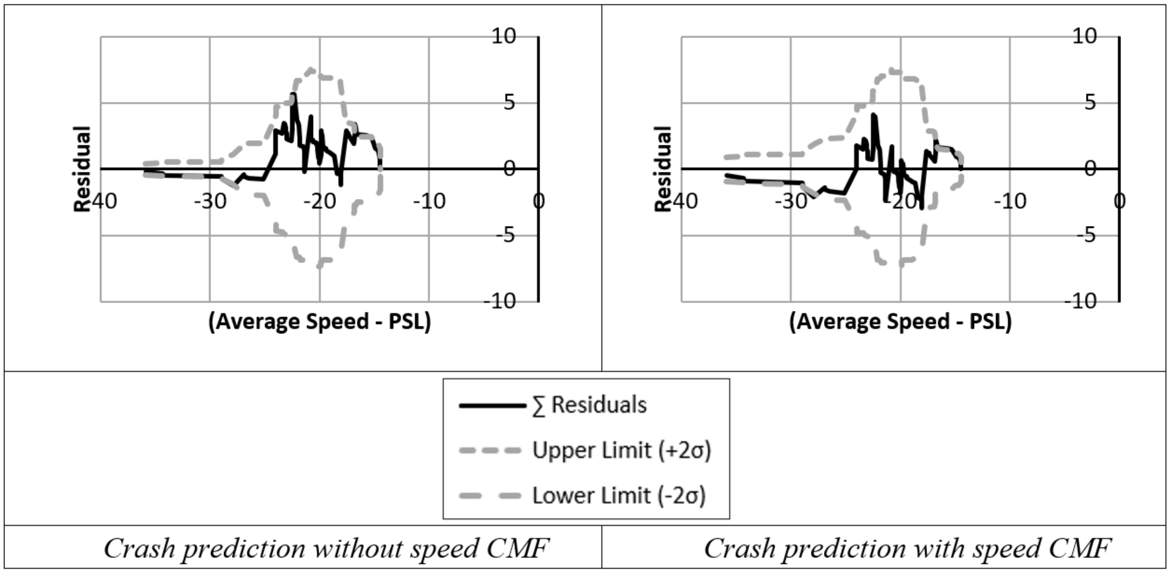
—Not applicable.
Note: Bold row indicates the best speed CMF.

Table 254. U6U speed CMF for SVFI crashes (Washington).

Speed CMF	Value
Speed measure	(SpdAve − PSL)
CMF equation	$y = -0.0597 \times x - 0.3408$
R-square	0.2
Speed measure boundaries	(−35.90, −14.00)
Base condition	−22
t-Test (*p*-value)	0.94
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.23

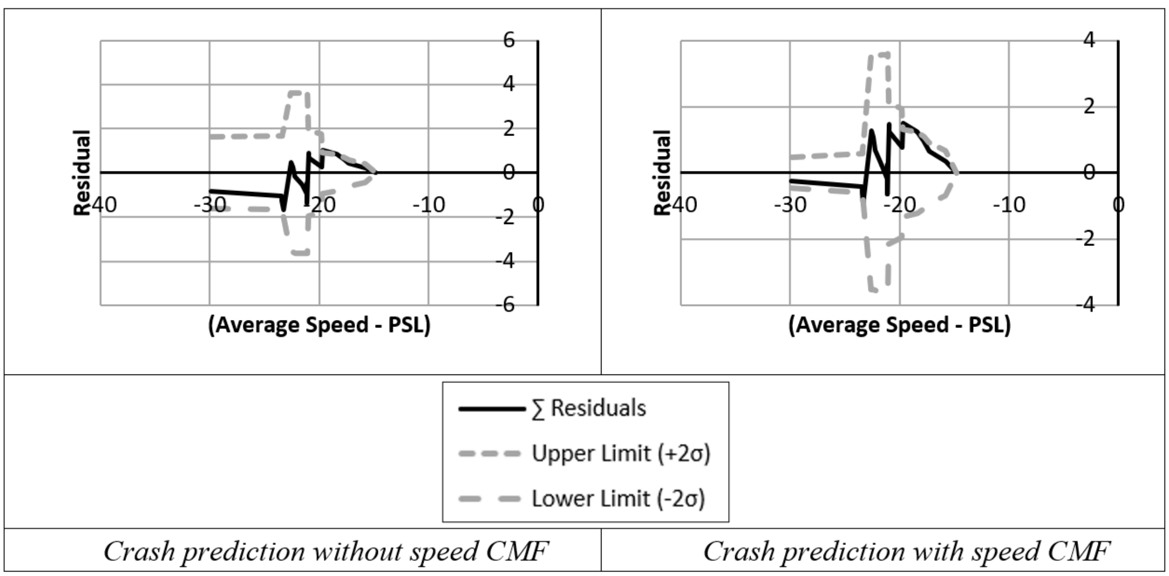
Table 255. U6U speed CMF for SVFI crashes (North Carolina).

Speed CMF	Value
Speed measure	(SpdAve − PSL)
CMF equation	$y = 0.1104 \times x + 3.651$
R-square	0.17
Speed measure boundaries	(−30.00, −14.18)
Base condition	−24
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.33



Source: FHWA.

Figure 121. Graph. CURE plots of U6U speed CMF for SVFI crashes (Washington).



Source: FHWA.

Figure 122. Graph. CURE plots of U6U speed CMF for SVFI crashes (North Carolina).

U6U Speed CMF for SVPDO Crashes

Table 256 to table 259 and figure 123 and figure 124 show the SVPDO crash severity scale statistics for U6U (AASHTO 2010).

Table 256. Summary of U6U speed CMF development statistics for SVPDO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.62	6	5.4	0.398	—	0.660	—
SpdStd	**0.54**	**6**	**4.9**	**0.385**	**−3.2**	**0.665**	**0.7**
SpdStd	*0.00*	*6*	*5.9*	*0.409*	*2.9*	*0.659*	*−0.1*
(SpdAve − PSL)	0.64	6	4.8	0.395	−0.7	0.693	5.0
|SpdAve − PSL|	0.67	6	4.9	0.394	−1.0	0.684	3.6
SpdStd/SpdAve	0.83	6	5.5	0.403	1.4	0.669	1.4

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 257. Summary of U6U speed CMF development statistics for SVPDO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.82	1	2.4	0.500	—	0.613	—
SpdStd	1.07	1	4.0	0.674	34.8	1.042	69.9
(SpdAve − PSL)	1.85	1	2.4	0.478	−4.5	0.584	−4.8
|SpdAve − PSL|	**1.61**	**1**	**1.7**	**0.451**	**−9.8**	**0.535**	**−12.8**
SpdStd/SpdAve	1.85	1	2.4	0.478	−4.5	0.584	−4.8
NA	NA	1	—	—	—	—	—

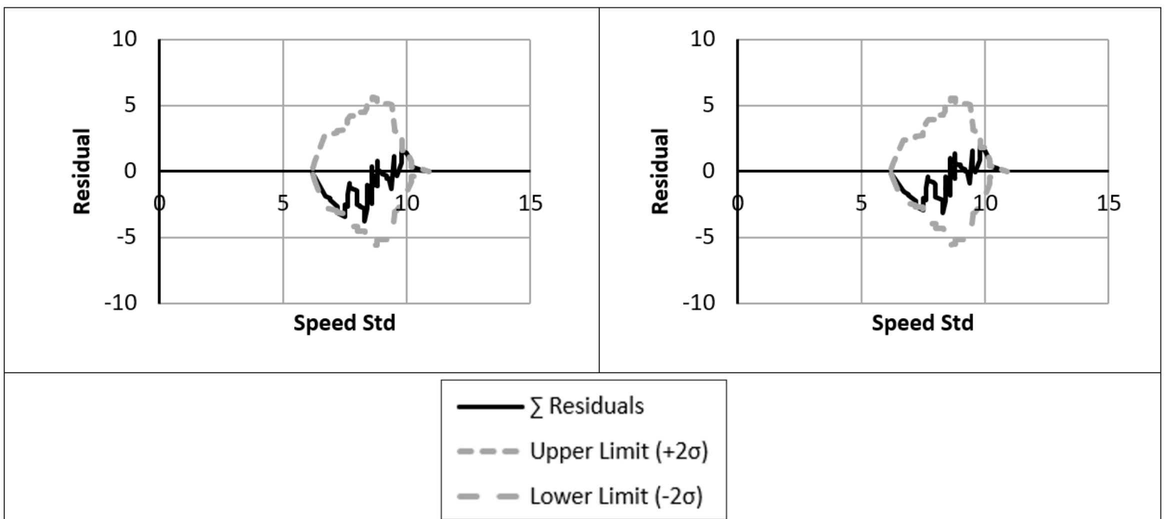
—Not applicable.
Note: Bold row indicates the best speed CMF; .

Table 258. U6U speed CMF for SVPDO crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.0876 \times x + 0.2568$
R-square	0.174
Speed measure boundaries	(6.20, 10.90)
Base condition	8
t-Test (p-value)	0.94
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.08

Table 259. U6U speed CMF for SVPDO crashes (North Carolina).

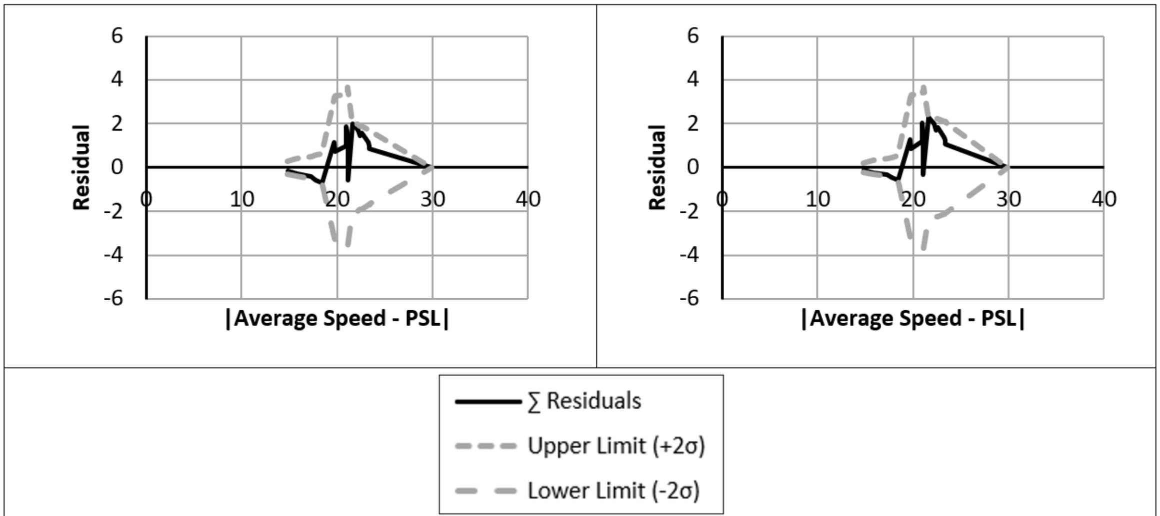
Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 0.0385 \times x + 0.3298$
R-square	0.05
Speed measure boundaries	(14.80, 30.00)
Base condition	17
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.12



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 123. Graph. CURE plots of U6U speed CMF for SVPDO crashes (Washington).



Crash prediction without speed CMF | *Crash prediction with speed CMF*

Source: FHWA.

Figure 124. Graph. CURE plots of U6U speed CMF for SVPDO crashes (North Carolina).

U6U Speed CMF for MVFI Crashes

Table 260 to table 263 and figure 125 and figure 126 show the MVFI crash severity scale statistics for U6U (AASHTO 2010).

Table 260. Summary of U6U speed CMF development statistics for MVFI crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.32	22	21.6	1.244	—	1.674	—
SpdStd	0.35	22	25.9	1.344	8.0	1.739	3.9
(SpdAve − PSL)	**0.37**	**22**	**19.7**	**1.089**	**−12.5**	**1.504**	**−10.2**
|SpdAve − PSL|	0.37	22	19.8	1.097	−11.9	1.507	−10.0
SpdStd/SpdAve	0.42	22	22.0	1.233	−0.9	1.654	−1.2
NA	NA	22	—	—	—	—	—

—Not applicable.
Note: Bold row indicates the best speed CMF.

Table 261. Summary of U6U speed CMF development statistics for MVFI crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	2.23	14	26.6	2.902	—	3.598	—
(SpdAve − PSL)	**2.32**	**14**	**24.6**	**2.468**	**−14.9**	**3.136**	**−12.8**
|SpdAve − PSL|	2.16	14	27.9	3.203	10.4	3.999	11.1
|SpdAve − PSL|	*3.16*	*14*	*29.5*	*3.545*	*22.2*	*4.503*	*25.2*
SpdStd/SpdAve	2.69	14	26.5	2.972	2.4	3.635	1.0
SpdStd/SpdAve	*3.27*	*14*	*26.5*	*2.988*	*3.0*	*3.643*	*1.3*

—Not applicable.

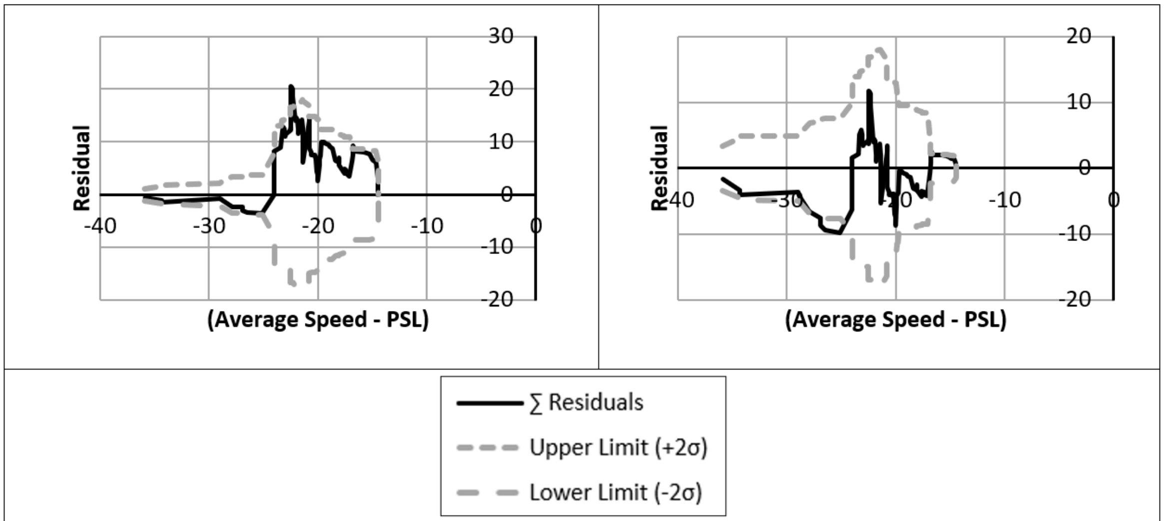
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 262. U6U speed CMF for MVFI crashes (Washington).

Speed CMF	Value
Speed measure	(SpdAve − PSL)
CMF equation	$y = -0.1038 \times x - 1.3122$
R-square	0.46
Speed measure boundaries	(−35.90, 14.00)
Base condition	−22
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.40

Table 263. U6U speed CMF for MVFI crashes (North Carolina).

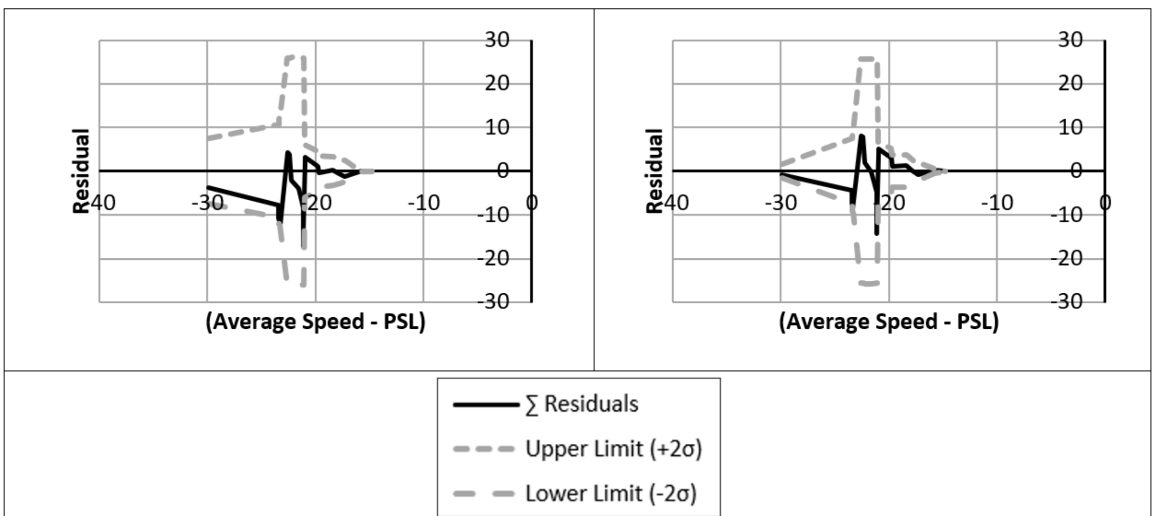
Speed CMF	Value
Speed measure	(SpdAve − PSL)
CMF equation	$y = 0.0477 \times x + 2.1473$
R-square	0.08
Speed measure boundaries	(−30.00, −14.80)
Base condition	−24
t-Test (*p*-value)	0.01
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.14



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 125. Graph. CURE plots of U6U speed CMF for MVFI crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 126. Graph. CURE plots of U6U speed CMF for MVFI crashes (North Carolina).

U6U Speed CMF for MVPDO Crashes

Table 264 to table 267 and figure 127 and figure 128 show the MVPDO crash severity scale statistics for U6U (AASHTO 2010).

Table 264. Summary of U6U speed CMF development statistics for MVPDO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.55	71	60.3	3.439	—	4.608	—
(SpdAve − PSL)	0.64	71	53.3	3.112	−9.5	4.196	−8.9
|SpdAve − PSL|	**0.60**	**71**	**54.6**	**3.051**	**−11.3**	**4.173**	**−9.4**
|SpdAve − PSL|	*0.90*	*71*	*55.5*	*3.141*	*−8.7*	*4.220*	*−8.4*
SpdStd/SpdAve	0.72	71	61.8	3.397	−1.2	4.534	−1.6
SpdStd/SpdAve	*0.85*	*71*	*61.9*	*3.394*	*−1.3*	*4.529*	*−1.7*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 265. Summary of U6U speed CMF development statistics for MVPDO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	2.71	41	52.1	4.647	—	6.162	—
SpdStd	2.86	41	62.2	6.422	38.2	9.283	50.7
SpdStd	*3.21*	*41*	*75.3*	*8.754*	*88.4*	*13.913*	*125.8*
(SpdAve − PSL)	**2.83**	**41**	**43.8**	**2.750**	**−40.8**	**3.940**	**−36.1**
SpdStd/SpdAve	3.57	41	52.0	5.009	7.8	6.528	5.9
SpdStd/SpdAve	*4.80*	*41*	*51.9*	*5.204*	*12.0*	*6.742*	*9.4*

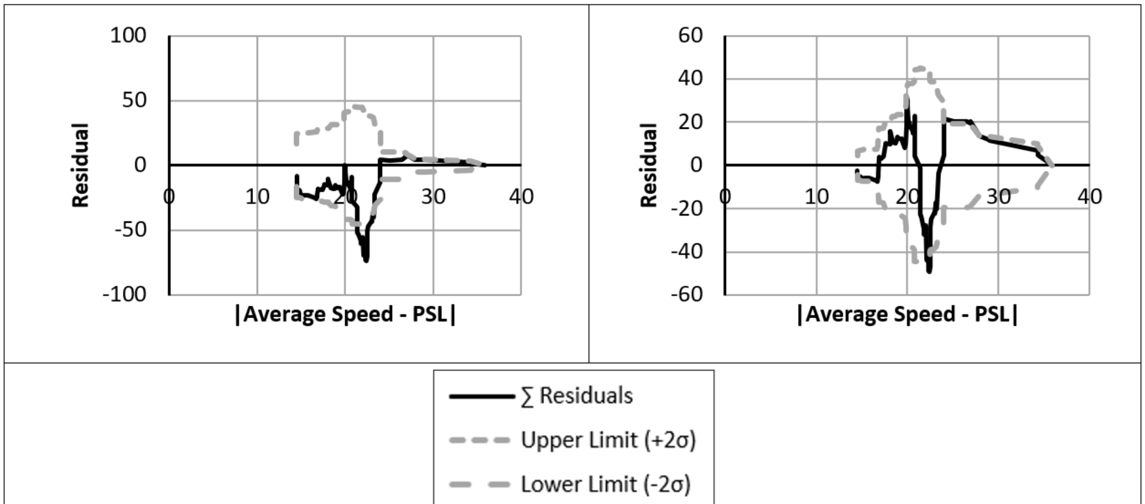
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 266. U6U speed CMF for MVPDO crashes (Washington).

Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 0.1146 \times x - 1.4054$
R-square	0.39
Speed measure boundaries	(14.00, 35.90)
Base condition	21
t-Test (p-value)	0.45
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.45

Table 267. U6U speed CMF for MVPDO crashes (North Carolina).

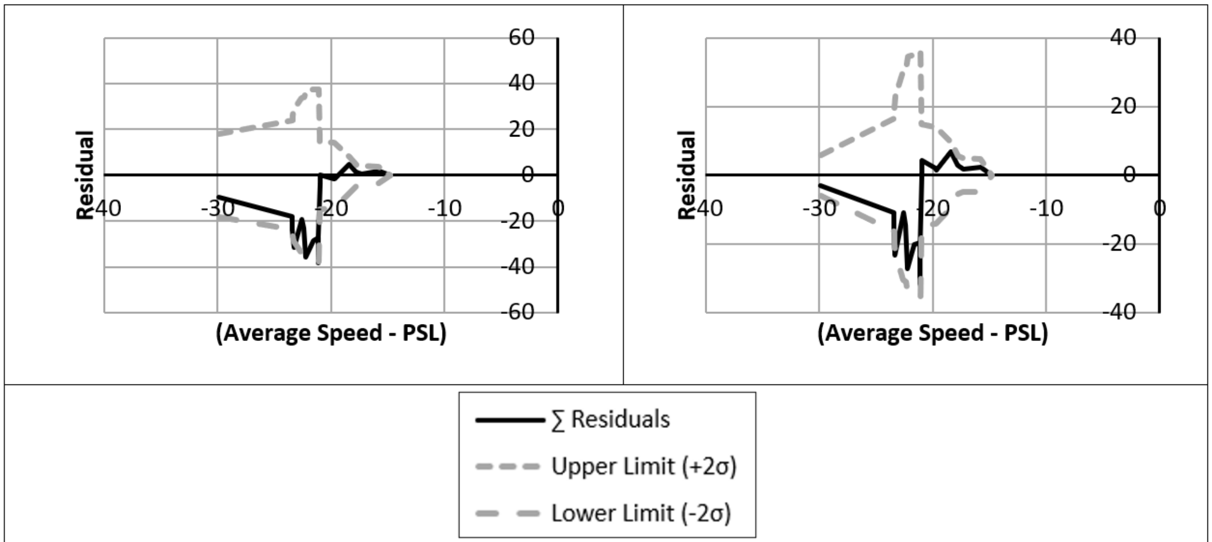
Speed CMF	Value
Speed measure	(SpdAve − PSL)
CMF equation	$y = 0.0419 \times x + 1.8603$
R-square	0.1
Speed measure boundaries	(−30.00, −14.80)
Base condition	−21
t-Test (p-value)	0.1
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.13



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 127. Graph. CURE plots of U6U speed CMF for MVPDO crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 128. Graph. CURE plots of U6U speed CMF for MVPDO crashes (North Carolina).

Table 268 and table 269 show the U6U CURE plot summary for Washington and North Carolina, respectively.

Table 268. CURE plots summary of U6U (Washington).

Crash	Crash Prediction Method	Within CURE (%)	Change to HSM (%)	|Maximum CURE Deviation|	Change to HSM (%)
KABCO	HSM (without speed CMF)	69.39	—	41.48	—
KABCO	HSM × speed CMF	89.80	20	6.27	−85
KABC	HSM (without speed CMF)	87.76	—	4.29	—
KABC	HSM × speed CMF	92.86	5	2.14	−50
O	HSM (without speed CMF)	66.33	—	34.26	—
O	HSM × speed CMF	81.63	15	9.11	−73
SVFI	HSM (without speed CMF)	92.86	—	0.70	—
SVFI	HSM × speed CMF	92.86	0	0.45	−35
SVPDO	HSM (without speed CMF)	96.94	—	0.29	—
SVPDO	HSM × speed CMF	96.94	0	0.23	−18
MVFI	HSM (without speed CMF)	87.76	—	3.92	—
MVFI	HSM × speed CMF	92.86	5	2.09	−47
MVPDO	HSM (without speed CMF)	67.35	—	31.08	—
MVPDO	HSM × speed CMF	82.65	15	6.75	−78

—Not applicable.

Table 269. CURE plots summary of U6U (North Carolina).

Crash	Crash Prediction Method	Within CURE (%)	Change to HSM (%)	|Maximum CURE Deviation|	Change to HSM (%)
KABCO	HSM (without speed CMF)	95.45	—	0.00	—
KABCO	HSM default	95.45	0	0.00	0
KABC	HSM (without speed CMF)	95.45	—	0.00	—
KABC	HSM × speed CMF	95.45	0	0.00	−97
O	HSM (without speed CMF)	86.36	—	2.73	—
O	HSM × speed CMF	95.45	9	0.00	−100
SVFI	HSM (without speed CMF)	86.36	—	0.12	—
SVFI	HSM × speed CMF	90.91	5	0.18	51
SVPDO	HSM (without speed CMF)	86.36	—	0.08	—
SVPDO	HSM × speed CMF	90.91	5	0.06	−19
MVFI	HSM (without speed CMF)	95.45	—	0.00	—
MVFI	HSM × speed CMF	95.45	0	0.00	−46
MVPDO	HSM (without speed CMF)	86.36	—	2.58	—
MVPDO	HSM × speed CMF	90.91	5	0.37	−86

—Not applicable.

U6D SPEED CMFs

Table 270 and table 271 show the six-lane divided urban and suburban arterials (including a raised or depressed median) (U6D) statistics.

Table 270. Summary descriptive statistics of U6D (North Carolina).

Dataset	Segments (No.)	Length (mile)	KABC (No.)	PDO (No.)	Total (No.)	SVFI (No.)	SVPDO (No.)	MVFI (No.)	MVPDO (No.)
Training	228	25.7	406	1,184	1,590	43	72	358	1,106
Test	76	9	150	478	628	24	30	124	448
All	304	34.7	556	1,662	2,218	67	102	482	1,554

Note: Values for KABC, PDO, Total, SVFI, SVPDO, MVFI, and MVPDO represent observed crashes from 2017-2018.

Table 271. *R*-square values of speed CMF equations of U6D (North Carolina).

Speed Measure	KABCO (L)	KABCO (P)	KABC (L)	KABC (P)	O (L)	O (P)	SVFI (L)	SVFI (P)	SVPDO (L)	SVPDO (P)	MVFI (L)	MVFI (P)	MVPDO (L)	MVPDO (P)
SpdStd	***0.64***	***0.64***	***0.42***	***0.42***	***0.65***	***0.66***	0.06	0.01	***0.16***	***0.15***	***0.46***	***0.46***	***0.64***	***0.65***
(SpdAve – PSL)	***0.68***	—	***0.47***	—	***0.70***	—	***0.59***	—	***0.04***	—	***0.70***	—	***0.67***	—
|SpdAve – PSL|	0.55	0.55	***0.37***	***0.42***	0.57	0.55	***0.46***	***0.17***	0.00	0.00	***0.62***	***0.63***	0.60	0.56
SpdStd/ SpdAve	***0.66***	***0.69***	0.17	0.24	***0.68***	***0.69***	***0.35***	***0.28***	***0.56***	***0.54***	0.30	0.38	***0.65***	***0.66***

—Not applicable.

Note: Bold italic numbers indicate the top five potential speed CMFs for each crash type/severity level.

U6D Speed CMF for KABCO Crashes

Table 272 and table 273 and figure 129 show the KABCO crash severity scale statistics for U6D (AASHTO 2010).

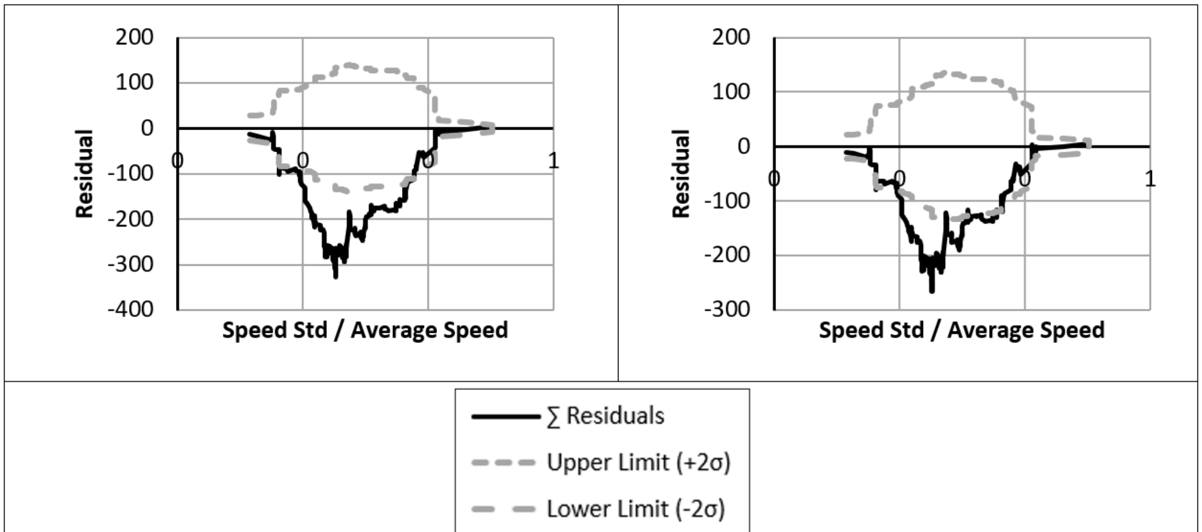
Table 272. Summary of U6D speed CMF development statistics for KABCO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	2.20	628	624.1	5.287	—	7.951	—
SpdStd	2.25	628	642.8	5.323	0.7	7.906	−0.6
SpdStd	*2.29*	*628*	*641.7*	*5.323*	*0.7*	*7.900*	*−0.7*
(SpdAve − PSL)	2.18	628	663.3	5.426	2.6	8.079	1.6
SpdStd/SpdAve	**2.46**	**628**	**639.7**	**5.286**	**0.0**	**7.898**	**−0.7**
SpdStd/SpdAve	*2.63*	*628*	*652.1*	*5.293*	*0.1*	*7.940*	*−0.1*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 273. U6D speed CMF for KABCO crashes (North Carolina).

Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 0.9988 \times x + 0.6463$
R-square	0.64
Speed measure boundaries	(0.11, 0.50)
Base condition	0.35
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.07



Crash prediction without speed CMF | *Crash prediction with speed CMF*

Source: FHWA.

Figure 129. Graph. CURE plots of U6D speed CMF for KABCO crashes (North Carolina).

U6D Speed CMF for KABC Crashes

Table 274 and table 275 and figure 130 show the KABC crash severity scale statistics for U6D (AASHTO 2010).

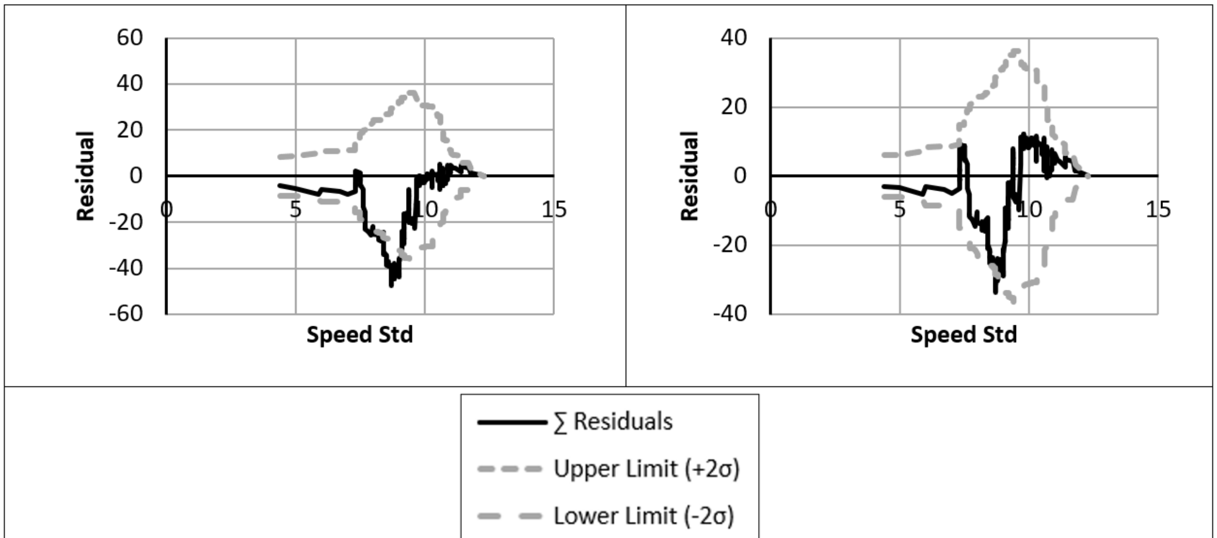
Table 274. Summary of U6D speed CMF development statistics for KABC crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.36	150	159.2	1.622	—	2.385	—
SpdStd	1.39	150	162.1	1.644	1.3	2.377	−0.3
SpdStd	***1.40***	***150***	***162.1***	***1.642***	***1.3***	***2.374***	***−0.4***
(SpdAve − PSL)	1.36	150	165.0	1.653	1.9	2.409	1.0
|SpdAve − PSL|	1.40	150	164.2	1.649	1.7	2.404	0.8
|SpdAve − PSL|	*1.41*	*150*	*165.7*	*1.658*	*2.2*	*2.412*	*1.2*

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 275. U6D speed CMF for KABC crashes (North Carolina).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.336 \times x^{0.4904}$
R-square	0.26
Speed measure boundaries	(0.11, 0.50)
Base condition	9
t-Test (*p*-value)	0.05
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.06



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 130. Graph. CURE plots of U6D speed CMF for KABC crashes (North Carolina).

U6D Speed CMF for O Crashes

Table 276 and table 277 and figure 131 show the O crash severity scale statistics for U6D (AASHTO 2010).

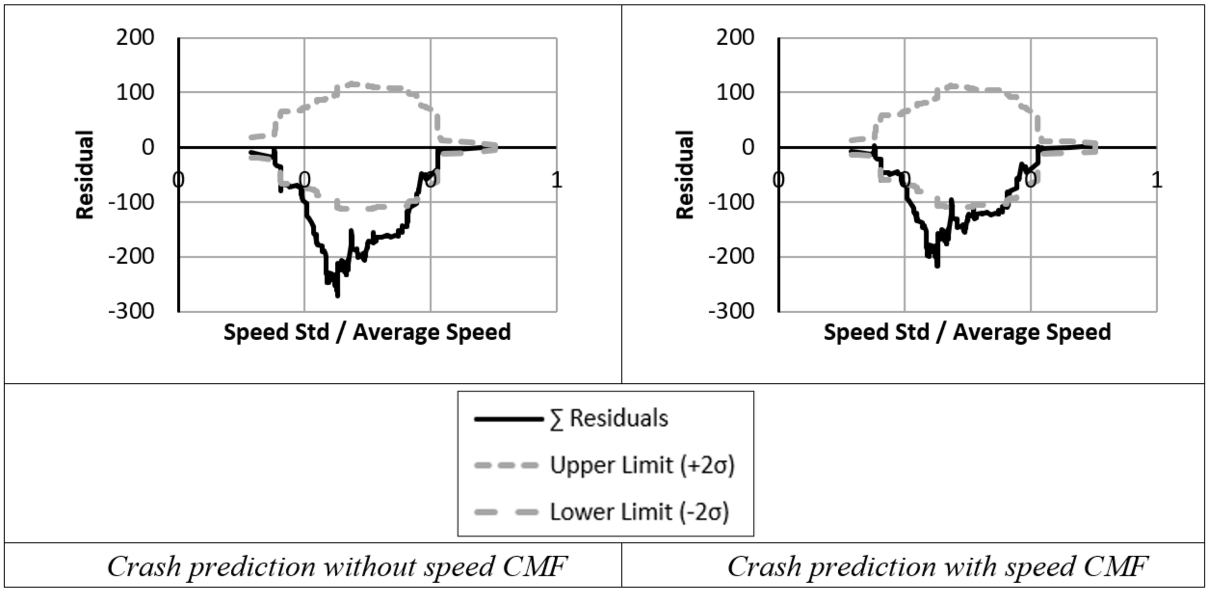
Table 276. Summary of U6D speed CMF development statistics for O crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	2.80	478	463.7	4.028	—	6.060	—
SpdStd	2.85	478	479.5	4.050	0.5	6.028	−0.5
SpdStd	*2.92*	*478*	*478.4*	*4.051*	*0.6*	*6.020*	*−0.7*
(SpdAve − PSL)	2.75	478	496.9	4.090	1.5	6.152	1.5
SpdStd/SpdAve	**3.20**	**478**	**478.3**	**3.954**	**−1.8**	**6.007**	**−0.9**
SpdStd/SpdAve	*3.53*	*478*	*488.9*	*3.955*	*−1.8*	*6.059*	*0.0*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 277. U6D speed CMF for O crashes (North Carolina).

Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 1.186 \times x + 0.5814$
R-square	0.67
Speed measure boundaries	(0.11, 0.50)
Base condition	0.35
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.08



Source: FHWA.

Figure 131. Graph. CURE plots of U6D speed CMF for O crashes (North Carolina).

U6D Speed CMF for SVFI Crashes

Table 278 and table 279 and figure 132 show the SVFI statistics for U6D.

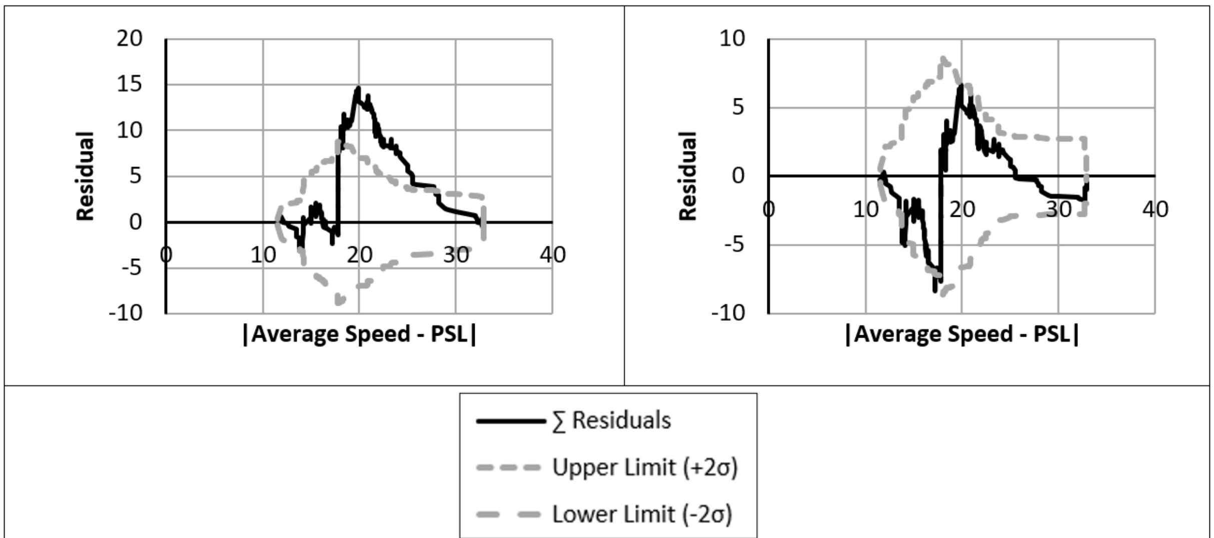
Table 278. Summary of U6D speed CMF development statistics for SVFI crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.26	24	15.7	0.399	—	0.666	—
(SpdAve − PSL)	1.31	24	14.1	0.384	−3.8	0.664	−0.3
|SpdAve − PSL|	**1.23**	**24**	**14.3**	**0.383**	**−4.0**	**0.664**	**−0.4**
|SpdAve − PSL|	*1.35*	*24*	*13.7*	*0.383*	*−4.1*	*0.676*	*1.5*
SpdStd/SpdAve	1.17	24	15.5	0.397	−0.5	0.667	0.1
SpdStd/SpdAve	*1.28*	*24*	*15.3*	*0.395*	*−0.9*	*0.671*	*0.6*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 279. U6D speed CMF for SVFI crashes (North Carolina).

Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = -0.0655 \times x + 2.2988$
R-square	0.41
Speed measure boundaries	(11.50, 32.90)
Base condition	20
t-Test (*p*-value)	0.87
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.30



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 132. Graph. CURE plots of U6D speed CMF for SVFI crashes (North Carolina).

U6D Speed CMF for SVPDO Crashes

Table 280 and table 281 and figure 133 show the SVPDO statistics for U6D.

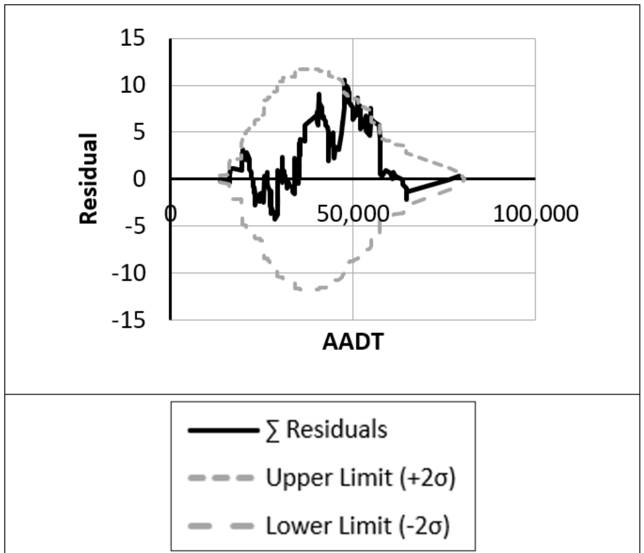
Table 280. Summary of U6D speed CMF development statistics for SVPDO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	**1.74**	**30**	**26.3**	**0.507**	**—**	**0.724**	**—**
SpdStd	1.72	30	26.7	0.508	0.2	0.726	0.2
SpdStd	*1.80*	*30*	*26.9*	*0.508*	*0.3*	*0.727*	*0.3*
(SpdAve − PSL)	1.76	30	26.6	0.510	0.7	0.727	0.3
SpdStd/SpdAve	2.00	30	26.8	0.512	1.0	0.725	0.1
SpdStd/SpdAve	*2.10*	*30*	*26.9*	*0.513*	*1.3*	*0.726*	*0.2*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 281. U6D speed CMF for SVPDO crashes (North Carolina).

Speed CMF	Value
Speed measure	NA
CMF equation	NA
R-square	NA
Speed measure boundaries	NA
Base condition	NA
t-Test (*p*-value)	NA
Estimated CMF Clearinghouse star quality rating	NA
CMF standard error	NA



Crash prediction without speed CMF

Source: FHWA.

Figure 133. Graph. CURE plot of U6D speed CMF for SVPDO crashes (North Carolina).

U6D Speed CMF for MVFI Crashes

Table 282 and table 283 and figure 134 show the MVFI statistics for U6D.

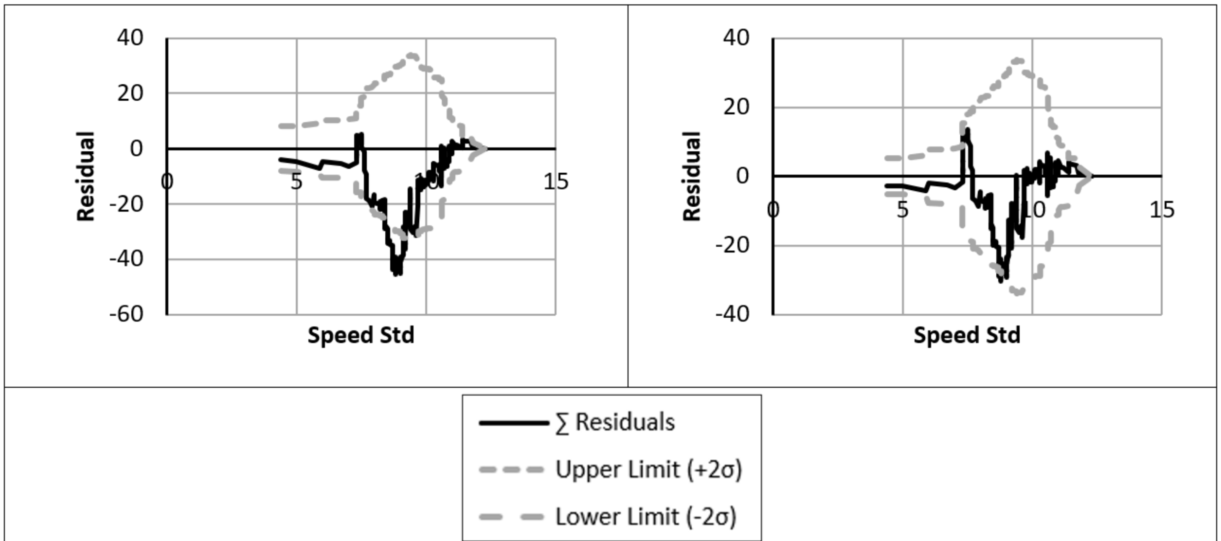
Table 282. Summary of U6D speed CMF development statistics for MVFI crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.45	124	141.8	1.442	—	2.081	—
SpdStd	1.47	124	144.9	1.464	1.5	2.071	−0.5
SpdStd	***1.50***	***124***	***144.8***	***1.463***	***1.4***	***2.069***	***−0.6***
(SpdAve − PSL)	1.44	124	149.3	1.494	3.6	2.120	1.8
|SpdAve − PSL|	1.50	124	148.7	1.489	3.2	2.114	1.6
|SpdAve − PSL|	*1.51*	*124*	*149.9*	*1.499*	*3.9*	*2.124*	*2.1*

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 283. U6D speed CMF for MVFI crashes (North Carolina).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.2606 \times x^{0.6054}$
R-square	0.37
Speed measure boundaries	(4.40, 12.30)
Base condition	9
t-Test (*p*-value)	0.08
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.08



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 134. Graph. CURE plots of U6D speed CMF for MVFI crashes (North Carolina).

U6D Speed CMF for MVPDO Crashes

Table 284 and table 285 and figure 135 show the MVPDO statistics for U6D.

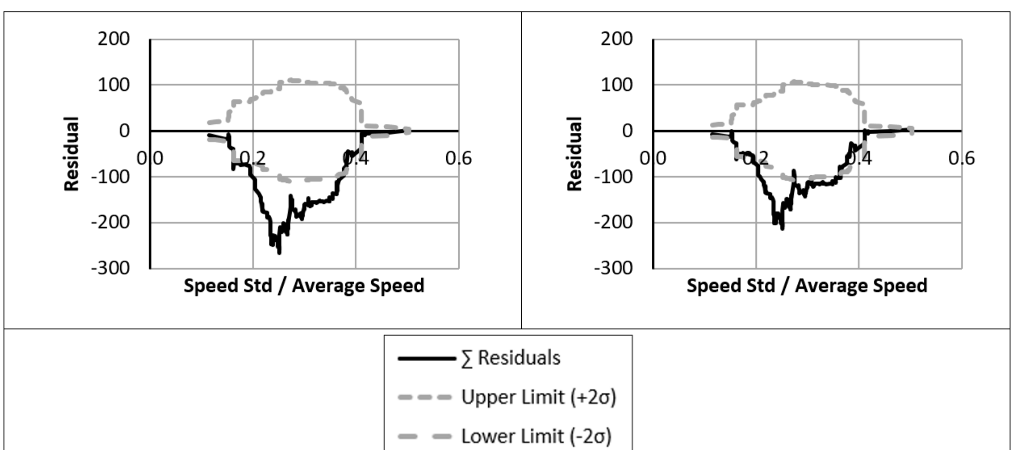
Table 284. Summary of U6D speed CMF development statistics for MVPDO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	2.90	448	436.8	3.906	—	5.959	—
SpdStd	2.96	448	452.8	3.924	0.5	5.929	−0.5
SpdStd	*3.05*	*448*	*451.4*	*3.918*	*0.3*	*5.917*	*−0.7*
(SpdAve − PSL)	2.84	448	470.7	3.881	−0.6	6.040	1.4
SpdStd/SpdAve	**3.31**	**448**	**451.1**	**3.799**	**−2.7**	**5.905**	**−0.9**
SpdStd/SpdAve	*3.74*	*448*	*462.5*	*3.785*	*−3.1*	*5.962*	*0.0*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 285. U6D speed CMF for MVPDO crashes (North Carolina).

Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 1.215 \times x + 0.5746$
R-square	0.63
Speed measure boundaries	(0.11, 0.50)
Base condition	0.35
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.08



Crash prediction without speed CMF | *Crash prediction with speed CMF*

Source: FHWA.

Figure 135. Graph. CURE plots of U6D speed CMF for MVPDO crashes (North Carolina).

Table 286 shows the U6D CURE plot summary for North Carolina.

Table 286. CURE plots summary of U6D (North Carolina).

Crash	Crash Prediction Method	Within CURE (%)	Change to HSM (%)	|Maximum CURE Deviation|	Change to HSM (%)
KABCO	HSM (without speed CMF)	12.83	—	203.81	—
KABCO	HSM × speed CMF	25.99	13	149.24	−27
KABC	HSM (without speed CMF)	70.39	—	19.28	—
KABC	HSM × speed CMF	92.43	22	6.51	−66
O	HSM (without speed CMF)	12.50	—	174.08	—
O	HSM × speed CMF	25.33	13	125.33	−28
SVFI	HSM (without speed CMF)	46.05	—	7.53	—
SVFI	HSM × speed CMF	91.78	46	1.79	−76
SVPDO	HSM (without speed CMF)	91.78	—	1.42	—
SVPDO	HSM default	91.78	0	1.42	0
MVFI	HSM (without speed CMF)	73.03	—	16.69	—
MVFI	HSM × speed CMF	96.71	24	2.24	−87
MVPDO	HSM (without speed CMF)	12.17	—	171.58	—
MVPDO	HSM × speed CMF	21.38	9	124.89	−27

—Not applicable.

U7T SPEED CMFs

Table 287 and table 288 show the seven-lane urban and suburban arterials including a center two-way, left-turn lane (U7T) statistics.

Table 287. Summary descriptive statistics of U7T (Washington).

Dataset	Segments (No.)	Length (mile)	KABC (No.)	PDO (No.)	Total (No.)	SVFI (No.)	SVPDO (No.)	MVFI (No.)	MVPDO (No.)
Training	88	12.6	192	363	555	21	21	171	342
Test	29	4.1	66	113	179	7	2	59	111
All	117	16.7	258	476	734	28	23	230	453

Note: Values for KABC, PDO, Total, SVFI, SVPDO, MVFI, and MVPDO represent observed crashes from 2017-2018.

Table 288. *R*-square values of speed CMF equations of U7T (Washington).

Speed Measure	KABCO (L)	KABCO (P)	KABC (L)	KABC (P)	O (L)	O (P)	SVFI (L)	SVFI (P)	SVPDO (L)	SVPDO (P)	MVFI (L)	MVFI (P)	MVPDO (L)	MVPDO (P)
SpdStd	***0.62***	***0.58***	***0.46***	***0.39***	***0.69***	***0.68***	***0.41***	***0.34***	***0.72***	—	***0.45***	***0.38***	***0.66***	***0.65***
(SpdAve − PSL)	0.01	—	0.01	—	0.01	—	0.07	—	0.05	—	0.01	—	0.01	—
|SpdAve − PSL|	0.01	***0.03***	0.01	***0.03***	0.01	***0.03***	***0.08***	0.08	***0.41***	***0.36***	0.01	***0.03***	0.01	***0.02***
SpdStd/ SpdAve	***0.64***	***0.64***	***0.56***	***0.56***	***0.67***	***0.67***	***0.94***	***0.94***	***0.26***	***0.26***	***0.50***	***0.50***	***0.69***	***0.69***

—Not applicable.

Note: Bold italic numbers indicate the top five potential speed CMFs for each crash type/severity level.

U7T Speed CMF for KABCO Crashes

Table 289 and table 290 and figure 136 show the KABCO crash severity scale statistics for U7T (AASHTO 2010).

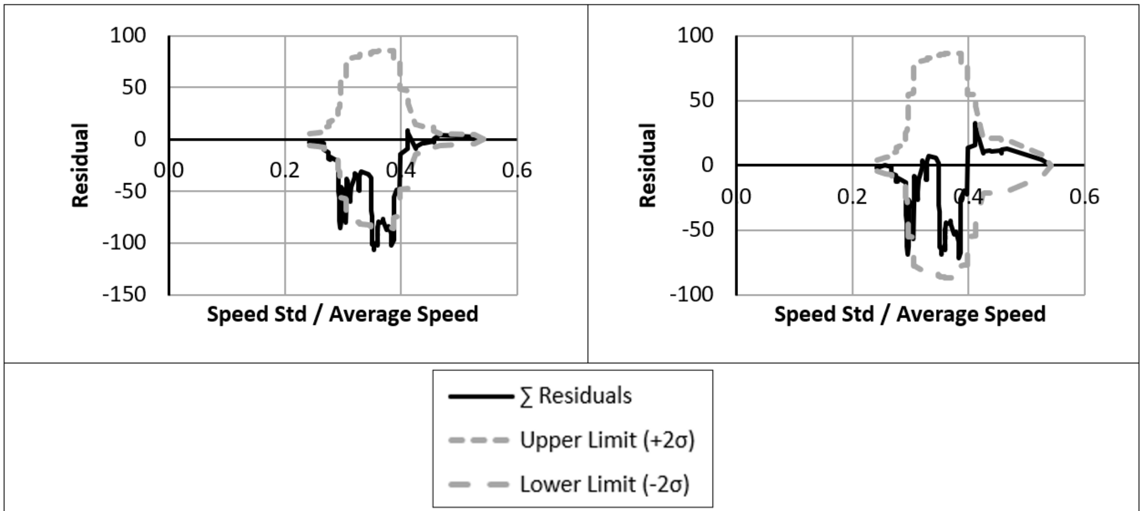
Table 289. Summary of U7T speed CMF development statistics for KABCO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.36	179	188.4	0.854	—	2.888	—
SpdStd	1.56	179	187.7	0.877	2.7	3.198	10.8
SpdStd	*1.41*	*179*	*186.1*	*0.909*	*6.4*	*3.344*	*15.8*
|SpdAve − PSL|	*1.66*	*179*	*188.0*	*0.876*	*2.5*	*2.989*	*3.5*
SpdStd/SpdAve	1.69	179	180.3	0.842	−1.5	3.021	4.6
SpdStd/SpdAve	***1.88***	***179***	***177.1***	***0.837***	***−2.1***	***3.080***	***6.7***

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 290. U7T speed CMF for KABCO crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 1.8807 \times x^{0.8739}$
R-square	0.39
Speed measure boundaries	(0.24, 0.54)
Base condition	0.49
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.10



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 136. Graph. CURE plots of U7T speed CMF for KABCO crashes (Washington).

U7T Speed CMF for KABC Crashes

Table 291 and table 292 and figure 137 show the KABC crash severity scale statistics for U7T (AASHTO 2010).

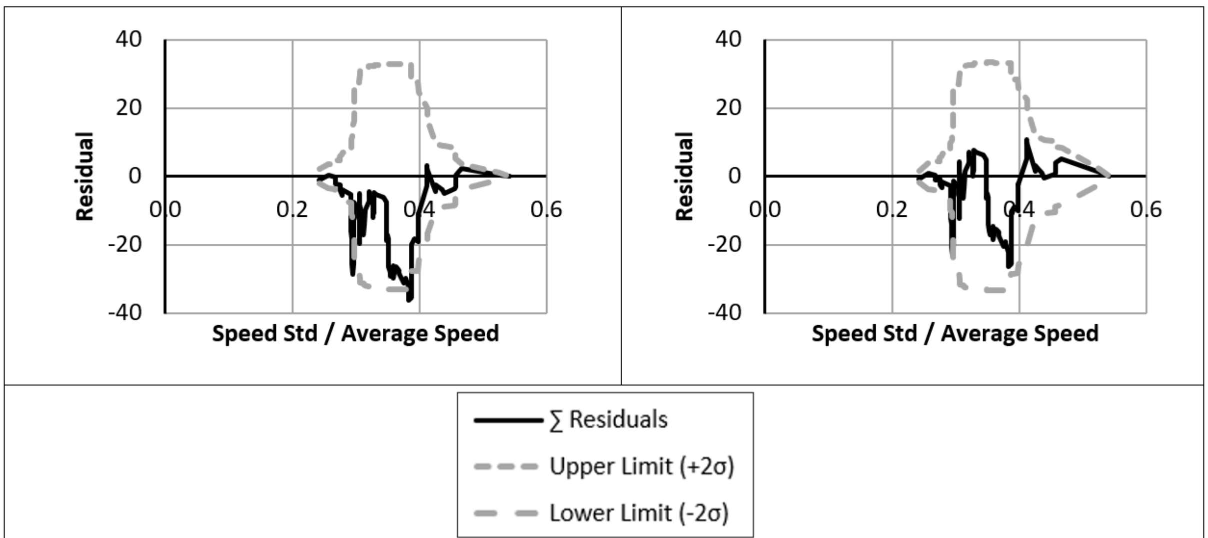
Table 291. Summary of U7T speed CMF development statistics for KABC crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	66	65.0	0.320	—	1.137	—	66
SpdStd	66	64.6	0.336	5.0	1.228	8.0	66
SpdStd	*66*	*63.7*	*0.353*	*10.5*	*1.311*	*15.2*	*66*
|SpdAve − PSL|	*66*	*64.8*	*0.321*	*0.4*	*1.152*	*1.3*	*66*
SpdStd/SpdAve	66	62.3	0.318	−0.6	1.178	3.6	66
SpdStd/SpdAve	***66***	***61.4***	***0.317***	***−0.8***	***1.194***	***5.0***	***66***

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 292. U7T speed CMF for KABC crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 1.7867 \times x^{0.794}$
R-square	0.39
Speed measure boundaries	(0.24, 0.54)
Base condition	0.48
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.09



Crash prediction without speed CMF | *Crash prediction with speed CMF*

Source: FHWA.

Figure 137. Graph. CURE plots of U7T speed CMF for KABC crashes (Washington).

U7T Speed CMF for O Crashes

Table 293 and table 294 and figure 138 show the O crash severity scale statistics for U7T (AASHTO 2010).

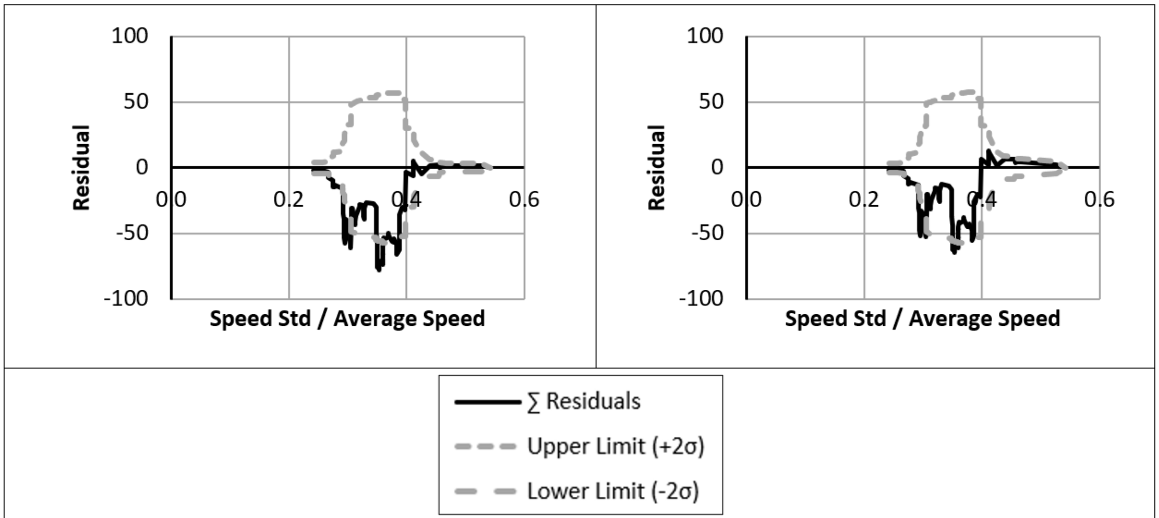
Table 293. Summary of U7T speed CMF development statistics for O crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.59	113	124.2	0.566	—	1.937	—
SpdStd	1.82	113	124.2	0.586	3.5	2.145	10.7
SpdStd	*2.36*	*113*	*123.4*	*0.604*	*6.8*	*2.207*	*13.9*
|SpdAve − PSL|	*2.01*	*113*	*124.0*	*0.580*	*2.5*	*2.025*	*4.5*
SpdStd/SpdAve	**1.99**	**113**	**118.8**	**0.561**	**−0.9**	**2.021**	**4.3**
SpdStd/SpdAve	*2.24*	*113*	*116.4*	*0.560*	*−1.0*	*2.062*	*6.5*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 294. U7T speed CMF for O crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 1.189 \times x + 0.4667$
R-square	0.37
Speed measure boundaries	(0.24, 0.54)
Base condition	0.45
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.06



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 138. Graph. CURE plots of U7T speed CMF for O crashes (Washington).

U7T Speed CMF for SVFI Crashes

Table 295 and table 296 and figure 139 show the SVFI statistics for U7T.

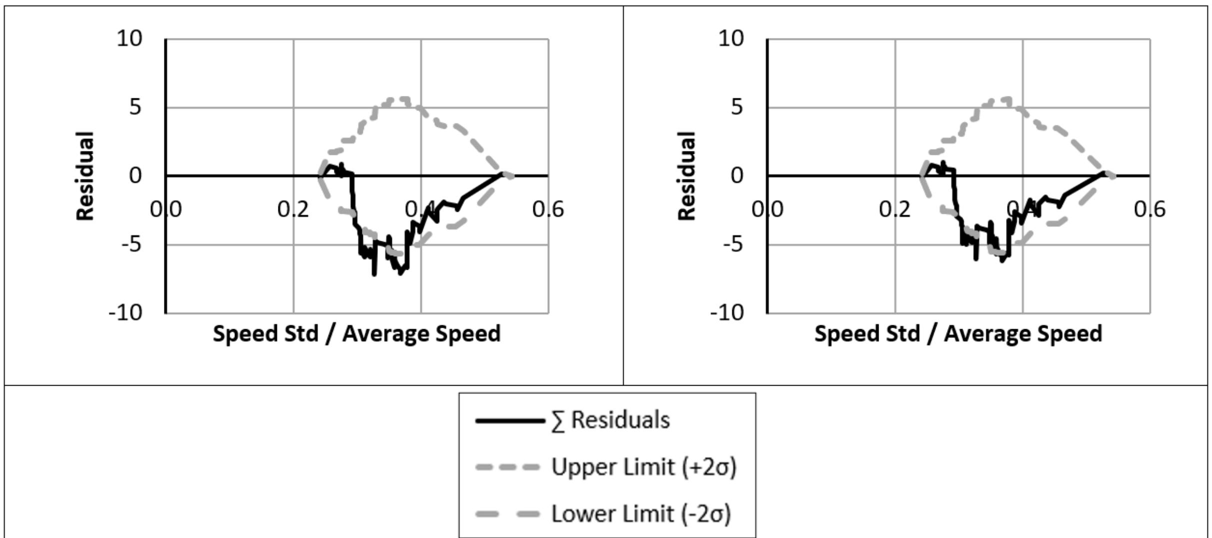
Table 295. Summary of U7T speed CMF development statistics for SVFI crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.42	7	7.1	0.388	—	0.640	—
SpdStd	1.67	7	6.3	0.368	−5.3	0.636	−0.5
SpdStd	*1.83*	*7*	*7.4*	*0.403*	*3.9*	*0.673*	*5.2*
|SpdAve − PSL|	1.40	7	7.1	0.388	−0.2	0.640	0.1
SpdStd/SpdAve	**1.86**	**7**	**6.8**	**0.374**	**−3.6**	**0.627**	**−1.9**
SpdStd/SpdAve	*1.88*	*7*	*6.8*	*0.375*	*−3.4*	*0.628*	*−1.8*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 296. U7T speed CMF for SVFI crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 1.6838 \times x + 0.2628$
R-square	0.72
Speed measure boundaries	(0.24, 0.54)
Base condition	0.44
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.09



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 139. Graph. CURE plots of U7T speed CMF for SVFI crashes (Washington).

U7T Speed CMF for SVPDO Crashes

Table 297 and table 298 and figure 140 show the SVPDO statistics for U7T.

Table 297. Summary of U7T speed CMF development statistics for SVFI crashes (Washington).

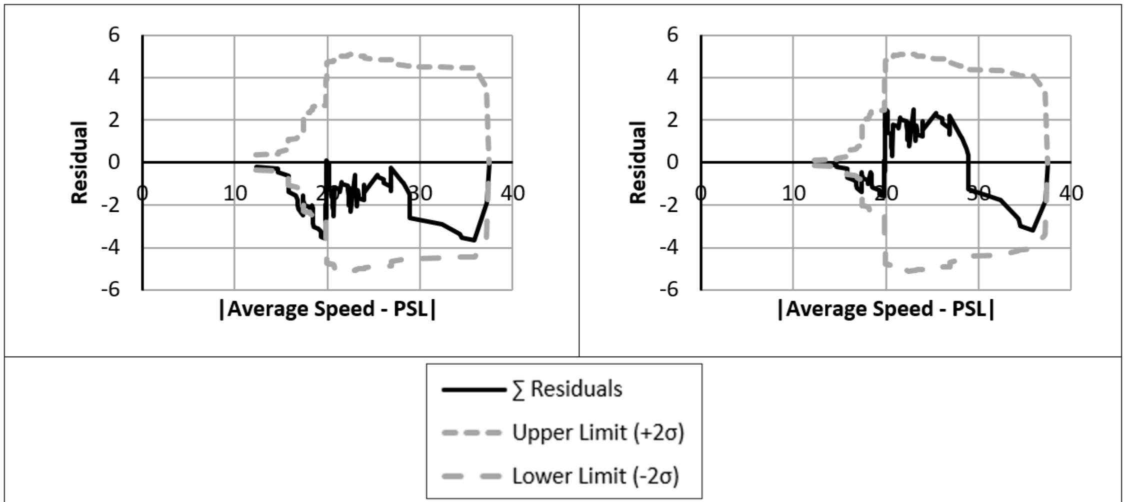
Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.13	2	7.3	0.260	—	0.297	—
SpdStd	1.40	2	7.6	0.244	−6.2	0.292	−1.5
|SpdAve − PSL|	1.13	2	7.4	0.254	−2.2	0.291	−2.0
|SpdAve − PSL|	***1.16***	***2***	***7.4***	***0.249***	***−4.2***	***0.289***	***−2.4***
SpdStd/SpdAve	1.29	2	7.2	0.257	−0.9	0.296	−0.3
SpdStd/SpdAve	*1.57*	*2*	*7.1*	*0.256*	*−1.6*	*0.295*	*−0.4*

—Not applicable.

Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 298. U7T speed CMF for SVPDO crashes (Washington).

Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 0.0062 \times x^{1.6135}$
R-square	0.39
Speed measure boundaries	(12.30, 37.50)
Base condition	23
t-Test (*p*-value)	0.28
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.34



Crash prediction without speed CMF	Crash prediction with speed CMF

Source: FHWA.

Figure 140. Graph. CURE plots of U7T speed CMF for SVPDO crashes (Washington).

U7T Speed CMF for MVFI Crashes

Table 299 and table 300 and figure 141 show the MVFI statistics for U7T.

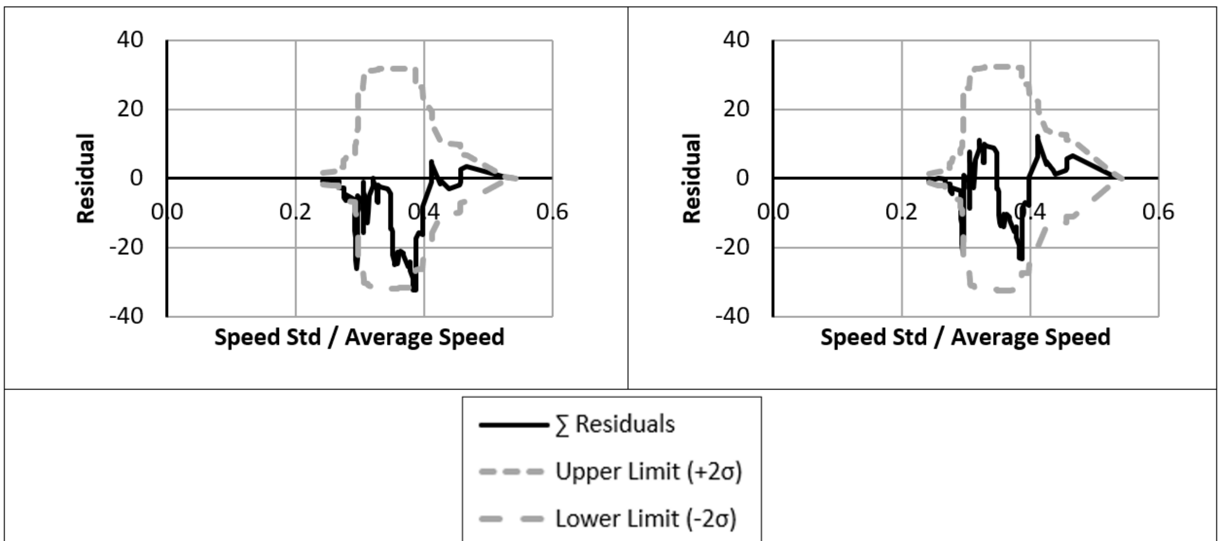
Table 299. Summary of U7T speed CMF development statistics for MVFI crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.18	59	58.9	1.897	—	2.840	—
SpdStd	1.38	59	58.8	1.991	4.9	3.055	7.6
SpdStd	*1.78*	*59*	*58.1*	*2.077*	*9.5*	*3.245*	*14.2*
|SpdAve − PSL|	*1.42*	*59*	*58.8*	*1.906*	*0.5*	*2.868*	*1.0*
SpdStd/SpdAve	1.45	59	56.4	1.888	−0.5	2.950	3.8
SpdStd/SpdAve	***1.69***	***59***	***55.4***	***1.885***	***−0.6***	***3.001***	***5.6***

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 300. U7T speed CMF for MVFI crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 1.8003 \times x^{0.8339}$
R-square	0.34
Speed measure boundaries	(0.24, 0.54)
Base condition	0.49
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.09



Crash prediction without speed CMF | *Crash prediction with speed CMF*

Source: FHWA.

Figure 141. Graph. CURE plots of U7T speed CMF for MVFI crashes (Washington).

U7T Speed CMF for MVPDO Crashes

Table 301 and table 302 and figure 142 show the MVPDO statistics for U7T.

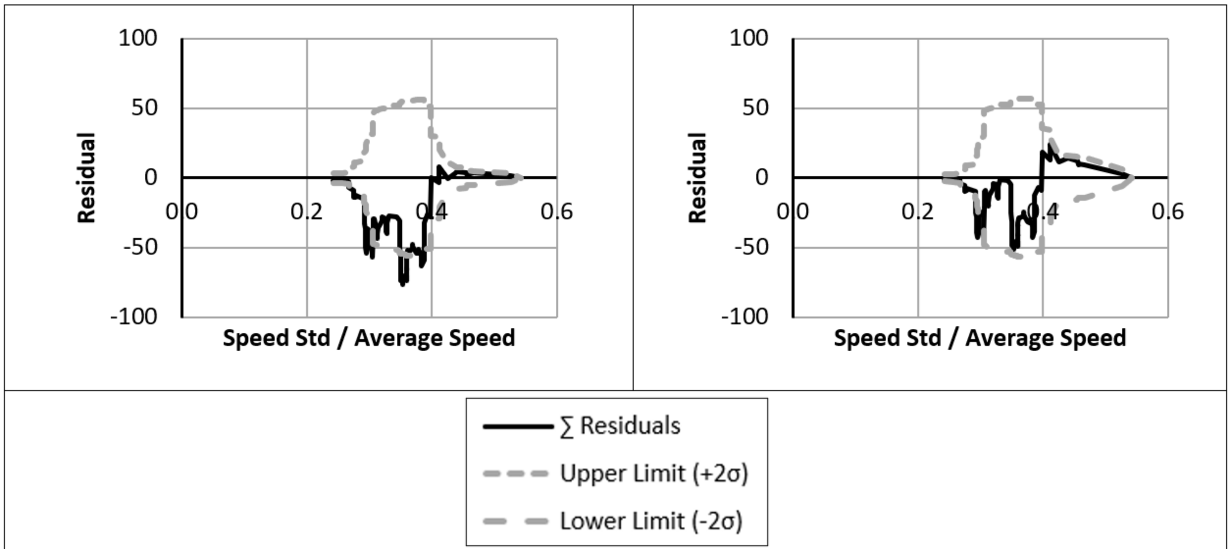
Table 301. Summary of U7T speed CMF development statistics for MVPDO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.64	111	116.9	3.431	—	4.830	—
SpdStd	1.86	111	116.4	3.506	2.2	5.326	10.3
SpdStd	*1.88*	*111*	*115.6*	*3.612*	*5.3*	*5.475*	*13.3*
|SpdAve − PSL|	2.13	111	116.7	3.489	1.7	4.991	3.3
SpdStd/SpdAve	2.06	111	111.6	3.405	−0.8	5.044	4.4
SpdStd/SpdAve	***2.32***	***111***	***109.2***	***3.393***	***−1.1***	***5.147***	***6.6***

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 302. U7T speed CMF for MVPDO crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 1.9491 \times x^{0.9404}$
R-square	0.37
Speed measure boundaries	(0.24, 0.54)
Base condition	0.49
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★ (2)
CMF standard error	0.10



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 142. Graph. CURE plots of U7T speed CMF for MVPDO crashes (Washington).

Table 303 shows the U7T CURE plot summary for Washington.

Table 303. CURE plots summary of U7T (Washington).

Crash	Crash Prediction Method	Within CURE (%)	Change to HSM (%)	|Maximum CURE Deviation|	Change to HSM (%)
KABCO	HSM (without speed CMF)	58.12	—	43.65	—
KABCO	HSM × speed CMF	87.18	29	32.55	−25
KABC	HSM (without speed CMF)	85.47	—	13.08	—
KABC	HSM × speed CMF	91.45	6	9.40	−28
O	HSM (without speed CMF)	51.28	—	30.23	—
O	HSM × speed CMF	64.96	14	26.47	−12
SVFI	HSM (without speed CMF)	52.14	—	2.71	—
SVFI	HSM × speed CMF	69.23	17	1.70	−37
SVPDO	HSM (without speed CMF)	83.76	—	1.06	—
SVPDO	HSM × speed CMF	90.60	7	0.58	−45
MVFI	HSM (without speed CMF)	84.62	—	12.52	—
MVFI	HSM × speed CMF	89.74	5	9.20	−27
MVPDO	HSM (without speed CMF)	52.14	—	28.20	—
MVPDO	HSM × speed CMF	79.49	27	21.04	−25

—Not applicable.

APPENDIX F. DETAILS OF FREEWAY SPEED CMFs

This appendix provides details of rural and urban freeway speed CMFs. Note that, for brevity, only the speed CMF plots of rural freeways are reported in appendix F.

RURAL FREEWAY SPEED CMFs

Table 304 through table 307 show the rural freeways statistics.

Table 304. Summary descriptive statistics of rural freeways (Washington).

Dataset	Segments (No.)	Length (mile)	KABC (No.)	PDO (No.)	Total (No.)	SVFI (No.)	SVPDO (No.)	MVFI (No.)	MVPDO (No.)
Training	513	246.7	594	1,753	2,347	359	1,130	235	623
Test	171	82.1	171	516	687	114	334	57	182
All	684	328.8	765	2,269	3,034	473	1,464	292	805

Note: Values for KABC, PDO, Total, SVFI, SVPDO, MVFI, and MVPDO represent observed crashes from 2017-2018.

Table 305. Summary descriptive statistics of rural freeways (North Carolina).

Dataset	Segments (No.)	Length (mile)	KABC (No.)	PDO (No.)	Total (No.)	SVFI (No.)	SVPDO (No.)	MVFI (No.)	MVPDO (No.)
Training	457	157.9	709	2,173	2,882	306	979	400	1,163
Test	152	48.1	201	645	846	81	273	117	355
All	609	206	910	2,818	3,728	387	1,252	517	1,518

Note: Values for KABC, PDO, Total, SVFI, SVPDO, MVFI, and MVPDO represent observed crashes from 2017-2018

Table 306. *R*-square values of speed CMF equations of rural freeway (Washington).

Speed Measure	KABCO (L)	KABCO (P)	KABC (L)	KABC (P)	O (L)	O (P)	SVFI (L)	SVFI (P)	SVPDO (L)	SVPDO (P)	MVFI (L)	MVFI (P)	MVPDO (L)	MVPDO (P)
SpdStd	***0.91***	***0.93***	***0.72***	***0.73***	***0.92***	***0.93***	***0.66***	***0.67***	***0.95***	***0.96***	***0.79***	***0.82***	***0.81***	***0.83***
(SpdAve – PSL)	***0.46***	—	0.45	—	***0.46***	—	***0.51***	—	***0.64***	—	0.14	—	0.02	—
|SpdAve – PSL|	0.37	0.46	0.41	***0.48***	0.34	0.45	0.46	***0.52***	0.48	0.55	0.14	***0.19***	0.01	***0.05***
SpdStd/ SpdAve	***0.70***	***0.77***	***0.52***	***0.59***	***0.74***	***0.82***	0.47	***0.54***	***0.81***	***0.87***	***0.54***	***0.61***	***0.55***	***0.63***

—Not applicable.

Note: Bold italic numbers indicate the top five potential speed CMFs for each crash type/severity level.

Table 307. *R*-square values of speed CMF equations of rural freeway (North Carolina).

Speed Measure	KABCO (L)	KABCO (P)	KABC (L)	KABC (P)	O (L)	O (P)	SVFI (L)	SVFI (P)	SVPDO (L)	SVPDO (P)	MVFI (L)	MVFI (P)	MVPDO (L)	MVPDO (P)
SpdStd	***0.95***	***0.97***	***0.84***	***0.86***	***0.95***	***0.97***	0.02	0.07	***0.75***	***0.77***	***0.87***	***0.88***	***0.91***	***0.93***
(SpdAve − PSL)	***0.57***	—	0.64	—	***0.51***	—	***0.46***	—	***0.17***	—	***0.41***	—	0.29	—
|SpdAve − PSL|	0.51	0.55	0.70	***0.71***	0.43	0.47	***0.53***	***0.46***	0.13	0.15	0.35	0.37	0.30	***0.32***
SpdStd/ SpdAve	***0.87***	***0.92***	***0.71***	***0.76***	***0.90***	***0.95***	***0.25***	***0.31***	***0.89***	***0.87***	***0.75***	***0.80***	***0.76***	***0.83***

—Not applicable.

Note: Bold italic numbers indicate the top five potential speed CMFs for each crash type/severity level.

Rural Freeway Speed CMF for KABCO Crashes

Table 308 to table 311 and figure 143 to figure 145 show the KABCO crash severity scale statistics for rural freeways (AASHTO 2014).

Table 308. Summary of rural freeway speed CMF development statistics for KABCO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.15	687	705.3	2.337	—	3.242	—
SpdStd	1.23	687	695.2	2.169	−7.2	2.966	−8.5
SpdStd	***1.22***	***687***	***693.8***	***2.158***	***−7.7***	***2.943***	***−9.2***
SpdStd/SpdAve	*1.30*	*687*	*700.4*	*2.226*	*−4.8*	*3.057*	*−5.7*
SpdStd/SpdAve	1.29	687	703.6	2.291	−2.0	3.168	−2.3
(SpdAve − PSL)	1.18	687	699.3	2.260	−3.3	3.120	−3.8

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 309. Summary of rural freeway speed CMF development statistics for KABCO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.31	846	771.7	3.242	—	5.505	—
SpdStd	1.42	846	783.7	2.929	−9.7	5.009	−9.0
SpdStd	***1.41***	***846***	***785.2***	***2.925***	***−9.8***	***4.998***	***−9.2***
SpdStd/SpdAve	*1.52*	*846*	*775.7*	*3.034*	*−6.4*	*5.222*	*−5.2*
SpdStd/SpdAve	1.54	846	773.3	3.149	−2.9	5.373	−2.4
(SpdAve − PSL)	1.31	846	781.8	3.025	−6.7	5.183	−5.8

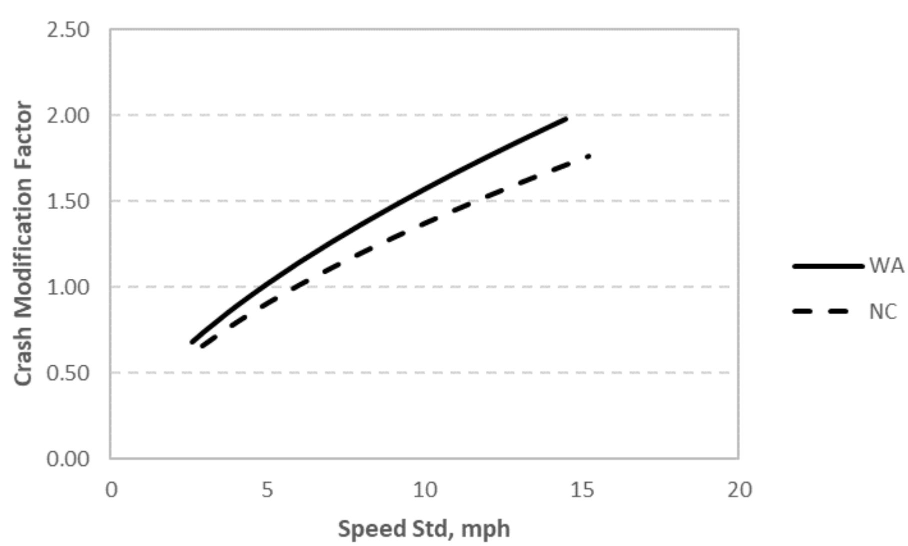
—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 310. Rural freeway speed CMF for KABCO crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.3731 \times x^{0.6237}$
R-square	0.93
Speed measure boundaries	(2.60, 14.50)
Base condition	5
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.23

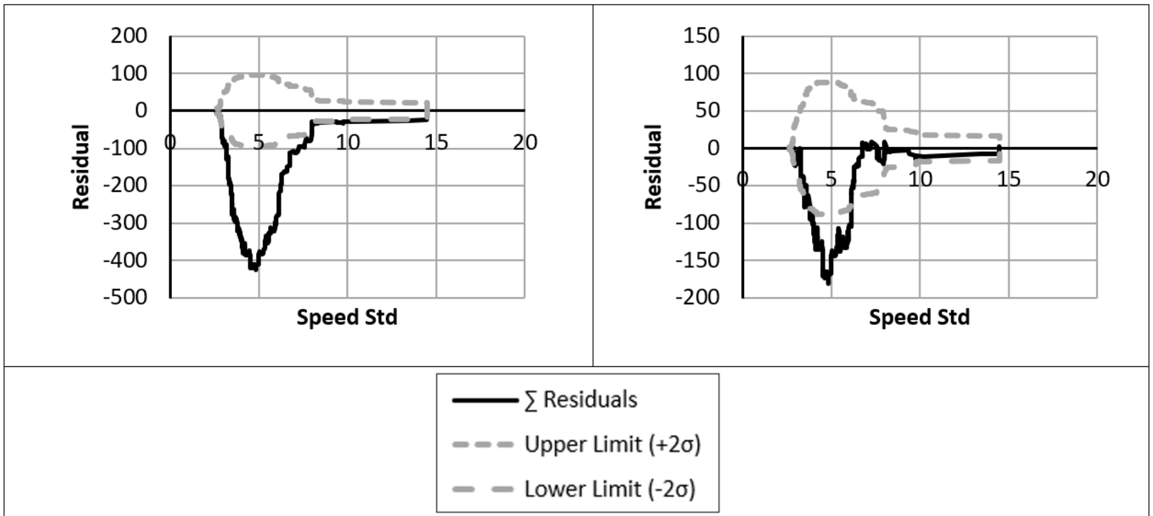
Table 311. Rural freeway speed CMF for KABCO crashes (North Carolina).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.3492 \times x^{0.5952}$
R-square	0.95
Speed measure boundaries	(2.90, 15.20)
Base condition	6
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.17



Source: FHWA.

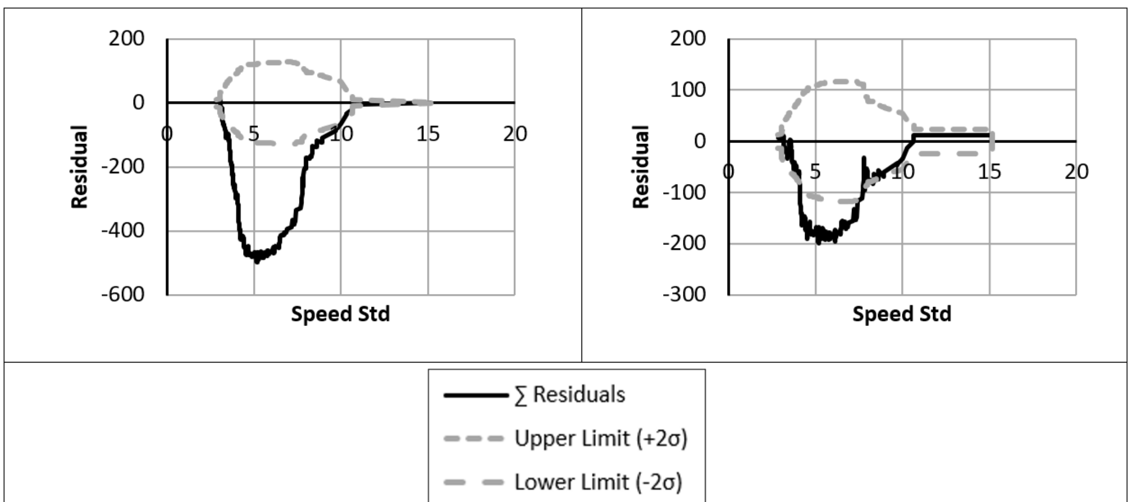
Figure 143. Graph. Rural freeway speed CMF for KABCO crashes (Washington and North Carolina).



Crash prediction without speed CMF	Crash prediction with speed CMF

Source: FHWA.

Figure 144. Graph. CURE plots of rural freeway speed CMF for KABCO crashes (Washington).



Crash prediction without speed CMF	Crash prediction with speed CMF

Source: FHWA.

Figure 145. Graph. CURE plots of rural freeway speed CMF for KABCO crashes (North Carolina).

Rural Freeway Speed CMF for KABC Crashes

Table 312 to table 315 and figure 146 to figure 148 show the KABC crash severity scale statistics for rural freeways (AASHTO 2014).

Table 312. Summary of rural freeway speed CMF development statistics for KABC crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.80	171	182.7	0.885	—	1.177	—
SpdStd	0.87	171	179.4	0.849	−4.1	1.109	−5.7
SpdStd	***0.90***	***171***	***178.7***	***0.845***	***−4.5***	***1.100***	***−6.5***
|SpdAve − PSL|	*0.87*	*171*	*179.2*	*0.860*	*−2.8*	*1.127*	*−4.2*
SpdStd/SpdAve	0.92	171	182.1	0.874	−1.2	1.159	−1.5
SpdStd/SpdAve	*0.96*	*171*	*181.0*	*0.861*	*−2.7*	*1.132*	*−3.8*

—Not applicable.
Note: Ialic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 313. Summary of rural freeway speed CMF development statistics for KABC crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.08	201	191.9	1.013	—	1.585	—
|SpdAve − PSL|	*1.12*	*201*	*196.0*	*0.994*	*−1.9*	*1.540*	*−2.8*
SpdStd	1.16	201	194.9	0.967	−4.5	1.519	−4.2
SpdStd	***1.16***	***201***	***195.4***	***0.967***	***−4.5***	***1.518***	***−4.3***
SpdStd/SpdAve	1.29	201	192.3	1.001	−1.1	1.566	−1.2
SpdStd/SpdAve	*1.29*	*201*	*193.0*	*0.983*	*−2.9*	*1.543*	*−2.7*

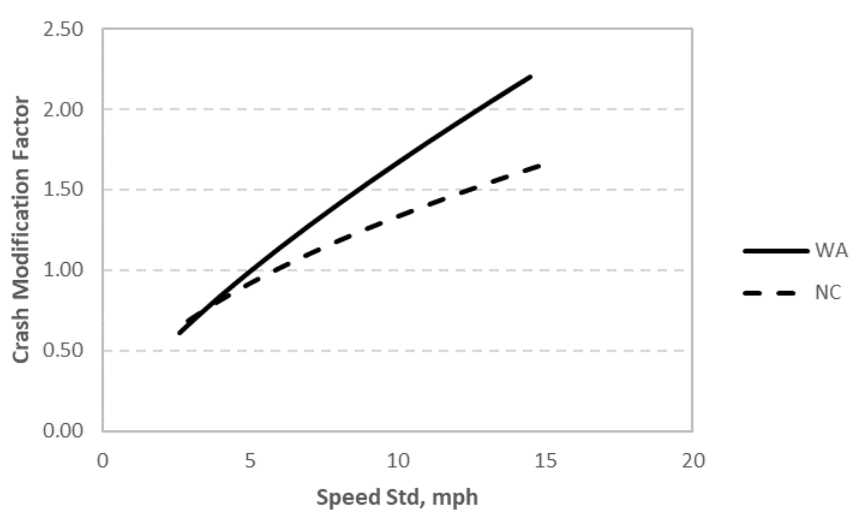
—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 314. Rural freeway speed CMF for KABC crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.2981 \times x^{0.7471}$
R-square	0.77
Speed measure boundaries	(2.60, 14.50)
Base condition	5
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.27

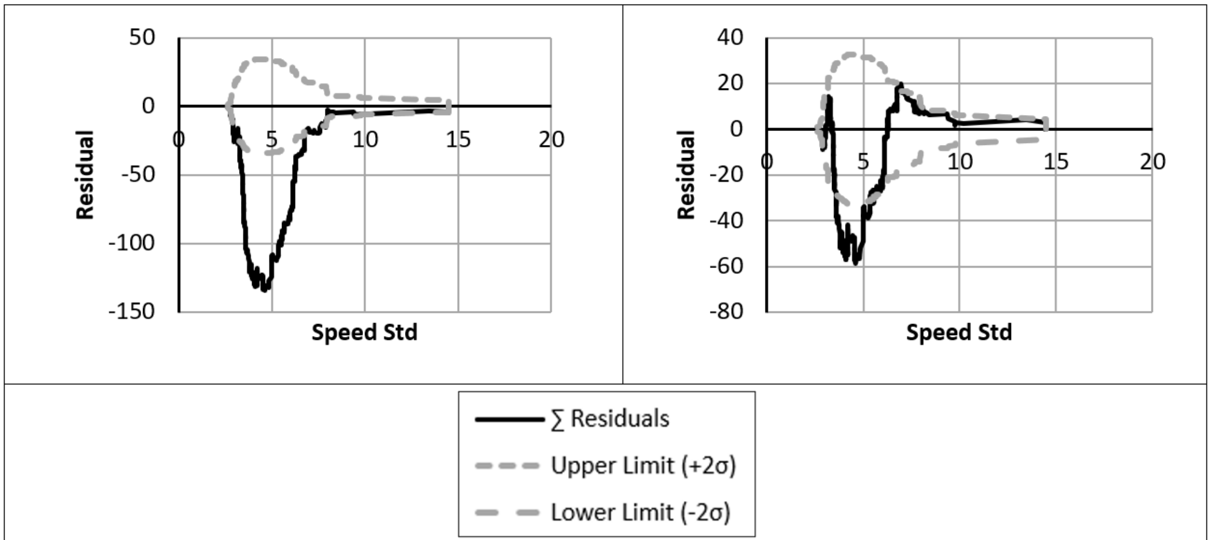
Table 315. Rural freeway speed CMF for KABC crashes (North Carolina).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.3835 \times x^{0.5404}$
R-square	0.76
Speed measure boundaries	(2.90, 15.20)
Base condition	6
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.15



Source: FHWA.

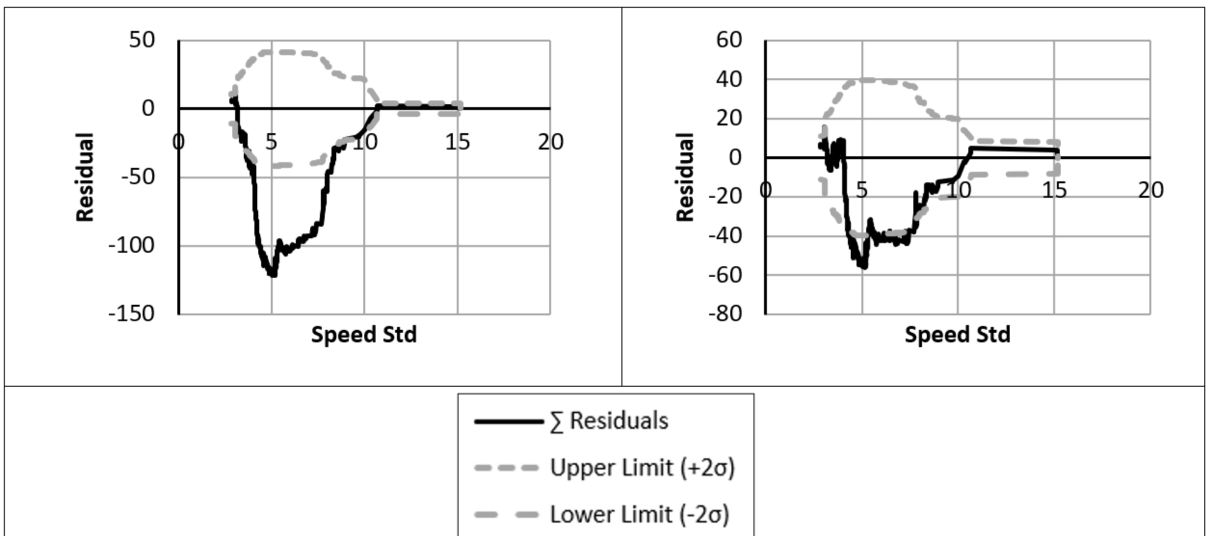
Figure 146. Graph. Rural freeway speed CMF for KABC crashes (Washington and North Carolina).



Crash prediction without speed CMF	Crash prediction with speed CMF

Source: FHWA.

Figure 147. Graph. CURE plots of rural freeway speed CMF for KABC crashes (Washington).



Crash prediction without speed CMF	Crash prediction with speed CMF

Source: FHWA.

Figure 148. Graph. CURE plots of rural freeway speed CMF for KABC crashes (North Carolina).

Rural Freeway Speed CMF for O Crashes

Table 316 to table 319 and figure 149 to figure 151 show the O crash severity scale statistics for rural freeways (AASHTO 2014).

Table 316. Summary of rural freeway speed CMF development statistics for O crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.34	516	520.8	1.855	—	2.557	—
SpdStd	1.42	516	514.3	1.746	−5.8	2.392	−6.5
SpdStd	***1.42***	***516***	***513.5***	***1.742***	***−6.1***	***2.381***	***−6.9***
SpdStd/SpdAve	*1.49*	*516*	*517.7*	*1.775*	*−4.3*	*2.443*	*−4.5*
SpdStd/SpdAve	1.49	516	519.7	1.823	−1.7	2.510	−1.8
(SpdAve − PSL)	1.37	516	517.1	1.804	−2.7	2.489	−2.6

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 317. Summary of rural freeway speed CMF development statistics for O crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.41	645	579.3	2.566	—	4.432	—
SpdStd	1.52	645	587.9	2.354	−8.3	4.054	−8.5
SpdStd	***1.51***	***645***	***588.9***	***2.351***	***−8.4***	***4.047***	***−8.7***
SpdStd/SpdAve	*1.62*	*645*	*582.1*	*2.429*	*−5.3*	*4.220*	*−4.8*
SpdStd/SpdAve	1.65	645	580.4	2.499	−2.6	4.333	−2.2
(SpdAve − PSL)	1.40	645	585.8	2.424	−5.5	4.196	−5.3

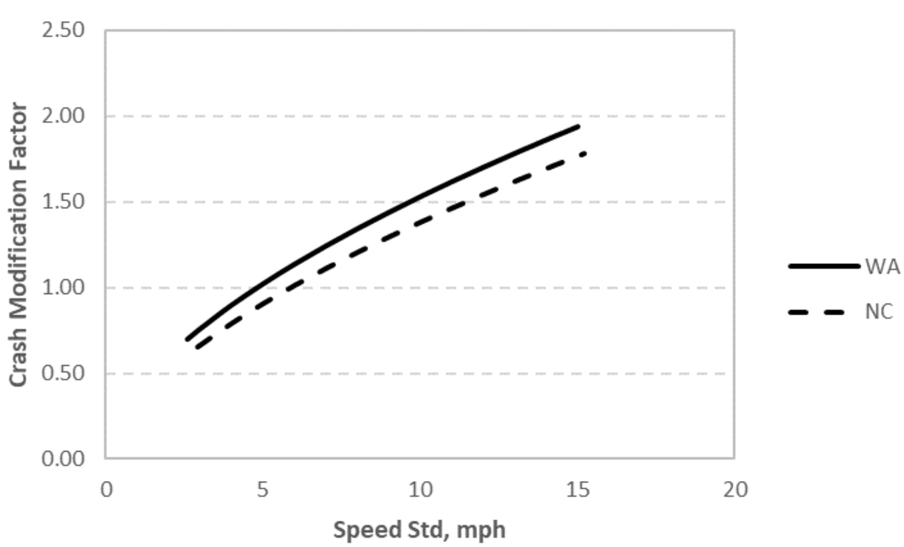
—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 318. Rural freeway speed CMF of for O crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.3992 \times x^{0.5838}$
R-square	0.94
Speed measure boundaries	(2.60, 14.50)
Base condition	5
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.21

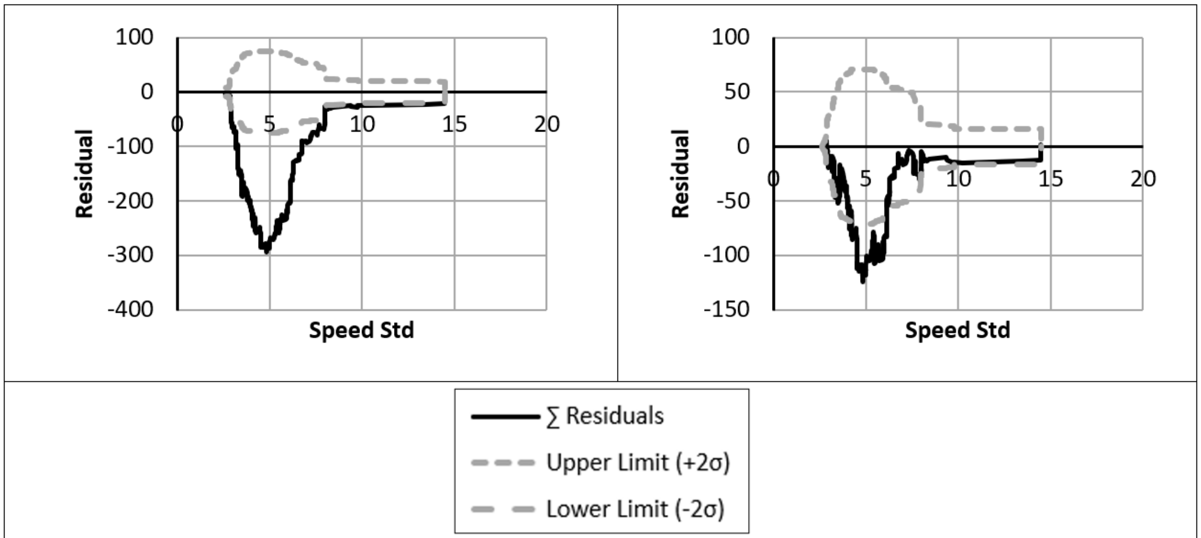
Table 319. Rural freeway speed CMF for O crashes (North Carolina).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.3402 \times x^{0.609}$
R-square	0.98
Speed measure boundaries	(2.90, 15.20)
Base condition	6
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.17



Source: FHWA.

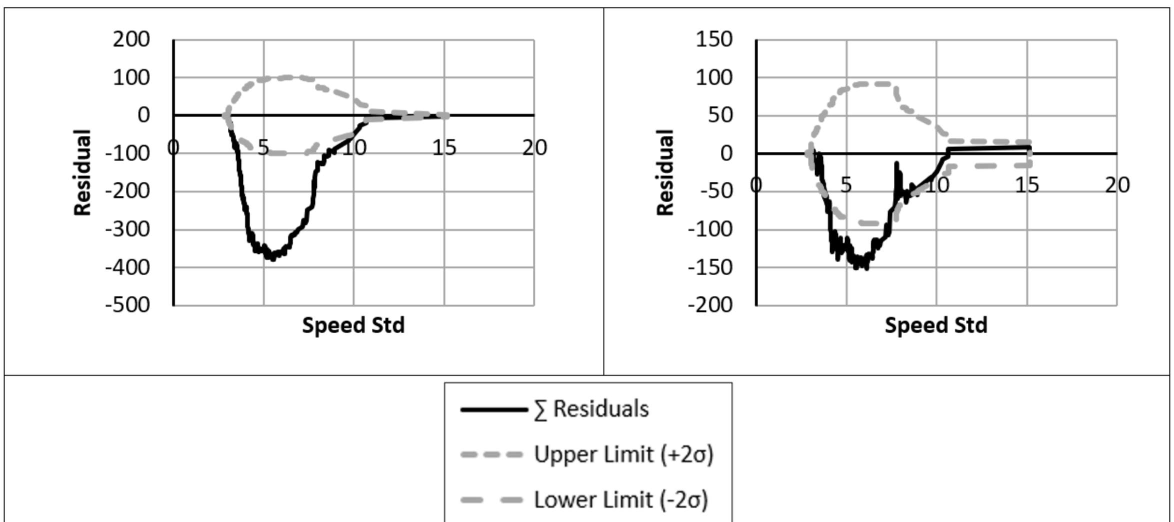
Figure 149. Graph. Rural freeway speed CMF for O crashes (Washington and North Carolina).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 150. Graph. CURE plots of rural freeway speed CMF for O crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 151. Graph. CURE plots of rural freeway speed CMF for O crashes (North Carolina).

Rural Freeway Speed CMF for SVFI Crashes

Table 320 to table 323 and figure 152 to figure 155 show the SVFI statistics for rural freeways (AASHTO 2014).

Table 320. Summary of rural freeway speed CMF development statistics for SVFI crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.67	114	113.2	0.710	—	0.881	—
SpdStd	0.73	114	110.9	0.696	−2.0	0.856	−2.8
SpdStd	***0.77***	***114***	***110.3***	***0.695***	***−2.1***	***0.853***	***−3.1***
(SpdAve − PSL)	0.70	114	111.3	0.695	−2.0	0.867	−1.5
|SpdAve − PSL|	*0.74*	*114*	*110.6*	*0.691*	*−2.6*	*0.864*	*−1.9*
SpdStd/SpdAve	*0.82*	*114*	*111.9*	*0.699*	*−1.6*	*0.863*	*−2.0*

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 321. Summary of rural freeway speed CMF development statistics for SVFI crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.84	81	84.6	0.591	—	0.919	—
(SpdAve − PSL)	0.86	81	85.6	0.594	0.5	0.924	0.5
|SpdAve − PSL|	0.86	81	85.5	0.593	0.5	0.923	0.4
|SpdAve − PSL|	*0.87*	*81*	*85.6*	*0.594*	*0.6*	*0.924*	*0.6*
SpdStd/SpdAve	**0.89**	**81**	**84.6**	**0.590**	**−0.1**	**0.919**	**0.0**
SpdStd/SpdAve	*0.89*	*81*	*84.7*	*0.589*	*−0.2*	*0.920*	*0.1*

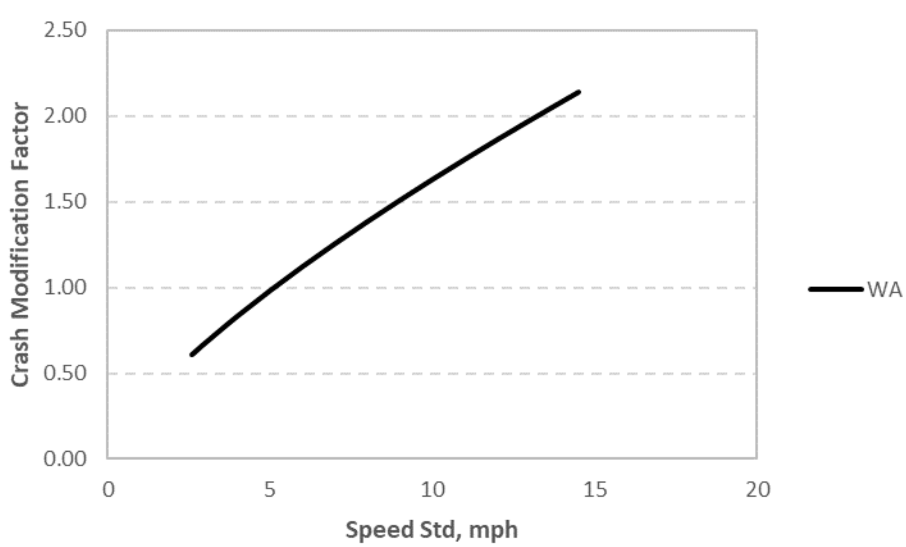
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 322. Rural freeway speed CMF for SVFI crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.3019 \times x^{0.7323}$
R-square	0.63
Speed measure boundaries	(2.60, 14.50)
Base condition	5
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.26

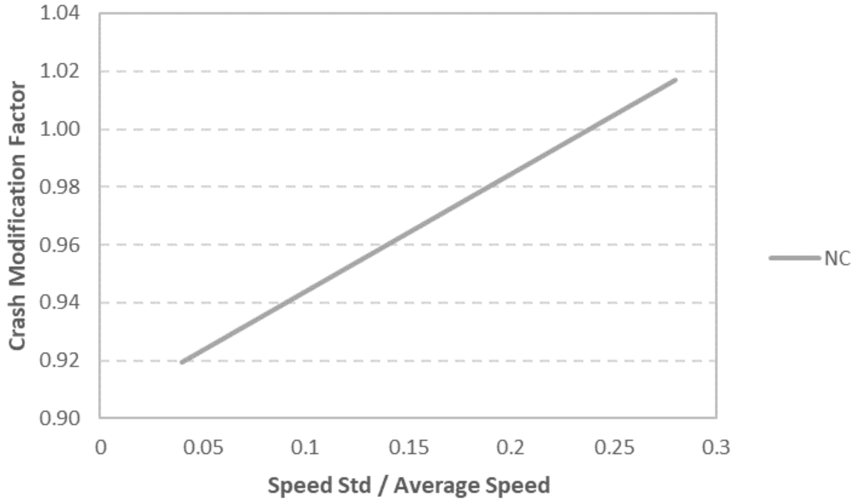
Table 323. Rural freeway speed CMF for SVFI crashes (North Carolina).

Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 0.406 \times x + 0.9034$
R-square	0.27
Speed measure boundaries	(0.04, 0.28)
Base condition	0.24
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.01



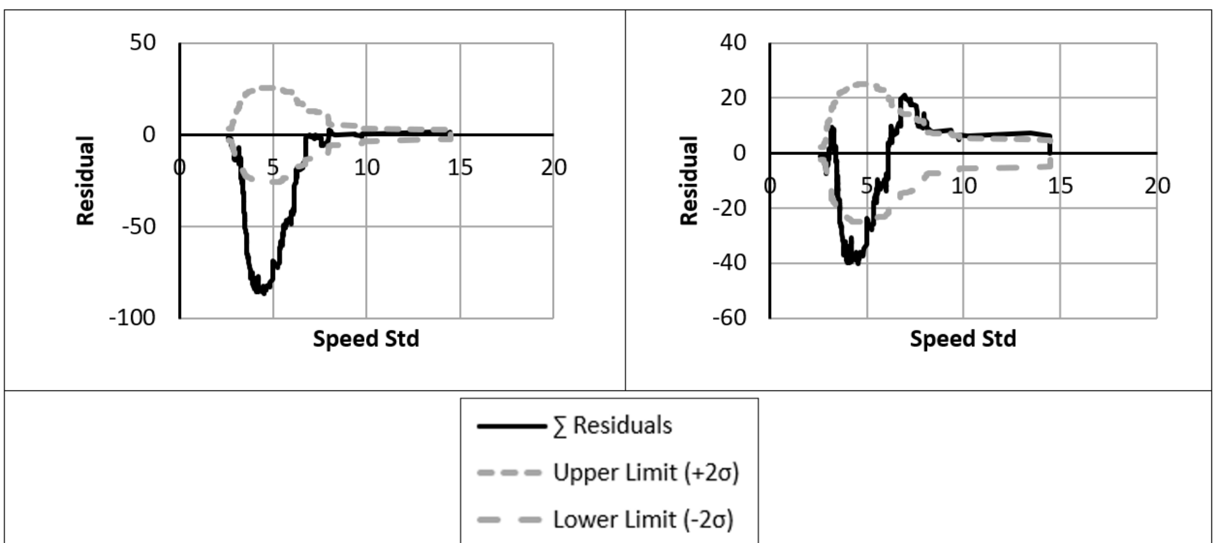
Source: FHWA.

Figure 152. Graph. Rural freeway speed CMF for SVFI crashes (Washington).



Source: FHWA.

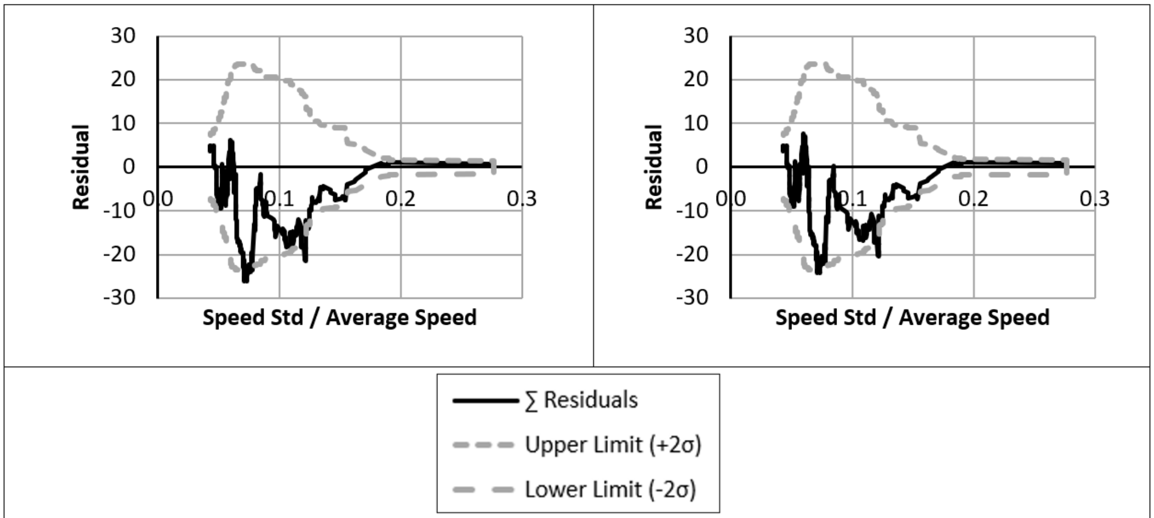
Figure 153. Graph. Rural freeway speed CMF for SVFI crashes (North Carolina).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 154. Graph. CURE plots of rural freeway speed CMF for SVFI crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 155. Graph. CURE plots of rural freeway speed CMF for SVFI crashes (North Carolina).

Rural Freeway Speed CMF for SVPDO Crashes

Table 324 to table 327 and figure 156 to figure 158 show the SVPDO statistics for rural freeways (AASHTO 2014).

Table 324. Summary of rural freeway speed CMF development statistics for SVPDO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.25	334	349.8	1.270	—	1.713	—
SpdStd	**1.32**	**334**	**346.6**	**1.247**	**−1.8**	**1.663**	**−3.0**
SpdStd	*1.31*	*334*	*346.2*	*1.250*	*−1.6*	*1.662*	*−3.0*
SpdStd/SpdAve	*1.38*	*334*	*348.2*	*1.252*	*−1.4*	*1.674*	*−2.3*
SpdStd/SpdAve	1.39	334	349.2	1.262	−0.6	1.696	−1.0
(SpdAve − PSL)	1.30	334	347.0	1.248	−1.8	1.674	−2.3

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 325. Summary of rural freeway speed CMF development statistics for SVPDO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.10	273	263.3	1.297	—	1.925	—
SpdStd	1.12	273	264.5	1.279	−1.4	1.872	−2.8
SpdStd	***1.12***	***273***	***264.8***	***1.277***	***−1.5***	***1.865***	***−3.1***
SpdStd/SpdAve	1.15	273	263.4	1.292	−0.4	1.912	−0.7
SpdStd/SpdAve	*1.14*	*273*	*263.7*	*1.286*	*−0.8*	*1.893*	*−1.6*
(SpdAve − PSL)	1.09	273	264.3	1.284	−1.0	1.893	−1.6

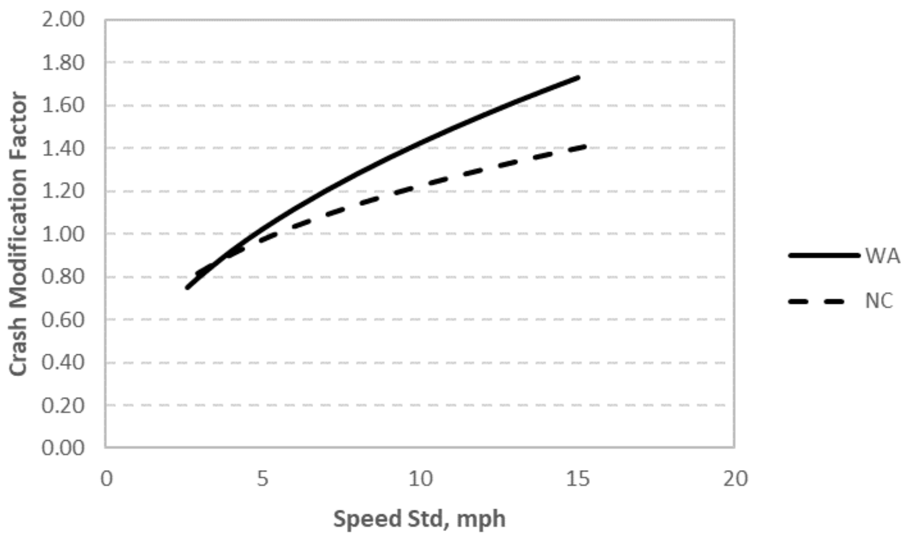
—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 326. Rural freeway speed CMF for SVPDO crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.4734 \times x^{0.4789}$
R-square	0.96
Speed measure boundaries	(2.60, 14.50)
Base condition	5
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.17

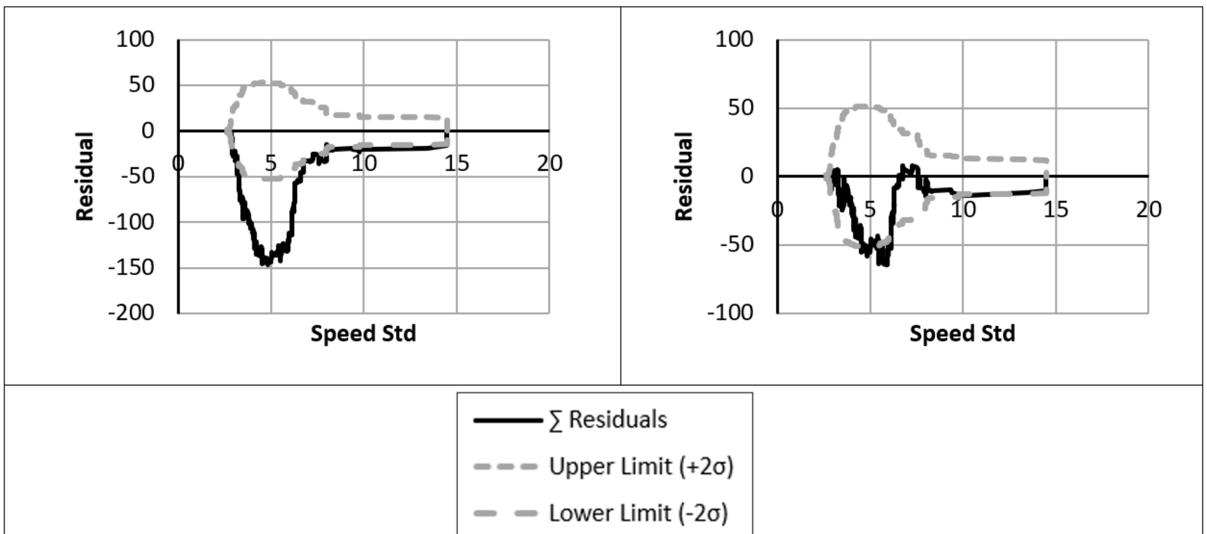
Table 327. Rural freeway speed CMF for SVPDO crashes (North Carolina).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.5747 \times x^{0.3296}$
R-square	0.71
Speed measure boundaries	(2.90, 15.20)
Base condition	5
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.10



Source: FHWA.

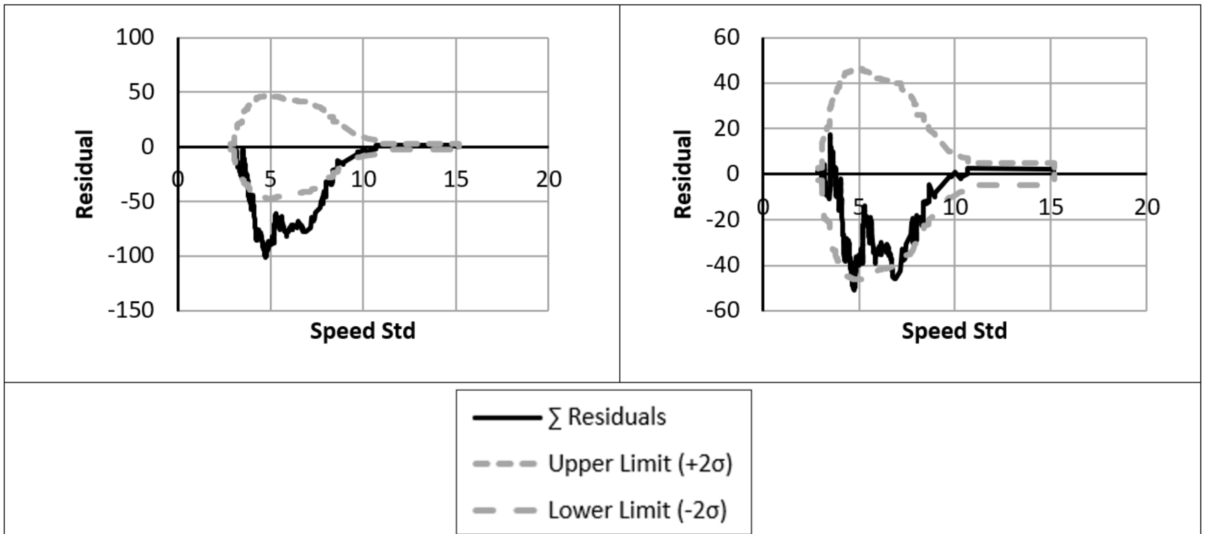
Figure 156. Graph. Rural freeway speed CMF for SVPDO crashes (Washington and North Carolina).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 157. Graph. CURE plots of rural freeway speed CMF for SVPDO crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 158. Graph. CURE plots of rural freeway speed CMF for SVPDO crashes (North Carolina).

Rural Freeway Speed CMF for MVFI Crashes

Table 328 to table 331 and figure 159 to figure 161 show the MVFI statistics for rural freeways (AASHTO 2014).

Table 328. Summary of rural freeway speed CMF development statistics for MVFI crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.14	57	66.6	0.493	—	0.687	—
SpdStd	1.23	57	65.6	0.483	−2.0	0.672	−2.1
SpdStd	***1.25***	***57***	***65.4***	***0.481***	***−2.3***	***0.671***	***−2.4***
|SpdAve − PSL|	*1.18*	*57*	*65.6*	*0.486*	*−1.3*	*0.677*	*−1.4*
SpdStd/SpdAve	1.30	57	66.4	0.490	−0.5	0.683	−0.6
SpdStd/SpdAve	*1.35*	*57*	*66.1*	*0.487*	*−1.2*	*0.676*	*−1.6*

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 329. Summary of rural freeway speed CMF development statistics for MVFI crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.39	117	105.4	0.645	—	1.044	—
SpdStd	**1.54**	**117**	**108.1**	**0.616**	**−4.4**	**0.998**	**−4.4**
SpdStd	*1.55*	*117*	*108.3*	*0.615*	*−4.6*	*1.001*	*−4.1*
(SpdAve − PSL)	1.35	117	107.1	0.624	−3.2	1.001	−4.1
SpdStd/SpdAve	1.80	117	105.8	0.630	−2.3	1.024	−1.9
SpdStd/SpdAve	*1.79*	*117*	*106.4*	*0.625*	*−3.1*	*1.007*	*−3.5*

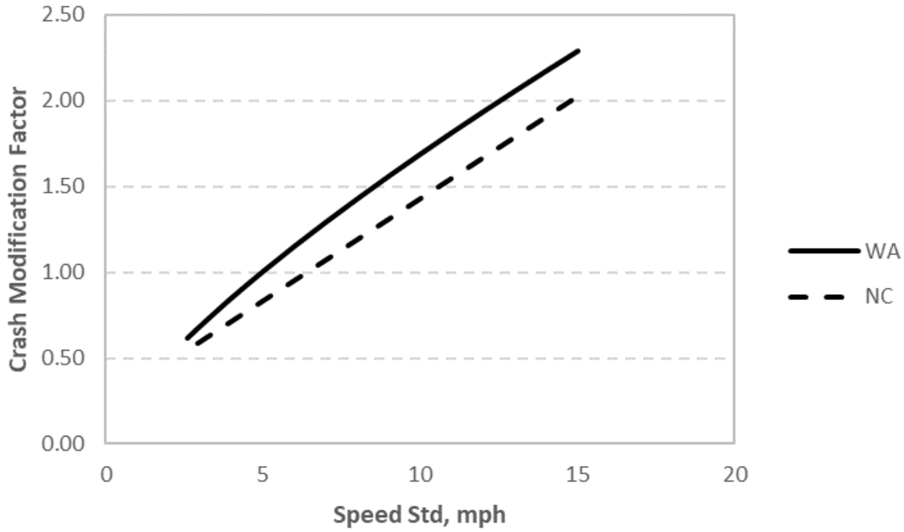
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 330. Rural freeway speed CMF for MVFI crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.2992 \times x^{0.7516}$
R-square	0.93
Speed measure boundaries	(2.60, 14.50)
Base condition	5
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.28

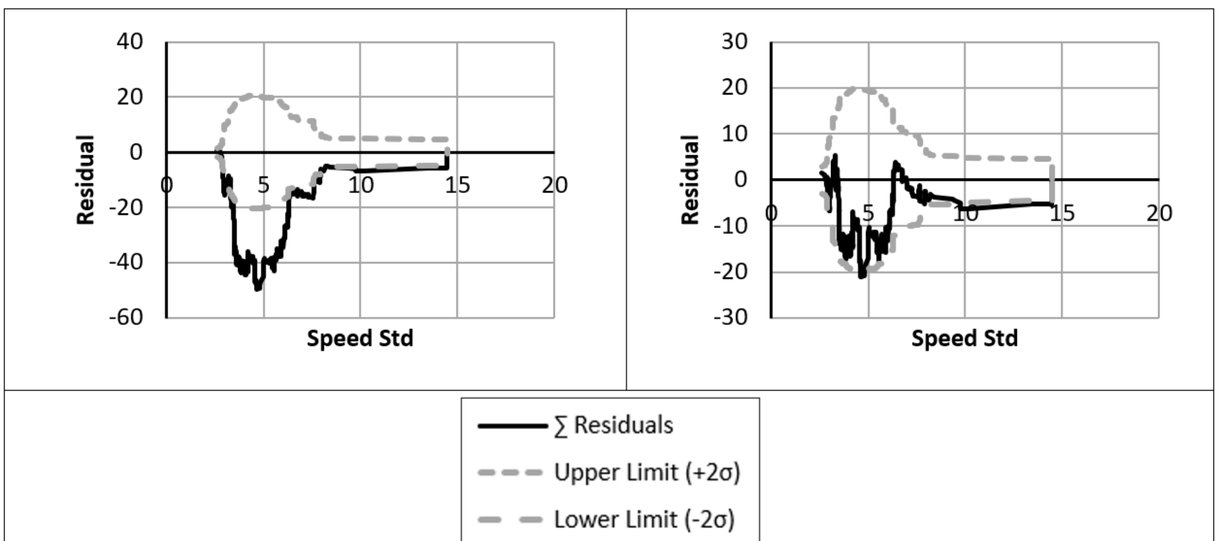
Table 331. Rural freeway speed CMF for MVFI crashes (North Carolina).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.1188 \times x + 0.2423$
R-square	0.88
Speed measure boundaries	(2.90, 15.20)
Base condition	6
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.19



Source: FHWA.

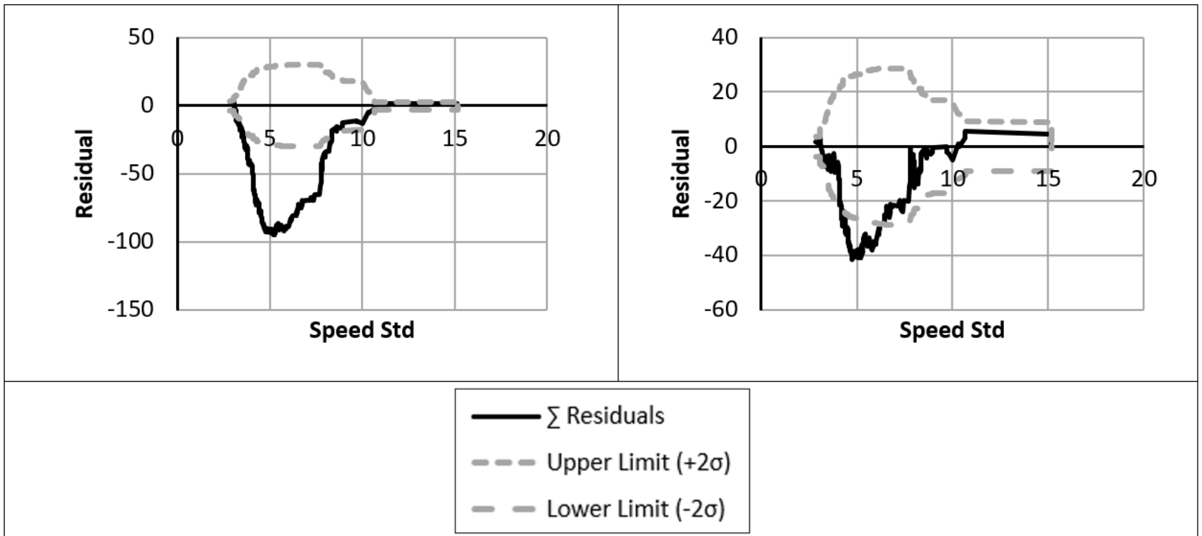
Figure 159. Graph. Rural freeway speed CMF for MVFI crashes (Washington and North Carolina).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 160. Graph. CURE plots of rural freeway speed CMF for MVFI crashes (Washington).



Crash prediction without speed CMF | *Crash prediction with speed CMF*

Source: FHWA.

Figure 161. Graph. CURE plots of rural freeway speed CMF for MVFI crashes (North Carolina).

Rural Freeway Speed CMF for MVPDO Crashes

Table 332 to table 335 and figure 162 to figure 165 show the MVPDO statistics for rural freeways (AASHTO 2014).

Table 332. Summary of rural freeway speed CMF development statistics for MVPDO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.54	182	167.6	0.948	—	1.411	—
SpdStd	1.63	182	164.3	0.911	−3.9	1.335	−5.4
SpdStd	***1.65***	***182***	***163.7***	***0.906***	***−4.4***	***1.326***	***−6.0***
|SpdAve − PSL|	*1.54*	*182*	*166.3*	*0.937*	*−1.1*	*1.390*	*−1.5*
SpdStd/SpdAve	1.70	182	167.1	0.938	−1.0	1.392	−1.3
SpdStd/SpdAve	*1.75*	*182*	*166.2*	*0.925*	*−2.4*	*1.360*	*−3.6*

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 333. Summary of rural freeway speed CMF development statistics for MVPDO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.80	355	306.4	1.666	—	3.067	—
SpdStd	2.01	355	314.1	1.586	−4.8	3.103	1.2
SpdStd	*1.99*	*355*	*315.1*	*1.583*	*−5.0*	*3.147*	*2.6*
|SpdAve − PSL|	*1.79*	*355*	*314.6*	*1.617*	*−2.9*	*3.164*	*3.2*
SpdStd/SpdAve	**2.29**	**355**	**307.7**	**1.644**	**−1.3**	**3.041**	**−0.9**
SpdStd/SpdAve	*2.27*	*355*	*309.6*	*1.622*	*−2.6*	*3.048*	*−0.6*

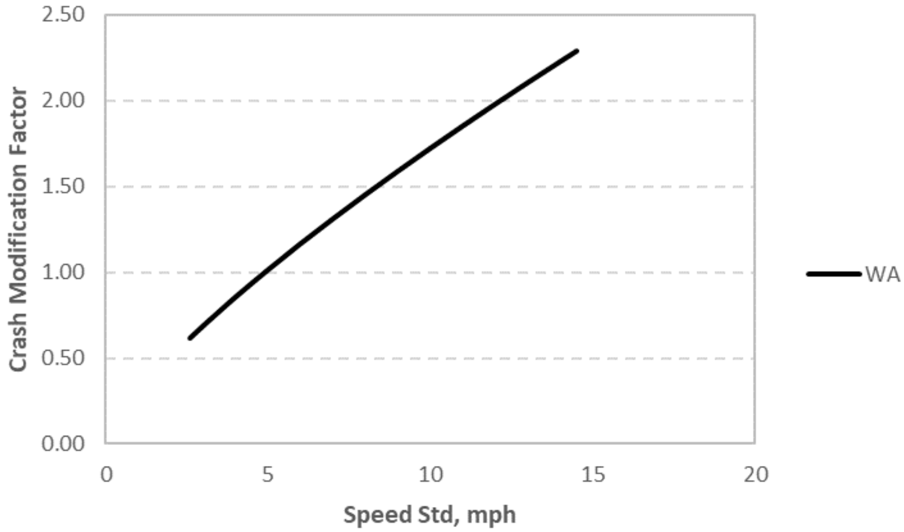
—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 334. Rural freeway speed CMF for MVPDO crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.2953 \times x^{0.7659}$
R-square	0.88
Speed measure boundaries	(2.60, 14.50)
Base condition	5
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.28

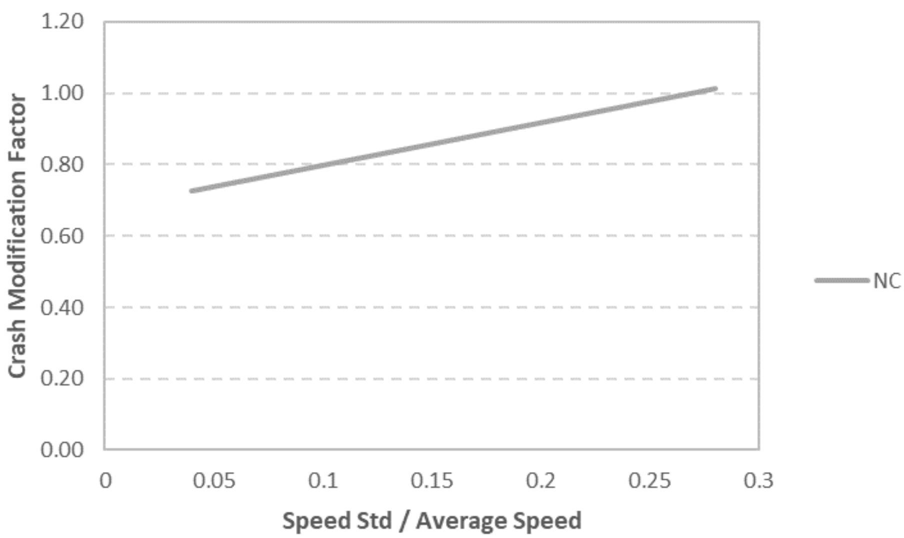
Table 335. Rural freeway speed CMF for MVPDO crashes (North Carolina).

Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 1.2003 \times x + 0.6771$
R-square	0.76
Speed measure boundaries	(0.04, 0.28)
Base condition	0.27
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.04



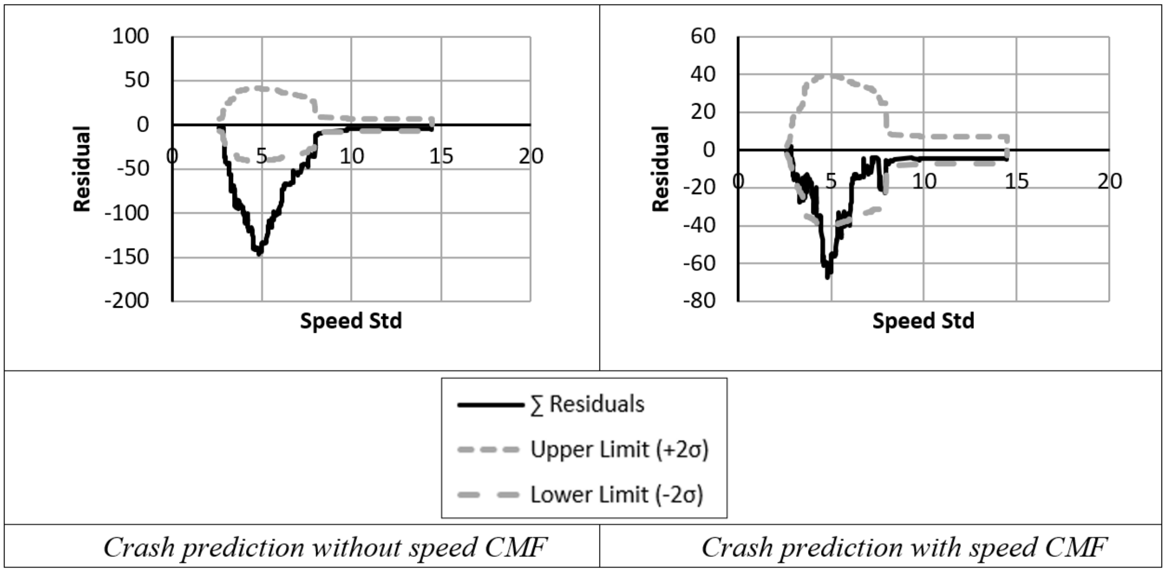
Source: FHWA.

Figure 162. Graph. Rural freeway speed CMF for MVPDO crashes (Washington).



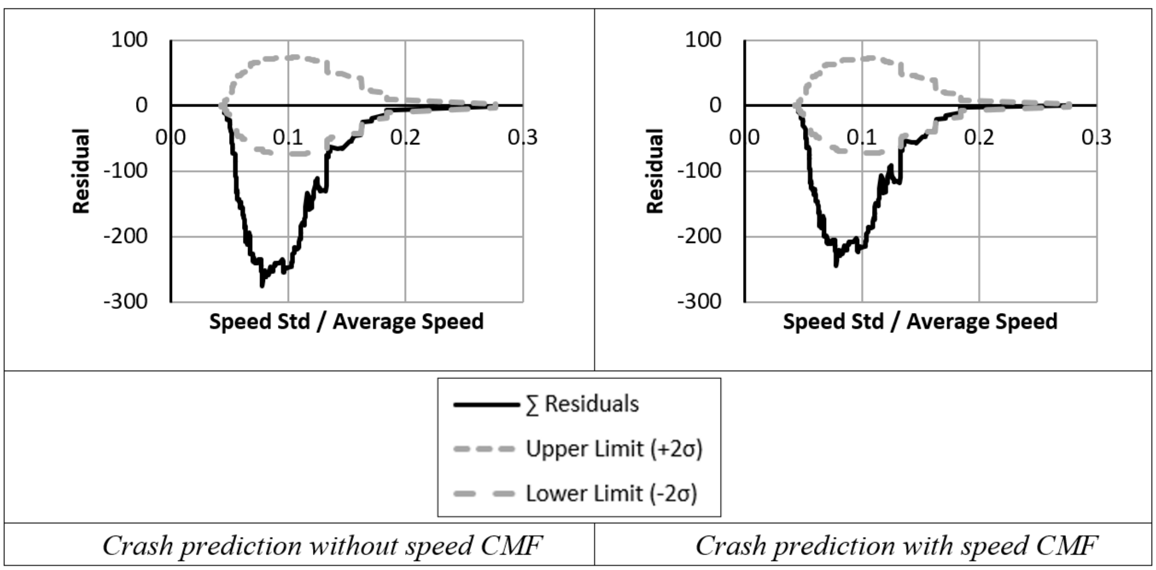
Source: FHWA.

Figure 163. Graph. Rural freeway speed CMF for MVPDO crashes (North Carolina).



Source: FHWA.

Figure 164. Graph. CURE plots of rural freeway speed CMF for MVPDO crashes (Washington).



Source: FHWA.

Figure 165. Graph. CURE plots of rural freeway speed CMF for MVPDO crashes (North Carolina).

Table 336 and table 337 show the rural freeways CURE plot summary for Washington and North Carolina, respectively.

Table 336. CURE plots summary of rural freeways (Washington).

Crash	Crash Prediction Method	Within CURE (%)	Change to HSM (%)	|Maximum CURE Deviation|	Change to HSM (%)
KABCO	HSM (without speed CMF)	2.34	—	328.78	—
KABCO	HSM × speed CMF	50.15	48	92.31	−72
KABC	HSM (without speed CMF)	9.06	—	99.87	—
KABC	HSM × speed CMF	59.06	50	25.89	−74
O	HSM (without speed CMF)	3.36	—	218.16	—
O	HSM × speed CMF	69.88	67	53.38	−76
SVFI	HSM (without speed CMF)	22.51	—	60.70	—
SVFI	HSM × speed CMF	56.14	34	16.37	−73
SVPDO	HSM (without speed CMF)	9.80	—	94.55	—
SVPDO	HSM × speed CMF	84.06	74	16.20	−83
MVFI	HSM (without speed CMF)	9.94	—	29.41	—
MVFI	HSM × speed CMF	97.08	87	1.46	−95
MVPDO	HSM (without speed CMF)	4.68	—	105.86	—
MVPDO	HSM × speed CMF	77.78	73	28.23	−73

—Not applicable.

Table 337. CURE plots summary of rural freeways (North Carolina).

Crash	Crash Prediction Method	Within CURE (%)	Change to HSM (%)	|Maximum CURE Deviation|	Change to HSM (%)
KABCO	HSM (without speed CMF)	7.39	—	375.94	—
KABCO	HSM × speed CMF	41.71	34	91.51	−76
KABC	HSM (without speed CMF)	20.69	—	80.18	—
KABC	HSM × speed CMF	56.16	35	16.26	−80
O	HSM (without speed CMF)	6.40	—	280.08	—
O	HSM × speed CMF	33.66	27	60.80	−78
SVFI	HSM (without speed CMF)	89.16	—	5.35	—
SVFI	HSM × speed CMF	96.22	7	4.39	−18
SVPDO	HSM (without speed CMF)	25.29	—	54.64	—
SVPDO	HSM × speed CMF	93.60	68	5.95	−89
MVFI	HSM (without speed CMF)	9.52	—	66.12	—
MVFI	HSM × speed CMF	53.20	44	15.55	−76
MVPDO	HSM (without speed CMF)	2.13	—	205.19	—
MVPDO	HSM × speed CMF	2.63	0	176.36	−14

—Not applicable.

URBAN FREEWAY SPEED CMFs

Table 338 through table 341 show the urban freeways statistics.

Table 338. Summary descriptive statistics of urban freeways (Washington).

Dataset	Segments (No.)	Length (mile)	KABC (No.)	PDO (No.)	Total (No.)	SVFI (No.)	SVPDO (No.)	MVFI (No.)	MVPDO (No.)
Training	246	71.4	486	1,238	1,724	153	431	333	807
Test	82	24.5	151	420	571	44	160	107	260
All	328	95.9	637	1,658	2,295	197	591	440	1,067

Note: Values for KABC, PDO, Total, SVFI, SVPDO, MVFI, and MVPDO represent observed crashes from 2017-2018.

Table 339. Summary descriptive statistics of urban freeways (North Carolina).

Dataset	Segments (No.)	Length (mile)	KABC (No.)	PDO (No.)	Total (No.)	SVFI (No.)	SVPDO (No.)	MVFI (No.)	MVPDO (No.)
Training	442	108.2	915	3,217	4,132	285	992	623	2,181
Test	147	36.3	298	934	1,232	108	302	186	623
All	589	144.5	1,213	4,151	5,364	393	1,294	809	2,804

Note: Values for KABC, PDO, Total, SVFI, SVPDO, MVFI, and MVPDO represent observed crashes from 2017-2018.

Table 340. *R*-square values of speed CMF equations of urban freeway (Washington).

Speed Measure	KABCO (L)	KABCO (P)	KABC (L)	KABC (P)	O (L)	O (P)	SVFI (L)	SVFI (P)	SVPDO (L)	SVPDO (P)	MVFI (L)	MVFI (P)	MVPDO (L)	MVPDO (P)
SpdStd	***0.91***	***0.91***	0.67	0.67	***0.97***	***0.97***	***0.07***	0.03	***0.40***	***0.45***	***0.81***	0.78	0.89	0.89
(SpdAve − PSL)	***0.92***	—	***0.90***	—	0.92	—	***0.04***	—	***0.55***	—	***0.97***	—	***0.95***	—
|SpdAve − PSL|	***0.92***	***0.92***	***0.87***	***0.88***	***0.94***	***0.92***	0.02	***0.04***	***0.78***	***0.82***	***0.96***	***0.96***	***0.94***	***0.93***
SpdStd/ SpdAve	0.83	0.89	***0.71***	***0.79***	0.86	***0.92***	***0.06***	***0.05***	0.08	0.12	0.80	***0.85***	***0.92***	***0.95***

—Not applicable.
Note: Bold italic numbers indicate the top five potential speed CMFs for each crash type/severity level.

Table 341. *R*-square values of speed CMF equations of urban freeway (North Carolina).

Speed Measure	KABCO (L)	KABCO (P)	KABC (L)	KABC (P)	O (L)	O (P)	SVFI (L)	SVFI (P)	SVPDO (L)	SVPDO (P)	MVFI (L)	MVFI (P)	MVPDO (L)	MVPDO (P)
SpdStd	***0.92***	***0.92***	***0.91***	***0.92***	***0.91***	***0.91***	***0.63***	***0.58***	***0.64***	***0.63***	***0.92***	***0.93***	***0.94***	***0.94***
(SpdAve – PSL)	0.87	—	0.73	—	0.88	—	***0.48***	—	0.43	—	***0.64***	—	0.83	—
|SpdAve – PSL|	***0.90***	***0.90***	***0.75***	***0.79***	***0.91***	***0.91***	0.37	0.46	***0.43***	0.43	0.60	0.63	***0.85***	***0.85***
SpdStd/ SpdAve	0.82	***0.87***	0.74	***0.80***	0.84	***0.88***	***0.62***	***0.62***	***0.63***	***0.67***	***0.64***	***0.70***	0.77	***0.83***

—Not applicable.
Note: Bold italic numbers indicate the top five potential speed CMFs for each crash type/severity level.

Urban Freeway Speed CMF for KABCO Crashes

Table 342 to table 345 and figure 166 and figure 167 show the KABCO crash severity scale statistics for urban freeways (AASHTO 2014).

Table 342. Summary of urban freeway speed CMF development statistics for KABCO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.10	571	627.8	4.585	—	7.248	—
SpdStd	**1.13**	**571**	**659.0**	**4.422**	**−3.6**	**6.427**	**−11.3**
SpdStd	*1.13*	*571*	*659.7*	*4.451*	*−2.9*	*6.464*	*−10.8*
(SpdAve − PSL)	1.15	571	659.2	4.538	−1.0	6.835	−5.7
|SpdAve − PSL|	1.17	571	658.4	4.530	−1.2	6.829	−5.8
|SpdAve − PSL|	*1.18*	*571*	*660.4*	*4.537*	*−1.0*	*6.832*	*−5.7*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 343. Summary of urban freeway speed CMF development statistics for KABCO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.44	1,232	1,268.9	5.537	—	9.997	—
SpdStd	1.55	1,232	1,222.1	5.260	−5.0	9.224	−7.7
SpdStd	***1.55***	***1,232***	***1,217.4***	***5.256***	***−5.1***	***9.218***	***−7.8***
|SpdAve − PSL|	*1.56*	*1,232*	*1,239.6*	*5.235*	*−5.4*	*9.303*	*−6.9*
|SpdAve − PSL|	1.58	1,232	1,244.2	5.245	−5.3	9.351	−6.5
SpdStd/SpdAve	*1.72*	*1,232*	*1,241.8*	*5.238*	*−5.4*	*9.407*	*−5.9*

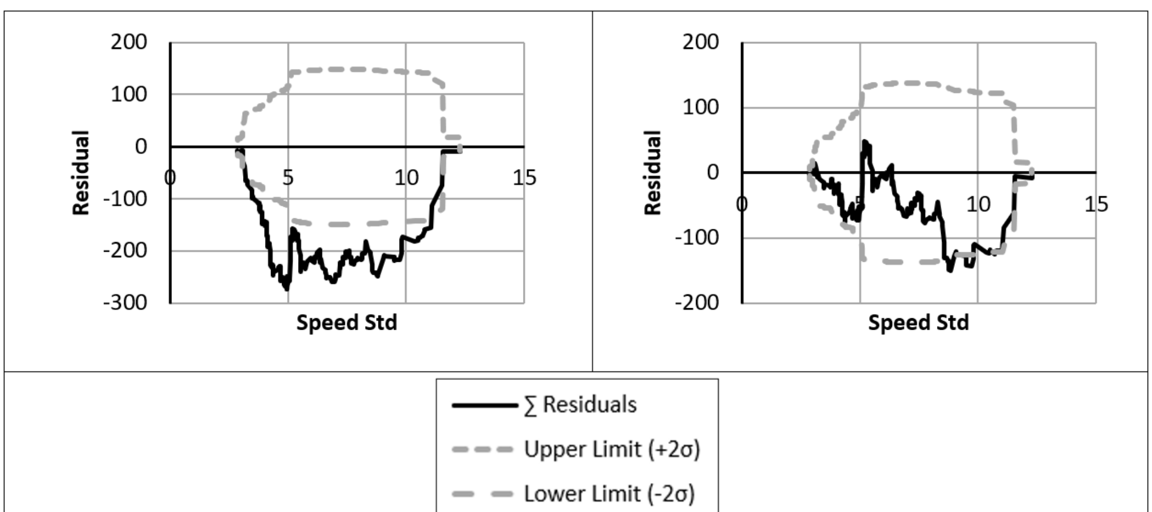
—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 344. Urban freeway speed CMF for KABCO crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.1059 \times x + 0.3651$
R-square	0.94
Speed measure boundaries	(2.90, 12.30)
Base condition	6
t-Test (p-value)	0.07
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.23

Table 345. Urban freeway speed CMF for KABCO crashes (North Carolina).

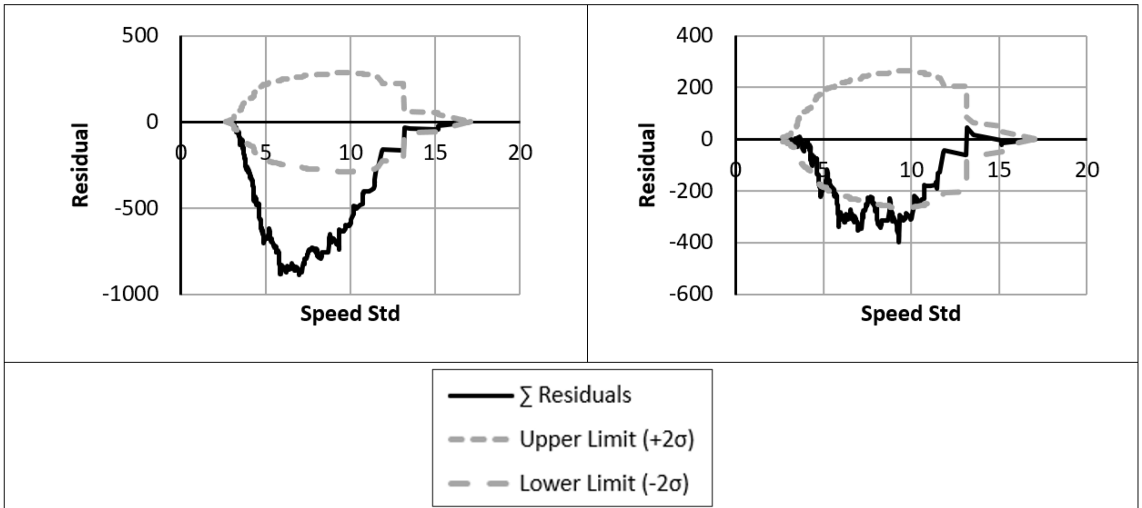
Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.2957 \times x^{0.6163}$
R-square	0.89
Speed measure boundaries	(2.70, 17.10)
Base condition	7
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.17



Crash prediction without speed CMF | *Crash prediction with speed CMF*

Source: FHWA.

Figure 166. Graph. CURE plots of urban freeway speed CMF for KABCO crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 167. Graph. CURE plots of urban freeway speed CMF for KABCO crashes (North Carolina).

Urban Freeway Speed CMF for KABC Crashes

Table 346 to table 349 and figure 168 and figure 169 show the KABC crash severity scale statistics for urban freeways (AASHTO 2014).

Table 346. Urban freeway speed CMF development statistics for KABC crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.90	151	176.2	1.702	—	2.576	—
(SpdAve − PSL)	0.95	151	185.3	1.689	−0.7	2.434	−5.5
|SpdAve − PSL|	0.97	151	185.2	1.688	−0.8	2.433	−5.5
|SpdAve − PSL|	*0.98*	*151*	*186.5*	*1.692*	*−0.6*	*2.435*	*−5.5*
SpdStd/SpdAve	1.04	151	177.6	1.671	−1.8	2.487	−3.5
SpdStd/SpdAve	***1.06***	***151***	***180.1***	***1.635***	***−3.9***	***2.384***	***−7.4***

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 347. Urban freeway speed CMF development statistics for KABC crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.02	298	281.0	1.467	—	2.543	—
SpdStd	1.07	298	272.7	1.425	−2.8	2.433	−4.3
SpdStd	***1.07***	***298***	***271.1***	***1.426***	***−2.8***	***2.428***	***−4.5***
|SpdAve − PSL|	1.08	298	276.9	1.436	−2.1	2.471	−2.8
|SpdAve − PSL|	*1.07*	*298*	*275.4*	*1.429*	*−2.6*	*2.457*	*−3.4*
SpdStd/SpdAve	*1.16*	*298*	*276.0*	*1.430*	*−2.5*	*2.461*	*−3.2*

—Not applicable.

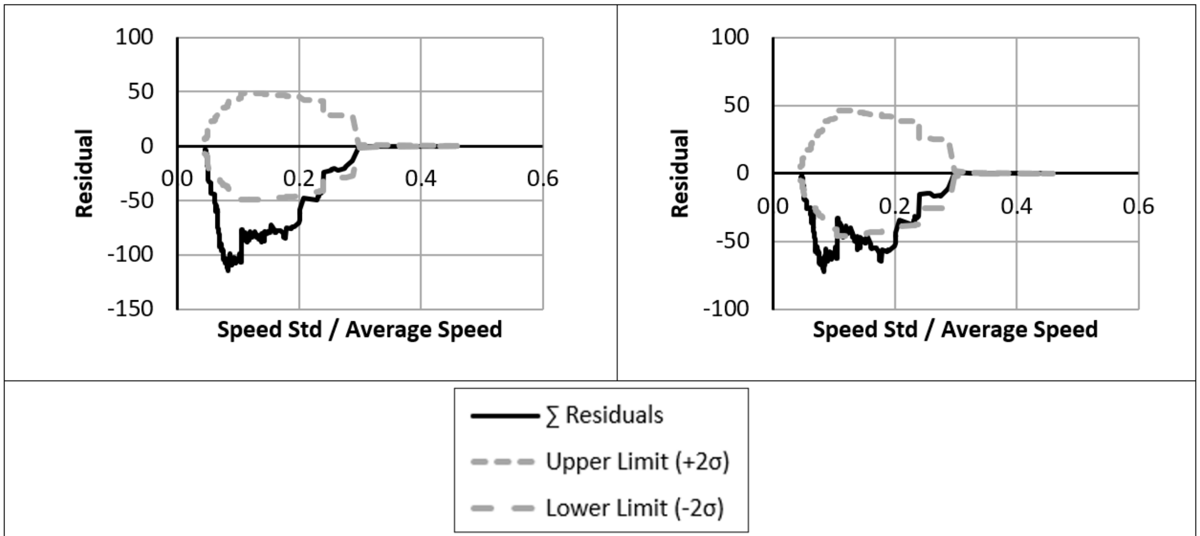
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 348. Urban freeway speed CMF for KABC crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 2.0677 \times x^{0.3962}$
R-square	0.83
Speed measure boundaries	(0.05, 0.46)
Base condition	0.16
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.16

Table 349. Urban freeway speed CMF for KABC crashes (North Carolina).

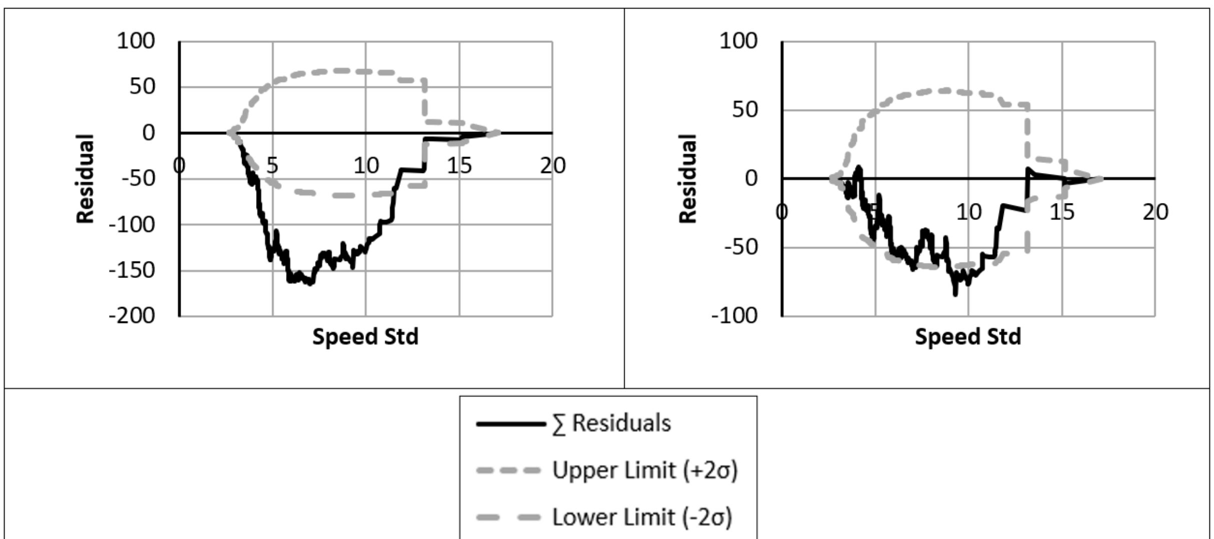
Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.3628 \times x^{0.5196}$
R-square	0.88
Speed measure boundaries	(2.70, 17.10)
Base condition	7
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.17



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 168. Graph. CURE plots of urban freeway speed CMF for KABC crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 169. Graph. CURE plots of urban freeway speed CMF for KABC crashes (North Carolina).

Urban Freeway Speed CMF for O Crashes

Table 350 to table 353 and figure 170 and figure 171 show the O crash severity scale statistics for urban freeways (AASHTO 2014).

Table 350. Urban freeway speed CMF development statistics for O crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.21	420	452.3	3.331	—	5.233	—
SpdStd	**1.24**	**420**	**474.8**	**3.320**	**−0.3**	**4.851**	**−7.3**
SpdStd	*1.24*	*420*	*474.0*	*3.329*	*0.0*	*4.887*	*−6.6*
|SpdAve − PSL|	*1.28*	*420*	*474.1*	*3.402*	*2.1*	*4.993*	*−4.6*
|SpdAve − PSL|	1.28	420	474.7	3.413	2.5	4.998	−4.5
SpdStd/SpdAve	*1.36*	*420*	*461.6*	*3.291*	*−1.2*	*4.962*	*−5.2*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 351. Urban freeway speed CMF development statistics for O crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.63	934	988.5	4.431	—	7.847	—
SpdStd	1.76	934	950.7	4.209	−5.0	7.215	−8.1
SpdStd	***1.77***	***934***	***947.8***	***4.205***	***−5.1***	***7.211***	***−8.1***
|SpdAve − PSL|	1.80	934	968.2	4.232	−4.5	7.274	−7.3
|SpdAve − PSL|	*1.79*	*934*	*965.1*	*4.222*	*−4.7*	*7.246*	*−7.7*
SpdStd/SpdAve	*0.48*	*934*	*975.0*	*4.267*	*−3.7*	*7.455*	*−5.0*

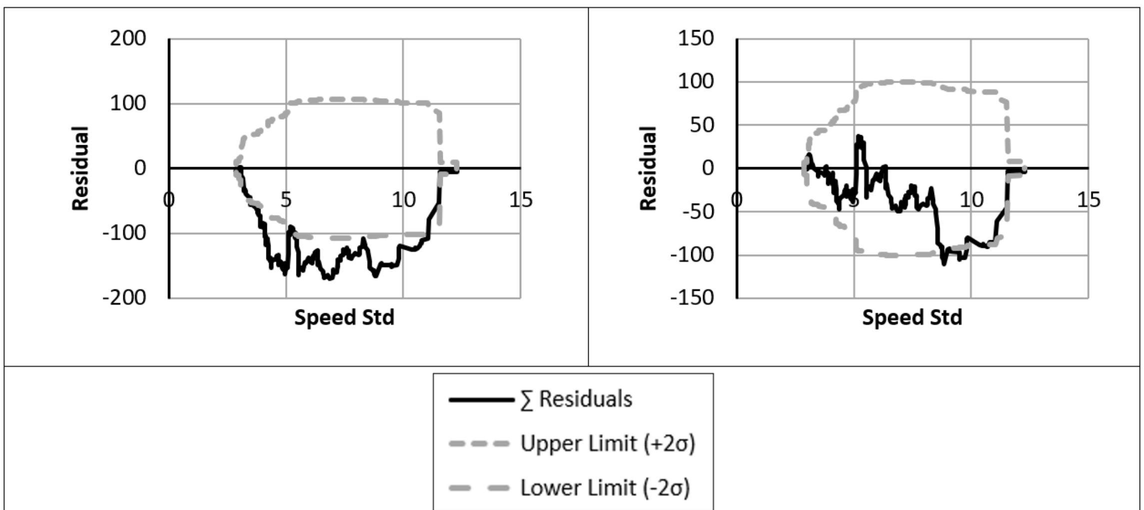
—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 352. Urban freeway speed CMF for O crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.0909 \times x + 0.4516$
R-square	0.97
Speed measure boundaries	(2.90, 12.30)
Base condition	6
t-Test (p-value)	0.04
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.20

Table 353. Urban freeway speed CMF for O crashes (North Carolina).

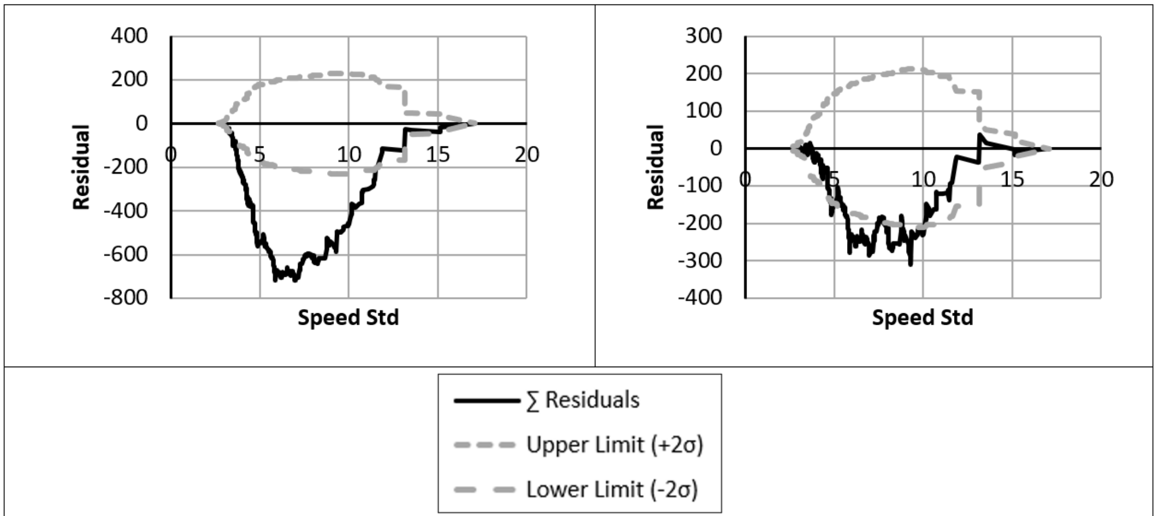
Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.2795 \times x^{0.6422}$
R-square	0.88
Speed measure boundaries	(2.70, 17.10)
Base condition	7
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.20



Crash prediction without speed CMF | *Crash prediction with speed CMF*

Source: FHWA.

Figure 170. Graph. CURE plots of urban freeway speed CMF for O crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 171. Graph. CURE plots of urban freeway speed CMF for O crashes (North Carolina).

Urban Freeway Speed CMF for SVFI Crashes

Table 354 to table 357 and figure 172 and figure 173 show the SVFI statistics for urban freeways (AASHTO 2014).

Table 354. Summary of urban freeway speed CMF development statistics for SVFI crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.61	44	54.3	0.665	—	0.863	—
SpdStd	*0.61*	*44*	*54.1*	*0.667*	*0.3*	*0.868*	*0.6*
(SpdAve − PSL)	**0.63**	**44**	**54.5**	**0.665**	**0.0**	**0.861**	**−0.2**
|SpdAve − PSL|	*0.64*	*44*	*54.6*	*0.666*	*0.2*	*0.862*	*−0.1*
SpdStd/SpdAve	0.58	44	54.2	0.665	0.1	0.865	0.2
SpdStd/SpdAve	*0.60*	*44*	*54.2*	*0.665*	*0.1*	*0.865*	*0.2*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 355. Summary of urban freeway speed CMF development statistics for SVFI crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.91	108	91.8	0.683	—	1.013	—
SpdStd	0.93	108	90.1	0.680	−0.5	1.009	−0.4
SpdStd	*0.94*	*108*	*89.9*	*0.679*	*−0.6*	*1.009*	*−0.4*
SpdStd/SpdAve	0.97	108	91.4	0.681	−0.4	1.011	−0.2
SpdStd/SpdAve	***0.96***	***108***	***90.8***	***0.679***	***−0.6***	***1.009***	***−0.4***
(SpdAve − PSL)	0.93	108	91.2	0.681	−0.3	1.012	0.0

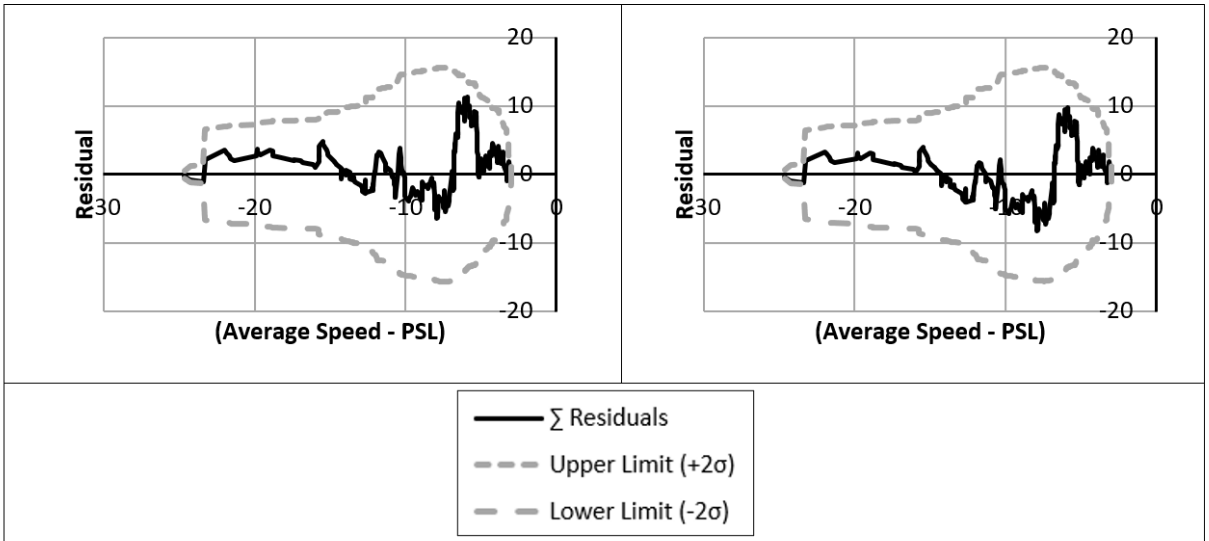
—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 356. Urban freeway speed CMF for SVFI crashes (Washington).

Speed CMF	Value
Speed measure	(SpdAve − PSL)
CMF equation	$y = -0.0057 \times x + 0.9423$
R-square	0.03
Speed measure boundaries	(−24.70, −3.00)
Base condition	−10
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.03

Table 357. Urban freeway speed CMF for SVFI crashes (North Carolina).

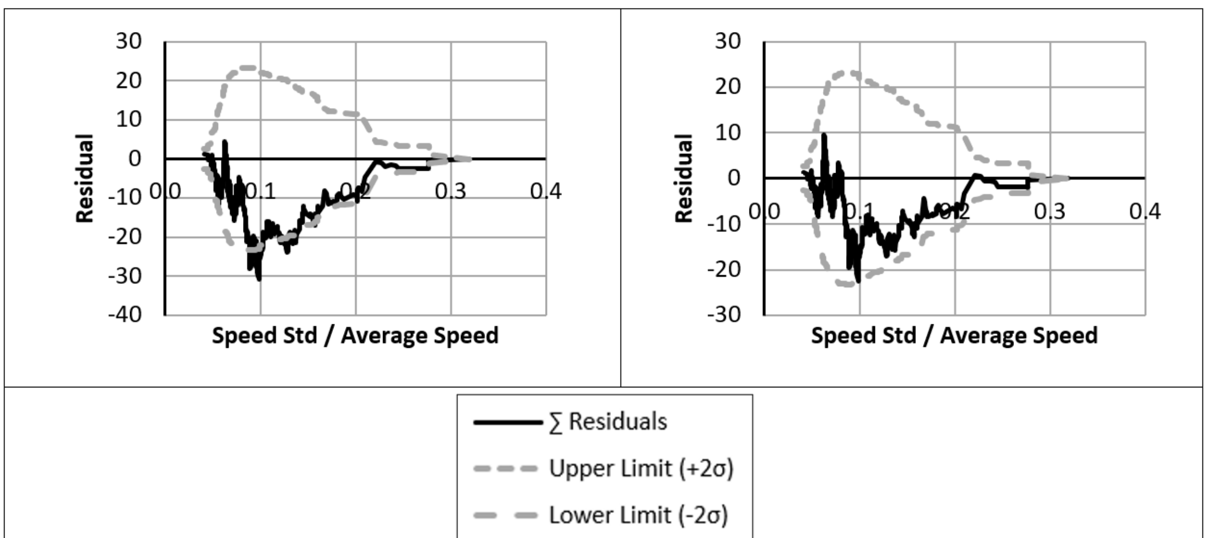
Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 1.28 \times x^{0.1307}$
R-square	0.39
Speed measure boundaries	(0.04, 0.32)
Base condition	0.15
t-Test (*p*-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.05



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 172. Graph. CURE plots of urban freeway speed CMF for SVFI crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 173. Graph. CURE plots of urban freeway speed CMF for SVFI crashes (North Carolina).

Urban Freeway Speed CMF for SVPDO Crashes

Table 358 to table 361 and figure 174 and figure 175 show the SVPDO statistics for urban freeways (AASHTO 2014).

Table 358. Summary of urban freeway speed CMF development statistics for SVPDO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	0.97	160	151.6	1.412	—	2.064	—
SpdStd	0.97	160	153.0	1.418	0.4	2.104	1.9
SpdStd	*0.98*	*160*	*153.1*	*1.426*	*1.0*	*2.126*	*3.0*
|SpdAve − PSL|	**0.99**	**160**	**153.6**	**1.401**	**−0.8**	**2.100**	**1.7**
|SpdAve − PSL|	*0.99*	*160*	*154.2*	*1.410*	*−0.2*	*2.128*	*3.1*
(SpdAve − PSL)	0.99	160	153.8	1.401	−0.8	2.105	2.0

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 359. Summary of urban freeway speed CMF development statistics for SVPDO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.32	302	333.7	1.773	—	2.518	—
SpdStd	1.38	302	327.0	1.686	−4.9	2.388	−5.2
SpdStd	***1.39***	***302***	***325.6***	***1.680***	***−5.3***	***2.379***	***−5.5***
|SpdAve − PSL|	1.39	302	331.4	1.742	−1.8	2.454	−2.6
SpdStd/SpdAve	1.43	302	332.5	1.755	−1.0	2.487	−1.3
SpdStd/SpdAve	*1.42*	*302*	*329.9*	*1.732*	*−2.4*	*2.446*	*−2.9*

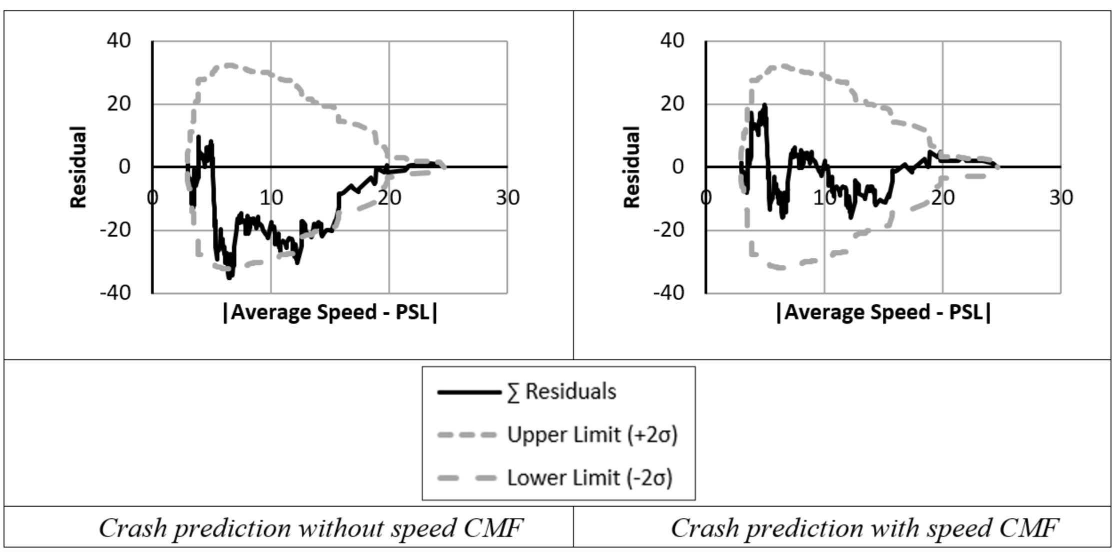
—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 360. Urban freeway speed CMF for SVPDO crashes (Washington).

Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 0.0218 \times x + 0.81$
R-square	0.41
Speed measure boundaries	(3.00, 24.70)
Base condition	9
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.10

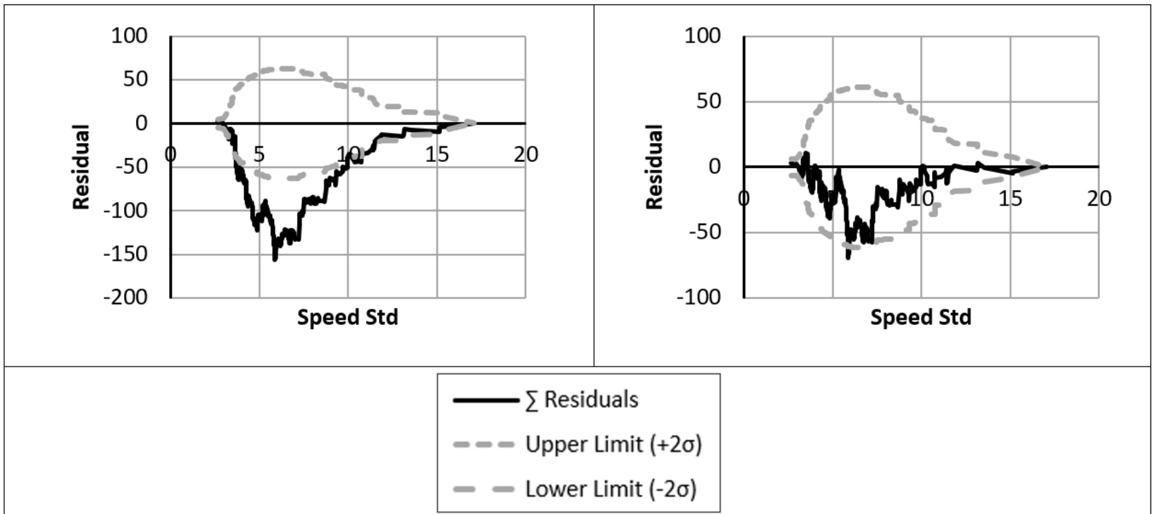
Table 361. Urban freeway speed CMF for SVPDO crashes (North Carolina).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.4335 \times x^{0.4577}$
R-square	0.81
Speed measure boundaries	(2.70, 17.10)
Base condition	6
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.15



Source: FHWA.

Figure 174. Graph. CURE plots of urban freeway speed CMF for SVPDO crashes (Washington).



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 175. Graph. CURE plots of urban freeway speed CMF for SVPDO crashes (North Carolina).

Urban Freeway Speed CMF for MVFI Crashes

Table 362 to table 365 and figure 176 and figure 177 show the MVFI statistics for urban freeways (AASHTO 2014).

Table 362. Summary of urban freeway speed CMF development statistics for MVFI crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.15	107	123.2	1.342	—	2.060	—
SpdStd	**1.19**	**107**	**135.7**	**1.155**	**−14.0**	**1.701**	**−17.4**
(SpdAve − PSL)	1.22	107	135.2	1.296	−3.4	1.898	−7.9
|SpdAve − PSL|	1.28	107	135.3	1.297	−3.4	1.899	−7.8
|SpdAve − PSL|	*1.30*	*107*	*135.4*	*1.304*	*−2.9*	*1.911*	*−7.2*
SpdStd/SpdAve	*1.59*	*107*	*128.7*	*1.239*	*−7.7*	*1.829*	*−11.2*

—Not applicable.
Note: Bold row indicates the best speed CMF; italic row indicates power function.

Table 363. Summary of urban freeway speed CMF development statistics for MVFI crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.06	186	185.0	1.134	—	2.023	—
SpdStd	1.13	186	179.5	1.072	−5.5	1.927	−4.7
SpdStd	***1.12***	***186***	***178.2***	***1.068***	***−5.9***	***1.923***	***−5.0***
(SpdAve − PSL)	1.11	186	181.7	1.099	−3.1	1.948	−3.7
SpdStd/SpdAve	1.29	186	183.9	1.116	−1.6	1.984	−2.0
SpdStd/SpdAve	*1.28*	*186*	*181.5*	*1.096*	*−3.4*	*1.950*	*−3.6*

—Not applicable.

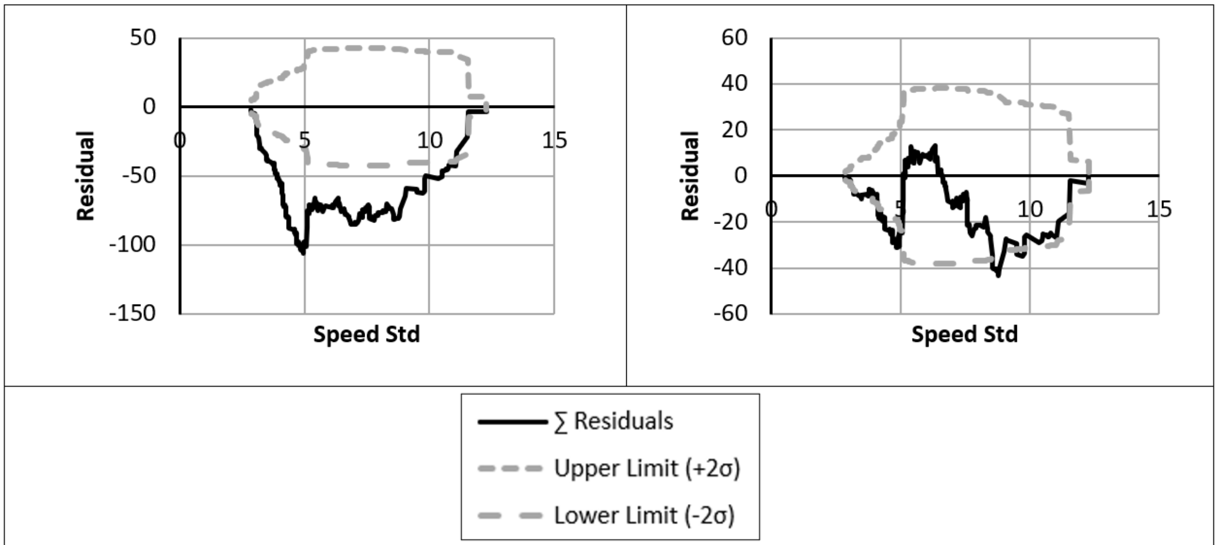
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 364. Urban freeway speed CMF for MVFI crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.2048 \times x - 0.2433$
R-square	0.8
Speed measure boundaries	(2.90, 12.30)
Base condition	6
t-Test (p-value)	0.08
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.44

Table 365. Urban freeway speed CMF for MVFI crashes (North Carolina).

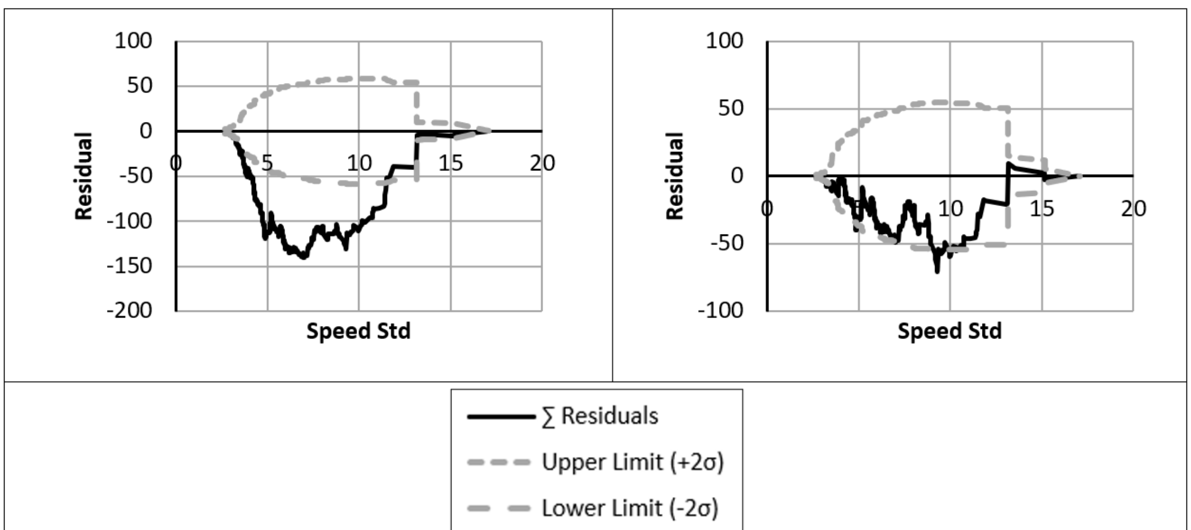
Speed CMF	Value
Speed measure	SpdStd
CMF equation	$y = 0.2565 \times x^{0.6834}$
R-square	0.94
Speed measure boundaries	(2.70, 17.10)
Base condition	7
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.21



Crash prediction without speed CMF | *Crash prediction with speed CMF*

Source: FHWA.

Figure 176. Graph. CURE plots of urban freeway speed CMF for MVFI crashes (Washington).



Crash prediction without speed CMF | *Crash prediction with speed CMF*

Source: FHWA.

Figure 177. Graph. CURE plots of urban freeway speed CMF for MVFI crashes (North Carolina).

Urban Freeway Speed CMF for MVPDO Crashes

Table 366 to table 369 and figure 178 show the MVPDO statistics for urban freeways (AASHTO 2014).

Table 366. Summary of urban freeway speed CMF development statistics for MVPDO crashes (Washington).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.40	260	303.1	2.821	—	4.220	—
(SpdAve − PSL)	1.50	260	337.7	2.618	−7.2	4.027	−4.6
|SpdAve − PSL|	1.56	260	338.2	2.621	−7.1	4.036	−4.4
|SpdAve − PSL|	*1.59*	*260*	*338.6*	*2.634*	*−6.6*	*4.073*	*−3.5*
SpdStd/SpdAve	1.83	260	310.9	2.686	−4.8	3.955	−6.3
SpdStd/SpdAve	***1.93***	***260***	***319.9***	***2.575***	***−8.7***	***3.827***	***−9.3***

—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 367. Summary of urban freeway speed CMF development statistics for MVPDO crashes (North Carolina).

Speed CMF	CF	Observed Crashes (No.)	Predicted Crashes (No.)	MAD	Change (%)	RMSE	Change (%)
HSM default (no speed CMF)	1.79	623	630.8	3.039	—	6.503	—
SpdStd	1.95	623	607.0	2.996	−1.4	6.096	−6.3
SpdStd	*1.96*	*623*	*605.3*	*3.004*	*−1.1*	*6.100*	*−6.2*
|SpdAve − PSL|	1.98	623	615.1	2.907	−4.3	6.030	−7.3
|SpdAve − PSL|	***1.97***	***623***	***612.2***	***2.907***	***−4.3***	***5.997***	***−7.8***
SpdStd/SpdAve	*2.33*	*623*	*616.5*	*2.962*	*−2.5*	*6.137*	*−5.6*

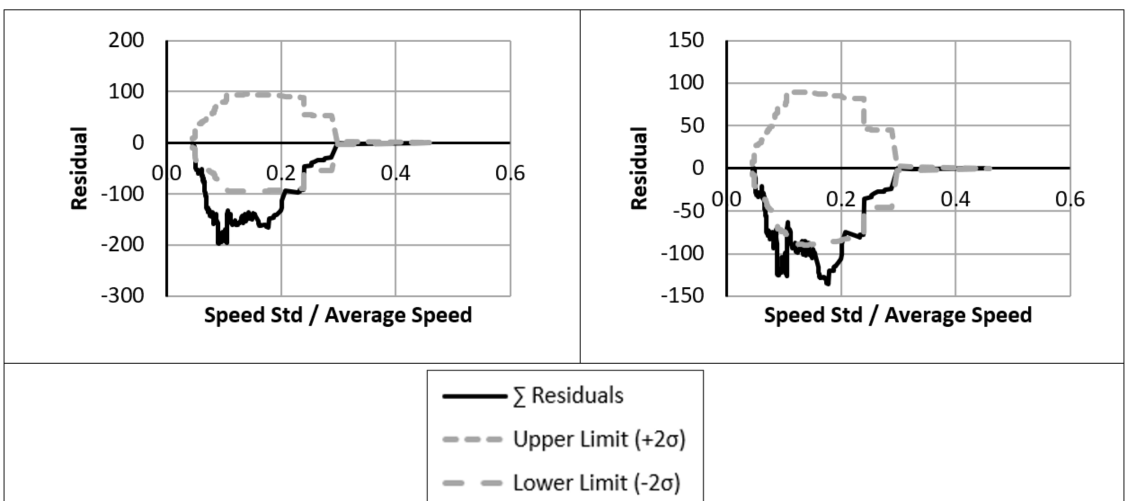
—Not applicable.
Note: Italic row indicates power function; rows that are both bold and italics indicate the best speed CMF with power function.

Table 368. Urban freeway speed CMF of for MVPDO crashes (Washington).

Speed CMF	Value
Speed measure	SpdStd/SpdAve
CMF equation	$y = 1.9858 \times x^{0.391}$
R-square	0.88
Speed measure boundaries	(0.05, 0.46)
Base condition	0.17
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.15

Table 369. Urban freeway speed CMF of for MVPDO crashes (North Carolina).

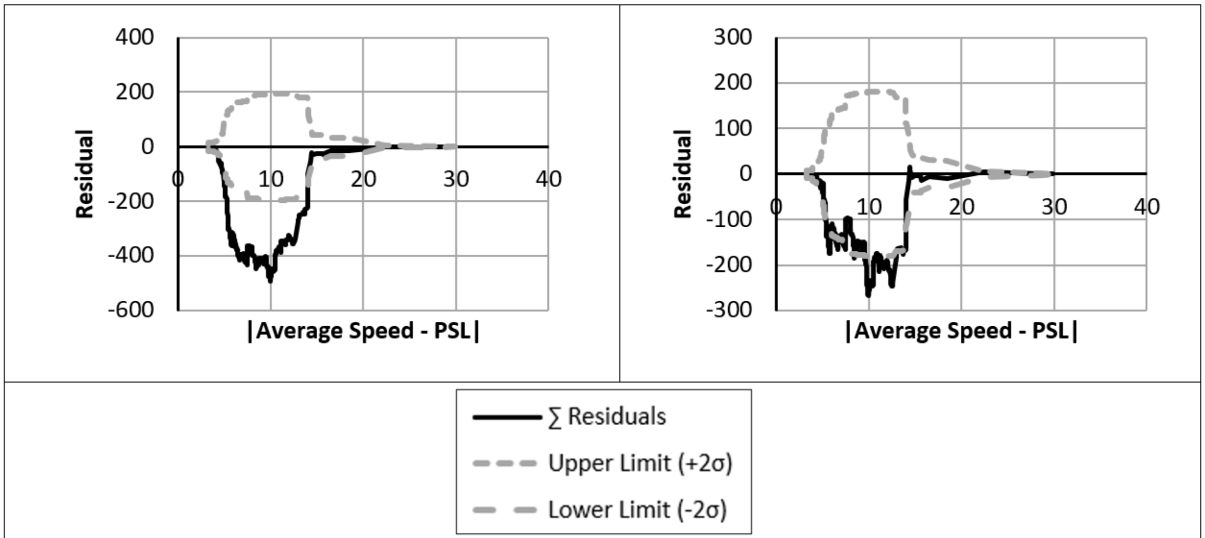
Speed CMF	Value
Speed measure	|SpdAve − PSL|
CMF equation	$y = 0.2652 \times x^{0.5905}$
R-square	0.81
Speed measure boundaries	(3.20, 29.90)
Base condition	9
t-Test (p-value)	0.00
Estimated CMF Clearinghouse star quality rating	★★★ (3)
CMF standard error	0.18



Crash prediction without speed CMF	*Crash prediction with speed CMF*

Source: FHWA.

Figure 178. Graph. CURE plots of urban freeway speed CMF for MVPDO crashes (Washington).



Crash prediction without speed CMF	Crash prediction with speed CMF

Source: FHWA.

Figure 179. Graph. CURE plots of urban freeway speed CMF for MVPDO crashes (North Carolina).

Table 370 and table 371 show the urban freeways CURE plot summary for Washington and North Carolina, respectively.

Table 370. CURE plots summary of urban freeways (Washington).

Crash	Crash Prediction Method	Within CURE (%)	Change to HSM (%)	|Maximum CURE Deviation|	Change to HSM (%)
KABCO	HSM (without speed CMF)	9.15	—	159.29	—
KABCO	HSM × CMF for SpdStd	92.99	84	21.07	−87
KABC	HSM (without speed CMF)	6.40	—	75.67	—
KABC	HSM × CMF for SpdStd	24.70	18	37.45	−51
O	HSM (without speed CMF)	15.55	—	80.14	—
O	HSM × CMF for SpdStd	92.68	77	16.30	−80
SVFI	HSM (without speed CMF)	99.70	—	0.00	—
SVFI	HSM × CMF for SpdStd	99.70	0	0.00	0
SVPDO	HSM (without speed CMF)	91.46	—	4.86	—
SVPDO	HSM × CMF for SpdStd	99.70	8	0.00	−100
MVFI	HSM (without speed CMF)	3.05	—	76.82	—
MVFI	HSM × CMF for SpdStd	66.46	63	12.51	−84
MVPDO	HSM (without speed CMF)	9.15	—	119.89	—
MVPDO	HSM × CMF for SpdStd	32.32	23	54.79	−54

—Not applicable.

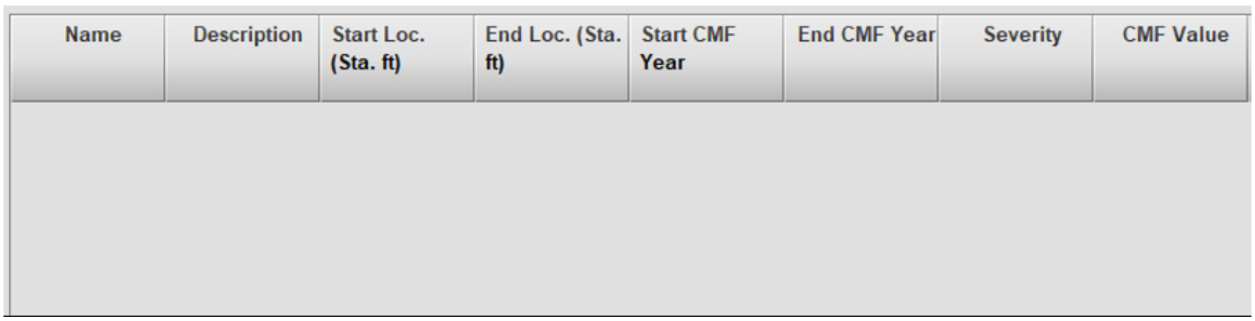
Table 371. CURE plots summary of urban freeways (North Carolina).

Crash	Crash Prediction Method	Within CURE (%)	Change to HSM (%)	|Maximum CURE Deviation|	Change to HSM (%)
KABCO	HSM (without speed CMF)	3.57	—	637.62	—
KABCO	HSM × speed CMF	59.59	56	131.58	−79
KABC	HSM (without speed CMF)	3.57	—	99.66	—
KABC	HSM × speed CMF	92.87	89	20.21	−80
O	HSM (without speed CMF)	3.90	—	523.47	—
O	HSM × speed CMF	59.25	55	109.92	−79
SVFI	HSM (without speed CMF)	82.00	—	7.60	—
SVFI	HSM × speed CMF	99.83	18	0.00	−100
SVPDO	HSM (without speed CMF)	11.88	—	93.52	—
SVPDO	HSM × speed CMF	97.96	86	9.18	−90
MVFI	HSM (without speed CMF)	2.55	—	88.32	—
MVFI	HSM × speed CMF	90.32	88	16.45	−81
MVPDO	HSM (without speed CMF)	4.24	—	298.55	—
MVPDO	HSM × speed CMF	57.89	54	86.11	−71

—Not applicable.

APPENDIX G. IMPLEMENTATION CASE

The developed speed CMFs in this study can be added to the CMF Clearinghouse and can also be implemented in HSM-related evaluation tools, such as FHWA's Interactive Highway Safety Design Model (IHSDM) (FHWA 2023a, 2023b). IHSDM provides the capability of including "User Defined CMFs" in crash prediction module (CPM) evaluations (figure 180). The IHSDM allows for the integration of user-defined CMFs into the HSM Part C crash prediction models. These CMFs are termed "external" because they can be sourced from various external references chosen by the user, such as CMFs from Part D of the HSM or any CMF available in the CMF Clearinghouse (FHWA 2023b).



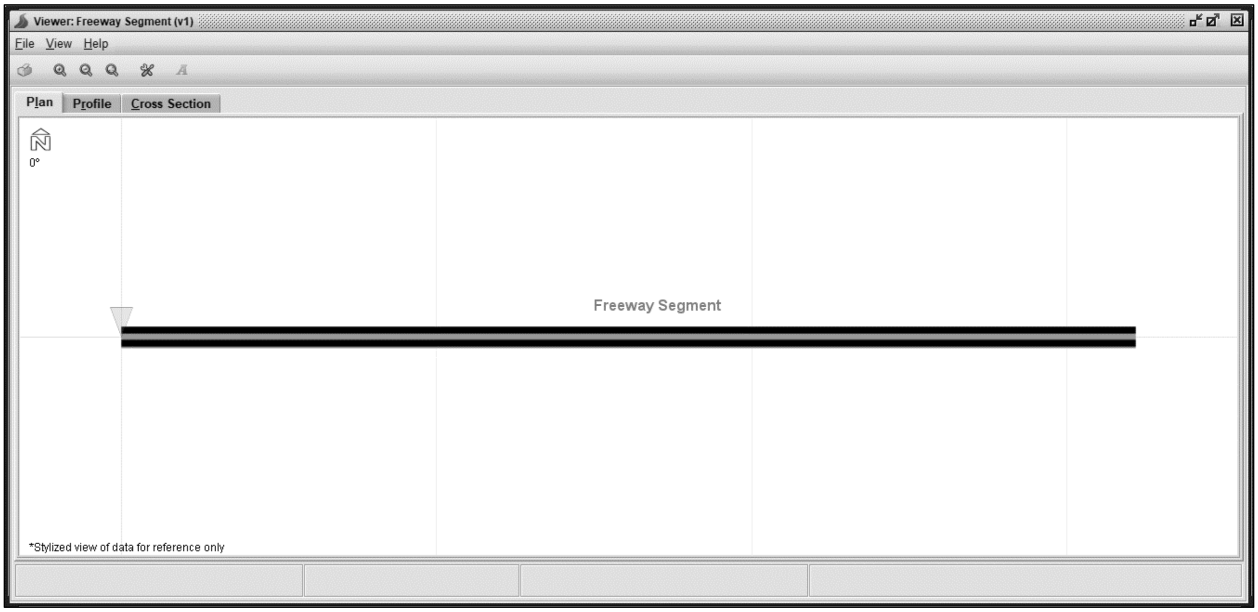
Source: FHWA. Created using IHSDM software.

Figure 180. Screenshot. "User-Defined CMF" editor in IHSDM (FHWA 2023b).

As an example, the following assumptions are made for an example freeway segment in Alabama (a State other than Washington is used for demonstration purposes):

- Rural freeway segment: 1.0 mi.
- Annual average daily traffic (AADT): 120,000.
- SpdStd: 7.5 mph.
- Washington equation used: $Speed_{CMF} = 0.3731 \times (SpdStd)^{0.6237} = 0.3731 \times (7.5)^{0.6237} = 1.31$.
- CFs assumed to be 1.0.
- Base conditions for the rest.
- Analysis period: 2022–27.

The simple tangent 1.0-mi freeway segment is shown in figure 181. The entered required information in "User-Defined CMF" editor in IHSDM is shown in figure 182.



Source: FHWA. Created using IHSDM software.

Figure 181. Screenshot. Sample 1.0-mi freeway segment in IHSDM (FHWA 2023b).

Name	Description	Start Loc. (Sta. ft)	End Loc. (Sta. ft)	Start CMF Year	End CMF Year	Severity	CMF Value
Speed Std	Speed Std = 7.5 (using WA Eq.)	0.000	52+80.000			Total	1.3100

Source: FHWA. Created using IHSDM software.

Figure 182. Screenshot. "User-Defined CMF" editor in IHSDM with entered information for test case speed CMF (FHWA 2023b).

Running the CPM evaluation twice—the first time for the HSM default and the second time for the HSM default and external speed CMF—resulted in two different sets of predicted crashes, as shown in figure 183. For the example 1.0-mi freeway segment, the total predicted crashes were 147.10 based on using HSM default crash prediction for 2022–27 period; however, after the speed CMF was applied to the HSM default crash prediction, the total predicted crashes increased to 192.70. Fatal and injury crashes increased from 51.02 to 66.83 and PDO crashes increased from 96.08 to 125.87.

HSM Default

First Year of Analysis	2022
Last Year of Analysis	2027
Effective Length (mi)	1.0000
Average Future Road AADT (vpd)	120,000
Predicted Crashes	
Total Crashes	147.10
Fatal and Injury Crashes	51.02
Property-Damage-Only Crashes	96.08
Percent of Total Predicted Crashes	
Percent Fatal and Injury Crashes (%)	35
Percent Property-Damage-Only Crashes (%)	65

HSM Default x Speed CMF

First Year of Analysis	2022
Last Year of Analysis	2027
Effective Length (mi)	1.0000
Average Future Road AADT (vpd)	120,000
Predicted Crashes	
Total Crashes	192.70
Fatal and Injury Crashes	66.83
Property-Damage-Only Crashes	125.87
Percent of Total Predicted Crashes	
Percent Fatal and Injury Crashes (%)	35
Percent Property-Damage-Only Crashes (%)	65

Source: FHWA. Created using IHSDM software.

Figure 183. Screenshot. Comparison of HSM default and HSM default × speed CMF for test case speed CMF (FHWA 2023b).

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