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MARYLAND DEPARTMENT OF TRANSPORTATION STATE HIGHWAY ADMINISTRATION RESEARCH REPORT

THE DEVELOPMENT OF LOCAL CALIBRATION FACTORS – PHASE II: MARYLAND FREEWAYS AND RAMPS

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16. Abstract

The goal of the study was to develop local calibration factors (LCFs) for Maryland freeways in order to apply the predictive methods of the Highway Safety Manual (HSM) to the state. LCFs were computed for freeway segments, speed-change lanes, and signalized and stop-controlled ramp terminals (intersections of the entrance/exit ramps and the crossroads). Ramps (facilities connecting local roads to freeway travel lanes) and collector-distributor roads were excluded from the study due to insufficient historical crash data. LCFs for the studied facility types were smaller than 1.0, implying on average Maryland had fewer crashes than predicted crashes estimated by the HSM predictive method during the study period. LCFs for ramp terminals were extremely low. Due to potential under-reporting of property damage only (PDO) crashes on ramps, it is recommended that applying LCFs developed with PDO crashes should be done with caution. The report concludes with a discussion on the interpretation of LCFs and data limitations. It should be noted that Baltimore City was not part of this study.

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EXECUTIVE SUMMARY

The purpose of the study was to develop local calibration factors (LCFs) for freeways in Maryland, using the Highway Safety Manual (HSM) supplement (2014). The supplement added four additional facility types (freeway segments, speed-change lanes, ramps and collector-distributor (C-D) roads, and crossroad ramp terminals). A ramp is a facility that connects local roads to freeway travel lanes; on the other hand, a ramp terminal is defined as the intersection of either the entrance or exit ramp and the crossroad.

The initial data set of these four facility types in Maryland had approximately 2.569 million data points. After cleaning and customizing them for the study purpose, samples were drawn and additional required/desirable data were gathered for sampled sites. The average predicted crash frequency by facility type was computed using the interactive highway safety design model (IHSDM). The predicted frequency was compared to observed number of crashes to derive LCFs. Maryland LCFs were all smaller than 1.0, implying Maryland had on average fewer crashes than predicted crashes estimated by HSM default methods (Table 1). LCFs for ramp terminals were extremely low. After the comparison of HSM default crash proportion and the Maryland-specific data, the use of the Maryland data was suggested. Due to potential under-reporting of minor and property damage only (PDO) crashes on ramps, it is recommended that using LCFs including PDO crashes should be done with caution. The LCFs are summarized in Table **1**. As a note, due to insufficient crash data, LCFs of ramps and collector-distributor (C-D) roads were not computed in this study.

Table 1. Summary of Maryland LCFs (2008-2010)

Facility	Crash Type	Number of Segments	Observed Crashes	Predicted Crashes	LCF
Freeways	FI MV	564	1,190	2,617.94	0.4546
	PDO MV	564	1,890	6,610.84	0.2859
	FI SV	564	910	1,451.53	0.6269
	PDO SV	564	1,735	2,705.70	0.6412
Speed-Change Lanes	FI En	264	358	605.63	0.5911
	PDO En	264	600	1,139.64	0.5265
	FI Ex	254	336	438.32	0.7666
	PDO Ex	254	572	649.53	0.8806
Ramp Terminals	ST FI*	147	83	122.85	0.6756
	SG FI	172	425	1,213.81	0.3501
	ST PDO*	147	77	203.91	0.3776
	SG PDO	172	511	1,690.71	0.3022
Ramps & C-D Roads	Insufficient Crash Data				

Notes: Asterisks: facility types that did not meet the HSM minimum annual crashes of 100; MV: multiple vehicle crashes; SV: single vehicle crashes; FI: Fata and injury crashes; PDO: Crashes with property damage only; ST: Stop-controlled intersection; SG: Signalized intersection; En: Ramp-entrance speed-change lane; and Ex: Ramp-exit speed change lane

INTRODUCTION

The Highway Safety Manual (HSM), published in 2010, has provided researchers and practitioners with tools to measure the potential safety impacts of existing, proposed and planned highways at the site, corridor and system levels (AASHTO, 2010). The incorporation of the HSM procedures will help transportation agencies make evidence-based informed investment decisions.

Building on the successful completion of the Phase I study (Shin, Lee, & Dadvar, 2014) that developed Local Calibration Factors (LCF) for roadways maintained by the Maryland Department of Transportation State Highway Administration (SHA), this phase II project calculated LCFs for freeways in Maryland using the data between 2008 and 2010. An LCF is, for a given facility type during a specified time period, a ratio of the sum of the observed crashes to the predicted crashes using a corresponding safety performance function (SPF) of the Highway Safety Manual (HSM) (AASHTO, 2010). The purpose of LCFs is to account for study area specific attributes that cannot be captured by the HSM's base SPFs—for example, climate, driver populations, crash reporting thresholds and others.

This report discusses LCF development procedures, including data collection and compilation; crash frequency analysis; and LCF computation for freeway segments, speed-change lanes, and ramp terminals. Using data provided by SHA and supplementary data collected or estimated from various sources, twelve LCFs were developed. It should be noted that LCFs for ramps and collector-distributor roads were not developed due to a lower number of crashes (222 crashes for the three-year study period) than the minimum threshold (300 crashes) of the HSM. In addition, the facility types within Baltimore City were not part of this study.

Study Objectives

The primary goal was to explore the recommended calibration procedures and compute LCFs for Maryland-specific application to freeways and ramps. The specific objectives are to:

1) Conduct an in-depth review of the HSM chapters for freeways and ramps;
2) Identify the HSM's data requirements, collect readily available data;
3) Develop additional data collection strategies and supplement the original data sets obtained from SHA;
4) Compute predicted crash frequencies by site type, crash types, and crash severities employing the HSM's SPFs; and
5) Derive LCFs by comparing predicted and observed crashes.

Report Structure

The following chapter provides a review of literature that includes a brief introduction of the HSM and its predictive methods and the commonly identified issues from a few previous LCF development studies. Then, data collection, compilation, and limitations are discussed. After describing the LCF process, Maryland-specific LCFs are presented. The last chapter summarizes the discussion of the developed LCFs, findings of the study, barriers that the study team encountered, and future study suggestions.

THE NEW HSM CHAPTERS

The HSM supplement contains two new chapters (AASHTO, 2014). Chapter 18 covers predictive methods for freeway facilities:

- Rural freeway segment with four to eight lanes and urban freeways segments with four to ten lanes (Table 2)
    - *A freeway segment* is defined as a length of freeway consisting of *n* through-lanes with a constant cross section providing two directions of travel physically separated by a median. SPFs for freeway segments are divided further by (1) crash types—multiple vehicle crashes (MV) and single vehicle crashes (SV) and (2) by crash severity types—fatal and injury crashes (FI) and property damage only crashes (PDO).
- Freeway speed-change lanes associated with entrance ramps and exit ramps (Table 3).
    - *A speed-change lane* is defined as a *ramp entrance (EN)* or *ramp exit (EX).* The SPFs are further divided by crash severity—FI and PDO.

Chapter 19 provides predictive methods for ramps:

- Ramp segments or collector-distributor (C-D) roadways (Table 4).
    - They are defined as a length of roadways (one or two lanes) with a constant cross section providing one direction of travel. Crashes are predicted by MV and SV; and FI and PDO.
- Crossroad ramp terminals (Table 5).
    - *A crossroad ramp terminal* is a controlled terminal between a ramp and a crossroad. Crossroad ramp terminal crashes are predicted by traffic control types and crash severity (FI and PDO).

The *Used Acronym* in the below tables is the redefined acronyms by the study team in order to make HSM's definitions intuitive and self-explanatory.

Table 2. Freeway Segments

Area Type	Cross Section	HSM Acronym	Used Acronym	Crash Type	Crash Severity
Rural	Four-lane divided	4	RF4	MV or SV	FI or PDO
	Six-lane divided	6	RF6	MV or SV	FI or PDO
	Eight-lane divided	8	RF8	MV or SV	FI or PDO
Urban	Four-lane divided	4	UF4	MV or SV	FI or PDO
	Six-lane divided	6	UF6	MV or SV	FI or PDO
	Eight-lane divided	8	UF8	MV or SV	FI or PDO
	Ten-lane divided	10	UF10	MV or SV	FI or PDO

Notes: R - rural; U - urban; F - freeway; MV - multiple vehicle crashes; SV - single vehicle crashes; FI - fatal and injury crashes; and PDO - property damage only crashes

Table 3. Speed-Change Lanes

Area Type	Cross Section	HSM Acronym	Used Acronym	Crash Type	Crash Severity
Rural	Ramp entrance to four-lane divided	4EN	RSCen4	All	FI or PDO
	Ramp entrance to six-lane divided	6EN	RSCen6	All	FI or PDO
	Ramp entrance to eight-lane divided	8EN	RSCen8	All	FI or PDO
	Ramp exit from four-lane divided	4EX	RSCex4	All	FI or PDO
	Ramp exit from six-lane divided	6EX	RSCex6	All	FI or PDO
	Ramp exit from eight-lane divided	8EX	RSCex8	All	FI or PDO
Urban	Ramp entrance to four-lane divided	4EN	USCen4	All	FI or PDO
	Ramp entrance to six-lane divided	6EN	USCen6	All	FI or PDO
	Ramp entrance to eight-lane divided	8EN	USCen8	All	FI or PDO
	Ramp entrance to ten-lane divided	10EN	USCen10	All	FI or PDO
	Ramp exit from four-lane divided	4EX	USCex4	All	FI or PDO
	Ramp exit from six-lane divided	6EX	USCex6	All	FI or PDO
	Ramp exit from eight-lane divided	8EX	USCex8	All	FI or PDO
	Ramp exit from ten-lane divided	10EX	USCex10	All	FI or PDO

Table 4. Ramps and Collector-Distributor Road Segments

Area Type	Cross Section	HSM Acronym	Used Acronym	Crash Type	Crash Severity
Rural	One-lane entrance ramp	1EN	RRmen1	MV or SV	FI or PDO
	One-lane exit ramp	1EX	RRmex1	MV or SV	FI or PDO
	One-lane C-D road	1	RCD1	MV or SV	FI or PDO
Urban	One-lane entrance ramp	1EN	URmen1	MV or SV	FI or PDO
	Two-lane entrance ramp	2EN	URmen2	MV or SV	FI or PDO
	One-lane exit ramp	1EX	URmex1	MV or SV	FI or PDO
	Two-lane exit ramp	2EX	URmex2	MV or SV	FI or PDO
	One-lane C-D road	1	UCD1	MV or SV	FI or PDO
	Two-lane C-D road	2	UCD2	MV or SV	FI or PDO

Table 5. Ramp Terminals

Area Type	Ramp Terminal Site Type	Cross Section	Control Type	HSM Acronym	Used Acronym	Crash Type	Crash Severity
Rural	A2	2-4 lanes	ST	NA	RA$_{2}$ST	All types	FI or PDO
	A2	2-4 lanes	SG	NA	RA$_{2}$SG	All types	FI or PDO
	A4	2-4 lanes	ST	NA	RA$_{4}$ST	All types	FI or PDO
	A4	2-4 lanes	SG	NA	RA$_{4}$SG	All types	FI or PDO
	B2	2-4 lanes	ST	NA	RB$_{2}$ST	All types	FI or PDO
	B2	2-4 lanes	SG	NA	RB$_{2}$SG	All types	FI or PDO
	B4	2-4 lanes	ST	NA	RB$_{4}$ST	All types	FI or PDO
	B4	2-4 lanes	SG	NA	RB$_{4}$SG	All types	FI or PDO
	D3en	2-4 lanes	ST	NA	RD$_{3en}$ST	All types	FI or PDO
	D3en	2-4 lanes	SG	NA	RD$_{3en}$SG	All types	FI or PDO
	D3ex	2-4 lanes	ST	NA	RD$_{3ex}$ST	All types	FI or PDO
	D3ex	2-4 lanes	SG	NA	RD$_{3ex}$SG	All types	FI or PDO
	D4	2-4 lanes	ST	NA	RD$_{4}$ST	All types	FI or PDO
	D4	2-4 lanes	SG	NA	RD$_{4}$SG	All types	FI or PDO
Urban	A2	2-6 lanes	ST	NA	UA$_{2}$ST	All types	FI or PDO
	A2	2-6 lanes	SG	NA	UA$_{2}$SG	All types	FI or PDO
	A4	2-6 lanes	ST	NA	UA$_{4}$ST	All types	FI or PDO
	A4	2-6 lanes	SG	NA	UA$_{4}$SG	All types	FI or PDO
	B2	2-6 lanes	ST	NA	UB$_{2}$ST	All types	FI or PDO
	B2	2-6 lanes	SG	NA	UB$_{2}$SG	All types	FI or PDO
	B4	2-6 lanes	ST	NA	UB$_{4}$ST	All types	FI or PDO
	B4	2-6 lanes	SG	NA	UB$_{4}$SG	All types	FI or PDO
	D3en	2-6 lanes	ST	NA	UD$_{3en}$ST	All types	FI or PDO
	D3en	2-6 lanes	SG	NA	UD$_{3en}$SG	All types	FI or PDO
	D3ex	2-6 lanes	ST	NA	UD$_{3ex}$ST	All types	FI or PDO
	D3ex	2-6 lanes	SG	NA	UD$_{3ex}$SG	All types	FI or PDO
	D4	2-6 lanes	ST	NA	UD$_{4}$ST	All types	FI or PDO
	D4	2-6 lanes	SG	NA	UD$_{4}$SG	All types	FI or PDO

Predictive Method

The predictive method includes safety performance functions (SPFs) for estimating the expected average crash frequency (by crash type and severity) for each facility type. It consists of eighteen sequential steps with a feedback loop, which can be applied to existing facility types, design alternatives for improving an existing freeway and planning a new freeway. (AASHTO, 2014). A general form of a predictive model consists of three components as shown below.

Equation 1. Calibrated Predicted Crash Frequency

$$N_{p,w,x,y,z} = \underbrace{N_{spf,w,x,y,z}}_{(1)} \times \underbrace{\left(CMF_{1,w,x,y,z} \times CMF_{2,w,x,y,z} \times \ldots \times CMF_{m,w,s,y,z}\right)}_{(2)} \times \underbrace{C_{w,x,y,z}}_{(3)}$$

Where,

$N_{p,w,x,y,z}$	Predicted annual average crash frequency for a study year for site type, *w*, cross section/control type, *x*, crash type, *y*, and severity, *z*.
$N_{spf,w,x,y,z}$	Predicted annual average crash frequency determined for base conditions of the SPF developed for site type, *w*, cross section or control type, *x*, crash type, *y*, and severity, *z*.
$CMF_{m,w,x,y,z}$	Crash modification factors of site type, *w*, cross section or control type, *x*, crash type, *y*, and severity, *z* for specific geometric design and traffic control features.
$C_{w,x,y,z}$	Calibration factor to adjust SPF for local conditions for site type, *w*, cross section or control type, *x*, crash type, *y*, and severity, *z*.

The first part of Equation 1$N_{spf,w,x,y,z}$, is the base SPF. Depending on facility types, a base SPF is defined as a function of AADT and segment length or AADT only. The second part of Equation 1 is a set of crash modification factors (CMFs). A CMF is a multiplicative factor and is used for evaluating the crash impact of a geometric condition (Crash Modification Factors Clearninghouse). A CMF may have value either equal to, less than (i.e., reduction in crashes), or greater than 1.0 (increase in crashes). The predicted crash frequency computed by the base SPF, $N_{spf,w,x,y,z}$, remains the same or changes depending on CMF values of geometric attributes of the segment.

While various combinations of crash types, control types, number of lanes and crash severity, shown in Table 2 through 5 yield 288 facility types, LCFs for 24 parent facility types (Table 7) cover all 288 individual facility types. It was clarified by the author of the new chapters, Dr. James Bonneson, stating that:

> *"The effect of area type is accurately quantified by the model and require no special calibration by area type. … [To] accurately quantify the LCF for a given combination of crash type and severity category, you should include in the set of calibration sites a representative mixture of 4, 6, 8, and 10 lanes and urban, rural sites."*

The study team followed Dr. Bonneson's advice. However, as a matter of research and curiosity and also like one of the past studies in Missouri , the study team also developed LCFs that are further disaggregated by area type, cross section and/or ramp terminal configuration type in addition to the 24 LCFs. The results and recommendations are presented in Appendix G.

Table 6 shows CMFs used by facility types (AASHTO, 2014). When predicting the average crash frequency, freeway segments require the most (11) CMFs, followed by signalized ramp terminal (9 CMFs). The last part of Equation 1 is an LCF. The LCF is developed to account for visible and invisible local-specific conditions such as climate, driver populations, animal populations, and crash reporting thresholds that cannot be captured by the base SPFs and CMFs. An LCF is computed as follows:

Equation 2. Calculation of Local Calibration Factor

$$LCF = \frac{\sum_{All\ sites} N_{Observed}}{\sum_{All\ sites} N_{Predicted\ (Uncalibrated)}}$$

Where,

$N_{Predicted\ (Uncalibrated)}$ Uncalibrated total predicted crash frequency.
$N_{Objerved}$ Total number of observed crashes during the study period.

While various combinations of crash types, control types, number of lanes and crash severity, shown in Table 2 through 5 yield 288 facility types, LCFs for 24 parent facility types (Table 7) cover all 288 individual facility types. It was clarified by the author of the new chapters, Dr. James Bonneson, stating that:

> *"The effect of area type is accurately quantified by the model and require no special calibration by area type. … [To] accurately quantify the LCF for a given combination of crash type and severity category, you should include in the set of calibration sites a representative mixture of 4, 6, 8, and 10 lanes and urban, rural sites."*

The study team followed Dr. Bonneson's advice. However, as a matter of research and curiosity and also like one of the past studies in Missouri (Sun, Brown, Edara, Claros, & Nam, 2014), the study team also developed LCFs that are further disaggregated by area type, cross section and/or ramp terminal configuration type in addition to the 24 LCFs. The results and recommendations are presented in Appendix G.

Table 6. CMFs for Facility Types of the HSM Supplement to the 1st Edition

Crash Modification Factor		Facility Type							Total
		Freeway Segments	Ramp Entrance (Speed-Change Lanes)	Ramp Exit (Speed-Change Lanes)	Ramps	Collector-Distributor Roads	Ramp Terminals (Signalized)	Ramp Terminals (Stop-Controlled)	
1	CMF for Horizontal Curves	*	*	*	*	*			5
2	CMF for Lane Width	*	*	*	*	*			5
3	CMF for Inside Shoulder Width	*	*	*					3
4	CMF for Median Width	*	*	*					3
5	CMF for Median Barrier	*	*	*					3
6	CMF for High Volume	*	*	*					3
7	CMF for Lane Change	*							1
8	CMF for Outside Shoulder Width	*							1
9	CMF for Shoulder Rumble Strip	*							1
10	CMF for Outside Clearance	*							1
11	CMF for Outside Barrier	*							1
12	CMF for Ramp Entrances		*						1
13	CMF for Ramp Exits			*					1
14	CMF for Right Shoulder Width				*	*			2
15	CMF for Left Shoulder Width				*	*			2
16	CMF for Right Side Barrier				*	*			2
17	CMF for Left Side Barrier				*	*			2
18	CMF for Lane add or drop				*	*			2
19	CMF for Ramp Speed-Change Lane				*	*			2
20	CMF for Weaving Section					*			1
21	CMF for Exit Ramp Capacity						*	*	2
22	CMF for Crossroad Left-Turn Lane						*	*	2
23	CMF for Crossroad Right-Turn Lane						*	*	2
24	CMF for Access Point Frequency						*	*	2
25	CMF for Segment Length						*	*	2
26	CMF for Median Width						*	*	2
27	CMF for Protected Left-Turn Operation						*		1
28	CMF for Channelized Right Turn on Crossroad						*		1
29	CMF for Channelized Right Turn on Exit Ramp						*		1
30	CMF for Non-Ramp Public Street Leg						*		1
31	CMF for Skew Angle							*	1
Total		11	7	7	8	9	10	7	59

Source: (AASHTO, 2014)

Table 7. Predictive Models in Chapters 18 and 19 that Need Calibration

Chapter	Facility Type	Site Type and Cross Section or Control Type
Chapter 18	Freeways	Multiple-vehicle fatal and injury crashes, all cross sections
		Multiple-vehicle property damage only crashes, all cross sections
		Single-vehicle fatal and injury crashes, all cross sections
		Single-vehicle property damage only crashes, all cross sections
	Speed-Change Lanes	Ramp entrance speed-change lane, fatal and injury crashes of all types
		Ramp entrance speed-change lane, property damage only crashes of all types
		Ramp exit speed-change lane, fatal and injury crashes of all types
		Ramp exit speed-change lane, property damage only crashes of all types
Chapter 19	Ramps & C-D Roads	Entrance ramp, multiple-vehicle fatal and injury crashes, all lanes
		Entrance ramp, multiple-vehicle property damage only crashes, all lanes
		Entrance ramp, single-vehicle fatal and injury crashes, all lanes
		Entrance ramp, single-vehicle property damage only crashes, all lanes
		Exit ramp, multiple-vehicle fatal and injury crashes, all lanes
		Exit ramp, multiple-vehicle property damage only crashes, all lanes
		Exit ramp, single-vehicle fatal and injury crashes, all lanes
		Exit ramp, single-vehicle property damage only crashes, all lanes
		C-D road, multiple-vehicle fatal and injury crashes, all lanes
		C-D road, multiple-vehicle property damage only crashes, all lanes
		C-D road, single-vehicle fatal and injury crashes, all lanes
		C-D road, single-vehicle property damage only crashes, all lanes
	Ramp Terminals	One-way stop control, fatal and injury crashes of all types
		One-way stop control, property damage only crashes of all types
		Signal control, fatal and injury crashes of all types
		Signal control, property damage only crashes of all types

LITERATURE REVIEW

Six case studies directly or indirectly related to the new HSM chapters were identified and reviewed: five studies conducted in the United States and one study conducted in Italy.

HSM Calibration in Missouri

The Missouri Department of Transportation developed LCFs for five segments and eight intersection site types, as well as three freeway segment types—RF4, UF4, and UF6—for years 2009 to 2011 (Sun, Brown, Edara, Claros, & Nam, 2014). Two crash types (SV and MV) and two severity types (FI and PDO) were considered for all three freeway segments, resulting in 12 LCFs (Table 8). Freeway segments crash prediction was conducted using Appendix C's proposed freeway methodology of the first HSM edition. The selected facility types were state priorities with sufficient samples. A total of 140 freeway segments was selected. Calibration results showed that LCFs for FI crashes on all freeway facility types but UF6 were lower than the predicted average crash frequency based on the HSM method, ranging from 0.7 (UF4 FI SV) to 0.91 (RF4 FI MV). There were fewer FI crashes in Missouri during the study period than the HSM's minimum annual crash threshold (minimum 100 annual crashes).

The study pointed out a number of challenges faced over the study period. First, gathering HSM required data was a time-consuming task. Second, for several facility types, freeway FI crashes, as stated earlier, could not meet the HSM minimum annual crash requirement. Third, AADT values on ramps were not complete. Therefore, they had to be estimated based on two assumptions: (1) if one of the ramps did not have AADT, the same AADT value on the other ramp was used; and (2) if both ramps AADT were not available, 10% of the crossroad AADT was assigned. While these assumptions were arbitrary, the authors stated that the potential biased results would be marginal due to a very small number of sampled ramps and crashes. Fourth, the inclusion of the speed-change lanes as part of ramps would be problematic; it is likely that some of the non-ramp crashes were included in computing LCFs for ramp crashes. Fifth, crashes are often assigned to multiple segments when crashes occurred close to beginning or ending points of more than two segments. Sixth, one local police department did not collect PDO crashes, which likely would affect the reliability of PDO LCFs. Finally, sampled facilities had to be visually verified. Some facilities' actual geometric configurations did not match the database.

Table 8. Summary of LCFs in Missouri (2009-2011)

Facility Types	Crash Type	N	Observed Crashes	Predicted Crashes	LCF
RF4	FI MV*	47	150	164.84	0.91
	PDO MV	47	645	325.76	1.98
	FI SV*	47	268	348.05	0.77
	PDO SV	47	1229	813.91	1.51
UF4	FI MV*	39	153	109.29	1.4
	PDO MV	39	669	186.35	3.59
	FI SV*	39	142	202.86	0.7
	PDO SV	39	583	359.88	1.62
UF	FI MV	54	424	353.33	1.2
	PDO MV	54	1482	909.20	1.63
	FI SV*	54	206	203.96	1.01

Calibration in Florida

Lu (2013) developed Florida-specific SPFs including state-maintained roadways as well as freeways (i.e., Interstates). Expected crashes estimated by default *SafetyAnalysts* SPFs were compared to the observed crashes in Florida. The 2008 Roadway Characteristics Inventory (RCI), and crash and traffic data from 2007-2010 for both total and fatal and injury (FI) crashes were used. Almost half of freeway segments had LCF values larger than 1.0 and the rest smaller than 1.0, indicating that on average the crash frequency in Florida on freeway segments is comparable to HSM base conditions. However, for ramps the majority of LCFs were larger than 1.0 and many of them were larger than 2.0, meaning on average ramps in Florida expect to have twice the crash frequencies predicted by *SafetyAnalyst.* Florida-specific SPFs were compared to *Safety Analysts* SPFs using visual plots and statistical-goodness-of-fit tests such as evaluation statistics such as mean absolute deviance (MAD), mean square prediction error (MSPE) and Freeman-Tukey R^2 (R^2_{FT}). In most cases, the prediction performance of Florida-specific SPFs was superior to *SafetyAnalyst* default SPFs. Nevertheless, the author admitted that using *SafetyAnalyst* would be simpler due to a simple base model data requirement. More investigation is warranted.

Like most HSM studies, the data availability was one of the challenges. In addition, freeway ramp types in Florida were different from the 16 types included in *SafetyAnalyst.* In this case, developing state-specific SPFs is the only option.

HSM Calibration in Italy

La Torre et al (2014) computed LCFs for freeway segments and speed-change lanes of Italian motorways. Over 1,800 miles of roadway network and five-year crash data from 2005-2009 were utilized. The main purpose of the study was to evaluate the potential issues of applying the HSM method developed in the United States to a jurisdiction in Italy that has different environmental conditions, road characteristics, driver behaviours and crash reporting systems. The LCFs were computed based on 56 freeway sections including two-, three- or four-lane freeway segments distributed on the nationwide freeway network (Table 9). Mean absolute deviation (MAD), calibrated overdispersion parameter, Root means square error (RMSE), and residual plots were used to evaluate goodness-of-fit of calibrated models. The results demonstrated a good transferability of the predictive models to the Italian network, especially the freeway models for fatal and injury crashes.

Table 9. Summary of Computing LCFs in Italy (2005-2009)

Facility Types	Crash Type	Number of Crashes	LCF
Freeway Segments	FI MV	1380	1.52
	PDO MV	1380	1.19
	FI SV	1380	0.36
	PDO SV	1380	0.64
Speed-Change Lanes	FI En	90	2.70
	PDO En	90	2.95
	FI Ex	86	1.53
	PDO Ex	86	1.93

In addition to the data collection challenges, the other challenge of the study was the identification of accurate crash locations in speed-change lanes. To address this issue the study team used the description of the crashes that occurred near the actual location of the speed-change lanes (available in the accident database) for identification. Moreover, due to insufficient crash data on speed-change lanes, the study team considered a 50 annual crash threshold, instead of the HSM's minimum 100 annual crash threshold. Extending the study years from three (HSM recommendation) to five years was done for the same reason.

Challenges

Table 10 summarized the challenges addressed in the three case studies. As summarized in past studies for the state-maintained roadways, the common challenge across the studies was the data availability and data collection requirement (Shin, Lee, & Dadvar, 2014). Two studies pointed out the difficulty in meeting the minimum annual crash threshold. It should be noted that in Table 10, the issue with assigning crashes on speed-change lanes is the new problem with the freeway crash estimation. Both Missouri and Italy did not have crash location data with accurate location information for speed-change lane crash assignment.

Table 10. Summary of Challenges

Challenges	Missouri	Florida	Italy
Data availability/data collection burden	√	√	√
Meeting minimum annual crash threshold	√		√
Incomplete AADT on ramps	√		
Assigning crashes on speed-change lanes	√		√
Duplicated crash assignments	√		
Different data collection items within the state	√		
Discrepancy between actual and coded geometrics		√	
Availability of the same facility types profiled in HSM		√	

METHODOLOGY

LCF Development Process

This section describes the HSM's 18-step predictive method process. Figure 1 is a simplified procedure. First, the process starts with identifying study locations and initial data collection. As stated earlier, the study includes four freeway types, four speed-change lanes, and two signalized and stop-controlled ramp terminals facility types. Second, after identifying freeway facilities, homogenous roadway segments or intersections were identified. Homogeneity means that geometric characteristics within a segment do not vary. The segmentation criteria for freeways, ramps and C-D roads are summarized in Table 11. Third, once the initial dataset is compiled, sites for analyses are sampled. The HSM suggests that for each facility type, at least 30-50 sites with at least 100 total annual crashes should be selected. Fourth, for the Sampled sites, additional data was collected, which involved extensive manual data coding work. Finally, predicted crash frequencies by the HSM predictive method were computed and compared with observed crashes in Maryland to compute LCFs.

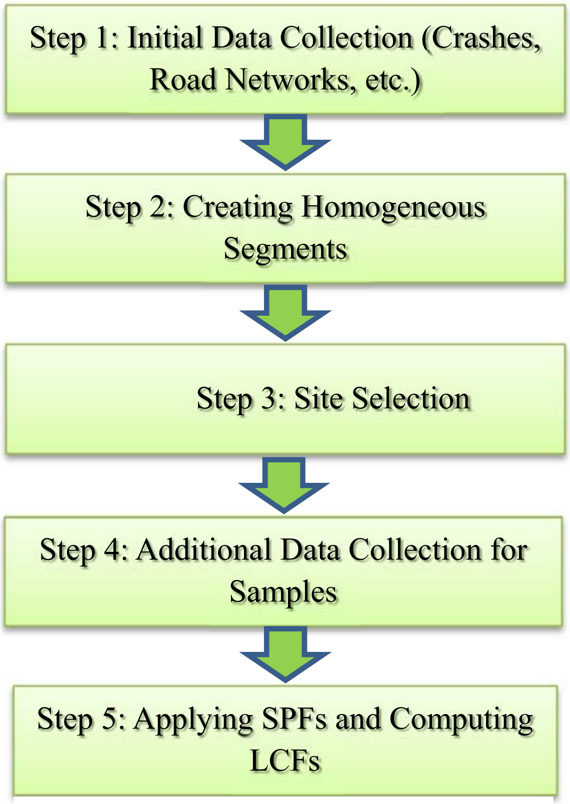


Figure 1. LCF Development Process

Table 11. Segmentation Criteria for Freeways, Ramps and C-D Roads

Facility	Segmentation Criteria
Freeways	Number of through lanes Lane width Outside and inside shoulder width Median width Ramp presence Clear zone width
Ramps and C-D Roads	Number of through lanes Lane width Right and left shoulder width Merging ramp or Collector-Distributor presence Diverging ramp or Collector-Distributor presence

Interactive Highway Safety Design Model (IHSDM)

IHSDM was the primary tool for estimating crash frequencies and computing LCFs. The IHSDM was developed for evaluating safety and operational effects of geometric design decisions on highways. IHSDM version 11.0.1, the latest version used in this project, includes six evaluation modules: (1) crash prediction module, (2) design consistency module, (3) intersection review module, (4) policy review module, (5) traffic analysis module, and (6) driver/vehicle module.

The IHSDM calibration utility provides all required steps to calculate LCFs for all facility types. The *Admin Tool* of the IHSDM enable users to compile data for developing LCFs such as roadway data, traffic data, crash data, and curve data (if required) and then apply the predictive method and compute LCFs.

Data Collection and Compilation

Data collection and compilation were the most challenging tasks in phase I. While understanding and following the HSM procedure was simple, collecting the required data was the most daunting task. Ninety-eight variables are required and only two variables are desirable. Unlike the Phase I study, the two desired variables should be treated as required variables. About 60% of the required variables were obtained from the SHA. Other variables had to be augmented with additional data collection. About 70% of this study effort was put into this task.

Data Collection Steps

The data collection task consisted of two steps. First, readily available data sets were collected. These included several required variables such as historical crash data, AADT, and roadway geometric information. Second, after selecting sample sites, additional data items were collected by manually counting/measuring features on aerial photos (i.e., Google Maps). The manually collected data were then stored as Excel tables for further data preparation, such as calculating the proportion of median barrier length of the selected freeway segment, distance to adjacent exit/entrance ramp, proportion of inside/outside rumble strips in the selected segment, exit ramp skew angle, presence of left-turn/right-turn lane, and distance to adjacent ramp terminal/next public street intersection. The additional data collection also involved manual extraction of curves from an SHA curve data set, and visual identification of the ramp terminal type and signal phasing. Finally, regression analysis was employed to estimate missing AADT for some ramps. In total, the study database consisted of 2.569 million data elements (Table 12).

Table 12. Analyzed Data Items

Data	Year	Count
UNIVERSE data	2008	177,701
	2009	180,722
	2010	185,164
MASTER data	2008	543,964
	2009	548,208
	2010	553,812
Crash data	2008-2010	282,310
ARAN (Automated Road Analyzer) Curve data	2013-2014	72,845
Manual data collection	Study period (otherwise the most recent year)	24,305
Total	2008-2010	2,569,031

Once initial datasets were collected, a list of available variables for HSM’s SPFs was identified. In some cases, several variables were combined to create a new variable. Then, data quality was checked for identifying missing, inconsistent, or counter-intuitive information. Vehicle crashes were assigned to segments and intersections. Most of this process was carried out in ArcGIS 10.1 of ESRI, a geographic information system (GIS) software for working with location information and maps. Figure 2 depicts the data compilation process.

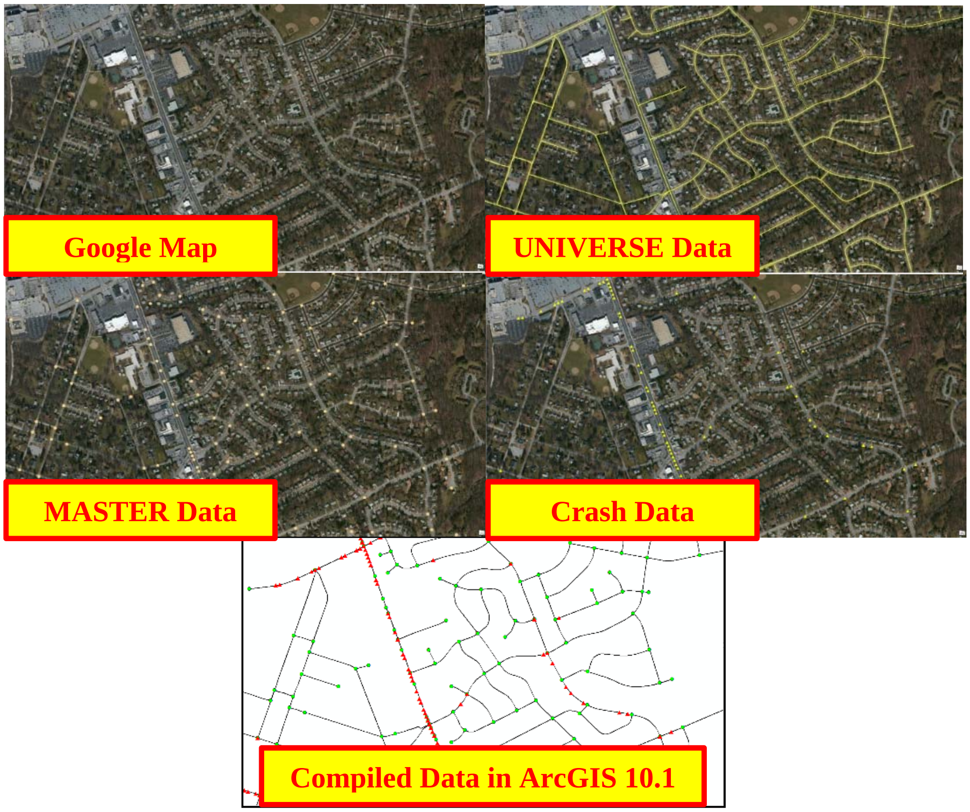


Figure 2. Data Compilation

Historical Crash Data

The study used 2008, 2009, and 2010 crash datasets that were the latest datasets available at the time of the study. The Baltimore City crash data was not included. The summary of the collected crash data is provided in Table 13. A total of 282,310 crashes occurred during the study period, resulting in 1,518 fatalities and 95,634 injuries. Roughly 77.5% of fatalities, 63.5% of injuries, and 74.9% of PDO crashes were from roadway crashes, and 22.5% of fatalities, 36.5% of injuries, and 25.1% of PDO crashes were from intersection crashes. Table 14 summarizes crashes by route type. There are 11 route types in the database. Route types of interest to this study are IS (Interstate freeways), some non-Interstate freeways of route types of US and MD, and finally RP (ramps). Nearly 8% of total crashes and 10% of fatal crashes occurred on Interstate freeways. Only 0.1% of crashes, including only one fatal crash, occurred on ramps during the same time period. Approximately 37% crashes of the total vehicle crashes occurred on MD and US roads during the study period; however, it should be noted that not all the roads of these two route types have the characteristics of the non-Interstate freeway.

Table 13. Summary of Crashes in All Roadway Types: 2008 – 2010

Year	Total Crashes	Fatal	Injury	PDO	Roadway Crashes			Intersection Crashes		
					Fatal	Injury	PDO	Fatal	Injury	PDO
2008	95,354	539	32,775	62,040	397	20,030	45,019	142	12,745	17,021
2009	96,421	516	32,372	63,533	426	22,406	50,772	90	9,966	12,761
2010	90,535	463	30,487	59,585	354	18,283	42,929	109	12,204	16,656
Total	282,310	1,518	95,634	185,158	1,177	60,719	138,720	341	34,915	46,438

Table 14. Summary of Crashes by Road Type: 2008 – 2010

Route Type	Total Crashes	% of Total Crashes	Fatal	% of Total Fatal Crashes	Injury	% of Total Injury Crashes	PDO	% of Total PDO crashes
CO	69,684	24.7	356	23.5	23,985	25.1	45,343	24.5
CY	52,927	18.7	112	7.4	13,376	14.0	39,439	21.3
GV	253	0.1	3	0.2	94	0.1	156	0.1
IS	22,765	8.1	147	9.7	7,972	8.3	14,646	7.9
MD	82,460	29.2	673	44.3	33,329	34.9	48,458	26.2
MU	12,856	4.6	18	1.2	3,828	4.0	9,010	4.9
OP	1,159	0.4	3	0.2	310	0.3	846	0.5
RP	222	0.1	1	0.1	62	0.1	159	0.1
SR	301	0.1	0	0.0	72	0.1	229	0.1
US	21,762	7.7	188	12.4	8,778	9.2	12,796	6.9
UU	17,921	6.3	17	1.1	3,828	4.0	14,076	7.6
Total	282,310	100.0	1,518	100.0	95,634	100.0	185,158	100.0

Crash data and roadway inventory data are two separate databases. Crash locations were referenced using descriptive geographic information in the crash table such as "Route_Number," "Log_Mile," "Logmile_Dir," and "Distance." Not all crashes were geocoded (Table 15). About 68.9 % of total crashes (i.e., 194,624 crashes) were successfully geocoded. The remaining crashes (roughly 31.3%) were not geocoded due to one of the three errors: *Route not found*, *Route measure not found, and Invalid location measure*.

Table 16 presents percentage of geocoded crashes by road type and crash severity level. Any data items with geocoding errors were removed from the dataset, which were about 4.8% of crashes on IS, 5.5% of crashes on MD and US roadways, and 100% of crashes on ramps. Unfortunately, not even a single crash on ramps was geocoded. Approximately 65% of PDO crashes were geocoded. The rate increased by about 10% for injury crashes (76%) and another 10% for fatal crashes (87%). Finally, geocoded crashes were spatially joined with GIS roadway network maps in order to create a dataset for sampling (i.e., site selection). Additional computations to complement historical data are summarized in Table 17. Appendix B provides the detailed list with descriptions of all data items.

Table 15. Summary of Geocoded Crashes by Road Type: 2008 – 2010

Route Type	Total Crashes	% of Total Geocoded Crashes	Fatal	% of Total Geocoded Fatal Crashes	Injury	% of Total Geocoded Injury Crashes	PDO	% of Total Geocoded PDO Crashes
CO	62,040	31.9	328	24.9	21,594	29.6	40,118	33.4
CY	0	0.0	0	0.0	0	0.0	0	0.0
GV	211	0.1	3	0.2	76	0.1	132	0.1
IS	21,673	11.1	137	10.4	7,598	10.4	13,938	11.6
MD	77,897	40.0	648	49.2	31,694	43.4	45,555	37.9
MU	11,275	5.8	11	0.8	3,428	4.7	7,836	6.5
OP	742	0.4	3	0.2	207	0.3	532	0.4
RP	0	0.0	0	0.0	0	0.0	0	0.0
SR	243	0.1	0	0.0	59	0.1	184	0.2
US	20,544	10.6	186	14.1	8,409	11.5	11,949	9.9
UU	0	0.0	0	0.0	0	0.0	0	0.0
Total	194,625	100	1,316	100	73,065	100	120,244	100

Table 16. Summary of Percentage of Geocoded Crashes by Road Type: 2008 – 2010

Route Type	Total Crashes (% Geocoded)	Fatal % Geocoded)	Injury (% Geocoded)	PDO (% Geocoded)
CO	89.0%	92.1%	90.0%	88.5%
CY	0.0%	0.0%	0.0%	0.0%
GV	83.4%	100.0%	80.9%	84.6%
IS	95.2%	93.2%	95.3%	95.2%
MD	94.5%	96.3%	95.1%	94.0%
MU	87.7%	61.1%	89.6%	87.0%
OP	64.0%	100.0%	66.8%	62.9%
RP	0.0%	0.0%	0.0%	0.0%
SR	80.7%	0.0%	81.9%	80.3%
US	94.4%	98.9%	95.8%	93.4%
UU	0.0%	0.0%	0.0%	0.0%
Total	68.9%	86.7%	76.4%	64.9%

Table 17. Complementing Historical Crash Data: 2008 – 2010

Data Item	Data Source	Data Collection Method
Observed Number of Crashes	SHA (MSP) + Auto or Manual Crash Side Identification	Crashes for freeways were geocoded more than 95% correctly for 2008-2010 and crash side was identified through extensive automatic and manual work
Collision Type (SV)	SHA (MSP) + Computation	Computing SV crash distributions
Collision Type (MV)	SHA (MSP) + Computation	Computing MV crash distributions
Ramp Type	SHA (UNIVERSE & MSP)	Crashes for ramps were not geocoded 2008-2010

Roadway Inventory Data

Roadway data was collected from four main sources: (1) SHA roadway network and point data GIS maps, (2) Complementing computation and manual data extraction, (3) computation based on HSM formula for some desirable variables, and (4) additional data collection/compilation efforts. Appendix B provides the detailed list with descriptions of all data items.

<u>SHA GIS Maps</u>

GIS maps of the Maryland roadway network (UNIVERSE database), and point data (MASTER database) were provided by SHA. The roadway network maps included many variables required by the HSM SPFs for roadway segments and intersections. Obtaining intersection locations (signalized or stop-controlled ramp terminals) was easy (using MASTER database), but making the data useful for the study was somewhat challenging (see "Creating Crossroad Ramp Terminals Database"). Tables 18 to 20 show variables directly available from the SHA GIS maps for freeways, speed-change lanes, and ramp terminals, respectively.

Table 18. Collected Variables Directly from SHA GIS Maps for Freeways

Data Item	Data Source	Data Collection Method
Area Type	SHA (UNIVERSE)	-
Number of Thru Lanes	SHA (UNIVERSE)	-
Length	SHA (UNIVERSE)	-
Effective Segment Length	SHA (UNIVERSE)	-
Average Inside Shoulder width	SHA (UNIVERSE)	-
Average Outside Shoulder width	SHA (UNIVERSE)	-
Proportion Weave Increasing	SHA (UNIVERSE)	There was no Type B weaving section in samples.
Length Weave Increasing	SHA (UNIVERSE)	-
Proportion Weave Decreasing	SHA (UNIVERSE)	There was no Type B weaving section in samples.
Length Weave Decreasing	SHA (UNIVERSE)	-
Year 1 AADT	SHA (UNIVERSE)	-
Year 2 AADT	SHA (UNIVERSE)	-
Year 3 AADT	SHA (UNIVERSE)	-

Table 19. Collected Variables Directly from SHA GIS Maps for Speed-Change Lanes

Data Item	Data Source
Area Type	SHA (UNIVERSE)
Number of Thru Lanes	SHA (UNIVERSE)
Length	SHA (UNIVERSE)
Average Lane Width	SHA (UNIVERSE)
Average Inside Shoulder width	SHA (UNIVERSE)
Ramp Length	SHA (UNIVERSE)
Ramp Side of Road	SHA (UNIVERSE)
Year 1 AADT	SHA (UNIVERSE)
Year 2 AADT	SHA (UNIVERSE)
Year 3 AADT	SHA (UNIVERSE)

Table 20. Collected Variables Directly from SHA GIS Maps for Ramp Terminals

Data Item	Data Source
Area Type	SHA (MASTER)
Width of left-turn lane (or bay) on the inside crossroad approach	SHA (UNIVERSE)
Width of left-turn lane (or bay) on the outside crossroad approach	SHA (UNIVERSE)
Crossroad median width	SHA (UNIVERSE)
Year 1 AADT for the crossroad leg between ramps	SHA (UNIVERSE)
Year 1 AADT for the crossroad leg outside of interchange	SHA (UNIVERSE)
Year 2 AADT for the crossroad leg between ramps	SHA (UNIVERSE)
Year 2 AADT for the crossroad leg outside of interchange	SHA (UNIVERSE)
Year 3 AADT for the crossroad leg between ramps	SHA (UNIVERSE)
Year 3 AADT for the crossroad leg outside of interchange	SHA (UNIVERSE)

Complementing Computation and Manual Data Extraction

While some variables, such as AADT and the total number of through lanes can be used without modification, some variables needed to be modified to obtain variables for HSM models. For example, to obtain effective median width, three columns (variables) should be summed up: median width, middle shoulders and turning lanes. Tables 21 to 23 show these variables available for freeways, speed-change lanes, and ramp terminals, respectively. Also, the tables provide notes on the methods of complementing incomplete data points.

Table 21. Variables Collected by Complementing SHA GIS Maps for Freeways

Data Item	Data Source	Data Collection Method
Average Lane Width	SHA (UNIVERSE) + Computation	Computing average segment length width (ArcGIS)
Effective Median Width	SHA (UNIVERSE) + Computation	Computing effective median width (ArcGIS)
Year 1 AADT Begin to Entry Increasing	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA
Year 1 AADT End to Exit Increasing	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA
Year 1 AADT End to Entry Increasing	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA
Year 1 AADT Begin to Exit Decreasing	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA
Year 2 AADT Begin to Entry Increasing	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA
Year 2 AADT End to Exit Increasing	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA

Data Item	Data Source	Data Collection Method
Year 2 AADT End to Entry Increasing	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA
Year 2 AADT Begin to Exit Decreasing	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA
Year 3 AADT Begin to Entry Increasing	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA
Year 3 AADT End to Exit Increasing	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA
Year 3 AADT End to Entry Increasing	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA
Year 3 AADT Begin to Exit Decreasing	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA
Curve Radius	SHA (ARAN) + Manual Extraction	Manual extraction of curve data from ARAN data of SHA (ArcGIS).
Curve Length Within Site	SHA (ARAN) + Manual Extraction & Measurement	Measuring curve length within the site using curve data from ARAN data of SHA(ArcGIS)
Curve Side of Road	SHA (ARAN) + Manual Extraction	Checking the curve side of road using curve data from ARAN data of SHA(ArcGIS)

Table 22. Variables Collected by Complementing SHA GIS Maps for Speed-Change Lanes

Data Item	Data Source	Data Collection Method
Effective Median Width	SHA (UNIVERSE) + Computation	Computing effective median width (ArcGIS)
Year 1 AADT of Ramp	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA
Year 2 AADT of Ramp	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA
Year 3 AADT of Ramp	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA
Curve Radius	SHA (ARAN) + Manual Extraction	Manual extraction of curve data from ARAN data of SHA (ArcGIS).
Curve Length Within Site	SHA (ARAN) + Manual Extraction & Measurement	Measuring curve length within the site using curve data from ARAN data of SHA(ArcGIS)
Curve Side of Road	SHA (ARAN) + Manual Extraction	Checking the curve side of road using curve data from ARAN data of SHA(ArcGIS)

Table 23. Variables Collected by Complementing SHA GIS Maps for Ramp Terminals

Data Item	Data Source	Data Collection Method
Type of traffic control	SHA (MASTER)	Double-checking the type of control (Google Earth)
Number of thru lanes on the inside crossroad approach	SHA (UNIVERSE) + Manual Checking	Double-checking number of lanes (Google Earth)
Number of thru lanes on the outside crossroad approach	SHA (UNIVERSE) + Manual Checking	Double-checking number of lanes (Google Earth)
Number of lanes on the exit ramp leg at the terminal	SHA (UNIVERSE) + Manual Checking	Double-checking number of lanes (Google Earth)
Presence of a left-turn lane (or bay) on the inside crossroad approach	SHA (UNIVERSE) + Manual Checking	Checking presence of left-turn lane (Google Earth)
Presence of a left-turn lane (or bay) on the outside crossroad approach	SHA (UNIVERSE) + Manual Checking	Checking presence of left-turn lane (Google Earth)
Presence of a right-turn lane (or bay) on the inside crossroad approach	SHA (UNIVERSE) + Manual Checking	Checking presence of right-turn lane (Google Earth)
Presence of a right-turn lane (or bay) on the outside crossroad approach	SHA (UNIVERSE) + Manual Checking	Checking presence of right-turn lane (Google Earth)
Presence of right-turn channelization on the inside crossroad approach	SHA (UNIVERSE) + Manual Checking	Checking presence of right-turn channelization (Google Earth)
Presence of right-turn channelization on the outside crossroad approach	SHA (UNIVERSE) + Manual Checking	Checking presence of right-turn channelization (Google Earth)
Presence of right-turn channelization on the exit ramp approach	SHA (UNIVERSE) + Manual Checking	Checking presence of right-turn channelization (Google Earth)
Year 1 AADT for the entrance ramp	SHA (UNIVERSE) + Estimation	Estimating ramp AADT if not available from SHA
Year 1 AADT for the exit ramp	SHA (UNIVERSE) + Estimation	Estimating ramp AADT if not available from SHA
Year 2 AADT for the entrance ramp	SHA (UNIVERSE) + Estimation	Estimating ramp AADT if not available from SHA

Data Item	Data Source	Data Collection Method
Year 2 AADT for the exit ramp	SHA (UNIVERSE) + Estimation	Estimating ramp AADT if not available from SHA
Year 3 AADT for the entrance ramp	SHA (UNIVERSE) + Estimation	Estimating ramp AADT if not available from SHA
Year 3 AADT for the exit ramp	SHA (UNIVERSE) + Estimation	Estimating ramp AADT if not available from SHA

Computation based on HSM formula

The variable, "Proportion of high volume" (AADT volume exceeds 1000 vehicles/hour/lane on a freeway), is the desired variable for SPFs for freeway segments and speed-change lanes. The proportions were computed using the HSM's suggested method (Table 24).

Table 24. Computed Desirable Variables Based on HSM Formula

Data Item	**Data Source**	**Data Collection Method**
Year 1-3 Proportion of High Volume for Freeway Segment	Computation	A default value can be computed as $P_{hv} = 1.0 - \exp(1.45 - 0.000124 \times AADT/n)$. If the value computed is less than 0.0, then it is set to 0.0. [n is the number of through lanes.]
Year 1-3 Proportion of High Volume for Speed-Change Lane	Computation	A default value can be computed as $P_{hv} = 1.0 - \exp(1.45 - 0.000124 \times AADT/n)$. If the value computed is less than 0.0, then it is set to 0.0. [n is the number of through lanes.]

Additional Data Collection

The following tables show additional variables collected for freeways, speed-change lanes, and ramp terminals, respectively (Tables 25 to 27). A more detailed discussion on additional data collection methods is provided later.

Table 25. Additional Data Collected for Freeways

Data Item	Data Source	Data Collection Method
Proportion Segment Length with Median Barrier	Manual Measurement	Measuring proportion of segment length with median barrier if segment includes part w/ and w/o median barrier (Google Earth)
Average Median Barrier Offset	Manual Measurement + Computation	Measuring barrier offset and then computing average inside shoulder width (Google Earth)
Proportion Segment Length with Outside Barrier	Manual Measurement	Measuring proportion of segment length with outside barrier if segment includes part w/ and w/o outside barrier (Google Earth)
Outside Barrier Length	Manual Measurement	Measuring outside barrier length (Google Earth)
Average Outside Barrier Offset	Manual Measurement + Computation	Measuring barrier offset and then computing average inside shoulder width (Google Earth)
Distance Begin to Entry Increasing	Manual Measurement	Measuring distance to gore point (Google Earth)
Distance End to Exit Increasing	Manual Measurement	Measuring distance to gore point (Google Earth)
Distance End to Entry Decreasing	Manual Measurement	Measuring distance to gore point (Google Earth)
Distance Begin to Exit Decreasing	Manual Measurement	Measuring distance to gore point (Google Earth)
Proportion Inside Rumble Strips	Manual Measurement	Measuring the proportion inside rumble strips (Google Earth)
Proportion Outside Rumble Strips	Manual Measurement	Measuring the proportion outside rumble strips (Google Earth)
Outside Clear Zone Width	Manual Measurement	Measuring clear zone width (Google Earth)

Table 26. Additional Data Collected for Speed-Change Lanes

Data Item	Data Source	Data Collection Method
Proportion Segment Length with Median Barrier	Manual Measurement	Measuring proportion of segment length with median barrier if segment includes part w/ and w/o median barrier (Google Earth)
Average Median Barrier Offset	Manual Measurement + Computation	Measuring barrier offset and then computing average inside shoulder width (Google Earth)

Table 27. Additional Data Collected for Ramp Terminals

Data Item	Data Source	Data Collection Method
Ramp Terminal Configuration	Manual Checking	Checking the ramp terminal configuration using the HSM and Google Earth
Presence of a non-ramp public street leg at the terminal	Manual Checking	Checking presence of a non-ramp public street leg (Google Earth)
Exit ramp skew angle	Manual Measurement	Using compass on Google Earth
Number of signalized driveways on the outside crossroad leg	Manual Counting	Counting number of signalized driveways (Google Earth)
Number of signalized public street approaches on the outside crossroad leg	Manual Counting	Counting number of signalized driveways (Google Earth)
Distance to the adjacent ramp terminal	Manual Measurement	Measuring the distance to adjacent ramp terminal (Google Earth)
Distance to the next public street intersection on the outside crossroad leg	Manual Measurement	Measuring the distance to the next public street intersection (Google Earth)
Presence of protected left-turn operation	Manual Checking	Checking presence of left-turn operation (Google Earth)

Data Generation

To compute predicted crash frequency and LCFs using IHSDM, the following datasets need to be compiled:

- Required site data
- Required crash/traffic data
- Desired site data
- Site Curve Data (not for ramp terminals though)
- Crash distribution data

As a note, the data should be collected for homogenous sites. A series of efforts have been carried out to create the required datasets. Most work was performed using ArcGIS 10.1 and some tasks were carried out using Microsoft Excel, IBM SPSS 22, and Google Earth. Figure 3 presents the diagram of the data flow for computing LCFs. In several steps of data generation, Python coding was used Appendix C.

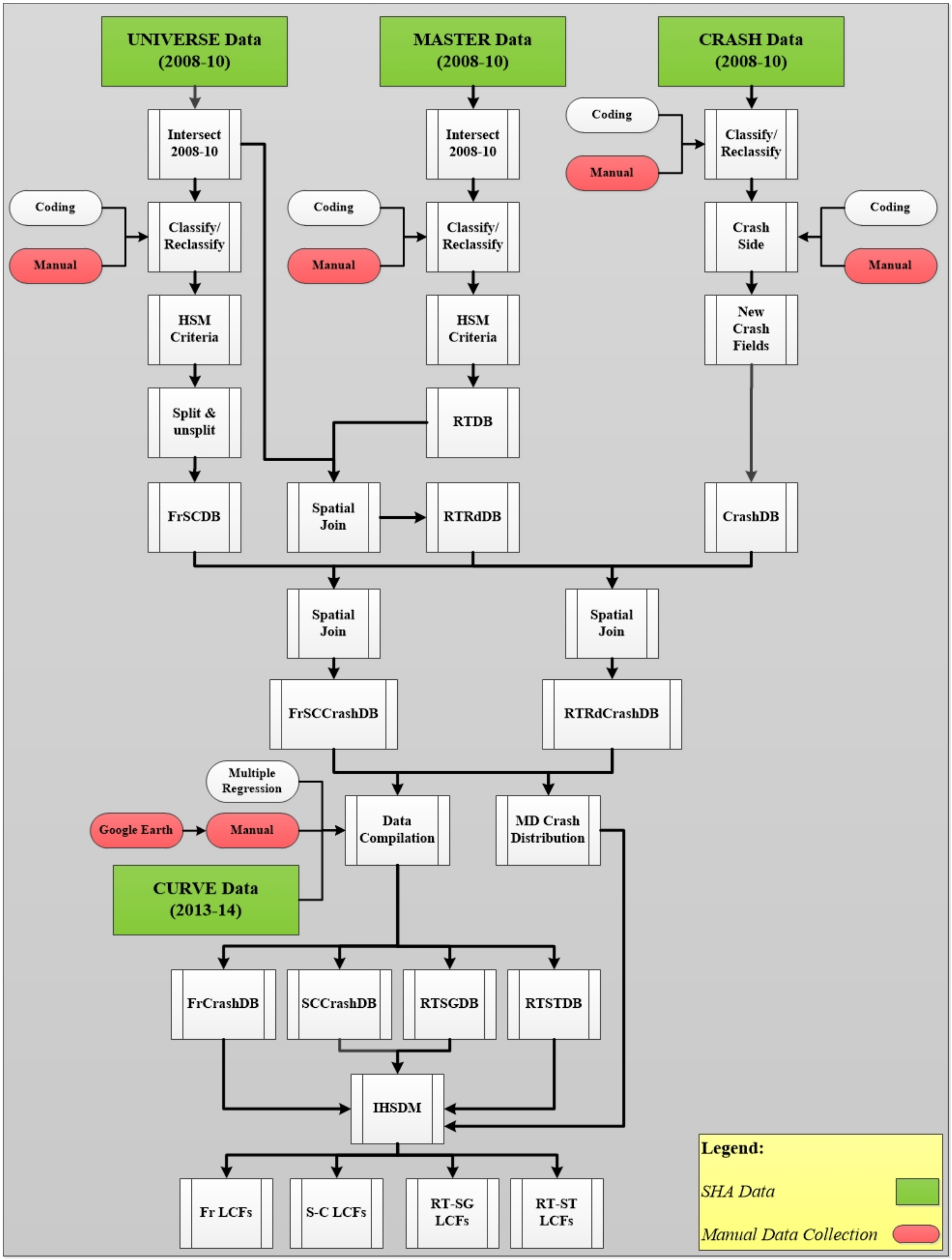


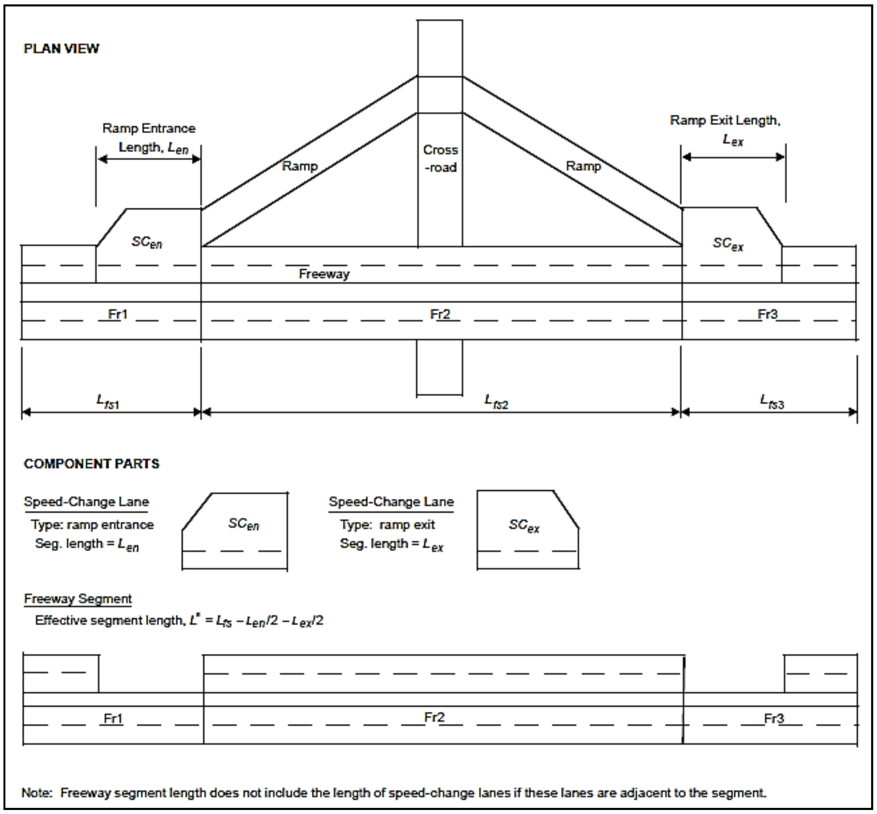
Figure 3. Diagram of Data Flow for Computing LCFs

Creating Homogenous Freeways and Speed-Change Lanes Databases

Freeways must be divided into homogenous segments. In general, the following elements should be evaluated in creating homogeneous freeway segments (AASHTO, 2014, pp. 18-22):

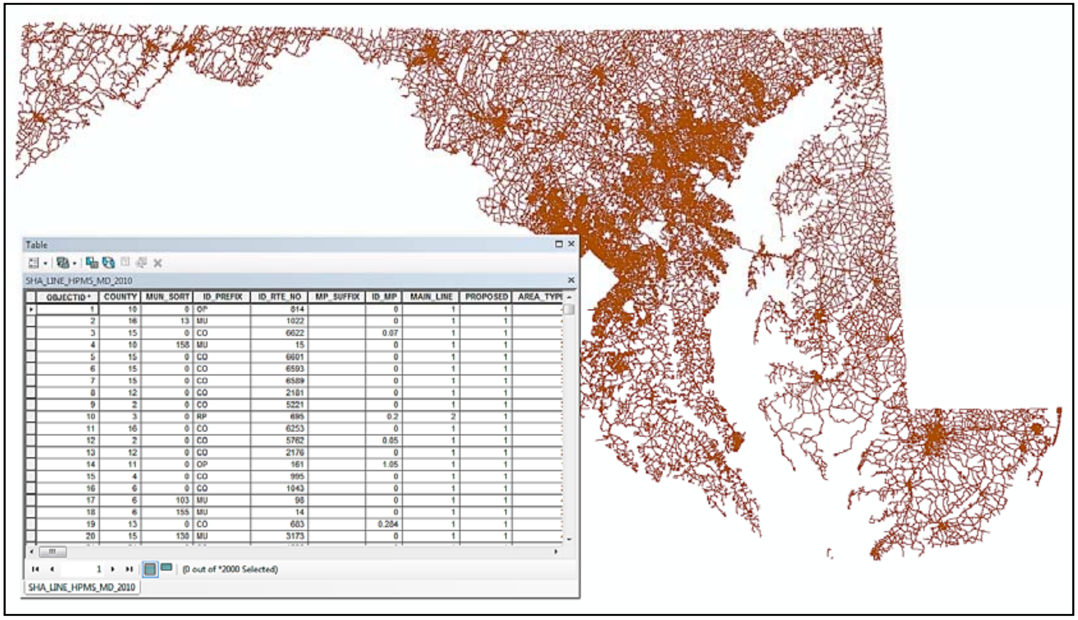
- Number of through lanes
- Lane width
- Outside/Inside shoulder width
- Median width
- Ramp Presence
- Clear zone width

Figure 4 illustrates the characteristics of freeway segments and speed-change lanes. A freeway segment can include speed-change lane parts on either side or both sides; however, the effective freeway segment length should be adjusted. A homogeneous site maintains constant traffic volume, key geometric design features, and traffic control features. Not all variables can be homogenous within the segment, but researchers should do their best in creating segments as homogenous as possible. If a certain variable changes (e.g., adding a lane), the segment should be divided into two at the location where the number of lanes changes. Depending on how roadway geometry data is collected and maintained, the detailed steps to be taken vary. The roadway geometry data provided by SHA was organized in such a way that variables between two mile points did not change. According to SHA, new mile points were added when new changes were made. Thus, the study team did not need to go through a time-consuming segmentation process. Figure 5 shows an example of the data table received from SHA for roadway data (UNIVERSE data, 2010).



Note: Freeway segment length does not include the length of speed-change lanes if these lanes are adjacent to the segment.

Figure 4. Freeway Segments and Speed-Change Lanes (Source: HSM Supplement, 2014)



OBJECTID *	COUNTY	MUN_SORT	ID_PREFIX	ID_RTE_NO	MP_SUFFIX	ID_MP	MAIN_LINE	PROPOSED	AREA_TYPE
1	10	0	OP	814		0	1	1	
2	16	13	MU	1022		0	1	1	
3	15	0	CO	6622		0.07	1	1	
4	10	158	MU	15		0	1	1	
5	15	0	CO	6601		0	1	1	
6	15	0	CO	6593		0	1	1	
7	15	0	CO	6589		0	1	1	
8	12	0	CO	2181		0	1	1	
9	2	0	CO	5221		0	1	1	
10	3	0	RP	695		0.2	2	1	
11	16	0	CO	6253		0	1	1	
12	2	0	CO	5762		0.05	1	1	
13	12	0	CO	2176		0	1	1	
14	11	0	OP	161		1.05	1	1	
15	4	0	CO	995		0	1	1	
16	6	0	CO	1043		0	1	1	
17	6	103	MU	98		0	1	1	
18	6	155	MU	14		0	1	1	
19	13	0	CO	683		0.284	1	1	
20	15	130	MU	3173		0	1	1	

(0 out of *2000 Selected)

Figure 5. An Example of Roadway DB (UNIVERSE) Received from SHA for 2010

Figure 6 summarizes steps of data preparation for freeway segments and speed-change lanes. Most of the work was done in ArcGIS 10.1 *ModelBuilder* including Python coding. The following datasets (shapefiles) were used:

- HMIS_2008_UNIVERSE (Line)
- HMIS_2008_ MASTER (Point)
- HMIS_2009_UNIVERSE (Line)
- HMIS_2009_ MASTER (Point)
- HMIS_2010_UNIVERSE (Line)
- HMIS_2010_ MASTER (Point)
- Maryland_Crashes_2008_2010 (Point)

Some preparation efforts were done prior to the start of the steps:

- Since HMIS_2008_UNIVERSE (Line) dataset does not have a "LOC_ERROR" field, it was manually added to the dataset by selecting all geocoded roadway segments and assigning values "1" for the newly added field of "LOC_ERROR."
- Adding a new field based on Shape_Length to three years of data for further cross check.

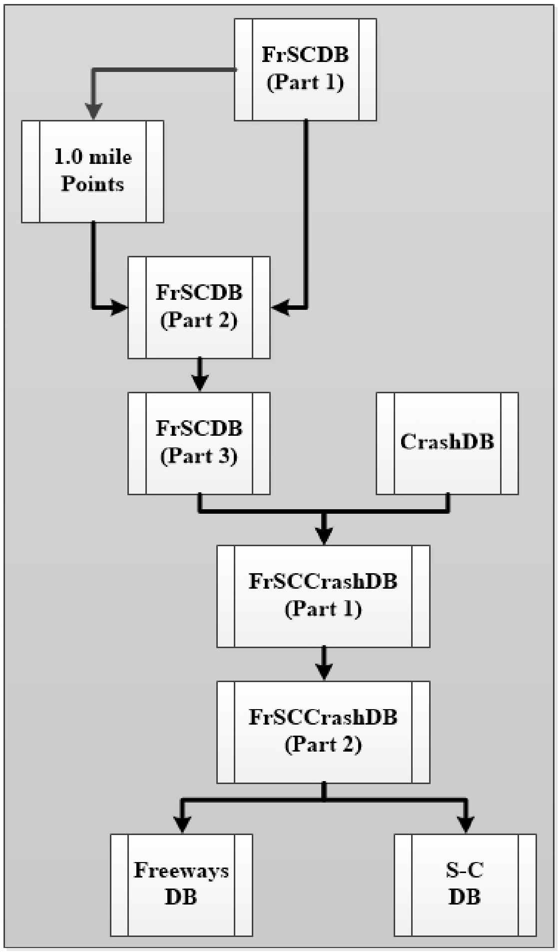


Figure 6. Steps of Creating Final Datasets for Freeway Segments and Speed-Change Lanes

Creating Freeway Segments and Speed-Change Lanes DB (FrSCDB (Part 1))

This step includes the following parts:

- Using Microsoft Excel, Python, or ArcGIS, select data records that meet the following criteria:
  - Road type is IS, MD, or US (MD and US types were selected to include non-Interstate freeways that meet HSM criteria.)
  - Is a freeway segment or speed-change lane
  - Roadway variables are consistent for the study period
- Create two fields:
  - "Fr_Cl": Freeway classification based on HSM definition and requirements
  - "Rt_SC_Cl" and "Lt_SC_Cl": Speed-Change Lane classification for right-side and left-side of the freeways
- Find MD/US roadway segments that meet the minimum distance criteria (using MASTER DB for three years) to qualify as non-Interstate freeway segments:
  - 0.5 miles from Toll Plaza
  - 0.5 miles from mainline signalized/stop controlled intersections
- Create homogeneous segments (see Figure 7 for details):

  - Generating end points in each year’s roadway dataset where roadway geometric features change
  - Merging end points from three years’ roadway datasets
  - Splitting the three datasets at merged end points
- Intersect three roadway datasets
- Create new fields (ID_MP, END_MP, etc.)
- Split based on key fields (area type, functional class, AADT, number of through lanes, median type, median width, shoulder type, shoulder width, speed limit, number of auxiliary lanes, width of auxiliary lanes, ID_Prefix, ID_MP, END_MP, NLFID, and ROUTEID)

Figure 8 shows a screenshot of this step in the ArcGIS 10.1 *ModelBuilder* environment.

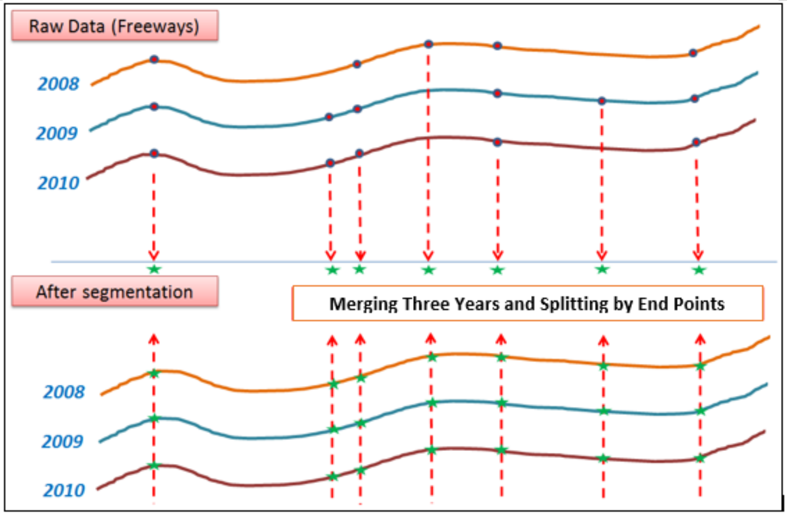


Figure 7. Creating Homogeneous Segments

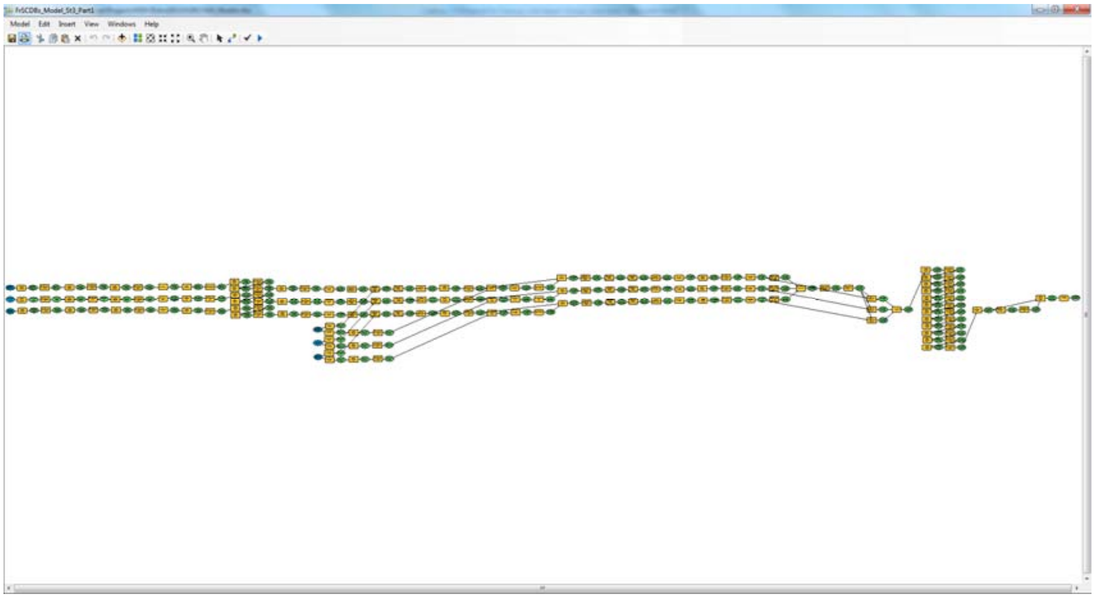
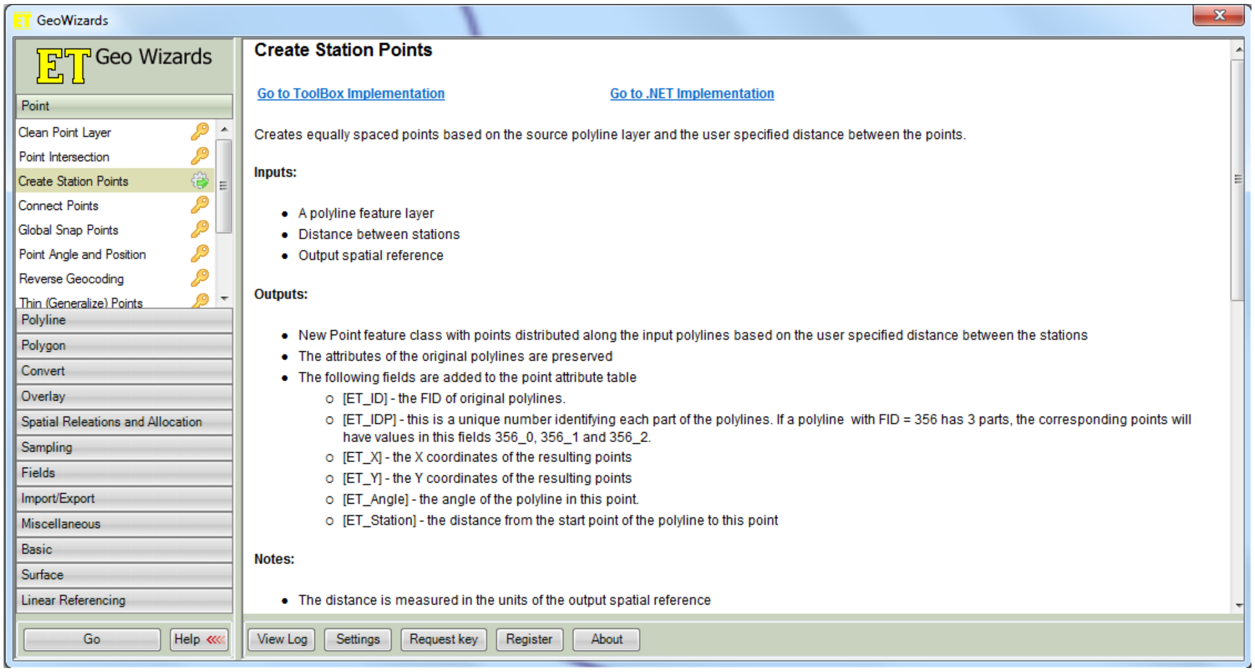


Figure 8. FrSCDB (Part 1) Screenshot in ArcGIS 10.1 *ModelBuilder* Environment

Generating 1-Mile Points

This step was done outside of the ArcGIS environment and the purpose was to split the homogeneous segments at mile points based on the HSM roadway segment length recommendation (Appendix B). Using ET Geo Wizards tool (Version 11.2), points were generated at one mile intervals. Figure 9 shows a screenshot of this step in ET Geo Wizards environment and Figure 10 shows an example of generated points for a long (>4 miles) freeway segment.



Create Station Points

Go to ToolBox Implementation

Go to .NET Implementation

Creates equally spaced points based on the source polyline layer and the user specified distance between the points.

Inputs:

- A polyline feature layer
- Distance between stations
- Output spatial reference

Outputs:

- New Point feature class with points distributed along the input polylines based on the user specified distance between the stations
- The attributes of the original polylines are preserved
- The following fields are added to the point attribute table
    - [ET_ID] - the FID of original polylines.
    - [ET_IDP] - this is a unique number identifying each part of the polylines. If a polyline with FID = 356 has 3 parts, the corresponding points will have values in this fields 356_0, 356_1 and 356_2.
    - [ET_X] - the X coordinates of the resulting points
    - [ET_Y] - the Y coordinates of the resulting points
    - [ET_Angle] - the angle of the polyline in this point.
    - [ET_Station] - the distance from the start point of the polyline to this point

Notes:

- The distance is measured in the units of the output spatial reference

Figure 9. Generating 1.0 Mile Points Screenshot in ET Geo Wizards Environment

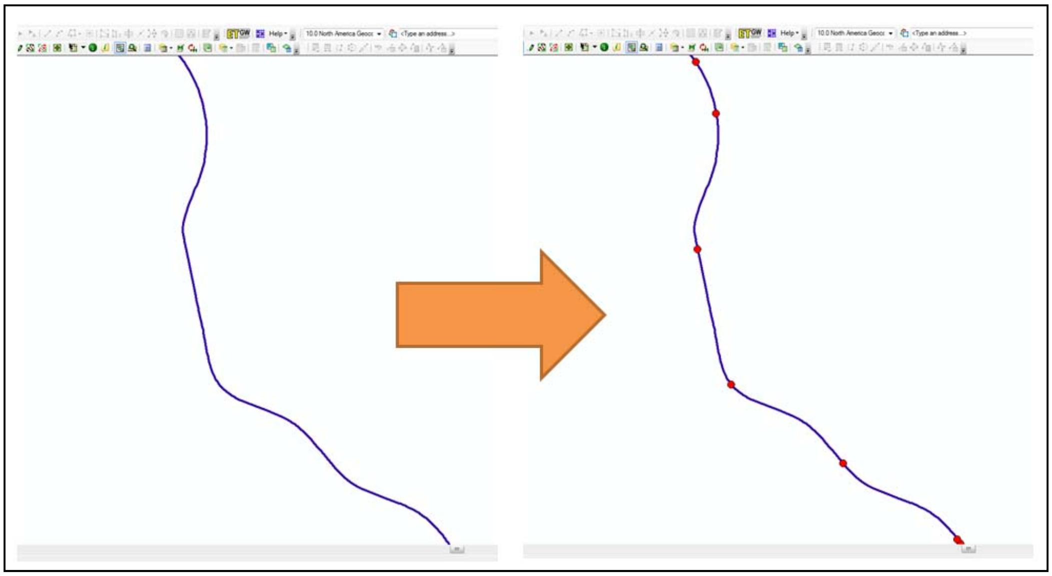


Figure 10. An Example of Generated 1.0 Mile Points for a Freeway Segment

Creating Freeway Segments and Speed-Change Lanes DB (FrSCDB (Part 2))

This step includes the following parts:

- Splitting the homogeneous segments (FrSCDB (Part 1)) at 1-mile points.
- Adding new fields:
  - Final_Seg_Len
  - Final ID_MP
  - Final END_MP

Figure 11 shows a screenshot of this step in the ArcGIS 10.1 *ModelBuilder* environment.

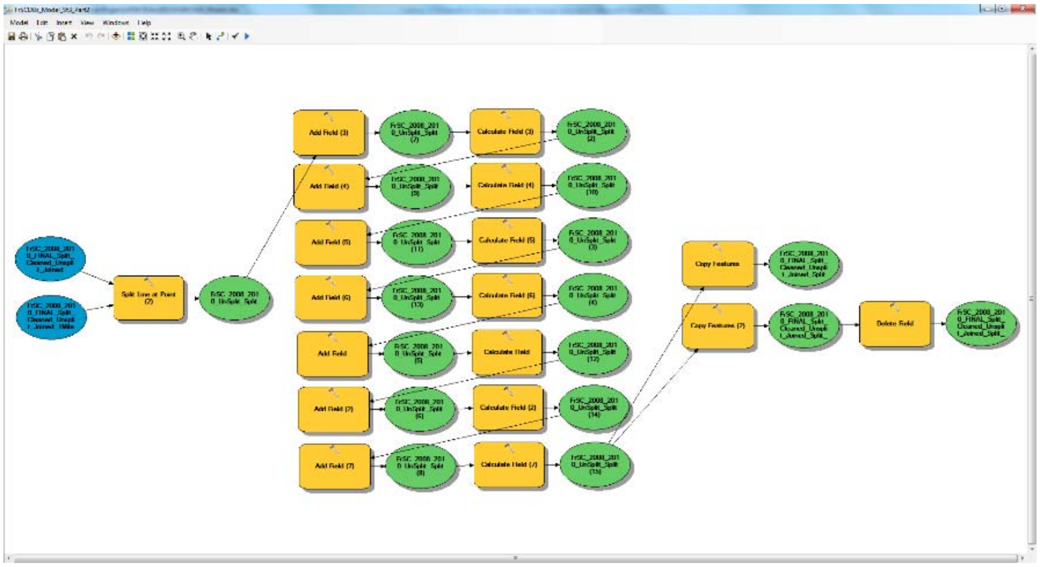


Figure 11. FrSCDB (Part 2) Screenshot in ArcGIS 10.1 *ModelBuilder* Environment

Creating Freeway Segments and Speed-Change Lanes DB (FrSCDB (Part 3))

This step includes following parts:

- Appending the result of the third step to itself because speed-change lanes may be on both sides of freeway (right-side and left-side)

- Adding a new field of “SC_Cl” which for the first half of the dataset has speed-change lanes from right-side and the rest from left-side
- Adding new fields “Fr_ID” and “SC_ID”

Figure 12 shows a screenshot of this step in the ArcGIS 10.1 *ModelBuilder* environment.

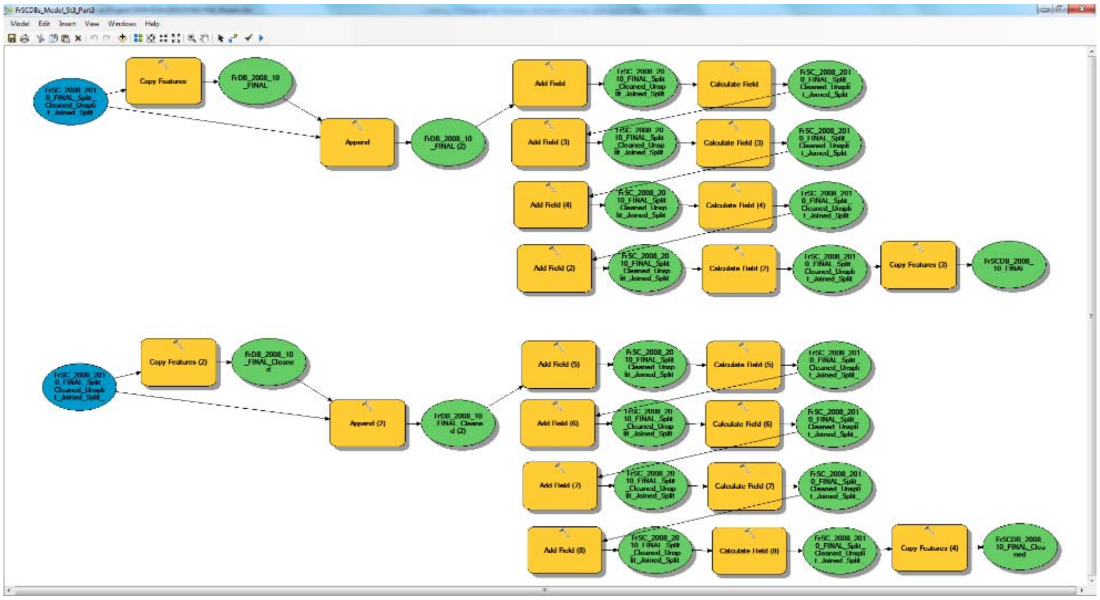


Figure 12. FrSCDB (Part 3) Screenshot in ArcGIS 10.1 *ModelBuilder* Environment

Table 28 presents the data reduction procedure. There were nearly 200,000 segments per roadway network dataset. After three data reduction steps, approximately 2,500 to 3,200 matching freeway segments and speed-change lanes remained in the database. After five more data compilation and cleaning steps, 1,769 freeway segments (some including either one or both sides speed-change lane) remained in the dataset.

Table 28. Summary of Data Reduction Procedure

Year		Roadway data			Total
		2008	2009	2010	
Original data from MSP database		177701	180722	185164	543587
% of original data		32.69%	33.25%	34.06%	100%
Step 1	"LOC_ERROR" = NO ERROR	177306	180146	184995	542447
	% reduction from original data	0.22%	0.32%	0.09%	0.21%

Step 2	"ID_PREFIX" = IS or MD or US	49470	51020	52818	153308
	% reduction from original data	72.16%	71.77%	71.48%	71.80%
Step 3	"Freeway" & "S-C" criteria	2664	2752	3184	8600
	% reduction from original data	98.50%	98.48%	98.28%	98.42%
Step 4	Split @ 1.0 Mile Points	3463	3481	3501	10445
	% reduction from original data	98.05%	98.07%	98.11%	98.08%
Step 5	Intersecting 3 years	3576			3576
	% reduction from original data	98.03%			98.03%
Step 6	Common Segments for 3 years	1907			1907
	% reduction from original data	98.95%			98.95%
Step 7	Un-Split based on key fields	1717			1717
	% reduction from original data	99.05%			99.05%
Step 8	**Split @ 1.0 Mile Points**	**1769**			**1769**
	% reduction from original data	99.02%			99.02%

Preparing Crash DB for Freeway Segments and Speed-Change Lanes

Only crashes that occurred on the speed-change lane's side of the roadway can be attributed to speed change lanes. Categorizing crashes with a "crash side" variable requires manual data preparation. On one hand, crash data includes "Inventory Direction," "Crash Lane," and "Vehicle Travel Direction," which follow four geographic directions (i.e., North, South, East, and West) and on the other hand, roadway data only includes right-side or left-side as geographic direction information. The purpose of this effort is to assign a value of either right-side or left-side to each individual crash based on crash data geographic direction variables. Using the combination of "Inventory Direction," "Crash Lane," and "Vehicle Travel Direction," nearly 89% of speed-change lanes crashes could be addressed. Then the study team tried to manually find some trends for crashes with unknown sides for circular freeways like I-495, I-695 and some roadways where the directions of road signs do not match actual road direction (e.g., I-195 and MD-32). Manual works complemented the data by nearly 9% which in total led to 98.63% of crashes with a known crash side. This was also a challenging task for the Missouri study (Sun, Brown, Edara, Claros, & Nam, 2014). Table 29 shows the details for crashes occurring on Interstate freeways.

Table 29. Summary of Crash Side Information

Crash Side	# Crashes	%	Crash Side	# Crashes	%
Left-side	3182	40.88%	Left-side	3182	40.88%
Right-side	3753	48.22%	Right-side	3753	48.22%
Unknown	848	10.90%	Unknown	107	1.37%
Total	**7783**	**100.00%**	***Manually Identified***	741	9.52%
			Total	**7783**	**100.00%**

There was an inconsistency between the HSM and Maryland on the definition of "Parked Vehicle Crash." The study team addressed this inconsistency by reclassifying it as following (using Python coding):

- HSM: Parked Vehicle Crash ➔ Single Vehicle Crash
- Maryland Data: Parked Vehicle Crash ➔ Multiple Vehicle Crash

Moreover, crash data should be in a format ready for the LCF development and the Maryland-specific crash distribution development. The study team reclassified crash data based on following considerations:

For developing LCFs:

- Year: 2008, 2009, and 2010
- Crash Side: Right, Left, and Unknown
- Crash Type: Single-Vehicle (SV), Multiple-Vehicle (MV)
- Crash Severity: Fatal and Injury (FI) and Property-Damage-Only (PDO)
- Resulting in 3 (2008/2009/2010) * 3 (Right/Left/Unknown) * 2 (FI/PDO) * 2 (SV/MV) = 36 dummy variables
  - Examples: 2008_Right_SV_FI and 2008_Right_SV_PDO.

For developing Maryland-specific crash distributions:

- Year: 2008, 2009, and 2010
- Crash Side: Right, Left, and Unknown
- Crash Type: Single-Vehicle (SV), Multiple-Vehicle (MV)
- Multiple-Vehicle (MV) Crash Type: Head-on, Right-Angle, Rear-End, Sideswipe Same Direction, and Other Multiple Vehicle Crashes
- Single-Vehicle (SV) Crash Type: Animal, Fixed Object, Other Object, Parked Vehicle, and Other Single Vehicle Crashes
- Crash Severity: Fatal and Injury (FI) and Property-Damage-Only (PDO)
- Resulting in 3 (2008/2009/2010) * 3 (Right/Left/Unknown) * 10 ([MV Crash Types + SV Crash Types]) * 2 (FI/PDO) = 180 dummy variables
  - Examples: 2008_Right_Head-on_FI and 2008_Right_Head-on_PDO.

Figure 13 shows a screenshot of this step in the ArcGIS 10.1 *ModelBuilder* environment.

Figure 13. CrashDB Screenshot in ArcGIS 10.1 *ModelBuilder* Environment

Crash Data Assignment to Freeway Segments and Speed-Change Lanes (FrSCCrashDB (Part 1))

After creating homogenous freeway segments (some including speed-change lane on either one or both sides) for the study years and also preparing crashes in an appropriate format, crashes were assigned to the network database (Figure 14). Like the Phase I study, this task was more difficult than initially expected. The reason was that there is no unique identifier that connects two databases. While NLFID is provided in both databases, it is not a unique identifier, making it impossible to link crashes to segments. The study team used the ArcGIS spatial join tool for crash assignment. Figure 15 illustrate an example of duplicated crash assignment. While a crash (red triangle) should be assigned to only one segment (AB), there were some crashes assigned to two segments. This is the case when a crash occurred near the point B where segments AB and BC meet. Due to a default search range of a GIS spatial join tool, the crash is assigned to both segments. NLFIDs of segments and crashes, mile post information, and other variables were compared to remove incorrectly assigned crashes.

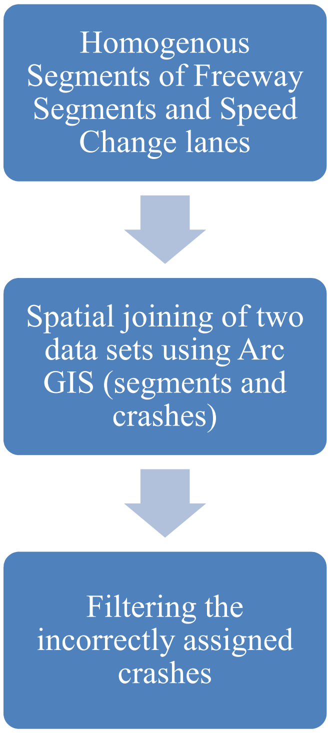


Figure 14. Crash Data Assignment to Freeway Segments and Speed-Change Lanes

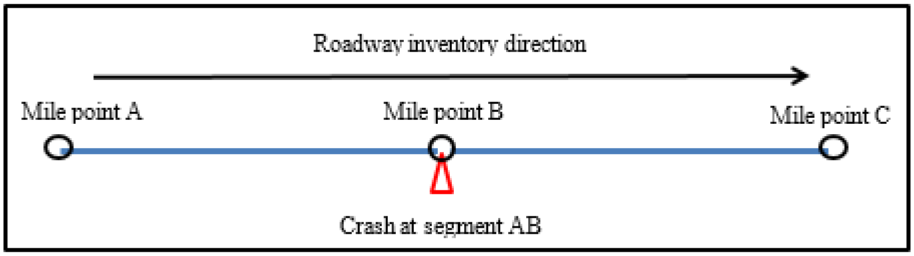


Figure 15. Potential Duplication of Assigned Crashes

Crash Data Assignment to Freeway Segments and Speed-Change Lanes (FrSCCrashDB (Part 2))

This step includes following parts:

- Data cleaning: After joining two datasets, some fields were not useful and were removed. For example, spatially joining the GIS feature classes generated variables such as “Join ID.”
- Adding new fields:

  - Twelve new crash fields for computing LCFs for freeway segments and six new crash fields for computing LCFs for speed-change lanes to define crash characteristics:
    - Examples: Fr_SV_FI_2008 and Fr_SV_PDO_2008.
    - Examples: SC_FI_2008 and SC_PDO_2008.
  - Twenty new crash fields for developing Maryland-specific crash distribution for freeway segments and speed-change lanes:
    - Examples: Fr_Head-on_FI and Fr_Head-on_PDO.
    - Examples: SV_Head-on_FI and SV_Head-on_PDO.
- Final data cleaning: two datasets were created for freeways and speed change lanes, respectively.

Figure 16 shows a screenshot of this step in the ArcGIS 10.1 *ModelBuilder* environment.

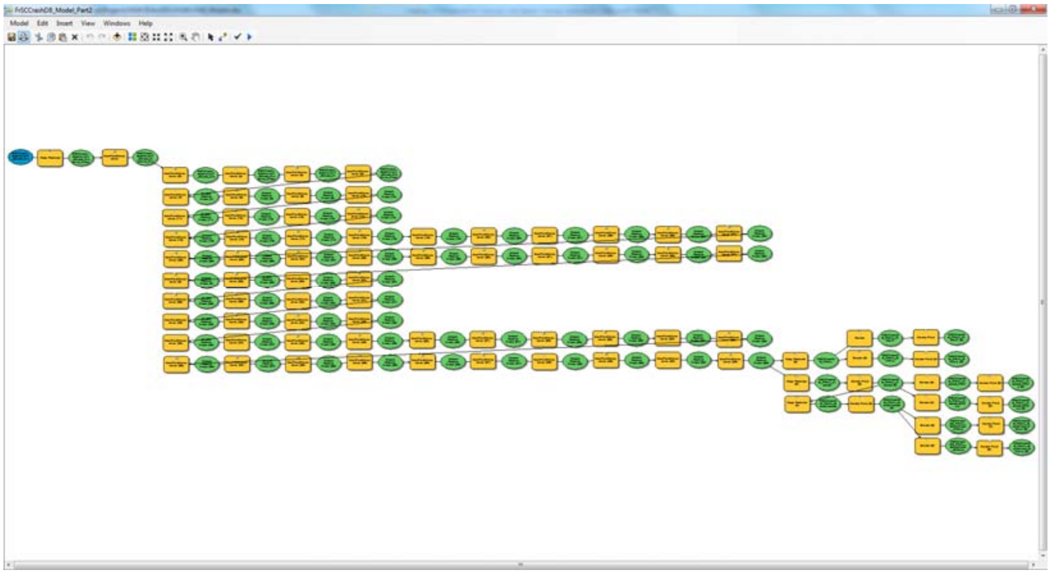


Figure 16. FrSCDB (Part 2) Screenshot in ArcGIS 10.1 *ModelBuilder* Environment

Of 84,277 segment crashes on IS, MD, and US roadways, 12,862 crashes were successfully assigned to the selected homogeneous freeway segments and speed-change lanes. The remaining crashes happened either on non-freeway MD and US roadways or outside of the homogeneous segments of the study period. Table 30 and 31 summarize such crash assignments.

Table 30. Summary of Crash Assignment to Freeway Segments

Facility Type	# of Segments	Total Length (Mile)	Average Length (Mile)	Total Crashes (2008-2010)	Crash Rate (Per Mile)
RF4	225	46.7	0.208	582	12.56
RF6	134	34.3	0.256	899	26.18
RF8	14	2.9	0.206	180	62.26
Rural (Subtotal)	*373*	*83.9*	*0.225*	*1,661*	*19.79*
UF4	651	86.4	0.133	1,648	19.08
UF6	452	65.1	0.144	2,059	31.64
UF8	289	45.6	0.158	3,188	69.85
UF10	4	0.7	0.166	8	12.01

Urban (Subtotal)	*1,396*	*197.8*	*0.142*	*6,903*	*34.90*
Total	1,769	281.7	0.159	8,564	30.40

Approximately 20% of freeway segment crashes are in rural areas and the rest are in urban (including suburban) areas, while 30% of total length of freeway segments are in rural areas.

Among three rural freeway segment types, RF4 (rural four-lane freeways) is the dominant type with 225 segments (60% of rural freeways) in 46.7 miles total length. RF6 (rural six-lane freeways) has the most crashes (889 crashes, 54% of rural total) and RF8 (rural eight-lane freeways) has the highest crash rate (62 crashes per mile).

On the urban (including suburban) side, UF4 (urban four-lane freeways) is the dominant type with 651 segments (47% of urban freeways) in 86.38 miles total length. UF8 (urban eight-lane freeways) has the most crashes (3,188 crashes, 46% of urban total) and the highest crash rate (70 crashes per mile). Very few (only four) freeway segments belong to UF10 (urban ten-lane freeways) with 0.666 miles of network and only eight crashes in the study period.

Table 31. Summary of Crash Assignment to Speed-Change Lanes

Facility Type	# of Segments	Total Length (Mile)	Average Length (Mile)	Total Crashes (2008-2010)	Crash Rate (Per Mile)
RSCen4	37	2.2	0.06	12	5.42
RSCen6	19	1.3	0.07	47	35.58
RSCen8	5	0.4	0.079	3	7.58
RSCex4	39	3.0	0.076	38	12.88
RSCex6	17	1.2	0.071	13	10.82
RSCex8	4	0.2	0.061	19	77.24
Rural (Subtotal)	*121*	*8.3*	*0.069*	*132*	*15.84*
USCen4	206	13.8	0.066	415	30.34
USCen6	163	11.9	0.073	589	49.58
USCen8	108	8.7	0.081	1130	129.86
USCex4	198	10.8	0.054	409	38.04
USCex6	187	14.4	0.077	811	56.14
USCex8	99	7.9	0.08	811	102.40
USCex10	1	0.1	0.109	1	9.17
Urban (Subtotal)	*962*	*67.6*	*0.070*	*4166*	*61.73*
Total	1083	75.9	0.07	4298	56.69

Approximately 11% of speed-change lanes (in terms of both number and total length) are in rural areas and the rest are in urban (including suburban) areas. Half of them are entrance facility types and the rest belongs to exit facility types. Only about 3% of crashes happened on rural speed-change lanes during the study period.

RSCen4 (rural speed-change lanes entering four-lane freeways) and RSCex4 (rural speed-change lanes exiting four-lane freeways) are the dominant speed-change lane types in rural areas, accounting for 63% in both number and total length of rural speed-change lanes. RSCen6 (rural speed-change lanes entering six-lane freeways) is the facility type with the most crashes (36% of rural speed-change lanes crashes), and RSCex8 (rural speed-change lanes exiting eight-lane freeways) has the highest crash rate, 77 crashes per mile (there are only 4 segments of RSCex8 with a total length of 0.246 miles).

In urban (including suburban) area, USCen4 (urban speed-change lanes entering four-lane freeways) (206 sites) and USCex4 (urban speed-change lanes exiting four-lane freeways) (198 sites) are the dominant speed-change lane types, accounting for 42% of urban speed-change lanes. USCen8 (urban speed-change lanes entering eight-lane freeways) and USCex8 (urban speed-change lanes exiting eight-lane freeways) have the most crashes (1,130 and 811 crashes respectively, accounting for 46% of urban speed-change lanes crashes). They are also the top two in terms of crash rate (130 and 102 crashes per mile respectively). Figure 17 shows an example of the final network at the interchange of I-495 and MD 295.

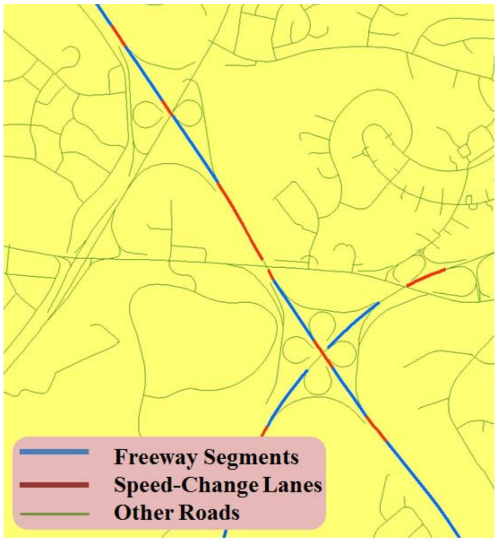


Figure 17. An Example of the Final Network at Interchange of I-495 and MD 295

Creating Crossroad Ramp Terminals Database

"A crossroad ramp terminal is a controlled terminal between a ramp and a crossroad" (AASHTO, 2014, pp. 19-1). While there are generally two types of crossroad ramp terminals, signalized and stop-controlled, the detailed configurations vary widely in different states in terms of the number of ramp legs, the number of left-turn movements, and the location of the crossroad left-turn storage (i.e., inside or outside of the interchange). Figure 18 summarizes the seven ramp terminal configurations identified in HSM. The names of these ramp terminals are:

- Three-leg ramp terminals:
    1. "A2": "three-leg ramp terminal at two-quadrant partial cloverleaf A"
    2. "B2": "three-leg ramp terminal at two-quadrant partial cloverleaf B"
    3. "D3en": "three-leg ramp terminal with diagonal entrance ramp"
    4. "D3ex": "three-leg ramp terminal with diagonal exit ramp"
- Four-leg ramp terminals:
    1. "A4": "four-leg ramp terminal at four-quadrant partial cloverleaf A"
    2. "B4": "four-leg ramp terminal at four-quadrant partial cloverleaf B"
    3. "D4": "four-leg ramp terminal with diagonal ramps"

The point GIS maps of the MASTER database include intersection information with traffic control types, but duplicating points need to be understood. For example, a four-leg intersection may have four points at the same location: two for beginning or ending mile points of the intersecting roads, and two for traffic control.

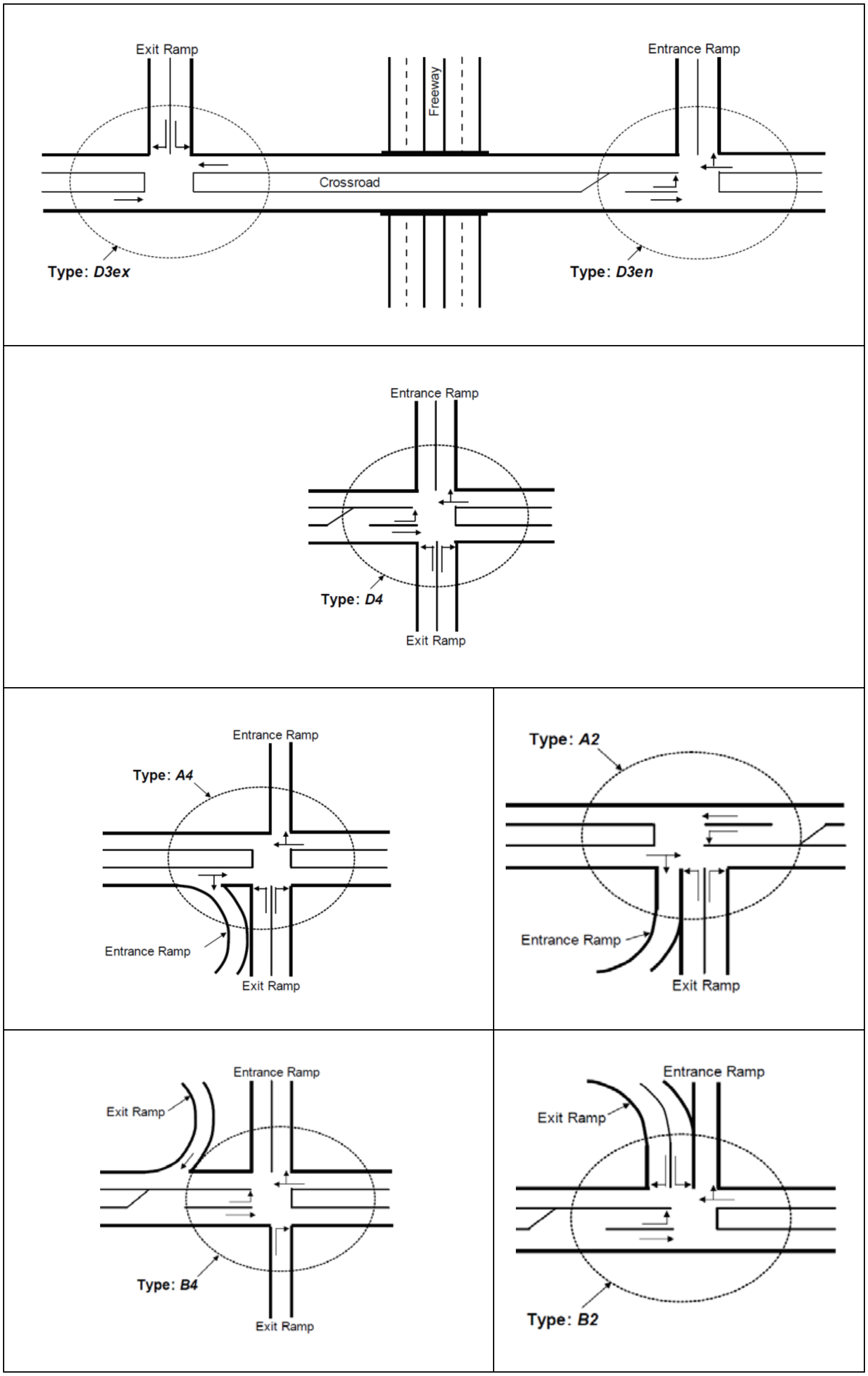


Figure 18. HSM Ramp Terminal Configurations

Figure 19 summarizes steps of data preparation for ramp terminals. Most of these steps were done in ArcGIS 10.1 with some Python coding, while manual identification of the ramp terminal configuration was done in Google Earth. The following shapefiles were used:

- HMIS_2008_UNIVERSE (Line)
- HMIS_2008_ MASTER (Point)
- HMIS_2009_UNIVERSE (Line)
- HMIS_2009_ MASTER (Point)
- HMIS_2010_UNIVERSE (Line)
- HMIS_2010_ MASTER (Point)
- Maryland_Crashes_2008_2010 (Point)

Prior to the start of the steps, the following changes were made:

- Since the HMIS_2008_UNIVERSE dataset does not have a "LOC_ERROR" field, it was manually added by selecting all geocoded roadway segments and then assigning values "1" for the newly added field of "LOC_ERROR."
- Adding year identifiers "OID_08," "OID_09," and "OID_10" to the 2008-2010 datasets before intersecting and combining them.

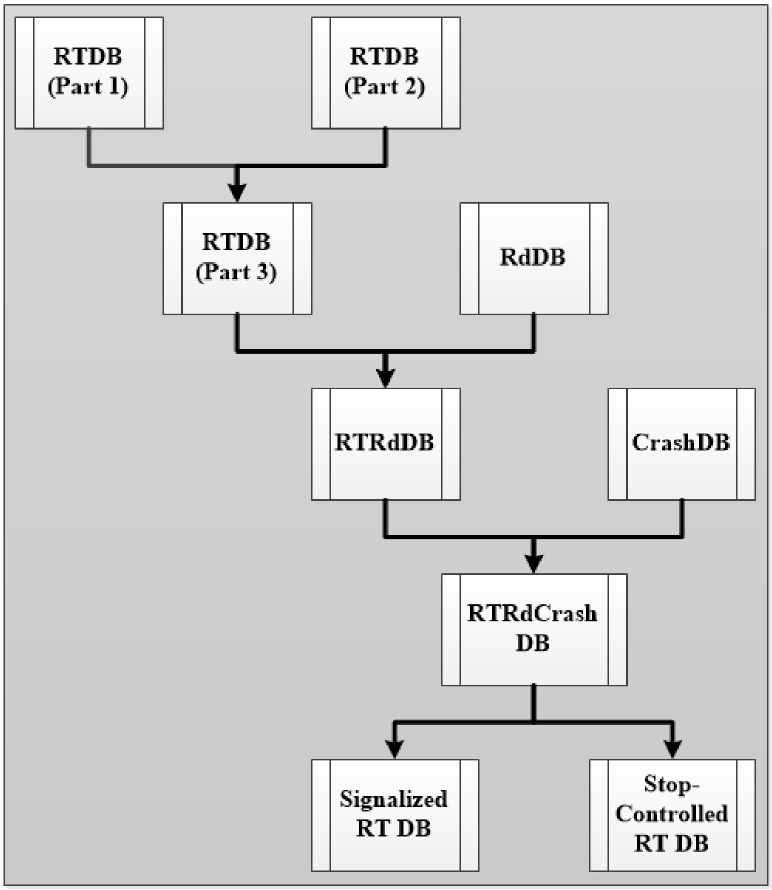


Figure 19. Steps of Creating Final Datasets for Ramp Terminals

Creating Ramp Terminals DB (RTDB (Part 1))

This step includes following parts:

- Selecting data points meeting the following criteria:
  - ID_Prefix: RP
  - MP_LOCATION_TYPE: 14 (signalized)
  - MPO_LOCATION_TYPE: 17 (stop-controlled)
- Intersecting the 2008-2010 datasets
- Selecting data points with consistent traffic control type for study period

Figure 20 shows a screenshot of this step in the ArcGIS 10.1 *ModelBuilder* environment.

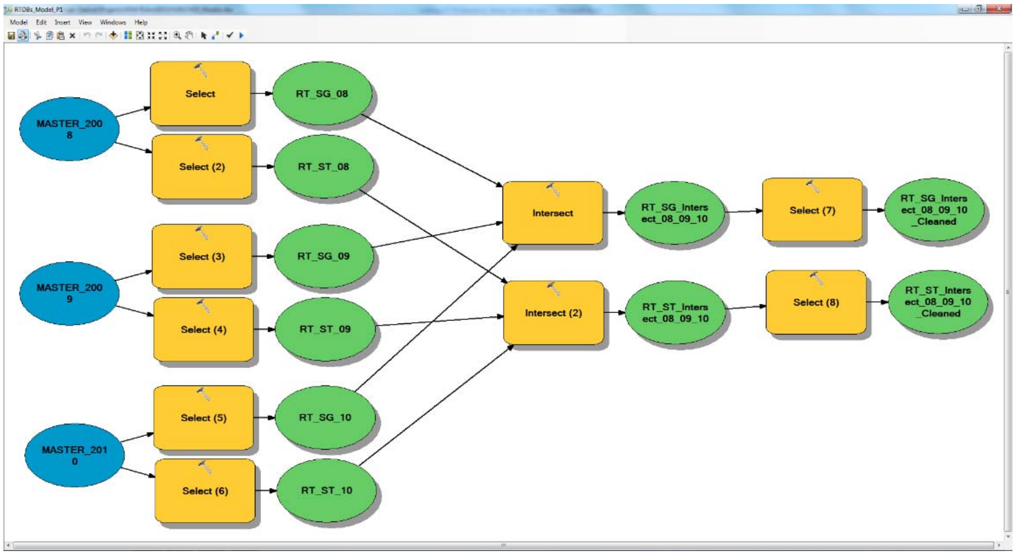


Figure 20. RTDB (Part 1) Screenshot in ArcGIS 10.1 *ModelBuilder* Environment

Creating Ramp Terminals DB (RTDB (Part 2))

When the traffic control type information was unavailable as a feature of a ramp data point but was a feature of the crossroad data point, these steps were completed:

- Selecting points meeting the following criteria:
  - ID_Prefix: Non-RP
  - MP_LOCATION_TYPE: 2 (ramp intersection) and/or 14 (signalized)
  - MP_LOCATION_TYPE: 2 (ramp intersection) and/or 17 (stop-controlled)
- Intersecting the 2008-2010 datasets
- Selecting data points with consistent traffic control type for study period

Figure 21 (next page) shows a screenshot of this step in the ArcGIS 10.1 *ModelBuilder* environment.

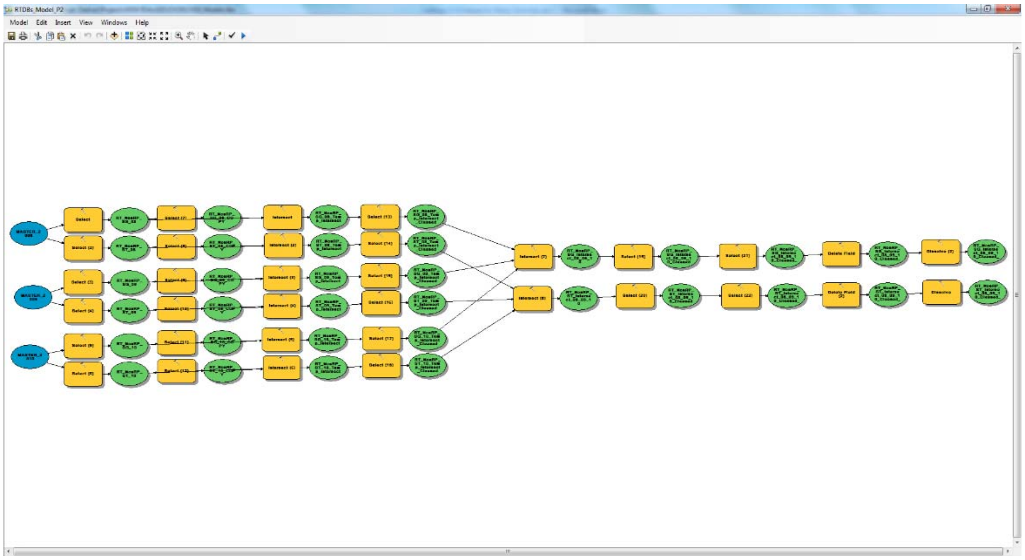


Figure 21. RTDB (Part 2) Screenshot in ArcGIS 10.1 *ModelBuilder* Environment

Creating Ramp Terminals DB (RTDB (Part 3))
After appending the result of the second step to the result of the first step, the signalized and stop-controlled ramp terminals were identified. The ramp terminal configurations were manually verified for accuracy using Google Maps. A new field of "RT_ID" was added to RTDB.

Preparing Roadway DB for Ramp Terminals (RdDB)
Roadway database (UNIVERSE) includes the following data that the ramp terminal predictive methods need:

- Traffic volume (AADT) on crossroads and ramps
- Area type
- Median width
- Number of through lanes on crossroads and ramps
- Presence of left-turn lanes
- Presence of right-turn lanes
- Left-turn lanes width

This step is to identify this data in the UNIVERSE database.

Merging Ramp Terminals DB and Roadway DB (RTRdDB)
Using the spatial join feature of ArcGIS 10.1 (join type: "One-to-Many" and 100 ft. search radius), RdDB was merged with RTDB to create RTRdDB.

Preparing Crash DB for Ramp Terminals (CrashDB)
Crash data was reclassified in the format required by HSM in the ArcGIS 10.1 *ModelBuilder*:

For developing LCFs:

- Year: 2008, 2009, and 2010
- Crash Severity: Fatal and Injury (FI) and Property-Damage-Only (PDO)
- Resulting in 3 (2008/2009/2010) * 2 (FI/PDO) = 6 dummy variables
    - Examples: 2008_FI and 2008_PDO.

For developing Maryland-specific crash distributions:

- Year: 2008, 2009, and 2010
- Crash Type: Single-Vehicle (SV), Multiple-Vehicle (MV)
- Multiple-Vehicle (MV) Crash Type: Head-on, Right-Angle, Rear-End, Sideswipe Same Direction, and Other Multiple Vehicle Crashes
- Single-Vehicle (SV) Crash Type: Animal, Fixed Object, Other Object, Parked Vehicle, and Other Single Vehicle Crashes
- Crash Severity: Fatal and Injury (FI) and Property-Damage-Only (PDO)
- Resulting in 3 (2008/2009/2010) * 10 ([MV Crash Types + SV Crash Types]) * 2 (FI/PDO) = 60 dummy variables
    - Examples: 2008_Head-on_FI and 2008_Right_Head-on_PDO.

Merging Ramp Terminals and Roadway DB and Crash DB (RTRdCrashDB)

In this step, crashes were assigned to the ramp terminals in RTRdDB, using the ArcGIS spatial join tool (join type: "One-to-Many" and 250 ft. search radius). Two types of incorrect crash assignments exist and NLFIDs of ramp terminals, crossroads, and other variables were compared to eliminate these errors:

- Duplicate crash assignments were made to neighboring ramp terminals with a distance less than the 250 ft. spatial join search radius.
- Crashes on freeway segments or speed-change lanes were incorrectly assigned to ramp terminals.

After assigning crashes, the following data fields were added to complete the final datasets:

- 6 new crash fields for computing LCFs for ramp terminals:
    - Examples: FI_2008 and PDO_2008.
- 20 new crash fields for Maryland-specific crash distribution for ramp terminals:
    - Examples: Head-on_FI and Head-on_PDO.

Figure 22 shows a screenshot of this step in the ArcGIS 10.*1 ModelBuilder* environment.

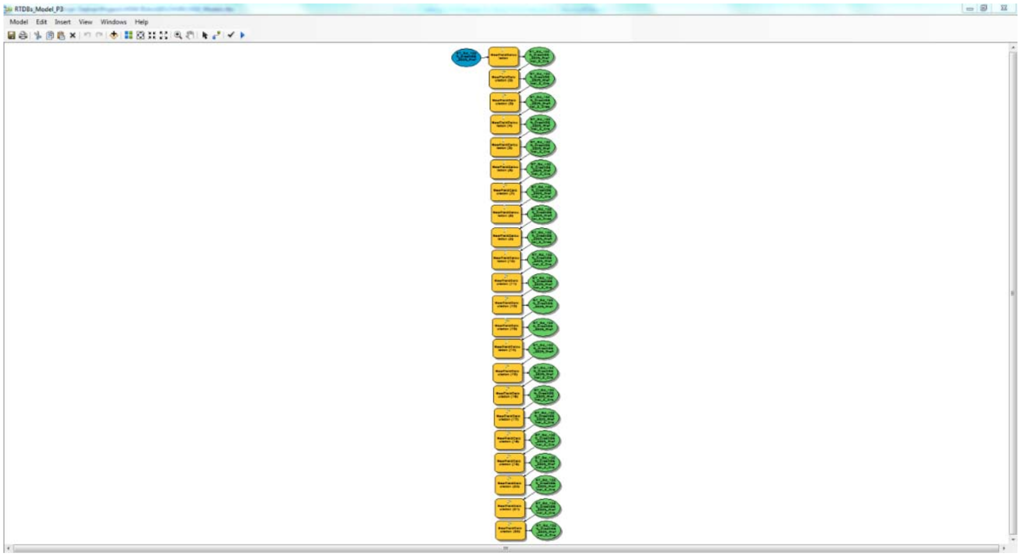


Figure 22. RTRdCrashDB Screenshot in ArcGIS 10.1 *ModelBuilder* Environment

Manual Identification of the Ramp Terminal Configuration Types

The ramp terminal configuration was identified manually in the Google Earth environment. XML files with KML format[1] were created for the ramp terminals and superimposed on Google Earth. Figure 23 to Figure 25 show some examples of identified ramp terminal types in the Google Earth environment.

Figure 23. Two "D4" Signalized Ramp Terminals at Interchange of I-95 and Riverside Parkway (MD-543)

Figure 24. Two "D4" Stop-Controlled Ramp Terminals at Interchange of I-695 and Cove Road

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[1] Keyhole Markup Language (KML) is an XML notation for expressing geographic annotation and visualization within Internet-based maps (two-dimensional).

Figure 25. An "A2" Signalized Ramp Terminal at Interchange of Patuxent Freeway (MD-32) and Annapolis Road (MD-175)

Table 32 summarizes crash assignment to signalized and stop-controlled ramp terminals. It should be noted that the number of ramp terminals at this step was not finalized yet and further manual efforts were required to identify ramp terminal types. There were 1,124 geocoded crashes that were assigned to ramp terminals. The majority of crashes happened on the signalized ramp terminals (86% of total crashes with an average of 5.20 crashes per ramp terminal).

Table 32. Summary of Crash Assignment to Ramp Terminals

Ramp Terminal Type	# of Ramp Terminals	% Ramp Terminals	Total Crashes (2008-2010)	Crash Rate (Per Ramp Terminal)
Signalized	185	53.8	962	5.20
Stop-Controlled	159	46.2	162	1.02
Total	344	100	1,124	3.27

Table 33 presents a summary of crash assignment by ramp terminals control and configuration types. Among the signalized ramp terminals, D4 is the dominant type with 59 sites (31.9% of signalized ramp terminals) and 358 crashes (37.2% of signalized ramp terminals crashes). A4 has the highest crash rate (6.71 crashes per site). Among the stop-controlled ramp terminals, D4 again is the dominant type with 61 sites (38.4% of stop-controlled ramp terminals) and 52 crashes (32.1% of stop-controlled ramp terminals crashes). D3en has the highest crash rate (3.5 crashes per site). The average crash rate of all ramp terminals is 3.27 crashes per ramp terminal.

Table 33. Crash Assignment by Ramp Terminals Control/ Configuration Type

Ramp Terminal Type		# Ramp Terminals	Total Crashes (2008-2010)	Crash Rate (Per Ramp Terminal)
Signalized	A2	23	111	4.83
	A4	7	47	6.71
	B2	20	128	6.40
	B4	6	21	3.50
	D3en	23	92	4.00
	D3ex	47	205	4.36
	D4	59	358	6.07
Subtotal (Signalized)		*185*	*962*	*5.20*
Stop-controlled	A2	20	32	1.60
	B2	20	29	1.45
	D3en	2	7	3.50
	D3ex	56	42	0.75
	D4	61	52	0.85
Subtotal (Stop-controlled)		*159*	*162*	*1.02*
Total		344	1,124	3.27

Sampling (Site Selection)

The sampling task followed the development of the homogeneous segments and intersection databases. The purpose of this task is to select candidate sites for calculating predicted crash frequencies and developing LCFs. Compared to the Phase I study, the whole population in this phase was relatively smaller, and almost all matching sites were included in the final datasets for developing Maryland LCFs.

The supplement to the HSM provides the following site selection criteria:

- The minimum samples size should be 30 to 50 sites per facility type.
- Samples should be drawn randomly.
- Each sample set should have at least 100 annual crashes.
- Segments should be between 0.1 and 1.0 mile in length (AASHTO, 2014, pp. Appendix B-4).
- Speed-change lanes are limited to 0.3 miles in length and if this length is exceeded, then the speed-change lane is counted as a through lane (AASHTO, 2014, pp. 18-15).

Freeway Segments

The study team considered the following criterion in addition to the general HSM guidelines for sampling:

- Freeway segments without speed-change lanes on either one side or both sides of the roadway

This criterion was applied because some freeway segments had speed-change lanes either on one side or both sides of the freeway segment.

Table 34 and 35 summarize freeway segments with speed-change lanes for the whole population (1,769 sites, 281.715 miles) and the population limited to those longer than 0.1 miles (744 sites, 232.080 miles), respectively. Only about 42% (744 freeway segments) of 1,769 freeway segments are longer than 0.1 miles (i.e., the HSM's requirement). About 7% (53 freeway segments) of the remaining freeway segments (accounts for 3.6% of total length) have speed-change lanes on both sides of the roadway. Due to the definitions of the "effective freeway segment length," their length would be considered as zero when applying the HSM predictive methods so they should be excluded. About 14.7% (110 freeway segments) of the remaining freeway segments have a speed-change lane on one side of the roadway, and they were excluded. The resulting dataset includes 581 freeway segments.

During the manual data collection, another 17 freeway segments were removed due to unavailable data. There were 564 freeway segments in the final sampling dataset (Table 36 and Table 37 for details). The tables summarize freeway segments by area type and facility type. There are more than 100 annual crashes for four different crash types during 2008-10: "Single-Vehicle and Fatal and Injury" (SV FI), "Single-Vehicle and Property Damage Only" (SV PDO), "Multiple-Vehicle and Fatal and Injury" (MV FI), and "Multiple-Vehicle Property Damage Only" (MV PDO).

Table 34. Summary of Freeway Segments with Speed-Change Lanes – Whole Population

Facility Type	Population		Both Sides S-C		One side S-C		Both Sides w/o S-C	
	#	Total Length (Miles)	#	Total Length (Miles)	#	Total Length (Miles)	#	Total Length (Miles)
RF4	225	46.723	9	0.473	58	4.221	158	42.029
RF6	134	34.333	6	0.476	24	1.571	104	32.286
RF8	14	2.891	2	0.194	5	0.255	7	2.442
Rural (Subtotal)	*373*	*83.947*	*17*	*1.143*	*87*	*6.047*	*269*	*76.757*
UF4	651	86.38	88	5.278	228	13.874	335	67.228
UF6	452	65.082	94	6.989	162	12.349	196	45.744
UF8	289	45.64	48	3.766	111	9.091	130	32.783
UF10	4	0.666	0	0	1	0.11	3	0.556
Urban (Subtotal)	*1396*	*197.768*	*230*	*16.033*	*502*	*35.424*	*664*	*146.311*
Total	1769	281.715	247	17.176	589	41.471	933	223.068

Table 35. Summary of Freeway Segments with Speed-Change Lanes – Population Longer than 0.1 Mile

Facility Type	Population Longer than 0.1 Mile		Both Sides S-C		One side S-C		Both Sides w/o S-C	
	#	Total Length (Miles)	#	Total Length (Miles)	#	Total Length (Miles)	#	Total Length (Miles)
RF4	119	41.100	1	0.124	11	1.924	107	39.052
RF6	77	31.442	1	0.119	5	0.742	71	30.581
RF8	6	2.445	0	0.000	1	0.112	5	2.333
Rural (Subtotal)	*202*	*74.987*	*2*	*0.243*	*17*	*2.778*	*183*	*71.966*
UF4	224	66.400	14	2.408	27	4.776	183	59.216
UF6	183	51.817	23	3.460	39	6.399	121	41.958
UF8	132	38.250	14	2.336	26	5.015	92	30.899
UF10	3	0.626	0	0.000	1	0.109	2	0.517
Urban (Subtotal)	*542*	*157.093*	*51*	*8.204*	*93*	*16.299*	*398*	*132.59*
Total	744	232.080	53	8.447	110	19.077	581	204.556

Table 36. Summary of Freeway Segments Sampled Sites by Crash Types

Facility Type	# of Segments	Total Length (Miles)	Min. Segment Length (Miles)	Max. Segment Length (Miles)	Average Length (Miles)	SV FI (2008-2010)	SV PDO (2008-2010)	MV FI (2008-2010)	MV PDO (2008-2010)	Total Crashes (2008-2010)	Crash Rate (Per Mile)
RF4	105	38.093	0.100	1.000	0.363	125	178	78	112	493	12.94
RF6	69	29.053	0.110	1.000	0.421	108	278	97	239	722	24.85
RF8	5	2.333	0.260	0.684	0.467	24	54	35	51	164	70.29
Rural (Subtotal)	*179*	*69.479*	*0.100*	*1.000*	*0.388*	*257*	*510*	*210*	*402*	*1379*	*19.85*
UF4	175	56.053	0.100	1.000	0.320	214	329	196	299	1038	18.52
UF6	119	41.448	0.103	1.000	0.348	217	433	269	377	1296	31.27
UF8	90	29.753	0.107	1.000	0.331	222	461	513	809	2005	67.39
UF10	1	0.165	0.165	0.165	0.165	0	2	2	3	7	42.37
Urban (Subtotal)	*385*	*127.419*	*0.100*	*1.000*	*0.331*	*653*	*1225*	*980*	*1488*	*4346*	*34.11*
Total	564	196.898	0.100	1.000	0.349	910	1735	1190	1890	5725	29.08

Table 37. Details of Freeway Segments Sampled Sites Crashes

Facility Type	# of Segments	SV FI (2008)	SV PDO (2008)	MV FI (2008)	MV PDO (2008)	SV FI (2009)	SV PDO (2009)	MV FI (2009)	MV PDO (2009)	SV FI (2010)	SV PDO (2010)	MV FI (2010)	MV PDO (2010)	Total Crashes (2008-10)
RF4	105	47	65	25	35	47	71	32	49	31	42	21	28	493
RF6	69	31	87	31	82	46	111	33	80	31	80	33	77	722
RF8	5	7	16	13	17	5	20	14	20	12	18	8	14	164
Rural (Subtotal)	*179*	*85*	*168*	*69*	*134*	*98*	*202*	*79*	*149*	*74*	*140*	*62*	*119*	*1379*
UF4	175	71	99	59	63	78	117	63	117	65	113	74	119	1038
UF6	119	65	139	89	130	89	168	93	134	63	126	87	113	1296
UF8	90	75	132	180	238	89	162	166	295	58	167	167	276	2005
UF10	1	0	0	1	0	0	2	0	2	0	0	1	1	7
Urban (Subtotal)	*385*	*211*	*370*	*329*	*431*	*256*	*449*	*322*	*548*	*186*	*406*	*329*	*509*	*4346*
Total	564	296	538	398	565	354	651	401	697	260	546	391	628	5725

Speed-Change Lanes

While a maximum length threshold for speed-change lanes is defined by the HSM as 0.3 miles (AASHTO, 2014, pp. 18-15), there is no minimum length threshold defined. They are categorized as "Intersections" in the HSM Table B-1 and the recommended roadway segment length boundaries do not apply. The study team decided to use 0.05 miles as the minimum length for speed-change lanes which resulted in 538 sites.

During the manual data collection 20 sites were removed due to unavailable data. Table 42 summarized the final dataset (518 speed-change lanes) by area type and facility type: 264 ramp-entrance speed-change lanes and 254 ramp-exit speed-change lanes. Based on the associated crash columns there are more than 100 annual crashes for two different crash types during 2008-10: i.e., "Fatal and Injury" (FI) and "Property Damage Only" (PDO).

Ramp Terminals

Twenty-five ramp terminals out of 344 identified ramp terminals (see "Manual Identification of the Ramp Terminal Configuration Types") were removed due to unavailable data, and there were 319 ramp terminals in the final dataset, including 172 signalized ramp terminals and 147 stop-controlled ramp terminals (Table 39 and Table 40). There are more than 100 annual crashes for two different crash types during 2008-10 for signalized ramp terminals: "Fatal and Injury" (FI) and "Property Damage Only" (PDO). However, there were very few observed crashes during the study period for stop-controlled ramp terminals (160 total crashes). The study team decided to develop LCFs for them despite their not meeting the minimum annual crashes, although their application should be followed with caution.

Ramps and Collector-Distributor Roads

None of the ramps and collector-distributor roads were included in the analysis due to insufficient crash data. Even though there was no geocoded crash data the study team conducted a general and comparative data screening on the 222 crashes on ramps and collector-distributor roads in the crash dataset during 2009-2010 (Appendix F).

All Sampled Sites

Table 41 summarizes all sampled sites for freeway segments, speed-change lanes, and ramp terminals (signalized and stop-controlled).

Table 38. Summary of Speed-Change Lanes Sampled Sites by Crash Types

Facility Type	# of Segments	Total Length (Miles)	Min. Segment Length (Miles)	Max. Segment Length (Miles)	Average Length (Miles)	FI (2008)	PDO (2008)	FI (2009)	PDO (2009)	FI (2010)	PDO (2010)	Total Crashes (2008-10)	Crash Rate (Per Mile)
RSCen4	16	1.5	0.051	0.211	0.094	0	2	0	2	0	1	5	3.34
RSCen6	9	1.0	0.059	0.195	0.103	2	4	3	13	6	8	36	38.66
RSCen8	4	0.4	0.063	0.112	0.092	0	2	0	0	0	0	2	5.43
RSCex4	21	1.8	0.051	0.175	0.086	1	1	1	4	2	5	14	7.78
RSCex6	11	1.0	0.059	0.167	0.090	0	1	1	2	1	3	8	8.13
RSCex8	2	0.2	0.097	0.097	0.097	0	3	2	3	1	3	12	62.06
Rural (Subtotal)	*63*	*5.8*	*0.051*	*0.211*	*0.092*	*3*	*13*	*7*	*24*	*10*	*20*	*77*	*13.33*
USCen4	85	7.0	0.050	0.250	0.083	17	13	13	37	16	27	123	17.52
USCen6	93	9.1	0.051	0.267	0.098	46	81	55	84	45	50	361	39.76
USCen8	57	6.0	0.051	0.279	0.105	55	92	55	96	45	88	431	71.80
USCex4	72	6.9	0.051	0.223	0.095	13	26	12	45	18	24	138	20.12
USCex6	98	10.0	0.051	0.238	0.102	44	60	76	112	48	87	427	42.59
USCex8	49	5.30	0.051	0.248	0.108	40	51	41	82	35	59	308	58.22
USCex10	1	0.1	0.109	0.109	0.109	0	1	0	0	0	0	1	9.15
Urban (Subtotal)	*455*	*44.4*	*0.050*	*0.279*	*0.098*	*215*	*324*	*252*	*456*	*207*	*335*	*1789*	*40.31*
Entrance (Subtotal)	*264*	*24.9*	*0.050*	*0.279*	*0.094*	*120*	*194*	*126*	*232*	*112*	*174*	*958*	*38.47*
Exit (Subtotal)	*254*	*25.3*	*0.051*	*0.248*	*0.099*	*98*	*143*	*133*	*248*	*105*	*181*	*908*	*35.94*
Total	518	50.161	0.050	0.279	0.097	218	337	259	480	217	355	1866	37.20

Table 39. Summary of Signalized Ramp Terminals Sampled Sites by Crash Types

Facility Type		# of Segments	FI (2008)	PDO (2008)	FI (2009)	PDO (2009)	FI (2008)	PDO (2008)	Total Crashes (2008-2010)	Crash Rate (Per Ramp Terminal)
Rural	A2	2	0	0	1	1	1	0	3	1.50
	B2	1	0	0	0	1	0	0	1	1.00
	D3ex	1	0	0	0	1	1	0	2	2.00
	D4	4	2	2	1	1	3	3	12	3.00
Rural (Subtotal)		*8*	*2*	*2*	*2*	*4*	*5*	*3*	*18*	*2.25*
Urban	A2	20	19	25	12	14	14	19	103	5.15
	A4	6	7	8	8	5	3	15	46	7.67
	B2	19	15	24	16	21	30	21	127	6.68
	B4	6	5	4	3	2	2	4	20	3.33
	D3en	22	10	16	11	14	12	23	86	3.91
	D3ex	44	32	35	21	38	35	42	203	4.61
	D4	47	54	53	45	52	62	67	333	7.09
Urban (Subtotal)		*164*	*142*	*165*	*116*	*146*	*158*	*191*	*918*	*5.60*
Total		172	144	167	118	150	163	194	936	5.44

Table 40. Summary of Stop-controlled Ramp Terminals Sampled Sites by Crash Types

Facility Type		# of Segments	FI (2008)	PDO (2008)	FI (2009)	PDO (2009)	FI (2008)	PDO (2008)	Total Crashes (2008-2010)	Crash Rate (Per Ramp Terminal)
Rural	A2	7	0	1	4	3	2	2	12	1.71
	B2	7	1	1	0	0	1	0	3	0.43
	D3en	1	0	0	0	0	1	0	1	1.00
	D3ex	22	1	3	1	0	0	0	5	0.23
	D4	30	3	2	1	2	3	0	11	0.37
Rural (Subtotal)		*67*	*5*	*7*	*6*	*5*	*7*	*2*	*32*	*0.48*
Urban	A2	9	4	4	1	3	3	3	18	2.00
	B2	10	2	5	5	4	5	5	26	2.60
	D3en	2	1	0	2	1	2	0	6	3.00
	D3ex	29	5	1	8	4	7	9	34	1.17
	D4	30	5	9	7	6	8	9	44	1.47
Urban (Subtotal)		*80*	*17*	*19*	*23*	*18*	*25*	*26*	*128*	*1.60*
Total		147	22	26	29	23	32	28	160	1.09

Table 41. All Samples by Facility Type

Facility Type	Population		Total Crashes (2008-2010)	Crash Rate (Per Mile or Per Ramp Terminal)	Calibration Dataset		Total Crashes (2008-2010)	Crash Rate (Per Mile or Per Ramp Terminal)
	# of segments	Total Length (Miles)			# of Segments	Total Length (Miles)		
(a) Freeway Segments								
RF4	225	46.7	582	12.46	105	38.1	493	12.94
RF6	134	34.3	899	26.18	69	29.1	722	24.85
RF8	14	2.9	180	62.26	5	2.3	164	70.29
Rural (Subtotal)	*373*	*83.9*	*1,661*	*19.79*	*179*	*69.5*	*1379*	*19.85*
UF4	651	86.4	1,648	19.08	175	56.1	1038	18.52
UF6	452	65.1	2,059	31.64	119	41.4	1296	31.27
UF8	289	45.6	3,188	69.85	90	29.8	2005	67.39
UF10	4	0.7	8	12.01	1	0.2	7	42.37
Urban (Subtotal)	*1396*	*197.8*	*6,903*	*34.9*	*385*	*127.4*	*4346*	*34.11*
Total	1769	281.7	8,564	30.4	564	196.9	5725	29.08
(b) Speed-Change Lanes								
RSCen4	37	2.2	12	5.42	16	1.5	5	3.34
RSCen6	19	1.3	47	35.58	9	0.9	36	38.66
RSCen8	5	0.4	3	7.58	4	0.4	2	5.43
RSCex4	39	3.0	38	12.88	21	1.80	14	7.78
RSCex6	17	1.2	13	10.82	11	1.0	8	8.13
RSCex8	4	0.2	19	77.24	2	0.2	12	62.06
Rural (Subtotal)	*121*	*8.3*	*132*	*15.84*	*63*	*5.8*	*77*	*13.33*
USCen4	206	13.7	415	30.34	85	7.0	123	17.52
USCen6	163	11.9	589	49.58	93	9.1	361	39.76
USCen8	108	8.7	1130	129.86	57	6.0	431	71.8
USCex4	198	10.8	409	38.04	72	6.9	138	20.12
USCex6	187	14.4	811	56.14	98	10.0	427	42.59
USCex8	99	7.9	811	102.4	49	5.3	308	58.22
USCex10	1	0.1	1	9.17	1	0.1	1	9.15
Urban (Subtotal)	*962*	*67.5*	*4166*	*61.73*	*455*	*44.4*	*1789*	*40.31*
Entrance (Subtotal)	*538*	*38.2*	*2196*	*57.5*	*264*	*24.9*	*958*	*38.47*
Exit (Subtotal)	*545*	*37.6*	*2102*	*55.86*	*254*	*25.3*	*908*	*35.94*
Total	1083	75.8	4298	56.69	518	50.2	1866	37.2

Facility Type	Population		Total Crashes (2008-2010)	Crash Rate (Per Mile or Per Ramp Terminal)	Calibration Dataset		Total Crashes (2008-2010)	Crash Rate (Per Mile or Per Ramp Terminal)
	# of segments	Total Length (Miles)			# of Segments	Total Length (Miles)		
(c) Ramp Terminals								
A2	23	NA	111	4.83	22	NA	106	4.82
A4	7	NA	47	6.71	6	NA	46	7.67
B2	20	NA	128	6.4	20	NA	128	6.40
B4	6	NA	21	3.5	6	NA	20	3.33
D3en	23	NA	92	4	22	NA	86	3.91
D3ex	47	NA	205	4.36	45	NA	205	4.56
D4	59	NA	358	6.07	51	NA	345	6.76
Subtotal (Signalized)	*185*	*NA*	*962*	*5.2*	*172*	*NA*	*936*	*5.44*
A2	20	NA	32	1.6	16	NA	30	1.88
B2	20	NA	29	1.45	17	NA	29	1.71
D3en	2	NA	7	3.5	3	NA	7	2.33
D3ex	56	NA	42	0.75	51	NA	39	0.76
D4	61	NA	52	0.85	60	NA	55	0.92
Subtotal (Stop-controlled)	*159*	*NA*	*162*	*1.02*	*147*	*NA*	*160*	*1.09*
Total	344	NA	1,124	3.27	319	NA	1,096	3.44

Additional Data Collection for Samples

Similar to the Phase I study, after the site selection task was completed, additional data items were collected for selected sites. About 40% of the data was not readily available and Google Earth was utilized for manually counting, extracting, and measuring variables. Multiple regression models were developed for estimating AADT on ramps.

Data Items Collected by Manual Extraction from SHA Datasets

The following variables were collected by manual extraction:

- Freeways:
    - Curve radius using: ARAN Curve data (shapefiles for 2013-2014)
    - Curve length within site: ARAN Curve data (shapefiles for 2013-2014)
    - Curve side of road: ARAN Curve data (shapefiles for 2013-2014)
    - AADT values of closest upstream/downstream entrance/exits ramps (2008-2010): UNIVERSE data (2008-2012)
- Speed-Change Lanes:
    - Curve radius: ARAN Curve data (shapefiles for 2013-2014)
    - Curve length within site: ARAN Curve data (shapefiles for 2013-2014)
    - Curve side of road: ARAN Curve data (shapefiles for 2013-2014)
    - AADT values of entrance/exits ramps (2008-2010): UNIVERSE data (2008-2012)

Figure 26 shows an example of curve data at the interchange of I-495 and MD 185 and Figure 27 shows an example of AADT data extraction for an exit ramp.

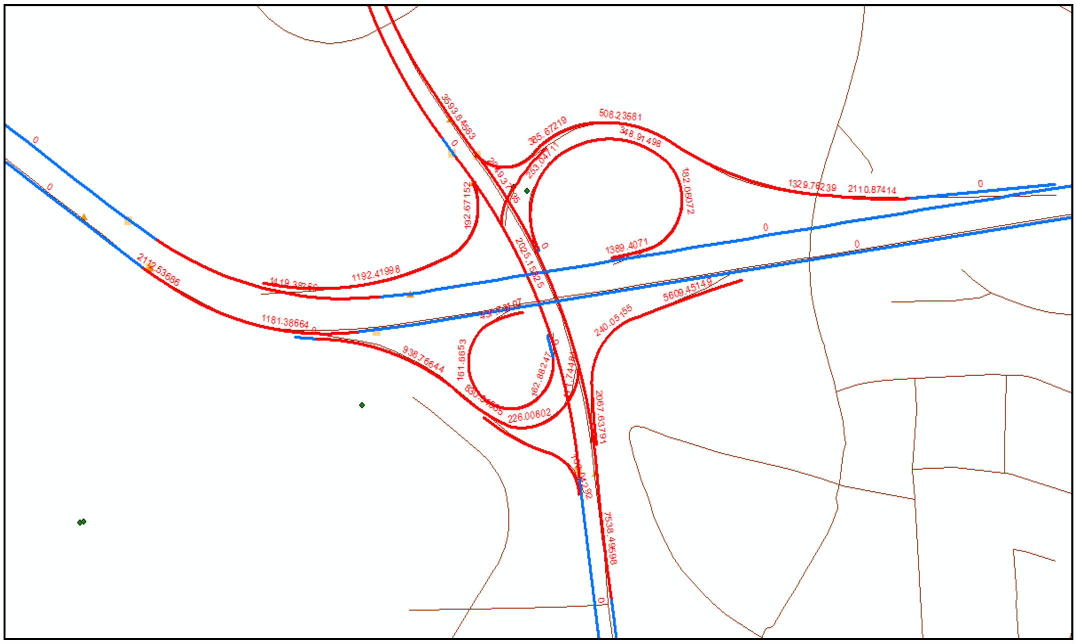
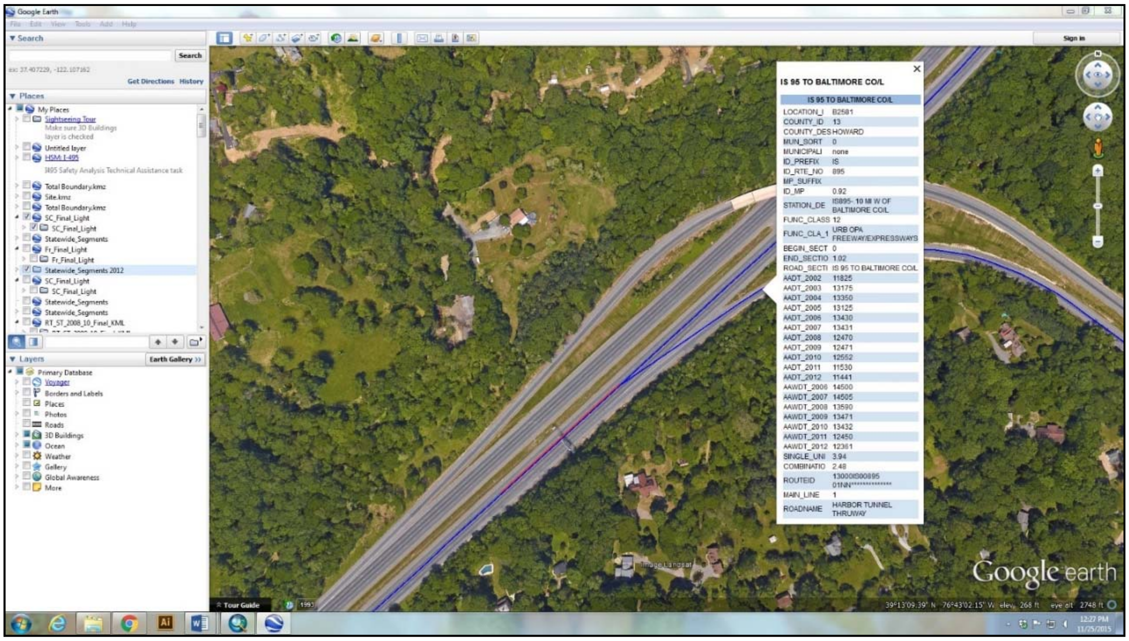


Figure 26. An Example of Curve Data Extraction at Interchange of I-495 and MD-185



IS 95 TO BALTIMORE CO/L

IS 95 TO BALTIMORE CO/L	
LOCATION_I	B2581
COUNTY_ID	13
COUNTY_DES	HOWARD
MUN_SORT	0
MUNICIPALI	none
ID_PREFIX	IS
ID_RTE_NO	895
MP_SUFFIX	
ID_MP	0.92
STATION_DE	IS895- 10 MI W OF BALTIMORE CO/L
FUNC_CLASS	12
FUNC_CLA_1	URB OPA FREEWAY/EXPRESSWAYS
BEGIN_SECT	0
END_SECTIO	1.02
ROAD_SECTI	IS 95 TO BALTIMORE CO/L
AADT_2002	11825
AADT_2003	13175
AADT_2004	13350
AADT_2005	13125
AADT_2006	13430
AADT_2007	13431
AADT_2008	12470
AADT_2009	12471
AADT_2010	12552
AADT_2011	11530
AADT_2012	11441
AAWDT_2006	14500
AAWDT_2007	14505
AAWDT_2008	13590
AAWDT_2009	13471
AAWDT_2010	13432
AAWDT_2011	12450
AAWDT_2012	12361
SINGLE_UNI	3.94
COMBINATIO	2.48
ROUTEID	13000IS00895 01NN**************
MAIN_LINE	1
ROADNAME	HARBOR TUNNEL THRUWAY

Figure 27. An Example of AADT Data Extraction for an Exit Ramp

Data Items Collected by Counting

Several data items on ramp terminals were collected by counting variables shown on Google Earth. XML files with KML format were created for the sampled segments and superimposed on Google Earth. Such data items include:

- Ramp Terminals:
  - Number of unsignalized driveways on the outside crossroad leg
  - Number of unsignalized public street approaches on the outside crossroad leg

Data Items Collected by Manual Checking

Several data items on freeway segments, speed-change lanes, and ramp terminals were collected by manually checking variables of interest on Google Earth:

- Freeways:
  - Crash-side for some roadways (see "
  - Preparing Crash DB for Freeway Segments and Speed-Change Lanes" for details.)
- Speed-Change Lanes:
  - Crash-side for some roadways (see "
  - Preparing Crash DB for Freeway Segments and Speed-Change Lanes" for details.)
- Ramp Terminals:
  - Ramp terminal configuration (see "Manual Identification of the Ramp Terminal Configuration Types" for details.)
  - Number of through lanes on the inside/outside crossroad approach (double-checking number of lanes extracted from SHA data using Google Earth)
  - Number of lanes on the exit ramp leg at the terminal (double-checking number of lanes extracted from SHA data using Google Earth)

    - Presence of a non-ramp public street leg at the terminal
    - Presence of a left-turn lane (or bay) on the inside/outside crossroad approach
    - Presence of a right-turn lane (or bay) on the inside/outside crossroad approach
    - Presence of right-turn channelization on the inside/outside crossroad approach
    - Presence of right-turn channelization on the exit ramp approach
    - Presence of protected left-turn operation

Data Items Collected by Manual Measurement

Several data items on freeway segments, speed-change lanes, and ramp terminals were collected by manual measurement on Google Earth:

- Freeways:
    - Proportion segment length with median barrier
    - Average median barrier offset
    - Outside barrier length
    - Proportion segment length with outside barrier
    - Average outside barrier offset
    - Distances to closest upstream/downstream entrance/exits ramps
    - Proportion inside/outside rumble strips
    - Outside clear zone width
    - Curve length within site
- Speed-Change Lanes:
    - Proportion segment length with median barrier
    - Average median barrier offset
    - Curve length within site
- Ramp Terminals:
    - Exit ramp skew angle
    - Distance to the adjacent ramp terminal
    - Distance to the next public street intersection on the outside crossroad leg

Figure 28 shows an example of median barrier offset measurement in Google Earth, Figure 29 demonstrates an example of outside clear zone width measurement, Figure 30 represents an example of measuring distance to the closest ramp, Figure 31 shows an example of identification of rumble strips, and Figure 32 demonstrates an example of exit ramp skew angle measurement by using an uploaded compass on Google Earth for a stop-controlled ramp terminal.

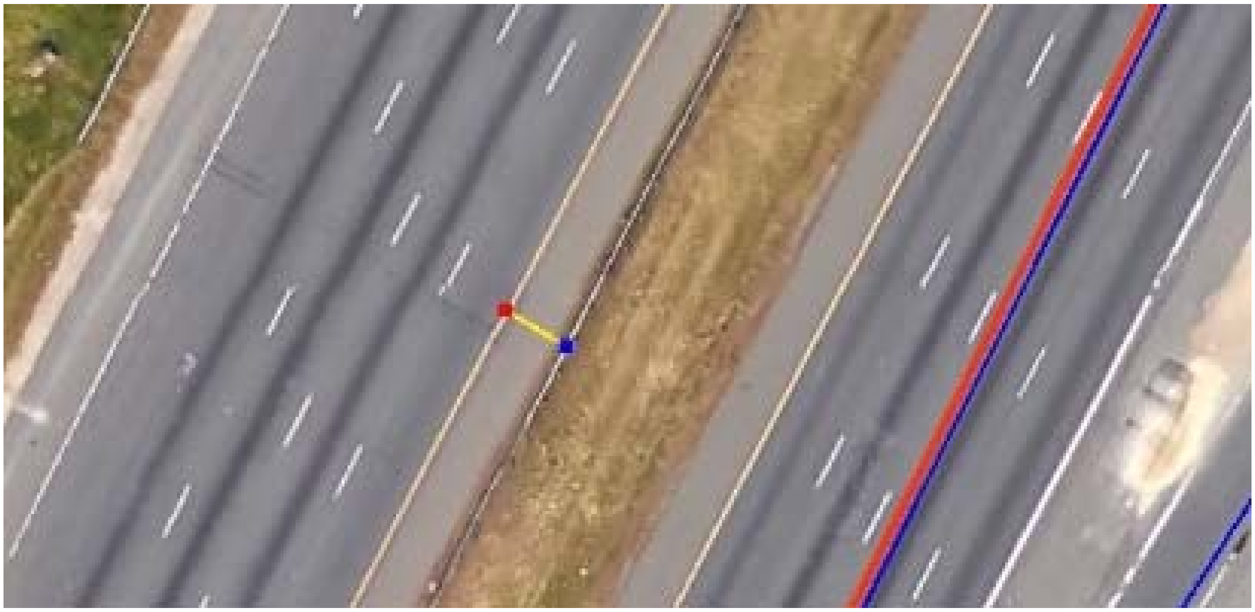


Figure 28. An Example of Median Barrier Offset Measurement

Figure 29. An Example of Outside Clear Zone Width Measurement

Figure 30. An Example of Distance to Closest Ramp Measurement

Figure 31. An Example of Identification of Rumble Strips in Google Earth StreetView

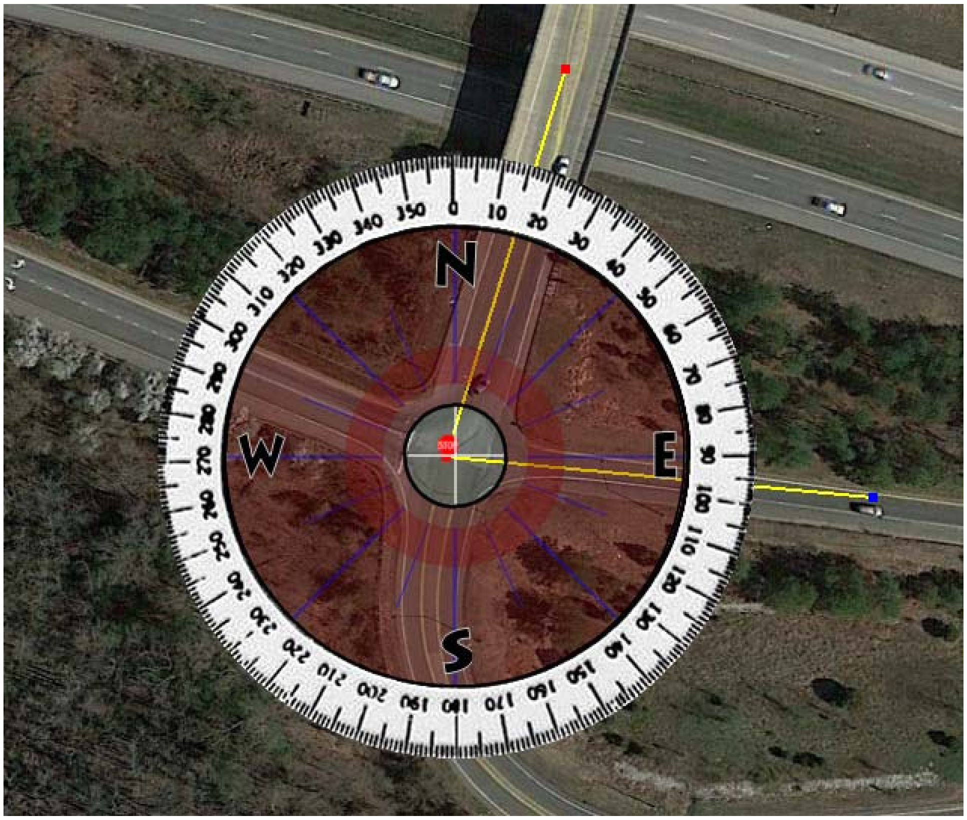


Figure 32. An Example of Exit Ramp Skew Angle Estimation in Google Earth

Estimation of AADT on Ramps

The AADT on ramps is a required variable for the HSM predictive method, but the information was not complete for the study period (2008-2010). The study team employed a multiple regression analysis to estimate missing AADT data on some ramps.

<u>Multiple Regression</u>

Multiple regression analysis is one of the most widely used and simple ways to estimate AADT due to its ease of application in many situations and straightforward interpretation of outputs (Washington, Karlaftis, & Mannering, 2003). AADT data for 2012 and roadway geometry variables were used as independent variables. The reason for using a relatively complete past year data (2012) rather than a more recent year data (e.g., 2014 or 2015) was to make it as close as possible to the study period (2008-2010). Moreover, the study team employed a backward approach: estimating $AADT_{2010}$ based on $AADT_{2012}$ then $AADT_{2009}$ based on complemented $AADT_{2010}$ and finally $AADT_{2008}$ based on $AADT_{2009}$.

<u>Selected Regression Models for Freeway Ramps</u>

The final models for estimating AADT values on ramps are presented below. Additional details for regression models are provided in appendices. Due to strong correlation between AADT data for different years, the selected models showed that ramps AADT is a function of succeeding years AADT. The R-squared values for the developed models are shown in Table 42. All models have R-squared values greater than 0.995.

Equation 3. AADT Estimation for Ramps of Freeways (2008 – 2010)

$$\text{Ramp\_AADT}_{2008} = (-27.083) + (0.996*\text{Ramp\_AADT}^{*}_{2009})$$
$$\text{Ramp\_AADT}_{2009} = (13.850) + (0.995*\text{Ramp\_AADT}^{*}_{2010})$$
$$\text{Ramp\_AADT}_{2010} = (-128.002) + (0.995*\text{Ramp\_AADT}^{*}_{2012})$$

Where,

$\text{Ramp\_AADT}_{2008,\,2009,\,2010}$ = Estimated values for AADT on ramps of freeways for 2008, 2009, and 2010,
$\text{Ramp\_AADT}^{*}_{2009,\,2010,\,2012}$ = Actual AADT data on ramps for 2009, 2010, and 2012.

Table 42. R-Squared Values for Ramps AADT Estimation Models of Freeways

Year	R-Squared	Adjusted R-Squared
2008	0.999	0.999
2009	0.999	0.999
2010	0.995	0.995

<u>Selected Regression Models for Speed-Change Lane Ramps</u>

Using the same procedure, ramps AADT values for speed-change lanes were estimated and the models are presented below. The R-squared values for the developed models are shown in Table 43. All models have R-squared values greater than 0.996.

Equation 4. AADT Estimation for Ramps of Speed-Change Lanes (2008-2010)

$$\text{Ramp\_AADT}_{2008} = (47.305) + (0.985*\text{Ramp\_AADT}^{*}_{2009})$$
$$\text{Ramp\_AADT}_{2009} = (-56.561) + (0.987*\text{Ramp\_AADT}^{*}_{2010}) + (510.643*\text{RURURB}_{1})$$
$$\text{Ramp\_AADT}_{2010} = (-131.052) + (1.010*\text{Ramp\_AADT}^{*}_{2012}) + (498.512*\text{COUNTY}_{10}) + (402.185*\text{COUNTY}_{15})$$

Where:

$\text{Ramp\_AADT}_{2008,\,2009,\,2010}$ = Estimated values for AADT on ramps of speed-change lanes for 2008, 2009, and 2010,
$\text{Ramp\_AADT}^{*}_{2009,\,2010,\,2012}$ = Actual AADT data on ramps for 2009, 2010, and 2012,
RURURB_{1} = 1 if area type is “rural,” otherwise 0,
COUNTY_{10} = 1 if county # is “10” (i.e., Frederick County), otherwise 0,
COUNTY_{15} = 1 if county # is “15” (i.e., Montgomery County), otherwise 0.

Table 43. R-Squared Values for Ramps AADT Estimation Models of Speed-Change Lane

Year	R-Squared	Adjusted R-Squared
2008	0.999	0.999
2009	0.997	0.997
2010	0.996	0.996

Selected Regression Models for Signalized Ramp Terminals

Using the same procedure, ramps AADT values for signalized ramp terminals were estimated and the models are presented below. The selected models showed that ramps AADT is a function of succeeding years AADT. The R-squared values for the developed models are shown in Table 44. The model for 2008 had a very good fit (R-squared = 0.999) but 2009 and 2010 models had slightly lower values (0.879 and 0.882, respectively).

Equation 5. AADT Estimation for Ramps of Signalized Ramp Terminals (2008-2010)

$$Ramp\_AADT_{2008} = (3.866) + (0.990*Ramp\_AADT^{*}_{2009})$$
$$Ramp\_AADT_{2009} = (496.330) + (0.874*Ramp\_AADT^{*}_{2010})$$
$$Ramp\_AADT_{2010} = (64.521) + (0.968*Ramp\_AADT^{*}_{2012})$$

Where,

$Ramp\_AADT_{2008, 2009, 2010}$ = Estimated values for AADT on ramps of signalized ramp terminals for 2008, 2009, and 2010,

$Ramp\_AADT^{*}_{2009, 2010, 2012}$ = Actual AADT data on ramps for 2009, 2010, and 2012.

Table 44. R-Squared Values for Ramps AADT Estimation of Signalized Ramp Terminals

Year	R-Squared	Adjusted R-Squared
2008	0.999	0.999
2009	0.881	0.879
2010	0.884	0.882

Selected Regression Models for Stop-controlled Ramp Terminals

Using the same procedure, ramps AADT values for stop-controlled ramp terminals were estimated and the models are presented below. The selected models showed that ramps AADT is a function of succeeding years AADT. The R-squared values for the developed models are shown in Table 45. All models have R-squared values greater than 0.993.

Equation 6. AADT Estimation for Ramps of Stop-controlled Ramp Terminals (2008-2010)

$$Ramp\_AADT_{2008} = (-4.336) + (0.991*Ramp\_AADT^{*}_{2009})$$
$$Ramp\_AADT_{2009} = (-29.357) + (0.997*Ramp\_AADT^{*}_{2010})$$
$$Ramp\_AADT_{2010} = (60.092) + (0.949*Ramp\_AADT^{*}_{2012})$$

Where,

$Ramp\_AADT_{2008, 2009, 2010}$ = Estimated values for AADT on ramps of stop-controlled ramp terminals for 2008, 2009, and 2010,

$Ramp\_AADT^{*}_{2009, 2010, 2012}$ = Actual AADT data on ramps for 2009, 2010, and 2012.

Table 45. R-Squared Values for Ramps AADT Estimation Models of Stop-controlled Ramp Terminals

Year	R-Squared	Adjusted R-Squared
2008	0.999	0.999
2009	0.997	0.997
2010	0.993	0.993

Computing Local Calibration Factors

An LCF of a facility is a ratio of the total observed crashes at the study sites to the total predicted crashes computed by an SPF (Equation 7). For example, if there were 300 observed crashes at all sampled sites for a particular facility type and total predicted crashes using an SPF were 400, then, the LCF for the site is 0.75, meaning that for the same type of facility the predicted crashes using a corresponding SPF should be adjusted by multiplying 0.75 in that jurisdiction.

Equation 7. Calculation of Local Calibration Factor

$$C = \frac{\sum_{All\ sites} N_{Observed}}{\sum_{All\ sites} N_{Predicted\ (Unadjusted)}}$$

Where:

$N_{Predicted\ (Unadjusted)}$ = Unadjusted total predicted crash frequency, and

$\mathrm{N}_{\mathrm{Objerved}}$ = Total number of observed crashes during the study period.

Unlike the facility types presented in the Phase I study (i.e., rural two-lane and multilane highways and urban and suburban arterials), LCFs of facility types in the new chapters of the HSM are independent from HSM-default crash distributions or locally derived ones. In the Phase I study, since the differentiation between crash types (i.e., single- and multiple-vehicle crashes combined with fatal and injury crashes and property damage only crashes) was not considered for all facility types, LCFs were developed for total crashes and, depending on facility types, for different severity levels. No separate LCFs were developed for single-vehicle vs. multiple-vehicle crashes. However, in the new chapters, application of either the HSM-default crash distribution or a locally derived one is a step after applying LCFs (AASHTO, 2014, pp. 18-13, 19-15). The study team created crash severity (for different KABCO crash severity[1]) and collision type (different categories of single- and multiple-vehicle crashes) proportion tables for Maryland. Tables 46 to 49 show the comparison between HSM-default crash distributions (from California, Minnesota, and Washington states) and those of Maryland for freeway segments, ramp-entrance speed-change lanes, ramp-exit speed-change lanes, and signalized ramp terminals, respectively. The minimum 200 crashes (collectively during a recent one- to three-year period) are required to replace the HSM default crash distribution, and stop-controlled ramp terminals with 160 crashes during the study period do not meet the requirement so the Maryland crash distribution was not calculated for that category. The proportions of crashes with animals are larger for Maryland for all different facility types. All other significant differences are highlighted in the tables.

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[1] KABCO scale is used to codify crash severity levels, which consists of fatal (K), incapacitating injury (A), non-Incapacitating injury (B), possible injury (C), and property damage only (O).

Table 46. Maryland Crash Distribution for Freeway Segments (2008-2010)

Area Type	Crash Type	Crash Type Category	HSM Default		Maryland-Specific	
			Proportion of Crashes by Severity		Proportion of Crashes by Severity	
			FI	PDO	FI	PDO
Rural	Multiple vehicle	Head-on	0.018	0.004	0.029	0.015
		Right-angle	0.056	0.030	0.024	0.015
		Rear-end	0.630	0.508	0.648	0.652
		Sideswipe	0.237	0.380	0.238	0.269
		Other MV crashes	0.059	0.078	0.062	0.050
	Single vehicle	Crash with animal	0.010	0.065	0.047	0.147
		Crash with fixed object	0.567	0.625	0.658	0.598
		Crash with other object	0.031	0.125	0.027	0.043
		Crash with parked vehicle	0.024	0.023	0.012	0.012
		Other SV crashes	0.368	0.162	0.257	0.200
Urban	Multiple vehicle	Head-on	0.008	0.002	0.017	0.007
		Right-angle	0.031	0.018	0.014	0.007
		Rear-end	0.750	0.690	0.669	0.681
		Sideswipe	0.180	0.266	0.246	0.251
		Other MV crashes	0.031	0.024	0.053	0.053
	Single vehicle	Crash with animal	0.004	0.022	0.026	0.116
		Crash with fixed object	0.722	0.716	0.625	0.612
		Crash with other object	0.051	0.139	0.026	0.043
		Crash with parked vehicle	0.015	0.016	0.032	0.020
		Other SV crashes	0.208	0.107	0.291	0.209

Notes: Lightly "Blue" and "Red" cells indicate significantly higher and lower proportions for Maryland State, respectively. "MV" stands for "multiple vehicle," "SV" stands for "single vehicle," "FI" stands for "fatal and injury," and "PDO" stands for "property damage only."

Table 47. Maryland Crash Distribution for Ramp-Entrance Speed-Change Lanes (2008-2010)

Area Type	Crash Type	Crash Type Category	HSM Default		MD-Specific	
			Proportion of Crashes by Severity		Proportion of Crashes by Severity	
			FI	PDO	FI	PDO
Rural	Multiple vehicle	Head-on	0.021	0.004	0.000	0.031
		Right-angle	0.032	0.013	0.000	0.000
		Rear-end	0.351	0.260	0.364	0.188
		Sideswipe	0.128	0.242	0.091	0.125
		Other MV crashes	0.011	0.040	0.000	0.063
	Single vehicle	Crash with animal	0.000	0.009	0.000	0.063
		Crash with fixed object	0.245	0.296	0.364	0.344
		Crash with other object	0.021	0.070	0.000	0.000
		Crash with parked vehicle	0.021	0.000	0.000	0.000
		Other SV crashes	0.170	0.066	0.182	0.188
Urban	Multiple vehicle	Head-on	0.004	0.001	0.012	0.012
		Right-angle	0.019	0.016	0.006	0.009
		Rear-end	0.543	0.530	0.409	0.370
		Sideswipe	0.133	0.252	0.176	0.130
		Other MV crashes	0.017	0.015	0.026	0.028
	Single vehicle	Crash with animal	0.000	0.002	0.000	0.028
		Crash with fixed object	0.194	0.129	0.265	0.310
		Crash with other object	0.019	0.036	0.000	0.012
		Crash with parked vehicle	0.004	0.003	0.012	0.007
		Other SV crashes	0.067	0.016	0.095	0.093

Notes: Lightly “Blue” and “Red” cells indicate significantly higher and lower proportions for Maryland State, respectively. “MV” stands for “multiple vehicle,” “SV” stands for “single vehicle,” “FI” stands for “fatal and injury,” and “PDO” stands for “property damage only.”

Table 48. Maryland Crash Distribution for Ramp-Exit Speed-Change Lanes (2008-2010)

Area Type	Crash Type	Crash Type Category	HSM Default		MD-Specific	
			Proportion of Crashes by Severity		Proportion of Crashes by Severity	
			FI	PDO	FI	PDO
Rural	Multiple vehicle	Head-on	0.000	0.000	0.000	0.040
		Right-angle	0.015	0.000	0.000	0.000
		Rear-end	0.463	0.304	0.222	0.240
		Sideswipe	0.104	0.243	0.222	0.160
		Other MV crashes	0.000	0.009	0.000	0.000
	Single vehicle	Crash with animal	0.000	0.061	0.000	0.080
		Crash with fixed object	0.224	0.235	0.333	0.400
		Crash with other object	0.030	0.061	0.000	0.000
		Crash with parked vehicle	0.000	0.017	0.000	0.000
		Other SV crashes	0.164	0.070	0.222	0.080
Urban	Multiple vehicle	Head-on	0.005	0.002	0.024	0.005
		Right-angle	0.011	0.012	0.018	0.009
		Rear-end	0.549	0.565	0.498	0.402
		Sideswipe	0.158	0.138	0.128	0.128
		Other MV crashes	0.016	0.016	0.031	0.051
	Single vehicle	Crash with animal	0.000	0.007	0.012	0.027
		Crash with fixed object	0.196	0.207	0.205	0.276
		Crash with other object	0.016	0.030	0.000	0.011
		Crash with parked vehicle	0.000	0.000	0.003	0.005
		Other SV crashes	0.049	0.023	0.080	0.084

Notes: Lightly "Blue" and "Red" cells indicate significantly higher and lower proportions for Maryland State, respectively. "MV" stands for "multiple vehicle," "SV" stands for "single vehicle," "FI" stands for "fatal and injury," and "PDO" stands for "property damage only."

Table 49. Maryland Crash Distribution for Signalized Ramp Terminals (2008-2010)

Area Type	Crash Type	Crash Type Category	HSM Default		MD-Specific	
			Proportion of Crashes by Severity		Proportion of Crashes by Severity	
			FI	PDO	FI	PDO
Rural	Multiple vehicle	Head-on	0.000	0.006	0.444	0.111
		Right-angle	0.333	0.187	0.222	0.444
		Rear-end	0.552	0.466	0.111	0.111
		Sideswipe	0.000	0.219	0.000	0.111
		Other MV crashes	0.014	0.013	0.000	0.000
	Single vehicle	Crash with animal	0.000	0.000	0.000	0.000
		Crash with fixed object	0.043	0.077	0.222	0.222
		Crash with other object	0.000	0.000	0.000	0.000
		Crash with parked vehicle	0.000	0.013	0.000	0.000
		Other SV crashes	0.058	0.019	0.000	0.000
Urban	Multiple vehicle	Head-on	0.011	0.007	0.358	0.272
		Right-angle	0.260	0.220	0.351	0.315
		Rear-end	0.625	0.543	0.220	0.263
		Sideswipe	0.042	0.149	0.015	0.051
		Other MV crashes	0.009	0.020	0.025	0.041
	Single vehicle	Crash with animal	0.000	0.000	0.000	0.000
		Crash with fixed object	0.033	0.050	0.015	0.049
		Crash with other object	0.001	0.002	0.002	0.000
		Crash with parked vehicle	0.001	0.002	0.000	0.000
		Other SV crashes	0.018	0.007	0.015	0.008

Notes: Lightly "Blue" and "Red" cells indicate significantly higher and lower proportions for Maryland State, respectively. "MV" stands for "multiple vehicle," "SV" stands for "single vehicle," "FI" stands for "fatal and injury," and "PDO" stands for "property damage only."

LCFs

Using IHSDM, predicted crashes were computed and LCFs were calculated. The results are summarized in Table 50. The Maryland LCFs were all smaller than 1.0. This indicates that the freeways, speed-change lanes, and ramp terminals in Maryland on an aggregate level encounter fewer crashes compared to HSM base conditions. The under-reporting the property-damage-only crashes may be the reason that the LCF value of multiple-vehicle PDO crashes on freeways was the lowest LCF value among the 12 developed LCFs.

Table 50. Summary of Maryland LCFs for New Chapters of the HSM (2008-2010)

Facility	Crash Type	# of Segments	Observed Crashes	Predicted Crashes	LCF
Freeways	FI MV	564	1,190	2,617.94	0.4546
	PDO MV	564	1,890	6,610.84	0.2859
	FI SV	564	910	1,451.53	0.6269
	PDO SV	564	1,735	2,705.70	0.6412
Speed-Change Lanes	FI En	264	358	605.63	0.5911
	PDO En	264	600	1,139.64	0.5265
	FI Ex	254	336	438.32	0.7666
	PDO Ex	254	572	649.53	0.8806
Ramp Terminals	ST FI*	147	83	122.85	0.6756
	SG FI	172	425	1,213.81	0.3501
	ST PDO*	147	77	203.91	0.3776
	SG PDO	172	511	1,690.71	0.3022
Ramps & C-D Roads	Insufficient Crash Data				

Notes: The asterisk denotes that the facility type did not meet the HSM minimum annual crashes of 100 and the associated LCF should be used cautiously. "MV" stands for "multiple vehicle," "SV" stands for "single vehicle," "FI" stands for "fatal and injury," "PDO" stands for "property damage only," "ST" stands for "stop-controlled," "SG" stands for "signalized," "En" refers to "ramp-entrance speed-change lane," and "Ex" refers to "ramp-exit speed-change lane."

Comparing HSM-default and Maryland-specific Crash Distributions

The prediction quality using either HSM-default or Maryland-specific crash distribution can be evaluated using the sum of squared deviation (SSD) for all sampled sites for freeway segments, speed-change lanes, and signalized ramp terminals. SSD can be calculated using Equation 8 and the lower the SSD value, the better the prediction quality.

Equation 8. Calculation of Sum of Squared Deviation

$$SSD = \sum_{i}^{n} (Observed\ Crashes - Predicted\ Crashes)^2$$

Where,

SSD = Sum of Squared Deviation

n = Number of sites for a facility type

Table 51 shows the results of SSD calculation. While freeway segments and speed-change lanes benefited 3.1% and 3.9% when using Maryland-specific crash distributions, signalized ramp terminals had a significant improvement (22.6%).

Table 51. Comparison of SSD Based on HSM-Default and Maryland-Specific Crash Distributions

Facility Type	HSM-Default	Maryland-Specific	% Improvement Using Maryland-Specific
Freeway Segments	21,925	21,242	3.1
Speed-Change Lanes	6,604	6,345	3.9
Signalized Ramp Terminals	3,283	2,541	22.6
Total	31,812	30,128	5.3

CONCLUSIONS

This study computed Maryland-specific LCFs for freeway segments, speed-change lanes, and crossroad ramp terminals. This chapter provides a summary of study conclusions and challenges that the team faced.

Maryland Local Calibration Factors

Table 50 presents the LCFs developed in this study and they are all smaller than 1.0. After the comparison of HSM default crash proportion and the Maryland-specific data, the use of the Maryland data was recommended.

Interpretation of LCFs

LCFs do not indicate good or bad about the level of safety. They only indicate whether the number of crashes on a certain facility are lower or higher than the HSM base model. In addition, LCFs are the average value of all sampled sites and they may or may not accurately predict site-specific crashes.

In general, LCFs for all facility types were less than 1.0 and all ranged between 0.2859 (of multiple-vehicle, property-damage-only crashes on freeway segments) to 0.8806 (of property-damage-only crashes on ramp-exit speed-change lanes). While lower LCFs means fewer crashes occurred in Maryland, please be advised that the following limitations exist with the data:

- ***Self-reporting system for property damage only (PDO) crashes—***Property-damage-only crashes are not required to be reported unless there is an injury or when an involved vehicle needs to be towed. This means lots of minor crashes might not be reported.
- ***Under-representation of ramp terminal crashes***—The unavailability of geocoded ramp crashes (those ramp crashes that were within 250 ft. of ramp terminals and also were "Intersection" or "Intersection-related") could be one of the main reasons for smaller LCFs for Maryland ramp terminals.
- ***Different urban population***—Differences in urban population between Maryland and the three states whose data were used for developing HSM may not be fully reflected. There are many cities with populations over 100,000 in Washington (e.g., Seattle [608,660], Spokane [208,916], Tacoma [198,397], and Vancouver [161,791]) and California (e.g., Los Angeles [3,792,621], San Diego [1,301,617], San Jose [945,942], San Francisco [805,235], Fresno [494,665], and Sacramento [466,488]). By contrast, after excluding Baltimore City from this study, the most populous city in Maryland is Frederick [65,239], followed by Rockville [61,209] (U.S. Census Bureau, 2012). It is possible the large population difference between Maryland and the aforementioned states causes the lower LCF values for Maryland.

Challenges: Data collection burden

Similar to what other states encountered when developing LCFs, the transportation database was not built for easy HSM adoption. Data items that were incomplete or not readily available include:

- For freeway segments:
    - Average median barrier offset
    - Proportion segment length with median barrier
    - Outside barrier length

  - Average outside barrier offset
  - Proportion segment length with outside barrier
  - Distances to closest upstream/downstream entrance/exits ramps
  - Proportion inside/outside rumble strips
  - Outside clear zone width
  - Curve length within site
- For speed-change lanes:
  - Identification of associated crashes. Making roadway data inventory and crash data integrated would solve the issue.
  - Proportion segment length with median barrier
  - Average median barrier offset
  - Curve length within site
- For ramp terminals:
  - Identification of the ramp terminal configuration type
  - Number of unsignalized driveways and public street approaches
  - Presence of a non-ramp public street leg at the terminal
  - Presence of a left-turn lane (or bay) on the inside/outside crossroad approach
  - Presence of a right-turn lane (or bay) on the inside/outside crossroad approach
  - Presence of right-turn channelization on the inside/outside crossroad approach
  - Presence of right-turn channelization on the exit ramp approach
  - Presence of protected left-turn operation
  - Exit ramp skew angle
  - AADT values for some ramps

For a full adoption of the HSM, several strategies need to be considered including establishing a centralized data warehouse, and developing an automated data generation module for the HSM applications. One of the barriers in data generation was the crash assignment to segments and intersections, and the inclusion of crash geo-reference information and the addition of network-level geometric data will greatly benefit such safety analysis. For example, the availability of the network-level curve data (ARAN Data) significantly reduced the amount of manual data extraction compared to the Phase I study.

APPENDIX A. LIST OF ACRONYMS AND ABBREVIATIONS

Table 52. List of Acronyms and Abbreviations

Acronym/ Abbreviation	Description
AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
CI	Confidence Interval
CL	Confidence Level
CMF	Crash Modification Factor
FHWA	Federal Highway Administration
GIS	Geographic Information System
HSM	Highway Safety Manual
IHSDM	Interactive Highway Safety Design Model
KML	Keyhole Markup Language
LCF	Local Calibration Factor
MDOT	Maryland Department of Transportation
MP	Mile Point
OOTS	Office of Traffic and Safety (of SHA)
PDO	Property Damage Only
R23ST	Rural Two-lane, Two-way Road with Unsignalized Three-leg Intersection (Stop Control on Minor-road Approaches)
R24SG	Rural Two-lane, Two-way Road with Signalized Four-leg Intersection
R24ST	Rural Two-lane, Two-way Road with Unsignalized Four-leg Intersection (Stop Control on Minor-road Approaches)
R2U	Undivided Rural Two-lane, Two-way Roadway Segments
R4D	Rural Four-lane Divided Segments
R4U	Rural Four-lane Undivided Segments
RA$_2$SG	Rural Signalized Three-leg Ramp Terminal at Two-quadrant Partial Cloverleaf A(A2)
RA$_2$ST	Rural Stop-Controlled Three-leg Ramp Terminal at Two-quadrant Partial Cloverleaf A(A2)
RA4SG	Rural Signalized Four-leg Ramp Terminal at Four-quadrant Partial Cloverleaf A(A4)
RA$_4$ST	Rural Stop-Controlled Four-leg Ramp Terminal at Four-quadrant Partial Cloverleaf A(A4)
RB$_2$SG	Rural Signalized Three-leg Ramp Terminal at Two-quadrant Partial Cloverleaf B(B2)
RB$_2$ST	Rural Stop-Controlled Three-leg Ramp Terminal at Two-quadrant Partial Cloverleaf B(B2)
RB$_4$SG	Rural Signalized Four-leg Ramp Terminal at Four-quadrant Partial Cloverleaf B(B4)
RB$_4$ST	Rural Stop-Controlled Four-Leg Ramp Terminal at Four-Quadrant Partial Cloverleaf B(B4)
RCD1	Rural One-Lane C-D roads
RD$_{3en}$SG	Rural Signalized Three-leg Ramp Terminal with Diagonal Entrance Ramp(D3en)

Acronym/ Abbreviation	**Description**
RD$_{3en}$ST	Rural Stop-Controlled Three-leg Ramp Terminal with Diagonal Entrance Ramp(D3en)
RD$_{3ex}$SG	Rural Signalized Three-leg Ramp Terminal with Diagonal Exit Ramp(D3ex)
RD$_{3ex}$ST	Rural Stop-Controlled Three-leg Ramp Terminal with Diagonal Exit Ramp(D3ex)
RD$_{4}$SG	Rural Signalized Four-leg Ramp Terminal with Diagonal Ramps(D4)
RD$_{4}$ST	Rural Stop-Controlled Four-leg Ramp Terminal with Diagonal Ramps(D4)
RF4	Rural Four-lane divided Freeways
RF6	Rural Six-lane divided Freeways
RF8	Rural Eight-lane divided Freeways
RM3ST	Rural Multilane Highway with Unsignalized Three-leg Intersection (Stop Control on Minor-road Approaches)
RM4SG	Rural Multilane Highway with Signalized Four-leg Intersection
RM4ST	Rural Multilane Highway with Unsignalized Four-leg Intersection (Stop Control on Minor-road Approaches)
RRmen1	Rural One-lane entrance ramps
RRmex1	Rural One-lane exit ramps
RSCen4	Rural Speed-Change Lane; Ramp entrance to four-lane divided Freeways
RSCen6	Rural Speed-Change Lane; Ramp entrance to six-lane divided Freeways
RSCen8	Rural Speed-Change Lane; Ramp entrance to eight-lane divided Freeways
RSCex4	Rural Speed-Change Lane; Ramp exit from four-lane divided Freeways
RSCex6	Rural Speed-Change Lane; Ramp exit from six-lane divided Freeways
RSCex8	Rural Speed-Change Lane; Ramp exit from eight-lane divided Freeways
SHA	Maryland State Highway Administration
SPF	Safety Performance Function
TWLTL	Two-Way Left-Turn Lane
U2U	Two-lane Undivided Urban and Suburban Arterial Segments
U3SG	Urban and Suburban Arterial with Signalized Three-leg Intersection
U3ST	Urban and Suburban Arterial with Unsignalized Three-leg Intersection (Stop Control on Minor-road Approaches)
U3T	Three-lane Urban and Suburban Arterials including a Center TWLTL
U4D	Four-lane Divided Urban and Suburban Arterials (i.e., Including a Raised or Depressed Median)
U4SG	Urban and Suburban Arterial with Signalized four-leg intersection
U4ST	Un-signalized four-leg intersection (stop control on minor-road approaches)
U4U	Four-lane undivided arterials
U5T	Five-lane arterials including a center TWLTL
UA$_{2}$SG	Urban Signalized Three-leg Ramp Terminal at Two-quadrant Partial Cloverleaf A(A2)
UA$_{2}$ST	Urban Stop-Controlled Three-leg Ramp Terminal at Two-quadrant Partial Cloverleaf A(A2)

Acronym/ Abbreviation	**Description**
UA$_4$SG	Urban Signalized Four-leg Ramp Terminal at Four-quadrant Partial Cloverleaf A(A4)
UA$_4$ST	Urban Stop-Controlled Four-leg Ramp Terminal at Four-quadrant Partial Cloverleaf A(A4)
UB$_2$SG	Urban Signalized Three-leg Ramp Terminal at Two-quadrant Partial Cloverleaf B(B2)
UB$_2$ST	Urban Stop-Controlled Three-Leg Ramp Terminal at Two-Quadrant Partial Cloverleaf B(B2)
UB$_4$SG	Urban Signalized Four-leg Ramp Terminal at Four-quadrant Partial Cloverleaf B(B4)
UB$_4$ST	Urban Stop-Controlled Four-leg Ramp Terminal at Four-quadrant Partial Cloverleaf B(B4)
UCD1	Urban One-lane C-D roads
UCD2	Urban Two-lane C-D roads
UD$_{3en}$SG	Urban Signalized Three-leg Ramp Terminal with Diagonal Entrance Ramp(D3en)
UD$_{3en}$ST	Urban Stop-Controlled Three-leg Ramp Terminal with Diagonal Entrance Ramp(D3en)
UD$_{3ex}$SG	Urban Signalized Three-leg Ramp Terminal with Diagonal Exit Ramp(D3ex)
UD$_{3ex}$ST	Urban Stop-Controlled Three-leg Ramp Terminal with Diagonal Exit Ramp(D3ex)
UD$_4$SG	Urban Signalized Four-leg Ramp Terminal with Diagonal Ramps(D4)
UD$_4$ST	Urban Stop-Controlled Four-leg Ramp Terminal with Diagonal Ramps(D4)
UF4	Urban Four-lane divided Freeways
UF6	Urban Six-lane divided Freeways
UF8	Urban Eight-lane divided Freeways
UF10	Urban Ten-lane divided Freeways
URmen1	Urban One-lane entrance ramps
URmen2	Urban Two-lane entrance ramps
URmex1	Urban One-lane exit ramps
URmex2	Urban Two-lane exit ramps
USCen4	Urban Speed-Change Lane; Ramp entrance to four-lane divided Freeways
USCen6	Urban Speed-Change Lane; Ramp entrance to six-lane divided Freeways
USCen8	Urban Speed-Change Lane; Ramp entrance to eight-lane divided Freeways
USCen10	Urban Speed-Change Lane; Ramp entrance to ten-lane divided Freeways
USCex4	Urban Speed-Change Lane; Ramp exit from four-lane divided Freeways
USCex6	Urban Speed-Change Lane; Ramp exit from six-lane divided Freeways
USCex8	Urban Speed-Change Lane; Ramp exit from eight-lane divided Freeways
USCex10	Urban Speed-Change Lane; Ramp exit from ten-lane divided Freeways
XML	Extensible Markup Language

APPENDIX B. THE HSM DATA NEEDS

Table 53. The HSM Data Needs for Freeways

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Area Type	●					Specifies the alignment area type. Types are urban, suburban and rural. The value of this item is used to select the appropriate crash prediction model.	Need actual data.	SHA (UNIVERSE)	-
Number of Thru Lanes	●					Number of Thru lanes, including both directions. The number of lanes on each direction of a site is expected to be the same. The value of this item must be an even number.	Need actual data.	SHA (UNIVERSE)	-
Length	●					Length of the roadway segment. The unit of measure is miles or kilometers. The value of this item must be greater than or equal to 0.0000 mi.	Need actual data.	SHA (UNIVERSE)	-

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Effective Segment Length	●					Effective length of the segment without the speed change lanes. The unit of measure is miles or kilometers. The value of this item must be greater than or equal to 0.0000 mi.	Need actual data.	SHA (UNIVERSE)	-
Average Lane Width	●					Average Width of lanes of the roadway segment. The unit of measure is feet or meters. The value of this item must be greater than or equal to 0.0000 ft.	Need actual data.	SHA (UNIVERSE) + Computation	Computing average segment length width (ArcGIS)
Effective Median Width	●					Effective width of the median, including inside shoulders. The unit of measure is feet or meters. The value of this item must be greater than or equal to 0.0000 ft.	Need actual data.	SHA (UNIVERSE) + Computation	Computing effective median width (ArcGIS)

Data Item	**Type**					**Description**	**The HSM Default Assumption**	**Data Source**	**Data Collection Method**
	Required site data	**Required crash/traffic**	**Desired site data**	**Site Curve Data**	**Crash distribution data**				
Proportion Segment Length with Median Barrier	●					Proportion of Segment length that has Median Barrier. The value of this item must be between (including) 0 and 1.	Need actual data.	Manual Measurement	Measuring proportion of segment length with median barrier if segment includes part w/ and w/o median barrier (Google Earth)
Average Median Barrier Offset	●					Average Median Barrier Distance, from edge of inside shoulder to barrier face. The unit of measure is feet or meters. The value of this item must be greater than or equal to 0.0000 ft.	Need actual data.	Manual Measurement + Computation	Measuring barrier offset and then computing average inside shoulder width (Google Earth)
Proportion Segment Length with Outside Barrier	●					Proportion of Segment length that has Outside Barrier. The value of this item must be between (including) 0 and 1.	Need actual data.	Manual Measurement	Measuring proportion of segment length with outside barrier if segment includes part w/ and w/o outside barrier (Google Earth)

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Outside Barrier Length	●					Outside Barrier Length. Added length for all Barriers for the site. The unit of measure is feet or meters. The value of this item must be greater than or equal to 0.0000 ft.	Need actual data.	Manual Measurement	Measuring outside barrier length (Google Earth)
Average Outside Barrier Offset	●					Average Median Barrier Offset, from edge of outside shoulder to barrier face. The unit of measure is feet or meters. The value of this item must be greater than or equal to 0.0000 ft.	Need actual data.	Manual Measurement + Computation	Measuring barrier offset and then computing average inside shoulder width (Google Earth)
Average Inside Shoulder width	●					Average Inside Shoulder width. The unit of measure is feet or meters. The value of this item must be greater than or equal to 0.0000 ft.	Need actual data.	SHA (UNIVERSE)	-

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Average Outside Shoulder width	●					Average Outside Shoulder width. The unit of measure is feet or meters. The value of this item must be greater than or equal to 0.0000 ft.	Need actual data.	SHA (UNIVERSE)	-
Proportion Weave Increasing	●					Proportion of segment length within a Type B weaving section for travel in increasing milepost direction. The value of this item must be between (including) 0 and 1.	Need actual data.	SHA (UNIVERSE)	There was no Type B weaving section in samples.
Length Weave Increasing	●					Weaving section length for travel in increasing milepost direction (may extend beyond segment boundaries). The unit of measure is feet or meters. The value of this item must be greater than or equal to 0.0000 ft.	Need actual data.	SHA (UNIVERSE)	-

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Proportion Weave Decreasing	●					Proportion of segment length within a Type B weaving section for travel in decreasing milepost direction. The value of this item must be between (including) 0 and 1.	Need actual data.	SHA (UNIVERSE)	There was no Type B weaving section in samples.
Length Weave Decreasing	●					Weaving section length for travel in decreasing milepost direction (may extend beyond segment boundaries). The unit of measure is feet or meters. The value of this item must be greater than or equal to 0.0000 ft.	Need actual data.	SHA (UNIVERSE)	-

Data Item	**Type**					**Description**	**The HSM Default Assumption**	**Data Source**	**Data Collection Method**
	Required site data	**Required crash/traffic**	**Desired site data**	**Site Curve Data**	**Crash distribution data**				
Distance Begin to Entry Increasing	●					Distance from segment begin milepost to nearest upstream entrance ramp gore point, for travel in increasing milepost direction. The unit of measure is feet or meters. The value of this item must be greater than or equal to 0.0000 ft.	Need actual data.	Manual Measurement	Measuring distance to gore point (Google Earth)
Distance End to Exit Increasing	●					Distance from segment end milepost to nearest downstream exit ramp gore point, for travel in increasing milepost direction. The unit of measure is feet or meters. The value of this item must be greater than or equal to 0.0000 ft.	Need actual data.	Manual Measurement	Measuring distance to gore point (Google Earth)

Data Item	**Type**					**Description**	**The HSM Default Assumption**	**Data Source**	**Data Collection Method**
	Required site data	**Required crash/traffic**	**Desired site data**	**Site Curve Data**	**Crash distribution data**				
Distance End to Entry Decreasing	●					Distance from segment end milepost to nearest upstream entrance ramp gore point, for travel in decreasing milepost direction. The unit of measure is feet or meters. The value of this item must be greater than or equal to 0.0000 ft.	Need actual data.	Manual Measurement	Measuring distance to gore point (Google Earth)
Distance Begin to Exit Decreasing	●					Distance from segment begin milepost to nearest downstream exit ramp gore point, for travel in decreasing milepost direction. The unit of measure is feet or meters. The value of this item must be greater than or equal to 0.0000 ft.	Need actual data.	Manual Measurement	Measuring distance to gore point (Google Earth)

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Years of Crash Data		●				Number of years of crash data for the site. Integer value expected. The value of this item must be greater than or equal to 1 and be less than or equal to 3.	Need actual data.	SHA (MSP)	3
Year 1		●				The year for the first year of data. Integer value expected. The unit of this item is year. The value of this item must be greater than or equal to 1970, and be less than or equal to 2050.	Need actual data.	SHA (MSP)	2008
Year 1 AADT		●				AADT for first year of data. Integer value expected. The value of this item must be greater than or equal to 0.	Need actual data.	SHA (UNIVERSE)	-

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Year 1 AADT Begin to Entry Increasing		●				AADT volume of entrance ramp located at the nearest (to the beginning of segment) upstream entrance ramp gore point (veh/day). The value of this item must be greater than or equal to 0 vpd, and less than or equal to 500,000 vpd.	Need actual data.	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA
Year 1 AADT End to Exit Increasing		●				AADT volume of exit ramp located at the nearest (to the end of segment) downstream exit ramp gore point (veh/day). The value of this item must be greater than or equal to 0 vpd, and less than or equal to 500,000 vpd.	Need actual data.	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Year 1 AADT End to Entry Increasing		●				AADT volume of entrance ramp located at the nearest (to the end of segment) upstream entrance ramp gore point (veh/day). The value of this item must be greater than or equal to 0 vpd, and less than or equal to 500,000 vpd.	Need actual data.	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA
Year 1 AADT Begin to Exit Decreasing		●				AADT volume of exit ramp located at the nearest (to the beginning of segment) downstream exit ramp gore point (veh/day). The value of this item must be greater than or equal to 0 vpd, and less than or equal to 500,000 vpd.	Need actual data.	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Year 1 Proportion of High Volume			●			Proportion of AADT during hours where volume exceeds 1000 veh/hour/lane. The value of this item must be between (including) 0 and 1.	A default value can be computed as Phv = 1.0 − exp (1.45 − 0.000124 × AADT/n). If the value computed is less than 0.0, then it is set to 0.0. [n is the number of through lanes.]	Computation	Computing the value based on HSM formula
Year 2		●				The year for the second year of data Integer value expected. The unit of this item is year. The value of this item must be greater than or equal to 1970, and	Need actual data.	SHA (MSP)	2009

Data Item	**Type**					**Description**	**The HSM Default Assumption**	**Data Source**	**Data Collection Method**
	Required site data	**Required crash/traffic**	**Desired site data**	**Site Curve Data**	**Crash distribution data**				
						be less than or equal to 2050.			
Year 2 AADT		●				AADT for second year of data. Integer value expected. The value of this item must be greater than or equal to 0.	Need actual data.	SHA (UNIVERSE)	-
Year 2 AADT Begin to Entry Increasing		●				AADT volume of entrance ramp located at the nearest (to the beginning of segment) upstream entrance ramp gore point (veh/day). The value of this item must be greater than or equal to 0 vpd, and less than or equal to 500,000 vpd.	Need actual data.	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Year 2 AADT End to Exit Increasing		●				AADT volume of exit ramp located at the nearest (to the end of segment) downstream exit ramp gore point (veh/day). The value of this item must be greater than or equal to 0 vpd, and less than or equal to 500,000 vpd.	Need actual data.	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA
Year 2 AADT End to Entry Increasing		●				AADT volume of entrance ramp located at the nearest (to the end of segment) upstream entrance ramp gore point (veh/day). The value of this item must be greater than or equal to 0 vpd, and less than or equal to 500,000 vpd.	Need actual data.	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	**Required crash/traffic**	**Desired site data**	**Site Curve Data**	**Crash distribution data**				
Year 2 AADT Begin to Exit Decreasing		●				AADT volume of exit ramp located at the nearest (to the beginning of segment) downstream exit ramp gore point (veh/day). The value of this item must be greater than or equal to 0 vpd, and less than or equal to 500,000 vpd.	Need actual data.	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA
Year 2 Proportion of High Volume			●			Proportion of AADT during hours where volume exceeds 1000 veh/hour/lane. The value of this item must be between (including) 0 and 1.	A default value can be computed as Phv = 1.0 − exp (1.45 − 0.000124 × AADT/n). If the value computed is less than 0.0, then it is set to 0.0. [n is the number of	Computation	Computing the value based on HSM formula

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
							through lanes.]		
Year 3		●				The year for the third year of data Integer value expected. The unit of this item is year. The value of this item must be greater than or equal to 1970, and be less than or equal to 2050.	Need actual data.	SHA (MSP)	2010

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Year 3 AADT		●				AADT for third year of data. Integer value expected. The value of this item must be greater than or equal to 0.	Need actual data.	SHA (UNIVERSE)	-
Year 3 AADT Begin to Entry Increasing		●				AADT volume of entrance ramp located at the nearest (to the beginning of segment) upstream entrance ramp gore point (veh/day). The value of this item must be greater than or equal to 0 vpd, and less than or equal to 500,000 vpd.	Need actual data.	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA
Year 3 AADT End to Exit Increasing		●				AADT volume of exit ramp located at the nearest (to the end of segment) downstream exit ramp gore point (veh/day). The value of this item must be greater than or equal to 0 vpd, and	Need actual data.	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
						less than or equal to 500,000 vpd.			
Year 3 AADT End to Entry Increasing		●				AADT volume of entrance ramp located at the nearest (to the end of segment) upstream entrance ramp gore point (veh/day). The value of this item must be greater than or equal to 0 vpd, and less than or equal to 500,000 vpd.	Need actual data.	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Year 3 AADT Begin to Exit Decreasing		●				AADT volume of exit ramp located at the nearest (to the beginning of segment) downstream exit ramp gore point (veh/day). The value of this item must be greater than or equal to 0 vpd, and less than or equal to 500,000 vpd.	Need actual data.	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA
Year 3 Proportion of High Volume			●			Proportion of AADT during hours where volume exceeds 1000 veh/hour/lane. The value of this item must be between (including) 0 and 1.	A default value can be computed as Phv = 1.0 − exp (1.45 − 0.000124 × AADT/n). If the value computed is less than 0.0, then it is set to 0.0. [n is the number of	Computation	Computing the value based on HSM formula

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	**Required crash/traffic**	**Desired site data**	**Site Curve Data**	**Crash distribution data**				
							through lanes.]		
Observed Number of Crashes		●				Total number of crashes observed at the site during the specified years. Integer value expected. The value of this item must be greater than or equal to 0.	Need actual data.	SHA (MSP) + Auto/Manual Crash Side Identification	Crashes for freeways were geocoded more than 95% correctly for 2008-2010 and crash side was identified through extensive automatic and manual work

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Proportion Inside Rumble Strips	●					Proportion of length of roadway that has Inside Rumble Strips. The value of this item must be between (including) 0 and 1.	Need actual data.	Manual Measurement	Measuring the proportion inside rumble strips (Google Earth)
Proportion Outside Rumble Strips	●					Proportion of length of roadway that has Outside Rumble Strips. The value of this item must be between (including) 0 and 1.	Need actual data.	Manual Measurement	Measuring the proportion outside rumble strips (Google Earth)
Outside Clear Zone Width	●					Average Outside Clear Zone Width. The unit of measure is feet or meters. The value of this item must be greater than or equal to 0.0000 ft.	Need actual data.	Manual Measurement	Measuring clear zone width (Google Earth)
Curve Radius				●		Radius of the horizontal curve. The unit of measure is feet or meters.	Need actual data.	SHA (ARAN) + Manual Extraction	Manual extraction of curve data from ARAN data of SHA (ArcGIS).

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Curve Length Within Site				●		Length of the horizontal curve within the specified site. The unit of measure is feet or meters. The value of this item must be greater than or equal to 0.00 ft.	Need actual data.	SHA (ARAN) + Manual Extraction & Measurement	Measuring curve length within the site using curve data from ARAN data of SHA(ArcGIS)
Curve Side of Road				●		Indicator if the horizontal curve is on one or both roadbeds, only applicable to curve and spiral elements.	Need actual data.	SHA (ARAN) + Manual Extraction	Checking the curve side of road using curve data from ARAN data of SHA(ArcGIS)
Collision Type (Single-Vehicle)					●	Types of collisions considered by the model. The available values are: o Collision with Animal o Collision with Fixed Object o Collision with Other Object o Collision with Parked Vehicles o Other Single-vehicle Collision	Need actual data.	SHA (MSP) + Computation	Computing SV crash distributions

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Collision Type (Multiple-Vehicle)					●	Types of collisions considered by the model. The available values are: o Head-on Collision o Rear-end Collision o Angle Collision o Sideswipe, Same Direction Collision o Other Multi-vehicle Collision	Need actual data.	SHA (MSP) + Computation	Computing MV crash distributions
Crash Severity					●	The crash severity, e.g. FI or PDO. Enumeration values: o Fatal and Injury - Fatal and injury (FI) crash severity o Property Damage Only - Property damage only (PDO) crash severity	Need actual data.	SHA (MSP)	-

Table 54. The HSM Data Needs for Speed-Change Lanes

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Area Type	●					Specifies the alignment area type. Types are urban, suburban and rural. The value of this item is used to select the appropriate crash prediction model.	Need actual data.	SHA (UNIVERSE)	-
Number of Thru Lanes	●					Number of Thru lanes, including both directions. The number of lanes on each direction of a site is expected to be the same. The value of this item must be an even number.	Need actual data.	SHA (UNIVERSE)	-
Length	●					Length of the roadway segment. The unit of measure is miles or kilometers. The value of this item must be greater	Need actual data.	SHA (UNIVERSE)	-

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
						than or equal to 0.0000 mi.			
Average Lane Width	●					Average Width of lanes of the roadway segment. The unit of measure is feet or meters. The value of this item must be greater than or equal to 0.0000 ft.	Need actual data.	SHA (UNIVERSE)	-
Effective Median Width	●					Effective width of the median, including inside shoulders. The unit of measure is feet or meters. The value of this item must be greater than or equal to 0.0000 ft.	Need actual data.	SHA (UNIVERSE) + Computation	Computing effective median width (ArcGIS)

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Proportion Segment Length with Median Barrier	●					Proportion of Segment length that has Median Barrier. The value of this item must be between (including) 0 and 1.	Need actual data.	Manual Measurement	Measuring proportion of segment length with median barrier if segment includes part w/ and w/o median barrier (Google Earth)
Average Median Barrier Offset	●					Average Median Barrier Distance, from edge of inside shoulder to barrier face. The unit of measure is feet or meters. The value of this item must be greater than or equal to 0.0000 ft.	Need actual data.	Manual Measurement + Computation	Measuring barrier offset and then computing average inside shoulder width (Google Earth)
Average Inside Shoulder width	●					Average Inside Shoulder width. The unit of measure is feet or meters. The value of this item must be greater than or equal to 0.0000 ft.	Need actual data.	SHA (UNIVERSE)	-

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Ramp Length	●					Length of the ramp. The unit of measure is feet or meters. The value of this item must be greater than or equal to 0.00 ft.	Need actual data.	SHA (UNIVERSE)	-
Ramp Side of Road	●					Specifies the side of the road (in the direction of travel) for the ramp, i.e., Inside (right side in direction of travel) or Outside (left side in direction of travel)	Need actual data.	SHA (UNIVERSE)	-
Years of Crash Data		●				Number of years of crash data for the site. Integer value expected. The value of this item must be greater than or equal to 1 and be less than or equal to 3.	Need actual data.	SHA (MSP)	3

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Year 1		●				The year for the first year of data. Integer value expected. The unit of this item is year. The value of this item must be greater than or equal to 1970, and be less than or equal to 2050.	Need actual data.	SHA (MSP)	2008
Year 1 AADT		●				AADT for first year of data. Integer value expected. The value of this item must be greater than or equal to 0.	Need actual data.	SHA (UNIVERSE)	-
Year 1 AADT of Ramp		●				AADT of the ramp. The value of this item must be greater than or equal to 0 vpd, and less than or equal to 500,000 vpd.	Need actual data.	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Year 1 Proportion of High Volume			●			Proportion of AADT during hours where volume exceeds 1000 veh/hour/land. The value of this item must be between (including) 0 and 1.	A default value can be computed as Phv = 1.0 − exp (1.45 − 0.000124 × AADT/n). If the value computed is less than 0.0, then it is set to 0.0. [n is the number of through lanes.]	Computation	Computing the value based on HSM formula
Year 2		●				The year for the second year of data Integer value expected. The unit of this item is year. The value of this item must be greater than or equal to 1970, and be less than or equal to 2050.	Need actual data.	SHA (MSP)	2009

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Year 2 AADT		●				AADT for second year of data. Integer value expected. The value of this item must be greater than or equal to 0.	Need actual data.	SHA (UNIVERSE)	-
Year 2 AADT of Ramp		●				AADT of the ramp. The value of this item must be greater than or equal to 0 vpd, and less than or equal to 500,000 vpd.	Need actual data.	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA
Year 2 Proportion of High Volume			●			Proportion of AADT during hours where volume exceeds 1000 veh/hour/land. The value of this item must be between (including) 0 and 1.	A default value can be computed as Phv = 1.0 − exp (1.45 − 0.000124 × AADT/n). If the value computed is less than 0.0, then it is set to 0.0. [n is the	Computation	Computing the value based on HSM formula

Data Item	**Type**					**Description**	**The HSM Default Assumption**	**Data Source**	**Data Collection Method**
	Required site data	**Required crash/traffic**	**Desired site data**	**Site Curve Data**	**Crash distribution data**				
							number of through lanes.]		
Year 3		●				The year for the third year of data Integer value expected. The unit of this item is year. The value of this item must be greater than or equal to 1970, and be less than or equal to 2050.	Need actual data.	SHA (MSP)	2010
Year 3 AADT		●				AADT for third year of data. Integer value expected. The value of this item must be greater than or equal to 0.	Need actual data.	SHA (UNIVERSE)	-

Data Item	**Type**					**Description**	**The HSM Default Assumption**	**Data Source**	**Data Collection Method**
	Required site data	**Required crash/traffic**	**Desired site data**	**Site Curve Data**	**Crash distribution data**				
Year 3 AADT of Ramp		●				AADT of the ramp. The value of this item must be greater than or equal to 0 vpd, and less than or equal to 500,000 vpd.	Need actual data.	SHA (UNIVERSE) + Manual Extraction + Estimation	Estimating ramp AADT if not available from SHA
Year 3 Proportion of High Volume			●			Proportion of AADT during hours where volume exceeds 1000 veh/hour/land. The value of this item must be between (including) 0 and 1.	A default value can be computed as Phv = 1.0 − exp (1.45 − 0.000124 × AADT/n). If the value computed is less than 0.0, then it is set to 0.0. [n is the number of through lanes.]	Computation	Computing the value based on HSM formula

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Observed Number of Crashes		●				Total number of crashes observed at the site during the specified years. Integer value expected. The value of this item must be greater than or equal to 0.	Need actual data.	SHA (MSP) + Auto/Manual Crash Side Identification	Crashes for freeways were geocoded more than 95% correctly for 2008-2010 and crash side was identified through extensive automatic and manual work
Curve Radius				●		Radius of the horizontal curve. The unit of measure is feet or meters.	Need actual data.	SHA (ARAN) + Manual Extraction	Manual extraction of curve data from ARAN data of SHA (ArcGIS).
Curve Length Within Site				●		Length of the horizontal curve within the specified site. The unit of measure is feet or meters. The value of this item must be greater than or equal to 0.00 ft.	Need actual data.	SHA (ARAN) + Manual Extraction & Measurement	Measuring curve length within the site using curve data from ARAN data of SHA(ArcGIS)
Curve Side of Road				●		Indicator if the horizontal curve is on one or both roadbeds, only applicable	Need actual data.	SHA (ARAN) + Manual Extraction	Checking the curve side of road using curve data from ARAN data of SHA(ArcGIS)

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
						to curve and spiral elements.			
Collision Type (Single-Vehicle)					●	Types of collisions considered by the model. The available values are: o Collision with Animal o Collision with Fixed Object o Collision with Other Object o Collision with Parked Vehicles o Other Single-vehicle Collision	Need actual data.	SHA (MSP) + Computation	Computing SV crash distributions

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Collision Type (Multiple-Vehicle)					●	Types of collisions considered by the model. The available values are: o Head-on Collision o Rear-end Collision o Angle Collision o Sideswipe, Same Direction Collision o Other Multi-vehicle Collision	Need actual data.	SHA (MSP) + Computation	Computing MV crash distributions
Severity					●	The crash severity, e.g. FI or PDO. Enumeration values: o Fatal and Injury - Fatal and injury (FI) crash severity o Property Damage Only - Property damage only (PDO) crash severity	Need actual data.	SHA (MSP)	-

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Ramp Type					●	Specifies if the crash is related to an entrance ramp or an exit ramp. Enumeration values are: o Entrance- Entrance ramp. o Exit- Exit ramp.	Need actual data.	SHA (UNIVERSE) & MSP	Crashes for ramps were not geocoded 2008-2010

Table 55. The HSM Data Needs for Ramp Terminals

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Ramp Terminal Configuration	●					Based on the HSM Figure 19-1.	Need actual data.	Manual Checking	Checking the ramp terminal configuration using the HSM and Google Earth
Area Type	●					Specifies the alignment area type. Types are urban, suburban and rural. The value of this item is used to select the appropriate crash prediction model.	Need actual data.	SHA (MASTER)	-
Type of traffic control	●					The options are signal, one-way stop control, and all-way stop control.	Need actual data.	SHA (MASTER)	Double-checking the type of control (Google Earth)

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Number of thru lanes on the inside crossroad approach	●					Number of lanes (shared or exclusive) serving through traffic on the crossroad approach that is nearest to the freeway (i.e., the inside approach). This variable includes only lanes that continue through the intersection. Count the lanes along the crosswalk (or the logical location of the crosswalk if it is not marked). The value of this item must be a number.	Need actual data.	SHA (UNIVERSE) + Manual Checking	Double-checking number of lanes (Google Earth)

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Number of thru lanes on the outside crossroad approach	●					Number of lanes (shared or exclusive) serving through traffic on the crossroad approach that is more distant from the freeway (i.e., the outside approach). This variable includes only lanes that continue through the intersection. Count the lanes along the crosswalk (or the logical location of the crosswalk if it is not marked). The value of this item must be a number.	Need actual data.	SHA (UNIVERSE) + Manual Checking	Double-checking number of lanes (Google Earth)

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Number of lanes on the exit ramp leg at the terminal	●					Lanes can serve any movement (left, right, or through). If right-turn channelization is provided, then count the lanes at the last point where all exiting movements are joined (i.e., count at the channelization gore point). All lanes counted must be fully developed for 100ft. or more before they intersect the crossroad. If a lane's development length is less than 100ft., then it is not counted as a lane. Lanes associated with the loop exit ramp at a B4 terminal configuration are not included in this count. The value of this item must be a number.	Need actual data.	SHA (UNIVERSE) + Manual Checking	Double-checking number of lanes (Google Earth)

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Presence of a non-ramp public street leg at the terminal	●					This data item is only for signal control type. This situation occurs occasionally. When it does, the public street leg is opposite from one ramp, and the other ramp either does not exist or is located at some distance from the subject ramp terminal such that it is not part of the terminal. The value of this item must be 1.0 if leg is present, 0.0 otherwise.	Need actual data.	Manual Checking	Checking presence of a non-ramp public street leg (Google Earth)
Exit ramp skew angle	●					This data item is only for one-way stop control type. Skew angle equals 90 minus the intersection angle (in degrees).	Need actual data.	Manual Measurement	Using compass on Google Earth

Data Item	**Type**					**Description**	**The HSM Default Assumption**	**Data Source**	**Data Collection Method**
	Required site data	**Required crash/traffic**	**Desired site data**	**Site Curve Data**	**Crash distribution data**				
Presence of a left-turn lane (or bay) on the inside crossroad approach	●					The lane (or bay) can have one or two lanes. A lane (or bay) is considered to be present when it (a) is for the exclusive use of a turn movement, (b) extends 100 ft. or more back from the stop line, and (c) ends at the intersection stop line. The value of this item must be 1.0 if left-turn lane (bay) is present, 0.0 otherwise.	Need actual data.	SHA (UNIVERSE) + Manual Checking	Checking presence of left-turn lane (Google Earth)
Presence of a left-turn lane (or bay) on the outside crossroad approach	●					The lane (or bay) can have one or two lanes. A lane (or bay) is considered to be present when it (a) is for the exclusive use of a turn movement, (b) extends 100 ft. or more back from the stop line, and (c) ends at the intersection stop line. The value of this item must be 1.0 if left-turn lane (bay) is present, 0.0 otherwise.	Need actual data.	SHA (UNIVERSE) + Manual Checking	Checking presence of left-turn lane (Google Earth)

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Width of left-turn lane (or bay) on the inside crossroad approach	●					This variable represents the total width of all lanes that exclusively serve turning vehicles on the subject approach. It is measured from the near edge of traveled way of the adjacent through lane to the near lane marking (or curb face) that delineates the median. The value of this item must be greater than or equal to 0.0000 ft.	Need actual data.	SHA (UNIVERSE)	-

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Width of left-turn lane (or bay) on the outside crossroad approach	●					This variable represents the total width of all lanes that exclusively serve turning vehicles on the subject approach. It is measured from the near edge of traveled way of the adjacent through lane to the near lane marking (or curb face) that delineates the median. The value of this item must be greater than or equal to 0.0000 ft.	Need actual data.	SHA (UNIVERSE)	-
Presence of a right-turn lane (or bay) on the inside crossroad approach	●					The lane (or bay) can have one or two lanes. The value of this item must be 1.0 if right-turn lane (bay) is present, 0.0 otherwise.	Need actual data.	SHA (UNIVERSE) + Manual Checking	Checking presence of right-turn lane (Google Earth)

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Presence of a right-turn lane (or bay) on the outside crossroad approach	●					The lane (or bay) can have one or two lanes. The value of this item must be 1.0 if right-turn lane (bay) is present, 0.0 otherwise.	Need actual data.	SHA (UNIVERSE) + Manual Checking	Checking presence of right-turn lane (Google Earth)
Number of unsignalized driveways on the outside crossroad leg	●					This data item is only for signal control type. This number represents the count of unsignalized driveways on the outside crossroad leg and within 250 ft. of the ramp terminal. The count is taken on both sides of the leg (i.e., it is a two-way total). The count should only include "active" driveways (i.e., those driveways with an average daily volume of 10 veh/day or more).	Need actual data.	Manual Counting	Counting number of unsignalized driveways (Google Earth)

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	**Required crash/traffic**	**Desired site data**	**Site Curve Data**	**Crash distribution data**				
Number of unsignalized public street approaches on the outside crossroad leg	●					This number represents the count of unsignalized public street approaches on the outside crossroad leg and within 250 ft. of the ramp terminal. The count is taken on both sides of the leg (i.e., it is a two-way total). If a public street approach is present at the terminal, then it is not counted for this entry.	Need actual data.	Manual Counting	Counting number of unsignalized driveways (Google Earth)
Distance to the adjacent ramp terminal	●					This data element represents the distance between the subject ramp terminal and the adjacent ramp terminal (measured along the crossroad from terminal center to terminal center). The value of this item must be greater than or equal to 0.0000 mi.	Need actual data.	Manual Measurement	Measuring the distance to adjacent ramp terminal (Google Earth)

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Distance to the next public street intersection on the outside crossroad leg	●					This data element represents the distance between the subject ramp terminal and the nearest public street intersection located in a direction away from the freeway (measured along the crossroad from subject terminal center to intersection center). The value of this item must be greater than or equal to 0.0000 mi.	Need actual data.	Manual Measurement	Measuring the distance to the next public street intersection (Google Earth)
Crossroad median width	●					This width is measured along a line perpendicular to the center line of the crossroad near the intersection. If no median exists, a width of 0ft. is used in the predictive model. The value of this item must be greater than or equal to 0 ft.	Need actual data.	SHA (UNIVERSE)	-

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Presence of protected left-turn operation	●					This data item is only for signal control type. The value of this item must be 1.0, if protected operation exists, 0.0 otherwise.	Need actual data.	Manual Checking	Checking presence of left-turn operation (Google Earth)
Presence of right-turn channelization on the inside crossroad approach	●					This data item is only for signal control type. This channelization creates a turning roadway serving right-turn vehicles. It is separated from the intersection by a triangular channelizing island (delineated by markings or raised curb). The gore point at the upstream end of the island must be within 200ft. of the downstream stop line for right-turn channelization to be considered "present." The value of this item must be 1.0, if right-turn channelization exists, 0.0 otherwise.	Need actual data.	SHA (UNIVERSE) + Manual Checking	Checking presence of right-turn channelization (Google Earth)

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Presence of right-turn channelization on the outside crossroad approach	●					This data item is only for signal control type. This channelization creates a turning roadway that serves right-turn vehicles. It is separated from the intersection by a triangular channelizing island (delineated by markings or raised curb). The gore point at the upstream end of the island must be within 200 ft. of the downstream stop line for right-turn channelization to be considered “present.” The value of this item must be 1.0 if right-turn channelization exists, 0.0 otherwise.	Need actual data.	SHA (UNIVERSE) + Manual Checking	Checking presence of right-turn channelization (Google Earth)

Data Item	**Type**					**Description**	**The HSM Default Assumption**	**Data Source**	**Data Collection Method**
	Required site data	**Required crash/traffic**	**Desired site data**	**Site Curve Data**	**Crash distribution data**				
Presence of right-turn channelization on the exit ramp approach	●					This data item is only for signal control type. This channelization creates a turning roadway that serves right-turn vehicles. It is separated from the intersection by a triangular channelizing island (delineated by markings or raised curb). The gore point at the upstream end of the island must be within 200 ft. of the downstream stop line for right-turn channelization to be considered “present.” The value of this item must be 1.0 if right-turn channelization exists, 0.0 otherwise.	Need actual data.	SHA (UNIVERSE) + Manual Checking	Checking presence of right-turn channelization (Google Earth)

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Years of Crash Data		●				Number of years of crash data for the site. Integer value expected. The value of this item must be greater than or equal to 1 and be less than or equal to 3.	Need actual data.	SHA (MSP)	3
Year 1		●				The year for the first year of data. Integer value expected. The unit of this item is year. The value of this item must be greater than or equal to 1970, and be less than or equal to 2050.	Need actual data.	SHA (MSP)	2008
Year 1 AADT for the entrance ramp		●				AADT for first year of data. Integer value expected. The value of this item must be greater than or equal to 0.	Need actual data.	SHA (UNIVERSE) + Estimation	Estimating ramp AADT if not available from SHA
Year 1 AADT for the exit ramp		●				AADT for first year of data. Integer value expected. The value of this item must be greater than or equal to 0.	Need actual data.	SHA (UNIVERSE) + Estimation	Estimating ramp AADT if not available from SHA

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Year 1 AADT for the crossroad leg between ramps		●				AADT for first year of data. Integer value expected. The value of this item must be greater than or equal to 0.	Need actual data.	SHA (UNIVERSE)	-
Year 1 AADT for the crossroad leg outside of interchange		●				AADT for first year of data. Integer value expected. The value of this item must be greater than or equal to 0.	Need actual data.	SHA (UNIVERSE)	-
Year 2		●				The year for the second year of data. Integer value expected. The unit of this item is year. The value of this item must be greater than or equal to 1970, and be less than or equal to 2050.	Need actual data.	SHA (MSP)	2009
Year 2 AADT for the entrance ramp		●				AADT for second year of data. Integer value expected. The value of this item must be greater than or equal to 0.	Need actual data.	SHA (UNIVERSE) + Estimation	Estimating ramp AADT if not available from SHA

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Year 2 AADT for the exit ramp		●				AADT for second year of data. Integer value expected. The value of this item must be greater than or equal to 0.	Need actual data.	SHA (UNIVERSE) + Estimation	Estimating ramp AADT if not available from SHA
Year 2 AADT for the crossroad leg between ramps		●				AADT for second year of data. Integer value expected. The value of this item must be greater than or equal to 0.	Need actual data.	SHA (UNIVERSE)	-
Year 2 AADT for the crossroad leg outside of interchange		●				AADT for second year of data. Integer value expected. The value of this item must be greater than or equal to 0.	Need actual data.	SHA (UNIVERSE)	-
Year 3		●				The year for the third year of data. Integer value expected. The unit of this item is year. The value of this item must be greater than or equal to 1970, and be less than or equal to 2050.	Need actual data.	SHA (MSP)	2010

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Year 3 AADT for the entrance ramp		●				AADT for third year of data. Integer value expected. The value of this item must be greater than or equal to 0.	Need actual data.	SHA (UNIVERSE) + Estimation	Estimating ramp AADT if not available from SHA
Year 3 AADT for the exit ramp		●				AADT for third year of data. Integer value expected. The value of this item must be greater than or equal to 0.	Need actual data.	SHA (UNIVERSE) + Estimation	Estimating ramp AADT if not available from SHA
Year 3 AADT for the crossroad leg between ramps		●				AADT for third year of data. Integer value expected. The value of this item must be greater than or equal to 0.	Need actual data.	SHA (UNIVERSE)	-
Year 3 AADT for the crossroad leg outside of interchange		●				AADT for third year of data. Integer value expected. The value of this item must be greater than or equal to 0.	Need actual data.	SHA (UNIVERSE)	-

Data Item	**Type**					**Description**	**The HSM Default Assumption**	**Data Source**	**Data Collection Method**
	Required site data	**Required crash/traffic**	**Desired site data**	**Site Curve Data**	**Crash distribution data**				
Collision Type (Single-Vehicle)					●	Types of collisions considered by the model. The available values are: o Collision with Animal o Collision with Fixed Object o Collision with Other Object o Collision with Parked Vehicles o Other Single-vehicle Collision	Need actual data.	SHA (MSP) + Computation	Computing SV crash distributions
Collision Type (Multiple-Vehicle)					●	Types of collisions considered by the model. The available values are: o Head-on Collision o Rear-end Collision o Angle Collision o Sideswipe, Same Direction Collision o Other Multi-vehicle Collision	Need actual data.	SHA (MSP) + Computation	Computing MV crash distributions

Data Item	Type					Description	The HSM Default Assumption	Data Source	Data Collection Method
	Required site data	Required crash/traffic	Desired site data	Site Curve Data	Crash distribution data				
Crash Severity					●	The crash severity, e.g. FI or PDO. Enumeration values: o Fatal and Injury - Fatal and injury (FI) crash severity o Property Damage Only - Property damage only (PDO) crash severity	Need actual data.	SHA (MSP)	-

APPENDIX C. PYTHON CODING SUMMARY

Freeway Segments HSM Classification

```
def FreewayClass (COUNTY, RURURB, ID_PREFIX, LT_THRU_LA, RT_THRU_LA,
MEDIAN_TY, FUNC_CL, THROUGH_LANES, LT_IN_AUX_NUMIA,
RT_IN_AUX_NUMIA, IS_HOV, REVERSIBLE_LANE, SPEED_LIMIT):
    if (ID_PREFIX in ['MD', 'US'] and SPEED_LIMIT >= 50):
        if (COUNTY !=24 and RURURB ==1 and LT_THRU_LA==2 and RT_THRU_LA==2 and
THROUGH_LANES ==4 and MEDIAN_TY in (1,2,3,4) and FUNC_CL in (1,2,11,12) and
LT_IN_AUX_NUMIA==0 and RT_IN_AUX_NUMIA==0 and IS_HOV !=1 and
REVERSIBLE_LANE !=1):
            return "RF4"
        elif (COUNTY !=24 and RURURB ==1 and LT_THRU_LA==3 and RT_THRU_LA==3
and THROUGH_LANES ==6 and MEDIAN_TY in (1,2,3,4) and FUNC_CL in (1,2,11,12) and
LT_IN_AUX_NUMIA==0 and RT_IN_AUX_NUMIA==0 and IS_HOV !=1 and
REVERSIBLE_LANE !=1):
            return "RF6"
        elif (COUNTY !=24 and RURURB ==1 and LT_THRU_LA==4 and RT_THRU_LA==4
and THROUGH_LANES ==8 and MEDIAN_TY in (1,2,3,4) and FUNC_CL in (1,2,11,12) and
LT_IN_AUX_NUMIA==0 and RT_IN_AUX_NUMIA==0 and IS_HOV !=1 and
REVERSIBLE_LANE !=1):
            return "RF8"
        elif (COUNTY !=24 and RURURB !=1 and LT_THRU_LA==2 and RT_THRU_LA==2
and THROUGH_LANES ==4 and MEDIAN_TY in (1,2,3,4) and FUNC_CL in (1,2,11,12) and
LT_IN_AUX_NUMIA==0 and RT_IN_AUX_NUMIA==0 and IS_HOV !=1 and
REVERSIBLE_LANE !=1):
            return "UF4"
        elif (COUNTY !=24 and RURURB !=1 and LT_THRU_LA==3 and RT_THRU_LA==3
and THROUGH_LANES ==6 and MEDIAN_TY in (1,2,3,4) and FUNC_CL in (1,2,11,12) and
LT_IN_AUX_NUMIA==0 and RT_IN_AUX_NUMIA==0 and IS_HOV !=1 and
REVERSIBLE_LANE !=1):
            return "UF6"
        elif (COUNTY !=24 and RURURB !=1 and LT_THRU_LA==4 and RT_THRU_LA==4
and THROUGH_LANES ==8 and MEDIAN_TY in (1,2,3,4) and FUNC_CL in (1,2,11,12) and
LT_IN_AUX_NUMIA==0 and RT_IN_AUX_NUMIA==0 and IS_HOV !=1 and
REVERSIBLE_LANE !=1):
           return "UF8"
        elif (COUNTY !=24 and RURURB !=1 and LT_THRU_LA==5 and RT_THRU_LA==5
and THROUGH_LANES ==10 and MEDIAN_TY in (1,2,3,4) and FUNC_CL in (1,2,11,12) and
LT_IN_AUX_NUMIA==0 and RT_IN_AUX_NUMIA==0 and IS_HOV !=1 and
REVERSIBLE_LANE !=1):
            return "UF10"
        else:
            return "NA"
    elif (ID_PREFIX == 'IS'):
        if (COUNTY !=24 and RURURB ==1 and LT_THRU_LA==2 and RT_THRU_LA==2 and
THROUGH_LANES ==4 and MEDIAN_TY in (1,2,3,4) and FUNC_CL in (1,2,11,12) and
```

```
LT_IN_AUX_NUMIA==0 and RT_IN_AUX_NUMIA==0 and IS_HOV !=1 and
REVERSIBLE_LANE !=1):
            return "RF4"
        elif (COUNTY !=24 and RURURB ==1 and LT_THRU_LA==3 and RT_THRU_LA==3
and THROUGH_LANES ==6 and MEDIAN_TY in (1,2,3,4) and FUNC_CL in (1,2,11,12) and
LT_IN_AUX_NUMIA==0 and RT_IN_AUX_NUMIA==0 and IS_HOV !=1 and
REVERSIBLE_LANE !=1):
            return "RF6"
        elif (COUNTY !=24 and RURURB ==1 and LT_THRU_LA==4 and RT_THRU_LA==4
and THROUGH_LANES ==8 and MEDIAN_TY in (1,2,3,4) and FUNC_CL in (1,2,11,12) and
LT_IN_AUX_NUMIA==0 and RT_IN_AUX_NUMIA==0 and IS_HOV !=1 and
REVERSIBLE_LANE !=1):
            return "RF8"
        elif (COUNTY !=24 and RURURB !=1 and LT_THRU_LA==2 and RT_THRU_LA==2
and THROUGH_LANES ==4 and MEDIAN_TY in (1,2,3,4) and FUNC_CL in (1,2,11,12) and
LT_IN_AUX_NUMIA==0 and RT_IN_AUX_NUMIA==0 and IS_HOV !=1 and
REVERSIBLE_LANE !=1):
            return "UF4"
        elif (COUNTY !=24 and RURURB !=1 and LT_THRU_LA==3 and RT_THRU_LA==3
and THROUGH_LANES ==6 and MEDIAN_TY in (1,2,3,4) and FUNC_CL in (1,2,11,12) and
LT_IN_AUX_NUMIA==0 and RT_IN_AUX_NUMIA==0 and IS_HOV !=1 and
REVERSIBLE_LANE !=1):
            return "UF6"
        elif (COUNTY !=24 and RURURB !=1 and LT_THRU_LA==4 and RT_THRU_LA==4
and THROUGH_LANES ==8 and MEDIAN_TY in (1,2,3,4) and FUNC_CL in (1,2,11,12) and
LT_IN_AUX_NUMIA==0 and RT_IN_AUX_NUMIA==0 and IS_HOV !=1 and
REVERSIBLE_LANE !=1):
           return "UF8"
        elif (COUNTY !=24 and RURURB !=1 and LT_THRU_LA==5 and RT_THRU_LA==5
and THROUGH_LANES ==10 and MEDIAN_TY in (1,2,3,4) and FUNC_CL in (1,2,11,12) and
LT_IN_AUX_NUMIA==0 and RT_IN_AUX_NUMIA==0 and IS_HOV !=1 and
REVERSIBLE_LANE !=1):
            return "UF10"
        else:
            return "NA"
    else:
        return "NA"

Expression:
FreewayClass (!COUNTY!, !RURURB!, !ID_PREFIX!, !LT_THRU_LA!, !RT_THRU_LA!,
!MEDIAN_TY!, !FUNC_CL!, !THROUGH_LANES!, !LT_IN_AUX_NUMIA!,
!RT_IN_AUX_NUMIA!, !IS_HOV!, !REVERSIBLE_LANE!, !SPEED_LIMIT!)
```

Right-Side Speed-Change Lanes HSM Classification

```
def RTSCClass (Fr_Cl, RT_OUT_AUX_NUMIA, RT_OUT_AUX_TY):
    if (Fr_Cl == 'RF4' and RT_OUT_AUX_NUMIA >= 1 and RT_OUT_AUX_TY ==2):
```

```
            return "RT_RSCen4"
    elif (Fr_Cl == 'RF4' and RT_OUT_AUX_NUMIA >= 1 and RT_OUT_AUX_TY ==3):
            return "RT_RSCex4"
    elif (Fr_Cl == 'RF6' and RT_OUT_AUX_NUMIA >= 1 and RT_OUT_AUX_TY ==2):
            return "RT_RSCen6"
    elif (Fr_Cl == 'RF6' and RT_OUT_AUX_NUMIA >= 1 and RT_OUT_AUX_TY ==3):
            return "RT_RSCex6"
    elif (Fr_Cl == 'RF8' and RT_OUT_AUX_NUMIA >= 1 and RT_OUT_AUX_TY ==2):
            return "RT_RSCen8"
    elif (Fr_Cl == 'RF8' and RT_OUT_AUX_NUMIA >= 1 and RT_OUT_AUX_TY ==3):
            return "RT_RSCex8"
    elif (Fr_Cl == 'UF4' and RT_OUT_AUX_NUMIA >= 1 and RT_OUT_AUX_TY ==2):
            return "RT_USCen4"
    elif (Fr_Cl == 'UF4' and RT_OUT_AUX_NUMIA >= 1 and RT_OUT_AUX_TY ==3):
            return "RT_USCex4"
    elif (Fr_Cl == 'UF6' and RT_OUT_AUX_NUMIA >= 1 and RT_OUT_AUX_TY ==2):
            return "RT_USCen6"
    elif (Fr_Cl == 'UF6' and RT_OUT_AUX_NUMIA >= 1 and RT_OUT_AUX_TY ==3):
            return "RT_USCex6"
    elif (Fr_Cl == 'UF8' and RT_OUT_AUX_NUMIA >= 1 and RT_OUT_AUX_TY ==2):
            return "RT_USCen8"
    elif (Fr_Cl == 'UF8' and RT_OUT_AUX_NUMIA >= 1 and RT_OUT_AUX_TY ==3):
            return "RT_USCex8"
    elif (Fr_Cl == 'UF10' and RT_OUT_AUX_NUMIA >= 1 and RT_OUT_AUX_TY ==2):
            return "RT_USCen10"
    elif (Fr_Cl == 'UF10' and RT_OUT_AUX_NUMIA >= 1 and RT_OUT_AUX_TY ==3):
            return "RT_USCex10"
    else:
            return "NA"

Expression:
RTSCClass (!Fr_Cl!, !RT_OUT_AUX_NUMIA!, !RT_OUT_AUX_TY!)
```

Left-Side Speed-Change Lanes HSM Classification

```
def LTSCClass (Fr_Cl, LT_OUT_AUX_NUMIA, LT_OUT_AUX_TY):
    if (Fr_Cl == 'RF4' and LT_OUT_AUX_NUMIA >= 1 and LT_OUT_AUX_TY ==2):
            return "LT_RSCen4"
    elif (Fr_Cl == 'RF4' and LT_OUT_AUX_NUMIA >= 1 and LT_OUT_AUX_TY ==3):
            return "LT_RSCex4"
    elif (Fr_Cl == 'RF6' and LT_OUT_AUX_NUMIA >= 1 and LT_OUT_AUX_TY ==2):
            return "LT_RSCen6"
    elif (Fr_Cl == 'RF6' and LT_OUT_AUX_NUMIA >= 1 and LT_OUT_AUX_TY ==3):
            return "LT_RSCex6"
    elif (Fr_Cl == 'RF8' and LT_OUT_AUX_NUMIA >= 1 and LT_OUT_AUX_TY ==2):
            return "LT_RSCen8"
    elif (Fr_Cl == 'RF8' and LT_OUT_AUX_NUMIA >= 1 and LT_OUT_AUX_TY ==3):
```

```
        return "LT_RSCex8"
    elif (Fr_Cl == 'UF4' and LT_OUT_AUX_NUMIA >= 1 and LT_OUT_AUX_TY ==2):
        return "LT_USCen4"
    elif (Fr_Cl == 'UF4' and LT_OUT_AUX_NUMIA >= 1 and LT_OUT_AUX_TY ==3):
        return "LT_USCex4"
    elif (Fr_Cl == 'UF6' and LT_OUT_AUX_NUMIA >= 1 and LT_OUT_AUX_TY ==2):
        return "LT_USCen6"
    elif (Fr_Cl == 'UF6' and LT_OUT_AUX_NUMIA >= 1 and LT_OUT_AUX_TY ==3):
        return "LT_USCex6"
    elif (Fr_Cl == 'UF8' and LT_OUT_AUX_NUMIA >= 1 and LT_OUT_AUX_TY ==2):
        return "LT_USCen8"
    elif (Fr_Cl == 'UF8' and LT_OUT_AUX_NUMIA >= 1 and LT_OUT_AUX_TY ==3):
        return "LT_USCex8"
    elif (Fr_Cl == 'UF10' and LT_OUT_AUX_NUMIA >= 1 and LT_OUT_AUX_TY ==2):
        return "LT_USCen10"
    elif (Fr_Cl == 'UF10' and LT_OUT_AUX_NUMIA >= 1 and LT_OUT_AUX_TY ==3):
        return "LT_USCex10"
    else:
        return "NA"

Expression:
LTSCClass (!Fr_Cl!, !LT_OUT_AUX_NUMIA!, !LT_OUT_AUX_TY!)
```

Final Speed-Change Lane HSM Classification

Part 1

```
def SCClass (Fr_ID, OBJECTID, Rt_SC_Cl, Lt_SC_Cl):
    if (Fr_ID == OBJECTID):
        return Rt_SC_Cl
    else:
        return Lt_SC_Cl

Expression:
SCClass (!Fr_ID!, !OBJECTID!, !Rt_SC_Cl!, !Lt_SC_Cl!)
```

Part 2

```
def (SC_Cl):
    if (SC_Cl == 'NA'):
        return "NA"
    else:
        return (SC_Cl[3:])

Expression:
FinalSC (!SC_Cl!)
```

Crash Type Classification

```
def Crashtype (NUM_VEH, HARM_EVENT, COLISION_T):
```

```
  if (NUM_VEH in [0,1,2,3,4,5,6,7,8,9,10,11,12,15,47]  and HARM_EVENT == '01' and
COLISION_T in ['01','02']):
      return "H_On"
  elif (NUM_VEH in [0,1,2,3,4,5,6,7,8,9,10,11,12,15,47]  and HARM_EVENT == '01' and
COLISION_T in ['11','12','13','14']):
      return "Rt_Angle"
  elif (NUM_VEH in [0,1,2,3,4,5,6,7,8,9,10,11,12,15,47] and HARM_EVENT == '01' and
COLISION_T in ['03','04','05']):
      return "R_End"
  elif (NUM_VEH in [0,1,2,3,4,5,6,7,8,9,10,11,12,15,47] and HARM_EVENT == '01' and
COLISION_T in ['06','07']):
      return "S_Swipe"
  elif (NUM_VEH in [1,2,3,4,5,6,7,8,9,10,11,12,15,47] and HARM_EVENT == '01' and
COLISION_T in ['08','09','10','15','88']):
      return "Other_MV"
  elif (NUM_VEH == 0 and HARM_EVENT == '01' and COLISION_T in ['08','09','10','15']):
      return "Other_MV"
  elif (NUM_VEH in [2,3,4,5,6,7,8,9,10,11,12,15,47] and HARM_EVENT == '01' and
COLISION_T == '00'):
      return "Other_MV"
  elif (NUM_VEH in [0,1] and HARM_EVENT == '08' and COLISION_T == '17'):
      return "Animal"
  elif (NUM_VEH == 01 and HARM_EVENT == '08' and COLISION_T == '88'):
      return "Animal"
  elif (NUM_VEH in [0,1] and HARM_EVENT == '09' and COLISION_T == '17'):
      return "Fixed_Obj"
  elif (NUM_VEH in [0,1] and HARM_EVENT == '10' and COLISION_T == '17'):
      return "Other_Obj"
  elif (NUM_VEH == 01 and HARM_EVENT == '10' and COLISION_T == '88'):
      return "Other_Obj"
  elif (NUM_VEH == 01 and HARM_EVENT == '09' and COLISION_T == '88'):
      return "Fixed_Obj"
  elif (NUM_VEH == 01 and HARM_EVENT == '02' and COLISION_T == '88'):
      return "Parked_Veh"
  elif (NUM_VEH in [0,1,2,3,4,5,6,7,8,9,10,11,12,15,47]  and HARM_EVENT == '02' and
COLISION_T == '17'):
      return "Parked_Veh"
  elif (NUM_VEH in [0,1,2,3,4,5,6,7,8,9,10,11,12,15,47]  and HARM_EVENT == '02' and
COLISION_T == '17'):
      return "Parked_Veh"
  elif (NUM_VEH in [0,1] and HARM_EVENT in ['03', '04', '05', '06', '07', '11', '12', '13', '14',
'16', '17', '19', '20', '88'] and COLISION_T == '17'):
      return "Other_SV"
  elif (NUM_VEH == 1 and HARM_EVENT == '01' and COLISION_T == '17'):
      return "Other_SV"
```

```
   elif (NUM_VEH in [2,3,4,5,6,7,8,9,10,11,12,15,47] and HARM_EVENT in ['03', '04', '05',
'06', '07', '11', '12', '13', '14', '16', '17', '19', '20', '88'] and COLISION_T == '17'):
        return "Other_SV"
   elif (NUM_VEH in [1,2,3,4,5,6,7,8,9,10,11,12,15,47] and HARM_EVENT in ['03', '04', '05',
'06', '07', '11', '12', '13', '14', '16', '17', '19', '20', '88'] and COLISION_T == '0'):
        return "Other_SV"
   else:
        return "U"

Expression:
Crashtype (!NUM_VEH!, !HARM_EVENT!, !COLISION_T!)
```

New Crash Fields

```
def FinalCrash (FIRST_Fr_Cl, FIRST_Rt_SC_Cl, FIRST_Lt_SC_Cl,
SUM_R_Animal_FI_2008, SUM_R_Animal_PDO_2008, SUM_R_Fixed_Obj_FI_2008,
SUM_R_Fixed_Obj_PDO_2008, SUM_R_Other_Obj_FI_2008,
SUM_R_Other_Obj_PDO_2008, SUM_R_Parked_Veh_FI_2008,
SUM_R_Parked_Veh_PDO_2008, SUM_R_Other_SV_FI_2008,
SUM_R_Other_SV_PDO_2008, SUM_R_H_On_FI_2008, SUM_R_H_On_PDO_2008,
SUM_R_Rt_Angle_FI_2008, SUM_R_Rt_Angle_PDO_2008, SUM_R_R_End_FI_2008,
SUM_R_R_End_PDO_2008, SUM_R_S_Swipe_FI_2008, SUM_R_S_Swipe_PDO_2008,
SUM_R_Other_MV_FI_2008, SUM_R_Other_MV_PDO_2008, SUM_R_U_FI_2008,
SUM_R_U_PDO_2008, SUM_R_Animal_FI_2009, SUM_R_Animal_PDO_2009,
SUM_R_Fixed_Obj_FI_2009, SUM_R_Fixed_Obj_PDO_2009, SUM_R_Other_Obj_FI_2009,
SUM_R_Other_Obj_PDO_2009, SUM_R_Parked_Veh_FI_2009,
SUM_R_Parked_Veh_PDO_2009, SUM_R_Other_SV_FI_2009,
SUM_R_Other_SV_PDO_2009, SUM_R_H_On_FI_2009, SUM_R_H_On_PDO_2009,
SUM_R_Rt_Angle_FI_2009, SUM_R_Rt_Angle_PDO_2009, SUM_R_R_End_FI_2009,
SUM_R_R_End_PDO_2009, SUM_R_S_Swipe_FI_2009, SUM_R_S_Swipe_PDO_2009,
SUM_R_Other_MV_FI_2009, SUM_R_Other_MV_PDO_2009, SUM_R_U_FI_2009,
SUM_R_U_PDO_2009, SUM_R_Animal_FI_2010, SUM_R_Animal_PDO_2010,
SUM_R_Fixed_Obj_FI_2010, SUM_R_Fixed_Obj_PDO_2010, SUM_R_Other_Obj_FI_2010,
SUM_R_Other_Obj_PDO_2010, SUM_R_Parked_Veh_FI_2010,
SUM_R_Parked_Veh_PDO_2010, SUM_R_Other_SV_FI_2010,
SUM_R_Other_SV_PDO_2010, SUM_R_H_On_FI_2010, SUM_R_H_On_PDO_2010,
SUM_R_Rt_Angle_FI_2010, SUM_R_Rt_Angle_PDO_2010, SUM_R_R_End_FI_2010,
SUM_R_R_End_PDO_2010, SUM_R_S_Swipe_FI_2010, SUM_R_S_Swipe_PDO_2010,
SUM_R_Other_MV_FI_2010, SUM_R_Other_MV_PDO_2010, SUM_R_U_FI_2010,
SUM_R_U_PDO_2010, SUM_L_Animal_FI_2008, SUM_L_Animal_PDO_2008,
SUM_L_Fixed_Obj_FI_2008, SUM_L_Fixed_Obj_PDO_2008, SUM_L_Other_Obj_FI_2008,
SUM_L_Other_Obj_PDO_2008, SUM_L_Parked_Veh_FI_2008,
SUM_L_Parked_Veh_PDO_2008, SUM_L_Other_SV_FI_2008,
SUM_L_Other_SV_PDO_2008, SUM_L_H_On_FI_2008, SUM_L_H_On_PDO_2008,
SUM_L_Rt_Angle_FI_2008, SUM_L_Rt_Angle_PDO_2008, SUM_L_R_End_FI_2008,
SUM_L_R_End_PDO_2008, SUM_L_S_Swipe_FI_2008, SUM_L_S_Swipe_PDO_2008,
SUM_L_Other_MV_FI_2008, SUM_L_Other_MV_PDO_2008, SUM_L_U_FI_2008,
```

```
SUM_L_U_PDO_2008, SUM_L_Animal_FI_2009, SUM_L_Animal_PDO_2009,
SUM_L_Fixed_Obj_FI_2009, SUM_L_Fixed_Obj_PDO_2009, SUM_L_Other_Obj_FI_2009,
SUM_L_Other_Obj_PDO_2009, SUM_L_Parked_Veh_FI_2009,
SUM_L_Parked_Veh_PDO_2009, SUM_L_Other_SV_FI_2009,
SUM_L_Other_SV_PDO_2009, SUM_L_H_On_FI_2009, SUM_L_H_On_PDO_2009,
SUM_L_Rt_Angle_FI_2009, SUM_L_Rt_Angle_PDO_2009, SUM_L_R_End_FI_2009,
SUM_L_R_End_PDO_2009, SUM_L_S_Swipe_FI_2009, SUM_L_S_Swipe_PDO_2009,
SUM_L_Other_MV_FI_2009, SUM_L_Other_MV_PDO_2009, SUM_L_U_FI_2009,
SUM_L_U_PDO_2009, SUM_L_Animal_FI_2010, SUM_L_Animal_PDO_2010,
SUM_L_Fixed_Obj_FI_2010, SUM_L_Fixed_Obj_PDO_2010, SUM_L_Other_Obj_FI_2010,
SUM_L_Other_Obj_PDO_2010, SUM_L_Parked_Veh_FI_2010,
SUM_L_Parked_Veh_PDO_2010, SUM_L_Other_SV_FI_2010,
SUM_L_Other_SV_PDO_2010, SUM_L_H_On_FI_2010, SUM_L_H_On_PDO_2010,
SUM_L_Rt_Angle_FI_2010, SUM_L_Rt_Angle_PDO_2010, SUM_L_R_End_FI_2010,
SUM_L_R_End_PDO_2010, SUM_L_S_Swipe_FI_2010, SUM_L_S_Swipe_PDO_2010,
SUM_L_Other_MV_FI_2010, SUM_L_Other_MV_PDO_2010, SUM_L_U_FI_2010,
SUM_L_U_PDO_2010, SUM_U_Animal_FI_2008, SUM_U_Animal_PDO_2008,
SUM_U_Fixed_Obj_FI_2008, SUM_U_Fixed_Obj_PDO_2008, SUM_U_Other_Obj_FI_2008,
SUM_U_Other_Obj_PDO_2008, SUM_U_Parked_Veh_FI_2008,
SUM_U_Parked_Veh_PDO_2008, SUM_U_Other_SV_FI_2008,
SUM_U_Other_SV_PDO_2008, SUM_U_H_On_FI_2008, SUM_U_H_On_PDO_2008,
SUM_U_Rt_Angle_FI_2008, SUM_U_Rt_Angle_PDO_2008, SUM_U_R_End_FI_2008,
SUM_U_R_End_PDO_2008, SUM_U_S_Swipe_FI_2008, SUM_U_S_Swipe_PDO_2008,
SUM_U_Other_MV_FI_2008, SUM_U_Other_MV_PDO_2008, SUM_U_U_FI_2008,
SUM_U_U_PDO_2008, SUM_U_Animal_FI_2009, SUM_U_Animal_PDO_2009,
SUM_U_Fixed_Obj_FI_2009, SUM_U_Fixed_Obj_PDO_2009, SUM_U_Other_Obj_FI_2009,
SUM_U_Other_Obj_PDO_2009, SUM_U_Parked_Veh_FI_2009,
SUM_U_Parked_Veh_PDO_2009, SUM_U_Other_SV_FI_2009,
SUM_U_Other_SV_PDO_2009, SUM_U_H_On_FI_2009, SUM_U_H_On_PDO_2009,
SUM_U_Rt_Angle_FI_2009, SUM_U_Rt_Angle_PDO_2009, SUM_U_R_End_FI_2009,
SUM_U_R_End_PDO_2009, SUM_U_S_Swipe_FI_2009, SUM_U_S_Swipe_PDO_2009,
SUM_U_Other_MV_FI_2009, SUM_U_Other_MV_PDO_2009, SUM_U_U_FI_2009,
SUM_U_U_PDO_2009, SUM_U_Animal_FI_2010, SUM_U_Animal_PDO_2010,
SUM_U_Fixed_Obj_FI_2010, SUM_U_Fixed_Obj_PDO_2010, SUM_U_Other_Obj_FI_2010,
SUM_U_Other_Obj_PDO_2010, SUM_U_Parked_Veh_FI_2010,
SUM_U_Parked_Veh_PDO_2010, SUM_U_Other_SV_FI_2010,
SUM_U_Other_SV_PDO_2010, SUM_U_H_On_FI_2010, SUM_U_H_On_PDO_2010,
SUM_U_Rt_Angle_FI_2010, SUM_U_Rt_Angle_PDO_2010, SUM_U_R_End_FI_2010,
SUM_U_R_End_PDO_2010, SUM_U_S_Swipe_FI_2010, SUM_U_S_Swipe_PDO_2010,
SUM_U_Other_MV_FI_2010, SUM_U_Other_MV_PDO_2010, SUM_U_U_FI_2010,
SUM_U_U_PDO_2010):
    if (FIRST_Rt_SC_Cl == 'NA' and FIRST_Lt_SC_Cl == 'NA'):
        return (SUM_R_Animal_FI_2008 + SUM_R_Fixed_Obj_FI_2008 +
SUM_R_Other_Obj_FI_2008 + SUM_R_Parked_Veh_FI_2008 + SUM_R_Other_SV_FI_2008
+ SUM_L_Animal_FI_2008 + SUM_L_Fixed_Obj_FI_2008 + SUM_L_Other_Obj_FI_2008 +
SUM_L_Parked_Veh_FI_2008 + SUM_L_Other_SV_FI_2008 + SUM_U_Animal_FI_2008 +
```

```
SUM_U_Fixed_Obj_FI_2008 + SUM_U_Other_Obj_FI_2008 + SUM_U_Parked_Veh_FI_2008
+ SUM_U_Other_SV_FI_2008)
    elif (FIRST_Rt_SC_Cl != 'NA' and FIRST_Lt_SC_Cl == 'NA'):
            return (SUM_L_Animal_FI_2008 + SUM_L_Fixed_Obj_FI_2008 +
SUM_L_Other_Obj_FI_2008 + SUM_L_Parked_Veh_FI_2008 + SUM_L_Other_SV_FI_2008
+ SUM_U_Animal_FI_2008 + SUM_U_Fixed_Obj_FI_2008 + SUM_U_Other_Obj_FI_2008 +
SUM_U_Parked_Veh_FI_2008 + SUM_U_Other_SV_FI_2008)
    elif (FIRST_Rt_SC_Cl == 'NA' and FIRST_Lt_SC_Cl != 'NA'):
            return (SUM_R_Animal_FI_2008 + SUM_R_Fixed_Obj_FI_2008 +
SUM_R_Other_Obj_FI_2008 + SUM_R_Parked_Veh_FI_2008 + SUM_R_Other_SV_FI_2008
+ SUM_U_Animal_FI_2008 + SUM_U_Fixed_Obj_FI_2008 + SUM_U_Other_Obj_FI_2008 +
SUM_U_Parked_Veh_FI_2008 + SUM_U_Other_SV_FI_2008)
    else:
            return (SUM_U_Animal_FI_2008 + SUM_U_Fixed_Obj_FI_2008 +
SUM_U_Other_Obj_FI_2008 + SUM_U_Parked_Veh_FI_2008 +
SUM_U_Other_SV_FI_2008)

Expression:
FinalCrash (!FIRST_Fr_Cl!, !FIRST_Rt_SC_Cl!, !FIRST_Lt_SC_Cl!,
!SUM_R_Animal_FI_2008!, !SUM_R_Animal_PDO_2008!, !SUM_R_Fixed_Obj_FI_2008!,
!SUM_R_Fixed_Obj_PDO_2008!, !SUM_R_Other_Obj_FI_2008!,
!SUM_R_Other_Obj_PDO_2008!, !SUM_R_Parked_Veh_FI_2008!,
!SUM_R_Parked_Veh_PDO_2008!, !SUM_R_Other_SV_FI_2008!,
!SUM_R_Other_SV_PDO_2008!, !SUM_R_H_On_FI_2008!, !SUM_R_H_On_PDO_2008!,
!SUM_R_Rt_Angle_FI_2008!, !SUM_R_Rt_Angle_PDO_2008!, !SUM_R_R_End_FI_2008!,
!SUM_R_R_End_PDO_2008!, !SUM_R_S_Swipe_FI_2008!, !SUM_R_S_Swipe_PDO_2008!,
!SUM_R_Other_MV_FI_2008!, !SUM_R_Other_MV_PDO_2008!, !SUM_R_U_FI_2008!,
!SUM_R_U_PDO_2008!, !SUM_R_Animal_FI_2009!, !SUM_R_Animal_PDO_2009!,
!SUM_R_Fixed_Obj_FI_2009!, !SUM_R_Fixed_Obj_PDO_2009!,
!SUM_R_Other_Obj_FI_2009!, !SUM_R_Other_Obj_PDO_2009!,
!SUM_R_Parked_Veh_FI_2009!, !SUM_R_Parked_Veh_PDO_2009!,
!SUM_R_Other_SV_FI_2009!, !SUM_R_Other_SV_PDO_2009!, !SUM_R_H_On_FI_2009!,
!SUM_R_H_On_PDO_2009!, !SUM_R_Rt_Angle_FI_2009!, !SUM_R_Rt_Angle_PDO_2009!,
!SUM_R_R_End_FI_2009!, !SUM_R_R_End_PDO_2009!, !SUM_R_S_Swipe_FI_2009!,
!SUM_R_S_Swipe_PDO_2009!, !SUM_R_Other_MV_FI_2009!,
!SUM_R_Other_MV_PDO_2009!, !SUM_R_U_FI_2009!, !SUM_R_U_PDO_2009!,
!SUM_R_Animal_FI_2010!, !SUM_R_Animal_PDO_2010!, !SUM_R_Fixed_Obj_FI_2010!,
!SUM_R_Fixed_Obj_PDO_2010!, !SUM_R_Other_Obj_FI_2010!,
!SUM_R_Other_Obj_PDO_2010!, !SUM_R_Parked_Veh_FI_2010!,
!SUM_R_Parked_Veh_PDO_2010!, !SUM_R_Other_SV_FI_2010!,
!SUM_R_Other_SV_PDO_2010!, !SUM_R_H_On_FI_2010!, !SUM_R_H_On_PDO_2010!,
!SUM_R_Rt_Angle_FI_2010!, !SUM_R_Rt_Angle_PDO_2010!, !SUM_R_R_End_FI_2010!,
!SUM_R_R_End_PDO_2010!, !SUM_R_S_Swipe_FI_2010!, !SUM_R_S_Swipe_PDO_2010!,
!SUM_R_Other_MV_FI_2010!, !SUM_R_Other_MV_PDO_2010!, !SUM_R_U_FI_2010!,
!SUM_R_U_PDO_2010!, !SUM_L_Animal_FI_2008!, !SUM_L_Animal_PDO_2008!,
!SUM_L_Fixed_Obj_FI_2008!, !SUM_L_Fixed_Obj_PDO_2008!,
```

```
!SUM_L_Other_Obj_FI_2008!, !SUM_L_Other_Obj_PDO_2008!,
!SUM_L_Parked_Veh_FI_2008!, !SUM_L_Parked_Veh_PDO_2008!,
!SUM_L_Other_SV_FI_2008!, !SUM_L_Other_SV_PDO_2008!, !SUM_L_H_On_FI_2008!,
!SUM_L_H_On_PDO_2008!, !SUM_L_Rt_Angle_FI_2008!, !SUM_L_Rt_Angle_PDO_2008!,
!SUM_L_R_End_FI_2008!, !SUM_L_R_End_PDO_2008!, !SUM_L_S_Swipe_FI_2008!,
!SUM_L_S_Swipe_PDO_2008!, !SUM_L_Other_MV_FI_2008!,
!SUM_L_Other_MV_PDO_2008!, !SUM_L_U_FI_2008!, !SUM_L_U_PDO_2008!,
!SUM_L_Animal_FI_2009!, !SUM_L_Animal_PDO_2009!, !SUM_L_Fixed_Obj_FI_2009!,
!SUM_L_Fixed_Obj_PDO_2009!, !SUM_L_Other_Obj_FI_2009!,
!SUM_L_Other_Obj_PDO_2009!, !SUM_L_Parked_Veh_FI_2009!,
!SUM_L_Parked_Veh_PDO_2009!, !SUM_L_Other_SV_FI_2009!,
!SUM_L_Other_SV_PDO_2009!, !SUM_L_H_On_FI_2009!, !SUM_L_H_On_PDO_2009!,
!SUM_L_Rt_Angle_FI_2009!, !SUM_L_Rt_Angle_PDO_2009!, !SUM_L_R_End_FI_2009!,
!SUM_L_R_End_PDO_2009!, !SUM_L_S_Swipe_FI_2009!, !SUM_L_S_Swipe_PDO_2009!,
!SUM_L_Other_MV_FI_2009!, !SUM_L_Other_MV_PDO_2009!, !SUM_L_U_FI_2009!,
!SUM_L_U_PDO_2009!, !SUM_L_Animal_FI_2010!, !SUM_L_Animal_PDO_2010!,
!SUM_L_Fixed_Obj_FI_2010!, !SUM_L_Fixed_Obj_PDO_2010!,
!SUM_L_Other_Obj_FI_2010!, !SUM_L_Other_Obj_PDO_2010!,
!SUM_L_Parked_Veh_FI_2010!, !SUM_L_Parked_Veh_PDO_2010!,
!SUM_L_Other_SV_FI_2010!, !SUM_L_Other_SV_PDO_2010!, !SUM_L_H_On_FI_2010!,
!SUM_L_H_On_PDO_2010!, !SUM_L_Rt_Angle_FI_2010!, !SUM_L_Rt_Angle_PDO_2010!,
!SUM_L_R_End_FI_2010!, !SUM_L_R_End_PDO_2010!, !SUM_L_S_Swipe_FI_2010!,
!SUM_L_S_Swipe_PDO_2010!, !SUM_L_Other_MV_FI_2010!,
!SUM_L_Other_MV_PDO_2010!, !SUM_L_U_FI_2010!, !SUM_L_U_PDO_2010!,
!SUM_U_Animal_FI_2008!, !SUM_U_Animal_PDO_2008!, !SUM_U_Fixed_Obj_FI_2008!,
!SUM_U_Fixed_Obj_PDO_2008!, !SUM_U_Other_Obj_FI_2008!,
!SUM_U_Other_Obj_PDO_2008!, !SUM_U_Parked_Veh_FI_2008!,
!SUM_U_Parked_Veh_PDO_2008!, !SUM_U_Other_SV_FI_2008!,
!SUM_U_Other_SV_PDO_2008!, !SUM_U_H_On_FI_2008!, !SUM_U_H_On_PDO_2008!,
!SUM_U_Rt_Angle_FI_2008!, !SUM_U_Rt_Angle_PDO_2008!, !SUM_U_R_End_FI_2008!,
!SUM_U_R_End_PDO_2008!, !SUM_U_S_Swipe_FI_2008!, !SUM_U_S_Swipe_PDO_2008!,
!SUM_U_Other_MV_FI_2008!, !SUM_U_Other_MV_PDO_2008!, !SUM_U_U_FI_2008!,
!SUM_U_U_PDO_2008!, !SUM_U_Animal_FI_2009!, !SUM_U_Animal_PDO_2009!,
!SUM_U_Fixed_Obj_FI_2009!, !SUM_U_Fixed_Obj_PDO_2009!,
!SUM_U_Other_Obj_FI_2009!, !SUM_U_Other_Obj_PDO_2009!,
!SUM_U_Parked_Veh_FI_2009!, !SUM_U_Parked_Veh_PDO_2009!,
!SUM_U_Other_SV_FI_2009!, !SUM_U_Other_SV_PDO_2009!, !SUM_U_H_On_FI_2009!,
!SUM_U_H_On_PDO_2009!, !SUM_U_Rt_Angle_FI_2009!,
!SUM_U_Rt_Angle_PDO_2009!, !SUM_U_R_End_FI_2009!, !SUM_U_R_End_PDO_2009!,
!SUM_U_S_Swipe_FI_2009!, !SUM_U_S_Swipe_PDO_2009!,
!SUM_U_Other_MV_FI_2009!, !SUM_U_Other_MV_PDO_2009!, !SUM_U_U_FI_2009!,
!SUM_U_U_PDO_2009!, !SUM_U_Animal_FI_2010!, !SUM_U_Animal_PDO_2010!,
!SUM_U_Fixed_Obj_FI_2010!, !SUM_U_Fixed_Obj_PDO_2010!,
!SUM_U_Other_Obj_FI_2010!, !SUM_U_Other_Obj_PDO_2010!,
!SUM_U_Parked_Veh_FI_2010!, !SUM_U_Parked_Veh_PDO_2010!,
!SUM_U_Other_SV_FI_2010!, !SUM_U_Other_SV_PDO_2010!, !SUM_U_H_On_FI_2010!,
```

```
!SUM_U_H_On_PDO_2010!, !SUM_U_Rt_Angle_FI_2010!,
!SUM_U_Rt_Angle_PDO_2010!, !SUM_U_R_End_FI_2010!, !SUM_U_R_End_PDO_2010!,
!SUM_U_S_Swipe_FI_2010!, !SUM_U_S_Swipe_PDO_2010!,
!SUM_U_Other_MV_FI_2010!, !SUM_U_Other_MV_PDO_2010!, !SUM_U_U_FI_2010!,
!SUM_U_U_PDO_2010!)
```

Finding Duplicates

```
d = []
def isDuplicate(t):
    import string
    global d
    iD = 0
    for item in d:
        if item == t:
            iD = 1
            continue
    if iD == 1:
        return 1
    elif iD == 0:
        d.append(t)
        return 0

isDuplicate(!REPORT_NO!)
```

APPENDIX D. DETAILS OF REGRESSION MODELS FOR RAMPS AADT ESTIMATION

The following tables include details of the regression models developed for estimation of AADT on ramps for freeways, speed-change lanes, and signalized and stop-controlled ramp terminals.

Table 56. Details for AADT Estimation for Ramps of Freeways – 2008

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.999[a]	.999	.999	663.209

a. Predictors: (Constant), AADT_2009

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	135421006012.703	1	135421006012.703	307882.969	.000[b]
	Residual	138551401.625	315	439845.719		
	Total	135559557414.328	316			

a. Dependent Variable: AADT_2008

b. Predictors: (Constant), AADT_2009

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-27.083	40.761		-.664	.507
	AADT_2009	.996	.002	.999	554.872	.000

a. Dependent Variable: AADT_2008

Table 57. Details for AADT Estimation for Ramps of Freeways – 2009

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000[a]	.999	.999	554.704

a. Predictors: (Constant), AADT_2010

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	136295184605.154	1	136295184605.154	442953.366	.000[b]
	Residual	96924386.203	315	307696.464		
	Total	136392108991.357	316			

a. Dependent Variable: AADT_2009

b. Predictors: (Constant), AADT_2010

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	13.850	34.086		.406	.685
	AADT_2010	.995	.001	1.000	665.547	.000

a. Dependent Variable: AADT_2009

Table 58. Details for AADT Estimation for Ramps of Freeways – 2010

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.998[a]	.995	.995	1425.807

a. Predictors: (Constant), AADT_2012

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	137087675367.977	1	137087675367.977	67433.670	.000[b]
	Residual	640371759.822	315	2032926.222		
	Total	137728047127.798	316			

a. Dependent Variable: AADT_2010

b. Predictors: (Constant), AADT_2012

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-128.002	87.849		-1.457	.146
	AADT_2012	.995	.004	.998	259.680	.000

a. Dependent Variable: AADT_2010

Table 59. Details for AADT Estimation for Ramps of Speed-Change Lanes – 2008

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.999 [a]	.999	.999	560.430

a. Predictors: (Constant), Ramp_09

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	55506730609.373	1	55506730609.373	176726.930	.000[b]
	Residual	77578230.145	247	314081.903		
	Total	55584308839.518	248			

a. Dependent Variable: Ramp_08

b. Predictors: (Constant), Ramp_09

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	47.305	40.267		1.175	.241
	Ramp_09	.985	.002	.999	420.389	.000

a. Dependent Variable: Ramp_08

Table 60. Details for AADT Estimation for Ramps of Speed-Change Lanes – 2009

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
2	.998[b]	.997	.997	848.973

b. Predictors: (Constant), Ramp_10, RURURB_1

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
2	Regression	57060618596.655	2	28530309298.327	39583.890	.000[c]
	Residual	177305872.148	246	720755.578		
	Total	57237924468.803	248			

a. Dependent Variable: Ramp_09

c. Predictors: (Constant), Ramp_10, RURURB_1

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
2	(Constant)	-57.561	64.286		-.895	.371
	Ramp_10	.987	.004	.999	280.158	.000
	RURURB_1	510.043	186.792	.010	2.731	.007

a. Dependent Variable: Ramp_09

Table 61. Details for AADT Estimation for Ramps of Speed-Change Lanes – 2010

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
3	.998[c]	.996	.996	932.467

c. Predictors: (Constant), Ramp_12, County_10, County_15

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
3	Regression	58465128283.994	3	19488376094.665	22413.465	.000[d]
	Residual	213026064.247	245	869494.140		
	Total	58678154348.241	248			

a. Dependent Variable: Ramp_10

d. Predictors: (Constant), Ramp_12, County_10, County_15

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
3	(Constant)	-131.052	72.755		-1.801	.073
	Ramp_12	1.010	.004	.998	258.662	.000
	County_10	-498.512	209.400	-.009	-2.381	.018
	County_15	402.185	194.691	.008	2.066	.040

a. Dependent Variable: Ramp_10

Table 62. Details for AADT Estimation for Ramps of Signalized Ramp Terminals – 2008

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.999[a]	.999	.999	30.057

a. Predictors: (Constant), 2009 Entrance/Exit AADT

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	717519270.598	1	717519270.598	794242.272	.000[b]
	Residual	56914.264	63	903.401		
	Total	717576184.862	64			

a. Dependent Variable: 2008 Entrance/Exit AADT

b. Predictors: (Constant), 2009 Entrance/Exit AADT

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.866	6.526		.592	.556
	2009 Entrance/Exit AADT	.990	.001	1.000	891.203	.000

a. Dependent Variable: 2008 Entrance/Exit AADT

Table 63. Details for AADT Estimation for Ramps of Signalized Ramp Terminals – 2009

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.938[a]	.881	.879	1176.774

a. Predictors: (Constant), 2010 Entrance/Exit AADT

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	644109414.781	1	644109414.781	465.129	.000[b]
	Residual	87242229.157	63	1384797.288		
	Total	731351643.938	64			

a. Dependent Variable: 2009 Entrance/Exit AADT

b. Predictors: (Constant), 2010 Entrance/Exit AADT

Coefficients[a]

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	496.330	247.945		2.002	.050
	2010 Entrance/Exit AADT	.874	.041	.938	21.567	.000

a. Dependent Variable: 2009 Entrance/Exit AADT

Table 64. Details for AADT Estimation for Ramps of Signalized Ramp Terminals – 2010

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.940[a]	.884	.882	1244.337

a. Predictors: (Constant), 2012 Entrance/Exit AADT

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	744774430.783	1	744774430.783	481.004	.000[b]
	Residual	97547537.617	63	1548373.613		
	Total	842321968.400	64			

a. Dependent Variable: 2010 Entrance/Exit AADT

b. Predictors: (Constant), 2012 Entrance/Exit AADT

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	64.521	270.747		.238	.812
	2012 Entrance/Exit AADT	.968	.044	.940	21.932	.000

a. Dependent Variable: 2010 Entrance/Exit AADT

Table 65. Details for AADT Estimation for Ramps of Stop-controlled Ramp Terminals – 2008

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.999[a]	.999	.999	16.404

a. Predictors: (Constant), 2009 Entrance/Exit AADT

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	97113043.003	1	97113043.003	360898.519	.000[b]
	Residual	6188.997	23	269.087		
	Total	97119232.000	24			

a. Dependent Variable: 2008 Entrance/Exit AADT

b. Predictors: (Constant), 2009 Entrance/Exit AADT

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-4.336	5.559		-.780	.443
	2009 Entrance/Exit AADT	.991	.002	1.000	600.748	.000

a. Dependent Variable: 2008 Entrance/Exit AADT

Table 66. Details for AADT Estimation for Ramps of Stop-controlled Ramp Terminals – 2009

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.999[a]	.997	.997	107.324

a. Predictors: (Constant), 2010 Entrance/Exit AADT

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	98545759.870	1	98545759.870	8555.478	.000[b]
	Residual	264924.130	23	11518.440		
	Total	98810684.000	24			

a. Dependent Variable: 2009 Entrance/Exit AADT

b. Predictors: (Constant), 2010 Entrance/Exit AADT

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-29.357	36.661		-.801	.431
	2010 Entrance/Exit AADT	.997	.011	.999	92.496	.000

a. Dependent Variable: 2009 Entrance/Exit AADT

Table 67. Details for AADT Estimation for Ramps of Stop-controlled Ramp Terminals – 2010

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.997[a]	.993	.993	171.031

a. Predictors: (Constant), 2012 Entrance/Exit AADT

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	98556891.108	1	98556891.108	3369.290	.000[b]
	Residual	672785.132	23	29251.527		
	Total	99229676.240	24			

a. Dependent Variable: 2010 Entrance/Exit AADT

b. Predictors: (Constant), 2012 Entrance/Exit AADT

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	60.092	57.716		1.041	.309
	2012 Entrance/Exit AADT	.949	.016	.997	58.046	.000

a. Dependent Variable: 2010 Entrance/Exit AADT

APPENDIX E. SAMPLED SITES

Freeway Segments

The final dataset included **564** freeway segments. The following figures depicted them.

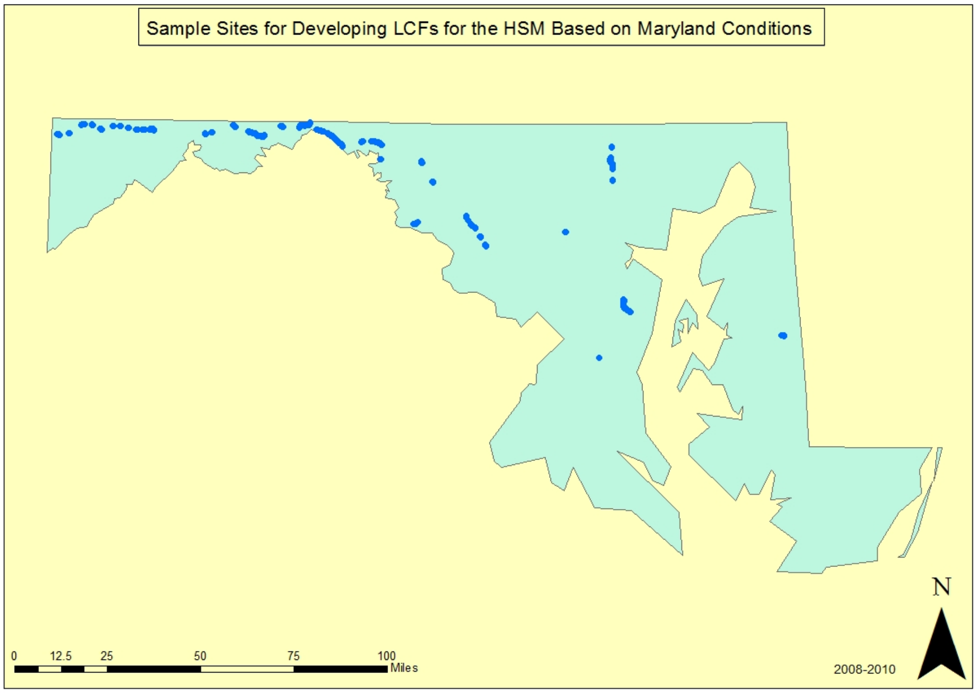

Figure 33. Rural Freeway; Four-lane divided (RF4) – 105 sites

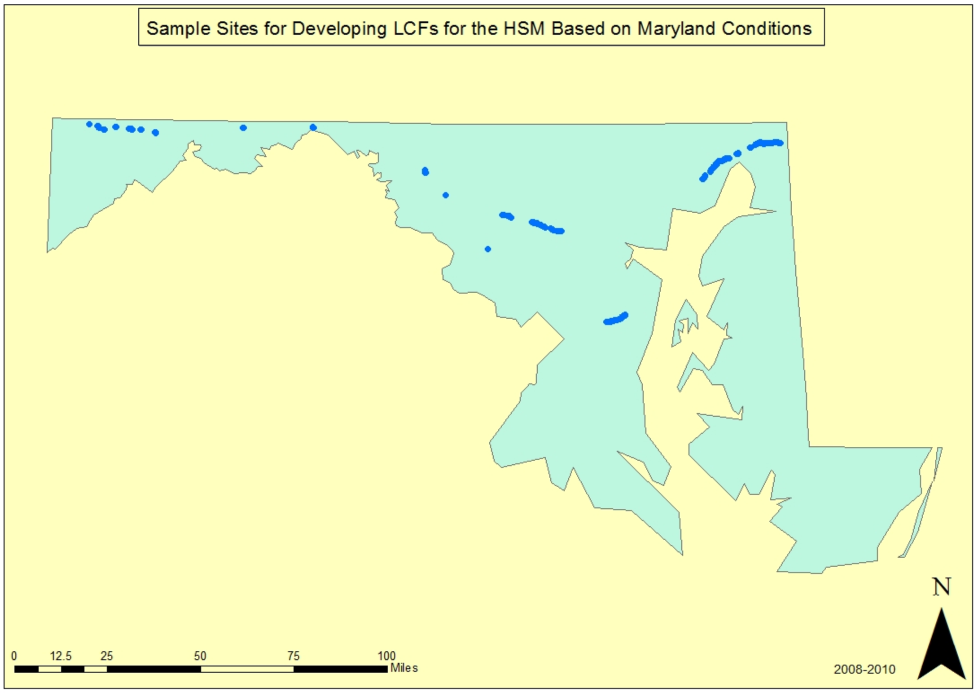

Figure 34. Rural Freeway; Six-lane divided (RF6) – 69 sites

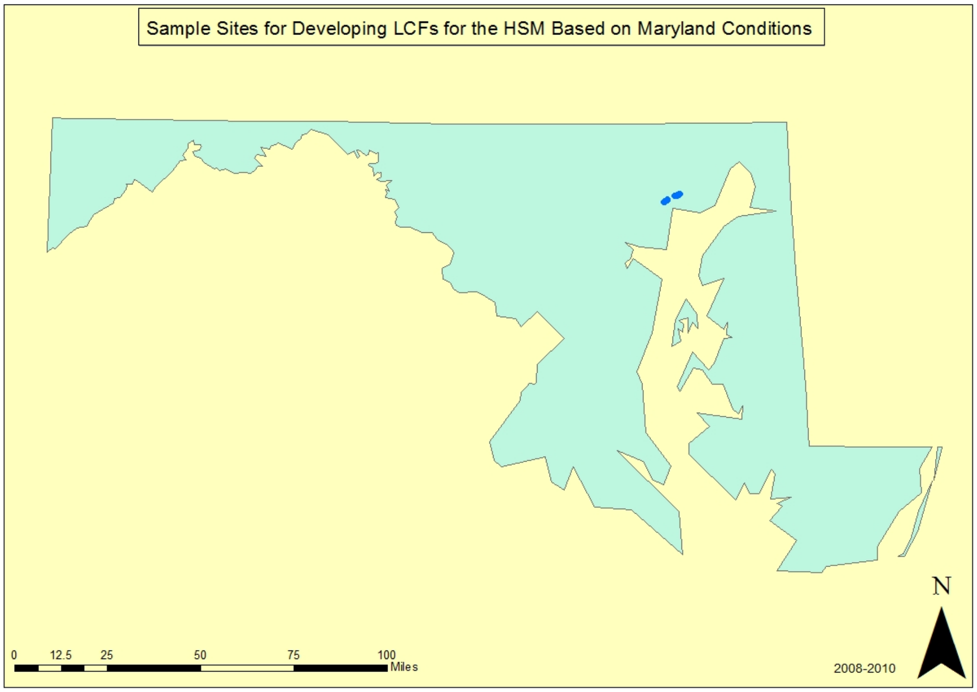

Figure 35. Rural Freeway; Eight-lane divided (RF8) – 5 sites

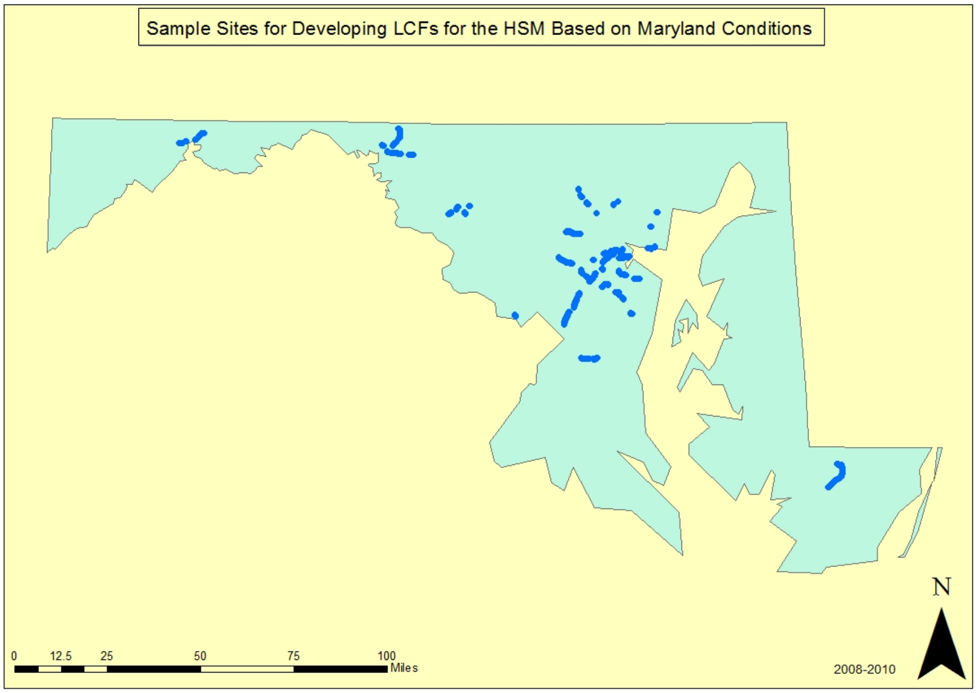

Figure 36. Urban Freeway; Four-lane divided (UF4) – 175 sites

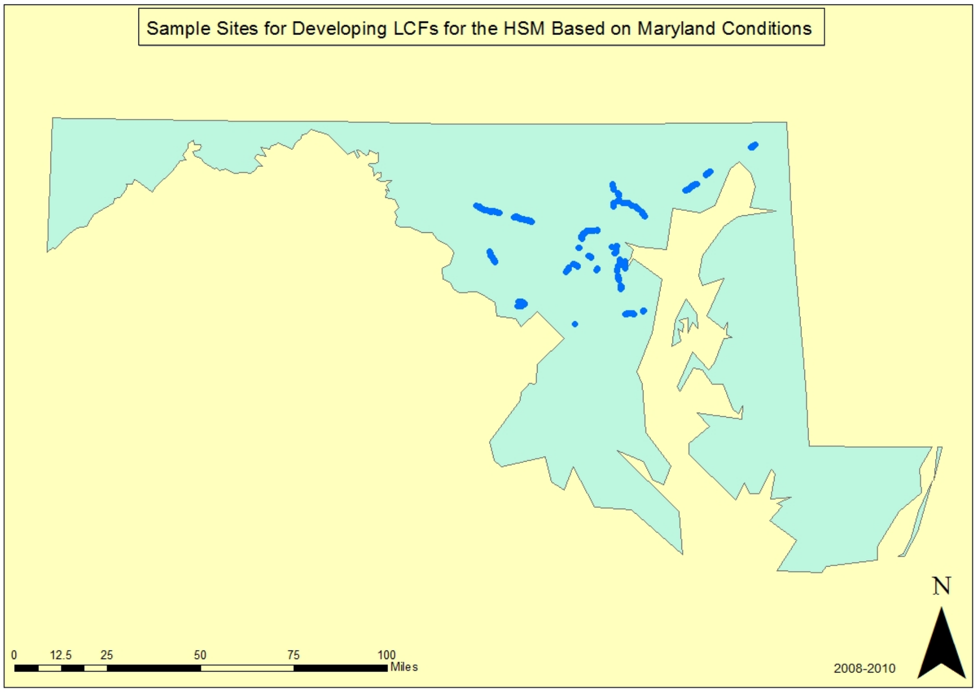

Figure 37. Urban Freeway; Six-lane divided (UF6) – 119 sites

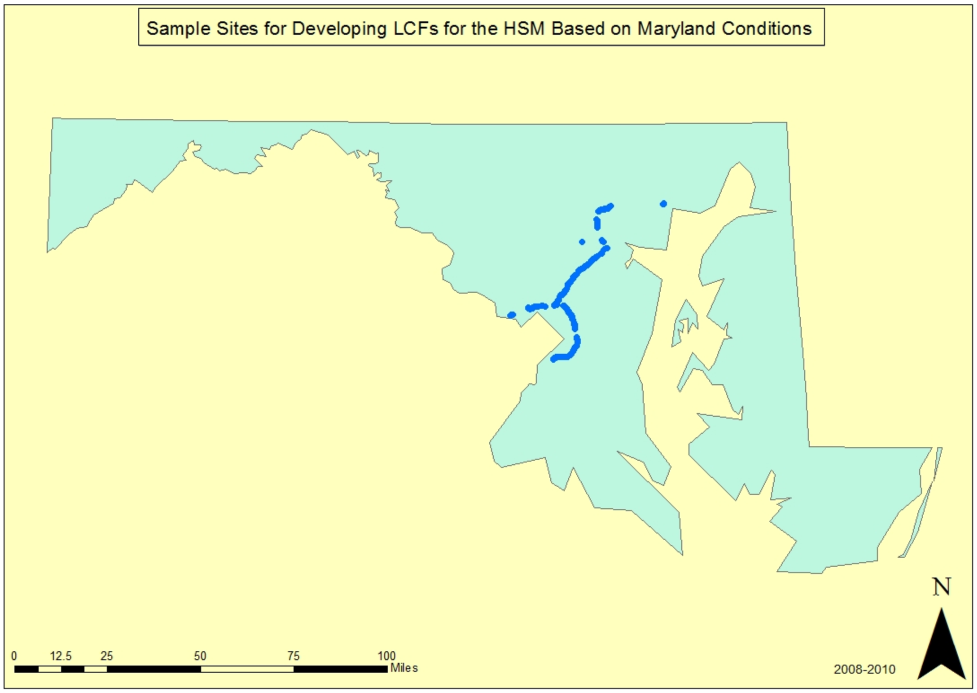

Figure 38. Urban Freeway; Eight-lane divided (UF8) – 90 sites

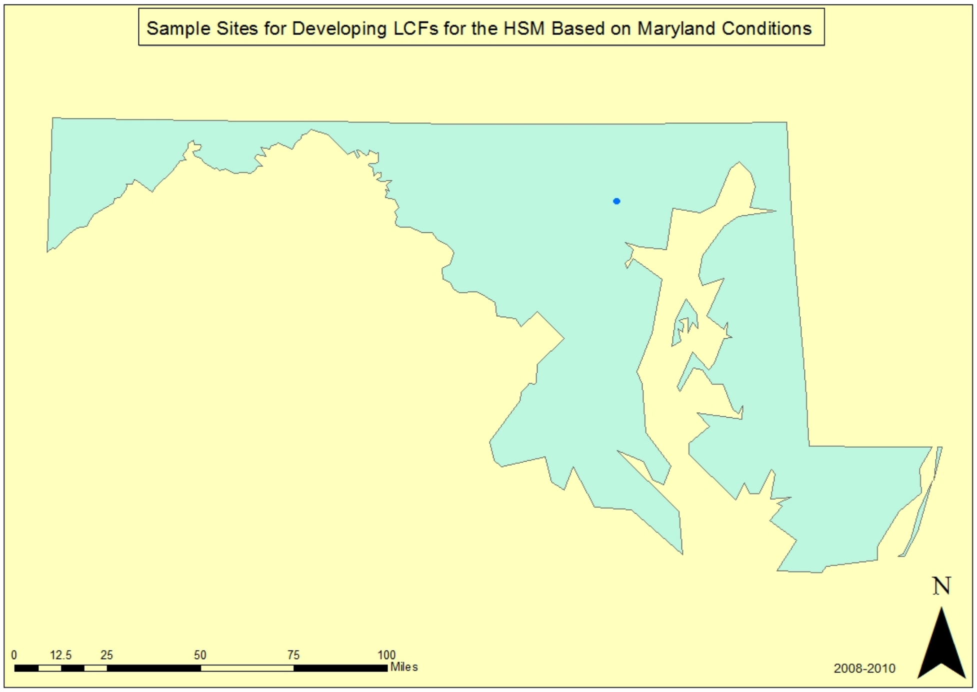

Figure 39. Urban Freeway; Ten-lane divided (UF10) – 1 site

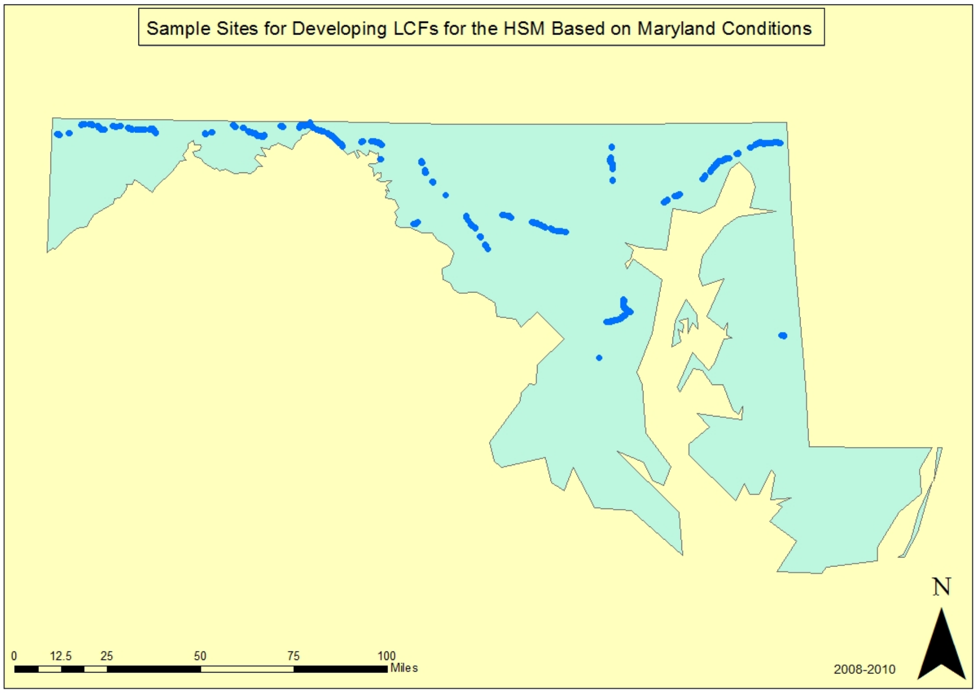

Figure 40. All Rural Freeway Segments – 179 sites

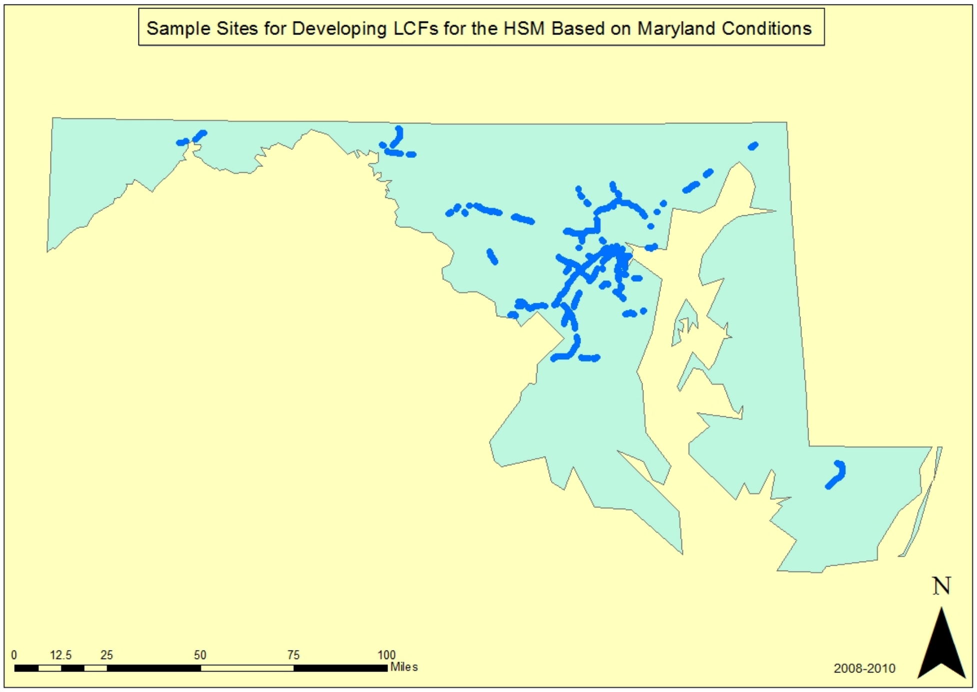

Figure 41. All Urban Freeway Segments – 385 sites

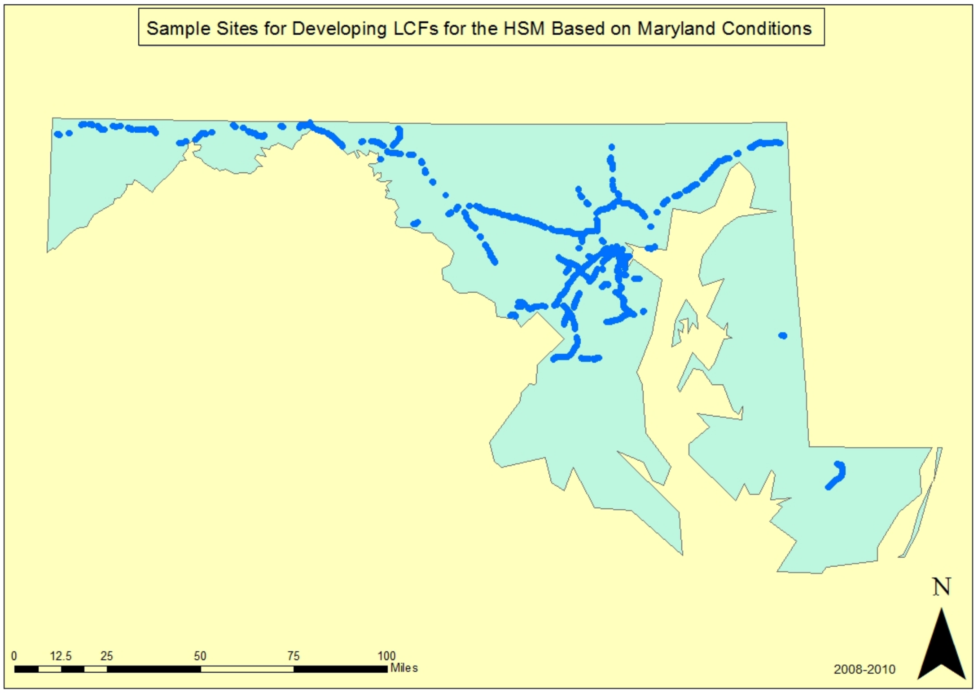

Figure 42. All Freeway Segments – 564 sites

Speed-Change Lanes

The final dataset included **518** speed-change lanes. The following figures depicted them. It should be noted that there was no sample of “Urban Speed-Change Lane; Ramp entrance to eight-lane divided (USCen10)” in the final dataset.

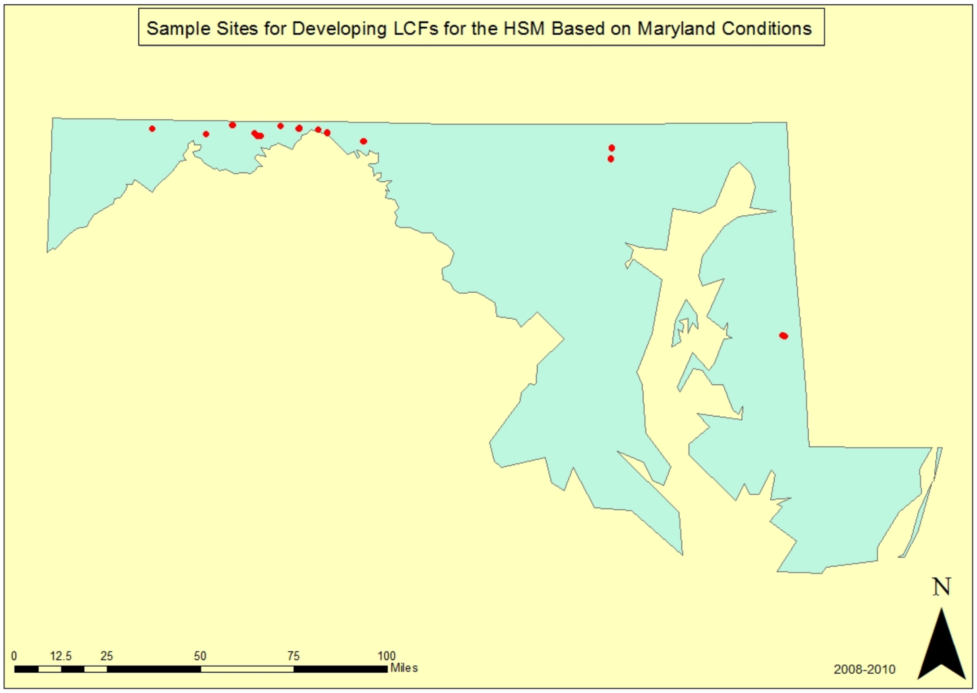

Figure 43. Rural Speed-Change Lane; Ramp entrance to four-lane divided (RSCen4) – 16 sites

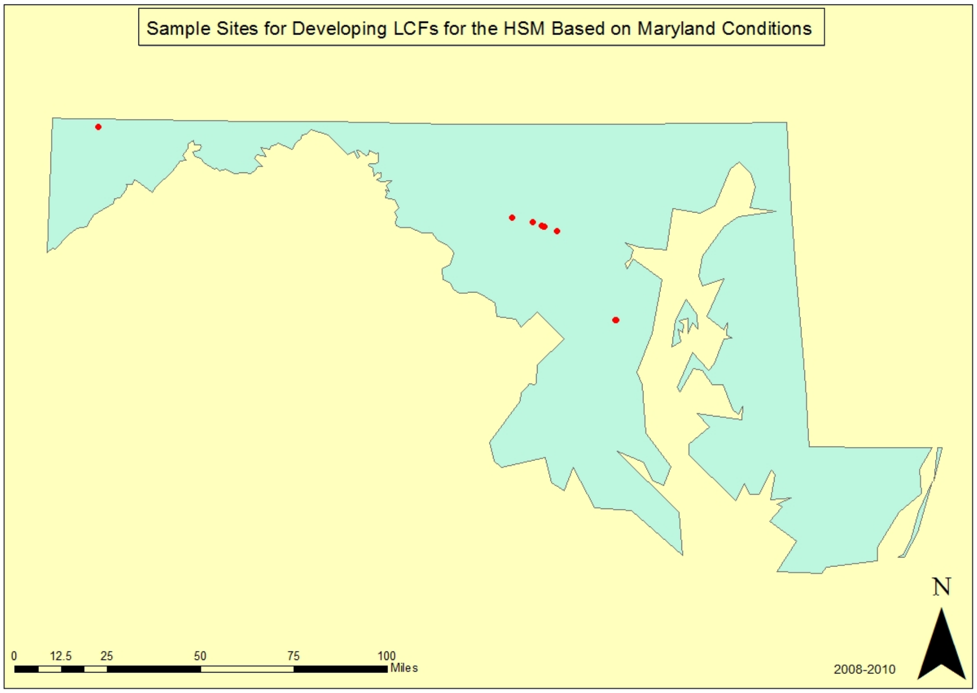

Figure 44. Rural Speed-Change Lane; Ramp entrance to six-lane divided (RSCen6) – 9 sites

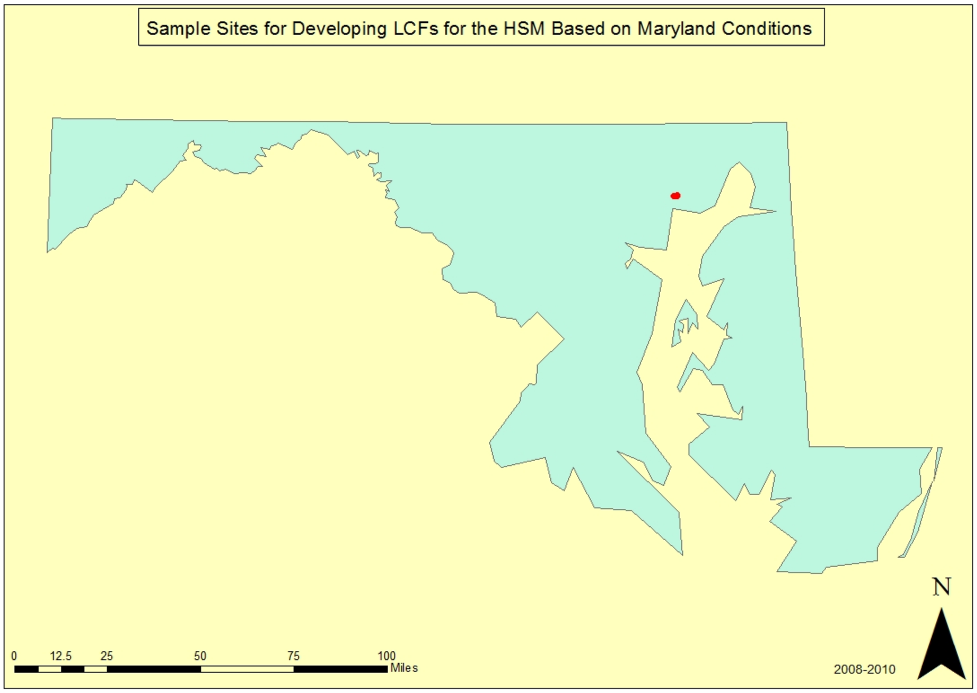

Figure 45. Rural Speed-Change Lane; Ramp entrance to eight-lane divided (RSCen8) – 4 sites

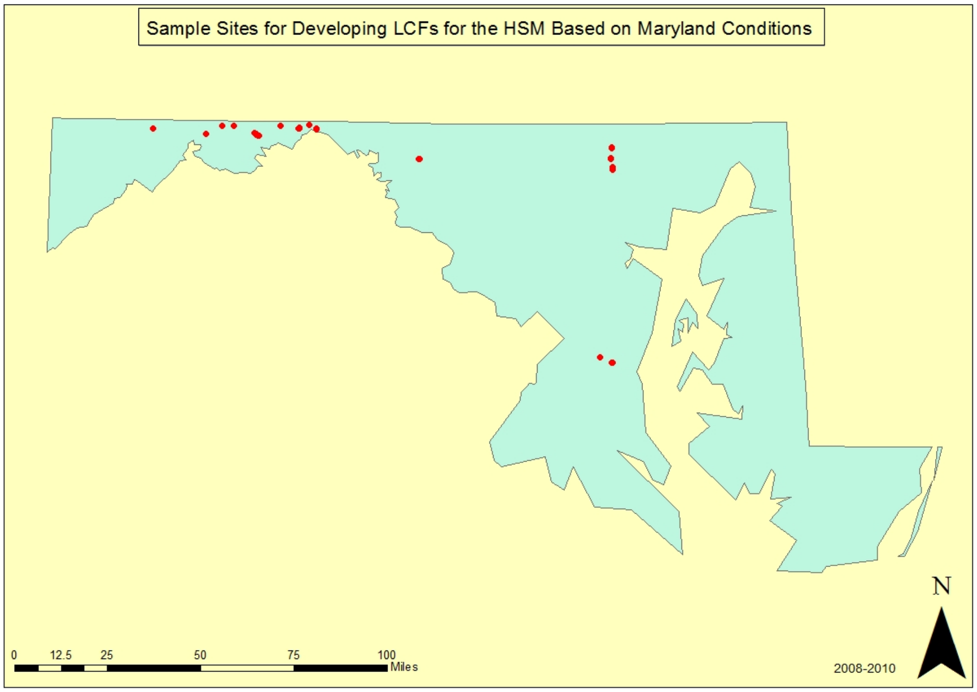

Figure 46. Rural Speed-Change Lane; Ramp exit from four-lane divided (RSCex4) – 21 sites

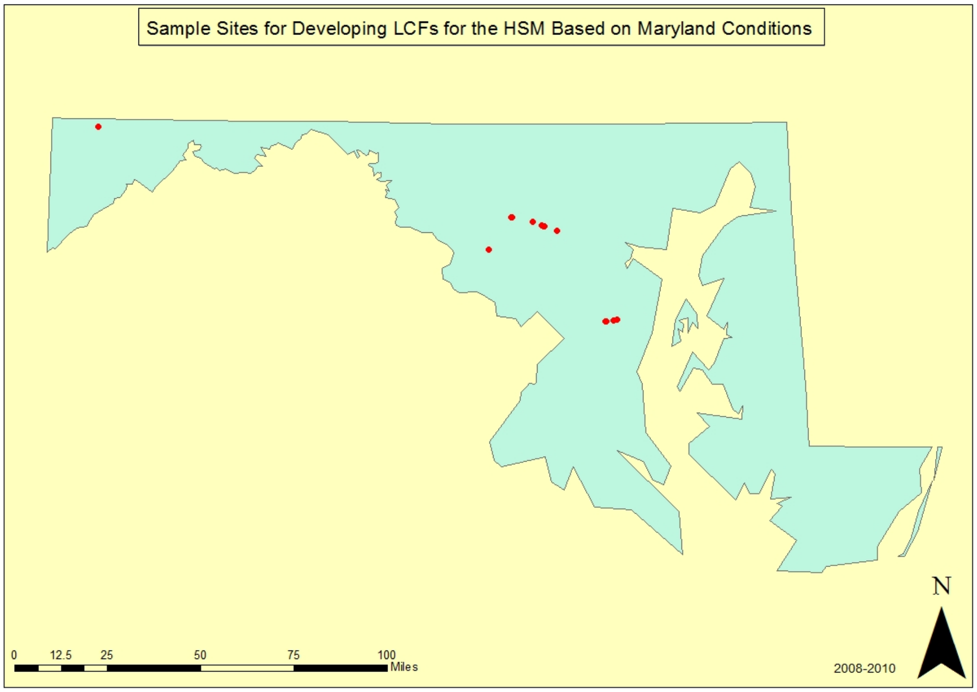

Figure 47. Rural Speed-Change Lane; Ramp exit from six-lane divided (RSCex6) – 11 sites

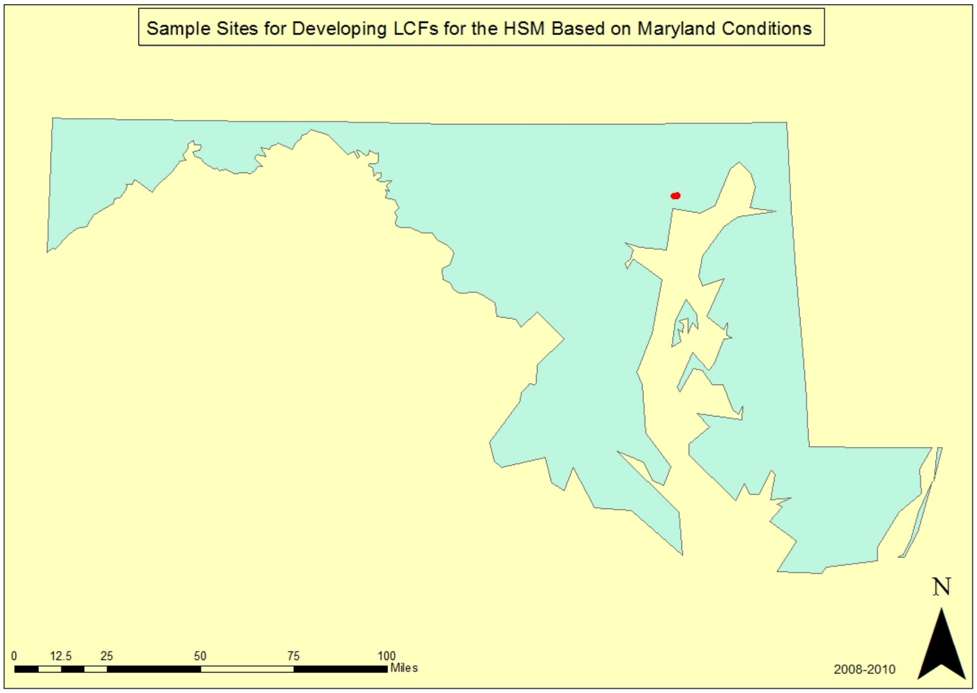

Figure 48. Rural Speed-Change Lane; Ramp exit from eight-lane divided (RSCex8) – 2 sites

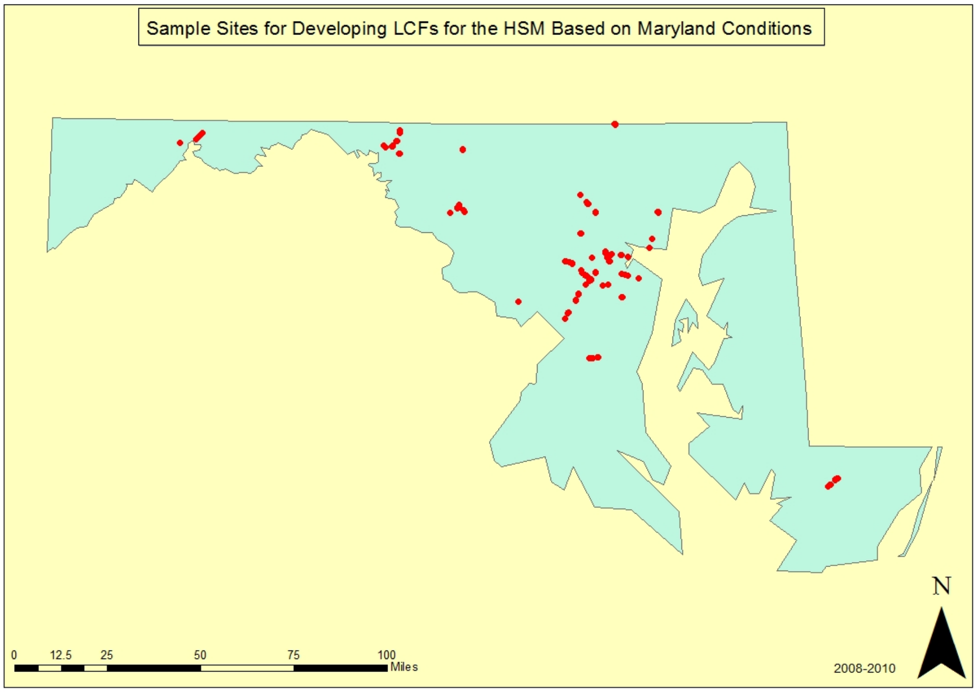

Figure 49. Urban Speed-Change Lane; Ramp entrance to four-lane divided (USCen4) – 85 sites

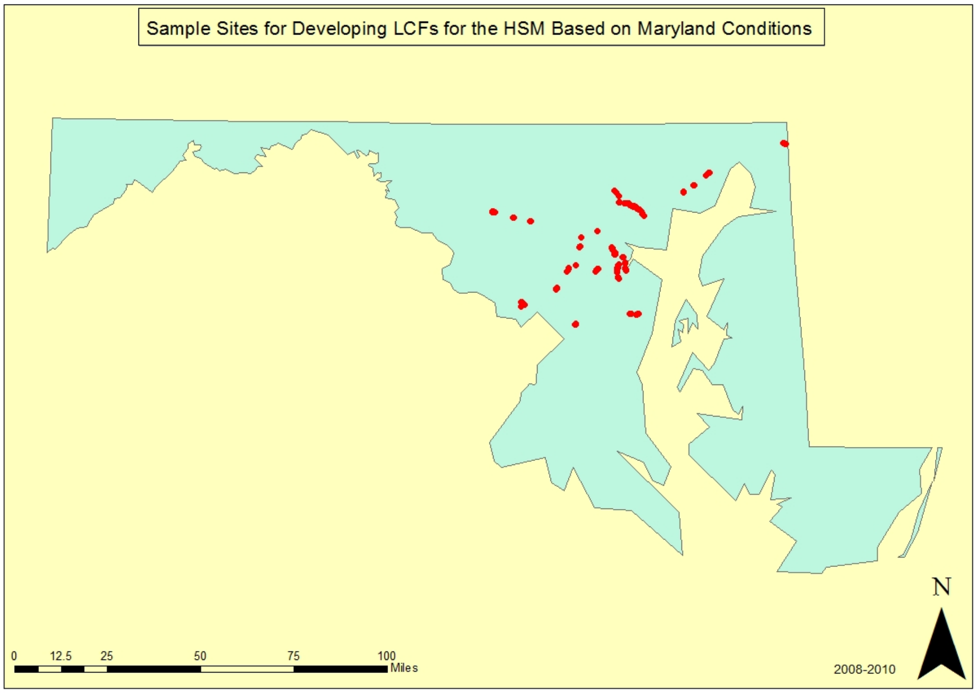

Figure 50. Urban Speed-Change Lane; Ramp entrance to six-lane divided (USCen6) – 93 sites

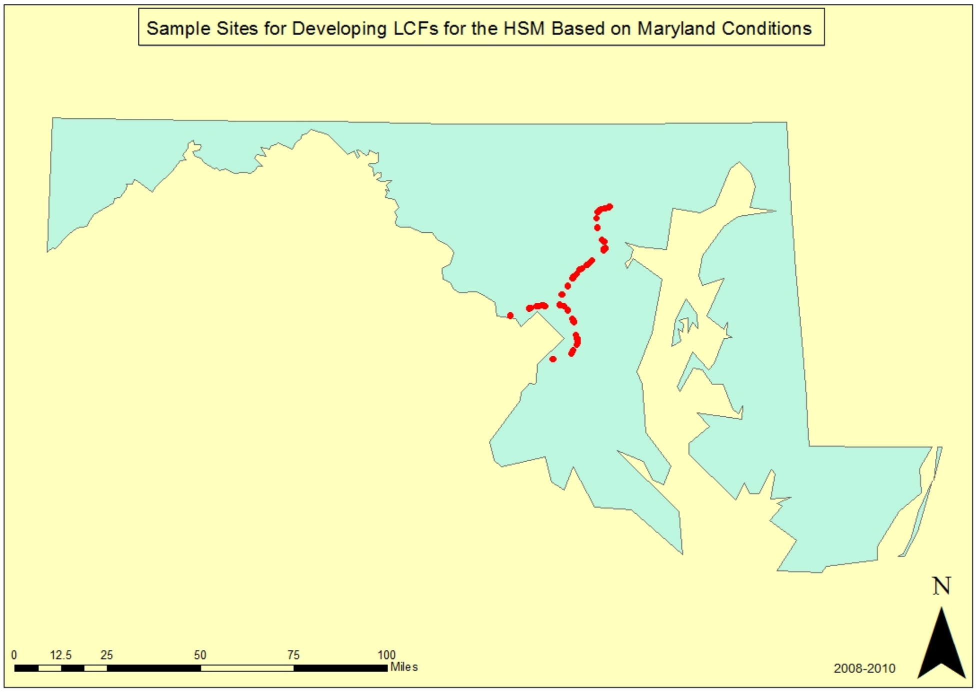

Figure 51. Urban Speed-Change Lane; Ramp entrance to eight-lane divided (USCen8) – 57 sites

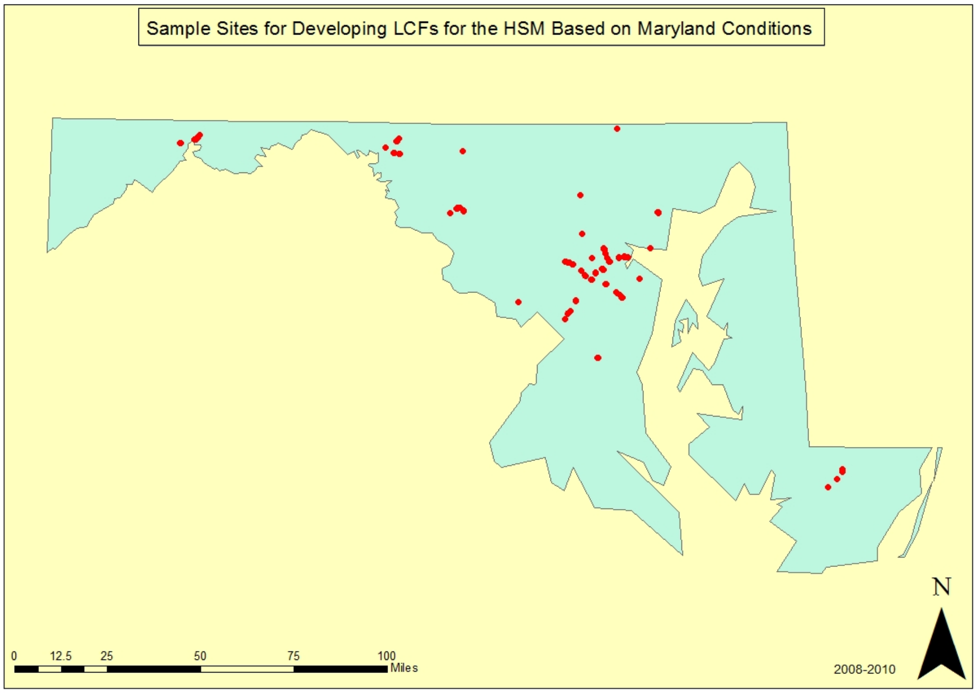

Figure 52. Urban Speed-Change Lane; Ramp exit from four-lane divided (USCex4) – 72 sites

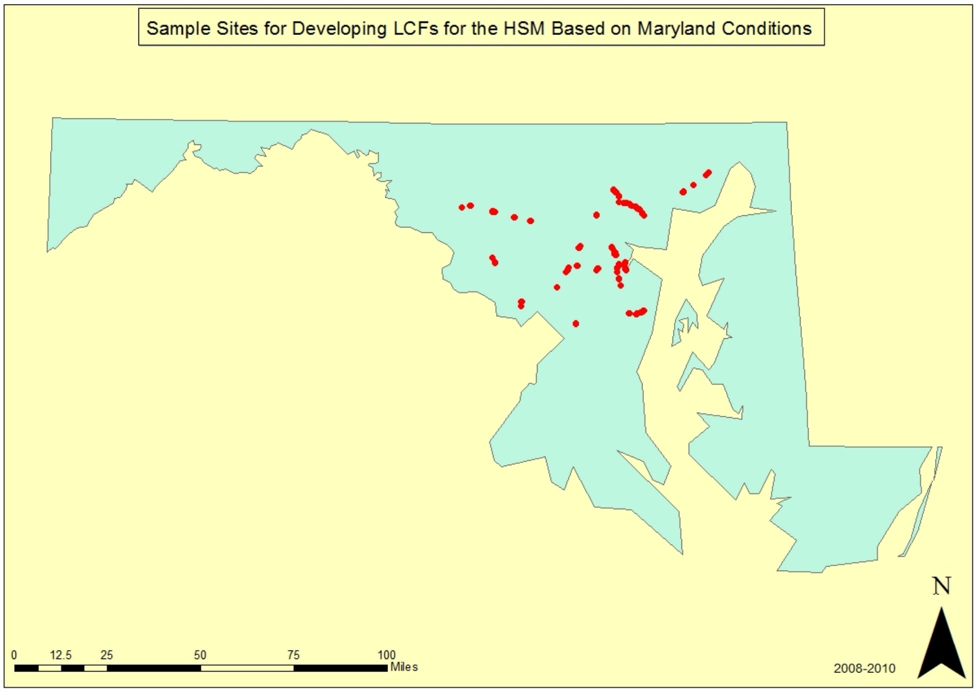

Figure 53. Urban Speed-Change Lane; Ramp exit from six-lane divided (USCex6) – 98 sites

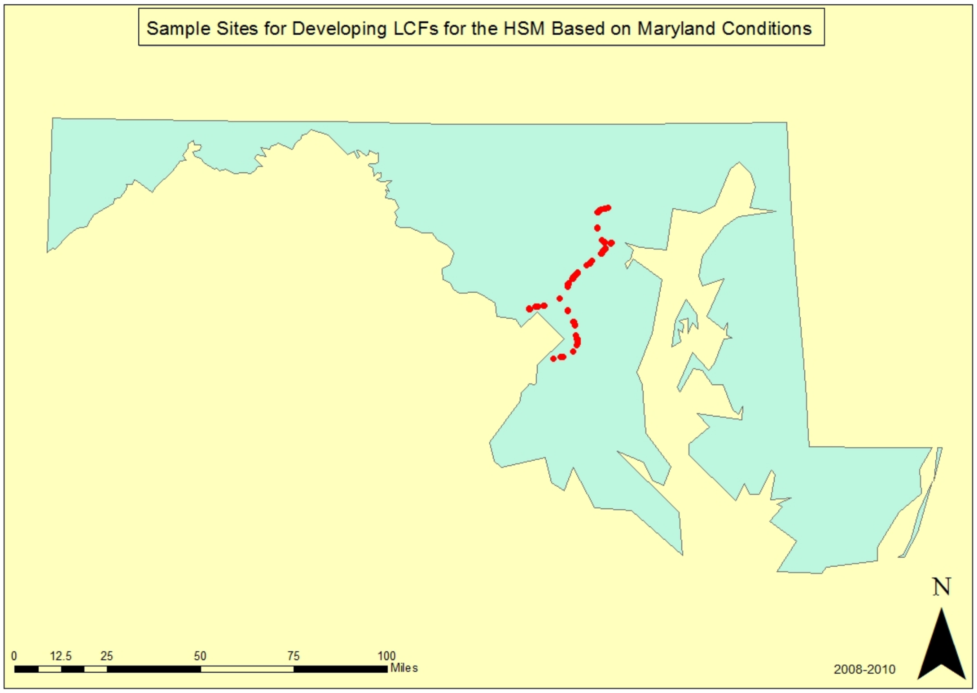

Figure 54. Urban Speed-Change Lane; Ramp exit from eight-lane divided (USCex8) – 49 sites

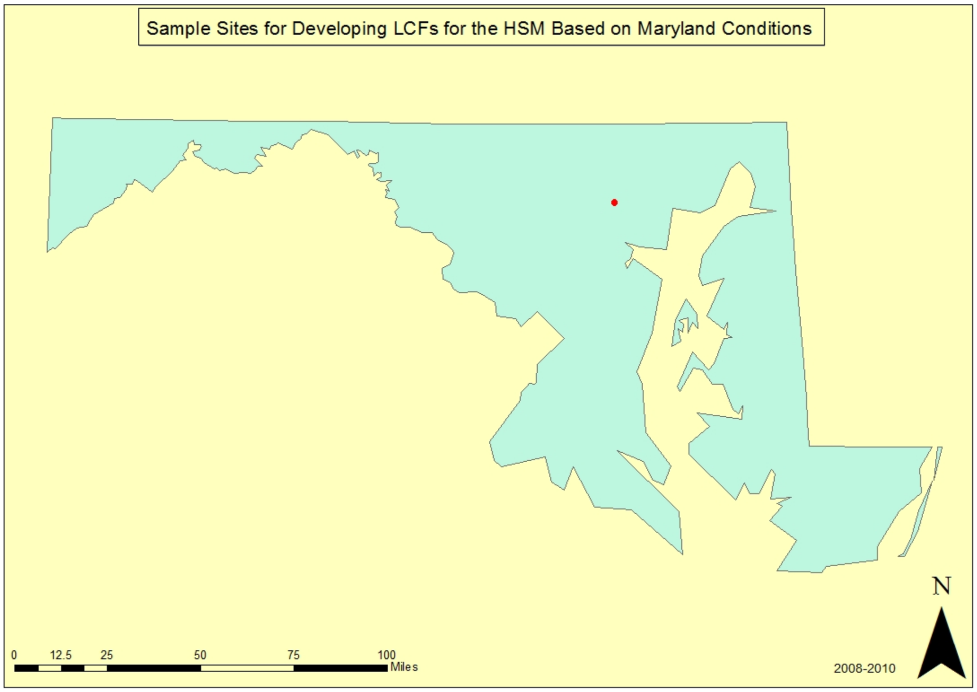

Figure 55. Urban Speed-Change Lane; Ramp exit from eight-lane divided (USCex10) – 1 site

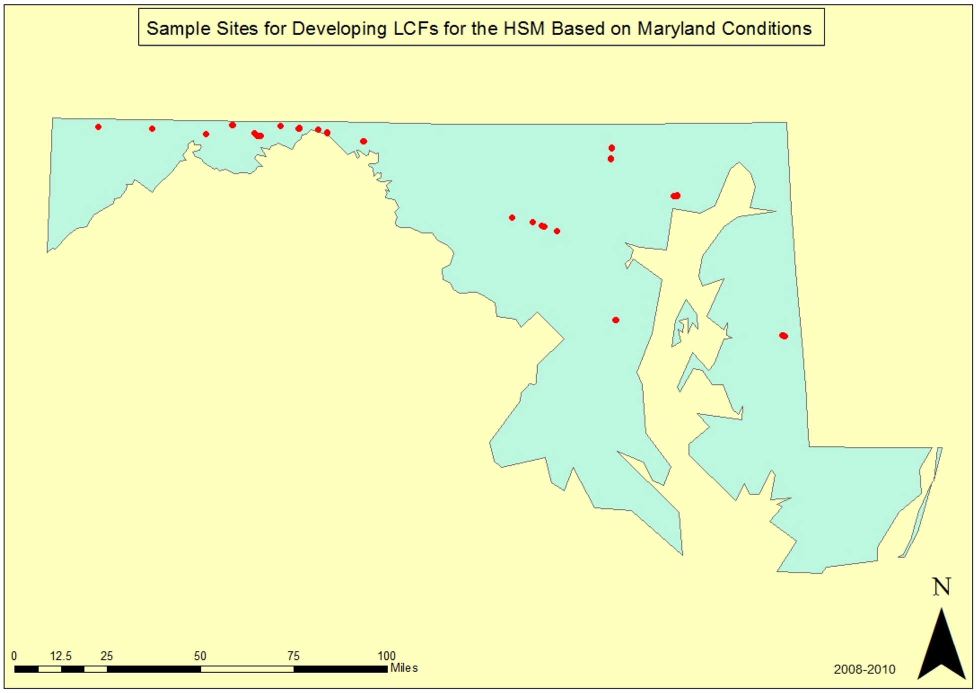

Figure 56. All Rural Speed-Change Lanes; Ramp Entrances – 29 sites

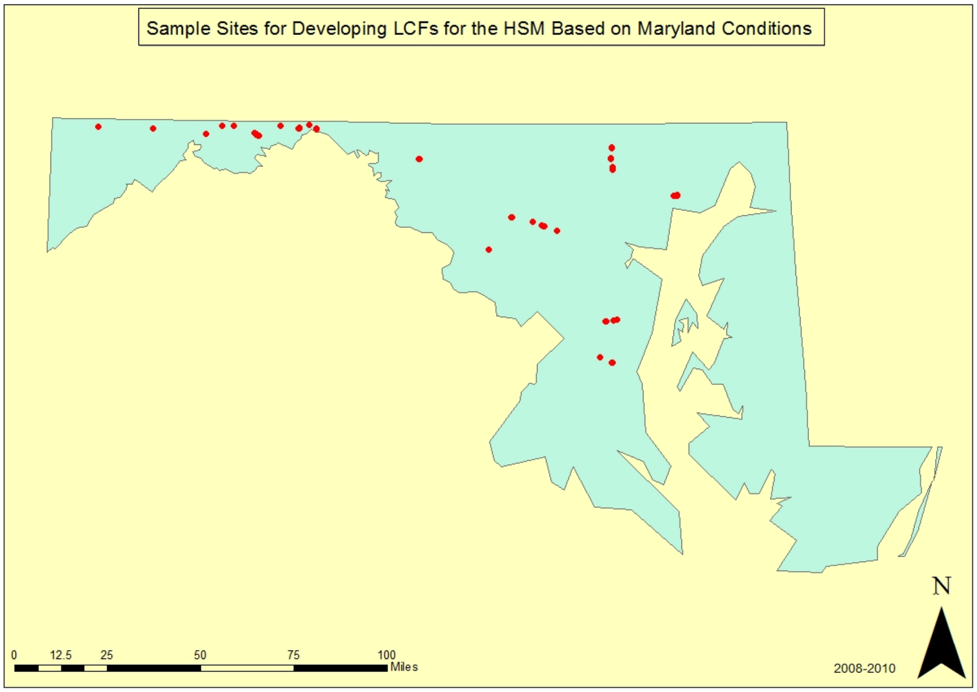

Figure 57. All Rural Speed-Change Lanes; Ramp Exits – 34 sites

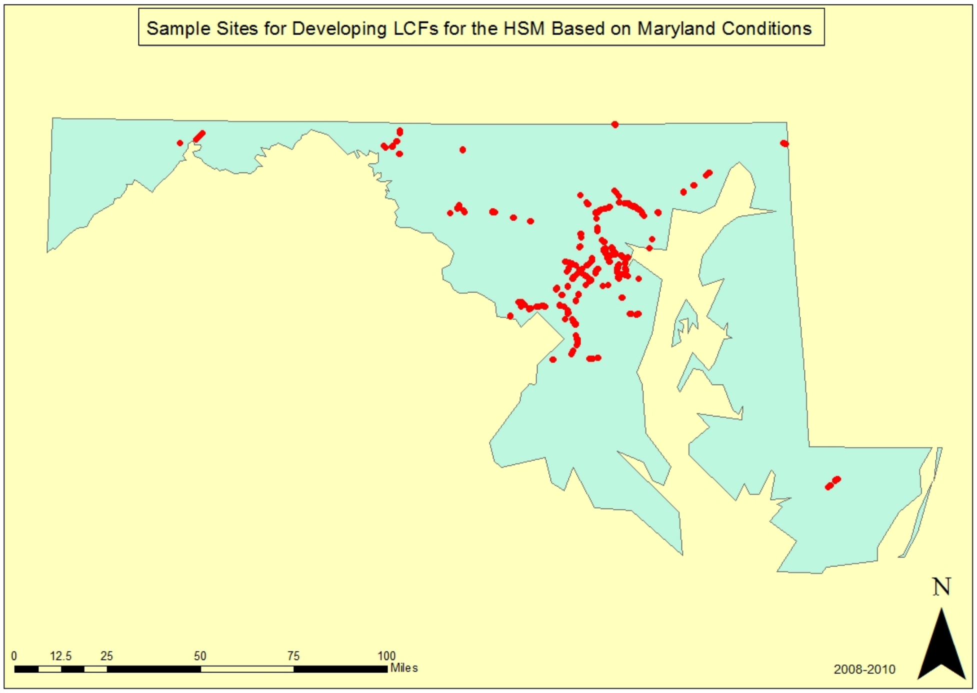

Figure 58. All Urban Speed-Change Lanes; Ramp Entrances – 235 sites

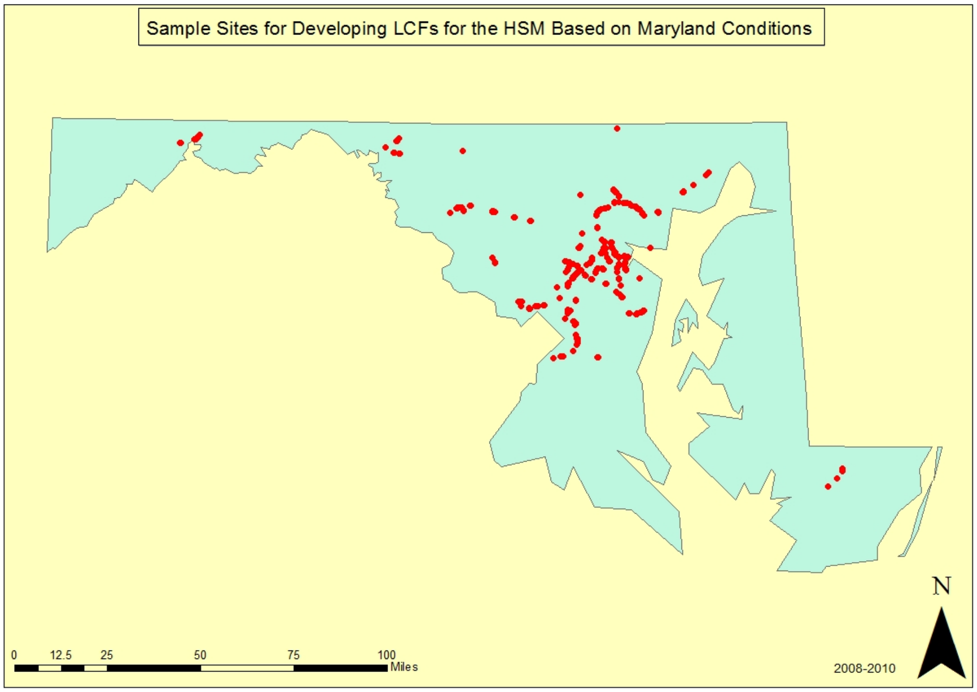

Figure 59. All Urban Speed-Change Lanes; Ramp Exits – 220 sites

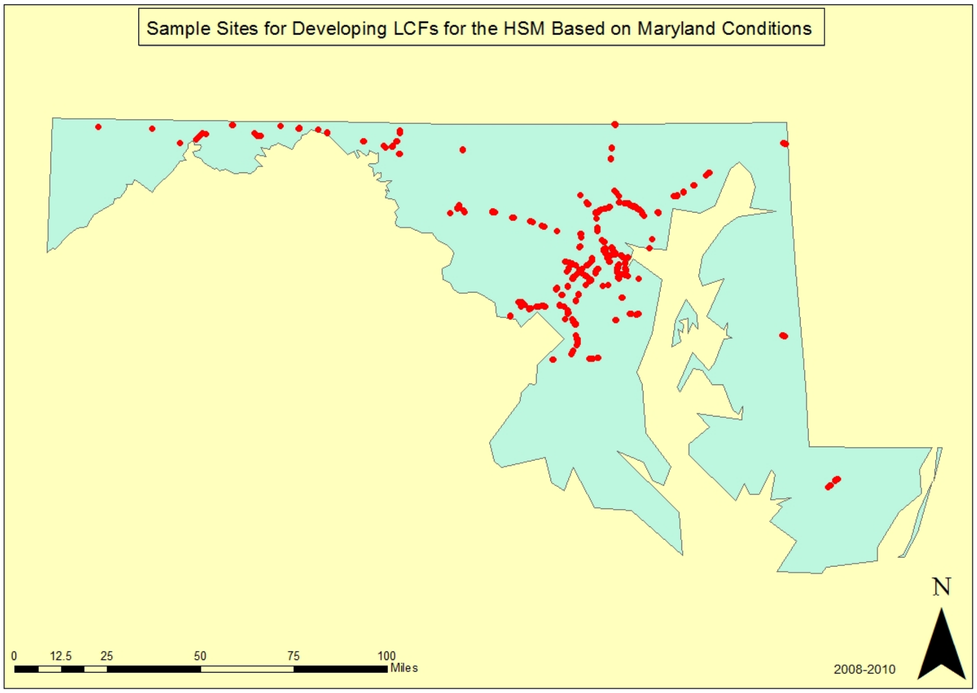

Figure 60. All Speed-Change Lanes; Ramp Entrances – 264 sites

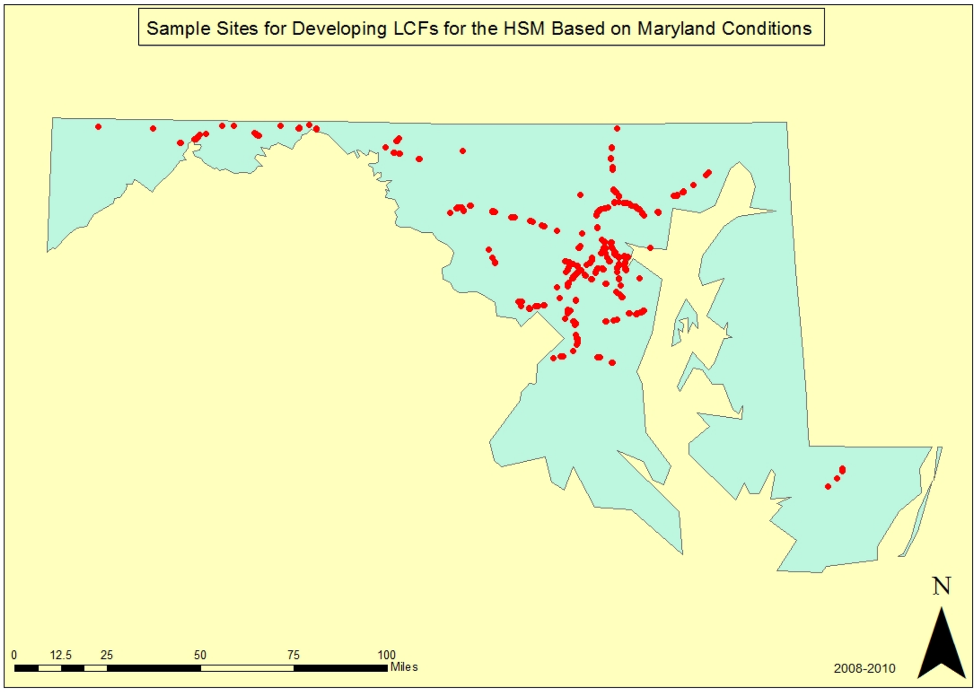

Figure 61. All Speed-Change Lanes; Ramp Exits – 254 sites

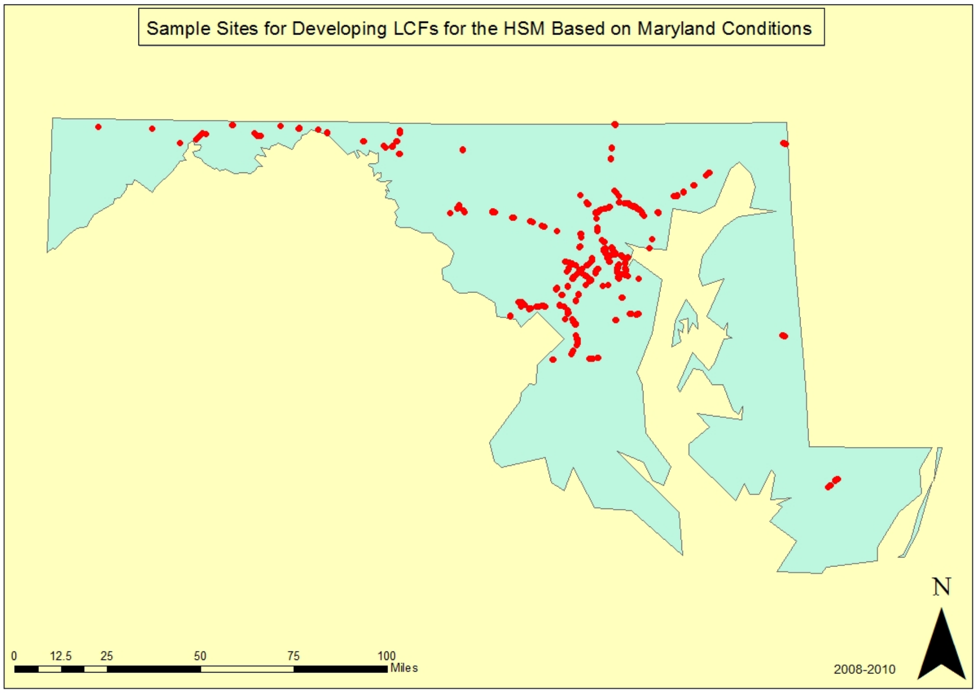

Figure 62. All Speed-Change Lanes – 518 sites

Stop-controlled Ramp Terminals

The final dataset included **147** stop-controlled ramp terminals. The following figures depicted them. It should be noted that there was no sample of “Rural A4 Ramp Terminal; Stop-controlled (RA$_4$ST),” “Rural B4 Ramp Terminal; Stop-controlled (RB$_4$ST),” “Urban A4 Ramp Terminal; Stop-controlled (UA$_4$ST),” and “Urban B4 Ramp Terminal; Stop-controlled (UB$_4$ST)” in the final dataset.

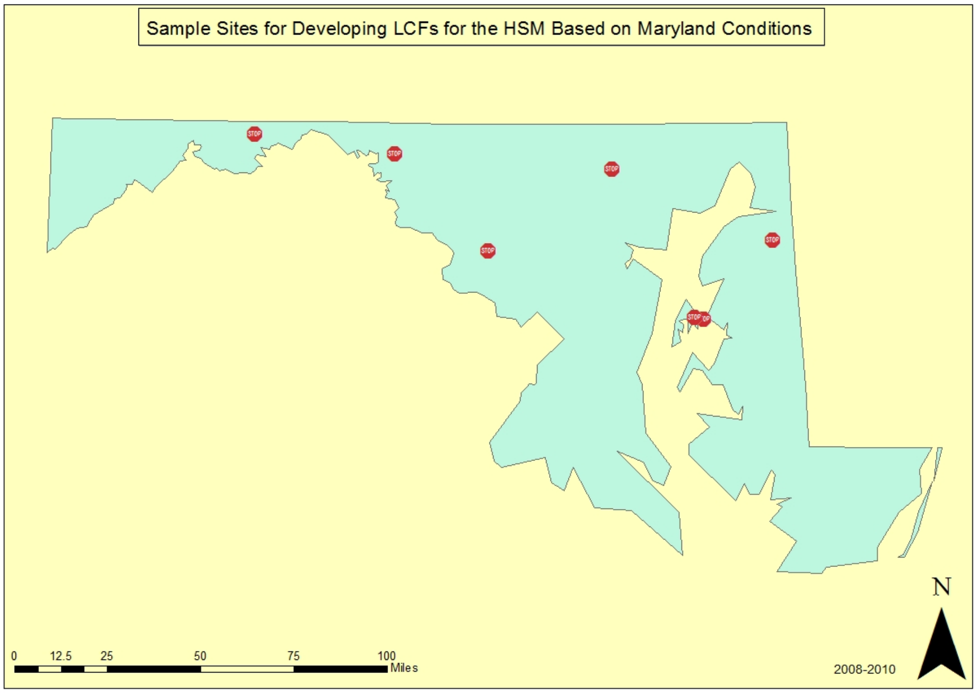

Figure 63. Rural A2 Ramp Terminal; Stop-controlled (RA$_2$ST) – 7 sites

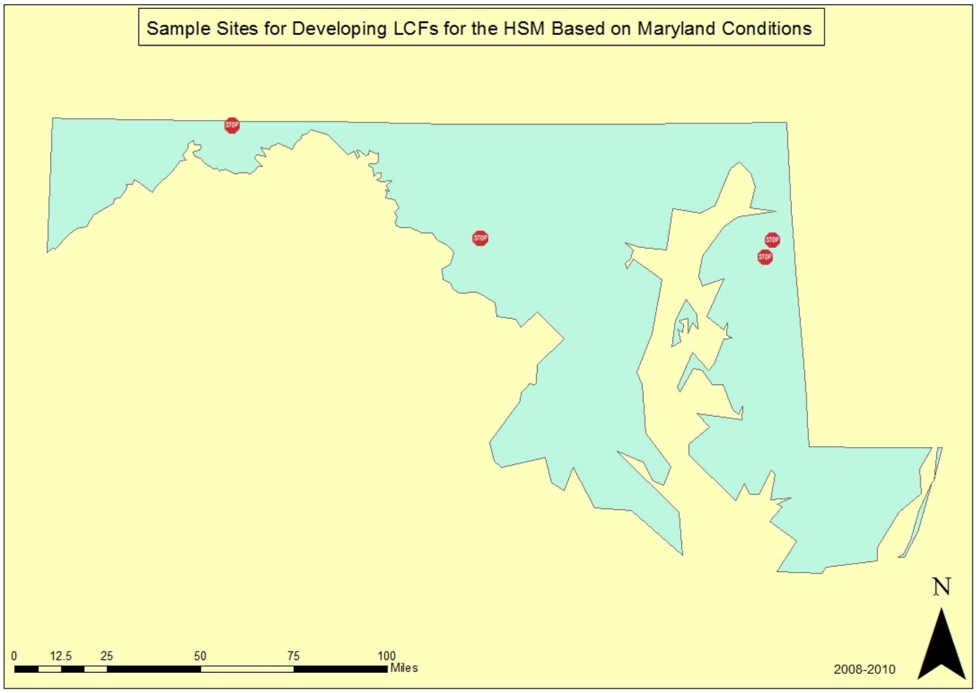

Figure 64. Rural B2 Ramp Terminal; Stop-controlled (RB_2ST) – 7 sites

Note: Some sites are close to each other causing the visible number of sites to be less than the actual number of sites.

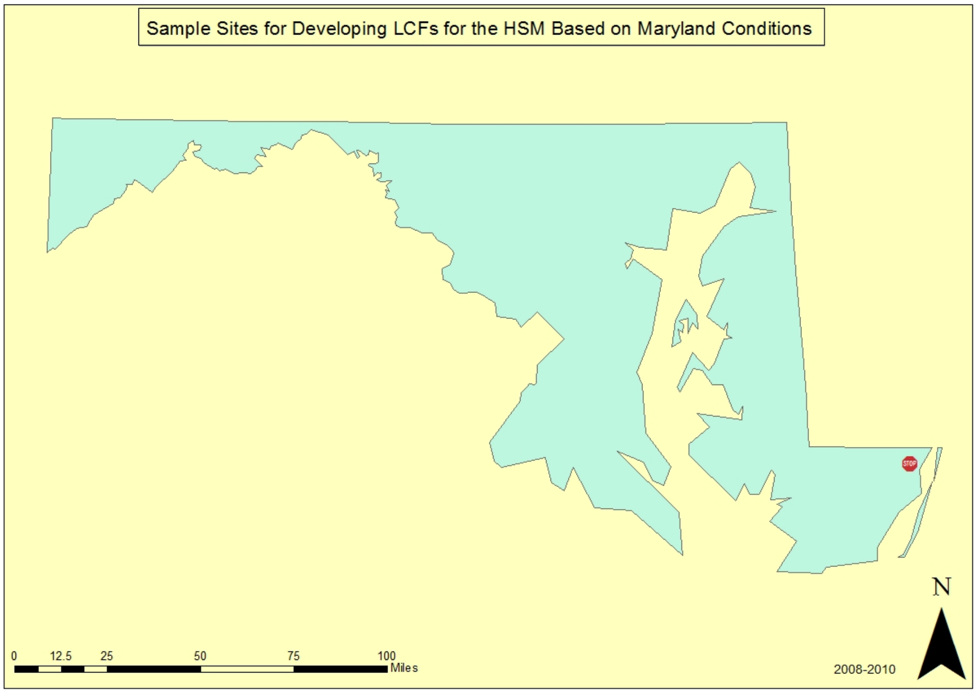

Figure 65. Rural D3en Ramp Terminal; Stop-controlled ($RD_{3en}ST$) – 1 site

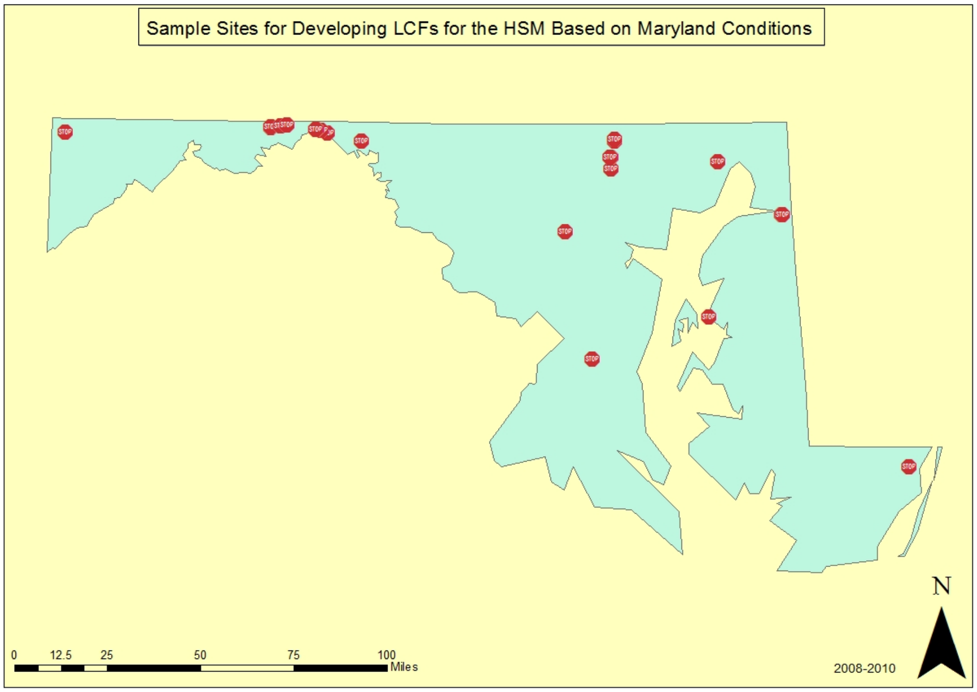

Figure 66. Rural D3ex Ramp Terminal; Stop-controlled ($RD_{3ex}ST$) – 22 sites

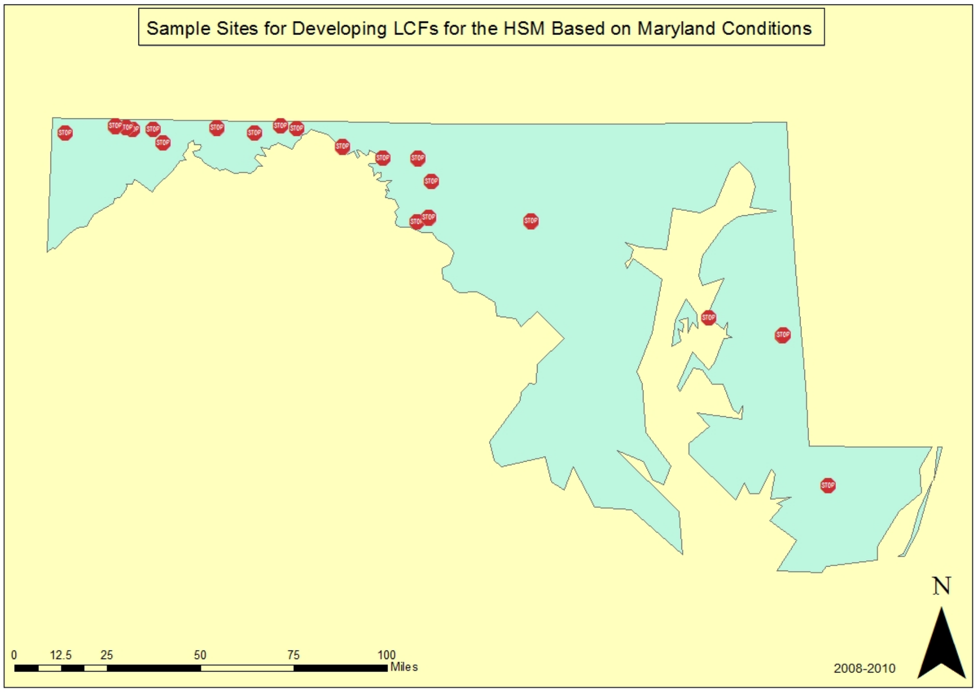

Figure 67. Rural D4 Ramp Terminal; Stop-controlled (RD_4ST) – 30 sites

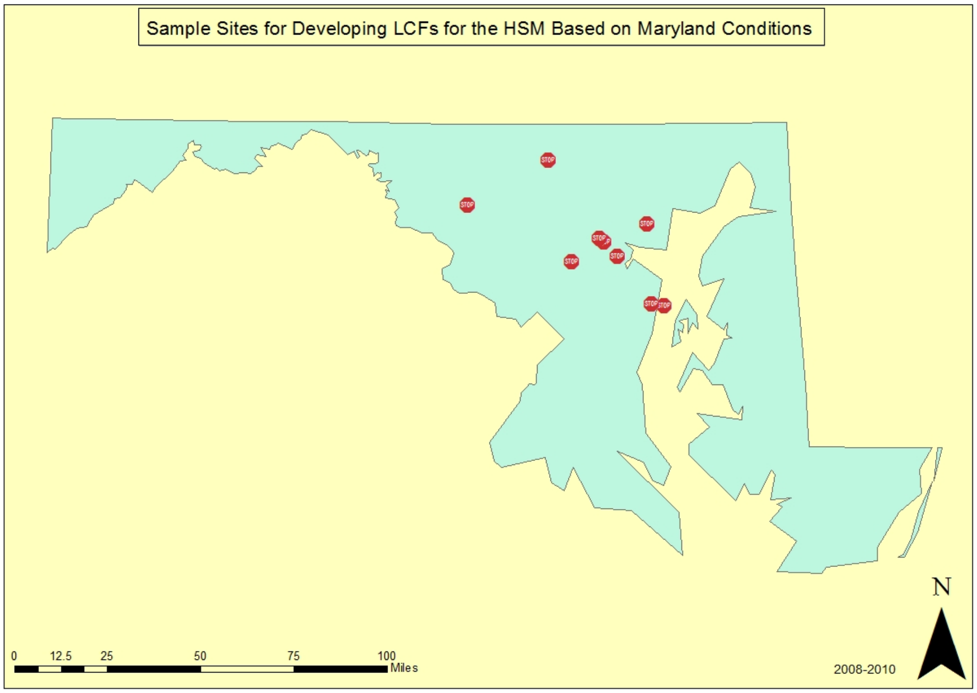

Figure 68. Urban A2 Ramp Terminal; Stop-controlled (UA_2ST) – 9 sites

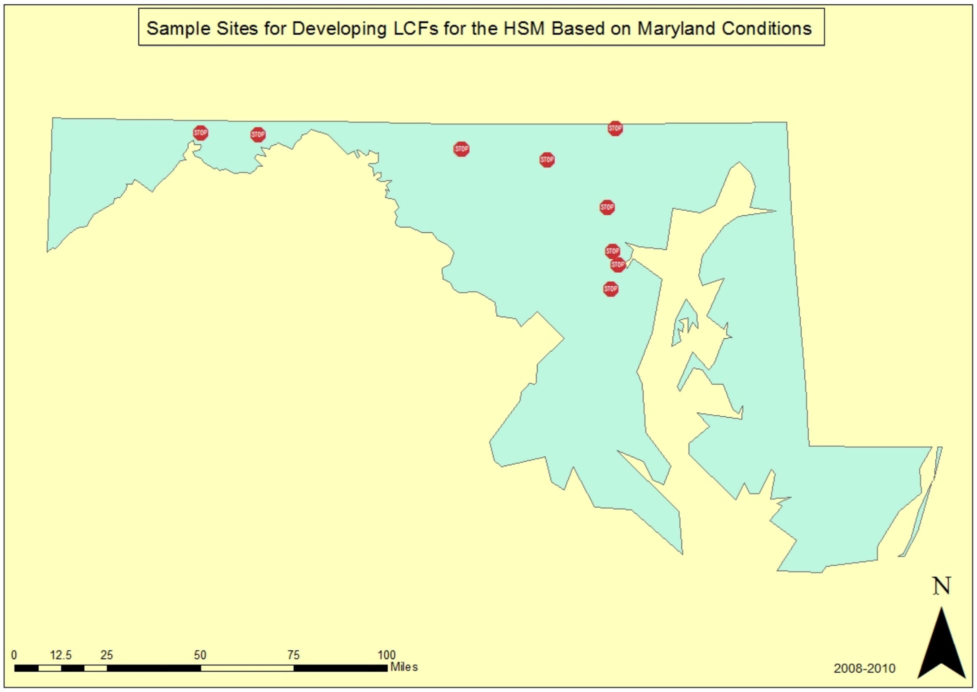

Figure 69. Urban B2 Ramp Terminal; Stop-controlled (UB_2ST) – 10 sites

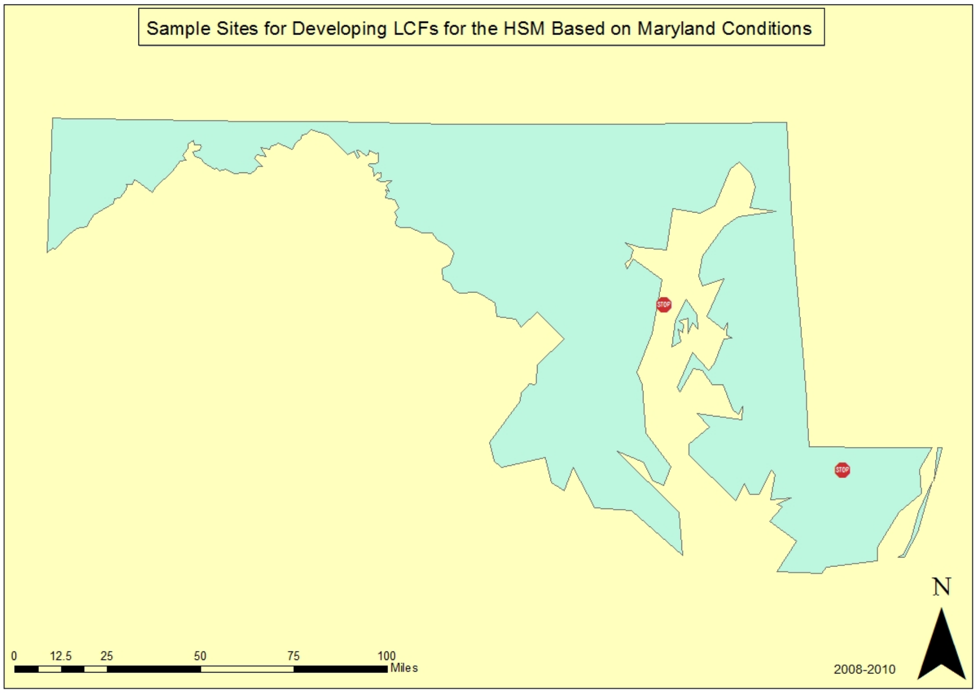

Figure 70. Urban D3en Ramp Terminal; Stop-controlled ($UD_{3en}ST$) – 2 sites

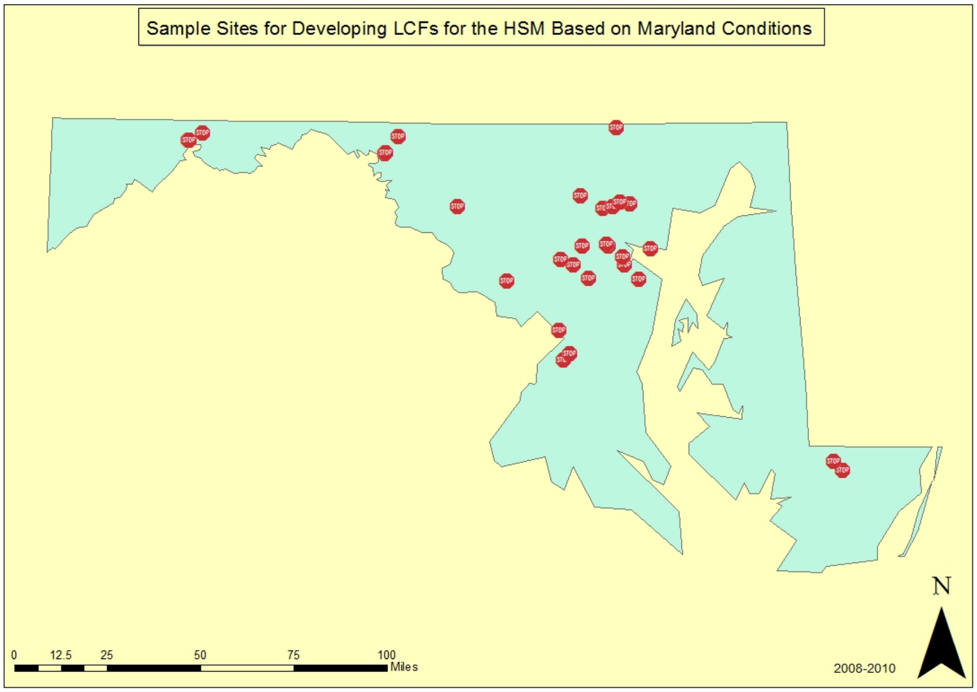

Figure 71. Urban D3ex Ramp Terminal; Stop-controlled ($UD_{3ex}ST$) – 29 sites

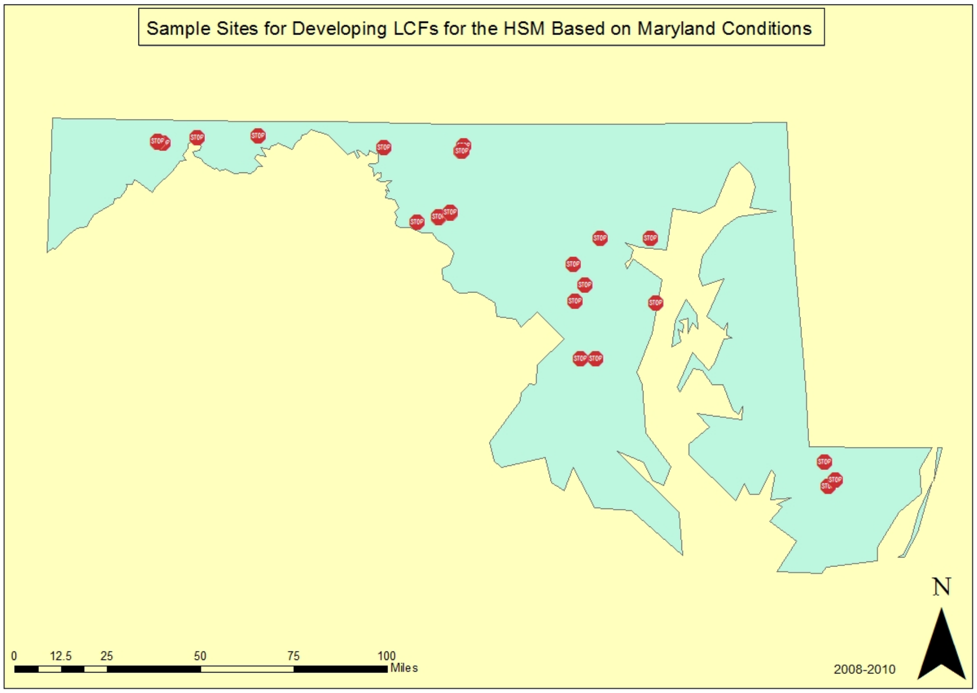

Figure 72. Urban D4 Ramp Terminal; Stop-controlled (UD_4ST) – 30 sites

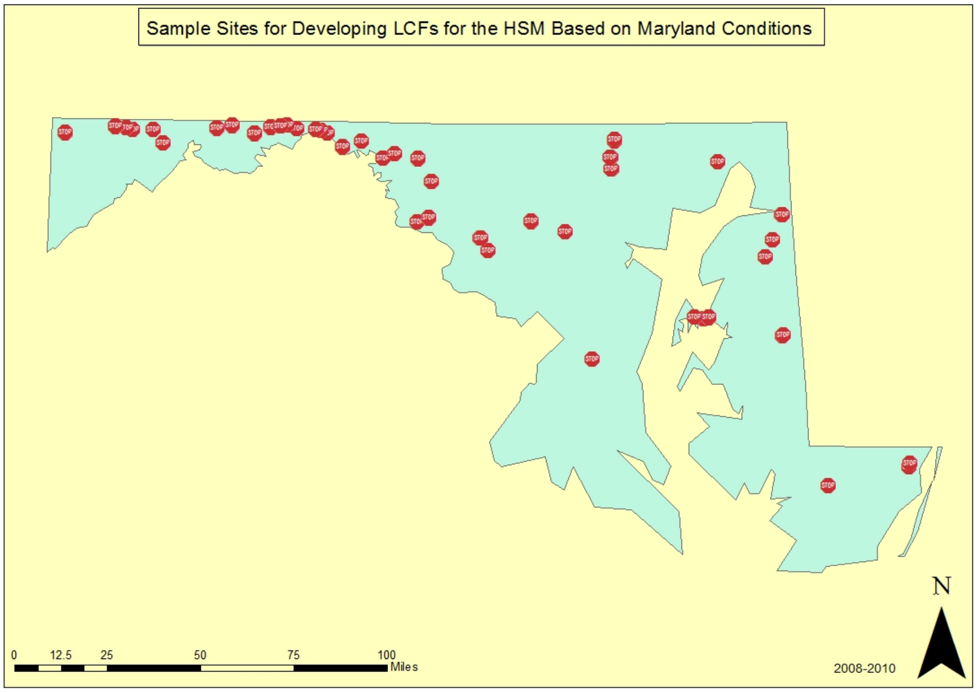

Figure 73. All Rural Stop-controlled Ramp Terminals – 67 sites

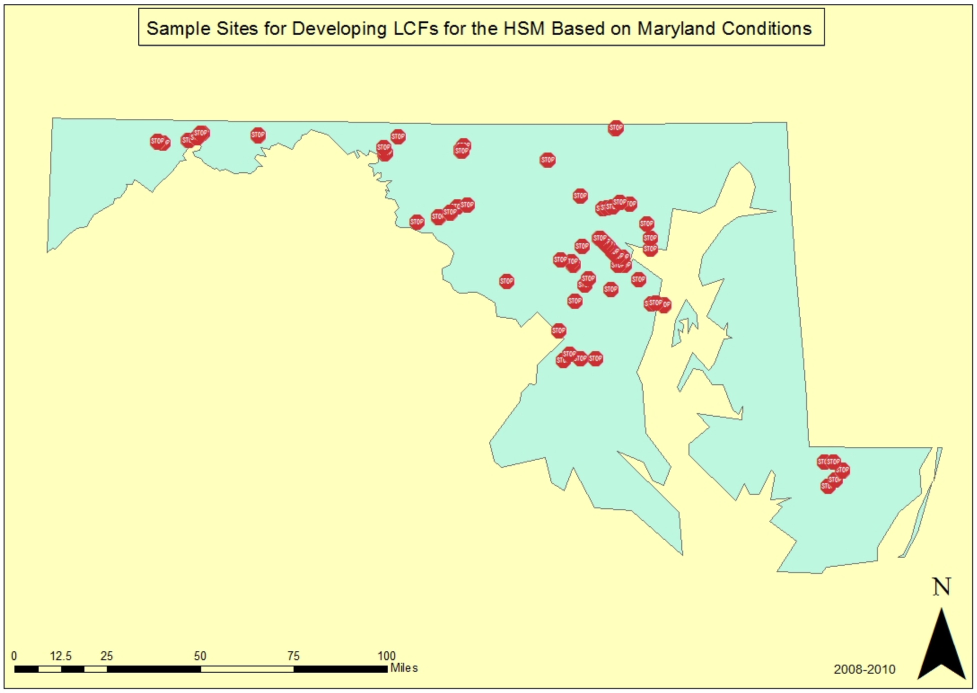

Figure 74. All Urban Stop-controlled Ramp Terminals – 80 sites

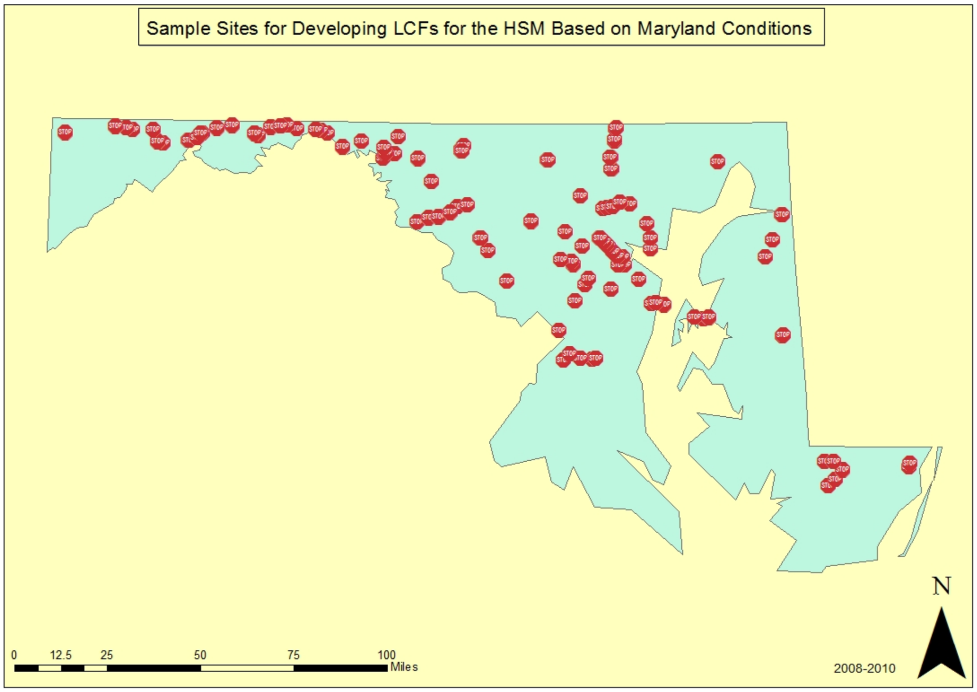

Figure 75. All Stop-controlled Ramp Terminals – 147 sites

Signalized Ramp Terminals

The final dataset included **172** signalized ramp terminals. The following figures depicted them. It should be noted that there was no sample of "Rural A4 Ramp Terminal; Signalized (RA_4SG)," "Rural B4 Ramp Terminal; Signalized (RB_4SG)," and "Rural D3en Ramp Terminal; Signalized ($RD_{3en}SG$)."

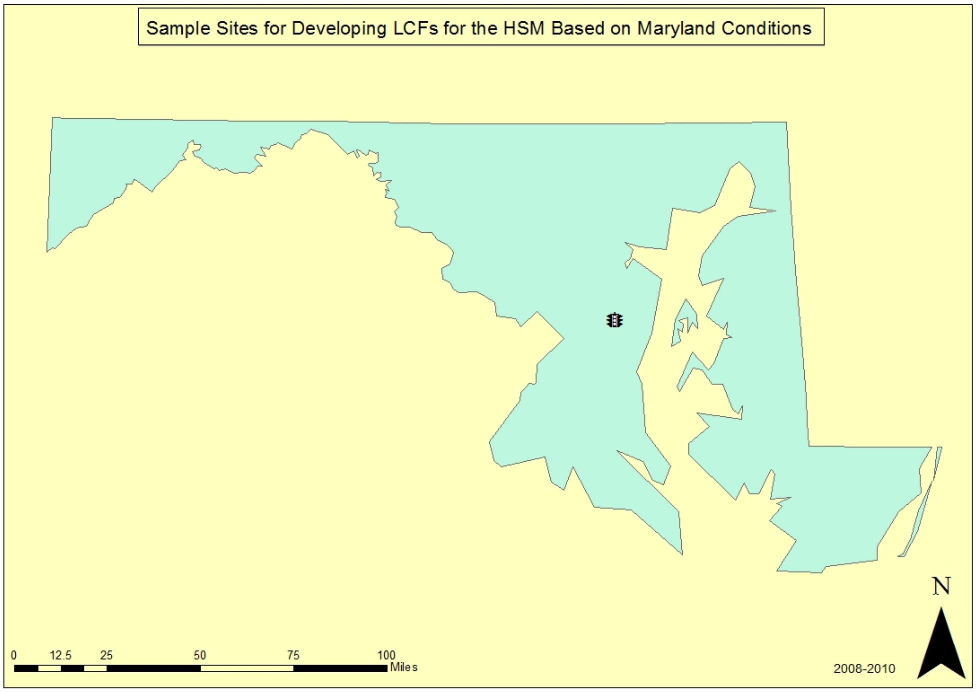

Figure 76. Rural A2 Ramp Terminal; Signalized (RA_2SG) – 2 sites

Note: Some sites are close to each other causing the visible number of sites to be less than the actual number of sites.

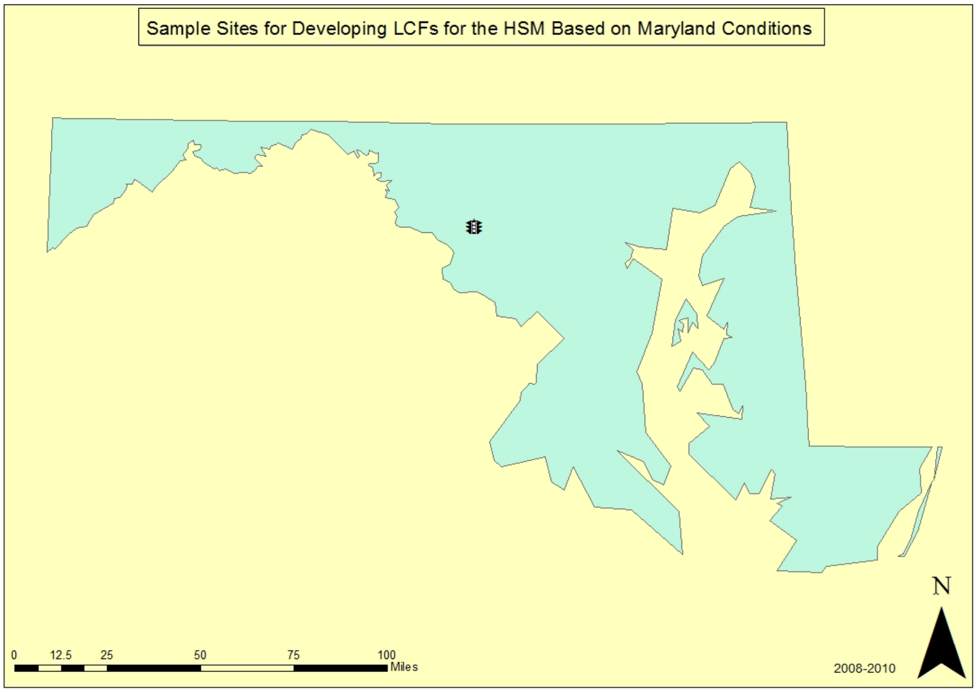

Figure 77. Rural B2 Ramp Terminal; Signalized (RB_2SG) – 1 site

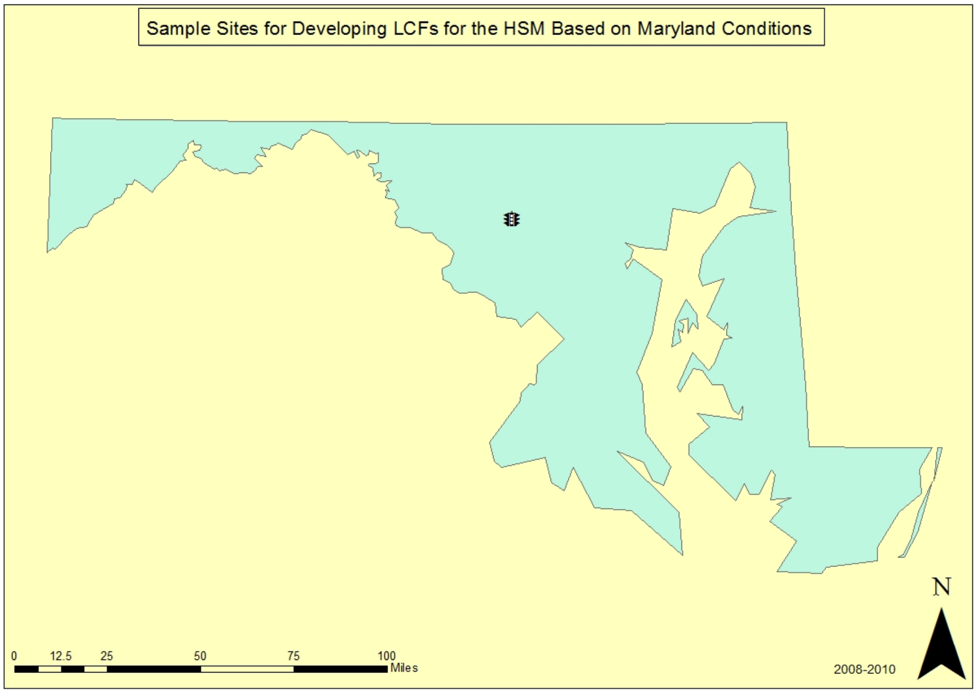

Figure 78. Rural D3ex Ramp Terminal; Signalized ($RD_{3ex}SG$) – 1 site

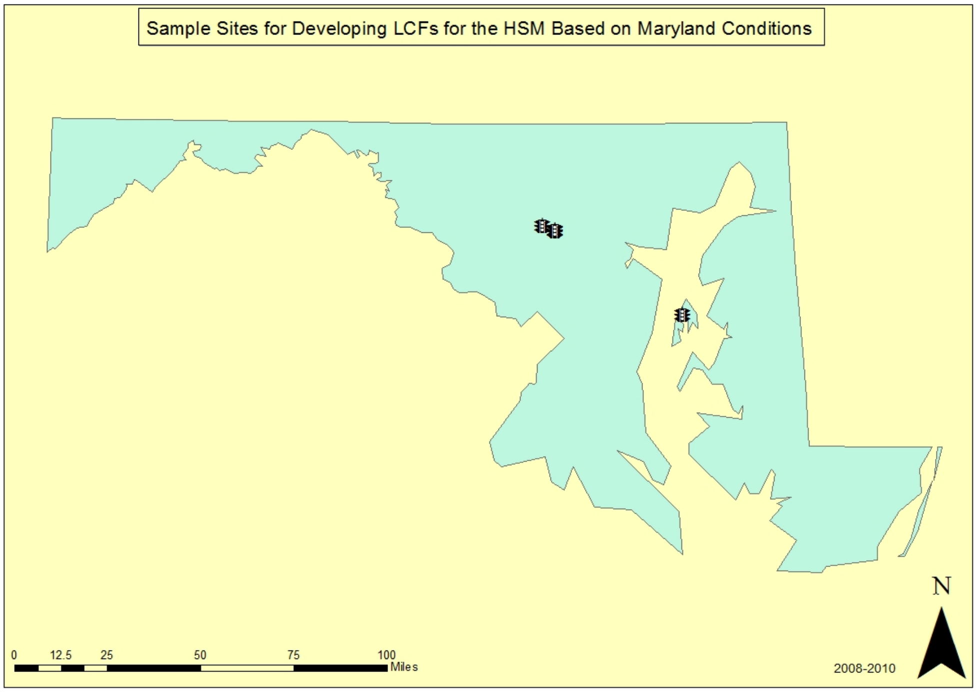

Figure 79. Rural D4 Ramp Terminal; Signalized (RD_4SG) – 4 sites

Note: Some sites are close to each other causing the visible number of sites to be less than the actual number of sites.

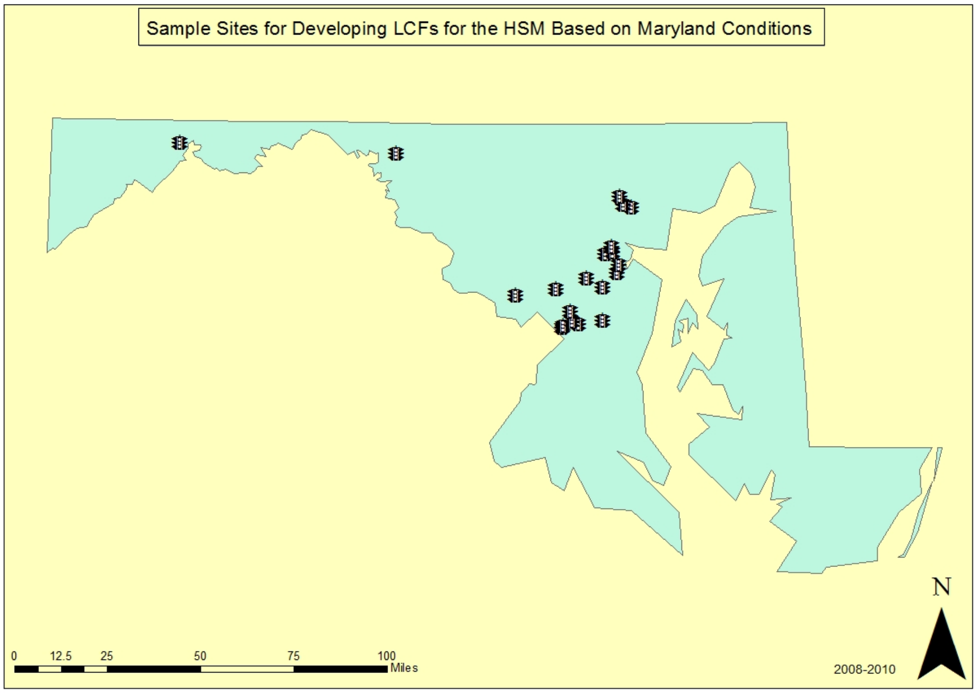

Figure 80. Urban A2 Ramp Terminal; Signalized (UA_2SG) – 20 sites

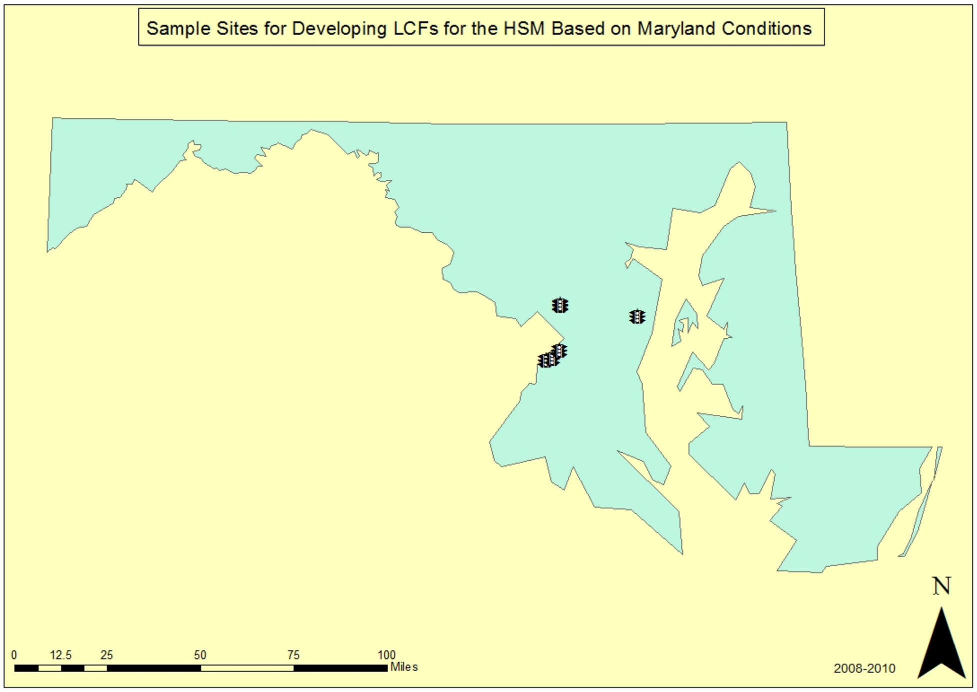

Figure 81. Urban A4 Ramp Terminal; Signalized (UA_4SG) – 6 sites

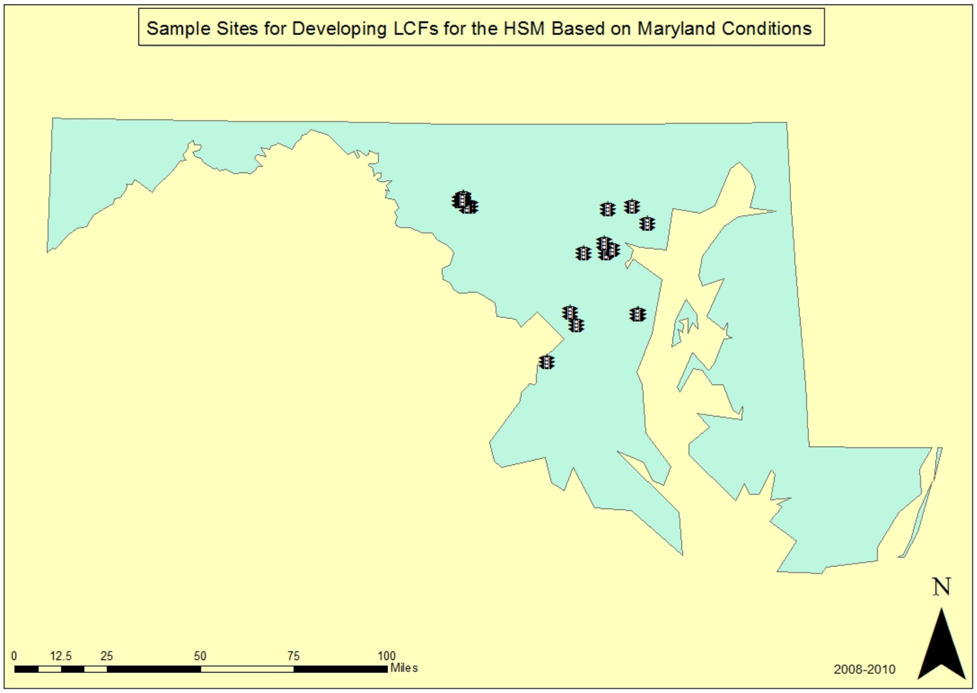

Figure 82. Urban B2 Ramp Terminal; Signalized (UB_2SG) – 19 sites

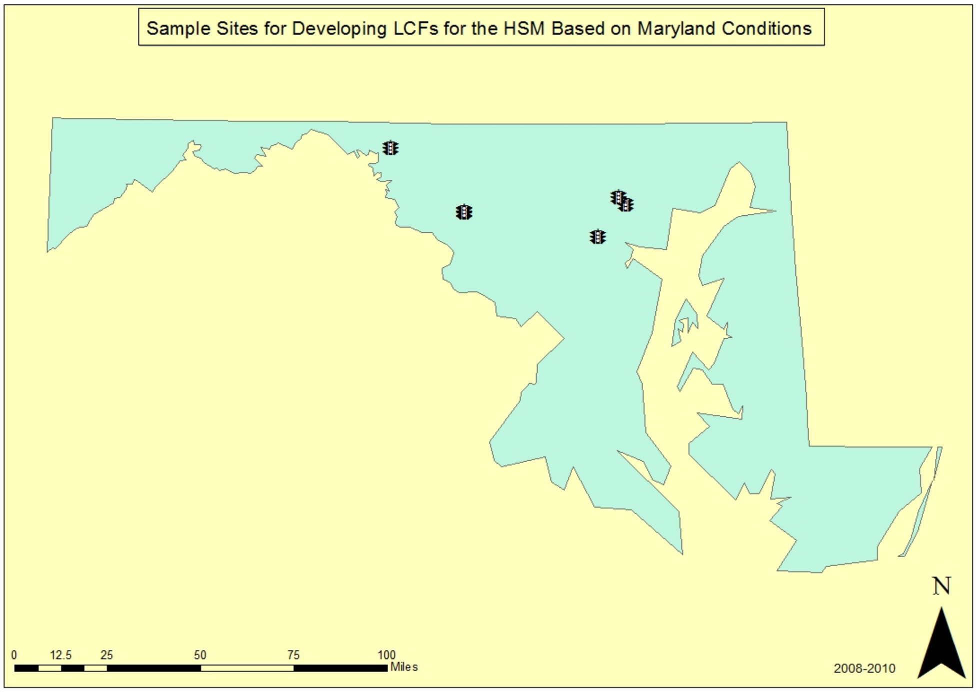

Figure 83. Urban B4 Ramp Terminal; Signalized (UB$_4$SG) – 6 sites
Note: Some sites are close to each other causing the visible number of sites to be less than the actual number of sites.

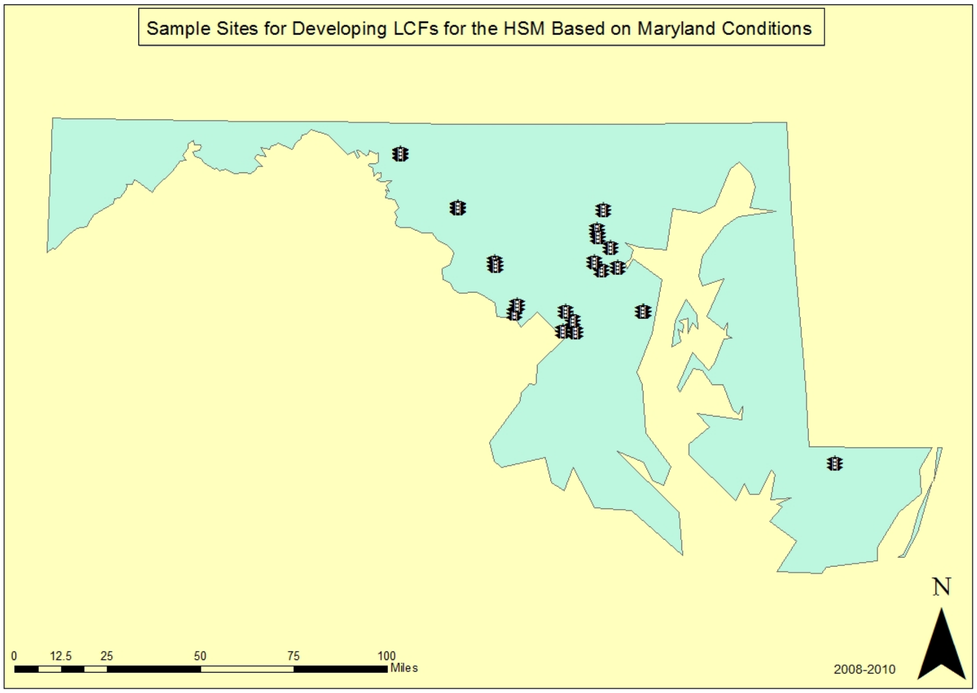

Figure 84. Urban D3en Ramp Terminal; Signalized (UD$_{3en}$SG) – 22 sites

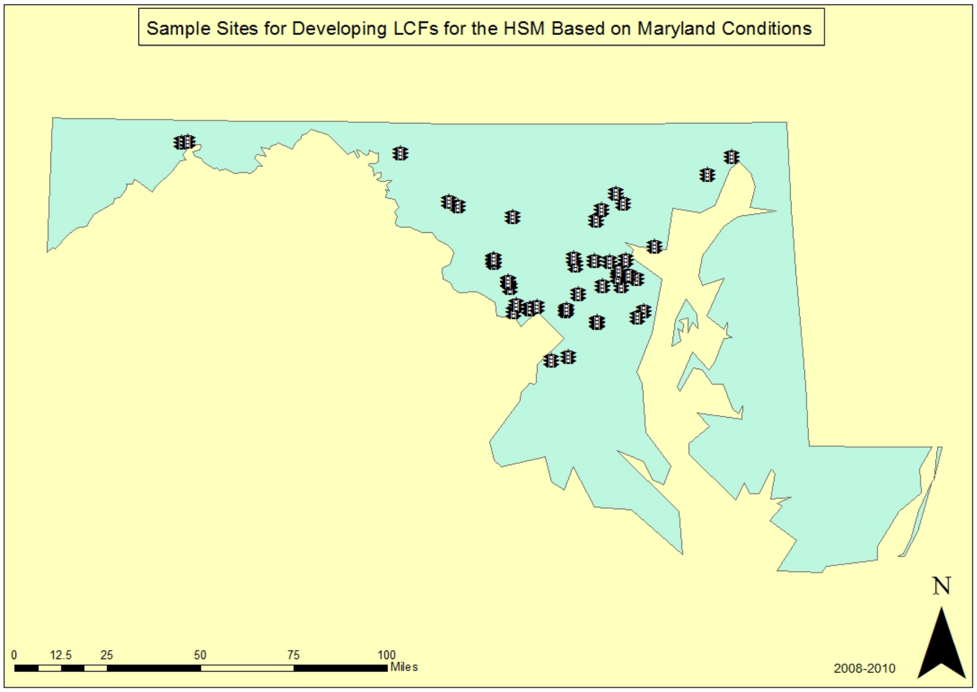

Figure 85. Urban D3ex Ramp Terminal; Signalized ($UD_{3ex}SG$) – 44 sites

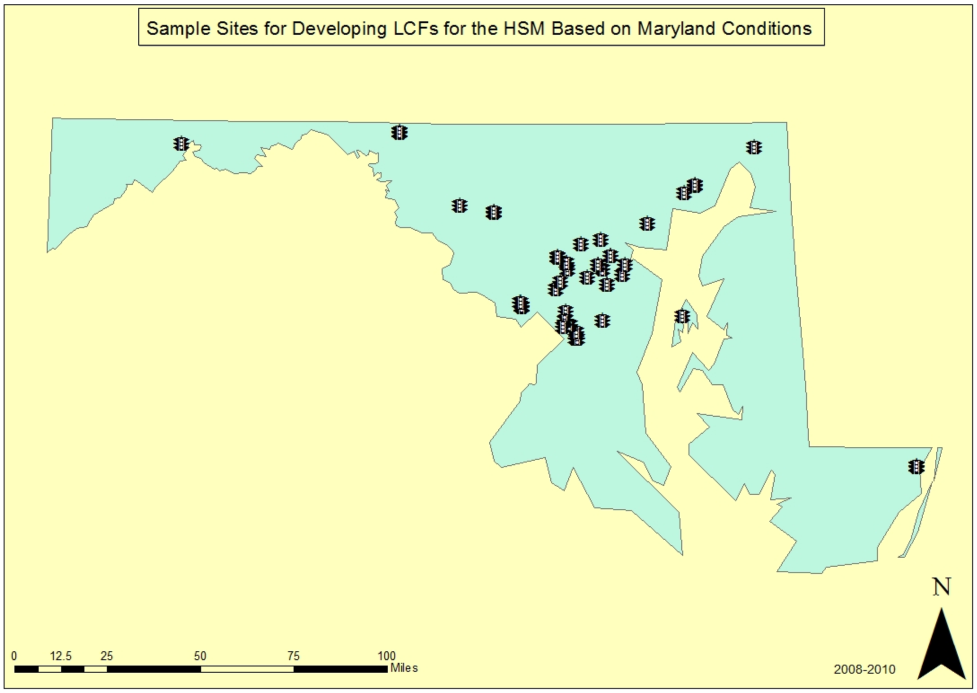

Figure 86. Urban D4 Ramp Terminal; Signalized (UD_4SG) – 47 sites

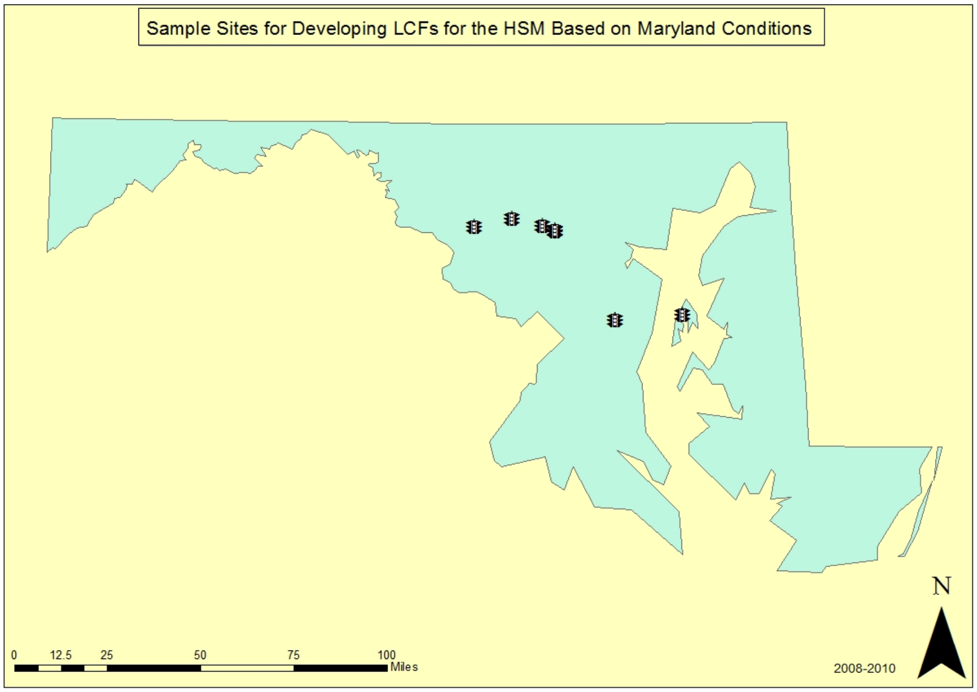

Figure 87. All Rural Signalized Ramp Terminals – 8 sites

Note: Some sites are close to each other causing the visible number of sites to be less than the actual number of sites.

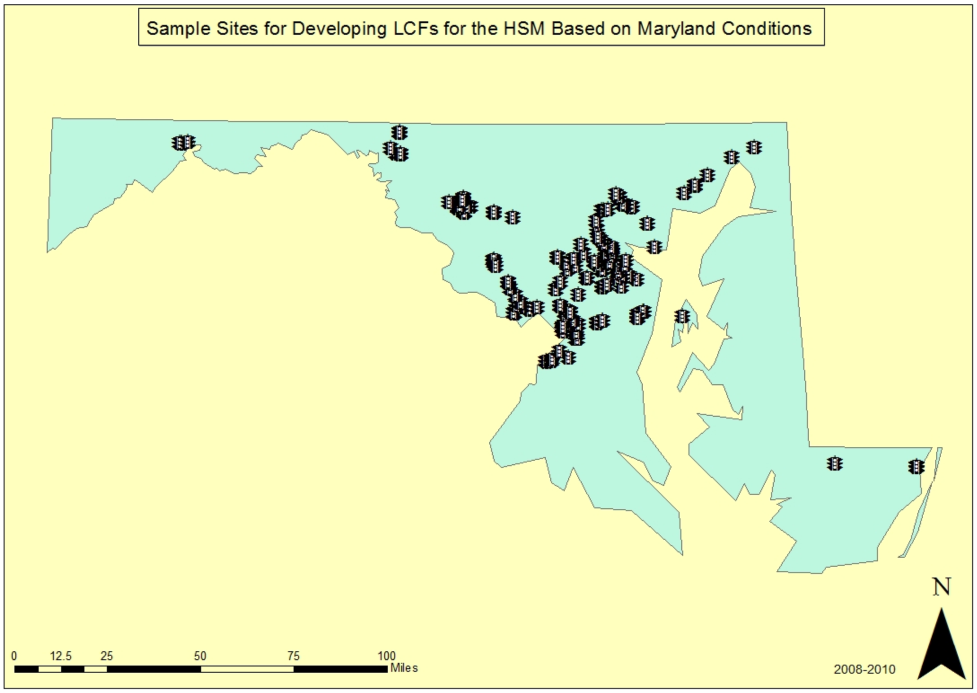

Figure 88. All Urban Signalized Ramp Terminals – 164 sites

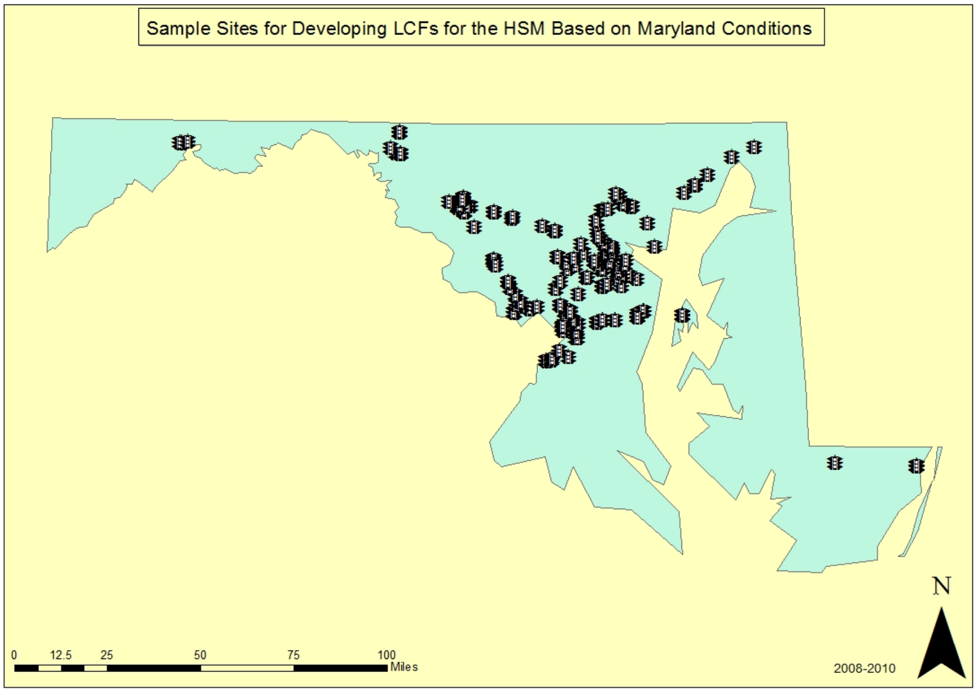

Figure 89. All Signalized Ramp Terminals – 172 sites

Combined Maps

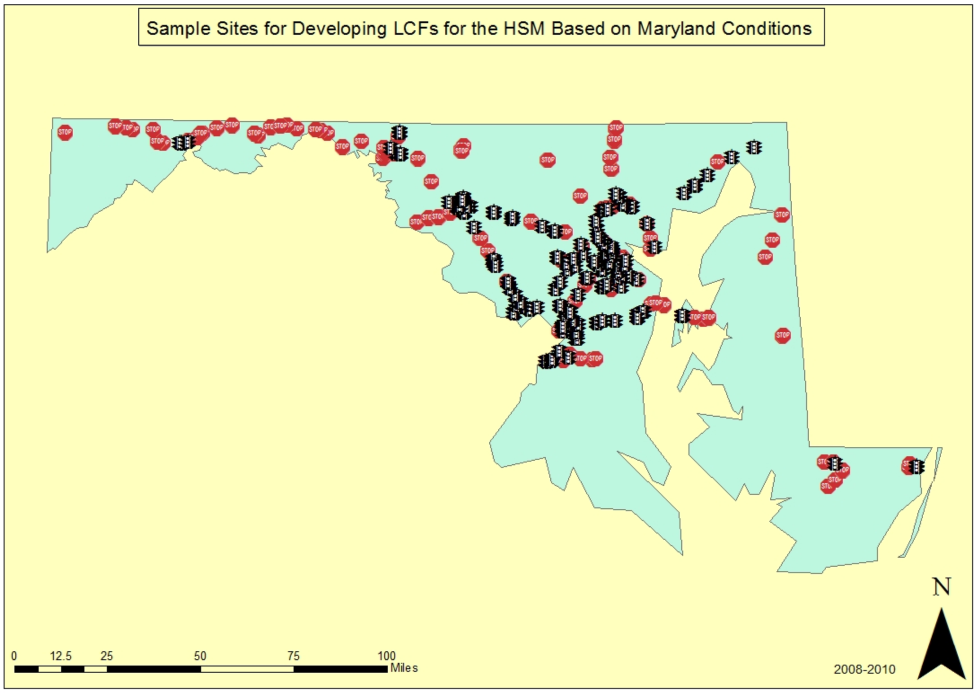

Figure 90. All Ramp Terminals – 319 sites

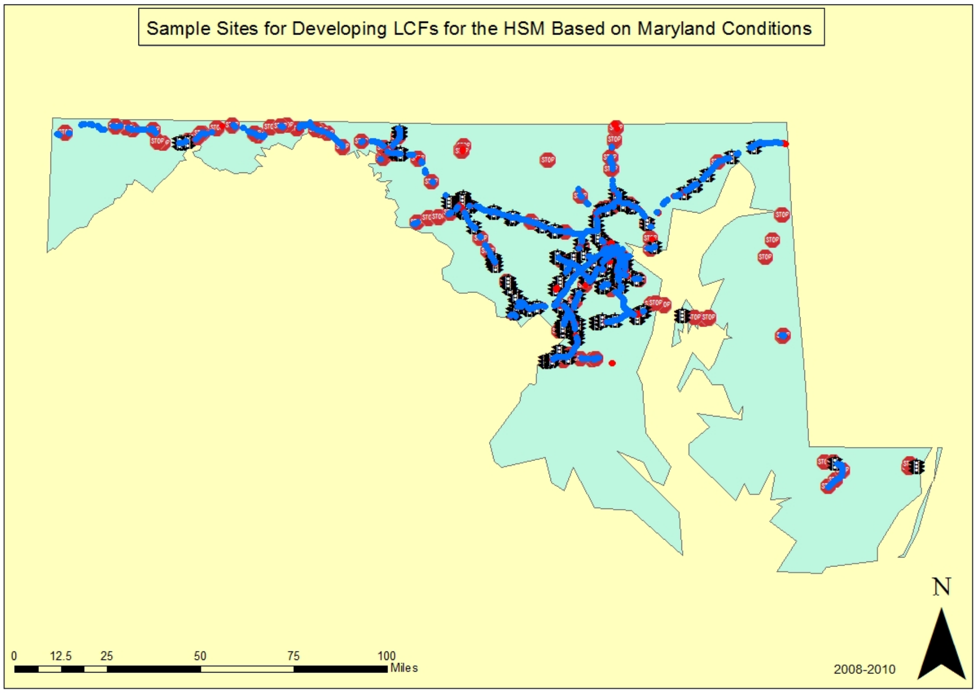

Figure 91. All Sampled Sites – 1,401 sites

APPENDIX F. MARYLAND RAMPS AND COLLECTOR-DISTRIBUTOR CRASH DATA SCREENING

Table 68 summarizes ramps and collector-distributor (C-D) roads (i.e., records with ID_PREFIX = RP in UNIVERSE database) in Maryland State during the study period (2008-10). Figure 93 also depicts Maryland ramps and C-D roads.

Table 68. Ramps and Collector-Distributor (C-D) Roads in Maryland (2008-2010)

Year	#	Total Length (Mile)
2008	8,593	579.923
2009	8,857	587.629
2010	9,430	591.901

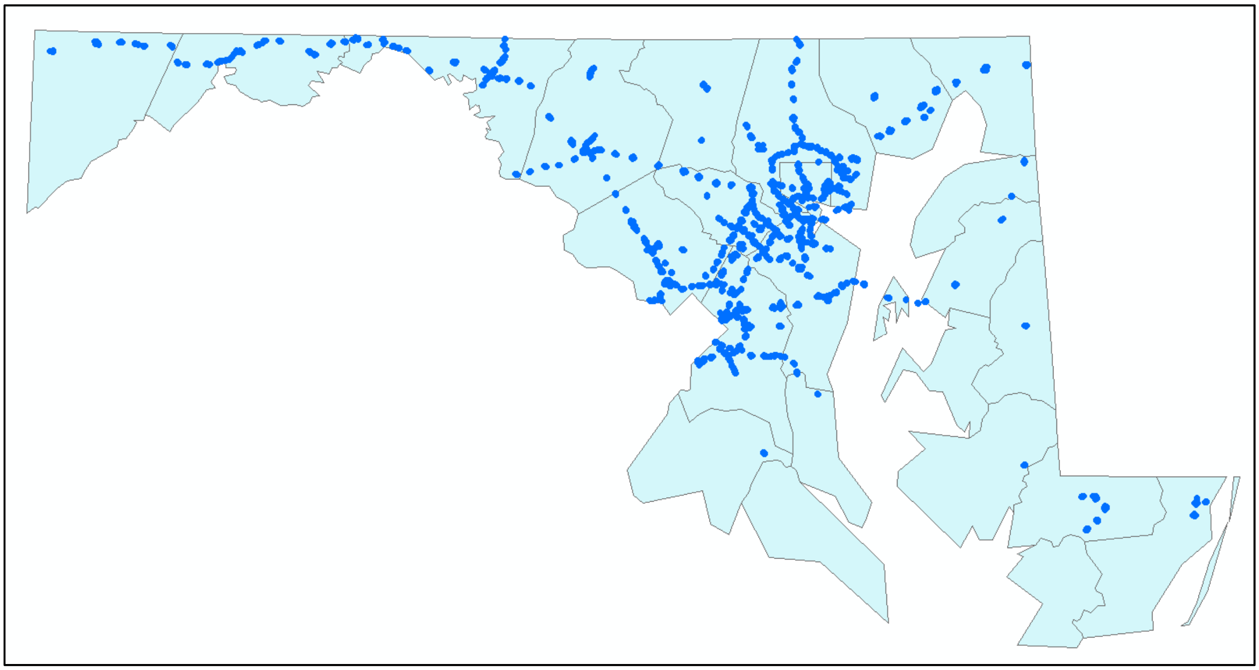

Figure 92. Maryland Ramps and Collector-Distributor (C-D) Roads (2008-2010)

However, there were only 222 crashes on ramps and C-D roads in Maryland during 2009-2010. After checking the original data, the study team realized there were no crashes in 2008 in the crash database. Moreover, there were not any geocoded crashes out of 222 ramps and C-D road crashes. This was one of the main reasons for excluding ramps and C-D roads from the scope of the study. The other reason was not meeting the minimum required HSM sampling recommendation. Table 69 shows the ramps and C-D roads crashes in Maryland by year. The majority of crashes happened in 2009 (56.3%). Table 70 shows ramp and C-D roads mileage and crashes by Maryland counties.

Table 69. Ramps and Collector-Distributor (C-D) Roads Crashes in Maryland (2009-2010)

Year	Frequency	%
2009	125	56.3
2010	97	43.7
Total	**222**	**100**

Table 70. Summary of Ramps and Collector-Distributor (C-D) Roads and Crashes in Maryland Counties (2009-2010)

County Name	Average Ramp & C-D Road Mileage (2009-10)	Average Ramp & C-D Mileage (2009-10) (%)	Crashes (2009-10)	Crashes (2009-10) (%)	% Mileage Share vs. % Crashes Share	2009-2010 Crashes Per Mile
Allegany	17.347	2.9%	3	1.4%	1.6%	0.173
Anne Arundel	87.105	14.8%	39	17.6%	-2.8%	0.448
Baltimore County	105.818	17.9%	28	12.6%	5.3%	0.265
Calvert	0.926	0.2%	0	0.0%	0.2%	0.000
Caroline	0.797	0.1%	1	0.5%	-0.3%	1.255
Carroll	3.26	0.6%	2	0.9%	-0.3%	0.613
Cecil	8.2625	1.4%	3	1.4%	0.0%	0.363
Charles	0.994	0.2%	0	0.0%	0.2%	0.000
Dorchester	1.47	0.2%	0	0.0%	0.2%	0.000
Frederick	29.109	4.9%	18	8.1%	-3.2%	0.618
Garrett	10.69	1.8%	0	0.0%	1.8%	0.000
Harford	16.55	2.8%	3	1.4%	1.5%	0.181
Howard	62.147	10.5%	17	7.7%	2.9%	0.274
Kent	1.27	0.2%	0	0.0%	0.2%	0.000
Montgomery	51.3235	8.7%	23	10.4%	-1.7%	0.448
Prince George's	102.422	17.4%	60	27.0%	-9.7%	0.586
Queen Anne's	4.45	0.8%	2	0.9%	-0.1%	0.449
St. Mary's	0	0.0%	0	0.0%	0.0%	0.000
Somerset	0	0.0%	0	0.0%	0.0%	0.000
Talbot	0	0.0%	0	0.0%	0.0%	0.000
Washington	32.393	5.5%	20	9.0%	-3.5%	0.617
Wicomico	9.925	1.7%	2	0.9%	0.8%	0.202
Worcester	5.884	1.0%	0	0.0%	1.0%	0.000
Baltimore City*	37.622	6.4%	1	0.5%	5.9%	0.027
Total	**589.765**	**100.0%**	**222**	**100.0%**	**0.0%**	**0.376**

Notes: Due to different data collection procedure “Baltimore City” crash data does not seem reliable.

Based on Table 70, Baltimore County is the top county in terms of mileage; 105.818 miles (17.9% of state ramps and C-D roads) followed by Prince George’s County; 102.422 miles (17.4%) and Anne Arundel County; 87.105 miles (14.8%). There are three counties without ramps or C-D roads: St. Mary’s, Somerset, and Talbot. Figure 93 shows Maryland ramps and C-D roads mileage by county.

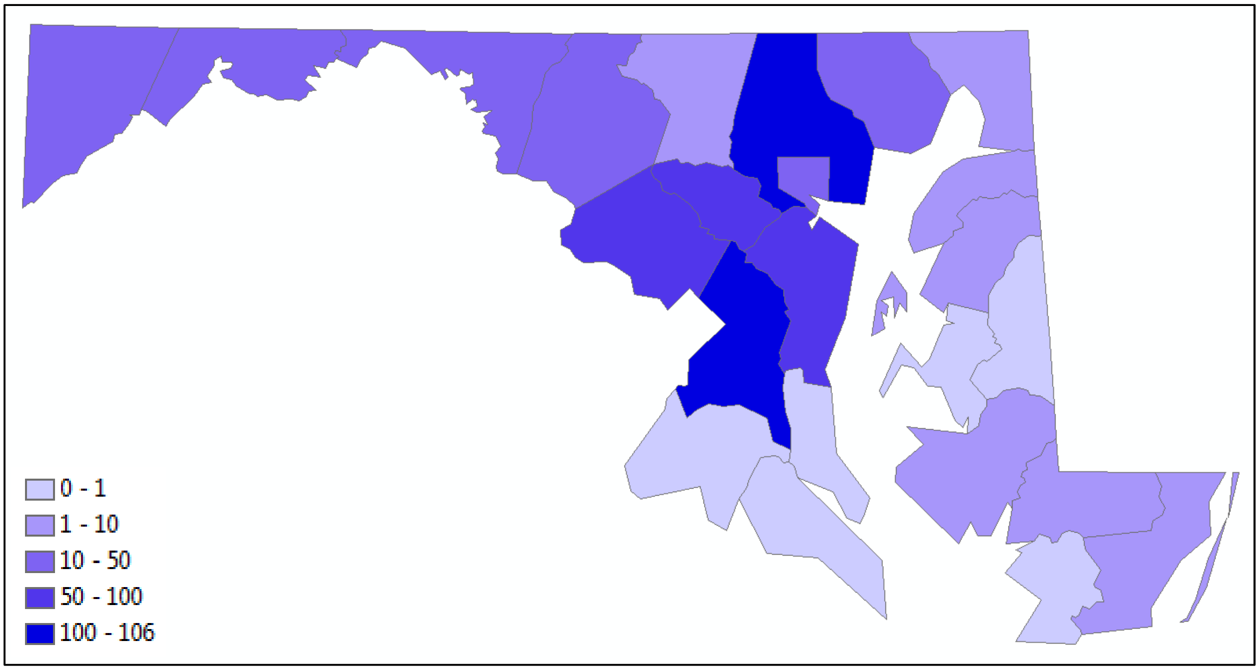

Figure 93. Maryland Ramps and Collector-Distributor (C-D) Roads Mileage by County (2009-2010)

Based on Table 70, Prince George's County had the highest number of crashes in 2009-2010 with 60 crashes (27% of ramps and C-D roads crashes) followed by Anne Arundel County, 39 crashes (17.6%) and Baltimore County, 28 crashes (12.6%). As a note these three counties also were the top three counties in terms of ramps and C-D roads mileage. There were three counties without ramps or C-D roads (i.e., St. Mary's, Somerset, and Talbot); six counties without any crashes during 2009-10; four counties with very low ramps and C-D roads mileage (less than 2 miles each of them: Calvert, Charles, Dorchester, and Kent); and two counties with some ramps and C-D roads mileage (Garret (10.69 miles) and Worcester (5.884 miles)). Figure 94 shows Maryland ramps and C-D roads crash counts by county; the same data in percentages is also depicted in Figure 95.

However, considering crash rate per mile, Caroline County has the highest crash rate, 1.255 crashes per mile (although there was only one crash in Caroline County and can be considered as a rare case), followed by Fredrick County (0.618 crashes per mile), and Washington County (0.617 crashes per mile). Allegany County has the lowest crash rate, 0.173 crashes per mile followed by Harford County (0.181 crashes per mile), Wicomico County (0.202 crashes per mile), and Baltimore County (0.265 crashes per mile). Figure 96 shows Maryland ramps and C-D roads crash rates per mile by county.

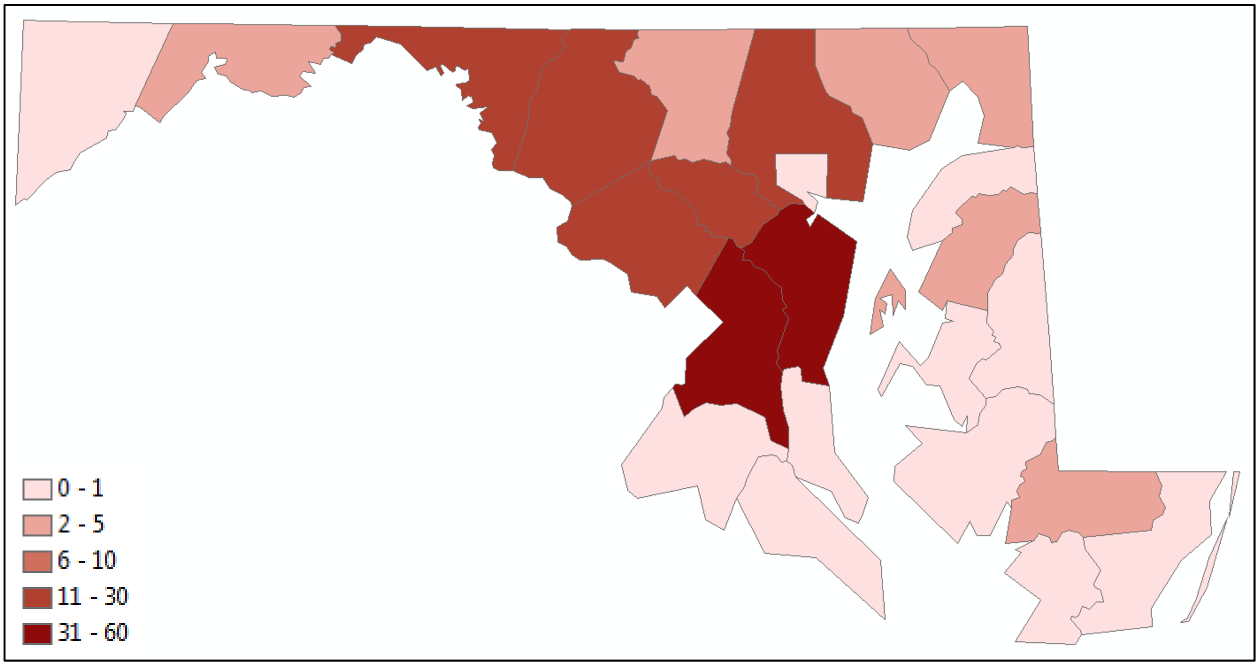

Figure 94. Maryland Ramps and Collector-Distributor (C-D) Roads Crashes (#) by County (2009-2010)

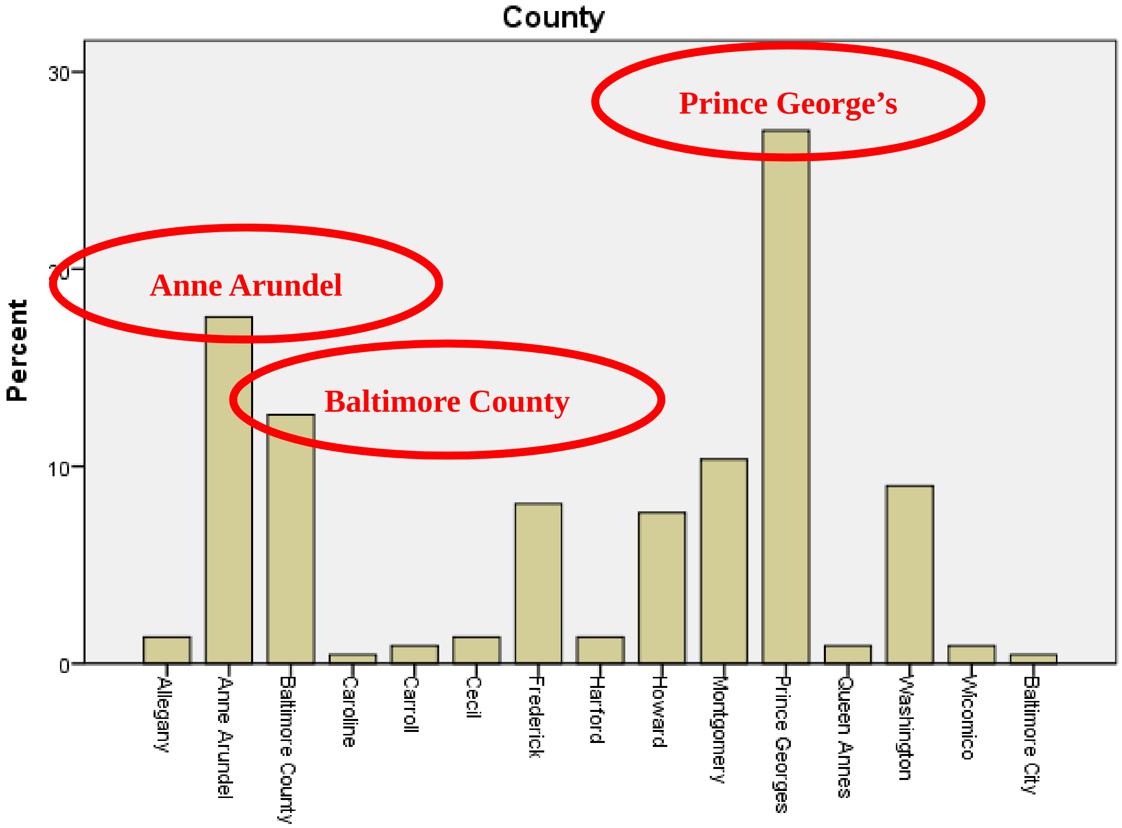

Figure 95. Maryland Ramps and Collector-Distributor (C-D) Roads Crashes (%) by County (2009-2010)

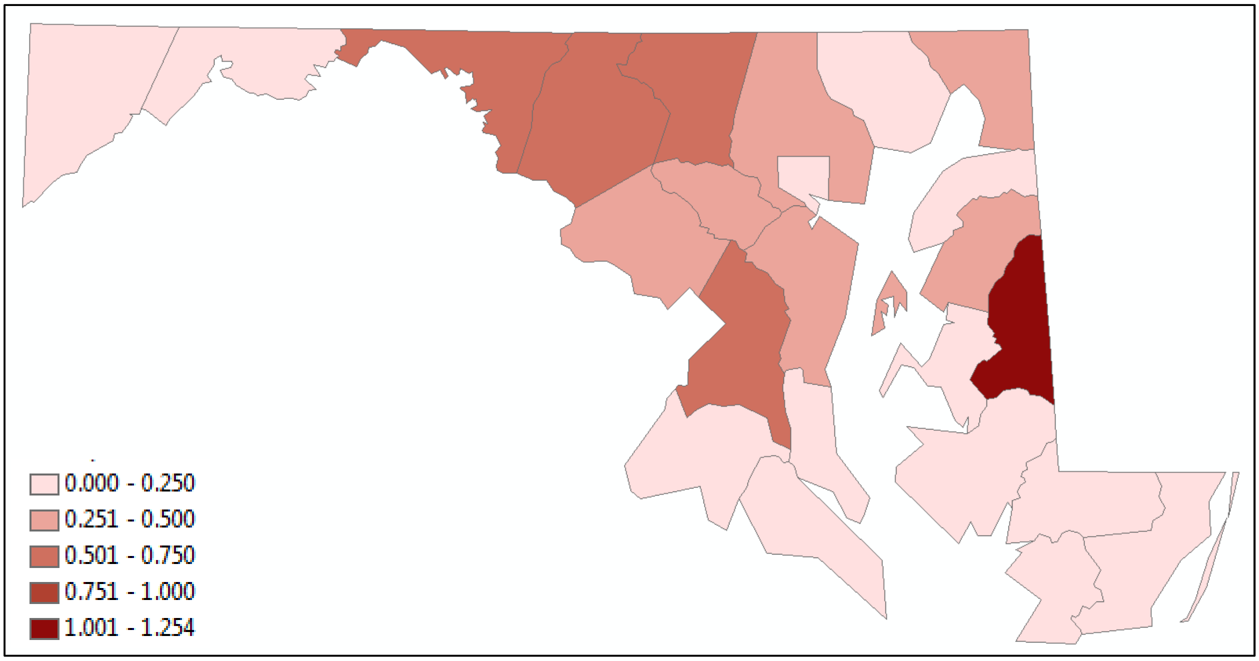

Figure 96. Maryland Ramps and Collector-Distributor (C-D) Roads Crash Rates by County (2009-2010)

Figure 97 summarizes ramps and C-D roads crashes by month. October was the dominant month with 29 crashes (13.1%) followed by July with 22 crashes (10%). Based on Figure 98, the majority of crashes happened during the daytime (7 AM – 10 PM), 170 crashes (76.6%). However, during the evening peak hours (especially at 4 PM) there were more crashes (Figure 99).

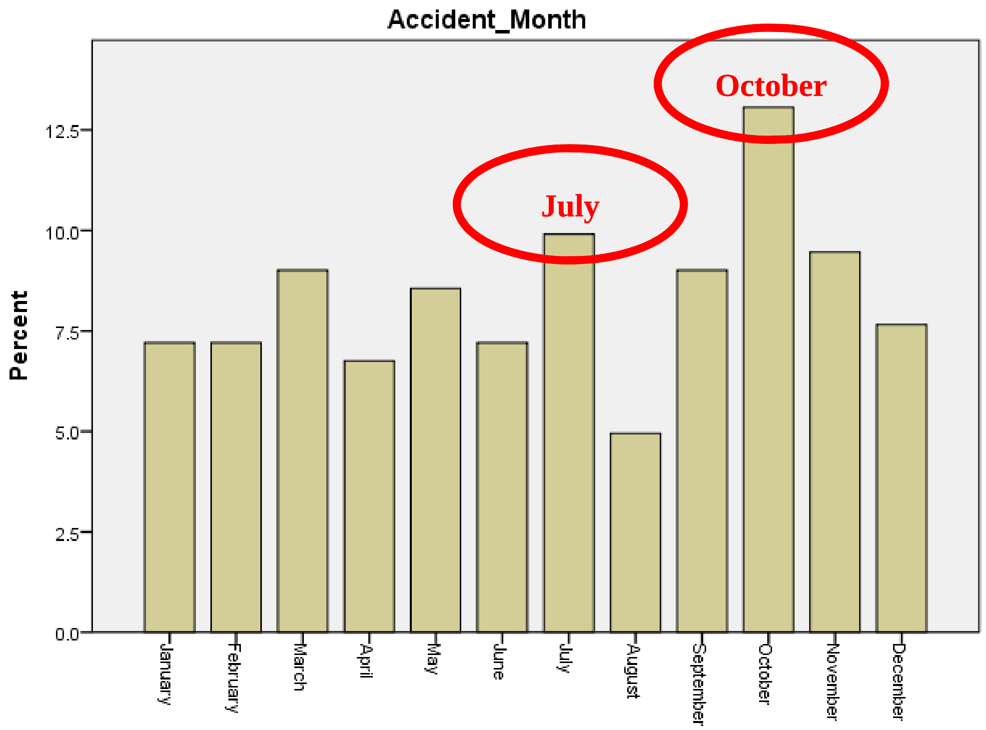

Figure 97. Ramps and Collector-Distributor (C-D) Roads Crashes by Month (2009-2010)

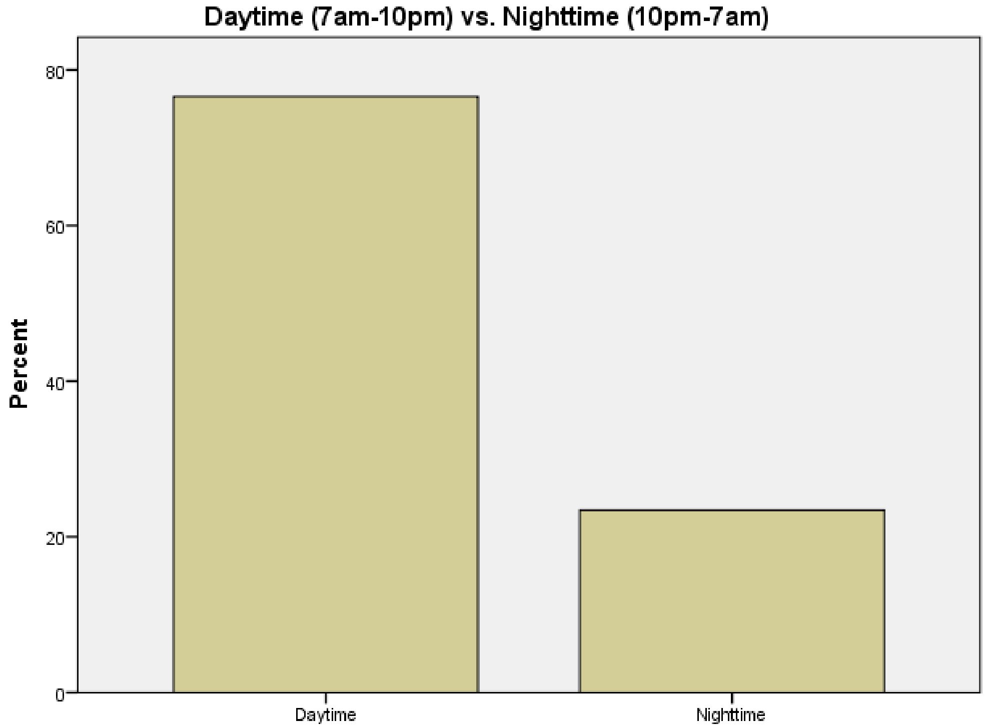

Figure 98. Ramps and Collector-Distributor (C-D) Roads Crashes by Time (2009-2010)

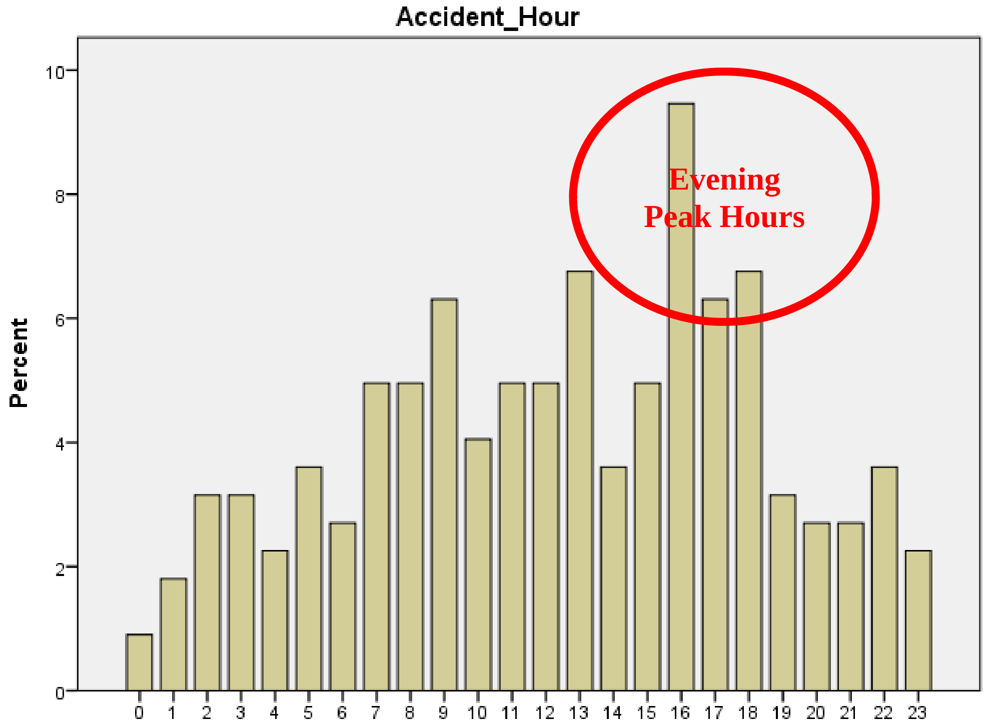

Figure 99. Ramps and Collector-Distributor (C-D) Roads Crashes by Hour (2009-2010)

Table 71 and Figure 100 summarize ramps and C-D roads crashes by route number. Ramps and C-D roads associated with I-95 had 56 crashes (25.2% of ramps and C-D roads crashes) followed by I-70 with 25 crashes (11.3%) and I-695 with 21 crashes (9.5%).

Table 71. Ramps and Collector-Distributor (C-D) Roads Crashes by Route Number (2009-2010)

Route Number	Frequency	%
0	5	2.3
3	1	0.5
13	1	0.5
15	12	5.4
28	1	0.5
29	7	3.2
32	4	1.8
43	1	0.5
50	10	4.5
68	3	1.4
70	25	11.3
81	5	2.3
83	2	0.9
95	56	25.2
97	12	5.4
105	1	0.5
150	1	0.5
175	1	0.5
195	3	1.4
216	1	0.5
270	15	6.8
295	10	4.5
340	1	0.5
495	4	1.8
500	1	0.5
595	8	3.6
695	21	9.5
895	2	0.9
965	1	0.5
1013	1	0.5
1015	1	0.5
1050	1	0.5
2004	1	0.5
2202	2	0.9
2402	1	0.5
Total	**222**	**100.0**

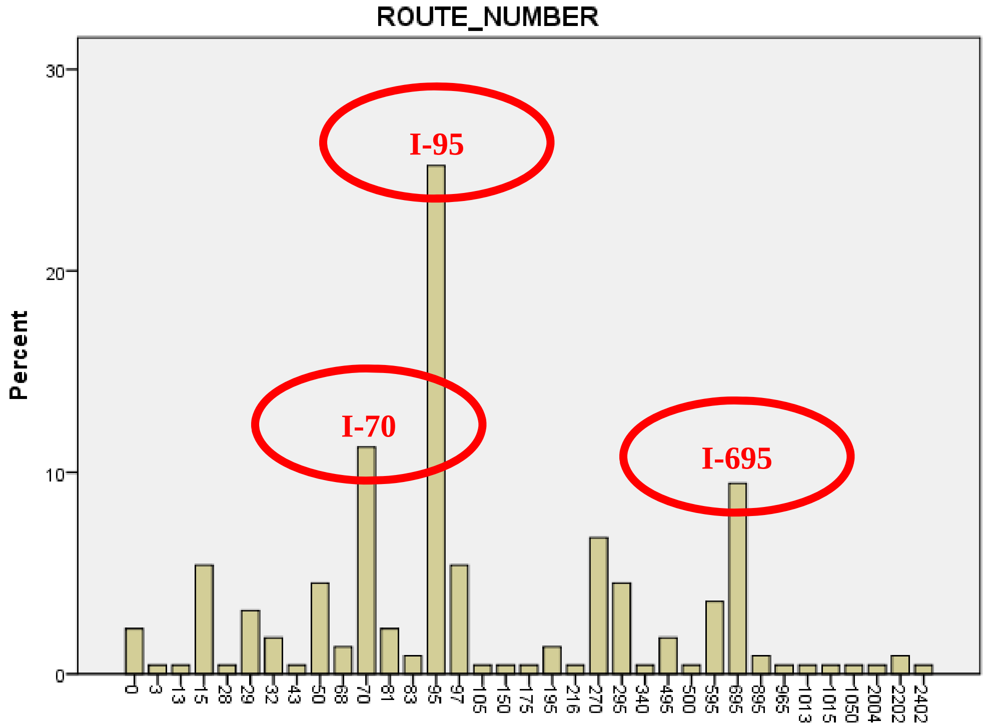

Figure 100. Ramps and Collector-Distributor (C-D) Roads Crashes by Route Number (2009-2010)

The proportions of crash severity levels of fatal (K), disabled (A), and injured (C) crashes on ramps are identical to those of all roads in the Maryland State (Table 72 and Figure 101); however, ramps and C-D roads face fewer possible injury crashes (11.3% vs. 16.4%) and more property-damage-only (PDO) crashes (71.6% vs. 65.9%).

There was only one fatal crash on a ramp on Route 3 in Anne Arundel County in 2009. The crash was a "Single-Vehicle" accident in which the driver who was under the influence of alcohol died hitting a tree.

Table 72. Comparison of Ramps and Collector-Distributor (C-D) Roads and All Roads by Crash Severity (2009-2010)

Crash Severity	**Ramps & C-D Roads**		**All Roads**	
	Frequency	**%**	**Frequency**	**%**
Not Injured (PDO)	159	71.6	123,118	65.9
Possible Injury (C)	25	11.3	30,742	16.4
Injured (B)	29	13.1	25,433	13.6
Disabled (A)	8	3.6	6,684	3.6
Fatal (K)	1	0.5	979	0.5
Total	**222**	**100.0**	**186956**	**100.0**

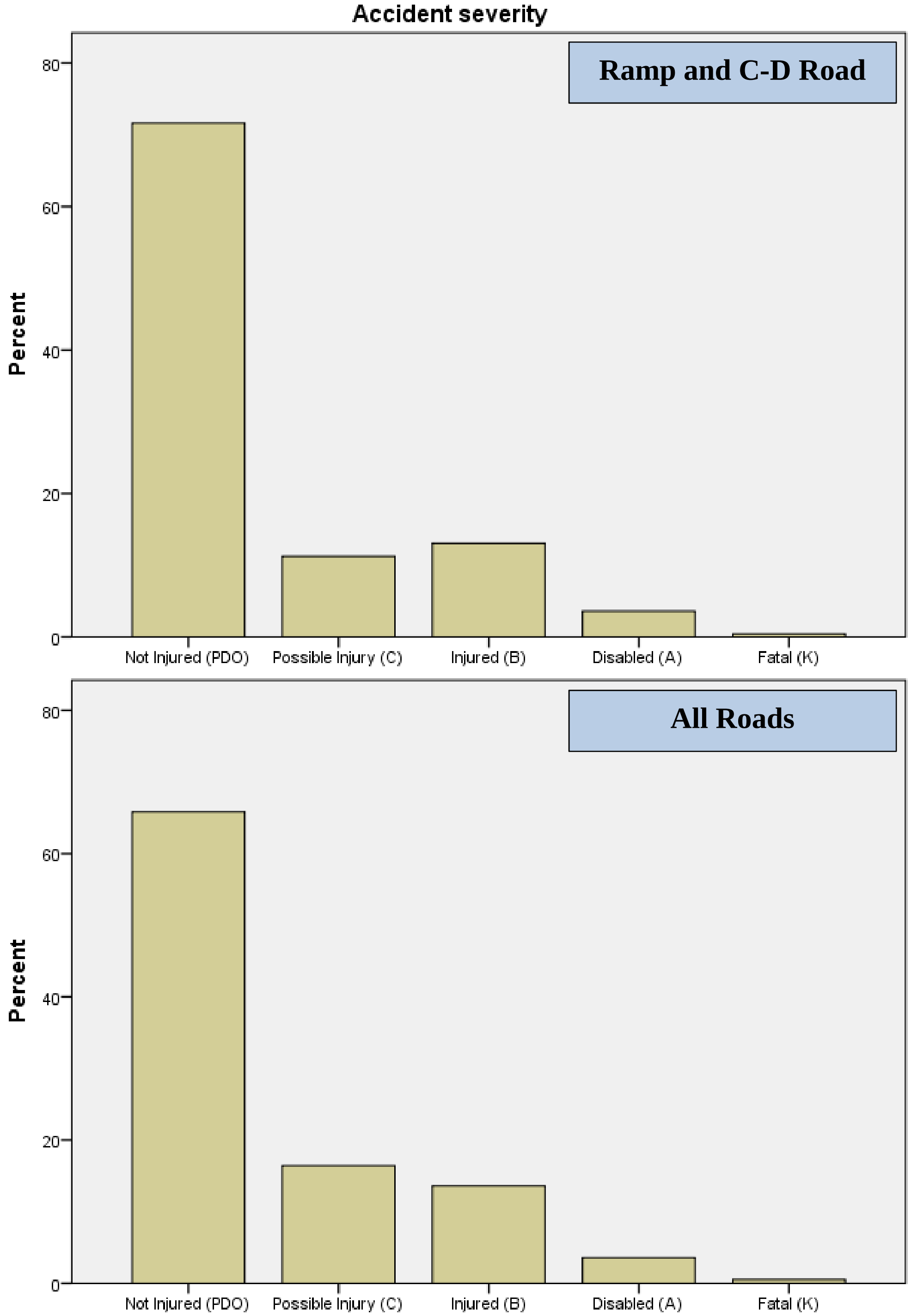

Figure 101. Comparison of Crash Severity of Ramps and Collector-Distributor (C-D) Roads and All Roads by Route Number (2009-2010)

Crash severity of ramps and C-D roads by year is presented in Table 73. Based on Table 74, during the nighttime (10 PM – 7 AM) there are more severe crashes.

Table 73. Ramps and Collector-Distributor (C-D) Roads Crashes by Crash Severity and Year (2009-2010)

Crash severity	2009		2010	
	Frequency	%	Frequency	%
Not Injured (PDO)	92	73.6	67	69.1
Possible Injury (C)	15	12.0	10	10.3
Injured (B)	12	9.6	17	17.5
Disabled (A)	5	4.0	3	3.1
Fatal (K)	1	0.8	0	0.0
Total	**125**	**100.0**	**97**	**100.0**

Table 74. Ramps and Collector-Distributor (C-D) Roads Crashes by Crash Severity and Time (2009-2010)

Crash severity	Daytime (7 AM - 10 PM)		Nighttime (10 PM - 7 AM)	
	Frequency	%	Frequency	%
Not Injured (PDO)	121	71.2	38	73.1
Possible Injury (C)	24	14.1	1	1.9
Injured (B)	20	11.8	9	17.3
Disabled (A)	4	2.4	4	7.7
Fatal (K)	1	0.6	0	0.0
Total	**170**	**100.0**	**52**	**100.0**

Based on Table 75 and Table 76, the majority of ramps and C-D roads crashes were not related to either alcohol or drugs (203 crashes; 91.4%). There were 16 UDI crashes (7.2%), and 3 crashes were associated with drugs (1.4%). There were not any crashes related to both alcohol and drugs. The severe types crashes (fatal (K), disabled (A), and injured (B)) increased when alcohol was involved (Table 76).

Table 75. Ramps and Collector-Distributor (C-D) Roads Crashes by Condition (2009-2010)

Condition	Frequency	%
Alcohol	16	7.2
Drugs	3	1.4
No alcohol or drugs	203	91.4
Total	**222**	**100.0**

Table 76. Ramps and Collector-Distributor (C-D) Roads Crashes by Crash Severity and Crash Condition (2009-2010)

Crash severity	Alcohol		Drugs		No alcohol or drugs	
	Frequency	%	Frequency	%	Frequency	%
Not Injured (PDO)	8	50.0	2	66.7	149	73.4
Possible Injury (C)	1	6.3	1	33.3	23	11.3
Injured (B)	5	31.3	0	0.0	24	11.8
Disabled (A)	1	6.3	0	0.0	7	3.4
Fatal (K)	1	6.3	0	0.0	0	0.0
Total	**16**	**100.0**	**3**	**100.0**	**203**	**100.0**

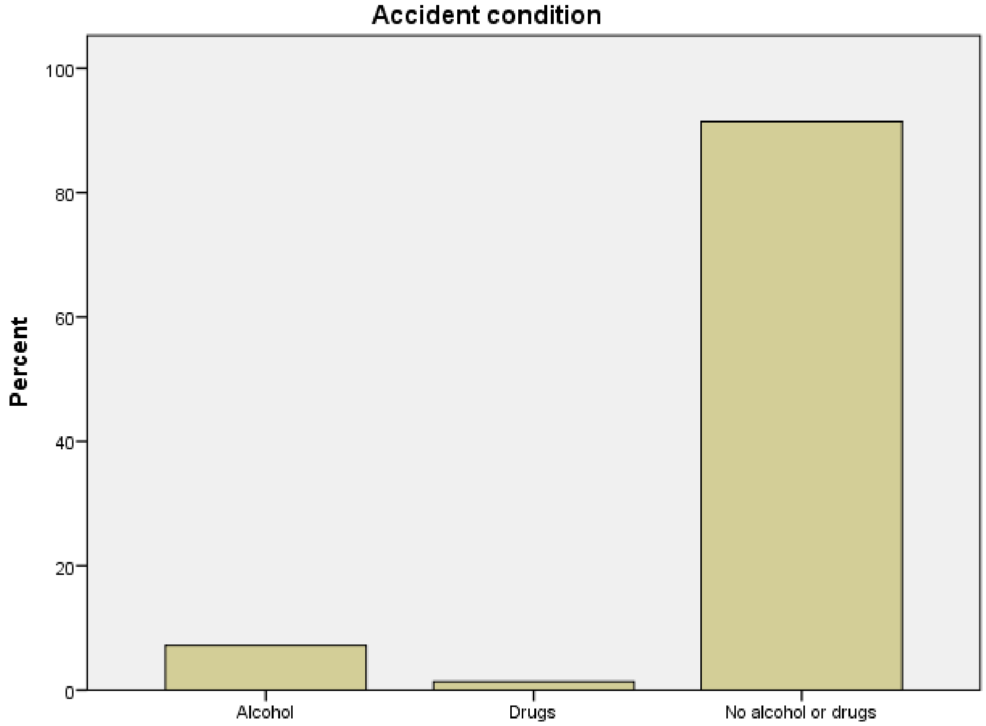

Figure 102. Ramps and Collector-Distributor (C-D) Roads Crashes by Condition (2009-2010)

Unlike all roads in Maryland, based on Figure 103, the majority of crashes on ramps and C-D roads were single-vehicle crashes (64% vs. 40%) and most of them were “Fixed-Object” (106 crashes; 47.7%). Based on Figure 105, among multiple-vehicle crashes on ramps, the dominant collision type was “Same Direction Rear-End” crashes (27% of ramps and C-D roads crashes).

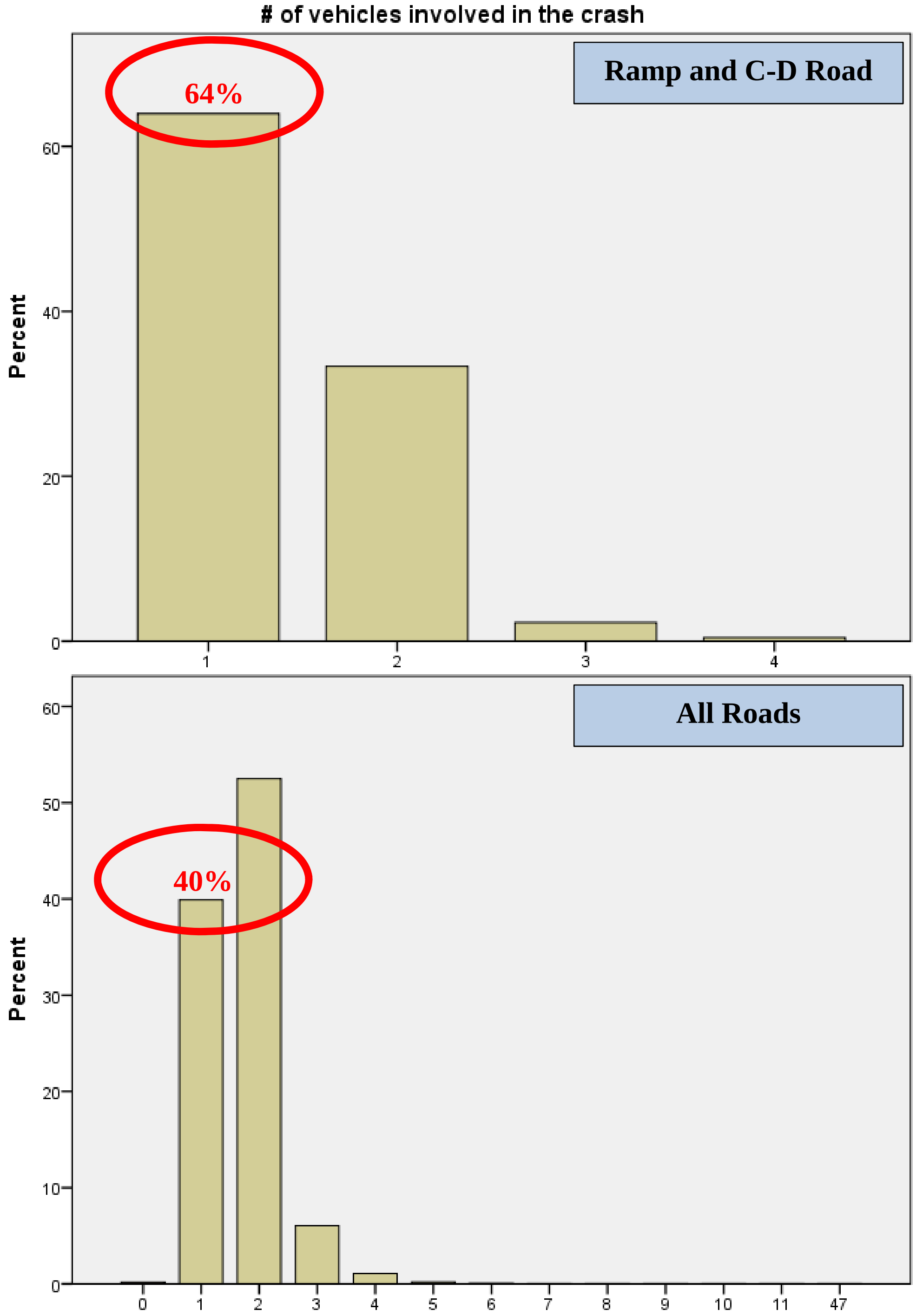

Figure 103. Comparison of Ramps and Collector-Distributor (C-D) Roads and All Roads by Number of Involved Vehicles at Crash Scene (2009-2010)

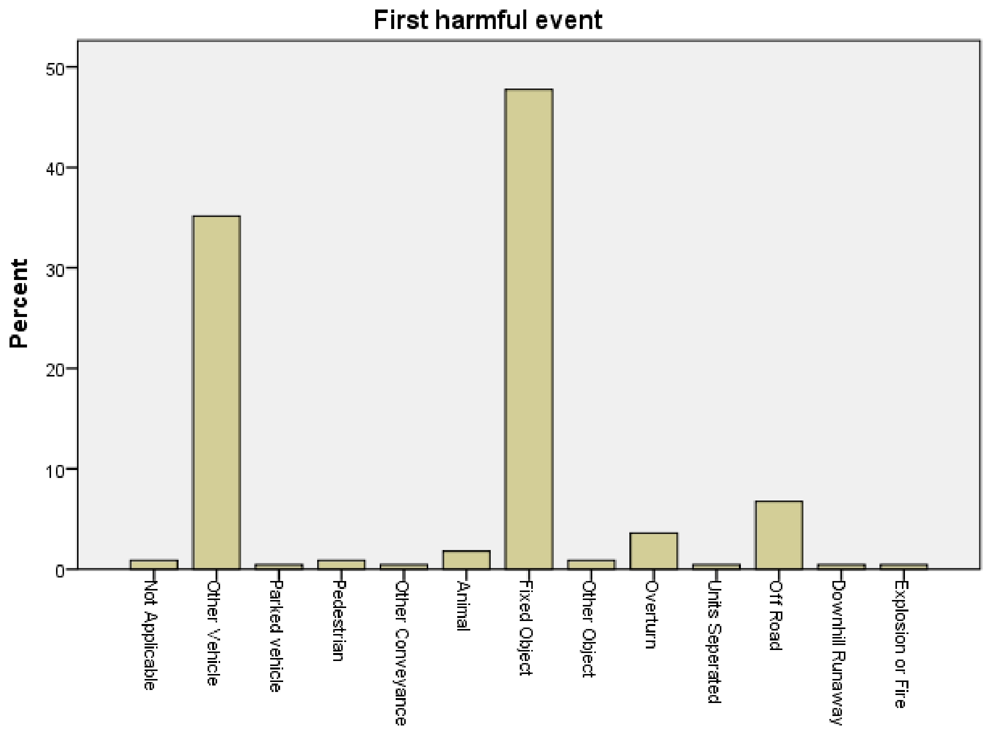

Figure 104. Ramps and Collector-Distributor (C-D) Roads Crashes by Harmful Event Type (2009-2010)

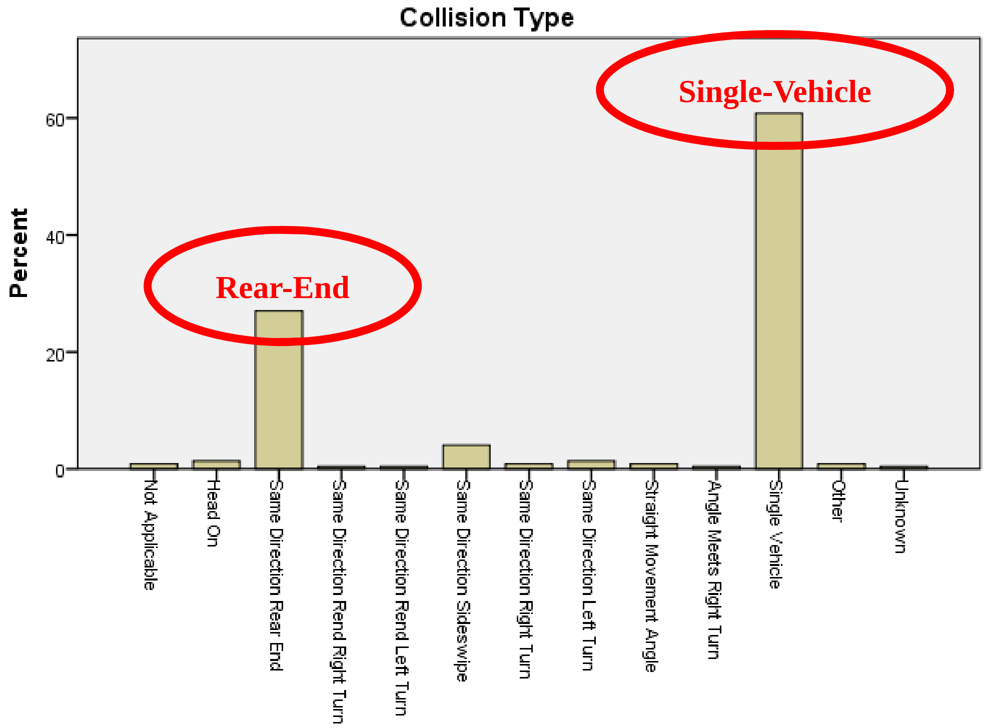

Figure 105. Ramps and Collector-Distributor (C-D) Roads Crashes by Collision Type (2009-2010)

Based on Table 77 and Figure 106, the top three crash circumstances of ramps and C-D roads are as follows:

- Too fast for conditions (80 crashes; 36%)
- Failure to drive within a single lane (50 crashes; 22.5%)
- Followed too closely (22 crashes; 9.9%)

Table 77. Ramps and Collector-Distributor (C-D) Roads Crashes by Contributing Circumstance (2009-2010)

Contributing Circumstance Type	Frequency	%
Not applicable	8	3.6
Under influence of drugs	1	0.5
Under influence of alcohol	9	4.1
Under influence of medication	1	0.5
Fell asleep, fainted, etc.	2	0.9
Failed to give full time and attention	15	6.8
Failure to drive within a single lane	50	22.5
Failed to yield right of way	5	2.3
Failed to obey other traffic control	1	0.5
Wrong way on one-way road	1	0.5
Exceeded the speed limit	3	1.4
Stopping in a lane/roadway	1	0.5
Too fast for conditions	80	36.0
Followed too closely	22	9.9
Improper lane change	2	0.9
Improper backing	3	1.4
Rain, snow	1	0.5
Animal	4	1.8
Brakes	3	1.4
Tires	1	0.5
Trailer coupling	1	0.5
Wet	3	1.4
Icy or snow-covered	3	1.4
Debris or obstruction	1	0.5
Other	1	0.5
Total	**222**	**100.0**

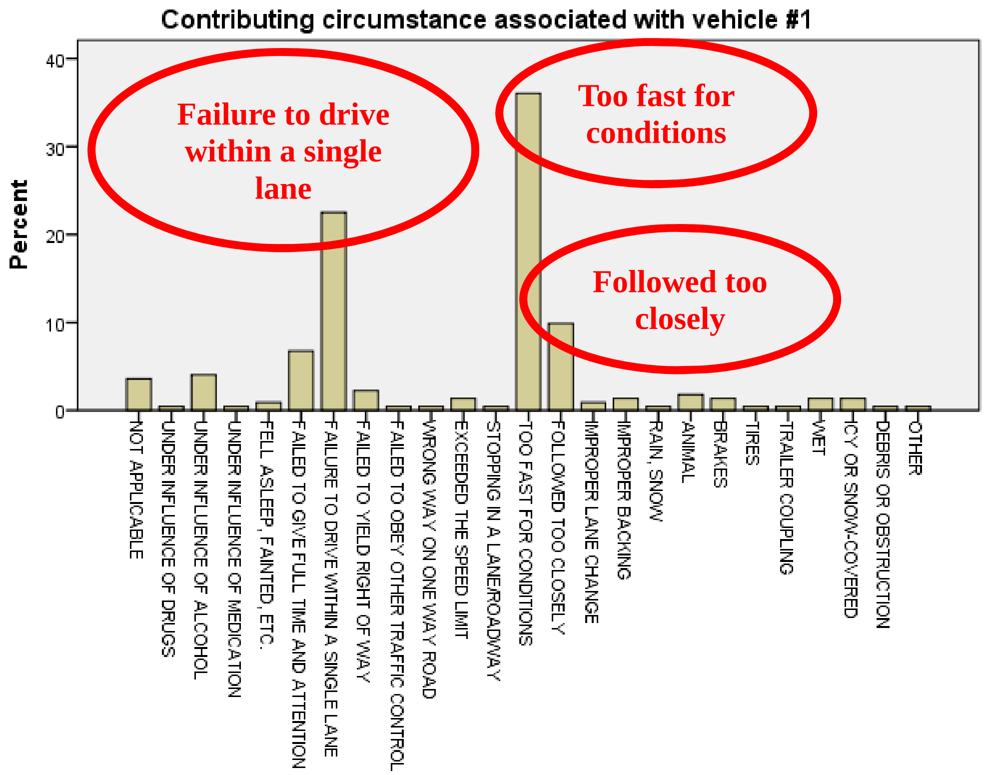

Figure 106. Ramps and Collector-Distributor (C-D) Roads Crashes by Contributing Circumstance (2009-2010)

Weather had a negative impact on the ramps and C-D roads in Maryland State during 2009-2010 because they faced 18% more crashes while the weather condition was “raining” (Table 78 and Figure 107).

Table 78. Comparison of Ramps and Collector-Distributor (C-D) Roads and All Roads by Weather Condition (2009-2010)

Weather condition	Ramps & C-D Roads		All Roads	
	Frequency	%	Frequency	%
Not Applicable	2	0.9	896	0.5
Clear/Cloudy	141	63.5	151,006	80.8
Foggy	0	0.0	1,277	0.7
Raining	70	31.5	26,050	13.9
Snow/Sleet	8	3.6	6,525	3.5
Severe Winds	0	0.0	227	0.1
Other	1	0.5	58	0.0
Unknown	0	0.0	917	0.5
Total	**222**	**100.0%**	**186,956**	**100.0%**

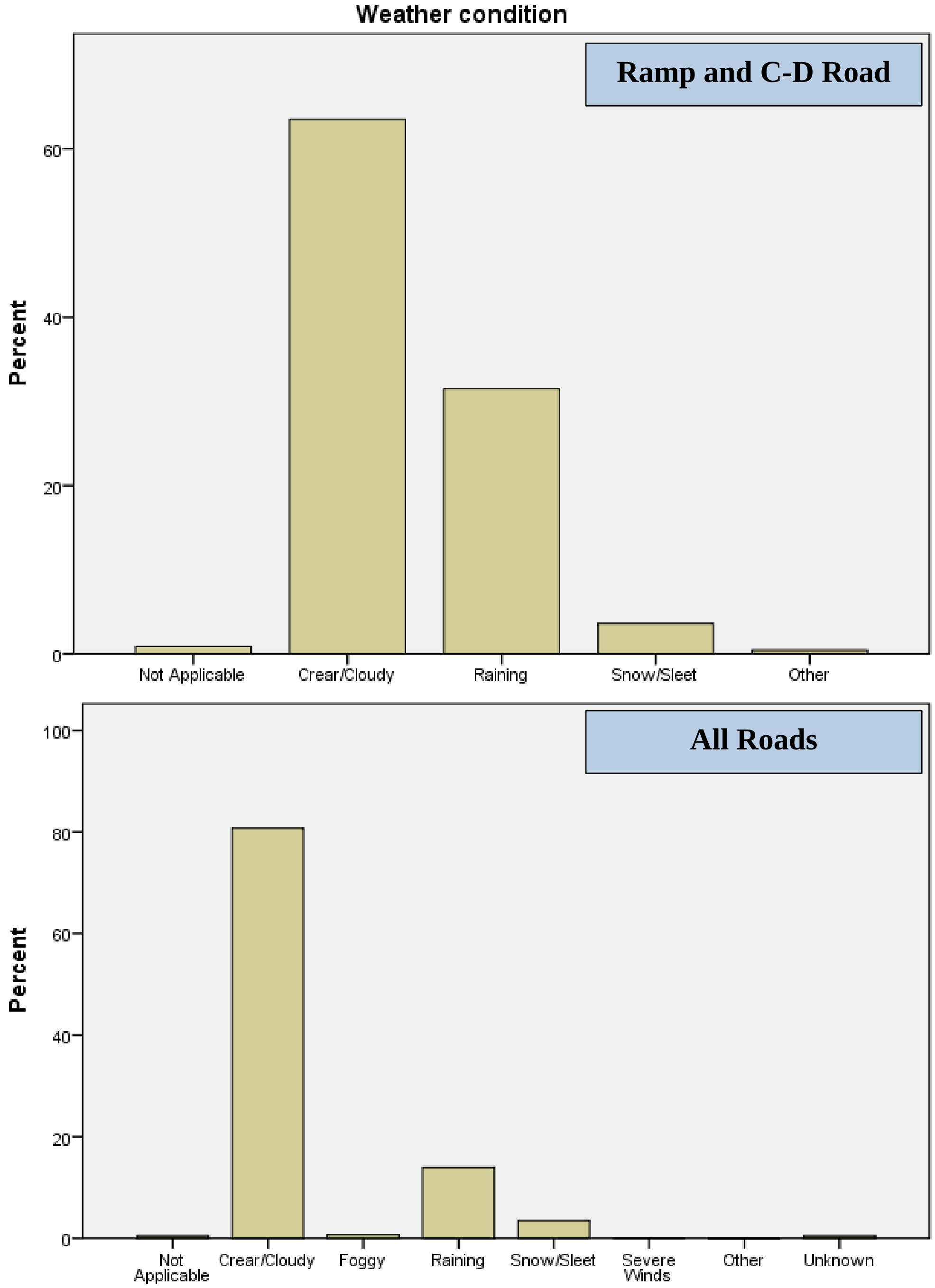

Figure 107. Comparison of Ramps and Collector-Distributor (C-D) Roads and All Roads by Weather Condition (2009-2010)

Highly correlated with weather, roadway surface conditions also had negative impacts on the ramps and C-D roads in Maryland State during 2009-2010 because 17.1% more crashes occurred on “wet” surfaces, 4.5% more crashes on “ice” surfaces, and 0.8% more crashes on “snow” surfaces (Table 79 and Figure 108).

Table 79. Comparison of Ramps and Collector-Distributor (C-D) Roads and All Roads by Surface Condition (2009-2010)

Surface Condition	Ramps & C-D Roads		All Roads	
	Frequency	%	Frequency	%
Not Applicable	1	0.5	585	0.3
Wet	85	38.3	39,668	21.2
Dry	113	50.9	136,341	72.9
Snow	9	4.1	6,169	3.3
Ice	14	6.3	3,436	1.8
Mud	0	0.0	53	0
Other	0	0.0	105	0.1
Unknown	0	0.0	599	0.3
Total	**222**	**100.0**	**186,956**	**100**

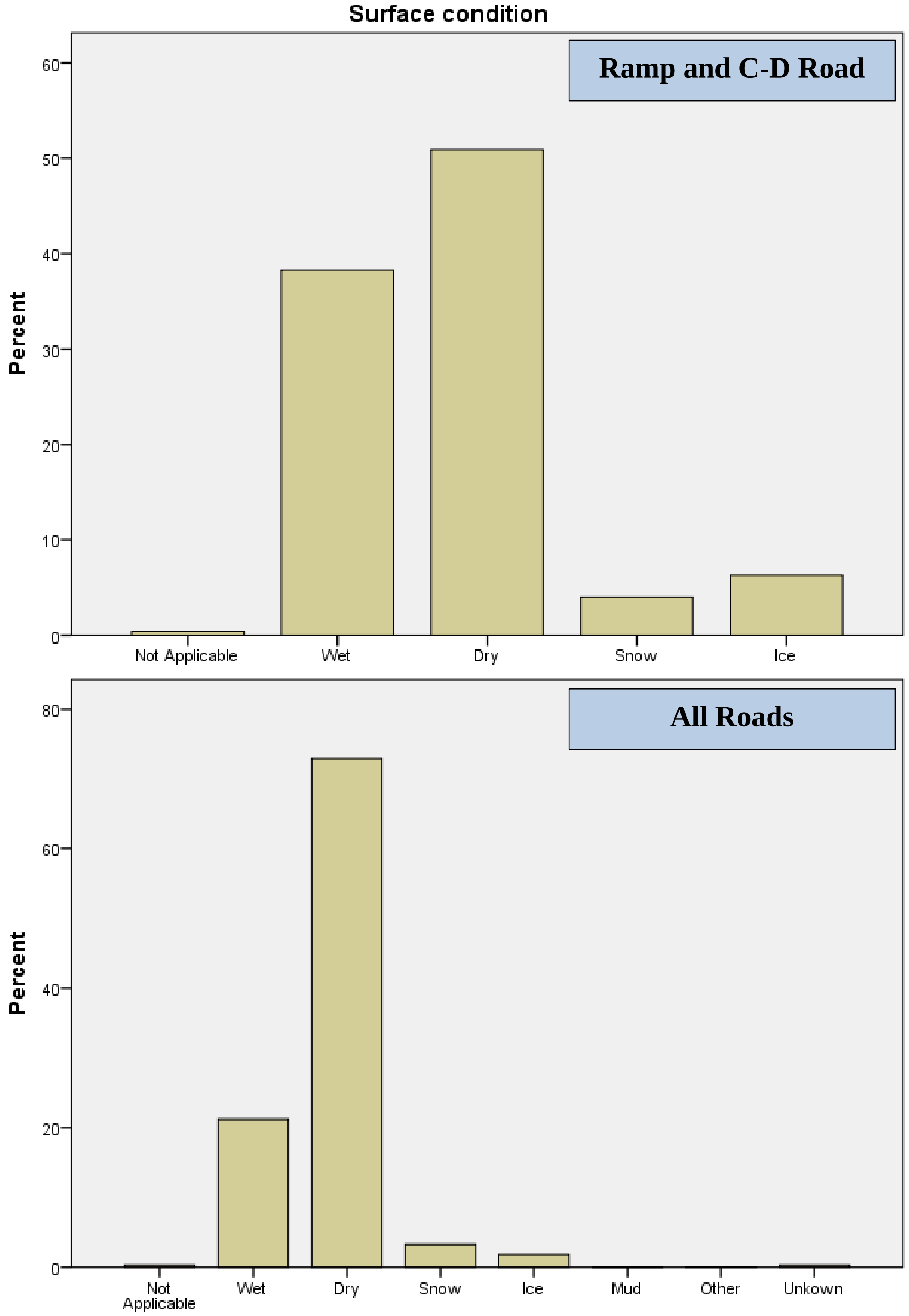

Figure 108. Comparison of Ramps and Collector-Distributor (C-D) Roads and All Roads by Roadway Surface Condition (2009-2010)

APPENDIX G. AGGREGATE VS. DISAGGREGATE CALIBRATION OF THE HIGHWAY SAFETY MANUAL

The authors conducted this task in order to generate new ideas for a future LCF methodology refinement endeavor. While all possible LCFs based on HSM-recommended categories were developed (see "LCFs" for details), the study team considered developing LCFs based on following schemes:

- Freeway segments and speed-change lanes
    - HSM Default: By HSM categories (4 Possible LCFs)
    - Scenario 1: By HSM categories and area type (8 possible LCFs)
    - Scenario 2: By HSM categories and # lanes (16 possible LCFs)
    - Scenario 3: By HSM categories, area type and # lanes (28 possible LCFs)
- Signalized ramp terminals
    - HSM Default: By HSM categories (2 possible LCFs)
    - Scenario 1: By HSM categories and area Type (4 possible LCFs)
    - Scenario 2: By HSM categories and ramp terminal configuration type (14 possible LCFs)
    - Scenario 3: By HSM categories, area type and ramp terminal configuration type (28 possible LCFs)

Stop-controlled ramp terminals were not part of this task due to insufficient total number of observed crashes (only 160 crashes) which was less than the HSM requirement.

As a metric of comparison of different scenarios, the study team used the sum of squared deviation (SSD) (see "Comparing HSM-default and Maryland-specific Crash Distributions" for details).

Freeway Segments

Another summary of the Maryland freeway segments dataset is presented in Table 80.

The results of computing LCFs following the HSM categories are provided in Table 81. All facilities meet the HSM sampling requirements and the results are similar to what has been presented in the report (see "LCFs").

The results of disaggregating HSM categories by area type (Scenario 1) are presented in Table 82. Two out of 8 categories (25%) do not meet the HSM required minimum annual crashes and both are of rural facility types: rural; multiple-vehicle; fatal and injury crashes (R_MV_FI) and rural; single-vehicle; fatal and injury crashes (R_SV_FI).

The results of disaggregating HSM categories by # lanes (Scenario 2) are presented in Table 83. Six out of 16 categories (37.5%) do not meet the HSM required minimum annual crashes and some also face very few cases causing them to not meet the minimum 30 sample size requirement as well. However, ten-lane freeways can be ignored because there is only one freeway segment matching this category in Maryland, so this facility type will not match the HSM requirements (four categories) anyway, and the other two categories are four-lane; multiple-vehicle; fatal and injury crashes (4_MV_FI) and eight-lane; single-vehicle; fatal and injury crashes (8_SV_FI).

The results of disaggregating HSM categories by both area type and # lanes (Scenario 3) are presented in Table 84. Since the number of categories increased relatively to the previous two categories, the majority of categories do not meet the HSM sampling requirements (22 out of 28 categories (78.6%)). In other words, only the following six categories (21.4%) could meet the

HSM requirements: urban eight-lane; multiple-vehicle; fatal and injury crashes (U8_MV_FI), rural eight-lane; multiple-vehicle; property-damage-only crashes (R8_MV_PDO), urban six-lane; multiple-vehicle; property-damage-only crashes (U6_MV_PDO), urban eight-lane; multiple-vehicle; property-damage-only crashes (U8_MV_PDO), urban four-lane; single-vehicle; property-damage-only crashes (U4_SV_PDO), urban six-lane; single-vehicle; property-damage-only (U6_SV_PDO), and urban eight-lane; single-vehicle; property-damage-only crashes (U8_SV_PDO).

Table 80. Maryland Freeway Segments Dataset Summary (2008-2010)

Freeways	#	Network				Crash Data											
						2008				2009				2010			
		Length (Mile)	Min. (Mile)	Max. (Mile)	Avg. (Mile)	SV_FI	SV_PDO	MV_FI	MV_PDO	SV_FI	SV_PDO	MV_FI	MV_PDO	SV_FI	SV_PDO	MV_FI	MV_PDO
RF4	105	38.09	0.10	1.00	0.36	47	65	25	35	47	71	32	49	31	42	21	28
RF6	69	29.05	0.11	1.00	0.42	31	87	31	82	46	111	33	80	31	80	33	77
RF8	5	2.33	0.26	0.68	0.47	7	16	13	17	5	20	14	20	12	18	8	14
UF4	175	56.05	0.10	1.00	0.32	71	99	59	63	78	117	63	117	65	113	74	119
UF6	119	41.45	0.10	1.00	0.35	65	139	89	130	89	168	93	134	63	126	87	113
UF8	90	29.75	0.11	1.00	0.33	75	132	180	238	89	162	166	295	58	167	167	276
UF10	1	0.17	0.17	0.17	0.17	0	0	1	0	0	2	0	2	0	0	1	1
Total	**564**	**196.90**	**0.10**	**1.00**	**0.35**	**296**	**538**	**398**	**565**	**354**	**651**	**401**	**697**	**260**	**546**	**391**	**628**

Notes: “MV” stands for “multiple vehicle,” “SV” stands for “single vehicle,” “FI” stands for “fatal and injury,” and “PDO” stands for “property damage only.”

Table 81. Maryland Freeway Segments LCFs based on the HSM Categories (2008-2010)

SPF	n	Observed Crashes	Predicted Crashes	LCF
MV_FI	564	1,190	2,617.94	0.4546
MV_PDO	564	1,890	6,610.84	0.2859
SV_FI	564	910	1,451.53	0.6269
SV_PDO	564	1,735	2,705.7	0.6412

Notes: The asterisk denotes that the facility type did not meet the HSM minimum annual crashes of 100 and the associated LCF should be used cautiously. “MV” stands for “multiple vehicle,” “SV” stands for “single vehicle,” “FI” stands for “fatal and injury,” and “PDO” stands for “property damage only.”

Table 82. Maryland Freeway Segments LCFs based on Scenario 1 (2008-2010)

SPF	n	Observed Crashes	Predicted Crashes	LCF
R_MV_FI*	179	210	338.86	0.6197
U_MV_FI	385	980	2,279.08	0.4300
R_MV_PDO	179	402	964.39	0.4168
U_MV_PDO	385	1,488	5,646.45	0.2635
R_SV_FI*	179	257	486.95	0.5278
U_SV_FI	385	653	964.58	0.6770
R_SV_PDO	179	510	894.25	0.5703
U_SV_PDO	385	1,225	1,811.45	0.6763

Notes: The asterisk denotes that the facility type did not meet the HSM minimum annual crashes of 100 and the associated LCF should be used cautiously. “MV” stands for “multiple vehicle,” “SV” stands for “single vehicle,” “FI” stands for “fatal and injury,” and “PDO” stands for “property damage only.” “R” and “U” refer to “rural” and “urban,” respectively.

Table 83. Maryland Freeway Segments LCFs based on Scenario 2 (2008-2010)

SPF	n	Observed Crashes	Predicted Crashes	LCF
4_MV_FI*	280	274	658.95	0.4158
6_MV_FI	188	366	768.35	0.4763
8_MV_FI	95	548	1184.59	0.4626
10_MV_FI*	1	2	6.05	0.3306
4_MV_PDO	280	411	1682.95	0.2442
6_MV_PDO	188	616	1853.82	0.3323
8_MV_PDO	95	860	3057.91	0.2812
10_MV_PDO*	1	3	16.16	0.1856
4_SV_FI	280	339	648.52	0.5227
6_SV_FI	188	325	500.06	0.6499
8_SV_FI*	95	246	300.6	0.8184
10_SV_FI*	1	0	2.35	0.0000
4_SV_PDO	280	507	1110.41	0.4566
6_SV_PDO	188	711	1026.68	0.6925
8_SV_PDO	95	515	564.48	0.9123
10_SV_PDO*	1	2	4.13	0.4843

Notes: The asterisk denotes that the facility type did not meet the HSM minimum annual crashes of 100 and the associated LCF should be used cautiously. “MV” stands for “multiple vehicle,” “SV” stands for “single vehicle,” “FI” stands for “fatal and injury,” and “PDO” stands for “property damage only.” Numbers refer to the number of cross lanes.

Table 84. Maryland Freeway Segments LCFs based on Scenario 3 (2008-2010)

SPF	n	Observed Crashes	Predicted Crashes	LCF
R4_MV_FI*	105	78	147.04	0.5305
R6_MV_FI*	69	97	157.13	0.6173
R8_MV_FI*	5	35	34.69	1.0089
U4_MV_FI*	175	196	511.91	0.3829
U6_MV_FI*	119	269	611.22	0.4401
U8_MV_FI	90	513	1149.9	0.4461
U10_MV_FI*	1	2	6.05	0.3306
R4_MV_PDO*	105	112	471.01	0.2378
R6_MV_PDO*	69	239	396.36	0.6030
R8_MV_PDO*	5	51	97.02	0.5257
U4_MV_PDO*	175	299	1211.94	0.2467
U6_MV_PDO	119	377	1457.46	0.2587
U8_MV_PDO	90	809	2960.89	0.2732
U10_MV_PDO*	1	3	16.16	0.1856
R4_SV_FI*	105	125	298.56	0.4187
R6_SV_FI*	69	108	171.35	0.6303
R8_SV_FI*	5	24	17.04	1.4085
U4_SV_FI*	175	214	349.96	0.6115
U6_SV_FI*	119	217	328.71	0.6602
U8_SV_FI*	90	222	283.56	0.7829
U10_SV_FI*	1	0	2.35	0.000
R4_SV_PDO*	105	178	489.36	0.3637
R6_SV_PDO*	69	278	368.13	0.7552
R8_SV_PDO*	5	54	36.76	1.4690
U4_SV_PDO	175	329	621.05	0.5297
U6_SV_PDO	119	433	658.55	0.6575
U8_SV_PDO	90	461	527.72	0.8736
U10_SV_PDO*	1	2	4.13	0.4843

Notes: The asterisk denotes that the facility type did not meet the HSM minimum annual crashes of 100 and the associated LCF should be used cautiously. “MV” stands for “multiple vehicle,” “SV” stands for “single vehicle,” “FI” stands for “fatal and injury,” and “PDO” stands for “property damage only.” “R” and “U” refer to “rural” and “urban,” respectively. Numbers refer to the number of cross lanes.

Table 85 shows the result of comparison of SSD values for different sampling schemes for freeway segments. All facility types faced prediction improvements in all scenarios. Disaggregation showed major improvements (1.1%-15.5%) for freeway segments especially when disaggregation was done by both area type and # lanes together. The difference was statistically significant (t (2255) =1.937, p=0.05). Moreover, applying Maryland-specific crash distribution improved predictions in all scenarios (2.4%-4.1%) indicating almost a constant improvement upon application of locally derived crash distributions. The results are also presented in Figure 109. Application of the Maryland-specific crash distribution is highly recommended but even though the results of disaggregation are promising the application of disaggregated LCFs should be followed cautiously.

Table 85. Maryland Freeway Segments LCFs – Comparing Different Scenarios based on All Samples' SSD (2008-2010)

Sc.	**HSM Default Crash Distribution**	**MD-Specific Crash Distribution**	**% Change**
HSM	21,925	21,242	-3.1%
Sc. 1	21,541	21,016	-2.4%
Sc. 2	19,974	19,146	-4.1%
Sc. 3	18,713	17,960	-4.0%
Sc.	**HSM Default Crash Distribution**	**MD-Specific Crash Distribution**	**% Change**
HSM	21,925	21,242	-3.1%
Sc. 1	21,541	21,016	-2.4%
% Change	-1.8%	-1.1%	
Sc.	**HSM Default Crash Distribution**	**MD-Specific Crash Distribution**	**% Change**
HSM	21,925	21,242	-3.1%
Sc. 2	19,974	19,146	-4.1%
% Change	-8.9%	-9.9%	
Sc.	**HSM Default Crash Distribution**	**MD-Specific Crash Distribution**	**% Change**
HSM	21,925	21,242	-3.1%
Sc. 3	18,713	17,960	-4.0%
% Change	-14.7%	-15.5%	

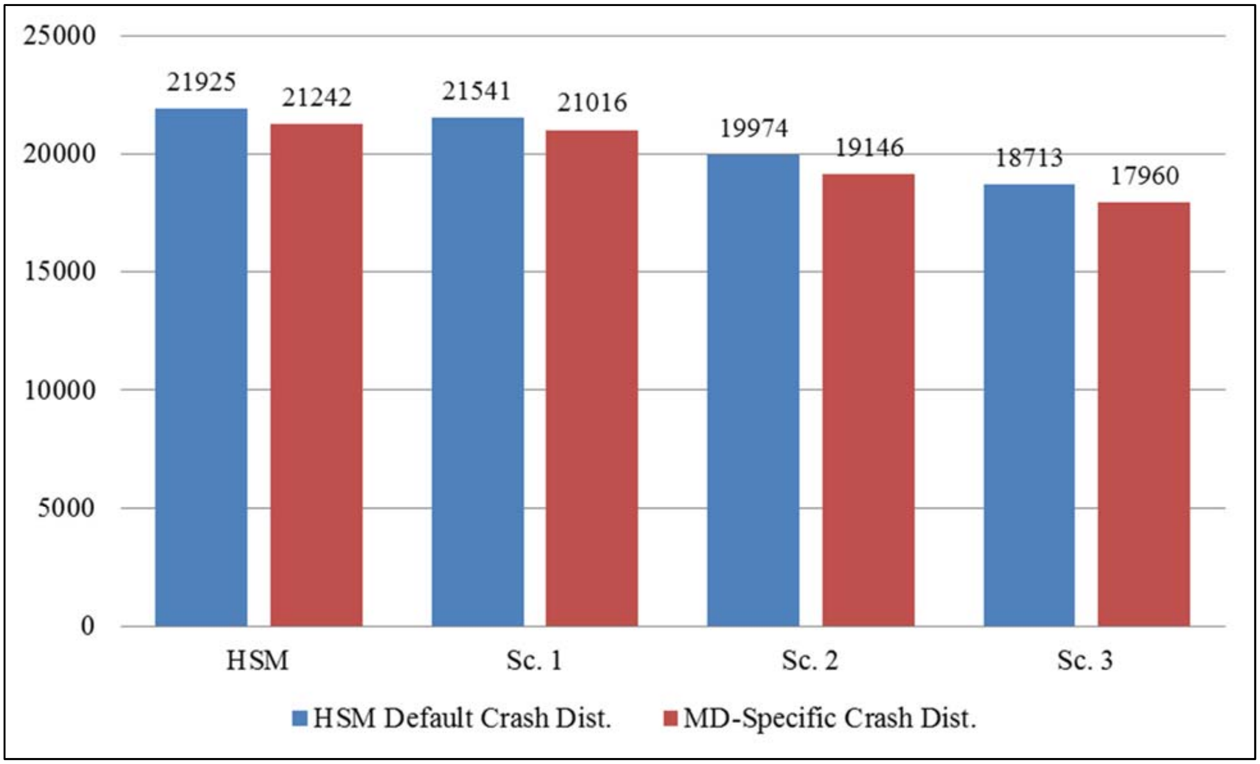

Figure 109. Maryland Freeway Segments LCFs – Comparing Different Scenarios based on All Samples' SSD (2008-2010)

Speed-Change Lanes

Another summary of Maryland speed-change lanes dataset is presented in Table 86.
The results of computing LCFs following the HSM categories are provided in Table 87. All facilities meet the HSM sampling requirements and the results are similar to what has been presented in the report (see "LCFs").

The results of disaggregating HSM categories by area type (Scenario 1) are presented in Table 88. All rural categories (4 out of 8 categories (50%)) do not meet the HSM required minimum annual crashes.

The results of disaggregating HSM categories by # lanes (Scenario 2) are presented in Table 89. All categories do not meet the HSM required minimum annual crashes and some also face very few cases causing them to not meet the minimum 30 sample size requirement as well.
The results of disaggregating HSM categories by both area type and # lanes (Scenario 3) are presented in Table 90. Again all categories do not meet the HSM sampling requirements.

Table 86. Maryland Speed-Change Lanes Dataset Summary (2008-2010)

Speed-Change Lanes	#	Length (Mile)	Min. (Mile)	Max. (Mile)	Avg. (Mile)	FI_2008	PDO_2008	FI_2009	PDO_2009	FI_2010	PDO_2010
RSCen4	16	1.50	0.05	0.21	0.09	0	2	0	2	0	1
RSCen6	9	0.93	0.06	0.19	0.10	2	4	3	13	6	8
RSCen8	4	0.37	0.06	0.11	0.09	0	2	0	0	0	0
RSCex4	21	1.80	0.05	0.18	0.09	1	1	1	4	2	5
RSCex6	11	0.98	0.06	0.17	0.09	0	1	1	2	1	3
RSCex8	2	0.19	0.10	0.10	0.10	0	3	2	3	1	3
USCen4	85	7.02	0.05	0.25	0.08	17	13	13	37	16	27
USCen6	93	9.08	0.05	0.27	0.10	46	81	55	84	45	50
USCen8	57	6.00	0.05	0.28	0.11	55	92	55	96	45	88
USCex4	72	6.86	0.05	0.22	0.10	13	26	12	45	18	24
USCex6	98	10.03	0.05	0.24	0.10	44	60	76	112	48	87
USCex8	49	5.29	0.05	0.25	0.11	40	51	41	82	35	59
USCex10	1	0.11	0.11	0.11	0.11	0	1	0	0	0	0
Total	**518**	**50.16**	**0.05**	**0.28**	**0.10**	**218**	**337**	**259**	**480**	**217**	**355**

Notes: “MV” stands for “multiple vehicle,” “SV” stands for “single vehicle,” “FI” stands for “fatal and injury,” “PDO” stands for “property damage only,” “En” refers to “ramp-entrance speed-change lane,” and “Ex” refers to “ramp-exit speed-change lane.”

Table 87. Maryland Speed-Change Lanes LCFs based on the HSM Categories (2008-2010)

SPF	n	Observed Crashes	Predicted Crashes	LCF
En_FI	264	358	605.46	0.5913
En_PDO	264	600	1,139.37	0.5266
Ex_FI	254	336	437.39	0.7682
Ex_PDO	254	572	648.37	0.8822

Notes: The asterisk denotes that the facility type did not meet the HSM minimum annual crashes of 100 and the associated LCF should be used cautiously. "MV" stands for "multiple vehicle," "SV" stands for "single vehicle," "FI" stands for "fatal and injury," "PDO" stands for "property damage only," "En" refers to "ramp-entrance speed-change lane," and "Ex" refers to "ramp-exit speed-change lane."

Table 88. Maryland Speed-Change Lanes LCFs based on Scenario 1 (2008-2010)

SPF	n	Observed Crashes	Predicted Crashes	LCF
R_En_FI*	35	12	26.39	0.4547
U_En_FI	240	357	591.64	0.6034
R_En_PDO*	35	34	62.58	0.5433
U_En_PDO	240	608	1,102.51	0.5515
R_Ex_FI*	37	10	27.82	0.3595
U_Ex_FI	226	339	421.11	0.8050
R_Ex_PDO*	37	25	41.34	0.6047
U_Ex_PDO	226	561	624.05	0.8990

Notes: The asterisk denotes that the facility type did not meet the HSM minimum annual crashes of 100 and the associated LCF should be used cautiously. "MV" stands for "multiple vehicle," "SV" stands for "single vehicle," "FI" stands for "fatal and injury," "PDO" stands for "property damage only," "En" refers to "ramp-entrance speed-change lane," and "Ex" refers to "ramp-exit speed-change lane." "R" and "U" refer to "rural" and "urban," respectively.

Table 89. Maryland Speed-Change Lanes LCFs based on Scenario 2 (2008-2010)

SPF	n	Observed Crashes	Predicted Crashes	LCF
4En_FI*	109	55	129.16	0.4258
6En_FI*	104	157	237.1	0.6622
8En_FI*	62	157	251.77	0.6236
4En_PDO*	109	118	229.39	0.5144
6En_PDO*	104	242	444.29	0.5447
8En_PDO*	62	282	491.41	0.5739
4Ex_FI*	98	60	87.18	0.6882
6Ex_FI*	111	170	189.45	0.8973
8Ex_FI*	53	119	168.62	0.7057
10Ex_FI*	1	0	3.68	0.0000
4Ex_PDO*	98	113	127.45	0.8866
6Ex_PDO*	111	267	279.91	0.9539
8Ex_PDO*	53	205	252.53	0.8118
10Ex_PDO*	1	1	5.5	0.1818

Notes: The asterisk denotes that the facility type did not meet the HSM minimum annual crashes of 100 and the associated LCF should be used cautiously. "MV" stands for "multiple vehicle," "SV" stands for "single vehicle," "FI" stands for "fatal and injury," "PDO" stands for "property damage only," "En" refers to "ramp-entrance speed-change lane," and "Ex" refers to "ramp-exit speed-change lane." Numbers refer to the number of cross lanes.

Table 90. Maryland Speed-Change Lanes LCFs based on Scenario 3 (2008-2010)

SPF	n	Observed Crashes	Predicted Crashes	LCF
R_4En_FI*	20	1	8.3	0.1205
U_4En_FI*	89	54	120.86	0.4468
R_6En_FI*	11	11	9.21	1.1944
U_6En_FI*	93	146	227.89	0.6407
R_8En_FI*	4	0	8.88	0.0000
U_8En_FI*	58	157	242.89	0.6464
R_4En_PDO*	20	5	20.68	0.2418
U_4En_PDO*	89	113	208.71	0.5414
R_6En_PDO*	11	27	22.54	1.1979
U_6En_PDO*	93	215	421.75	0.5098
R_8En_PDO*	4	2	19.36	0.1033
U_8En_PDO*	58	280	472.05	0.5932
R_4Ex_FI*	23	5	13.06	0.3828
U_4Ex_FI*	75	55	74.12	0.7420
R_6Ex_FI*	12	2	10.2	0.1961
U_6Ex_FI*	99	168	179.25	0.9372
R_8Ex_FI*	2	3	4.56	0.6579
U_8Ex_FI*	51	116	164.06	0.7071
U_10Ex_FI*	1	0	3.68	0.0000
R_4Ex_PDO*	23	10	19.25	0.5195
U_4Ex_PDO*	75	103	108.2	0.9519
R_6Ex_PDO*	12	6	15.27	0.3929
U_6Ex_PDO*	99	261	264.64	0.9862
R_8Ex_PDO*	2	9	6.82	1.3196
U_8Ex_PDO*	51	196	245.71	0.7977
U_10Ex_PDO*	1	1	5.5	0.1818

Notes: The asterisk denotes that the facility type did not meet the HSM minimum annual crashes of 100 and the associated LCF should be used cautiously. "MV" stands for "multiple vehicle," "SV" stands for "single vehicle," "FI" stands for "fatal and injury," "PDO" stands for "property damage only," "En" refers to "ramp-entrance speed-change lane," and "Ex" refers to "ramp-exit speed-change lane." "R" and "U" refer to "rural" and "urban," respectively. Numbers refer to the number of cross lanes.

Table 91 shows the result of comparison of SSD values for different sampling schemes for speed-change lanes. Disaggregation by area type (Scenario 1) could slightly worsen the crash prediction and the other two scenarios showed minor improvements (less than 1%). Application of Maryland-specific crash distributions improved predictions in all scenarios (3.8%-4.1%) indicating almost a constant improvement upon application of locally derived crash distribution. The results are also presented in Figure 110. Application of the Maryland-specific crash distribution is highly recommended but since there were not significant improvements by the results of disaggregation scenarios and many facility types did not meet the HSM sampling requirements, application of disaggregated LCFs is not recommended.

Table 91. Maryland Speed-Change Lanes LCFs – Comparing Different Scenarios based on All Samples' SSD (2008-2010)

Sc.	HSM Default Crash Distribution	MD-Specific Crash Distribution	% Change
HSM	6,604	6,345	-3.9%
Sc. 1	6,622	6,352	-4.1%
Sc. 2	6,565	6,313	-3.8%
Sc. 3	6,538	6,279	-4.0%
Sc.	**HSM Default Crash Distribution**	**MD-Specific Crash Distribution**	**% Change**
HSM	6,604	6,345	-3.9%
Sc. 1	6,622	6,352	-4.1%
% Change	0.3%	0.1%	
Sc.	**HSM Default Crash Distribution**	**MD-Specific Crash Distribution**	**% Change**
HSM	6,604	6,345	-3.9%
Sc. 2	6,565	6,313	-3.8%
% Change	-0.6%	-0.5%	
Sc.	**HSM Default Crash Distribution**	**MD-Specific Crash Distribution**	**% Change**
HSM	6,604	6,345	-3.9%
Sc. 3	6,538	6,279	-4.0%
% Change	-1.0%	-1.0%	

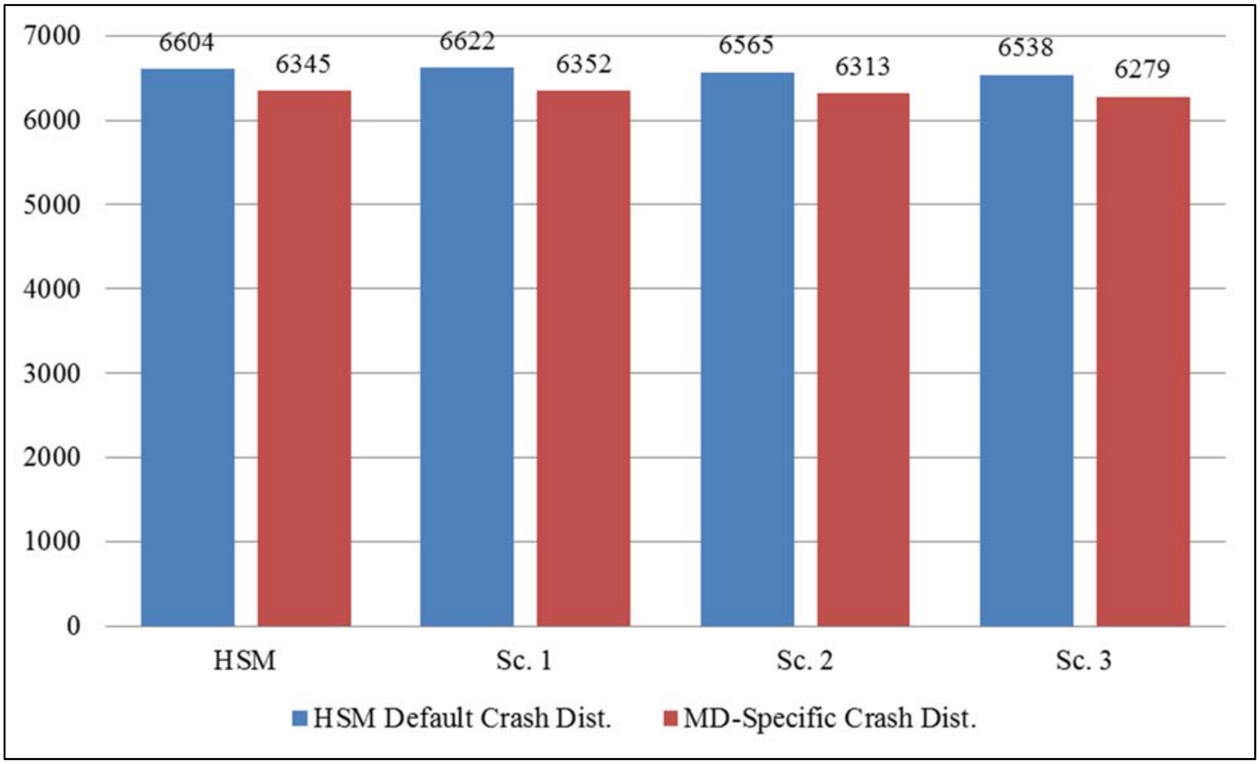

Figure 110. Maryland Freeway LCFs – Comparing Different Scenarios based on All Samples' SSD (2008-2010)

Signalized Ramp Terminals
Another summary of Maryland signalized ramp terminals dataset is presented in Table 92. The results of computing LCFs following the HSM categories are provided in Table 93. Both facilities meet the HSM sampling requirements and the results are similar to what has been presented in the report (see "LCFs").

The results of disaggregating HSM categories by area type (Scenario 1) are presented in Table 94. All rural categories (2 out of 4 categories (50%)) do not meet the HSM required minimum annual crashes.

The results of disaggregating HSM categories by ramp terminal configuration type (Scenario 2) are presented in Table 95. Since there are many different configuration types and Maryland is a relatively small network state, all categories do not meet the HSM required minimum annual crashes and some also have very few cases causing them to not meet the minimum 30 sample size requirement as well.

The results of disaggregating HSM categories by both area type and # lanes (Scenario 3) are presented in Table 96. Again all categories do not meet the HSM sampling requirements.

Table 92. Summary of Signalized Ramp Terminals Sampled Sites by Crash Types

Facility Type		**#**	**FI (2008)**	**PDO (2008)**	**FI (2009)**	**PDO (2009)**	**FI (2008)**	**PDO (2008)**	**Total Crashes (2008-2010)**	**Crash Rate (Per Ramp Terminal)**
Rural	A2	2	0	0	1	1	1	0	3	1.50
	B2	1	0	0	0	1	0	0	1	1.00
	D3ex	1	0	0	0	1	1	0	2	2.00
	D4	4	2	2	1	1	3	3	12	3.00
Rural (Subtotal)		*8*	*2*	*2*	*2*	*4*	*5*	*3*	*18*	*2.25*
Urban	A2	20	19	25	12	14	14	19	103	5.15
	A4	6	7	8	8	5	3	15	46	7.67
	B2	19	15	24	16	21	30	21	127	6.68
	B4	6	5	4	3	2	2	4	20	3.33
	D3en	22	10	16	11	14	12	23	86	3.91
	D3ex	44	32	35	21	38	35	42	203	4.61
	D4	47	54	53	45	52	62	67	333	7.09
Urban (Subtotal)		*164*	*142*	*165*	*116*	*146*	*158*	*191*	*918*	*5.60*
Total		**172**	**144**	**167**	**118**	**150**	**163**	**194**	**936**	**5.44**

Notes: "MV" stands for "multiple vehicle," "SV" stands for "single vehicle," "FI" stands for "fatal and injury," "PDO" stands for "property damage only," "ST" stands for "stop-controlled," and "SG" stands for "signalized."

Table 93. Maryland Signalized Ramp Terminals LCFs based on the HSM Categories (2008-2010)

SPF	n	Observed Crashes	Predicted Crashes	LCF
SG_FI	172	425	1213.81	0.3501
SG_PDO	172	511	1690.71	0.3022

Notes: The asterisk denotes that the facility type did not meet the HSM minimum annual crashes of 100 and the associated LCF should be used cautiously. "MV" stands for "multiple vehicle," "SV" stands for "single vehicle," "FI" stands for "fatal and injury," "PDO" stands for "property damage only," "ST" stands for "stop-controlled," and "SG" stands for "signalized."

Table 94. Maryland Signalized Ramp Terminals LCFs based on Scenario 1 (2008-2010)

SPF	n	Observed Crashes	Predicted Crashes	LCF
R_SG_FI*	8	9	55.191	0.1631
U_SG_FI	164	416	1158.618	0.3590
R_SG_PDO*	8	9	90.898	0.0990
U_SG_PDO	164	502	1599.815	0.3138

Notes: The asterisk denotes that the facility type did not meet the HSM minimum annual crashes of 100 and the associated LCF should be used cautiously. "MV" stands for "multiple vehicle," "SV" stands for "single vehicle," "FI" stands for "fatal and injury," "PDO" stands for "property damage only," "ST" stands for "stop-controlled," and "SG" stands for "signalized." "R" and "U" refer to "rural" and "urban," respectively.

Table 95. Maryland Signalized Ramp Terminals LCFs based on Scenario 2 (2008-2010)

SPF	n	Observed Crashes	Predicted Crashes	LCF
SG_A2_FI*	22	47	117.935	0.3985
SG_A4_FI*	7	18	101.094	0.1781
SG_B2_FI*	20	61	124.318	0.4907
SG_B4_FI*	5	10	28.834	0.3468
SG_D3en_FI*	22	33	55.15	0.5984
SG_D3ex_FI*	44	88	331.704	0.2653
SG_D4_FI*	52	168	454.774	0.3694
SG_A2_PDO*	22	59	179.787	0.3282
SG_A4_PDO*	7	29	149.689	0.1937
SG_B2_PDO*	20	67	203.399	0.3294
SG_B4_PDO*	5	9	55.186	0.1631
SG_D3en_PDO*	22	53	102.479	0.5172
SG_D3ex_PDO*	44	116	430.828	0.2692
SG_D4_PDO*	52	178	569.345	0.3126

Notes: The asterisk denotes that the facility type did not meet the HSM minimum annual crashes of 100 and the associated LCF should be used cautiously. "MV" stands for "multiple vehicle," "SV" stands for "single vehicle," "FI" stands for "fatal and injury," "PDO" stands for "property damage only," "ST" stands for "stop-controlled," and "SG" stands for "signalized." "A2," "A4," "B2," "B4," "D3en," "D3ex," and "D4" denote ramp terminal type.

Table 96. Maryland Signalized Ramp Terminals LCFs based on Scenario 3 (2008-2010)

SPF	n	Observed Crashes	Predicted Crashes	LCF
R_SG_A2_FI*	2	2	6.156	0.3249
U_SG_A2_FI*	20	45	111.779	0.4026
U_SG_A4_FI*	7	18	101.094	0.1781
R_SG_B2_FI*	1	0	2.973	0.0000
U_SG_B2_FI*	19	61	121.346	0.5027
U_SG_B4_FI*	5	10	28.834	0.3468
U_SG_D3en_FI*	22	33	55.150	0.5984
R_SG_D3ex_FI*	1	1	9.930	0.1007
U_SG_D3ex_FI*	43	87	321.774	0.2704
R_SG_D4_FI*	4	6	36.132	0.1661
U_SG_D4_FI*	48	162	418.641	0.3870
R_SG_A2_PDO*	2	1	11.752	0.0851
U_SG_A2_PDO*	20	58	168.034	0.3452
U_SG_A4_PDO*	7	29	149.689	0.1937
R_SG_B2_PDO*	1	1	7.704	0.1298
U_SG_B2_PDO*	19	66	195.695	0.3373
U_SG_B4_PDO*	5	9	55.186	0.1631
U_SG_D3en_PDO*	22	53	102.479	0.5172
R_SG_D3ex_PDO*	1	1	11.246	0.0889
U_SG_D3ex_PDO*	43	115	419.581	0.2741
R_SG_D4_PDO*	4	6	60.195	0.0997
U_SG_D4_PDO*	48	172	509.150	0.3378

Notes: The asterisk denotes that the facility type did not meet the HSM minimum annual crashes of 100 and the associated LCF should be used cautiously. “MV” stands for “multiple vehicle,” “SV” stands for “single vehicle,” “FI” stands for “fatal and injury,” “PDO” stands for “property damage only,” “ST” stands for “stop-controlled,” and “SG” stands for “signalized.” “R” and “U” refer to “rural” and “urban,” respectively. “A2,” “A4,” “B2,” “B4,” “D3en,” “D3ex,” and “D4” denote ramp terminal type.

Table 97 shows the result of comparison of SSD values for different sampling schemes for speed-change lanes. Disaggregation by area type (Scenario 1) could slightly worsen the crash prediction when applying HSM-default crash distribution and almost no changes when applying Maryland-specific crash distribution. The other two scenarios showed minor improvements (0.7%-1.8%). Application of Maryland-specific crash distribution improved predictions significantly in all scenarios (22.6%-23.3%) indicating a constant significant improvement upon application of locally derived crash distributions.

The results are also presented in Figure 111. Application of the Maryland-specific crash distribution is highly recommended but since there were not significant improvements by the results of disaggregation scenarios and many facility types did not meet the HSM sampling requirements, application of disaggregated LCFs is not recommended.

Table 97. Maryland Signalized Ramp Terminals LCFs – Comparing Different Scenarios based on All Samples' SSD (2008-2010)

Sc.	HSM Default Crash Distribution	MD-Specific Crash Distribution	% Change
HSM	3,283	2,541	-22.6%
Sc. 1	3,305	2,540	-23.1%
Sc. 2	3,224	2,494	-22.6%
Sc. 3	3,258	2,498	-23.3%
Sc.	**HSM Default Crash Distribution**	**MD-Specific Crash Distribution**	**% Change**
HSM	3,283	2,541	-22.6%
Sc. 1	3,305	2,540	-23.1%
% Change	0.7%	0.0%	
Sc.	**HSM Default Crash Distribution**	**MD-Specific Crash Distribution**	**% Change**
HSM	3,283	2,541	-22.6%
Sc. 2	3,224	2,494	-22.6%
% Change	-1.8%	-1.8%	
Sc.	**HSM Default Crash Distribution**	**MD-Specific Crash Distribution**	**% Change**
HSM	3,283	2,541	-22.6%
Sc. 3	3,258	2,498	-23.3%
% Change	-0.8%	-1.7%	

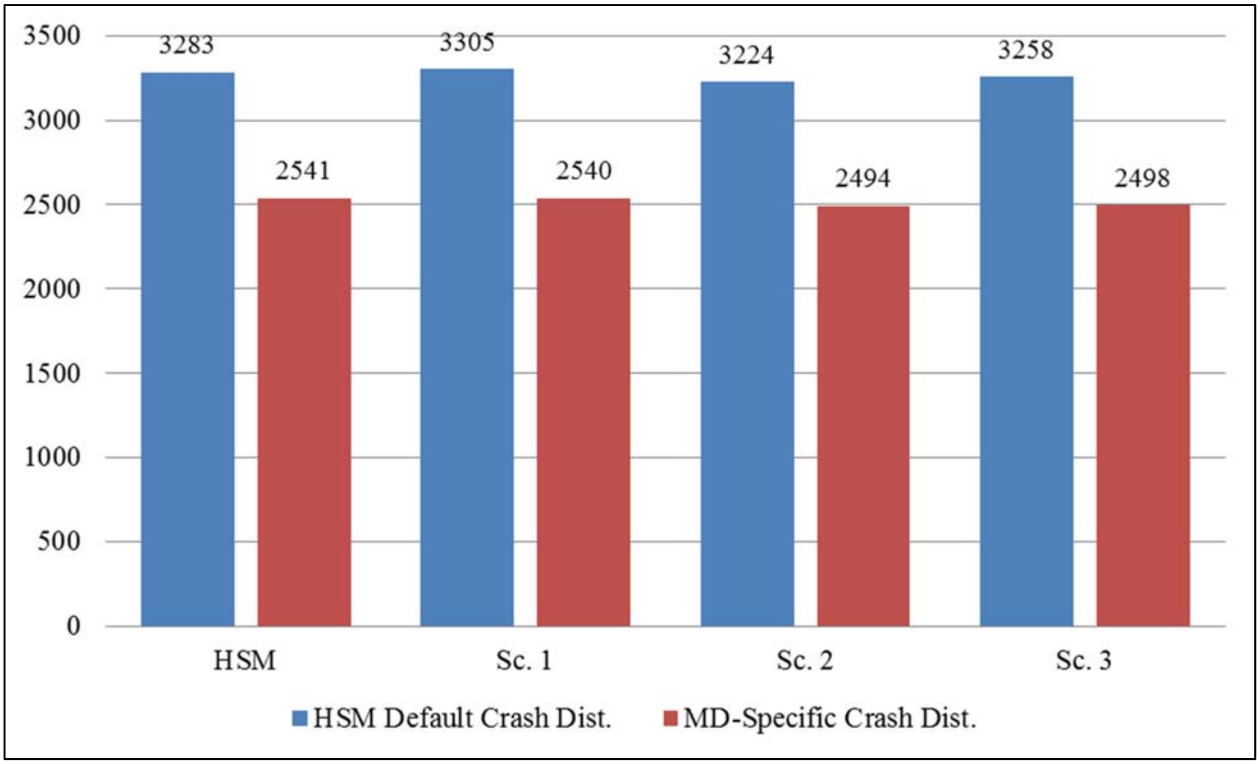

Figure 111. Maryland Signalized Ramp Terminals LCFs – Comparing Different Scenarios based on All Samples' SSD (2008-2010)

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