Michigan Urban Trunkline Segments Safety Performance Functions (SPFs) Development and Support

Final Report
July 2016

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16. Abstract

This study involves the development of safety performance functions (SPFs) for urban and suburban trunkline segments in the state of Michigan. Extensive databases were developed through the integration of traffic crash information, traffic volumes, and roadway geometry information. After these data were assembled, an exploratory analysis of the data was conducted to identify general crash trends. This included an assessment of the base models provided in the Highway Safety Manual (HSM), as well as a calibration exercise, which demonstrated significant variability in terms of the goodness-of-fit of the HSM models across various site types. Michigan-specific SPFs were estimated, including simple statewide models that consider only annual average daily traffic (AADT), as well as regionalized models which take into account regional differences in traffic patterns and roadway geometry. More detailed models were also developed, which considered additional geometric factors such as lane width, right and left shoulder widths, median width, driveway density, on-street parking driveway density by land use, school count, posted speed limit, and intersection and crossover density. Crash modification factors (CMFs) were also estimated, which can be used to adjust the SPFs to account for differences related to these factors. Separate SPFs were estimated for two-way arterials and one-way arterials. Additionally, severity distribution functions (SDFs) were estimated, which can be used to predict the proportion of injury crashes experienced. The SDFs may include various geometric, operation, and traffic variables that will allow the estimated proportion to be specific to an individual segment. Ultimately, the results of this study provide MDOT with a number of methodological tools that will allow for proactive safety planning activities, including network screening and identification of high-risk sites. These tools have been calibrated such that they can be applied at either the statewide level or within any of MDOT's seven geographic regions, providing additional flexibility to accommodate unique differences across the state. The report also documents procedures for maintaining and calibrating these SPFs over time, allowing for a consideration of general trends that are not directly reflected by the predictor variables.

17. Key Words

Safety performance function; segments; trunkline; crash modification factor

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10D	Ten-lane divided arterials
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3O	Three-lane one-way arterials
3SG	Three-leg signalized
3ST	Three-leg minor leg stop-controlled
3T	Three-lane arterials including a center two-way left-turn lane
4D	Four-lane divided arterials
4O	Four-lane one-way arterials
4SG	Four-leg signalized
4ST	Four-leg minor leg stop-controlled
4U	Four-lane undivided arterials
5T	Five-lane arterials including a center two-way left-turn lane
6D	Six-lane divided arterials
8D	Eight-lane divided arterials
AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
BMP	Beginning mile point
CARS	Crash Analysis Reporting System
CMF	Crash Modification Factor
DOT	Department of Transportation
EB	Empirical Bayes
EMP	End mile point
FHWA	Federal Highway Administration
FI	Fatal-and-injury
FMCSA	Federal Motor Carrier Safety Administration
GHSA	Governors Highway Safety Association
GIS	Geographic Information System
HSIP	Highway Safety Improvement Program
HSIS	Highway Safety Information System
HSM	Highway Safety Manual
IHSDM	Interactive Highway Safety Design Model
MCGI	Michigan Center for Geographic Information
MDOT	Michigan Department of Transportation
MiGDL	Michigan Geographic Data Library
MLD	Multilane divided
MLU	Multilane undivided
MMUCC	Model Minimum Uniform Crash Criteria
MP	Mile point
MPO	Metropolitan Planning Organization
MSP	Michigan State Police
MV	Multiple-Vehicle
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration

PDO	Property Damage-Only
PR	Physical Road
QA/QC	Quality Assurance/Quality Control
RAP	Research Advisory Panel
RHR	Roadside hazard rating
RTM	Regression to Mean
SDF	Severity Distribution Function
SPF	Safety Performance Function
SPR	State Planning and Research
SV	Single-vehicle
TWLTL	Two-way Left-Turn Lane
WSU	Wayne State University

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EXECUTIVE SUMMARY

Problem Statement

Federal legislation requires all states to have in place a Highway Safety Improvement Program (HSIP) that is data-driven and allows for proactive policies and programs aimed at improving highway safety by reducing the frequency and severity of traffic crashes. Given the prevailing focus on implementing roadway safety practices that are data-driven, there has been much research focused on gaining a more thorough understanding of how various factors affect the frequency, type, and severity of traffic crashes on specific roadway segments. Gaining a better understanding of these complex relationships provides traffic safety professionals with the ability to develop well-informed, targeted policies and programs to reduce traffic crashes and the resultant injuries and fatalities.

An important tool in this process is the American Association of State Highway and Transportation Officials' (AASHTO) *Highway Safety Manual* (*HSM*). Part C of the *HSM* provides a series of predictive models that can be utilized to estimate the frequency of traffic crashes on specific road facilities as a function of traffic volume, roadway geometry, type of traffic control, and other factors. These models, referred to as safety performance functions (SPFs), are useful for estimating the safety impacts of site-specific design alternatives or for prioritizing candidate locations for safety improvements on a network basis. As a part of this process, these SPFs can also be integrated with decision support tools, such as *Safety Analyst* and the *Interactive Highway Safety Design Model* (*IHSDM*).

While the SPFs presented in the *HSM* provide a useful tool for road agencies, it is recommended that these functions are either calibrated for local conditions or re-estimated using local data to improve their accuracy and precision. A variety of states have conducted research to this end, demonstrating that the accuracy of the SPFs from the *HSM* varies considerably from state to state, a result that may be reflective of differences in geography, design practices, driver behavior, crash reporting requirements, or other factors. The variation in the performance of HSM SPFs across jurisdictions motivates the need for Michigan-specific SPFs, which will allow the Michigan Department of Transportation (MDOT) to more efficiently invest available safety resources.

Study Objectives

Ultimately, this project aimed to develop a uniform and consistent approach that can be applied to estimate the safety performance of urban trunkline segments at the aggregate (i.e., total crash), crash type, and crash severity level. The product of this research provides important guidance to allow MDOT to make informed decisions as to planning and programming decisions for safety projects. The specific study objectives addressed as a part of this project in order to meet this goal are as follows:

1. Review and summarize previous and existing efforts to generate Safety Performance Function(s) for agencies.
2. Identify sites for the following urban segment types from existing Safety Analyst output:
    a. Urban Trunkline Two-Lane Undivided
    b. Urban Trunkline Three-Lane Undivided
    c. Urban Trunkline Four-Lane Undivided
    d. Urban Trunkline Four-Lane Divided
    e. Urban Trunkline Five-Lane Undivided
    f. Urban Trunkline Six-Lane Divided
    g. Urban Trunkline Eight-Lane Divided
    h. Urban Trunkline One-Way
3. Develop SPFs for each of the urban segment types listed above.
4. Define a maintenance cycle and process for updating SPFs

Data Collection

In order to develop a series of SPFs that will provide an accurate prediction of the safety performance of urban trunkline intersections, it was imperative to develop a robust, high-quality database, which includes traffic crash information, traffic volumes, and roadway geometry. These data were obtained from the following sources:

- Michigan State Police Statewide Crash Database;
- MDOT Sufficiency File;
- Michigan Geographic Data Library (MiGDL) All Roads File;
- MDOT Driveway File;
- WSU Curve Database;
- WSU Intersection Inventory; and
- Google Earth.

In addition to traffic volume, crash data, and a number of roadway geometric variables, crossover count and traffic control information was collected using aerial imagery.

These data were aggregated to develop a comprehensive database of segments over the five-year study period from 2008 to 2012. The final sample was comprised of the following number of locations by site type:

- 489 two-lane undivided (2U) segments;
- 236 three-lane (3T) segments;
- 373 four-lane undivided (4U) segments;
- 439 four-lane divided (4D) segments;
- 239 five-lane (5T) segments;
- 119 six-lane divided (6D) segments;
- 166 eight-lane divided (8D) segments
- 189 One-Way (OW) segments.

Data Analysis

After the data were assembled, an exploratory analysis of the data was conducted separately for each segment type to identify general crash trends using Michigan-specific data. Subsequently, a series of analytical tools were developed, which will allow MDOT to predict the frequency of crashes at each of the eight types of segments noted above.

First, the base SPFs from the Highway Safety Manual (HSM) were applied to the Michigan data. A calibration exercise illustrated that the models, without calibration, provided inconsistent fit across site types, crash types, and severity levels. After the calibration exercise, a series of Michigan-specific SPFs were developed. These SPFs included a series of statewide simple models which consider only annual average daily traffic (AADT) estimates as well as a series of regionalized models, which account for differences in traffic, environment, and roadway geometry.

Lastly, more detailed SPFs were estimated that considered traffic volume, speed limits, functional class, as well as numerous roadway geometric variables. These detailed statistical models may be utilized to account for the effects of this wide range of factors as they provide the greatest degree of accuracy. Separate SPFs were estimated for two-way and one-way arterials, and for those where at least one of the intersecting streets was one-way, as the factors affecting traffic safety were found to vary between these site types. The SPFs can be used to estimate the average crash frequency for stated base conditions, which are as follows:

- Tangent, straight (no horizontal curves),
- Flat (0% grade) roadway segments,
- 12-feet lane,
- 6-feet paved shoulder,
- No illumination,
- No passing lanes,
- No rumble strips,
- No two-way left-turn lane (TWLTL),
- Up to 5 driveways/mile,
- No automated speed enforcement,
- Typical roadside hazard rating (RHR) of 3 (i.e., clear zone about 10 feet; sideslope about 1V:3H, marginally recoverable).

Crash modification factors (CMFs) are then used to adjust the SPF estimate when the attributes of the subject site are not consistent with the base conditions. Several variables were incorporated in the development of the SPFs and CMFs including AADT, MDOT region, lane width, right and left shoulder widths, median width, driveway density, on-street parking driveway density by land use; school count, posted speed limit, and intersection and crossover density. All of the models developed as a part of this project were calibrated such that they can be applied at either the statewide level or within any of MDOT's seven geographic regions.

The SPFs can be used to predict the vehicle-involved crash frequency (i.e. single- and multi-vehicle crashes), as well as the number of pedestrian- or bicycle-related crashes as a proportion of vehicular crashes. Similar proportion data are provided for collision types, which can be used to disaggregate multi-vehicle crashes into various categories (e.g. rear-end, head-on, angle, etc.).

In addition to the Michigan-specific SPFs and CMFs, severity distribution functions (SDFs) were also developed for predicting the proportion of injury crashes that occur across different injury severity levels. The SDFs can be used with the SPFs to estimate the expected crash frequency for each severity category. The SDFs may include various geometric, operation, and traffic variables that will allow the estimated proportion to be specific to an individual segment.

Conclusions

Ultimately, the results of this study provide MDOT with a number of methodological tools for performing proactive safety planning activities such as network screening and identification of sites with the largest potential for safety improvement. These tools have been calibrated such that they can be applied at either the statewide level or within any of MDOT's seven geographic regions, providing additional flexibility to accommodate unique differences across the state.

In addition to these tools, this study also provides important insights into various aspects of MDOT's existing data systems. This includes the identification of various quality assurance/quality control issues, as well as the development of methods for effectively integrating available resources for safety analyses.

This report also documents the procedure for maintaining and calibrating these SPFs over time. Calibration will allow MDOT to account for yearly changes in traffic volumes and general trends in crashes over time that are not directly reflected by the predictor variables (e.g., recent declines in crashes at the statewide level). As MDOT continues to build its data system, the use of additional geographically-referenced geometric, operational, and traffic control data will allow for further refinements to these analytical tools.

1.0 INTRODUCTION

Recently, significant resources have been invested by transportation agencies to develop decision support tools that allow for proactive safety management. These efforts are consistent with federal requirements that State departments of transportation (DOTs) establish a Highway Safety Improvement Program (HSIP) that "emphasizes a data-driven, strategic approach to improving highway safety on all public roads that focuses on performance" [1].

The American Association of State Highway and Transportation Officials (AASHTO) *Highway Safety Manual* (*HSM*) provides a general framework that outlines methods by which DOTs and other road agencies can conduct quantitative safety analyses [2]. These analyses may include: predicting the number of traffic crashes, injuries, and fatalities expected to occur at a given location; estimating the impacts of various crash countermeasures; or evaluating the effectiveness of specific countermeasures or safety programs.

Part C of the *HSM* provides a series of crash prediction models that can be used to estimate the number of traffic crashes that would occur on specific road segments as a function of traffic volumes, segment length, roadway cross-sectional characteristics, and other factors. These models, which are referred to as safety performance functions (SPFs) can be integrated with various other decision support tools, such as *Safety Analyst* and the *Interactive Highway Safety Design Model* (*IHSDM*). It is important to note the *HSM* recommends these SPFs are either calibrated for local conditions or re-estimated using local data to improve their accuracy and precision [2]. A variety of states have conducted research to this end, including Colorado, Florida, Georgia, Illinois, Kansas, North Carolina, Oregon, Utah, and Virginia [3] [4] [5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15]. Collectively, these studies have shown that the accuracy of the SPFs from the *HSM* vary considerably from state to state, a result that may be reflective of differences in geography, design practices, driver behavior, differences in crash reporting requirements, or other factors.

This study involved the estimation of SPFs for urban and suburban trunkline segments under the jurisdiction of the Michigan Department of Transportation (MDOT). These SPFs were developed using a robust database that combined traffic volume, roadway geometry, and other support information from a diverse set of integrated databases.

In addition to the SPFs, a spreadsheet tool was developed that automates the processes used to estimate the frequency and severity of crashes by type for each segment category. Ultimately, these resources will allow MDOT to more effectively conduct proactive safety management, including the identification of high-risk locations and the selection of cost-effective countermeasures. These resources also provide a more thorough understanding of those factors affecting safety on Michigan roadways.

1.1 Background

The first edition of the *HSM* includes separate families of SPFs for three specific facility types: (1) Rural Two-Lane, Two-Way Roads; (2) Rural Multilane Highways; and (3) Urban and Suburban Arterials. Chapters 10, 11, and 12 of the *HSM* provide full details of the SPFs for these respective facility types, which were developed based upon the results of empirical studies [16] [17] [18] [19] [20] [21]. Subsequent research that will be integrated into the second edition of the *HSM* has analyzed other facility types, which include freeways and interchanges [22], as well as six-lane and one-way urban and suburban arterials [23].

Within each facility type, separate SPFs have been developed for intersections and road segments. For both location types, these SPFs can be used to estimate the total number of crashes expected during a given time period (typically one-year) under "base" conditions. Similar to the nomenclature from the *Highway Capacity Manual* [24], these base conditions generally refer to roadways with standard design elements (e.g., 12-ft lane widths). The *HSM* SPFs have been statistically estimated such that any variation from these base conditions is then captured in the form of crash modification factors (CMFs), which provide an estimate of the expected change in crash frequency that would correspond to specific changes in these baseline conditions (e.g., decreasing lane widths from 12 ft. to 11 ft.). The "base" SPFs provided in the *HSM* have been generally developed using data from the *Highway Safety Information System* (*HSIS*) [16] [17] [18] [19] [20] [21]. Table 1 provides a summary of the data used to develop the SPFs for urban and suburban arterial segments, which are presented in Chapter 12 of the HSM.

Table 1 shows that separate models have been developed for five different types of road segments:

- Two-lane undivided arterials (2U)
- Three-lane arterials including a center two-way left-turn lane (TWLTL) (3T)
- Four-lane undivided arterials (4U)
- Four-lane divided arterials (i.e., including a raised or depressed median) (4D)
- Five-lane arterials including a center TWLTL (5T)

Table 1. Data Used in the Development and Validation of SPFs for Urban and Suburban Arterial Segments in the *Highway Safety Manual* [20] [21]

Site Type	No. of Sites	State		Site Type	No. of Sites	State
2U	577	MN		4D	140	MI
3T	380	MN		5T	549	MI
4U	741	MN		2U	286	WA
4D	540	MN		3T	47	WA
5T	198	MN		4U	106	WA
2U	590	MI		4D	54	WA
3T	100	MI		5T	371	WA
4U	440	MI				
Note: (2U) two-lane undivided roads; (3T) three-lane roads w/TWLTL; (4U) four-lane undivided roads; (4D) four-lane divided roads; (5T) five-lane roads w/TWLTL						

It should be noted that these models were all developed and validated using data from three states. Given differences in drivers, roadways, and environmental conditions, it is unclear how well these SPFs would predict safety performance for urban trunkline road segments throughout Michigan, though some of the segments were located in Oakland County. Since the publication of the *HSM*, recent studies have involved the analysis of local data from more than ten states [3] [4] [5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15]. Collectively, these studies have indicated that direct application of the SPFs from the HSM does not tend to provide accurate results without either careful calibration or re-estimation using local data. These findings suggest that SPFs should be developed that are unique to Michigan's urban trunkline road segments.

In addition to providing tools to predict the total number of crashes on a given road segment, the *HSM* also presents methods to obtain estimates of crashes by type and injury severity level. The ability to provide estimates at this disaggregate level is important for several reasons. First, specific safety treatments often have differential effects on crashes by type or severity. For example, the installation of a cable median barrier may decrease the frequency of severe injury crashes, while increasing property-damage-only (PDO) crashes. If reliable estimates are available at the crash type level, road agencies will be able to more precisely estimate potential cost savings that coincide with implementation of a specific treatment. The provision of crash estimates by severity level is similarly important since safety treatments are generally given higher priority at those locations that are more prone to severe crashes.

While several methodological approaches could conceivably be utilized to provide such disaggregate level estimates, there are three distinct approaches considered in the HSM:

1. In Chapters 10 and 11, the total expected number of crashes are estimated for each location. These totals are then disaggregated based upon aggregate-level proportions provided by default collision type and crash severity distributions [24].

2. In Chapter 12, separate SPFs are provided to estimate the total expected number of crashes by aggregate crash type (e.g., single- and multi-vehicle, pedestrian, and bicycle-involved). Separate SPFs are also provided for fatal-and-injury (FI) crashes and property-damage-only (PDO) crashes. Chapter 11 of the HSM also presents separate SPFs for FI and PDO crashes.

3. More recently, *National Cooperative Highway Research Program (NCHRP) 17-45* has utilized a third approach, which involves the estimation of the total expected number of crashes for each location. In addition to this estimate, the proportions of crashes by collision type and severity level are also estimated as a function of traffic volumes and road segment characteristics using discrete outcome models. The results of this two-step process are then combined to determine the expected number of crashes at each site by type and severity.

Beyond the statistical issues involved with SPF development, it must be noted that the *HSM* "is written for practitioners at the state, county, metropolitan planning organization (MPO), or local level" [25]. This is important to recognize because it is imperative that a balance is struck between the accuracy of a model and its usefulness to practitioners.

1.2 Objectives

This research aims to develop a uniform, consistent approach that can be applied to estimate the safety performance of urban trunkline intersections at the aggregate (i.e., total crash), crash type, and crash severity levels. The study results provide important guidance to allow MDOT to make informed decisions as to planning and programming decisions for safety projects. The specific objectives of this study are as follows:

1. Review and summarize previous and existing efforts to generate Safety Performance Function(s) for agencies.

2. Identify sites for the following urban intersection types from existing Safety Analyst output:
   a. Two-Lane Undivided (2U)
   b. Three-Lane (3T)
   c. Four-Lane Undivided (4U)
   d. Four-Lane Divided (4D)
   e. Five-Lane (5T)
   f. Six-Lane Divided (6D)
   g. Eight-Lane Divided (8D)
   h. One-Way (OW)

3. Develop SPFs for each of the urban road segment types listed above.

4. Define a maintenance cycle and process for updating SPFs.

1.3 Report Structure

This report documents the activities involved in the development of safety performance functions (SPFs) and crash modification factors (CMFs) for Michigan urban and suburban road segments. The report is divided into six chapters. Chapter 2 provides a summary of the state-of-the-art research literature. Chapter 3 describes the data collection, including details of the data sources and activities involved in database development. Chapter 4 provides a preliminary visual analysis of the data, as well as a brief summary of the statistical methods utilized as a part of this study. Chapter 5 presents some preliminary results, which includes simple regression models using only AADT and MDOT region as predictor variables. Chapter 6 presents more detailed SPFs that consider a variety of geometric factors. The chapter also presents a series of CMFs, as well as details of severity distribution functions (SDFs) that are used to estimate crashes by severity. Chapter 7 discusses calibration and maintenance processes for updating the SPFs over time. This chapter also provides a demonstration of how crash frequency can be estimated for a given intersection. Conclusions and directions for future research are discussed in Chapter 8.

2.0 LITERATURE REVIEW

Given the current emphases on data-driven strategic approaches for safety analysis, a priority area at the national level has been the identification of high-risk intersections and road segments. Site identification is a critical component of a safety improvement program, and the effective identification of sites that are candidates for improvements can be costly [26]. Historically, a variety of methods have been used to identify and prioritize candidate sites for safety treatments. These have largely included simple methods such as the ranking of sites based upon system-wide crash frequency or crash rate data. There are several drawbacks to such approaches. For example, considering only crash frequency tends to ignore sites with low traffic volumes while using crash rates tends to disproportionately prioritize very low volume sites [27]. The use of crash rates also implicitly assumes a linear relationship between crashes and traffic volume, which is not necessarily well supported by safety research [28]. However, due to minimal data requirements, these methods are still widely used by DOTs in site screening and crash hot spot identification [29] [30].

A bigger concern is that, given the random nature of crashes on a location-by-location basis, short-term trends in crash frequency or rate are not necessarily good predictors of long-term crash frequency [29]. This concern relates largely to a phenomenon called regression-to-the-mean (RTM). In practical terms, RTM is demonstrated at roadway locations that experience particularly high short-term (e.g., one year) crash frequencies, followed by a decrease closer to the average of similar sites (i.e., regress to the mean) over the long term [30] [31]. To address such concerns, short-term site-specific crash counts can be combined with estimates from predictive regression models to develop more accurate estimates of long-term (i.e., future) safety performance. An important tool in this process is the AASHTO *Highway Safety Manual* (*HSM*) [2]. Part C of the *HSM* provides a series of predictive models, referred to as SPFs, which can be utilized to estimate the frequency of traffic crashes on specific road facilities as a function of traffic volume, roadway geometry, type of traffic control, and other factors.

2.1 Safety Performance Functions (SPFs) and Crash Modification Factors (CMFs)

SPFs establish a basis for evaluating roadway safety by considering the effects of traffic volume (AADT), roadway geometry, and other factors. For road segments, the following is a general formulation used to predict the number of crashes occurring on a given segment, N_{spf}:

$$N_{spf} = \exp(a + b \times ln(AADT) + ln(L)) \qquad (12-10)$$

where:

$AADT$ = average annual daily traffic volume (vehicles/day) on roadway segment;

L = length of roadway segment (mi); and

a, b = regression coefficients.

Although the HSM provides default SPF models, it is noteworthy that these models were developed using data from a few states. This makes the transferability of the SPFs a critical issue that needs to be handled by state agencies and DOTs when they attempt to implement these models. While these SPFs can be directly applied, the HSM recommends that the equations are either calibrated using local (i.e., state or regional) data or that jurisdiction-specific SPFs are developed. The calibrated model must sufficiently capture local road and traffic features [32]. Calibration of the SPFs is relatively straightforward, requiring the estimation of a calibration factor, *C*, as shown in the following equation:

$$N_{predicted} = N_{spf} \times C ,$$

where:

$N_{predicted}$ = predicted annual average crash frequency for a specific site;

N_{spf} = predicted average crash frequency for a site with base conditions; and

C = calibration factor to adjust SPF for local conditions.

This calibration factor is simply equal to the ratio of the number of observed crashes within the jurisdiction to the predicted number of crashes as estimated by the SPF. While calibration generally results in improved goodness-of-fit, research has shown that the suggested sample sizes for sites (30-50) and crashes (100 per year) in the HSM do not necessarily minimize predictive error in calibration [33].

In addition to calibration for local factors, it is also important to note that the SPFs from the HSM are estimated for "base" conditions. For example, the SPF for urban and suburban roadway segments assume the following base conditions:

- Tangent, straight (no horizontal curves),
- Flat (0% grade) roadway segments,
- 12-feet lane,
- 6-feet paved shoulder,
- No illumination,
- No passing lanes,
- No rumble strips,
- No two-way left-turn lane (TWLTL),
- Up to 5 driveways/mile,
- No automated speed enforcement,
- Typical roadside hazard rating (RHR) of 3 (i.e., clear zone about 10 feet; sideslope about 1V:3H, marginally recoverable).

At locations where base conditions are not met, the SPFs are multiplied by crash modification factors (CMFs), which adjust the SPF for non-base conditions as shown in the following equation:

$$N_{predicted} = N_{spf} \times C \times CMF_i \,,$$

where:

$N_{predicted}$ = predicted annual average crash frequency for a specific site;

N_{spf} = predicted average crash frequency for a site with base conditions;

C = calibration factor to adjust SPF for local conditions; and

CMF_i = crash modification factor for condition i.

These CMFs allow for crash estimates at locations that do not fit the "base" conditions. For example, the HSM provides a series of CMFs in Chapter 12 specific to intersections on urban and suburban arterials. Chapter 14 provides a catalog of various intersection CMFs based on prior empirical research. In addition, the Federal Highway Administration (FHWA) maintains the CMF Clearinghouse [34], a web-based database of CMFs that provides supporting documentation to assist users in estimating the impacts of various safety countermeasures.

2.2 Summary of State Efforts in SPF Calibration and Development

A recent study summarized the results of a nation-wide survey that was employed to assess the current status of safety analysis procedures at state departments of transportation [35]. The results of this survey demonstrated that most states experienced data-related issues that inhibited their ability to effectively conduct safety analyses. A Florida study cited that the data requirements of the HSM were challenging as many of the factors were not available in the state's roadway characteristics inventory database [36]. Similar results were found in Pennsylvania where several variables suggested in the *HSM* could not be included in SPFs due to lack of available data [37]. Several other studies have also identified data availability and completeness as hurdles in meeting the input requirements of the *HSM* and other related tools such as *Safety Analyst* [36] [37] [38]. A study in Georgia found that data quality and availability significantly affected the quality and reliability of SPFs [35]. Research in Kansas noted that the scarcity of intersection data did not allow for the development of separate models for 3-leg and 4-leg stop-controlled intersections [38]. Similarly, due to the lack of details on traffic control types within the Roadway Characteristic Inventory database, the analysis of unsignalized 3-leg and 4-leg intersections was not possible [39].

Specific areas of concern included a lack of sufficient data on traffic volumes and roadway characteristics, as well as a lack of geo-referenced spatial data [35]. In most states, traffic data is generally available for higher classes of roadways (e.g., interstates, state routes, etc.), but is limited for local and low volume roads [35] [39]. Research in Colorado found that volume data for side-streets were not generally available for more than one or two years, and in many cases the count data did not coincide with the study period [4]. Thus, it was necessary to normalize available side-street AADT data over the study period using growth rates derived from the mainline AADT volumes [4]. A study aiming to prepare Florida roads for deployment of Safety Analyst, upon reviewing the segment database, identified 13,000 segments which were missing volume data and were ultimately excluded from the analysis. Aside from this limitation, researchers collected volume data in different formats, including GIS, Excel, maps, and PDF. In some cases, AADT information had to be estimated through a travel demand model [39].

Table 1. Data Requirement [2]

Data element	Data Required	
	Required	Desirable
Segment length	X	
Presence of median	X	
Presence of center two-way left-turn lane	X	
Average annual daily traffic (AADT)	X	
Number of driveways by land-use type	X	
Low-speed vs. intermediate or high speed	X	
Presence of on-street parking	X	
Type of on-street parking	X	
Roadside fixed object density		X
Presence of lighting		X
Presence of automated speed enforcement		X

Table 1 shows the data elements required and desirable for SPF calibration. Aside from traffic volume information, several studies have documented limitations due to a lack of data, including a driveway count by land type, presence and type of parking, roadside fixed object density, presence of street lighting, and presence of automated speed enforcement [40] [14] [41] [33] [42] [43]. Due to absence of such data, certain studies resorted in manually collecting information through aerial imagery and other useful tools, which required significant effort and time. Due to the amount of effort required for data collection, certain studies only collected additional information for a subset of the facilities, thus not utilizing the entire population of sites for calibration or development [43], while others chose to exclude models from their analysis [41]. Other studies chose to use crash modification factors of 1.0 or default values from data utilized to develop urban and suburban SPFs for non-available variables [14] [41].

Another issue encountered by researchers when calibrating or developing SPFs for urban and suburban arterials was crash reporting thresholds. Research in Florida found that one of the limitations for computing calibration factors for urban roadways was the crash reporting system. The Crash Analysis Reporting System (CARS) database only includes long form reports filed for crashes involving injuries and/or fatalities. Short form reports are filed for property damage only crashes and are not coded in the CARS database. As a consequence, the researchers were able to develop calibration factors for fatal and injuries crashes, but not total crashes [14]. Similarly, in Oregon, drivers are responsible for filing a crash report if the crash results in property damage only. Aside from this, the crash reporting thresholds are higher in Oregon ($1,500) than the neighboring states of Washington and California ($700 and $750, respectively) [7]. This may cause a portion of PDO crashes not to be accounted for during calibration or development of SPFs. Underreporting of PDO crashes is also documented in a study by Shin et al. aiming to calibrate HSM SPFs for the state of Maryland [33]. A study in Riyadh, Saudi Arabia, aiming to calibrate HSM SPFs for urban 4-lane divided roads, examined only fatal and injury crashes. Non-injury crashes are collected by private agencies and are often not complete. The reporting threshold for crashes in Riyadh is $120 [44].

Despite these limitations, Table 2 shows a significant number of recent state-level efforts aimed at either calibrating the HSM SPFs or developing state-specific SPFs using local data. The table summarizes recent studies, including details of the types of segments that were considered as a part of each study, the number of sites that were included by type, and the number of years of data that were used for model calibration of estimation.

When examining SPF calibration for local conditions, there was significant variability in terms of whether the base models from the HSM over- or under-predicted crashes within specific states.

Research in Alabama [45] developed calibration factors for two-way two-lane rural roads and 4-lane divided roads based on the HSM calibration procedure, as well as utilizing a new methodology that considered the calibration factor as a part of the SPF. Both calibration factors overestimated crashes, however, and the HSM-recommended calibration method seemed to outperform the proposed new calibration method for these two types of facilities. A North Carolina study calibrated the HSM SPFs for five urban and suburban facilities and derived calibration factors ranging from 1.54 for 2-lane undivided segments to 4.04 for 4-lane undivided segments [9].

A study in Maryland [33] estimated mixed results in calibration of HSM SPFs of urban and suburban roadway segments. For total crash and fatal/injury crashes, the calibration factors showed that the HSM crash prediction models under-estimated crashes for 2-lane and 4-lane undivided segments and over predicted crashes for 3-lane and 5-lane with TWLTL segments. Also, 4-lane divided segment total crashes were underestimated while the fatal/injury crashes were overestimated. The researchers stated that the exclusion of Baltimore city may have biased the results of the study, especially during the calibration of the intersection crash prediction models.

Table 2. Summary of studies involving calibration or development of specific SPFs

Ref. #	State/ Country	Study Year	Site Type(s)	No. of Sites	No. of Years	Calibrated HSM SPFs	Jurisdiction Specific SPFs
[45]	AL	2012	4D	4000	4	Yes	Yes
[40]	AL	2015	2U, 3T, 4U, 4D, 5T	2613, 479, 1054, 3153, 1598	3	Yes	Yes
[14]	FL	2011	2U, 3T, 4U, 4D, 5T	5076, 709, 1251, 7506, 2868	5	Yes	Yes
[39]	FL	2012	2L, MLU, MLD	2038, 245, 6923	4	No	Yes
[6]	IL	2010	One-way, 2L, MLU, MLD	1263, 10091, 4285, 9118	5	No	Yes
[41]	LA	2015	2U, 3T, 4U, 4D, 5T	50, 32, 50, 50, 50	3	Yes	No
[33]	MD	2014	2U, 3T, 4U, 4D, 5T	7215, 537, 741, 5338, 276	3	Yes	No
[42]	MO	2013	2U, 4D, 5T	73, 66, 59	3	Yes	No
[46]	NJ	2013	2U	372	3	Yes	No
[9]	NC	2011	2U, 3T, 4U, 4D, 5T	59.39, 7.57, 15.29, 15.5, 12.46 (miles)	3, 5	Yes	Yes
[43]	OH	2015	2U, 3T, 4U, 4D, 5T	150, 150, 150, 150, 150	3	Yes	No
[7]	OR	2012	2U, 3T, 4U, 4D, 5T	491, 205, 375, 86, 323	3	Yes	No
[47]	OR	2001	Urban non-freeways	2257	2	No	Yes
[48]	PA	2016	2U, 4U, 4D,	530, 179, 306	5	No	Yes
[49]	TX	2008	2U, 4U, 2D, 4D, 6D, 8D	72, 140, 12, 492, 217, 9	3	Yes	No
[5]	VA	2010	2-lane (urban)	57605	5	No	Yes
[50]	WA	2004	4U	121.95 (miles)	4	No	Yes
[51]	Edmonton, Alberta	2014	Urban residential collectors	406	4	No	Yes
[52]	India	2013	Single and dual urban roads	141, 115	-	No	Yes
[44]	Saudi Arabia	2015	4D	172	3	Yes	Yes

Research in Louisiana determined that HSM SPFs significantly over-predicted crashes for 2-lane and 4-lane undivided segments and 4-lane divided segments, with calibration factors of 1.91, 1.59, and 2.54, respectively. On the contrary, crashes for 3-lane and 5-lane with TWLTL segments were severely underestimated, showing calibration factors of 0.26 and 0.06. Similarly, a study in Ohio underestimated crashes for all the urban segments in the HSM except 2-lane undivided segments, for which the calibration factor was 1.02. Statewide HSM model calibration in Missouri generally showed calibration factors less than 1.0, suggesting that Missouri facilities experienced fewer crashes than the national average [42]. The magnitude of these calibration factors was attributed to differences in crash definitions between Missouri and the states used as the basis for the *HSM*.

A study in Oregon estimated calibration factors for all five urban roadways included in the HSM. The calibration factors for urban segments were all less than 1.0 except for 4D segments. This could be indicative of the lack of 4-lane divided segments in Oregon urban areas; only 5.87 miles of this type of roadway were identified by the research team and used in the calibration data statewide. Thus, this calibration factor likely reflects 1) the small sample size, and 2) the difference between the higher design standards of the four-lane divided facilities in the HSM SPFs data set and the segments in the Oregon calibration set. The results of the calibration could also be attributed to the crash reporting system in Oregon, which allows drivers to not report crashes that result in vehicle damage of less than $1500.

Ultimately, it has been postulated that the differences in calibration factors are reflective of differences between individual jurisdictions and those states where the HSM models were developed [6] [9] [48] [51] [5] [11] [37] [50] [16] [18] [45].

Given the significant variability in predictive performance across regions, a number of states have developed SPFs specific to their jurisdictions. Research was conducted in Illinois [6] aiming to develop crash prediction models for crashes by severity level as well as a combination of all fatality and injury crashes. A multivariate analysis was also conducted to determine the importance of the 37 exposure variables considered in the study. Some variables had a larger impact than others, however, most were significant at a 90% confidence interval. The researchers also developed a Visual BASIC for Applications (VBA) tool to assist the department of transportation with future calibration of the newly developed SPFs as well as screening of the Illinois roadway network.

Safety performance functions were also developed as part of a study in North Carolina [9] for 16 roadway types, including urban 2-lane roads, urban multilane undivided roads, and divided roads. For 2-lane roads, the effect of volume was similar on the severity crash models.

In Pennsylvania [48], researchers developed regionalized crash prediction models to capture regional differences. SPFs were only developed for 2-lane undivided roads, 4-lane undivided roads, and 4-lane divided roads. The presence of center two-way left-turn lanes (TWLTLs) was incorporated within the SPFs for 2-lane undivided roads and 4-lane undivided roads as an indicator variable. The results showed that the degree of curvature was not statistically significant for the 4-lane undivided and divided segments, while it was statistically significant with a small impact for the 2-lane undivided segments. District level SPFs were also developed when possible and overall showed an improvement in performance when compared to the HSM SPFs.

Collectively, the domestic and foreign studies have indicated that direct application of the SPFs from the HSM (or other non-local source) does not tend to provide accurate results without either careful calibration or re-estimation using local data. Consequently, the primary purpose of this study was to develop a series of SPFs and other safety tools that can be used by MDOT as a part of their continuing traffic safety efforts.

3.0 DATA COLLECTION

Ultimately, the accuracy of an SPF depends largely on the quality of the data from which it is developed. The development of robust SPFs requires a crash database that is comprehensive and includes information on specific crash location, collision type, severity, and other salient factors. Roadway data is also important, including the physical features within the right-of-way. Roadway geometry data that are recommended for use in safety analyses include: lane width; shoulder width and type; horizontal curve length, radius, superelevation, grade, driveway density, and indicator variables for features such as auxiliary turn lanes [2].

In 2008, the Model Minimum Uniform Crash Criteria (MMUCC) guidelines were developed through the National Highway Traffic Safety Administration (NHTSA) in collaboration with the Governor's Highway Safety Association (GHSA), FHWA, Federal Motor Carrier Safety Administration (FMCSA), State DOTs, law enforcement agencies, and other traffic safety stakeholders. The MMUCC consists of a recommended minimum set of data elements for States to include in their crash forms and databases [53]. This set includes 110 data elements, 77 of which are to be collected at the scene, 10 data elements to be derived from the collected data, and 23 data elements to be obtained after linkage to driver history, injury, and roadway inventory data.

As a part of this study, the research team developed a comprehensive checklist of important data elements to be collected for the purposes of SPF development. As a starting point, an inventory file was developed based on yearly MDOT Sufficiency files. This file included location information for the following four types of site locations while Figure 1 indicates the total number of segments for each type considered for SPF development:

- 2-lane undivided roadways (2U)
- 2-lane divided roadways (2D)
- 3-lane undivided roadways (3U)
- 3-lane undivided roadways with presence of a two-way left turn lane (3T)
- 4-lane undivided roadways (4U)
- 4-lane undivided roadways with presence of a two-way left turn lane (4T)
- 4-lane divided roadways (4D)
- 5-lane undivided roadways with presence of a two-way left turn lane (5T)
- 6-lane undivided roadways (6U)
- 6-lane undivided roadways with presence of a two-way left turn lane (6T)
- 6-lane divided roadways (6D)
- 7-lane undivided roadways with presence of a two-way left turn lane (7T)
- 8-lane undivided roadways (8U)
- 8-lane divided roadways (8D)
- 10-lane divided roadways (10D)
- One-Way roadways

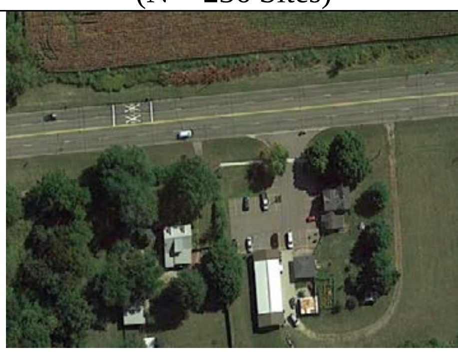
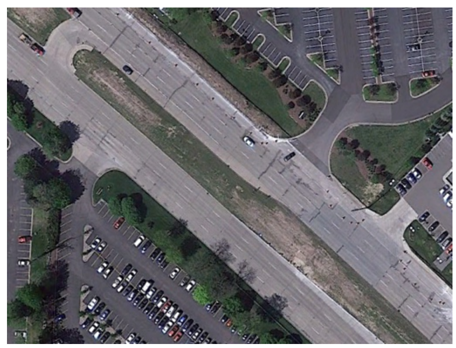
 2-lane undivided segments (N = 489 Sites)	 4-lane divided segments (N = 439 Sites)
 3-lane undivided segments with a TWLTL (N = 236 Sites)	 6-lane divided segments (N = 119 Sites)
 4-lane undivided segments (N = 373 Sites)	 8-lane divided segments (N = 166 Sites)
 5-lane undivided segments with a TWLTL (N = 239 Sites)	 One-way segments (N = 189 Sites)

Figure 1. Segment Site Types

For the purposes of SPF development, the HSM suggests a minimum sample size of 30 to 50 sites, which collectively experience a minimum of 100 total crashes per year. Several of the facility types did not have a sufficient sample size to be considered for SPF development (2D, 3U, 4T, 6U, 6T, 7T, 8U, and 10D). While the recommended number of sites were identified within most regions and site types, there are several regions where sufficient numbers of sites were not available as shown in Table 3. This was particularly true for 6D and 8D segments, which are mainly present in the Metro area.

Table 3. Sites by MDOT Region and Intersection Type

Segment	MDOT Region							
Type	Superior	North	Grand	Bay	Southwest	University	Metro	Total
One-Way	6	3	0	48	28	67	37	189
2U	66	48	54	61	105	108	47	489
3T	4	28	26	32	72	68	6	236
4U	45	7	116	20	54	66	65	373
5T	19	22	30	35	49	53	31	239
4D	49	37	51	62	64	80	96	439
6D	0	0	7	2	2	22	86	119
8D	0	0	2	0	0	2	162	166

Once segments were identified within each of the seven regions and eight site types, data were collected from existing data sources that were available either publicly or through MDOT. These data sources included the following databases and files:

- Michigan State Police Statewide Crash Database;
- MDOT Sufficiency File;
- Michigan Geographic Data Library (MiGDL) All Roads File;
- MDOT Driveway File;
- Wayne State University (WSU) Curve Database;
- WSU Intersection Inventory (prepared during a previous project); and
- Google Earth.

A quality assurance/quality control (QA/QC) process was implemented to verify the data in these sources using the MDOT PR Finder (http://www.mcgi.state.mi.us/prfinder/) and Google Earth. Further details of each respective data source is provided in the following sections of this report.

3.1 Michigan State Police Statewide Crash Database

The Michigan State Police (MSP) crash database contains details of all reported crash records in the state of Michigan. Records in this database are maintained at the crash-, vehicle-, and person-levels. There are a total of nine separate spreadsheets included in the database as illustrated in Figure 2.

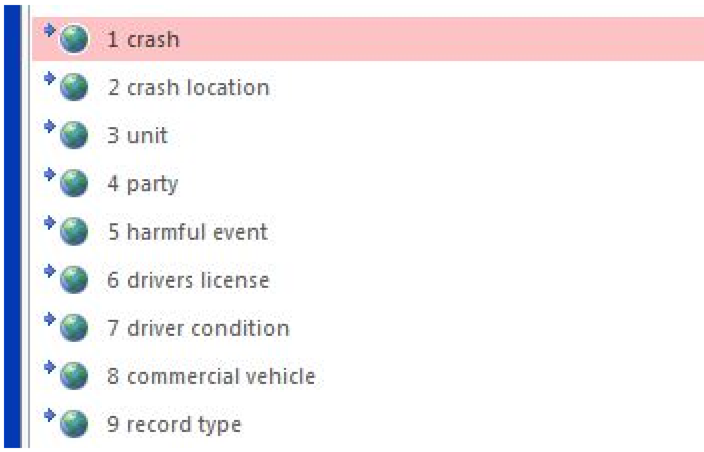


Figure 2. Spreadsheets of the MSP Crash Database

For the purposes of this report, only crash level data was needed from the "1 crash" and "2 crash location" files. These sheets were linked in Microsoft Access using the "crsh_id" field, as shown in Figure 3.

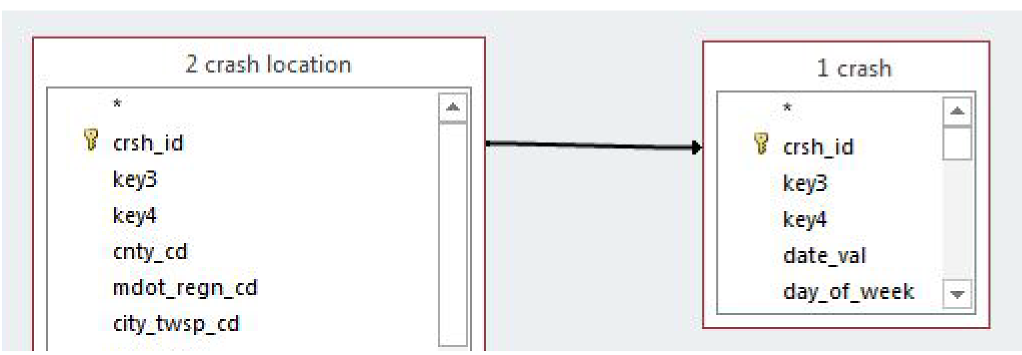


Figure 3. Joining of the MSP Crash Database Sheets

After joining the two sheets together, the information relevant to the report was exported. The relevant fields are defined below.

- crsh_id- unique identifier for each crash, and was used as the basis for linking the spreadsheets
- date_val-contains the date the crash occurred, which allowed the crash to be assigned to a particular year
- fatl_crsh_ind-identifies the crash as having at least one fatality
- num_injy_a-total number of people sustaining “A level” injuries in the crash
- num_injy_b-total number of people sustaining “B level” injuries in the crash
- num_injy_c-total number of people sustaining “C level” injuries in the crash
- prop_damg_crsh_ind-identifies the crash as being property damage only (PDO)
- crsh_typ_cd-defines the crash as single-vehicle or one of nine multiple-vehicle collision types
- rdwy_area_cd-indicates where on the roadway a crash occurred, allows for differentiation between intersection-related and non-intersection-related crashes.
- ped_invl_ind-indicates that a pedestrian was involved in the crash
- bcyl_invl_ind-indicates that a bicycle was involved in the crash
- intr_id-assigns the crash to a specific segment in the Calibration file
- PR-identifies the Physical Road on which the crash occurred
- MP-identifies the mile point along a Physical Road where a crash occurred

As was previously mentioned, this analysis was focused on “crash” level data. Crashes were defined based on the most significant injury sustained by anyone involved in the incident. Additionally, non-intersection related crashes were selected for the purposes of the analysis; the selection of non-intersection crashes was made possible through a field within the crash data called “mdot_area_type_cd” by selecting the “Mid-block” option. Crashes involving bicycles or pedestrians were separated from vehicle-only crashes for the purpose of the data analysis.

3.2 MDOT Sufficiency File

MDOT sufficiency files were made available for the years 2004 through 2014. The sufficiency files contain 122 fields for the state maintained roads in Michigan. The data is broken into segments of varying length. These segments are identified through a SuffID, a unique ID given to each segment. Additionally, the segments are identified through Physical Road (PR), Beginning Mile Point (BMP), and End Mile Point (EMP) coordinates. These three characteristics are used for geographically mapping the segments in ArcGIS and finding the segments through MDOT PR Finder and Google Earth.

3.3 Geographic Position from Michigan Geographic Data Library (MiGDL) All Roads file

In order to facilitate the use of Geographic Information System (GIS) software for this project, a GIS shapefile, allroads_miv13a.shp, was obtained from the Michigan Geographic Data Library through the Michigan Center for Geographic Information (MCGI) website. The file consists of all road segment statewide. Although the file has a total of 36 attribute fields, the following three were of particular use for this project:

- PR-Physical Road ID number
- BMP-Beginning PR mile point for linear referencing system
- EMP-Ending PR segment mile point

3.4 MDOT Driveway File

This file contains information about the number of driveways for each segment. Driveway density is calculated by dividing the total number of driveways by the segment length in miles. Driveway density was also separated in categories, namely, from 0-2, 2-5, 5-10, 10-20, 20-30, and 30 and more driveways/mile. Additional information is provided, such as the number of driveways per segment by type of driveway, including residential, commercial, industrial, field, private, other, and undefined.

3.5 WSU Curve Database

The curve information for each segment was obtained through a database created by WSU. The information includes number of curves with radii of up to 0.5 miles, length of the curved portion of the segment, fraction of segment length that is curved, and average radii of curves up to 0.5 miles for a segment. The information was organized in cumulative categories, decreasing in order of radii, from 0.5 mile radii to 0.088 mile radii.

3.6 WSU Intersection Inventory

An intersection inventory was developed during a prior project performed by WSU and funded by MDOT. The project developed SPFs for four types of intersections, 3ST, 3SG, 4ST, and 4SG, namely 3-leg with stop-control on the minor road, 3-leg signalized, 4-leg with stop control on the minor road, and 4-leg signalized intersection. The intersection inventory was developed through the utilization of the MDOT Calibration File. The intersections were represented with a PR and mile point (MP) and spatially matched to the segments. This was done to obtain the number of intersections and intersection density for each segment by type of intersection, namely, number of legs and intersection traffic control.

3.7 Data Review

Extensive data review was conducted to ensure that the final datasets included only urban and suburban segments categorized into their respective facilities and based upon the number of lanes and whether the two directions of roadway were separated by a painted or physical median. To begin, the rural segments were removed from the dataset. These were identified by the RURAL_URBAN field in the Sufficiency file. Next, the divided segments were separated from the undivided segments using the Direction field. Following that, the NUM_LANES field was used to separate the segments by the number of lanes. The TWLTL field was used to classify the segments that included a TWLTL for the undivided segments. The ROAD_TYPE field was used to separate out the one-way segments. When this process was completed, each segment was classified as one of the following road types: 2U, 3T, 4U, 5T, 4D, 6D, 8D, OW, and Other. The Other classification includes all the segments types with insufficient sample size (segments) for model development, namely 2D, 3U, 4T, 6U, 6T, 7T, 8U, and 10D segments. Due to their insufficient sample size as recommended by the HSM, these facilities were not considered for SPF development.

Each observation (row) of the assembled dataset represents one year of data for a specific segment; segments would have anywhere from one year to eleven years of data. For the purposes of the SPF development, the only segments considered for modeling were those with at least five years of data, selected as a sufficient number of years of data to develop robust SPFs while allowing for segments that experienced construction at the beginning or end of the total 11 year period to be included. A preliminary QA/QC process was used on the undivided facility types to ensure segments were classified appropriately. This involved a thorough QA/QC process on the 4U and 5T facility types, which had the highest percentage of incorrectly coded segments. Every segment originally assigned a 4U or 5T label for which five years of data were available were examined through the use of the Michigan PR Finder and Google Earth. Segments were categorized according to whether the segment was completely another facility type, mostly (>50%) another facility type, approximately 50% the listed type and 50% another type, mostly (>50%) the listed type, or completely the listed type. The segments that were completely or mostly of another facility type were reassigned to the appropriate facility type. Segments that were approximately half the listed type of facility were removed from the dataset. Using the historical aerial imagery in Google Earth, segments that experienced construction during any of the last five years were identified and removed from the dataset. Due to changes in the beginning and end mile points of the segments over the years, a number of segments of road were overrepresented. These were identified and only the most recent five years of observations were kept in the datasets. For each PR, any segments that overlapped were flagged in excel using a logic statement that compared the EMP of the previous segment to the BMP of the current segment. Any segments flagged in this way were manually reviewed and the newest five years of data were kept. These duplicates were typically caused by the MPs changing by 0.001 to 0.005 miles.

3.8 Manual Data Collection

Divided roadways in Michigan have different PR numbers for the opposing directions of travel. Due to the segmentation of the urban and suburban arterials, it was determined that the divided arterials would be analyzed directionally. This means that for each direction of travel of the divided road, there are five years of observations and data. This decision was made due to two constraints. The segmentation of some arterials did not often guarantee the same beginning and end mile point for the opposing direction of travel segments, thus hindering the linking of the two segments. Additionally, certain matching segments might not have been included in the final dataset due to lack of available data for five consecutive years or due to the presence of construction during one or more of the five years of data. Previous research recommends that due to differences in important geometric features such as grade, number of access points, or curvature, modeling for multilane divided roadways should be done by direction [50].

On certain divided roadways in the state of Michigan, vehicles are prevented from turning left at intersections. Instead, the vehicles have to travel downstream of the intersection and utilize a crossover for turning into the other direction of the roadway, and then making a right turn at the intended intersection or driveway (J-turn). Crossovers are channelized lanes that divert traffic from one direction of the roadway to the opposite direction, and they can be uncontrolled, yield controlled, stop controlled, or signalized. As a comprehensive database to classify these crossovers did not exist, an extensive review of the divided roadway facilities was conducted. Utilizing the MDOT PR Finder to identify the segments and Google Earth to collect aerial and street view information, the mile point information of each median crossover was collected as illustrated in Figure 4 below:

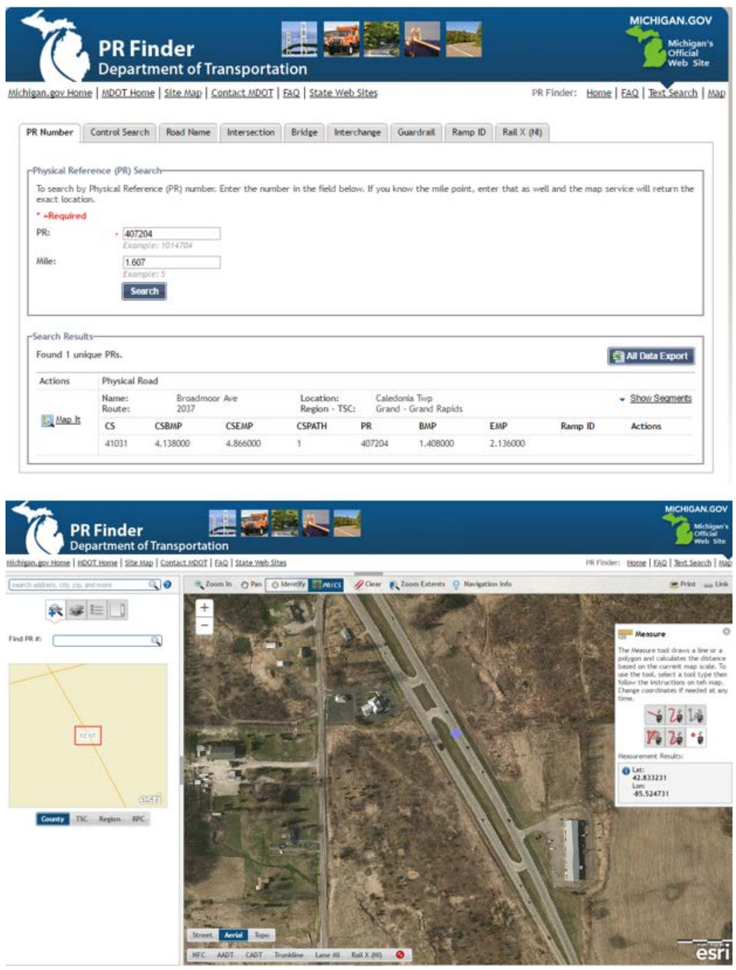


Figure 4. Screenshot of MDOT PR Finder utilization in the process of identifying crossover

Additionally, crossovers were classified based on whether they diverged or merged traffic from/into the segment of interest, traffic control type, and whether the crossover merged traffic into the opposite direction of the roadway, a driveway, or another roadway intersecting the segment of interest. Figure 5 illustrates diverging and merging crossovers:

Figure 5. Screenshot of a crossover on a 4D segment

Emergency crossovers were also recorded when they were identified; these were somewhat difficult to identify when signs were not present indicating the crossover was for use by authorized vehicles only. See Figure 6 for an example.

Figure 6. Emergency crossover example

Table 4 summarizes how the median crossover locations were classified based on the characteristics described previously.

Table 4. Classification of crossovers

Code	Description
O0	No traffic control, crossover merging traffic only in the opposite direction of roadway
O2	No traffic control, crossover merging traffic on a driveway
O4	No traffic control, crossover merging traffic into an intersecting roadway
Y0	Yield control, crossover merging traffic only in the opposite direction of roadway
Y2	Yield control, crossover merging traffic on a driveway
Y4	Yield control, crossover merging traffic into an intersecting roadway
0	Stop control, crossover merging traffic only in the opposite direction of roadway
2	Stop control, crossover merging traffic on a driveway
4	Stop control, crossover merging traffic into an intersecting roadway
1	Traffic signal, crossover merging traffic only in the opposite direction of roadway
3	Traffic signal, crossover merging traffic on a driveway
5	Traffic signal, crossover merging traffic into an intersecting roadway
9	Diverging crossover (diverging from the segment of interest)
E	Emergency crossover

Table 5 through Table 12 provide summary statistics for all relevant variables among all segment types considered in this report. Each table presents the minimum, maximum, mean value, and standard deviation for each variable of interest.

Table 5. Descriptive Statistics for Variables of Interest for 2-Lane Undivided Segments

Speed Limit	Less than 55 mph				55 mph			
Variable	Min	Max	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.
AADT	661	30145	8479	5085	234	26806	8547	5013
Segment length	0.01	4.77	0.75	0.72	0.20	5.63	1.18	0.88
Lane width	10.00	12.00	11.69	0.51	10.00	12.00	11.68	0.48
Right Shoulder Width	0.00	10.00	4.62	4.06	5.00	13.00	8.67	1.15
Left Shoulder Width	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Speed Limit	25.00	50.00	39.16	8.04	55.00	55.00	55.00	0.00
Driveway Count	0.00	413.00	32.14	42.79	0.00	402.00	29.52	40.47
Driveway Density	0.00	124.10	41.56	26.83	0.00	71.40	22.86	15.12
School Count	0.00	4.00	0.49	0.77	0.00	2.00	0.23	0.51
Commercial Vehicle %	0.35	32.01	3.72	2.93	0.48	32.07	4.47	2.83
Superior Region	0.00	1.00	0.17	0.38	0.00	1.00	0.09	0.29
North Region	0.00	1.00	0.07	0.26	0.00	1.00	0.13	0.34
Grand Region	0.00	1.00	0.10	0.30	0.00	1.00	0.12	0.33
Bay Region	0.00	1.00	0.13	0.33	0.00	1.00	0.12	0.33
Southwest Region	0.00	1.00	0.20	0.40	0.00	1.00	0.23	0.42
University region	0.00	1.00	0.19	0.39	0.00	1.00	0.26	0.44
Metro Region	0.00	1.00	0.14	0.34	0.00	1.00	0.04	0.20
Horizontal Curvature								
Count w/ radius < 0.500 mi	0.00	5.00	0.52	0.86	0.00	3.00	0.25	0.55
Length w/ radius < 0.500 mi	0.00	1.30	0.11	0.20	0.00	0.90	0.08	0.17
Length fraction w/ radius < 0.500 mi	0.00	1.00	0.16	0.27	0.00	1.00	0.08	0.20
3-Leg signalized intersection count	0.00	2.00	0.10	0.31	0.00	2.00	0.08	0.32
4-leg signalized intersection count	0.00	3.00	0.44	0.72	0.00	3.00	0.16	0.44
3-leg stop controlled intersection count	0.00	33.00	1.60	3.65	0.00	21.00	1.45	2.71
4-leg stop controlled intersection count	0.00	13.00	0.89	1.59	0.00	3.00	0.50	0.77

Table 6. Descriptive Statistics for Variables of Interest for 3-Lane Undivided with TWLTL Segments

Variable	Min	Max	Mean	Std. Dev.
AADT	2438	31024	11215	4529
Segment length	0.04	2.09	0.59	0.33
Lane width	11.00	12.00	11.91	0.29
Right Shoulder Width	0.00	12.00	3.32	4.17
Left Shoulder Width	0.00	0.00	0.00	0.00
Speed Limit	25.00	55.00	40.24	8.85
Driveway Count	0.00	92.00	26.08	19.16
Driveway Density	0.00	103.29	43.91	23.05
School Count	0.00	7.00	0.68	0.96
Commercial Vehicle %	0.68	32.00	3.64	2.54
Superior Region	0.00	1.00	0.02	0.13
North Region	0.00	1.00	0.12	0.32
Grand Region	0.00	1.00	0.11	0.31
Bay Region	0.00	1.00	0.14	0.34
Southwest Region	0.00	1.00	0.31	0.46
University region	0.00	1.00	0.29	0.45
Metro Region	0.00	1.00	0.03	0.16
Horizontal Curvature				
Count w/ radius < 0.500 mi	0.00	3.00	0.31	0.67
Length w/ radius < 0.500 mi	0.00	0.78	0.06	0.13
Length fraction w/ radius < 0.500 mi	0.00	1.00	0.11	0.25
3-Leg signalized intersection count	0.00	2.00	0.08	0.32
4-leg signalized intersection count	0.00	3.00	0.49	0.71
3-leg stop controlled intersection count	0.00	23.00	1.11	2.52
4-leg stop controlled intersection count	0.00	9.00	0.91	1.69

Table 7. Descriptive Statistics for Variables of Interest for 4-Lane Undivided Segments

Variable	Min	Max	Mean	Std. Dev.
AADT	3700	43824	13880	5901
Segment length	0.01	5.25	0.71	0.58
Lane width	10.00	12.00	11.33	0.66
Right Shoulder Width	0.00	12.00	1.63	3.43
Left Shoulder Width	0.00	0.00	0.00	0.00
Speed Limit	25.00	55.00	38.47	8.28
Driveway Count	0.00	278.00	32.81	34.05
Driveway Density	0.00	111.56	45.76	24.96
School Count	0.00	5.00	0.60	0.89
Commercial Vehicle %	0.59	21.00	3.44	2.42
Superior Region	0.00	1.00	0.08	0.27
North Region	0.00	1.00	0.09	0.29
Grand Region	0.00	1.00	0.13	0.33
Bay Region	0.00	1.00	0.15	0.35
Southwest Region	0.00	1.00	0.21	0.40
University region	0.00	1.00	0.22	0.42
Metro Region	0.00	1.00	0.13	0.34
Horizontal Curvature				
Count w/ radius < 0.500 mi	0.00	7.00	0.34	0.77
Length w/ radius < 0.500 mi	0.00	1.10	0.07	0.15
Length fraction w/ radius < 0.500 mi	0.00	1.00	0.10	0.21
3-Leg signalized intersection count	0.00	2.00	0.17	0.43
4-leg signalized intersection count	0.00	5.00	0.75	1.05
3-leg stop controlled intersection count	0.00	22.00	1.46	2.82
4-leg stop controlled intersection count	0.00	11.00	1.00	1.74

Table 8. Descriptive Statistics for Variables of Interest for 5-Lane Undivided with TWLTL Segments

Variable	Min	Max	Mean	Std. Dev.
AADT	4103	51235	20301	7878
Segment length				
Lane width	10.00	12.00	11.82	0.43
Right Shoulder Width	0.00	10.00	1.43	3.23
Left Shoulder Width	0.00	0.00	0.00	0.00
Speed Limit	25.00	55.00	43.03	7.19
Driveway Count	0.00	254.00	32.11	30.05
Driveway Density	0.00	96.00	40.10	21.27
School Count	0.00	6.00	0.48	0.86
Commercial Vehicle %	0.44	57.00	3.64	3.96
Superior Region	0.00	1.00	0.11	0.31
North Region	0.00	1.00	0.08	0.28
Grand Region	0.00	1.00	0.12	0.32
Bay Region	0.00	1.00	0.14	0.35
Southwest Region	0.00	1.00	0.15	0.35
University region	0.00	1.00	0.18	0.39
Metro Region	0.00	1.00	0.22	0.41
Horizontal Curvature				
Count w/ radius < 0.500 mi	0.00	4.00	0.19	0.51
Length w/ radius < 0.500 mi	0.00	1.23	0.05	0.14
Length fraction w/ radius < 0.500 mi	0.00	1.00	0.07	0.21
3-Leg signalized intersection count	0.00	4.00	0.13	0.46
4-leg signalized intersection count	0.00	8.00	0.56	0.99
3-leg stop controlled intersection count	0.00	56.00	0.77	3.14
4-leg stop controlled intersection count	0.00	10.00	0.39	1.08

Table 9. Descriptive Statistics for Variables of Interest for 4-Lane Divided Segments

Speed Limit	Less than 55 mph				55 mph			
Variable	**Min**	**Max**	**Mean**	**Std. Dev.**	**Min**	**Max**	**Mean**	**Std. Dev.**
AADT	2500	35820	10502	6094	1855	26716	9730	5257
Segment length	0.04	5.14	0.69	0.63	0.02	4.41	1.19	0.76
Lane width	11.00	12.00	11.78	0.41	11.00	12.00	11.83	0.38
Right Shoulder Width	0.00	12.00	5.28	4.88	0.00	11.00	9.15	1.32
Left Shoulder Width	0.00	10.00	3.34	3.69	0.00	10.00	6.46	2.05
Median width	2.00	550.00	49.46	80.97	10.00	196.00	50.77	27.91
Speed Limit	25.00	70.00	44.29	9.42	55.00	55.00	55.00	0.00
Driveway Count	0.00	66.00	5.25	9.47	0.00	72.00	6.28	10.82
Driveway Density	0.00	77.92	7.48	10.45	0.00	31.51	4.52	6.00
School Count	0.00	3.00	0.35	0.74	0.00	3.00	0.33	0.70
Commercial Vehicle %	0.55	32.08	4.46	3.69	1.00	14.98	5.22	3.07
Superior Region	0.00	1.00	0.08	0.28	0.00	1.00	0.14	0.35
North Region	0.00	1.00	0.05	0.21	0.00	0.00	0.00	0.00
Grand Region	0.00	1.00	0.26	0.44	0.00	1.00	0.34	0.47
Bay Region	0.00	1.00	0.07	0.25	0.00	1.00	0.04	0.21
Southwest Region	0.00	1.00	0.16	0.37	0.00	1.00	0.13	0.34
University region	0.00	1.00	0.14	0.35	0.00	1.00	0.20	0.40
Metro Region	0.00	1.00	0.23	0.42	0.00	1.00	0.14	0.34
Horizontal Curvature								
Count w/ radius < 0.500 mi	0.00	3.00	0.41	0.71	0.00	4.00	0.31	0.63
Length w/ radius < 0.500 mi	0.00	0.55	0.08	0.13	0.00	0.92	0.09	0.18
Length fraction w/ radius < 0.500 mi	0.00	1.00	0.16	0.28	0.00	1.00	0.13	0.27
3-Leg signalized intersection count	0.00	1.00	0.09	0.29	0.00	3.00	0.08	0.31
4-leg signalized intersection count	0.00	3.00	0.31	0.68	0.00	2.00	0.15	0.39
3-leg stop controlled intersection count	0.00	5.00	0.29	0.80	0.00	10.00	0.32	1.09
4-leg stop controlled intersection count	0.00	3.00	0.20	0.49	0.00	6.00	0.19	0.66
No traffic control crossovers	0.00	10.00	0.38	1.45	0.00	7.00	0.35	1.25
Yield controlled crossovers	0.00	7.00	0.45	1.32	0.00	15.00	1.03	2.22
Stop controlled crossovers	0.00	9.00	0.65	1.47	0.00	15.00	1.32	2.41
Signalized crossovers	0.00	3.00	0.11	0.39	0.00	4.00	0.22	0.58
Emergency crossovers	0.00	4.00	0.07	0.43	0.00	7.00	0.24	0.95

Table 10. Descriptive Statistics for Variables of Interest for 6-Lane Divided Segments

Variable	Min	Max	Mean	Std. Dev.
AADT	3499	77600	21381	10300
Segment length	0.13	3.01	0.84	0.59
Lane width	10.00	12.00	11.77	0.59
Right Shoulder Width	0.00	183.00	57.05	40.78
Left Shoulder Width	0.00	12.00	2.71	4.54
Median width	0.00	10.00	1.34	2.80
Speed Limit	25.00	55.00	44.13	7.18
Driveway Count	0.00	87.00	12.25	16.61
Driveway Density	0.00	51.87	12.31	12.22
School Count	0.00	4.00	0.60	0.87
Commercial Vehicle %	0.40	16.00	3.19	2.22
Superior Region	0.00	0.00	0.00	0.00
North Region	0.00	0.00	0.00	0.00
Grand Region	0.00	1.00	0.06	0.24
Bay Region	0.00	1.00	0.02	0.13
Southwest Region	0.00	1.00	0.02	0.13
University region	0.00	1.00	0.18	0.39
Metro Region	0.00	1.00	0.72	0.45
Horizontal Curvature				
Count w/ radius < 0.500 mi	0.00	2.00	0.38	0.64
Length w/ radius < 0.500 mi	0.00	0.53	0.07	0.13
Length fraction w/ radius < 0.500 mi	0.00	1.00	0.16	0.29
3-Leg signalized intersection count	0.00	2.00	0.12	0.35
4-leg signalized intersection count	0.00	5.00	0.39	0.78
3-leg stop controlled intersection count	0.00	20.00	1.08	2.92
4-leg stop controlled intersection count	0.00	5.00	0.27	0.86
No traffic control crossovers	0.00	2.00	0.03	0.20
Yield controlled crossovers	0.00	1.00	0.02	0.13
Stop controlled crossovers	0.00	11.00	2.24	2.37
Signalized crossovers	0.00	5.00	0.74	1.04
Emergency crossovers	0.00	0.00	0.00	0.00

Table 11. Descriptive Statistics for Variables of Interest for 8-Lane Divided Segments

Variable	Min	Max	Mean	Std. Dev.
AADT	6059	77600	24881	9401
Segment length	0.14	4.02	1.05	0.73
Lane width	10.00	12.00	11.69	0.58
Right Shoulder Width	0.00	12.00	0.81	2.81
Left Shoulder Width	0.00	10.00	0.48	1.91
Median width	14.00	183.00	60.29	29.61
Speed Limit	30.00	55.00	44.25	5.08
Driveway Count	0.00	102.00	21.13	21.58
Driveway Density	0.00	49.19	18.55	11.57
School Count	0.00	4.00	0.61	0.92
Commercial Vehicle %	0.54	10.45	2.56	1.50
Superior Region	0.00	0.00	0.00	0.00
North Region	0.00	0.00	0.00	0.00
Grand Region	0.00	1.00	0.01	0.11
Bay Region	0.00	0.00	0.00	0.00
Southwest Region	0.00	0.00	0.00	0.00
University region	0.00	1.00	0.01	0.11
Metro Region	0.00	1.00	0.98	0.15
Horizontal Curvature				
Count w/ radius < 0.500 mi	0.00	1.00	0.04	0.19
Length w/ radius < 0.500 mi	0.00	0.25	0.01	0.03
Length fraction w/ radius < 0.500 mi	0.00	0.26	0.01	0.03
3-Leg signalized intersection count	0.00	2.00	0.03	0.20
4-leg signalized intersection count	0.00	5.00	0.25	0.64
3-leg stop controlled intersection count	0.00	32.00	0.94	3.66
4-leg stop controlled intersection count	0.00	1.00	0.03	0.17
No traffic control crossovers	0.00	0.00	0.00	0.00
Yield controlled crossovers	0.00	0.00	0.00	0.00
Stop controlled crossovers	0.00	12.00	3.10	2.70
Signalized crossovers	0.00	8.00	1.11	1.35
Emergency crossovers	0.00	1.00	0.01	0.11

Table 12. Descriptive Statistics for Variables of Interest for One-Way Segments

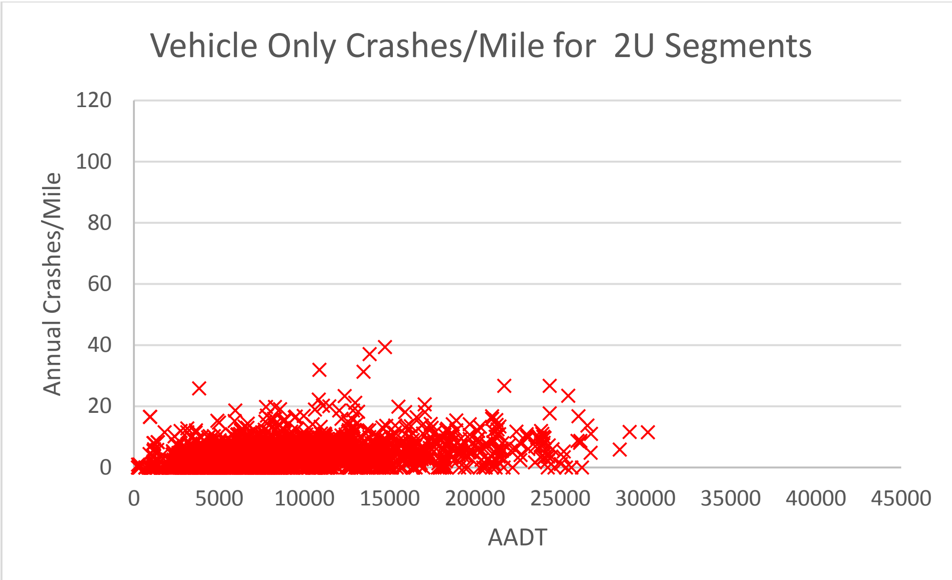
Variable	Min	Max	Mean	Std. Dev.
AADT	1212	27036	10736	4746
Segment length	0.04	1.32	0.38	0.28
Lane width	10.00	12.00	11.73	0.50
Right Shoulder Width	0.00	0.00	0.00	0.00
Left Shoulder Width	0.00	0.00	0.00	0.00
Speed Limit	25.00	45.00	33.97	4.73
Driveway Count	0.00	88.00	18.47	18.70
Driveway Density	0.00	123.38	45.35	31.05
School Count	0.00	3.00	0.70	0.88
Commercial Vehicle %	0.72	25.12	3.76	2.76
Superior Region	0.00	1.00	0.03	0.18
North Region	0.00	1.00	0.02	0.13
Grand Region	0.00	0.00	0.00	0.00
Bay Region	0.00	1.00	0.25	0.44
Southwest Region	0.00	1.00	0.15	0.36
University region	0.00	1.00	0.35	0.48
Metro Region	0.00	1.00	0.20	0.40
Horizontal Curvature				
Count w/ radius < 0.500 mi	0.00	4.00	0.44	0.78
Length w/ radius < 0.500 mi	0.00	0.85	0.07	0.14
Length fraction w/ radius < 0.500 mi	0.00	1.00	0.20	0.35
3-Leg signalized intersection count	0.00	1.00	0.03	0.18
4-leg signalized intersection count	0.00	5.00	0.67	0.99
3-leg stop controlled intersection count	0.00	10.00	0.43	1.24
4-leg stop controlled intersection count	0.00	11.00	0.80	1.72

4.0 PRELIMINARY ANALYSIS

After the database was assembled, a series of preliminary analyses were conducted to examine general trends across the sample of study locations. This included assessing the univariate relationships between traffic crashes and each prospective predictor variable. Correlation among predictor variables was also examined and provided insights for the subsequent estimation of the SPFs.

Figure 7 through Figure 10 provide summary plots of the crash per mile rate versus AADT for various site and crash types. These figures show that a non-linear relationship generally exists between traffic flow and the number of crashes. Crashes are shown to increase less rapidly at higher volumes, which is consistent with prior research in this area.

When examining these figures, there are several segment locations for various facility types that experienced significantly higher or lower numbers of crashes over the study period. As a part of the data collection process, careful quality assurance and quality control procedures were followed. This included a review of these potential outliers. Ultimately, all of the intersections included in the study were similar in terms of their geometric and traffic control characteristics. No sites were removed on the basis of their crash history during the study period. It is important to note that these figures represent only the effects of traffic volumes. Consequently, the effects of other important predictor variables are not reflected here. As an example, for all facilities, fewer crashes tended to be observed at locations where two or more schools were located nearby, despite the speed limit.



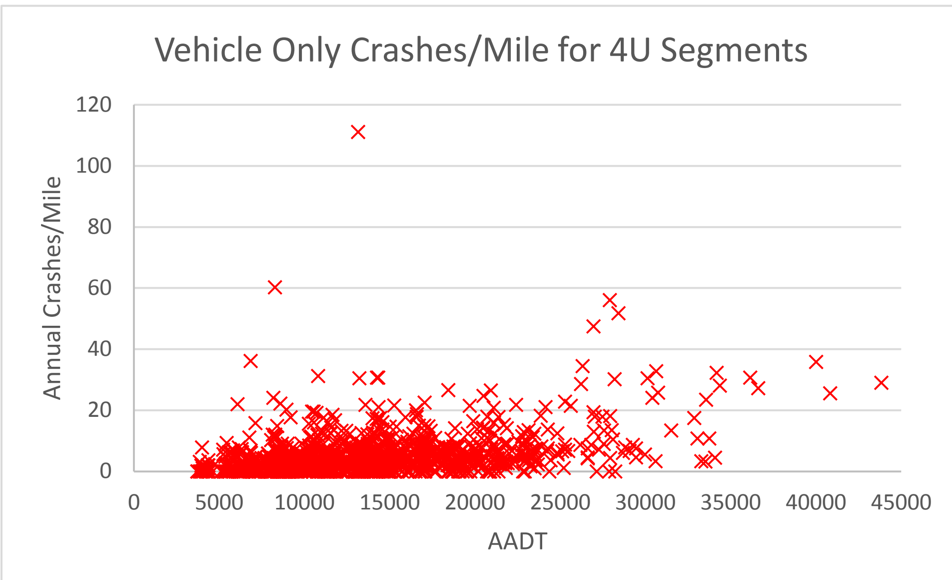
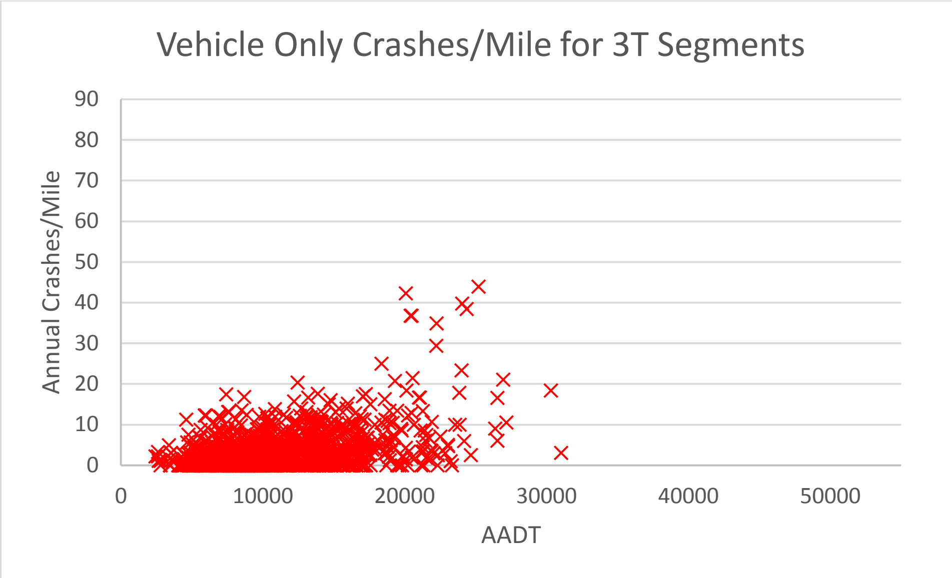


Figure 7. Relationship between Vehicle-Only Crashes/Mile and AADT for 2U and 4U Segments



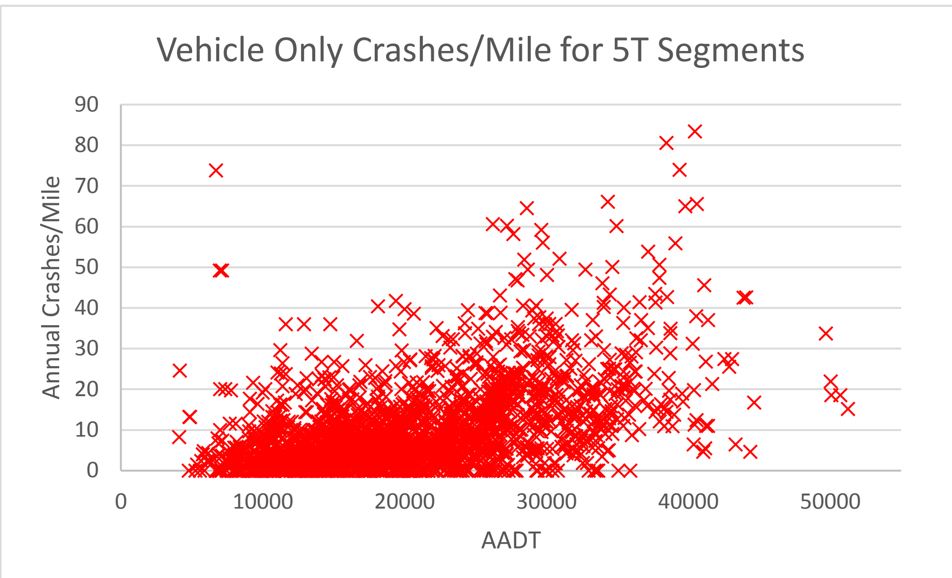


Figure 8. Relationship between Vehicle-Only Crashes/Mile and AADT for 3T and 5T Segments

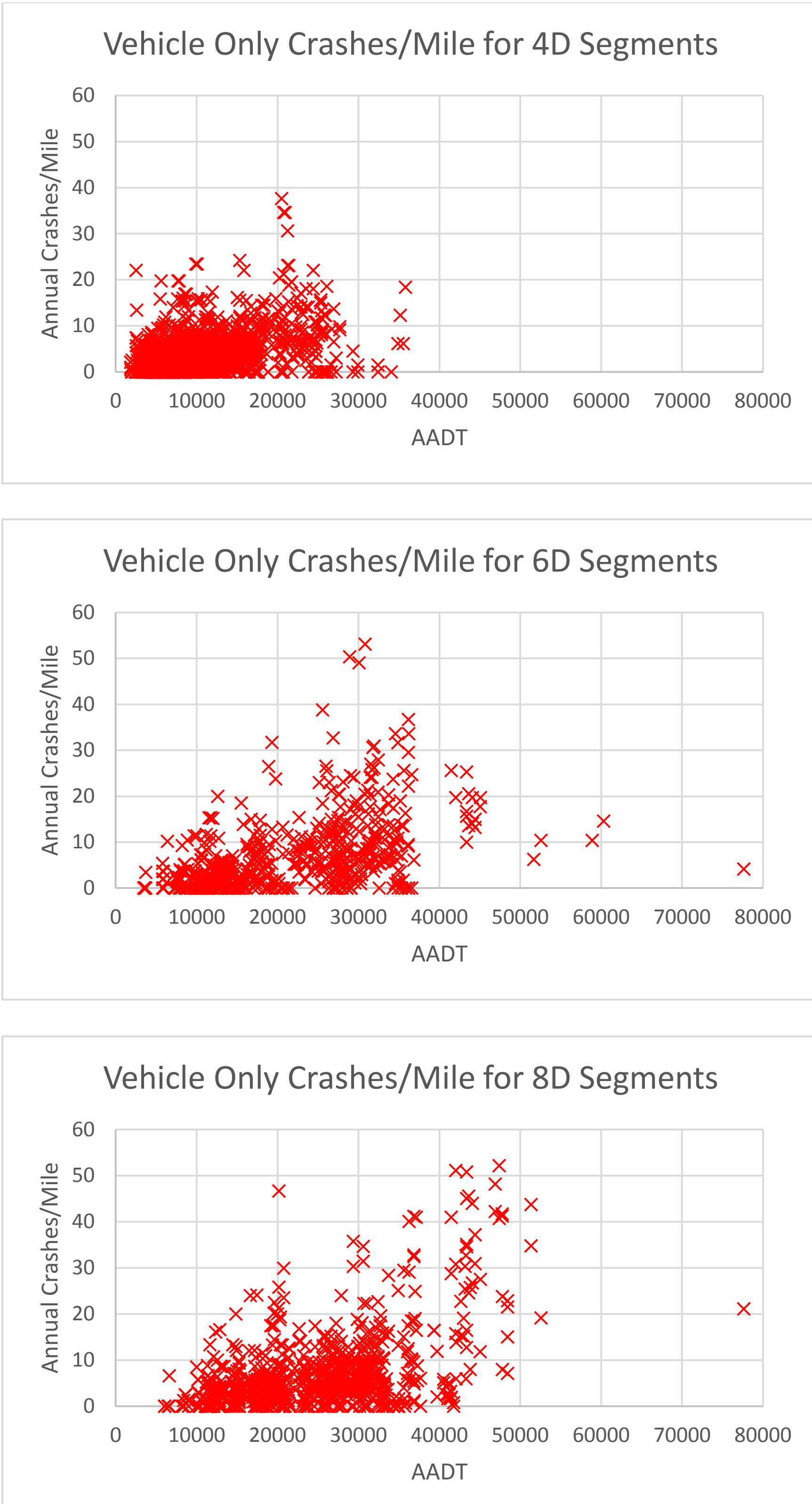


Figure 9. Relationship between Vehicle-Only Crashes/Mile and AADT for 4D, 6D, and 8D Segments

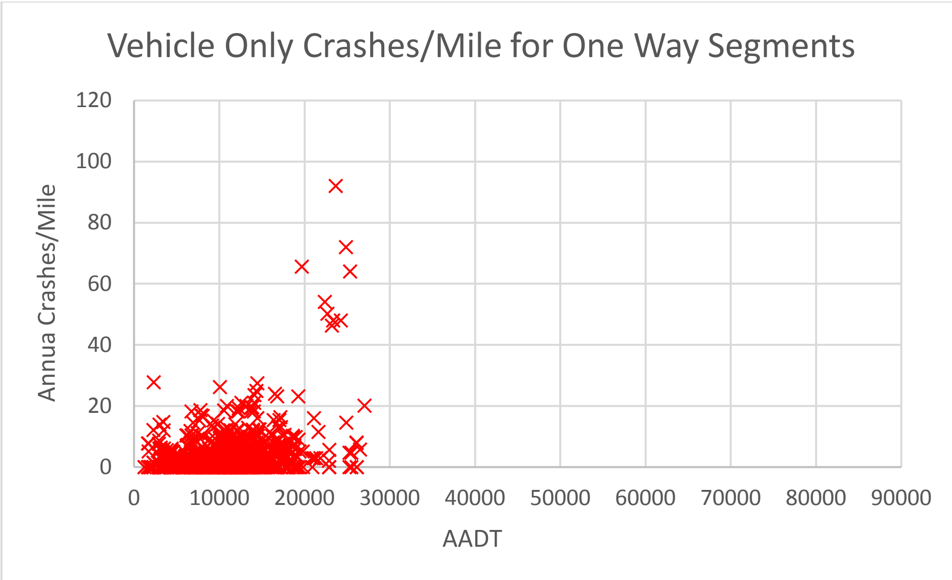
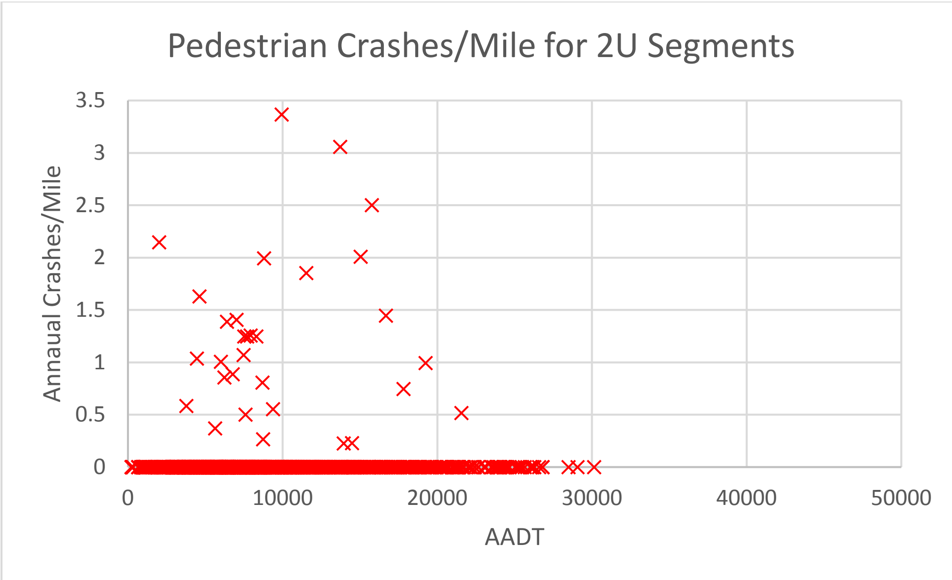


Figure 10. Relationship between Vehicle-Only Crashes/Mile and AADT for One-way Segments

Figure 11 through Figure 14 show the relationship between the rate of pedestrian crashes/mile and AADT, while Figure 15 through Figure 18 show the relationship between the rate of bicycle crashes/mile and AADT. For several of the facilities, more crashes involving non-motorized users occurred on roads with lower levels of AADT. This could reflect the fact that pedestrians and bicyclists prefer to ride on roads with less traffic, thus making these types of facilities more prone to experiencing non-motorized crashes.



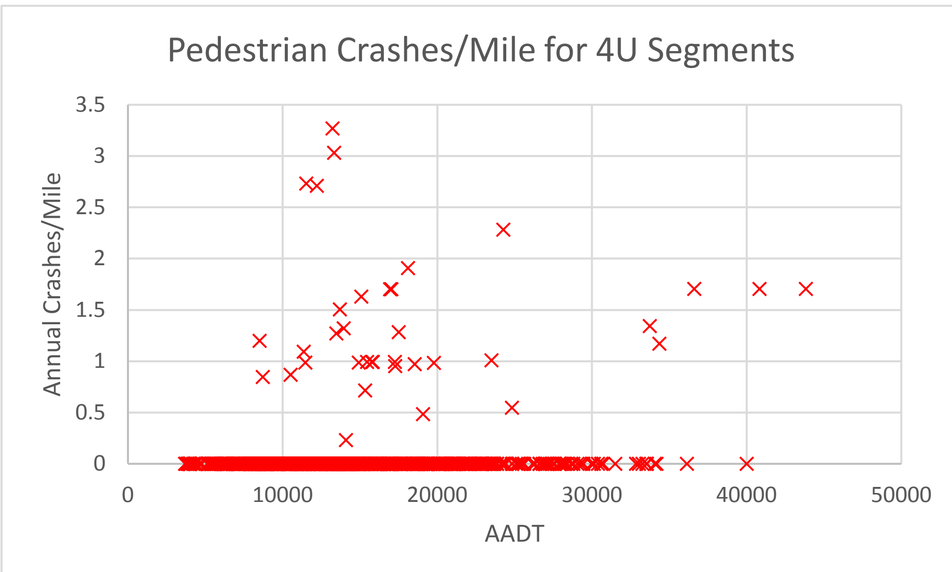
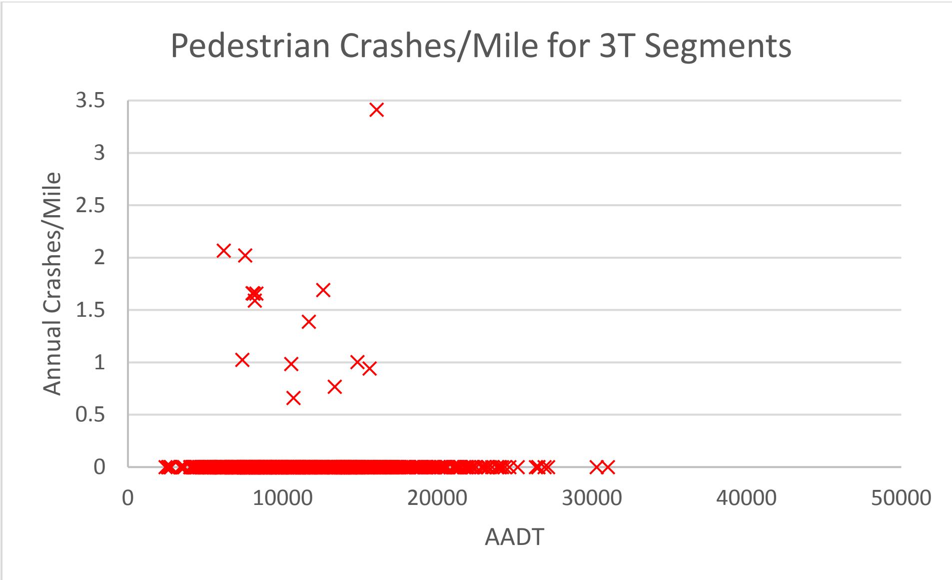


Figure 11. Relationship between Pedestrian Crashes/Mile and AADT for 2U and 4U Segments



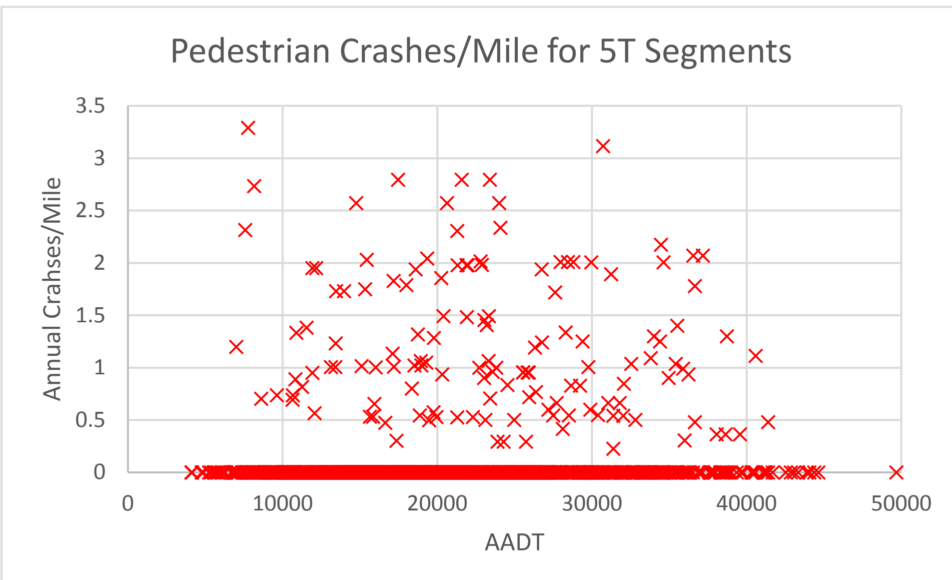


Figure 12. Relationship between Pedestrian Crashes/Mile and AADT for 3T and 5T Segments

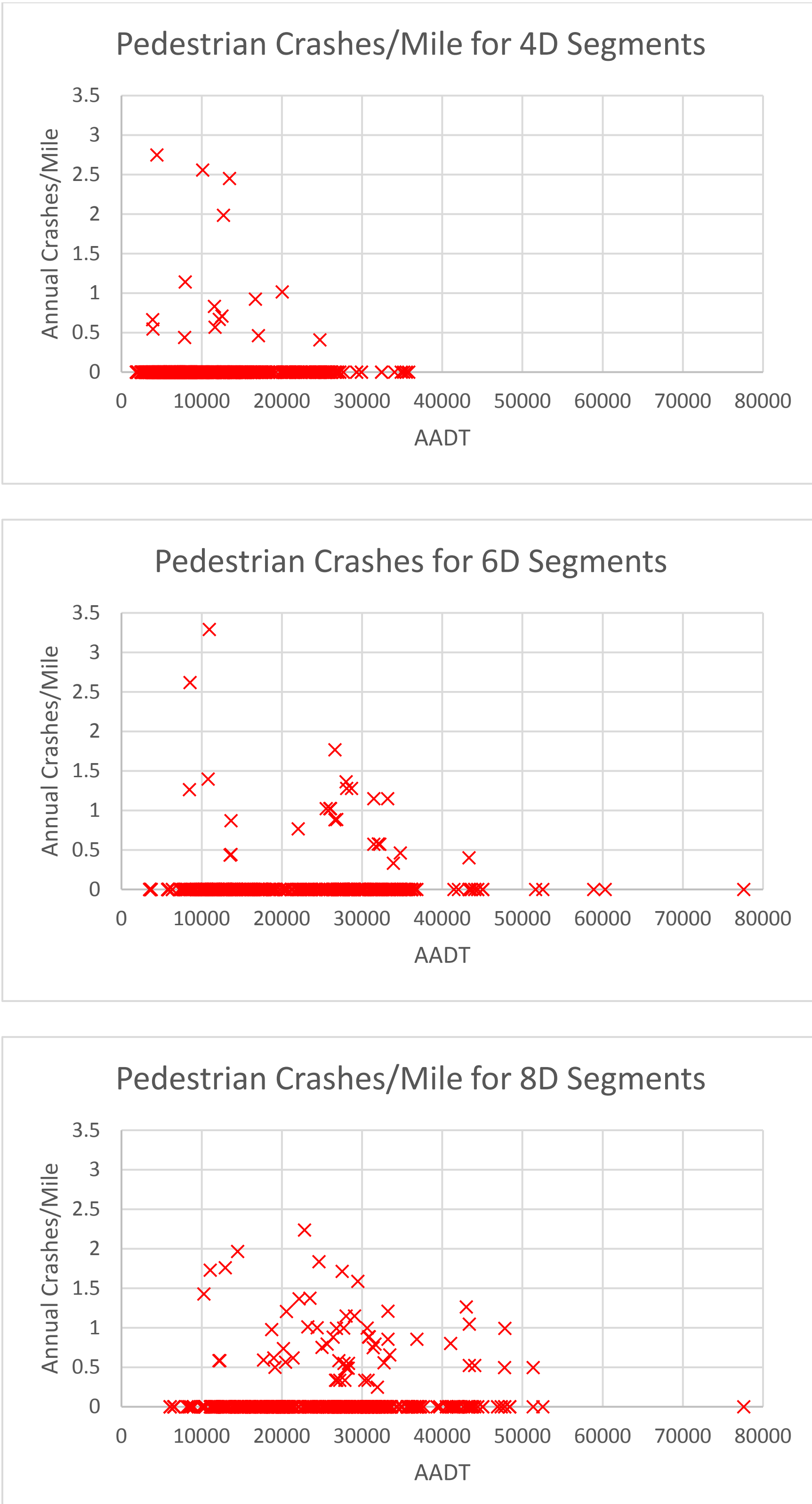


Figure 13. Relationship between Pedestrian Crashes/Mile and AADT for 4D, 6D, and 8D Segments

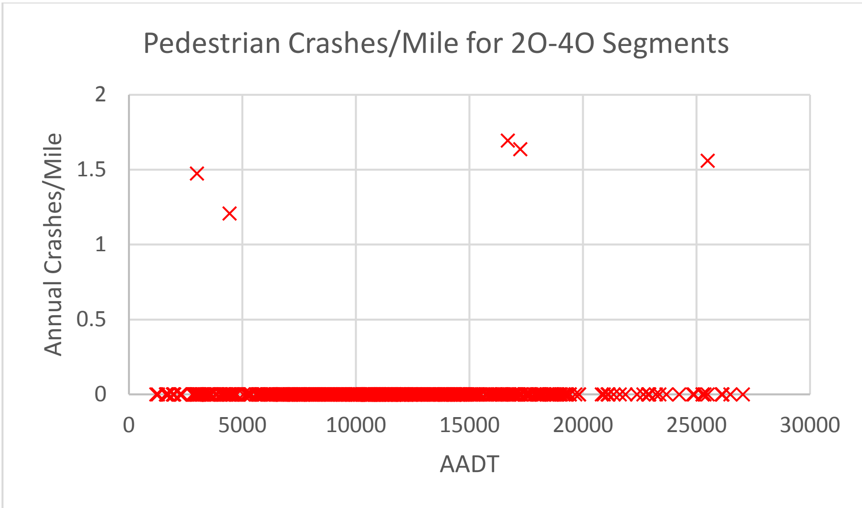


Figure 14. Relationship between Pedestrian Crashes/Mile and AADT for 2O-4O Segments

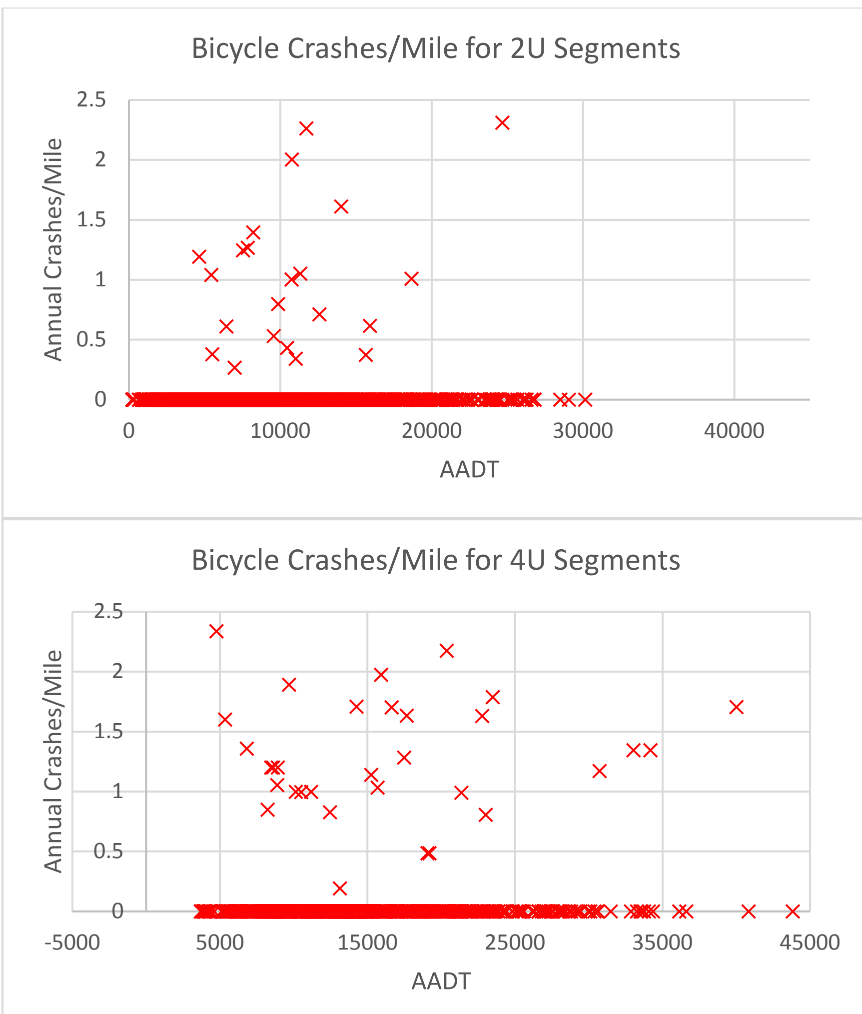
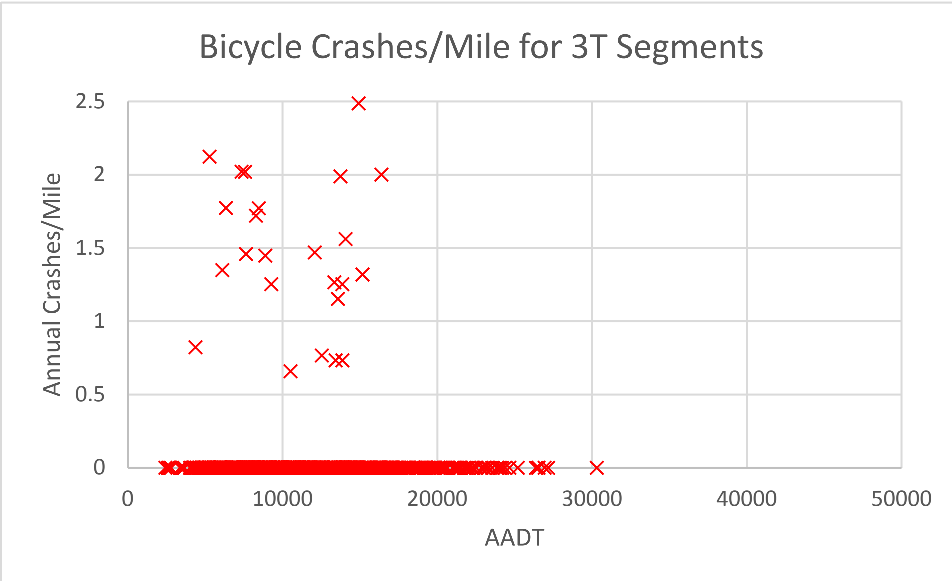


Figure 15. Relationship between Bicycle Crashes/Mile and AADT for 2U and 4U Segments



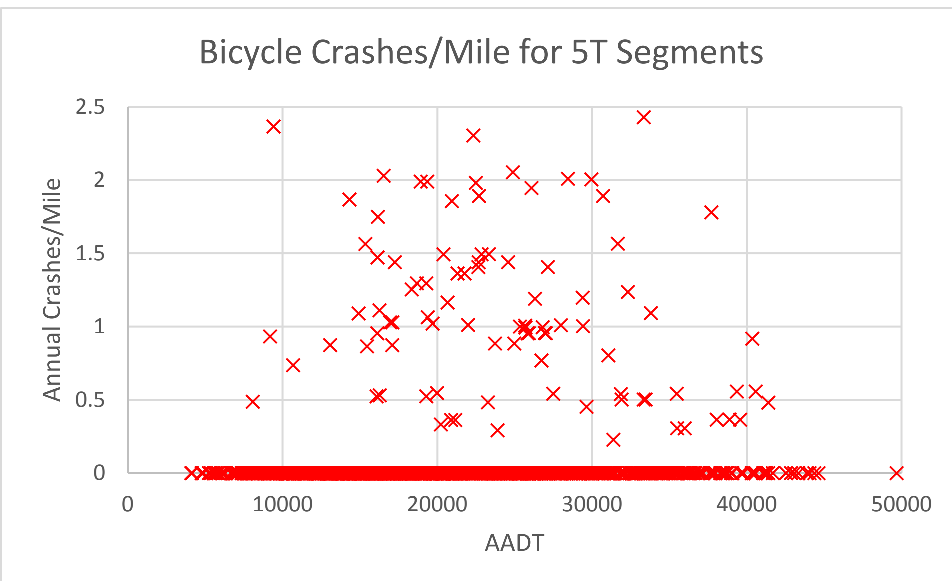


Figure 16. Relationship between Bicycle Crashes/Mile and AADT for 3T and 5T Segments

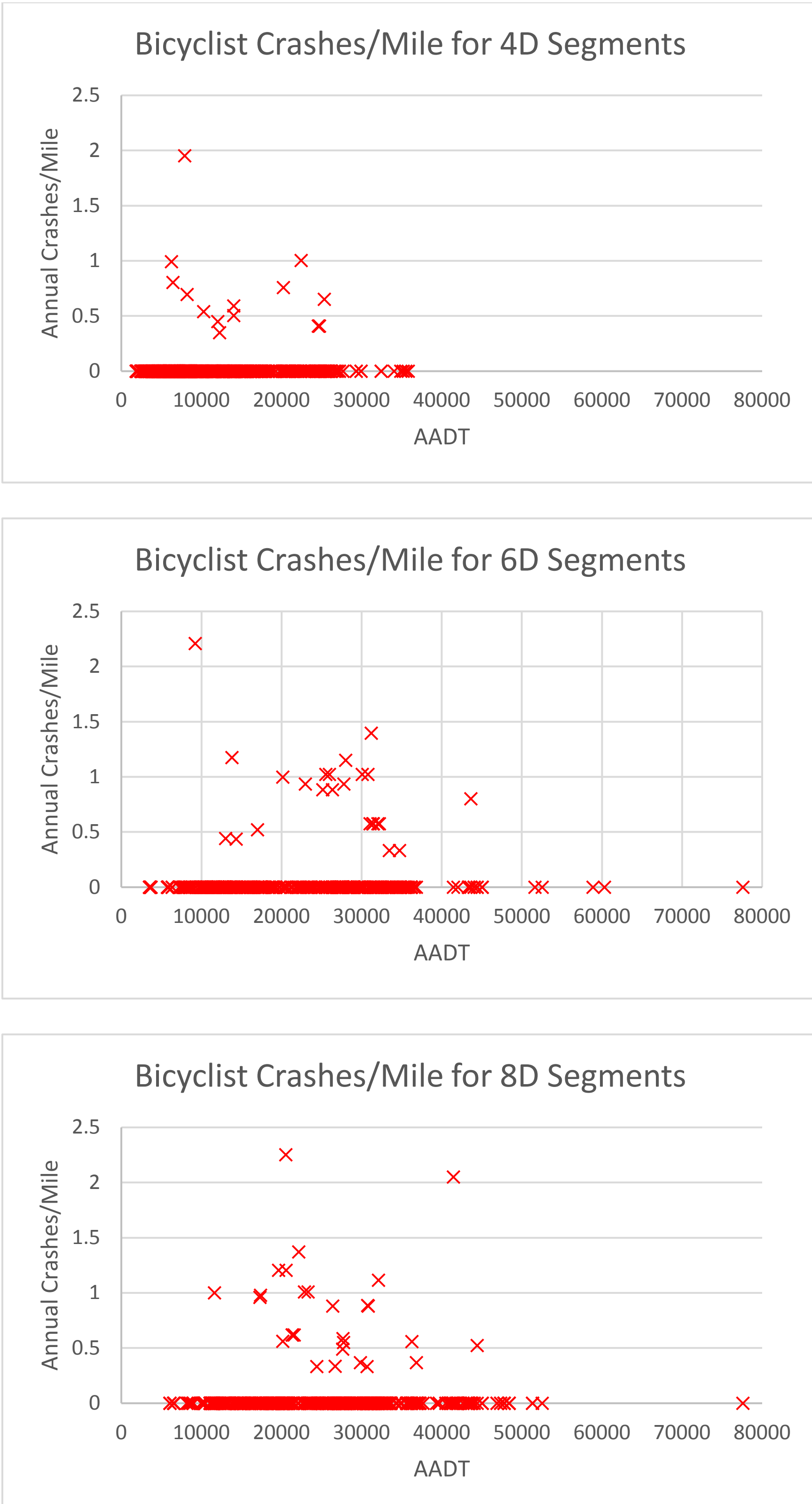


Figure 17. Relationship between Bicycle Crashes/Mile and AADT for 4D, 6D, and 8D Segments

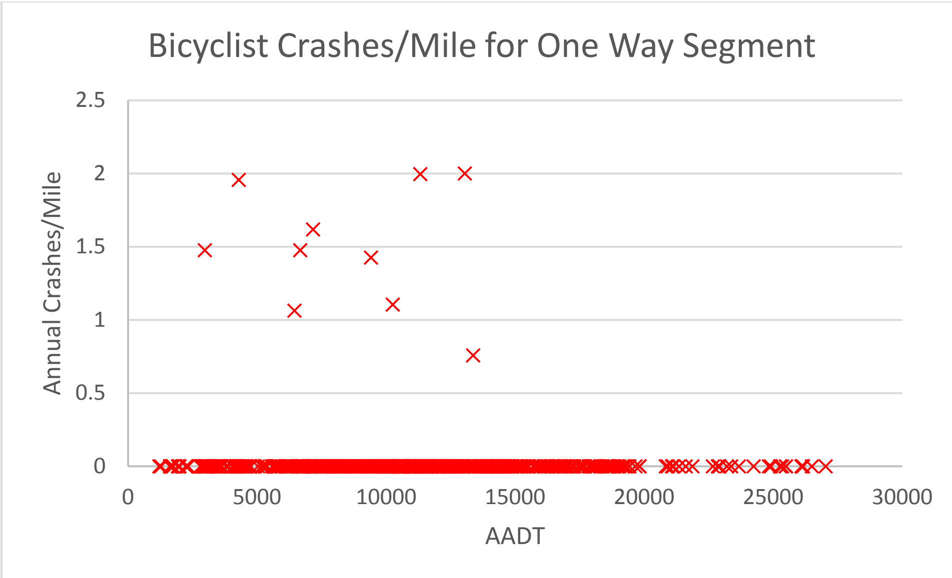


Figure 18. Relationship between Bicycle Crashes/Mile and AADT for One-way Segments

4.1 Development of Safety Performance Functions

After examining these general relationships between crashes and traffic volume within each of the four site types, a series of SPFs were developed with varying degrees of complexity. These SPFs take the form of generalized linear models. As crash data are comprised of non-negative integers, traditional regression techniques (e.g., ordinary least-squares) are generally not appropriate. Given the nature of such data, the Poisson distribution has been shown to provide a better fit and has been used widely to model crash frequency data. In the Poisson model, the probability of segment *i* experiencing y_i crashes during a one-year period is given by:

$$P(y_i) = \frac{EXP(-\lambda_i)\lambda_i^{y_i}}{y_i!},$$

where $P(y_i)$ is probability of segment *i* experiencing y_i crashes and λ_i is the Poisson parameter for segment *i*, which is equal to the segments expected number of crashes per year, $E[y_i]$. Poisson models are estimated by specifying the Poisson parameter λ_i (the expected number of crashes per period) as a function of explanatory variables, the most common functional form being $\lambda_i = \exp(\beta X_i)$, where X_i is a vector of explanatory variables and β is a vector of estimable parameters.

A limitation of this model is the underlying assumption of the Poisson distribution that the variance is equal to the mean. As such, the model cannot handle overdispersion, wherein the variance is greater than the mean. Overdispersion is common in crash data and may be caused by data clustering, unaccounted temporal correlation, model misspecification, or ultimately by the nature of the crash data, which are the product of Bernoulli trials with unequal probability of events [54]. Overdispersion is generally accommodated through the use of negative binomial models (also referred to as Poisson-gamma models).

The negative binomial model is derived by rewriting the Poisson parameter for each segment as $\lambda_i = \exp(\beta X_i + \varepsilon_i)$, where $EXP(\varepsilon_i)$ is a gamma-distributed error term with a mean of one and variance α. The addition of this term allows the variance to differ from the mean as $VAR[y_i] = E[y_i] + \alpha E[y_i]^2$. The negative binomial model is preferred over the Poisson model since the latter cannot handle overdispersion and, as such, may lead to biased parameter estimates [55]. Consequently, the *HSM* recommends using the negative binomial model for the development of SPFs.

If the overdispersion parameter (α) is equal to zero, the negative binomial reduces to the Poisson model. Estimation of λ_i can be conducted through standard maximum likelihood procedures. While alternatives, such as the Conway-Maxwell model, have the advantage of accommodating both overdispersion and underdispersion (where the variance is less than the mean) [56], the negative binomial model remains the standard in SPF development.

The overdispersion parameter from the negative binomial model is also utilized in the empirical Bayes (EB) method for evaluating the effectiveness of safety improvements as described in the *HSM*. The α parameter is used to determine the weighted adjustment factor, *w*, which is then used to estimate the expected number of crashes at a given location when combining observed crash data with the number of crashes predicted by an SPF. The formula for this weighting factor is:

$$w = \frac{1}{1 + (\alpha \times N_{spf})},$$

where:

α = overdispersion parameter, and

N_{spf} = predicted number of crashes by SPF.

Upon determining w, the expected number of crashes can then be determined as follows:

$$N_{expected} = w \times N_{spf} + (1 - w) \times N_{observed} \text{ ,}$$

where:

$N_{expected}$ = expected number of crashes determined by the EB method,

w= weighted adjustment factor, and

$N_{observed}$ = observed number of crashes at a site.

For further details of the EB method, refer to the HSM [2].

As a part of this study, SPFs were examined at four levels of detail:

- Uncalibrated HSM – The segment models from Chapter 12 of the HSM were applied directly using traffic volume data for the study sites.
- Calibrated HSM – The predicted number of crashes based upon the SPFs from the HSM were calibrated based upon the observed crashes at the study sites.
- Michigan-Specific Models with AADT and Regional Indicators – A series of Michigan-specific models were developed using only AADT information. A simple statewide model was estimated, as well as a similar model that included a series of binary indicator variable for each MDOT region.
- Fully Specified Michigan-Specific Models – A series of detailed models were subsequently developed in consideration of AADT, regional indicator variables, and a diverse range of geometric variables.

The uncalibrated and calibrated HSM models are discussed in Section 4.2 while the Michigan-specific SPFs are presented in Chapter 5.

4.2 Comparison of Uncalibrated and Calibrated HSM Models

The base SPFs from Chapter 12 of the HSM were first applied to the datasets for each of the five segment types for which the HSM SPFs exist, namely 2U, 3T, 4U, 4D, and 5T. These base models only require the AADT as an input value. While these models generally apply to base conditions (i.e., 12-ft lanes, 6-feet paved shoulders, tangent and flat sections, no lighting, no two-way-left-turn-lane, etc), they were applied directly to the study datasets without adjusting for those locations where the base conditions were not present (e.g., sites with lanes narrower than 12 ft). Separate estimates were obtained for total crashes, property damage only (PDO) crashes, and fatal/injury (FI) crashes.

After applying these models, the resulting estimates for each study location were then compared to the observed values. The ratio of the total observed crashes to the estimated crashes (from the base SPFs) for the entire sample is used to estimate a calibration factor, which provides a measure of how close the base SPFs from the HSM fit the Michigan data. The calibration factor for each of the three models (i.e., total, PDO, and FI) and each of the five site types (2U, 3T, 4U, 4D, and 5T) are presented in Table 13.

Table 13. Calibration Factors for HSM Models

	Segment Types	**2U**	**3T**	**4U**	**5T**	**4D**
Single-Vehicle	Total	3.498	4.224	2.133	1.099	1.971
	PDO	4.372	5.472	2.301	1.31	2.092
	Fatal-Injury	1.302	1.506	1.059	0.628	1.396
Multi-Vehicle	Total	1.529	1.874	1.943	1.466	0.579
	PDO	1.555	2.061	2.431	1.530	0.621
	Fatal-Injury	1.260	1.443	1.156	1.066	0.104

By briefly scanning the calibration factors derived from the *HSM* models, it is evident that the accuracy of the base SPFs from the HSM vary widely by site type, crash type, and crash severity level. It is also very clear that the parameter estimates of the Michigan specific models are noticeably different from the parameters for the *HSM* models. These differences are reflective of several factors, including state-specific differences (e.g., driver characteristics, road design standards, weather, etc.), as well as the fact that only AADT was considered (and not geometric or road use characteristics).

5.0 MICHIGAN-SPECIFIC SAFETY PERFORMANCE FUNCTIONS

Having established that the base SPFs from the HSM do not provide consistent fit across segment types, crash types, and crash severity levels, the research team developed a series of Michigan-specific SPFs. This chapter presents a number of simple models, which can be applied without any roadway geometry data. These SPFs were developed in two general forms:

- Michigan-Specific Models with AADT – A series of Michigan-specific models were developed using only annual average daily traffic (AADT) as a predictor variable.
- Michigan-Specific Models with AADT and Regional Indicators – Similar models were estimated that included AADT as well as a series of binary indicator variables for each MDOT region.

These models are considered valid only for the range of AADT values with which they were estimated. These AADT values can be found in Table 14. Minimum AADT values were rounded down to the nearest 100 while maximum AADT values were rounded up to the nearest 100.

Table 14. Model AADT Ranges

Facility Type	Min AADT	Max AADT
2U55E	200	26900
2U55L	600	30200
3T	2400	31100
4U	3700	43900
5T	4100	51300
4D	1800	35900
6D	3400	77600
8D	6000	77600
2O	1200	26200
3O	2200	26200
4O	2900	27100

5.1 SPFs with AADT only and SPFs with AADT and Regional Indicator Variables

This section presents the results of separate SPFs for FI crash rates, PDO crash rates, and total crash rates for each of the eight site types. Results are presented in Table 14 through Table 28. For each site type, the results are first presented for the general statewide model and followed by a model that has been calibrated at the regional level. The regionally calibrated models account for general differences in safety performance across the seven MDOT regions. For these models, the parameter estimates are provided for AADT and each region. In each model, the Metro region serves as the baseline and indicator variables are then used to adjust the estimates to fit other regions. Graphical representation of the SPFs are provided in Figure 19 to Figure 33. These figures are also provided for both the statewide and regional SPFs.

Table 14 and Figure 19 present the SPFs for 2-lane undivided (2U) segments. For these locations, the effect of AADT on the FI crash rate is almost elastic, as shown from the AADT coefficient and the relationship between crashes/mile and AADT. The AADT effect on PDO crashes and total crashes is less pronounced, indicating that the majority of crashes are PDO crashes.

Table 15. SPF for Crashes on 2U Segments with AADT Only

Variable	Fatal & Injury Crashes			Property Damage Only Crashes			All Crash Severities		
	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic
Intercept	-9.128	0.477	-19.124	-4.199	0.291	-14.439	-4.502	0.272	-16.545
AADT	0.966	0.052	18.613	0.601	0.032	18.665	0.655	0.030	21.761
Inverse Dispersion Parameter	14.280	-		2.850	0.022		3.190	0.019	

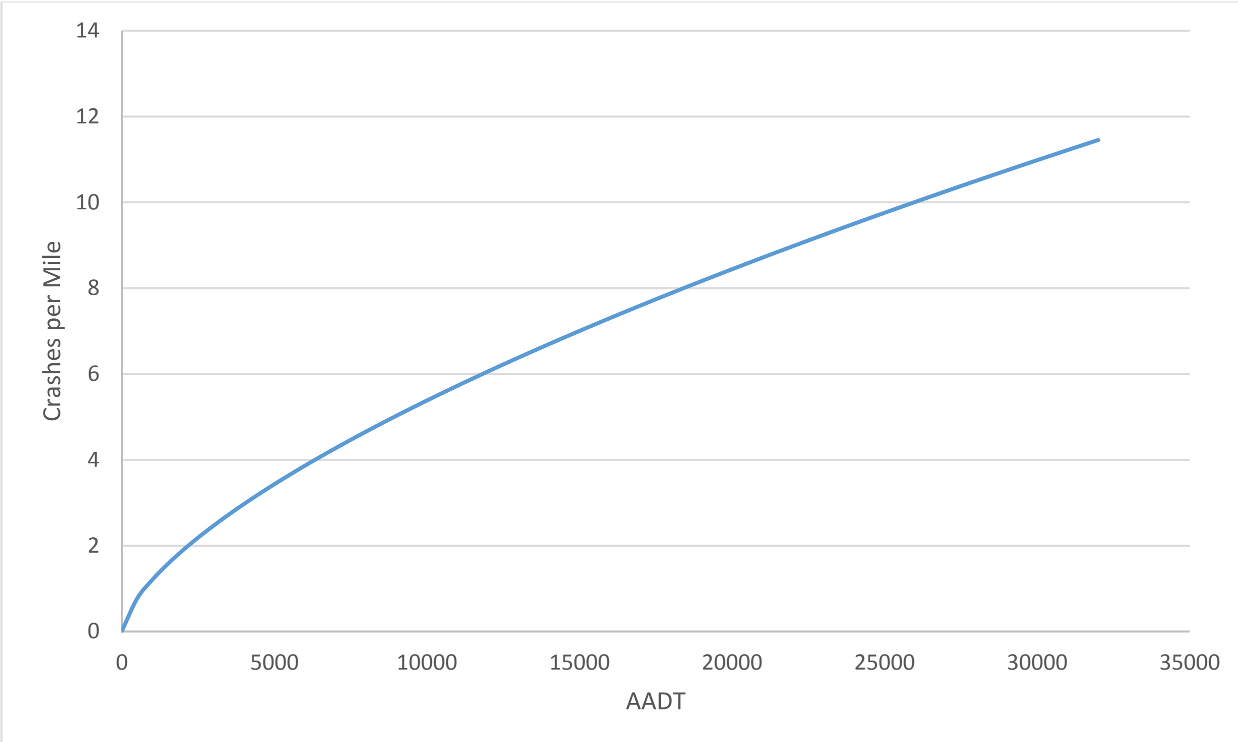


Figure 19. Total Annual Crashes per Mile for 2U Segments

Table 15 and Figure 20 present the SPFs with regional indicators for 2-lane undivided segments. AADT has a higher effect on fatal and injury crash rates as compared to PDO or total crash rates. For PDO and total crash rate models, the only region indicator that is statistically significant is Grand Region, where crash rates are higher than in the Metro region. In the case of the fatal and injury crash rate model, the only statistically significant regions are Superior, North, and Southwest, all of which have lower crash rates compared to the Metro region.

Table 16. SPF for Crashes on 2U Segments with AADT and Regional Indicators

Variable	Fatal and Injury Crashes			Property Damage Only Crashes			All Crash Severities		
	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic
Intercept	-8.016	0.528	-15.177	-3.960	0.324	-12.241	-4.145	0.303	-13.697
AADT	0.856	0.056	15.224	0.566	0.034	16.462	0.608	0.032	18.916
Superior Region Effect	-0.416	0.131	-3.186	-0.108	0.082	-1.319	-0.143	0.076	-1.876
North Region Effect	-0.233	0.108	-2.157	0.132	0.076	1.745	0.086	0.071	1.210
Grand Region Effect	0.053	0.094	0.566	0.376	0.073	5.182	0.345	0.068	5.103

Bay Region Effect	0.001	0.091	0.015	-0.031	0.071	-0.430	-0.003	0.066	-0.047
Southwest Region Effect	-0.296	0.096	-3.082	0.066	0.067	0.993	0.015	0.062	0.240
University Region Effect	-0.061	0.083	-0.735	0.112	0.064	1.742	0.089	0.060	1.493
Inverse Dispersion Parameter	0.066	-		0.336	0.021		0.301	0.019	

*Note: Metro Region Effect serves as baseline reference category

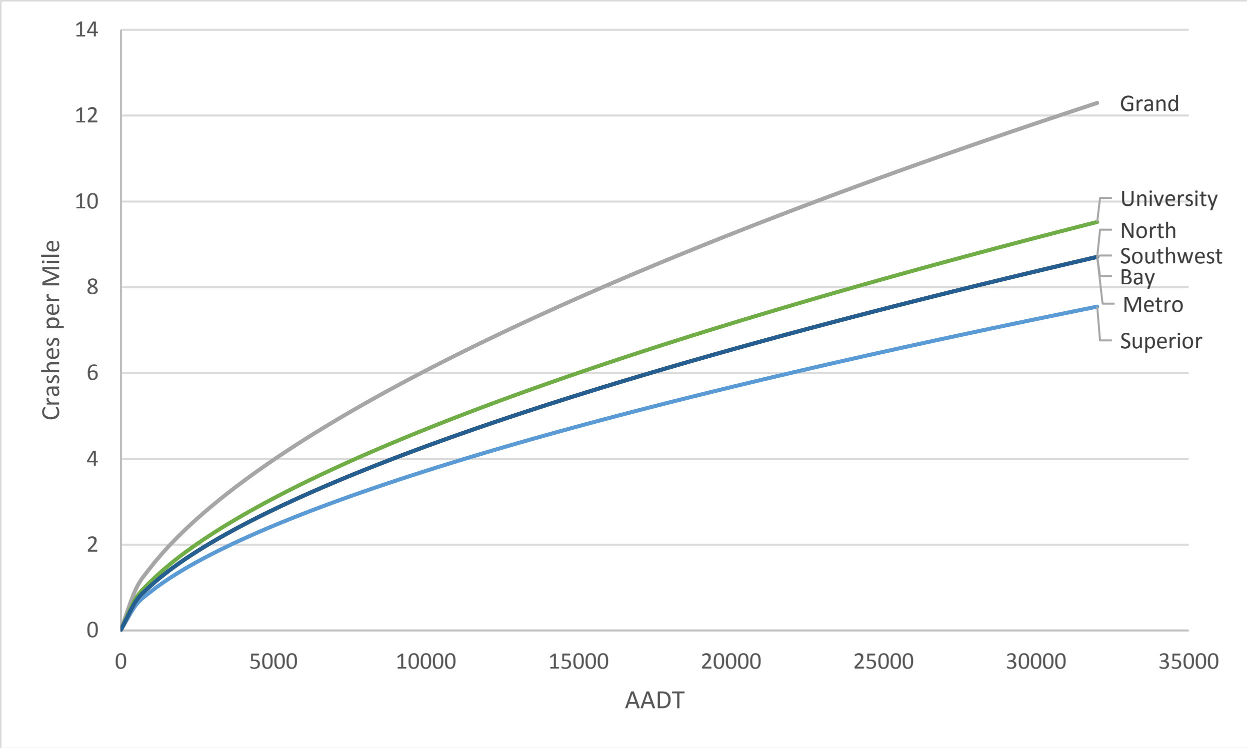


Figure 20. Total Annual Crashes per Mile for 2U Segments with Regional Indicators

Table 16 and Figure 21 present the relationship of crash rate and AADT for 3-lane undivided segments with a TWLTL. For all three severity models, AADT has a pronounced effect on crash rate as observed by the coefficients for AADT within the model results. As shown in Table 17, none of the regional indicators are statistically significant. Additionally, Superior region had not experienced fatal or injury crashes on 3T segments during the study period.

Table 17. SPF for Crashes on 3T Segments with AADT Only

Variable	Fatal & Injury Crashes			Property Damage Only Crashes			All Crash Severities		
	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic
Intercept	-11.105	1.262	-8.802	-9.516	0.732	-12.993	-9.112	0.682	-13.355
AADT	1.151	0.134	8.596	1.145	0.078	14.642	1.122	0.073	15.391
Inverse Dispersion Parameter	1.790	0.125		2.010	0.048		2.105	0.043	

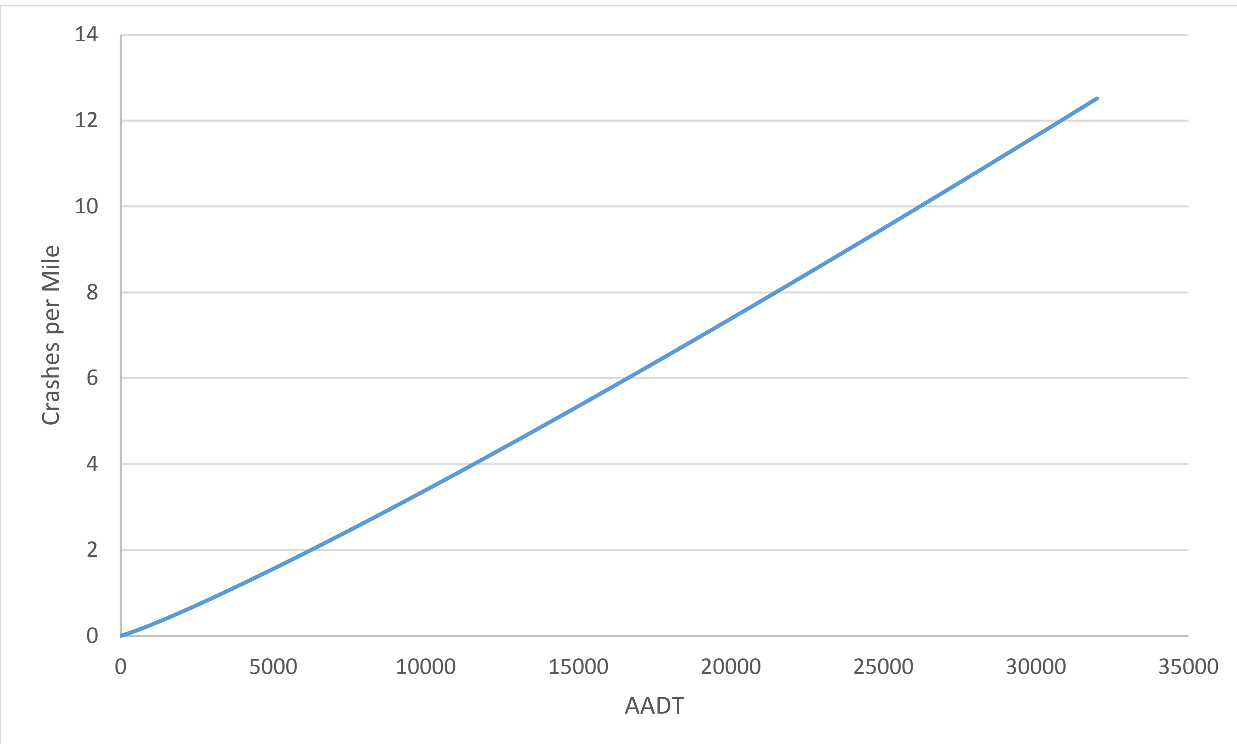


Figure 21. Total Annual Crashes per Mile for 3T Segments

Table 18. SPF for Crashes on 3T Segments with AADT and Regional Indicators

Variable	Fatal and Injury Crashes			Property Damage Only Crashes			All Crash Severities		
	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic
Intercept	-10.673	1.320	-8.084	-8.923	0.778	-11.463	-8.463	0.728	-11.631
AADT	1.100	0.138	7.988	1.085	0.080	13.529	1.061	0.075	14.170
Superior Region Effect	-	-	-	0.328	0.310	1.058	0.084	0.302	0.279
North Region Effect	0.061	0.291	0.210	-0.006	0.195	-0.031	-0.053	0.183	-0.290
Grand Region Effect	-0.006	0.299	-0.020	0.028	0.196	0.143	-0.032	0.184	-0.176
Bay Region Effect	-0.011	0.292	-0.038	-0.104	0.194	-0.536	-0.142	0.182	-0.779
Southwest Region Effect	-0.049	0.272	-0.180	-0.201	0.184	-1.091	-0.231	0.173	-1.334
University Region Effect	0.188	0.268	0.703	0.075	0.182	0.413	0.029	0.171	0.169
Inverse Dispersion Parameter	1.855	0.124		2.100	0.047		0.456	0.042	

*Note: Metro Region Effect serves as baseline reference category

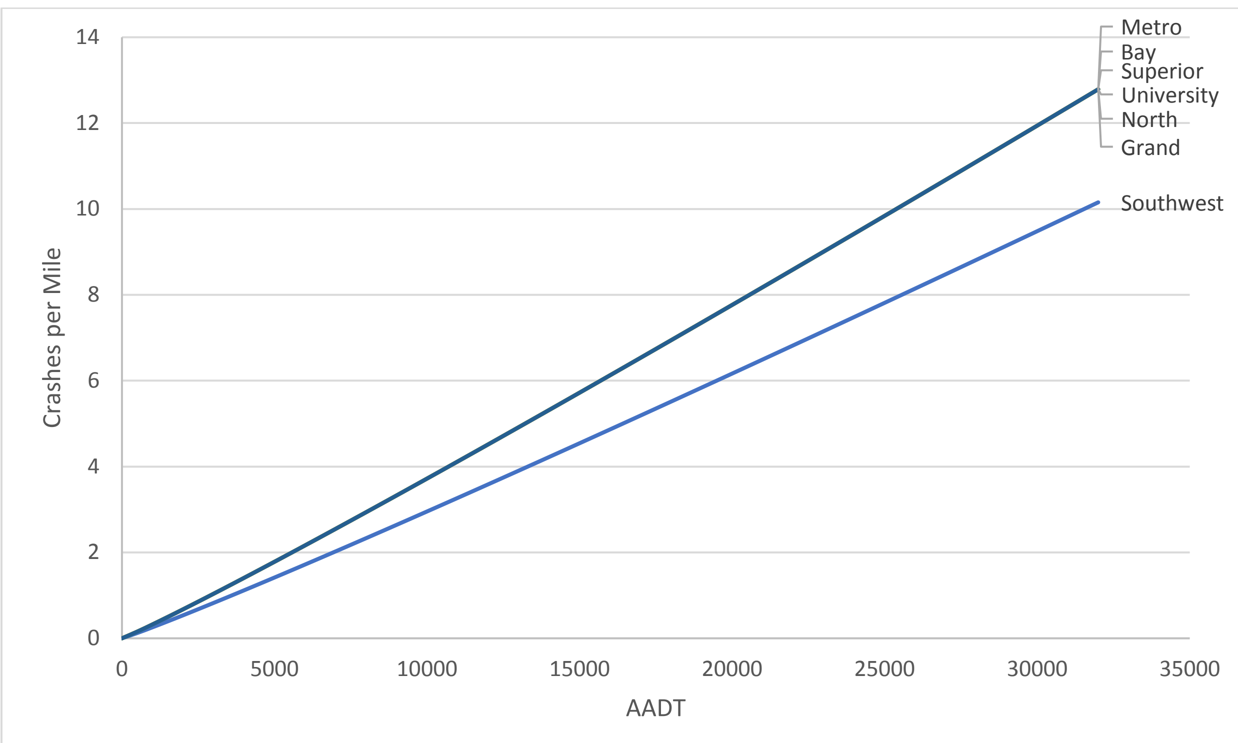


Figure 22. Total Annual Crashes per Mile for 3T Segments with Regional Indicators

Table 18 and Figure 23 depict the relationship of crash rate and AADT for 4-lane undivided segments. AADT had a stronger influence on the FI crash rate than on total or PDO crash rate.

Table 19. SPF for Crashes on 4U Segments with AADT Only

Variable	Fatal & Injury Crashes			Property Damage Only Crashes			All Crash Severities		
	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic
Intercept	-13.529	0.914	-14.807	-8.201	0.643	-12.746	-8.573	0.608	-14.098
AADT	1.410	0.095	14.921	1.006	0.067	14.948	1.067	0.064	16.777
Inverse Dispersion Parameter	30.300	-		2.390	0.038		2.488	0.034	

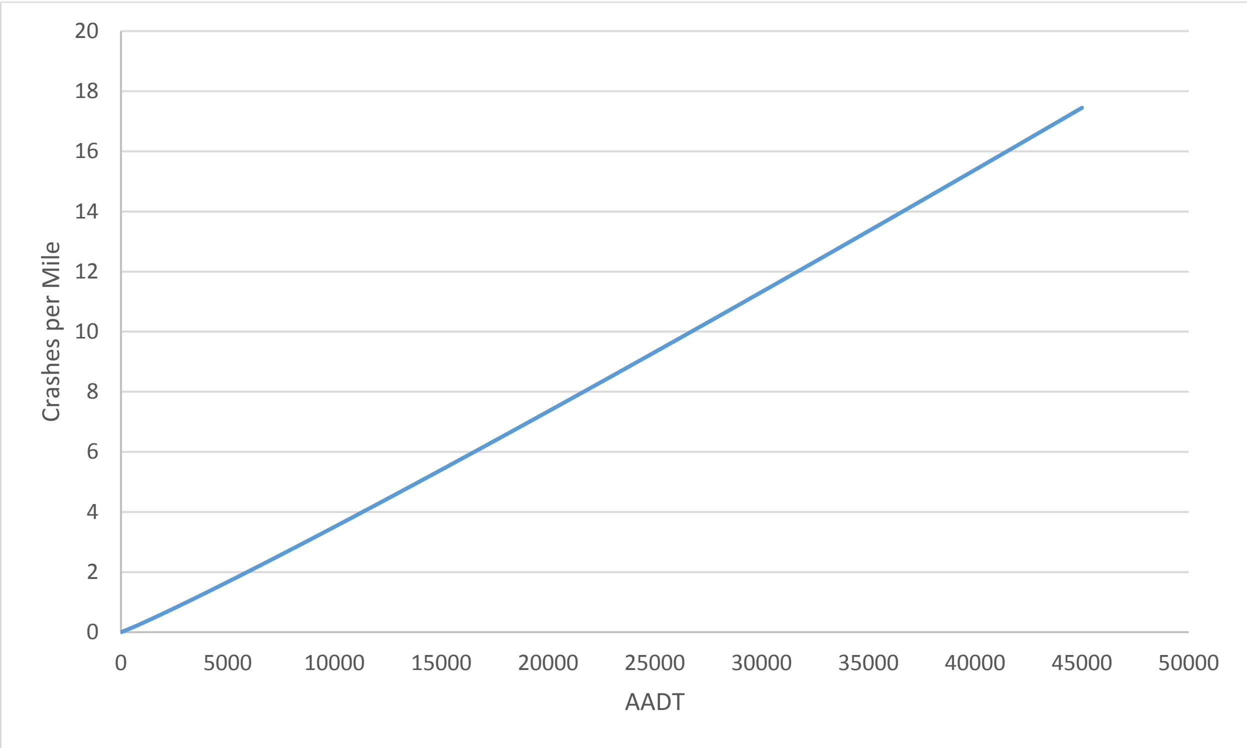


Figure 23. Total Annual Crashes per Mile for 4U Segments

Table 19 and Figure 24 show the results for the regionally calibrated model for 4-lane undivided segments. The AADT effects on crash rates follow the same trends as in all three severity models. The Bay region experienced the lowest crash rate for total crashes and PDO crashes. For the FI severity model, the Superior region had the lowest crash rate, while Grand region had the highest.

Table 20. SPF for Crashes on 4U Segments with AADT and Regional Indicators

Variable	Fatal and Injury Crashes			Property Damage Only Crashes			All Crash Severities		
	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic
Intercept	-12.655	1.035	-12.231	-7.543	0.677	-11.143	-7.855	0.635	-12.363
AADT	1.330	0.104	12.788	0.941	0.069	13.717	0.998	0.064	15.487
Superior Region Effect	-0.478	0.207	-2.309	-0.273	0.131	-2.084	-0.331	0.122	-2.702
North Region Effect	-0.411	0.157	-2.625	-0.140	0.114	-1.228	-0.207	0.107	-1.931
Grand Region Effect	0.266	0.137	1.940	0.194	0.109	1.786	0.209	0.101	2.070
Bay Region Effect	-0.176	0.136	-1.291	-0.365	0.105	-3.470	-0.366	0.098	-3.727
Southwest Region Effect	-0.375	0.143	-2.619	-0.207	0.101	-2.045	-0.259	0.095	-2.737
University Region Effect	0.075	0.123	0.609	0.245	0.094	2.601	0.190	0.088	2.152
Inverse Dispersion Parameter	10.630	-		2.650	0.035		0.358	0.031	

*Note: Metro Region Effect serves as baseline reference category

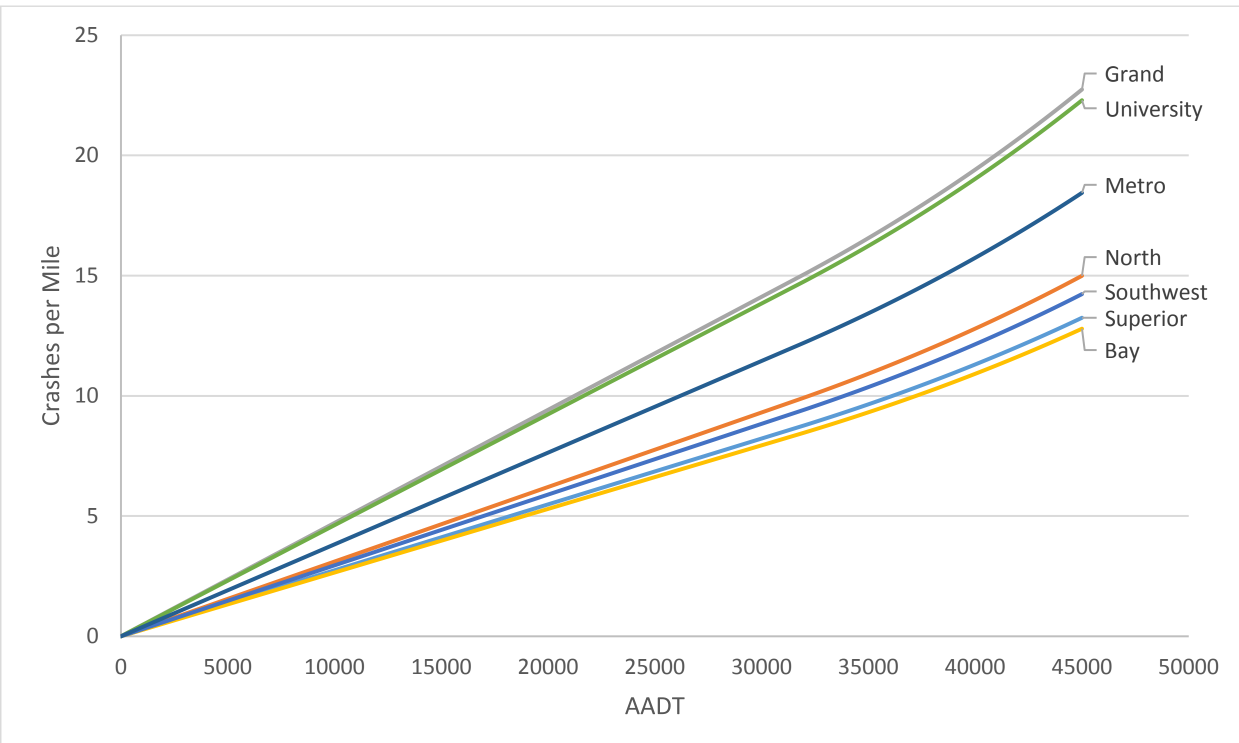


Figure 24. Total Annual Crashes per Mile for 4U Segments with Regional Indicators

Table 20 and Table 21 show the results for the AADT only and the AADT with regional effects models for all three crash severities for 5-lane segments with TWLTL. The AADT effects on crashes was similar for the two sets of models, having an emphasized effect on FI crashes. For total crashes, the Superior region had the lowest crash rate and the Grand region had the highest. On the other two severity models, some regional effects were not statistical significant; however, for FI crash rate models the Superior region had the lowest crash rate and the Grand region had the highest crash rate. For the PDO crash rate model, the Metro region had the lowest crash rate.

Table 21. SPF for Crashes on 5T Segments with AADT Only

Variable	Fatal & Injury Crashes			Property Damage Only Crashes			All Crash Severities		
	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic
Intercept	-14.619	0.636	-22.975	-9.708	0.458	-21.187	-9.900	0.438	-22.608
AADT	1.540	0.064	24.252	1.185	0.046	25.705	1.227	0.044	27.823
Inverse Dispersion Parameter	2.800	0.033		2.100	0.023		2.155	0.021	

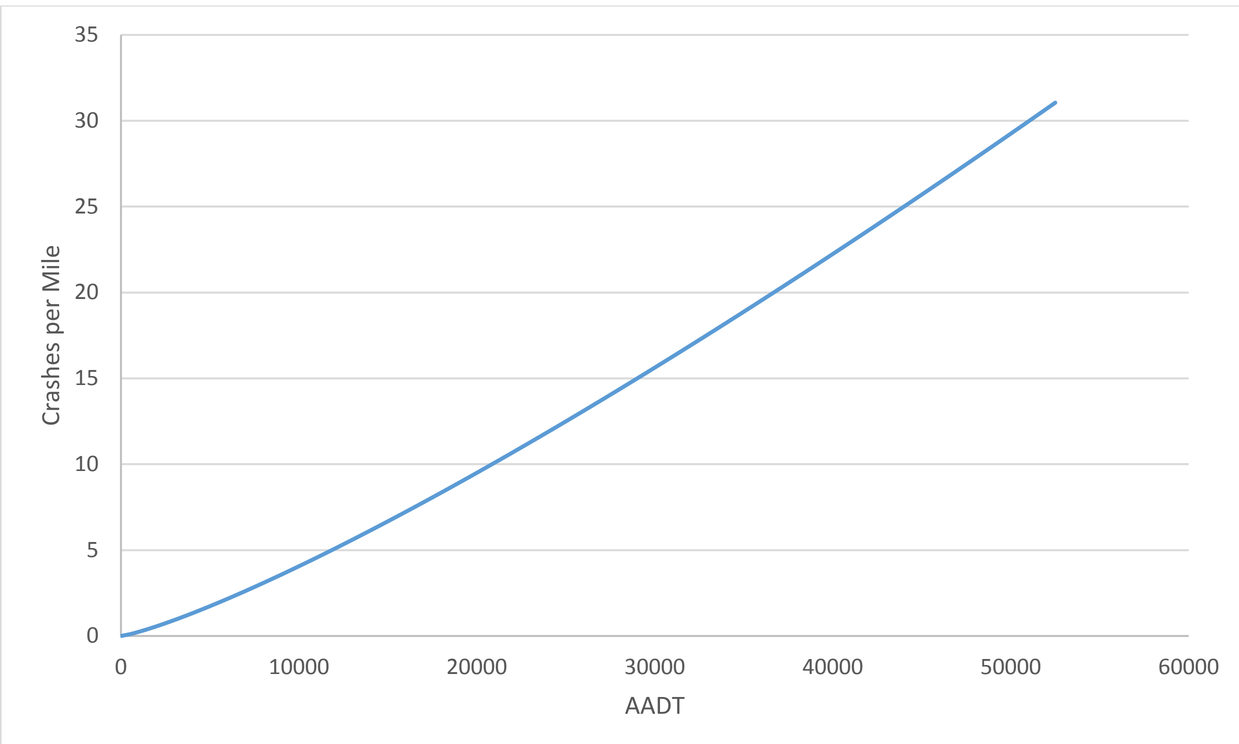


Figure 25. Total Annual Crashes per Mile for 5T Segments

Table 22. SPF for Crashes on 5T Segments with AADT and Regional Indicators

Variable	Fatal and Injury Crashes			Property Damage Only Crashes			All Crash Severities		
	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic
Intercept	-13.760	0.718	-19.170	-10.117	0.517	-19.576	-9.968	0.491	-20.290
AADT	1.446	0.070	20.569	1.206	0.051	23.740	1.217	0.048	25.170
Superior Region Effect	-0.442	0.114	-3.867	-0.066	0.078	-0.849	-0.155	0.074	-2.090
North Region Effect	0.040	0.096	0.418	0.366	0.075	4.880	0.297	0.072	4.130
Grand Region Effect	0.292	0.071	4.124	0.304	0.062	4.903	0.312	0.060	5.237
Bay Region Effect	0.057	0.080	0.717	0.243	0.063	3.876	0.204	0.060	3.402
Southwest Region Effect	0.086	0.083	1.035	0.295	0.065	4.545	0.240	0.062	3.871
University Region Effect	0.189	0.070	2.688	0.283	0.057	4.939	0.272	0.055	4.942
Inverse Dispersion Parameter	2.910	0.032		2.202	0.022		0.443	0.020	

*Note: Metro Region Effect serves as baseline reference category

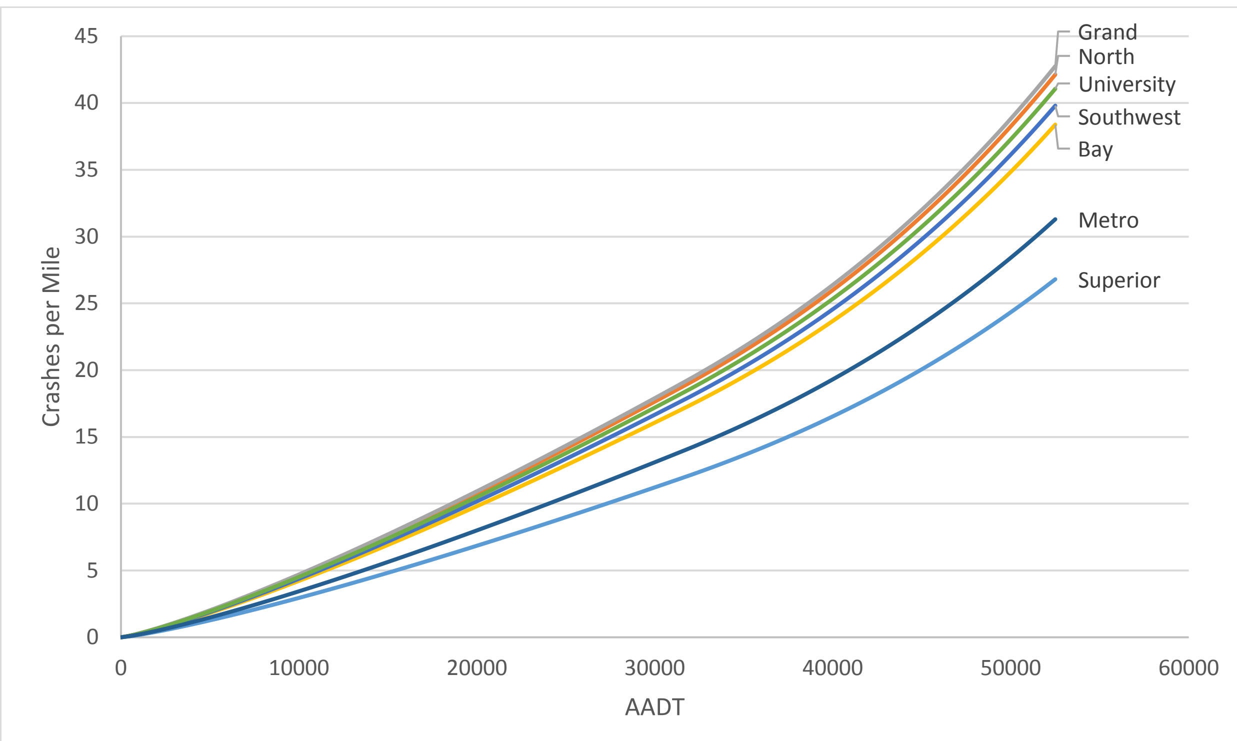


Figure 26. Total Annual Crashes per Mile for 5T Segments with Regional Indicators

Table 22 and Table 23 describe the relationship between AADT and crash rate for different crash severities among 4-lane divided segments. The AADT effects on crash rates are similar for the AADT only and the AADT with regional calibration models. Regional effects are not statistically significant for FI crash rate models. For the other two severity models, total crash rate and PDO crash rates are highest in Superior region and lowest in North region.

Table 23. SPF for Crashes on 4D Segments with AADT Only

Variable	Fatal & Injury Crashes			Property Damage Only Crashes			All Crash Severities		
	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic
Intercept	-10.624	0.646	-16.438	-6.815	0.372	-18.345	-6.909	0.351	-19.661
AADT	1.087	0.069	15.822	0.857	0.040	21.318	0.886	0.038	23.316
Inverse Dispersion Parameter	3.920	0.063		2.710	0.028		2.890	0.025	

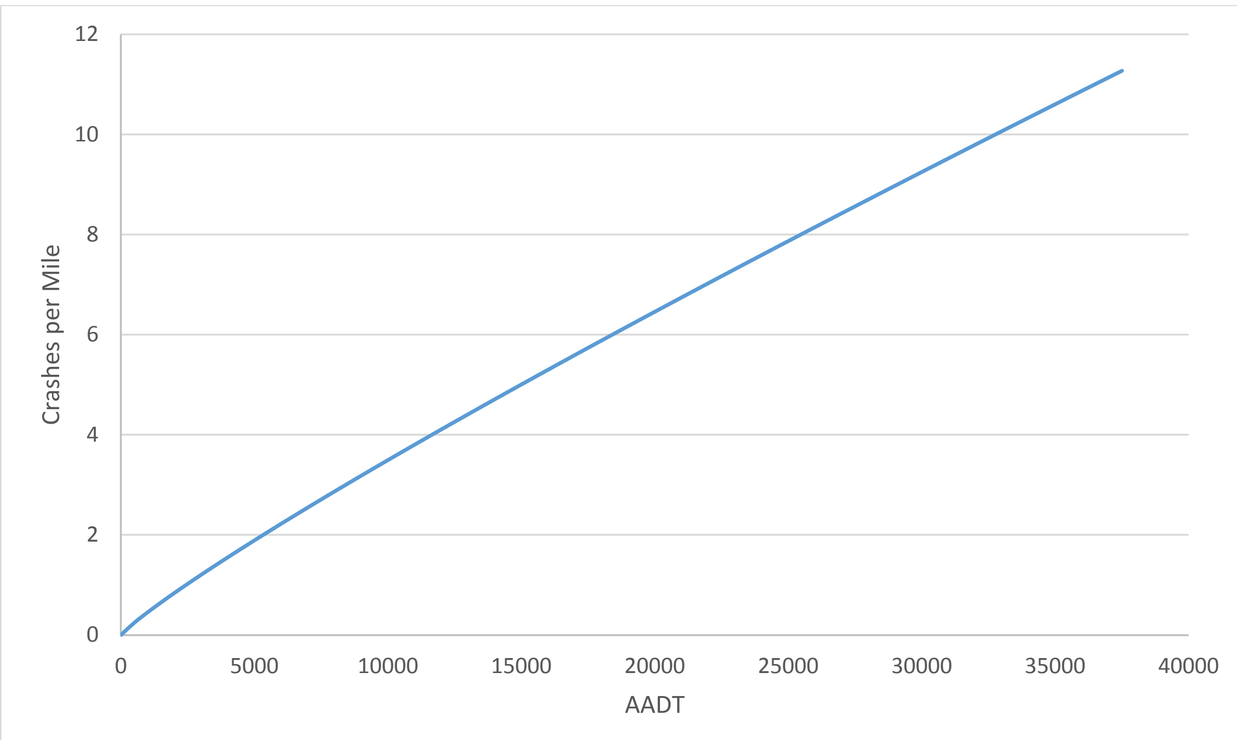


Figure 27. Total Annual Crashes per Mile for 4D Segments

Table 24. SPF for Crashes on 4D Segments with AADT and Regional Indicators

Variable	Fatal and Injury Crashes			Property Damage Only Crashes			All Crash Severities		
	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic
Intercept	-10.221	0.823	-12.413	-6.450	0.463	-13.937	-6.971	0.396	-17.601
AADT	1.041	0.085	12.261	0.814	0.048	16.853	0.890	0.042	21.390
Superior Region Effect	0.141	0.147	0.960	0.290	0.083	3.486	0.245	0.068	3.606
North Region Effect	-0.119	0.321	-0.371	-0.349	0.191	-1.830	-0.375	0.174	-2.160
Grand Region Effect	0.089	0.085	1.052	0.095	0.057	1.661	0.092	0.053	1.729
Bay Region Effect	0.152	0.189	0.806	-0.059	0.114	-0.516	-0.045	0.107	-0.421
Southwest Region Effect	-0.074	0.153	-0.485	-0.210	0.087	-2.408	-0.075	0.077	-0.964
University Region Effect	-0.232	0.150	-1.544	-0.032	0.081	-0.394	-0.003	0.070	-0.047
Inverse Dispersion Parameter	4.310	0.061		2.840	0.028		0.343	0.023	

*Note: Metro Region Effect serves as baseline reference category

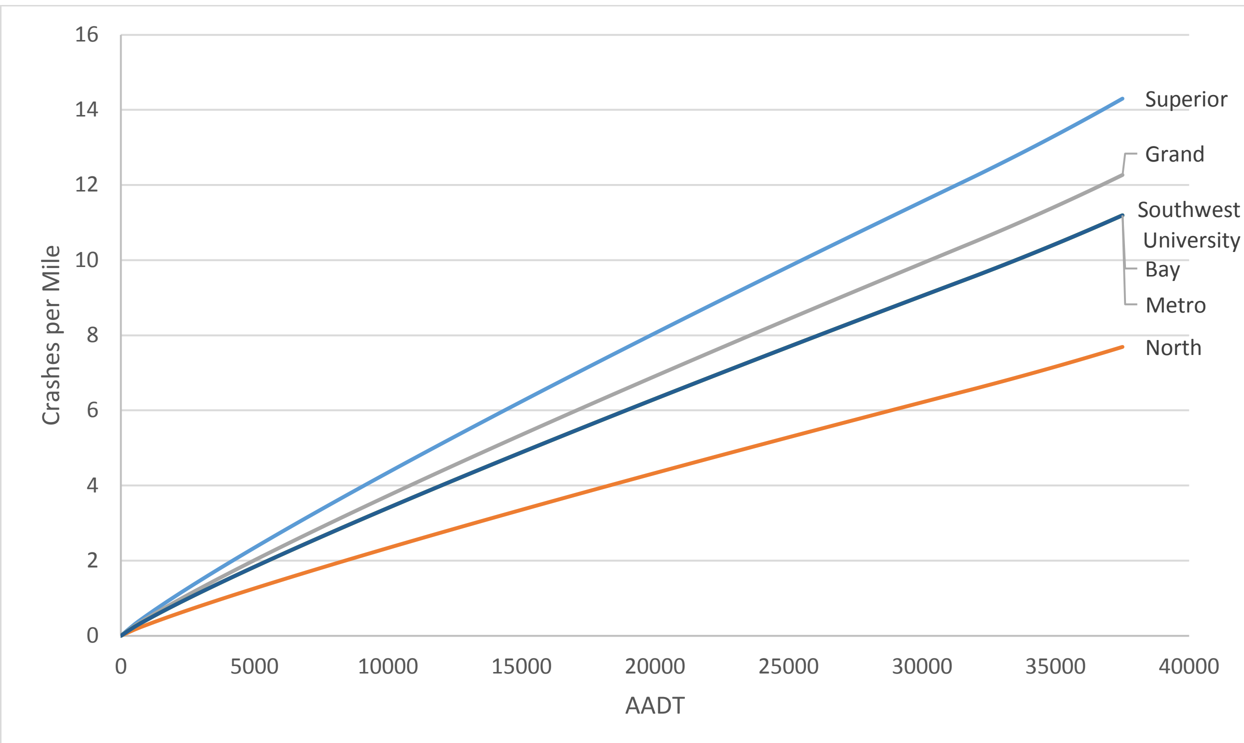


Figure 28. Total Annual Crashes per Mile for 4D Segments with Regional Indicators

Table 24 and Table 25 show similar relationships between AADT and the different severity crash rates for 6-lane divided segments. The only statistically significant region is University, exhibiting lower crash rates for total, FI, and PDO models.

Table 25. SPF for Crashes on 6D Segments with AADT Only

Variable	Fatal & Injury Crashes			Property Damage Only Crashes			All Crash Severities		
	Value	**Std. Error**	**t-statistic**	**Value**	**Std. Error**	**t-statistic**	**Value**	**Std. Error**	**t-statistic**
Intercept	-12.630	1.225	-10.312	-11.689	0.891	-13.113	-11.427	0.846	-13.513
AADT	1.292	0.121	10.678	1.341	0.089	15.067	1.336	0.085	15.811
Inverse Dispersion Parameter	2.650	0.073		1.710	0.057		1.740	0.053	

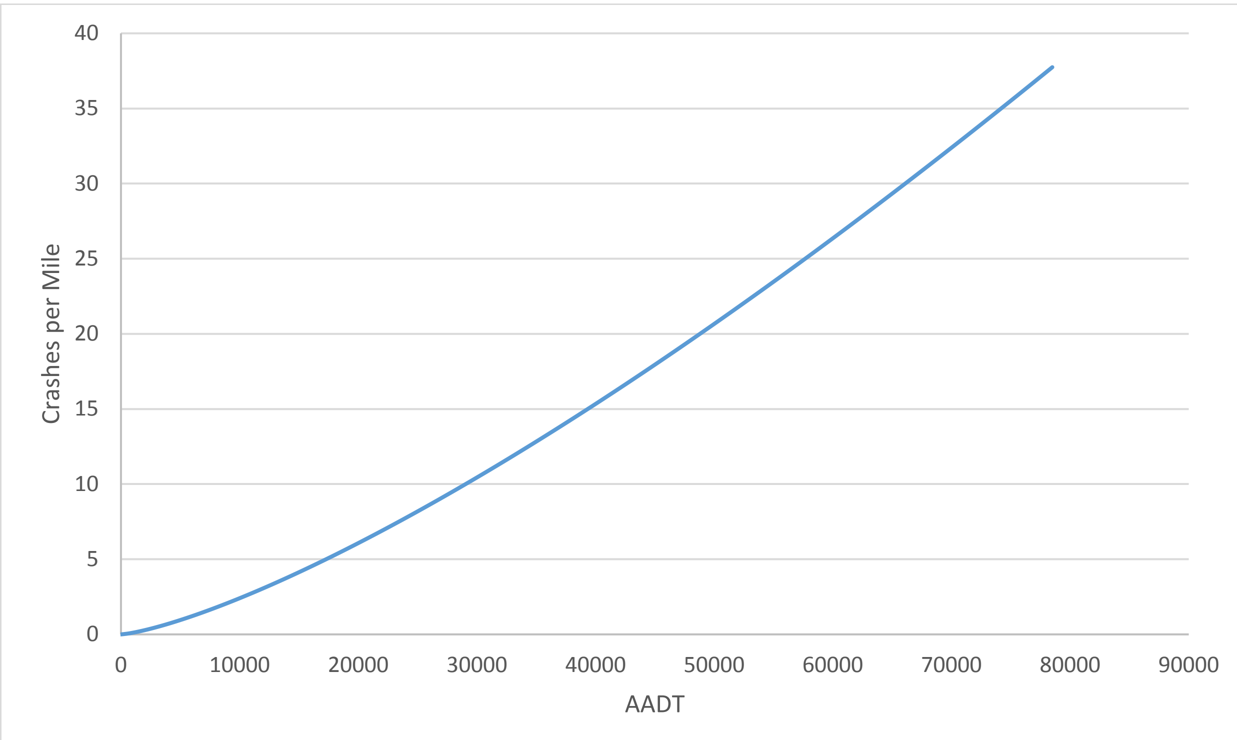


Figure 29. Total Annual Crashes per Mile for 6D Segments

Table 26. SPF for Crashes on 6D Segments with AADT and Regional Indicators

Variable	Fatal and Injury Crashes			Property Damage Only Crashes			All Crash Severities		
	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic
Intercept	-11.566	1.385	-8.354	-10.806	1.086	-9.951	-10.254	1.032	-9.935
AADT	1.189	0.136	8.743	1.255	0.107	11.707	1.222	0.102	11.973
Superior Region Effect	-	-	-	-	-	-	-	-	-
North Region Effect	-	-	-	-	-	-	-	-	-
Grand Region Effect	0.111	0.224	0.496	0.214	0.167	1.282	0.188	0.161	1.167
Bay Region Effect	-	-	-	-0.074	0.497	-0.149	-0.335	0.493	-0.679
Southwest Region Effect	0.036	0.744	0.048	-0.073	0.458	-0.159	-0.064	0.420	-0.153
University Region Effect	-0.518	0.272	-1.906	-0.339	0.162	-2.090	-0.385	0.153	-2.521
Inverse Dispersion Parameter	2.690	0.073		1.740	0.057		0.562	0.052	

*Note: Metro Region Effect serves as baseline reference category

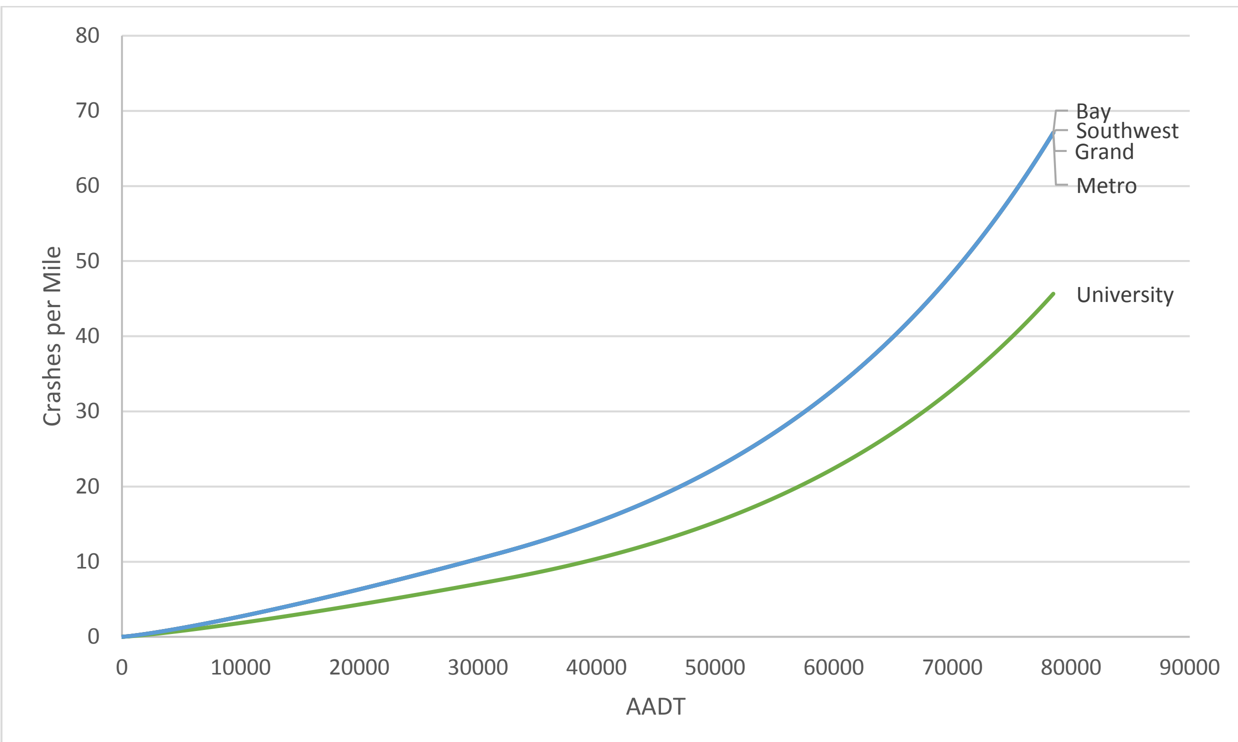


Figure 30. Total Annual Crashes per Mile for 6D Segments with Regional Indicators

Table 26 shows the AADT only model results for total, FI, and PDO crash rates for 8-lane divided segments. Regional effects are not statistically significant; however, this is indicative of the distribution of 8D segments, which are for the most part located in the Metro Region. Therefore, it is not possible to deduce any information regarding regional effects on crash rates for this type of facility.

Table 27. SPF for Crashes on 8D Segments with AADT Only

Variable	Fatal & Injury Crashes			Property Damage Only Crashes			All Crash Severities		
	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic
Intercept	-14.194	1.188	-11.945	-12.527	0.817	-15.331	-11.955	0.779	-15.351
AADT	1.437	0.116	12.356	1.405	0.080	17.475	1.372	0.077	17.888
Inverse Dispersion Parameter	1.700	0.069		1.990	0.038		2.000	0.035	

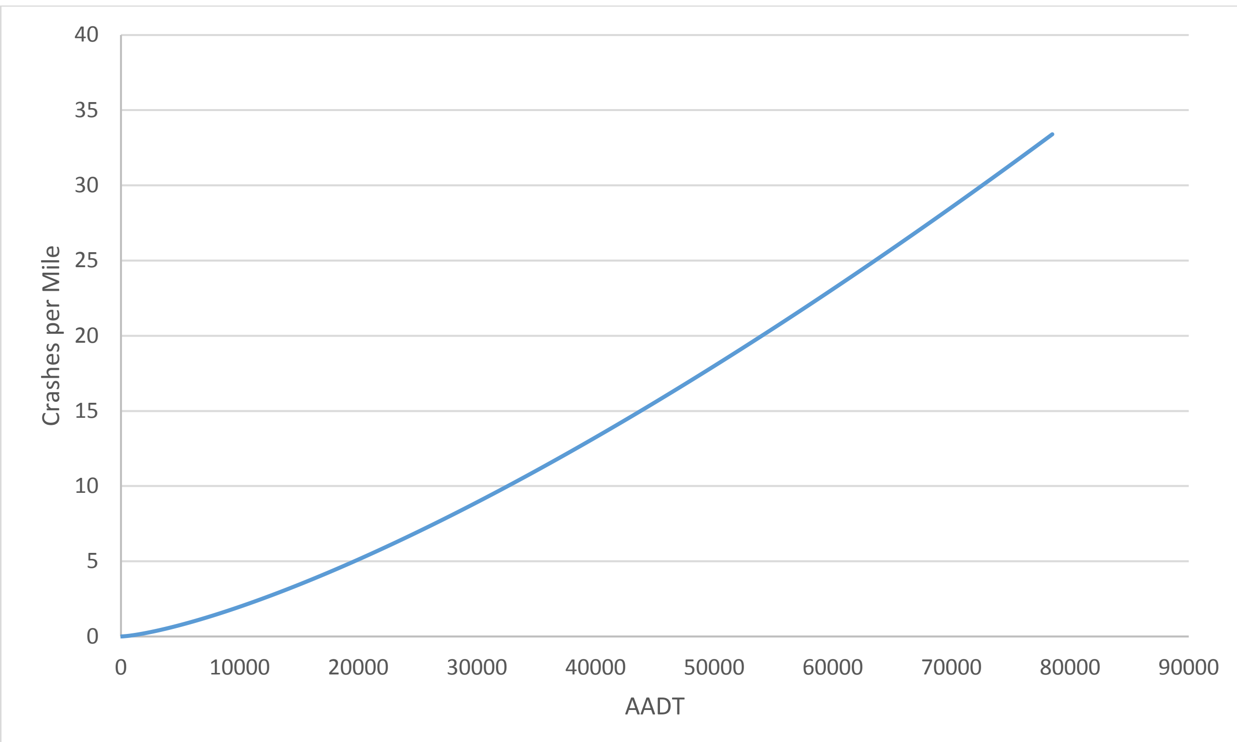


Figure 31. Total Annual Crashes per Mile for 8D Segments

Table 27 shows the statewide AADT only model results for one-way segments. It can be observed that AADT has an elastic effect on crashes for total and PDO crash rate models.

Table 28. SPF for Crashes on One-Way Segments with AADT Only

Variable	Fatal & Injury Crashes			Property Damage Only Crashes			All Crash Severities		
	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic
Intercept	-11.863	2.012	-5.898	-8.127	0.916	-8.871	-8.008	0.864	-9.271
AADT	1.203	0.215	5.606	1.000	0.098	10.163	1.003	0.093	10.808
Inverse Dispersion Parameter	0.860	0.361		1.144	0.095		1.220	0.084	

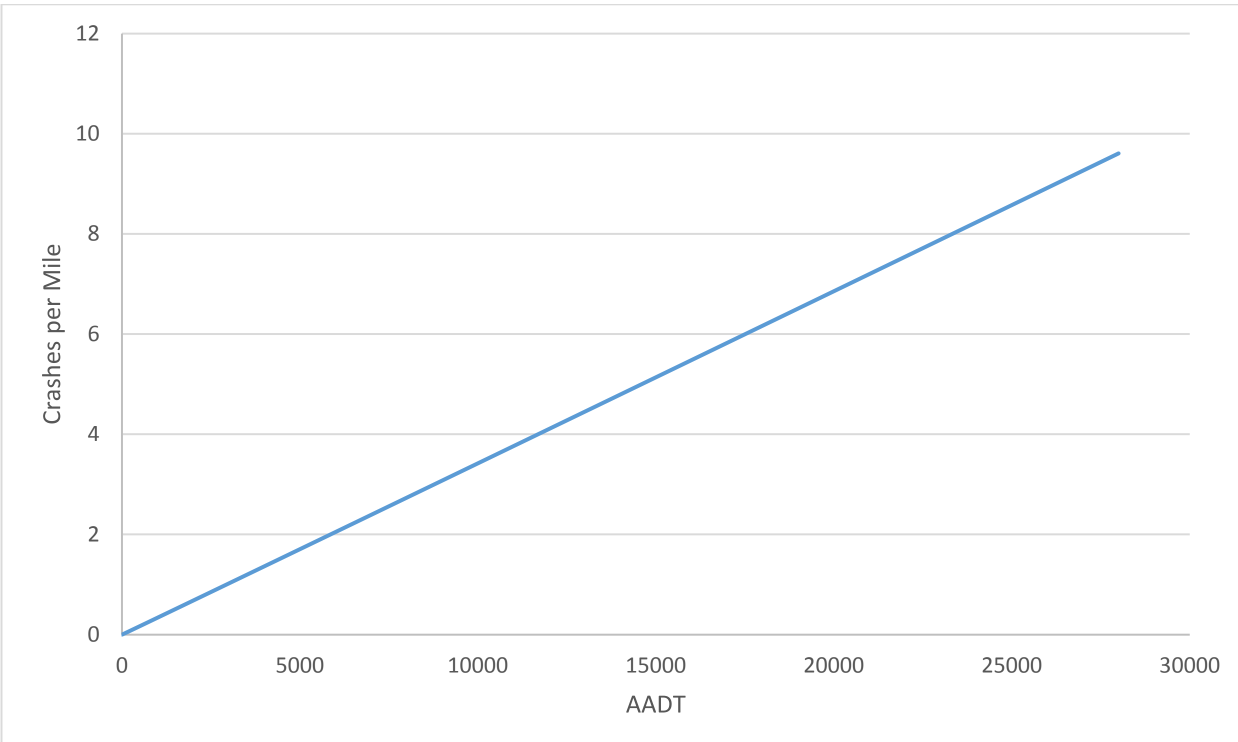


Figure 32. Total Annual Crashes per Mile for One-Way Segments

Table 28 shows the AADT with regional effects model for one-way segments. The AADT has an elastic effect on all three severity crash rates. The Bay Region had the lowest crash rate for total, FI, and PDO models. The Superior Region had the highest total and PDO crash rate, while the Metro Region had the highest FI crash rate.

Table 29. SPF for Crashes on One-Way Segments with AADT and Regional Indicators

Variable	Fatal and Injury Crashes			Property Damage Only Crashes			All Crash Severities		
	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic
Intercept	-9.627	1.897	-5.076	-8.366	0.946	-8.848	-7.903	0.885	-8.933
AADT	0.996	0.202	4.933	1.012	0.101	10.030	0.985	0.094	10.428
Superior Region Effect	-0.836	0.633	-1.321	1.130	0.220	5.136	0.933	0.214	4.361
North Region Effect	-	-	-	-0.501	1.037	-0.483	-0.752	1.034	-0.727
Grand Region Effect	-	-	-	-	-	-	-	-	-
Bay Region Effect	-1.235	0.304	-4.069	-0.545	0.145	-3.748	-0.642	0.138	-4.660
Southwest Region Effect	-0.585	0.294	-1.991	0.276	0.145	1.907	0.158	0.138	1.141
University Region Effect	-0.042	0.200	-0.210	0.306	0.119	2.569	0.257	0.112	2.289
Inverse Dispersion Parameter	1.140	0.310		1.470	0.082		0.649	0.073	

*Note: Metro Region Effect serves as baseline reference category

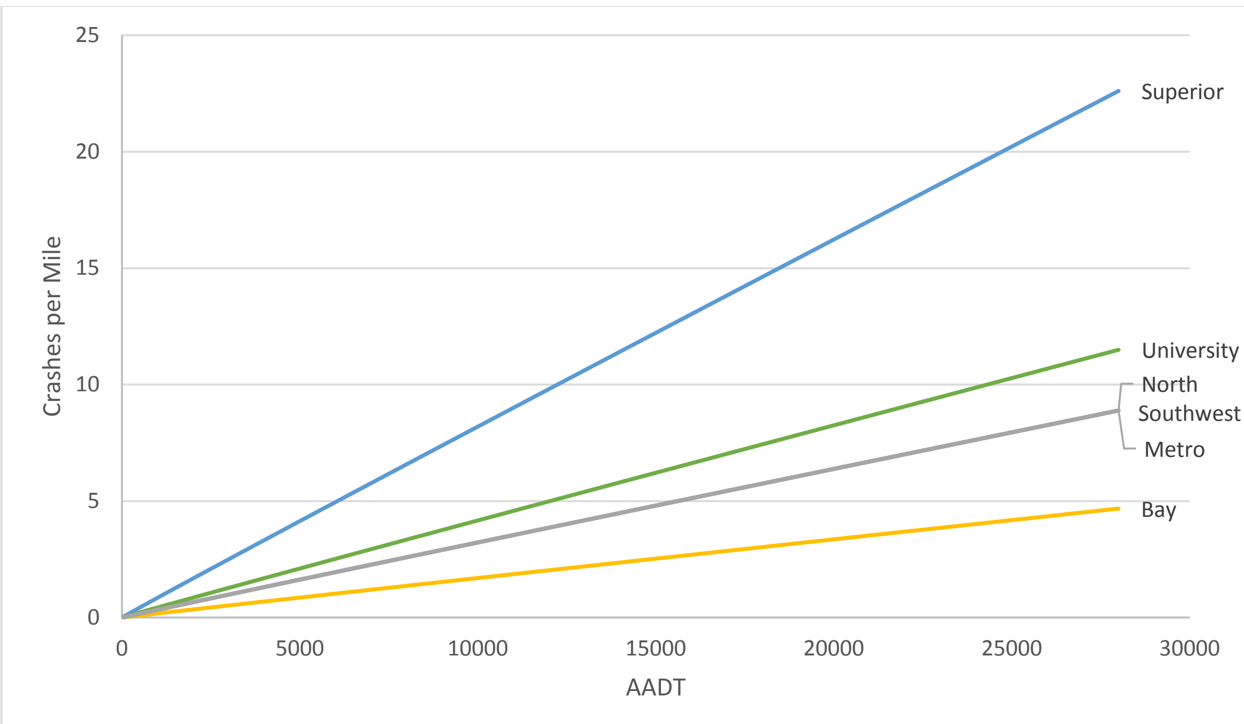


Figure 33. Total Annual Crashes per Mile for One-Way Segments with Regional Indicators

In addition to providing estimates of crashes by site type and region, it is also useful to predict how many crashes may be expected by type at a specific location. To this end, Table 29 provides details of the crash type distribution for each of the eight site types by severity level (FI versus PDO). Table 30 to Table 36 provide similar distributions for each of the MDOT regions.

Table 30. Statewide Distribution of Crashes by Collision Type

Manner of Collision	Statewide Proportion of Crashes by Severity Level for Specific Segment Types															
	2U		3T		4U		5T		4D		6D		8D		One-Way	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Single Vehicle	0.318	0.648	0.181	0.385	0.166	0.288	0.095	0.178	0.290	0.423	0.107	0.111	0.094	0.090	0.183	0.144
Rear-end	0.284	0.164	0.387	0.312	0.328	0.263	0.358	0.321	0.453	0.329	0.561	0.488	0.526	0.458	0.294	0.202
Rear-end Left-turn	0.033	0.010	0.014	0.004	0.057	0.023	0.006	0.006	0.010	0.009	0.007	0.018	0.010	0.011	0.006	0.014
Rear-end Right-turn	0.008	0.004	0.028	0.014	0.006	0.013	0.009	0.012	0.007	0.003	0.009	0.010	0.014	0.010	0.006	0.009
Head-on	0.083	0.006	0.039	0.009	0.055	0.006	0.041	0.009	0.016	0.005	0.005	0.003	0.009	0.003	0.017	0.005
Head-on Left-turn	0.021	0.008	0.049	0.015	0.055	0.021	0.071	0.031	0.005	0.002	0.000	0.001	0.001	0.000	0.000	0.004
Angle	0.112	0.051	0.163	0.122	0.169	0.137	0.272	0.209	0.088	0.050	0.127	0.077	0.145	0.109	0.139	0.120
Sideswipe-Same	0.035	0.051	0.022	0.081	0.041	0.176	0.042	0.165	0.056	0.135	0.075	0.241	0.095	0.252	0.200	0.419
Sideswipe-Opposite	0.042	0.019	0.028	0.017	0.022	0.020	0.016	0.022	0.008	0.007	0.004	0.005	0.004	0.009	0.006	0.013
Other MV	0.032	0.038	0.016	0.040	0.026	0.049	0.032	0.044	0.040	0.037	0.039	0.046	0.035	0.057	0.050	0.067
Pedestrian	0.019	0.000	0.031	0.000	0.041	0.002	0.035	0.001	0.014	0.000	0.036	0.001	0.045	0.001	0.028	0.001
Bicycle	0.013	0.000	0.043	0.002	0.035	0.003	0.023	0.001	0.012	0.000	0.031	0.001	0.020	0.001	0.072	0.002

Table 31. Distribution of Crashes by Collision Type for Superior Region Segments

Manner of Collision	Superior Region Proportion of Crashes by Severity Level for Specific Segment Types															
	2U		3T		4U		5T		4D		6D		8D		One-Way	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Single Vehicle	0.478	0.756	0.000	0.250	0.094	0.490	0.224	0.583	0.421	0.611	0.000	0.000	0.000	0.000	0.333	0.067
Rear-end	0.222	0.077	0.000	0.286	0.375	0.127	0.216	0.099	0.263	0.158	0.000	0.000	0.000	0.000	0.000	0.146
Rear-end Left-turn	0.044	0.004	0.000	0.000	0.031	0.032	0.000	0.004	0.000	0.011	0.000	0.000	0.000	0.000	0.000	0.000
Rear-end Right-turn	0.000	0.004	0.000	0.036	0.000	0.019	0.007	0.009	0.013	0.004	0.000	0.000	0.000	0.000	0.000	0.000
Head-on	0.067	0.004	0.000	0.036	0.063	0.006	0.104	0.013	0.013	0.011	0.000	0.000	0.000	0.000	0.000	0.034
Head-on Left-turn	0.011	0.002	0.000	0.000	0.031	0.032	0.037	0.016	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Angle	0.044	0.037	0.000	0.036	0.281	0.153	0.276	0.106	0.092	0.059	0.000	0.000	0.000	0.000	0.000	0.056
Sideswipe-Same	0.033	0.047	0.000	0.214	0.094	0.108	0.060	0.115	0.053	0.095	0.000	0.000	0.000	0.000	0.333	0.506
Sideswipe-Opposite	0.033	0.011	0.000	0.000	0.000	0.006	0.022	0.020	0.013	0.013	0.000	0.000	0.000	0.000	0.000	0.067
Other MV	0.022	0.060	0.000	0.143	0.031	0.025	0.030	0.032	0.092	0.040	0.000	0.000	0.000	0.000	0.000	0.112
Pedestrian	0.033	0.000	0.000	0.000	0.000	0.000	0.015	0.001	0.026	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bicycle	0.011	0.000	0.000	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.333	0.011

Table 32. Distribution of Crashes by Collision Type for North Region Segments

Manner of Collision	North Region Proportion of Crashes by Severity Level for Specific Segment Types															
	2U		3T		4U		5T		4D		6D		8D		1Way	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Single Vehicle	0.397	0.706	0.215	0.514	0.164	0.308	0.087	0.234	0.091	0.163	0.000	0.000	0.000	0.000	0.000	0.000
Rear-end	0.262	0.126	0.354	0.196	0.342	0.232	0.251	0.192	0.545	0.488	0.000	0.000	0.000	0.000	0.000	0.000
Rear-end Left-turn	0.028	0.020	0.015	0.000	0.068	0.021	0.004	0.008	0.091	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rear-end Right-turn	0.007	0.005	0.046	0.017	0.014	0.016	0.008	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Head-on	0.043	0.004	0.031	0.010	0.027	0.003	0.053	0.005	0.091	0.023	0.000	0.000	0.000	0.000	0.000	0.000
Head-on Left-turn	0.014	0.009	0.077	0.010	0.014	0.013	0.091	0.030	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Angle	0.113	0.046	0.123	0.066	0.233	0.168	0.373	0.231	0.000	0.070	0.000	0.000	0.000	0.000	0.000	0.000
Sideswipe-Same	0.028	0.038	0.015	0.122	0.041	0.192	0.042	0.227	0.182	0.140	0.000	0.000	0.000	0.000	0.000	1.000
Sideswipe-Opposite	0.043	0.018	0.062	0.028	0.027	0.011	0.027	0.027	0.000	0.070	0.000	0.000	0.000	0.000	0.000	0.000
Other MV	0.014	0.028	0.015	0.035	0.014	0.032	0.019	0.030	0.000	0.023	0.000	0.000	0.000	0.000	0.000	0.000
Pedestrian	0.021	0.000	0.031	0.000	0.014	0.000	0.034	0.002	0.000	0.023	0.000	0.000	0.000	0.000	0.000	0.000
Bicycle	0.028	0.000	0.015	0.000	0.041	0.005	0.011	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 33. Distribution of Crashes by Collision Type for Grand Region Segments

Manner of Collision	Grand Region Proportion of Crashes by Severity Level for Specific Segment Types															
	2U		3T		4U		5T		4D		6D		8D		1Way	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Single Vehicle	0.310	0.658	0.078	0.337	0.142	0.203	0.083	0.158	0.252	0.391	0.167	0.245	0.000	0.375	0.000	0.000
Rear-end	0.288	0.142	0.529	0.387	0.317	0.266	0.411	0.340	0.543	0.387	0.633	0.482	0.000	0.250	0.000	0.000
Rear-end Left-turn	0.035	0.015	0.020	0.004	0.058	0.023	0.003	0.005	0.011	0.011	0.000	0.000	0.000	0.000	0.000	0.000
Rear-end Right-turn	0.009	0.004	0.039	0.008	0.008	0.010	0.009	0.011	0.009	0.005	0.000	0.014	0.000	0.000	0.000	0.000
Head-on	0.097	0.004	0.059	0.008	0.025	0.010	0.041	0.008	0.013	0.005	0.000	0.000	0.000	0.000	0.000	0.000
Head-on Left-turn	0.022	0.010	0.039	0.042	0.117	0.033	0.073	0.033	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Angle	0.097	0.043	0.098	0.107	0.167	0.163	0.232	0.210	0.067	0.044	0.067	0.007	0.000	0.000	0.000	0.000
Sideswipe-Same	0.040	0.063	0.000	0.069	0.033	0.211	0.039	0.165	0.039	0.124	0.067	0.230	0.000	0.375	0.000	0.000
Sideswipe-Opposite	0.035	0.016	0.020	0.008	0.033	0.023	0.017	0.021	0.009	0.004	0.000	0.000	0.000	0.000	0.000	0.000
Other MV	0.027	0.043	0.039	0.031	0.025	0.055	0.036	0.049	0.032	0.028	0.067	0.022	0.000	0.000	0.000	0.000
Pedestrian	0.022	0.001	0.020	0.000	0.042	0.003	0.044	0.000	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bicycle	0.018	0.000	0.059	0.000	0.033	0.003	0.013	0.000	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 34. Distribution of Crashes by Collision Type for Bay Region Segments

Manner of Collision	Bay Region Proportion of Crashes by Severity Level for Specific Segment Types															
	2U		3T		4U		5T		4D		6D		8D		1Way	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Single Vehicle	0.256	0.666	0.203	0.425	0.167	0.470	0.113	0.274	0.415	0.627	0.000	0.500	0.000	0.000	0.250	0.297
Rear-end	0.329	0.147	0.373	0.274	0.375	0.188	0.344	0.275	0.293	0.162	0.000	0.000	0.000	0.000	0.313	0.156
Rear-end Left-turn	0.041	0.008	0.000	0.004	0.083	0.028	0.010	0.005	0.000	0.016	0.000	0.167	0.000	0.000	0.000	0.000
Rear-end Right-turn	0.020	0.007	0.017	0.000	0.000	0.016	0.008	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Head-on	0.065	0.006	0.034	0.008	0.083	0.004	0.035	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.063	0.000
Head-on Left-turn	0.033	0.008	0.051	0.004	0.042	0.020	0.065	0.027	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Angle	0.110	0.042	0.153	0.132	0.139	0.121	0.312	0.204	0.146	0.043	0.000	0.167	0.000	0.000	0.188	0.125
Sideswipe-Same	0.037	0.069	0.034	0.071	0.035	0.087	0.040	0.141	0.073	0.108	0.000	0.167	0.000	0.000	0.125	0.375
Sideswipe-Opposite	0.041	0.017	0.017	0.008	0.007	0.026	0.008	0.015	0.024	0.016	0.000	0.000	0.000	0.000	0.063	0.008
Other MV	0.033	0.028	0.000	0.071	0.028	0.038	0.030	0.036	0.024	0.027	0.000	0.000	0.000	0.000	0.000	0.039
Pedestrian	0.028	0.000	0.051	0.000	0.021	0.004	0.010	0.001	0.024	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bicycle	0.008	0.000	0.068	0.004	0.021	0.000	0.025	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 35. Distribution of Crashes by Collision Type for Southwest Region Segments

Manner of Collision	Southwest Region Proportion of Crashes by Severity Level for Specific Segment Types															
	2U		3T		4U		5T		4D		6D		8D		1Way	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Single Vehicle	0.352	0.736	0.219	0.387	0.252	0.287	0.100	0.163	0.400	0.660	0.000	0.286	0.000	0.000	0.158	0.199
Rear-end	0.186	0.108	0.336	0.286	0.330	0.301	0.275	0.309	0.225	0.125	0.500	0.286	0.000	0.000	0.316	0.270
Rear-end Left-turn	0.043	0.011	0.031	0.002	0.039	0.026	0.011	0.008	0.013	0.005	0.000	0.000	0.000	0.000	0.000	0.005
Rear-end Right-turn	0.010	0.003	0.039	0.018	0.019	0.012	0.011	0.015	0.013	0.002	0.000	0.000	0.000	0.000	0.000	0.010
Head-on	0.090	0.006	0.047	0.007	0.049	0.008	0.044	0.010	0.050	0.005	0.000	0.000	0.000	0.000	0.000	0.000
Head-on Left-turn	0.019	0.006	0.031	0.017	0.019	0.014	0.064	0.035	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.005
Angle	0.119	0.041	0.172	0.145	0.155	0.108	0.322	0.205	0.138	0.059	0.000	0.000	0.000	0.000	0.158	0.041
Sideswipe-Same	0.057	0.035	0.016	0.061	0.029	0.146	0.036	0.167	0.038	0.093	0.000	0.286	0.000	0.000	0.158	0.352
Sideswipe-Opposite	0.043	0.019	0.023	0.015	0.019	0.010	0.008	0.022	0.025	0.007	0.000	0.000	0.000	0.000	0.000	0.010
Other MV	0.057	0.034	0.016	0.059	0.019	0.079	0.039	0.064	0.050	0.042	0.000	0.143	0.000	0.000	0.053	0.102
Pedestrian	0.019	0.001	0.023	0.000	0.039	0.004	0.050	0.001	0.038	0.000	0.500	0.000	0.000	0.000	0.053	0.005
Bicycle	0.005	0.000	0.047	0.004	0.029	0.004	0.039	0.001	0.013	0.000	0.000	0.000	0.000	0.000	0.105	0.000

Table 36. Distribution of Crashes by Collision Type for University Region Segments

Manner of Collision	University Region Proportion of Crashes by Severity Level for Specific Segment Types															
	2U		3T		4U		5T		4D		6D		8D		1Way	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Single Vehicle	0.326	0.643	0.183	0.351	0.163	0.231	0.099	0.187	0.418	0.608	0.167	0.217	0.000	0.750	0.169	0.068
Rear-end	0.318	0.189	0.398	0.354	0.300	0.303	0.332	0.297	0.228	0.177	0.389	0.289	0.000	0.000	0.351	0.220
Rear-end Left-turn	0.027	0.006	0.005	0.006	0.039	0.019	0.007	0.006	0.000	0.009	0.000	0.000	0.000	0.000	0.000	0.023
Rear-end Right-turn	0.003	0.003	0.016	0.012	0.005	0.012	0.011	0.011	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.009
Head-on	0.088	0.007	0.022	0.008	0.049	0.005	0.024	0.009	0.025	0.004	0.000	0.012	0.000	0.000	0.000	0.007
Head-on Left-turn	0.016	0.004	0.059	0.012	0.049	0.014	0.072	0.024	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.005
Angle	0.107	0.055	0.177	0.128	0.192	0.141	0.277	0.220	0.165	0.038	0.167	0.157	0.000	0.000	0.117	0.145
Sideswipe-Same	0.016	0.038	0.027	0.085	0.039	0.204	0.041	0.178	0.076	0.131	0.056	0.301	0.000	0.250	0.234	0.460
Sideswipe-Opposite	0.048	0.023	0.022	0.021	0.020	0.024	0.021	0.024	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.007
Other MV	0.027	0.031	0.016	0.021	0.034	0.044	0.026	0.039	0.038	0.023	0.000	0.024	0.000	0.000	0.026	0.054
Pedestrian	0.008	0.001	0.038	0.000	0.064	0.000	0.047	0.001	0.025	0.000	0.167	0.000	0.000	0.000	0.026	0.000
Bicycle	0.016	0.001	0.038	0.001	0.044	0.003	0.042	0.003	0.025	0.000	0.056	0.000	0.000	0.000	0.078	0.002

Table 37. Distribution of Crashes by Collision Type for Metro Region Segments

Manner of Collision	Metro Region Proportion of Crashes by Severity Level for Specific Segment Types															
	2U		3T		4U		5T		4D		6D		8D		1Way	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Single Vehicle	0.253	0.434	0.000	0.347	0.144	0.185	0.081	0.078	0.251	0.293	0.103	0.100	0.094	0.089	0.185	0.179
Rear-end	0.297	0.296	0.400	0.333	0.311	0.299	0.402	0.413	0.494	0.403	0.563	0.496	0.526	0.458	0.231	0.163
Rear-end Left-turn	0.024	0.008	0.000	0.013	0.068	0.022	0.007	0.006	0.011	0.008	0.007	0.019	0.010	0.011	0.015	0.019
Rear-end Right-turn	0.007	0.005	0.000	0.040	0.000	0.011	0.008	0.012	0.006	0.002	0.010	0.010	0.014	0.010	0.015	0.015
Head-on	0.098	0.007	0.150	0.013	0.076	0.007	0.040	0.010	0.011	0.003	0.006	0.002	0.009	0.003	0.031	0.000
Head-on Left-turn	0.024	0.016	0.000	0.000	0.076	0.040	0.072	0.036	0.006	0.004	0.000	0.001	0.001	0.000	0.000	0.004
Angle	0.149	0.078	0.300	0.160	0.114	0.123	0.247	0.217	0.082	0.056	0.129	0.078	0.145	0.109	0.154	0.160
Sideswipe-Same	0.044	0.076	0.050	0.067	0.053	0.231	0.045	0.159	0.073	0.172	0.076	0.240	0.095	0.252	0.185	0.392
Sideswipe-Opposite	0.041	0.024	0.050	0.013	0.038	0.026	0.014	0.023	0.003	0.007	0.004	0.005	0.004	0.009	0.000	0.008
Other MV	0.037	0.055	0.000	0.013	0.023	0.053	0.034	0.046	0.040	0.052	0.039	0.047	0.035	0.057	0.092	0.061
Pedestrian	0.017	0.000	0.000	0.000	0.053	0.000	0.032	0.001	0.008	0.000	0.033	0.001	0.045	0.001	0.031	0.000
Bicycle	0.010	0.001	0.050	0.000	0.045	0.004	0.019	0.001	0.014	0.001	0.031	0.001	0.020	0.001	0.062	0.000

5.2 Michigan Specific SPFs for Pedestrian- and Bicycle-Involved Crashes

Pedestrian and cyclist volumes were not readily available for this study; however, the research team attempted to develop models for pedestrian and bicycle crashes based on vehicular AADT for total, FI, and PDO crashes as shown in Table 39 and Table 40.

Table 38. Michigan Specific AADT Only Pedestrian Crash Models

	Segment Types	Intercept (a)	AADT (b)	Overdispersion factor (k)
Total	2U	-19.53	0.38*	1.86E-14
	3T	-3.48*	-0.03*	7.16E-08
	4U	-21.04	1.87	2.00E-03
	5T	-9.28	0.69	0.12
	4D	-8.558	0.42*	1.03E-16
	6D	-5.52*	0.27*	1.58
	8D	-8.957	0.63*	1.04
	OneWay	-7.42*	0.36*	0.00
FI	2U	-21.05	0.54*	2.46E-15
	3T	-3.48*	-0.03*	7.16E-08
	4U	-22.49	2.00	0.00
	5T	-10.65	0.81	0.03
	4D	-8.15*	0.37*	9.92E-11
	6D	-4.60*	0.17*	0.87
	8D	-10.81	0.81	0.81
	OneWay	-0.90*	-0.37*	0.00
PDO	2U	-12.78	-0.65*	1.00
	3T	-	-	-
	4U	-14.64*	1.00*	0.00
	5T	-1.38*	-0.34*	2.96E-07
	4D	-20.04*	1.34*	1.00
	6D	-	-	-
	8D	1.68*	-0.65*	0.00
	OneWay	-178.87*	17.48*	0.00

*The variable was not significant at 95% confidence interval

Table 39. Michigan Specific AADT Only Bicycle Crash Models

	Segment Types	Intercept (a)	AADT (b)	Overdispersion factor (k)
Total	**2U**	-25.17	0.96	0.00
	3T	-4.11*	0.09*	0.00
	4U	-6.51*	0.36*	0.64
	5T	-13.34	1.05	0.00
	4D	-17.722	1.381	0.00
	6D	-11.325	0.83*	0.00
	8D	-3.16*	-0.02*	0.04
	OneWay	-0.24*	-0.32*	1.00
FI	**2U**	-26.88	1.13	0.00
	3T	-5.47*	0.22*	0.00
	4U	-5.61*	0.24*	2.62
	5T	-14.45	1.15	0.00
	4D	-20.046	1.610	0.00
	6D	-11.672	0.85*	0.06
	8D	-4.05*	0.06*	0.62
	OneWay	-3.92*	0.07*	1.00
PDO	**2U**	-15.58*	-0.38*	0.00
	3T	0.08*	-0.57*	0.00
	4U	-10.98*	0.69*	0.00
	5T	-9.67*	0.49*	0.00
	4D	-8.44*	0.18*	0.00
	6D	-11.06*	0.55*	0.00
	8D	1.51*	-0.71*	0.00
	OneWay	12.79*	-2.04*	0.00

*The variable was not significant at 95% confidence interval

Each of the models show that a majority of crashes increase with respect to traffic volumes. However, even in the highest volume cases, segments were generally expected to experience only a fraction of a crash per year. This is demonstrated by the crash proportions on Table 31 through Table 36. Bicycle FI crash proportions were relatively high for one-way segments in the Superior and Southwest Regions, and the pedestrian FI crash proportion was high for 6-lane divided segments in the University Region. In any case, these models provide a general starting point for pedestrian and bicycle safety analyses. As additional data becomes available, these models may be expanded to better understand the effects of geometric and traffic control factors on the crash risk for pedestrians and bicyclists. The lack of a reliable exposure measure to represent the amount of pedestrian or bicyclist activity on a given segment is also a limitation which may be addressed through future programs aimed at collecting data for non-motorized users.

Another point worth noting is that most of the parameters in the property damage only (PDO) models are not statistically significant. This is reflective, at least in part, of the fact that pedestrian- or bicycle-involved crashes that result in no injury are very rare and most crashes of this type tend to go unreported.

6.0 FULLY-SPECIFIED SPFS WITH AADT, REGIONAL INDICATORS, AND GEOMETRIC VARIABLES

After estimating the models considering only traffic volumes and MDOT region, more detailed models were specified that considered the full database developed by the research team. These fully-specified models were developed in a format similar to those presented in Chapter 12 of the HSM. This section briefly outlines the format of these SPFs, which are estimated in combination with CMFs where sufficient data are available. Separate models are estimated for intersections of two-way streets and one-way streets as the factors contributing to crashes in each setting are found to vary, as are the magnitudes of the relevant predictors.

The predicted average crash frequency for each roadway segment on a particular facility is computed as the sum of predicted average crash frequency of all crash types that occurred on the segment. The predicted average crash frequency is computed using the predictive model, where a model is the combination of a SPF and several CMFs. The SPF is used to estimate the average crash frequency for the stated base conditions. The CMFs are used to adjust the SPF estimate when the attributes of the subject site are not consistent with the base conditions. The predicted average crash frequency of a roadway segment is calculated as shown below.

$N_r = N_{br} + N_{pedr} + N_{biker}$

with,

$N_{br} = N_{mvr} + N_{svr}$

$N_{mvr} = N_{spfmv} \times (CMF_1 \times \ldots . \times CMF_p)$

$N_{svr} = N_{spfsv} \times (CMF_1 \times \ldots . \times CMF_p)$

$N_{pedr} = N_{br} \times f_{ped}$

$N_{biker} = N_{br} \times f_{bike}$

where,

$N_r =$ predicted average crash frequency of an individual segment for the selected year;

$N_{br} =$ predicted average crash frequency of an individual segment (excluding vehicle-pedestrian and vehicle-bicycle collisions);

$N_{pedr} =$ predicted average crash frequency of vehicle-pedestrian collisions for a segment ;

$N_{biker} =$ predicted average crash frequency of vehicle-bicycle collisions for a segment;

$N_{mvr} =$ predicted average crash frequency of multiple-vehicle crashes (excluding vehicle-pedestrian and vehicle-bicycle collisions) for a segment ;

$N_{svr} =$ predicted average crash frequency of single-vehicle crashes (excluding vehicle-pedestrian and vehicle-bicycle collisions) for a segment ;

$N_{spfmv} =$ predicted average crash frequency of multiple-vehicle crashes (excluding vehicle-pedestrian and vehicle-bicycle collisions) for base conditions ;

$N_{spfmv} =$ predicted average crash frequency of single-vehicle crashes (excluding vehicle-pedestrian and vehicle-bicycle collisions) for base conditions ;
$f_{ped} =$ pedestrian crash adjustment factor ;
$f_{bike} =$ bicycle crash adjustment factor ;
$CMF_1 \times \ldots . \times CMF_p =$ crash modification factors at site with geometric design features *p*.

SPFs and CMFs are provided for the various site types on urban and suburban highways listed in Table 41.

Table 40. List of Facility Types with SPFs

Site Type	Site Types with SPFs
Two-way Streets	Two-lane undivided arterials with 55 miles/hour posted speed (2U55E) Two-lane undivided arterials with less than 55 miles/hour posted speed (2U55L) Three-lane arterials including a center TWLTL (3T) Four-lane undivided arterials (4U) Four-lane divided arterials (including a raised or depressed median) (4D) Five-lane arterials including a center TWLTL (5T) Six-lane divided arterials (including a raised or depressed median) (6D) Eight-lane divided arterials (including a raised or depressed median) (8D)
One-way Streets	Two-lane one-way arterials (2O) Three-lane one-way arterials (3O) Four-lane one-way arterials (4O)

6.1 Model Development – Two-Way Arterials

The following regression model form was used to predict the average crash frequency along an individual roadway segment.

$$N_j = (N_{spfmv} I_{mv} CMF_{dw} + N_{spfsv} I_{sv} CMF_{fo}) \times CMF_{lw} \times CMF_{lsw} \times CMF_{rsw} \times CMF_{mw} \times CMF_{pk} \times CMF_{lgt} \times CMF_{spd}$$

with,

$$N_{spfmv} = n \times L \times e^{b_{mv} + b_{mv1} \ln(AADT) + b_{com} \frac{AADT_{com}}{AADT} + b_{r1} I_{r1} + b_{r2} I_{r2} + b_{r3} I_{r3} + b_{r4} I_{r4} + b_{r5} I_{r5} + b_{r6} I_{r6}}$$

$$N_{spfsv} = n \times L \times e^{b_{sv} + b_{sv1} \ln(AADT) + b_{com} \frac{AADT_{com}}{AADT} + b_{r1} I_{r1} + b_{r2} I_{r2} + b_{r3} I_{r3} + b_{r4} I_{r4} + b_{r5} I_{r5} + b_{r6} I_{r6}}$$

$$CMF_{lw} = e^{b_{lw}(W_l-12)}$$
$$CMF_{lsw} = e^{b_{lsw}(W_{lsw}-1.0)}$$
$$CMF_{mw} = e^{b_{mw}(\sqrt{W_m}-\sqrt{16})}$$
$$CMF_{dw} = e^{b_{dwc}(n_{dwc}-10)} \times e^{b_{dwi}(n_{dwi}-3)} \times e^{b_{dwr}(n_{dwr}-8)} \times e^{b_{dwo}(n_{dwo}-10)}$$

where,

$N_j =$ predicted annual average crash frequency for model *j* (*j*=*mv*, *sv*);
$N_{mv} =$ predicted annual average multiple-vehicle crash frequency;
$N_{sv} =$ predicted annual average single-vehicle crash frequency;
$I_{mv} =$ multiple-vehicle crash indicator variable (=1.0 if multiple-vehicle crash data, 0.0 otherwise) ;
$I_{sv} =$ single-vehicle crash indicator variable (=1.0 if single-vehicle crash data, 0.0 otherwise) ;
$n =$ number of years of crash data;
$AADT =$ annual average daily traffic, veh/day;
$AADT_{com} =$ commercial vehicle average annual daily traffic, veh/day;
$I_{r1} =$ Superior region indicator variable (=1.0 if site is in Superior region, 0.0 if it is not);
$I_{r2} =$ North region indicator variable (=1.0 if site is in North region, 0.0 if it is not);
$I_{r3} =$ Grand region indicator variable (=1.0 if site is in Grand region, 0.0 if it is not);
$I_{r4} =$ Bay region indicator variable (=1.0 if site is in Bay region, 0.0 if it is not);
$I_{r5} =$ Southwest region indicator variable (=1.0 if site is in Southwest region, 0.0 if it is not);
$I_{r6} =$ University region indicator variable (=1.0 if site is in University region, 0.0 if it is not);
$CMF_{lw} =$ lane width modification factor;
$CMF_{lsw} =$ left shoulder width crash modification factor;
$CMF_{rsw} =$ right shoulder width crash modification factor;
$CMF_{mw} =$ median width crash modification factor;
$CMF_{pk} =$ on-street parking crash modification factor;
$CMF_{fo} =$ roadside fixed objects crash modification factor;
$CMF_{dw} =$ driveway count crash modification factor;
$CMF_{lgt} =$ lighting crash modification factor;
$CMF_{spd} =$ automatic speed enforcement crash modification factor;
$W_l =$ average lane width, ft;
$W_{lsw} =$ average left shoulder width, ft;
$W_m =$ median width, ft;
$n_{dwc} =$ commercial driveway density, driveways/mile
$n_{dwi} =$ industrial driveway density, driveways/mile
$n_{dwr} =$ residential driveway density, driveways/mile
$n_{dwo} =$ other type driveway density, driveways/mile
$b_i =$ calibration coefficient for variable *i*.

The inverse dispersion parameter, K (which is the inverse of the over-dispersion parameter *k*), is allowed to vary with the segment length. The inverse dispersion parameter is calculated using the following equation:

$$K = L \times e^{\delta,j};\ j = mv, sv$$

where,

K	=	inverse dispersion parameter.
δ	=	calibration coefficient for inverse dispersion parameter.

6.1.1 Model Calibration

The predictive model calibration process consisted of the simultaneous calibration of multiple-vehicle and single-vehicle crash models and CMFs using the aggregate model represented by the equations above. The simultaneous calibration approach was needed because some CMFs were common to multiple-vehicle (MV) and single-vehicle (SV) crash models. The database assembled for calibration included two replications of the original database. The dependent variable in the first replication was set equal to the multiple-vehicle crashes. The dependent variable in the second replication was set equal to the single-vehicle crashes. The results of the multivariate regression model calibration are presented in the following tables.

Table 42 and Table 43 summarize the results for fatal and injury and PDO crashes, respectively, on two-way roadway segments. The t-statistics indicate a test of the hypothesis that the coefficient value is equal to 0.0. Those t-statistics with an absolute value that is larger than 2.0 indicate that the hypothesis can be rejected with the probability of error in this conclusion being less than 0.05. For those few variables where the absolute value of the t-statistic is smaller than 2.0, it was decided that the variable was important to the model and its trend was found to be consistent with previous research findings (even if the specific value was not known with a great deal of certainty as applied to this database). The indicator variables for some regions in the state were found to be significant. For the same conditions, the Grand Region experienced the highest number of fatal and injury crashes and PDO crashes, while the Superior Region experienced the least fatal and injury crashes. This is likely due to the differences between regions such as vertical grade, crash reporting, and weather.

The non-linear mixed modeling (NLMIXED) procedure in the SAS software was used to estimate the proposed model coefficients. This procedure was used because the proposed predictive model is both nonlinear and discontinuous. The log-likelihood function for the NB distribution was used to determine the best-fit model coefficients.

Table 41. Calibrated coefficients for fatal and injury crashes on two-way segments

Coefficient	Variable	Type	Value	Std. Dev	t-statistic
b_{mv}	Intercept for MV crashes	2U55E	-12.025	1.151	-10.45
		2U55L	-14.183	1.286	-11.03
		3T	-15.855	1.931	-8.21
		4U	-14.250	1.115	-12.79
		4D	-16.829	1.636	-10.29
		5T	-16.725	1.002	-16.70
		6D	-14.898	1.976	-7.54
		8D	-17.367	1.930	-9.00
b_{mv1}	AADT on MV crashes	2U55E	1.238	0.126	9.81
		2U55L	1.449	0.139	10.42
		3T	1.610	0.205	7.85
		4U	1.426	0.119	12.03
		4D	1.702	0.171	9.98
		5T	1.706	0.100	17.04
		6D	1.486	0.196	7.58
		8D	1.717	0.190	9.04
b_{sv}	Intercept for SV crashes	2U55E	-4.881	1.113	-4.39
		2U55L	-3.852	1.351	-2.85
		3T	-6.604	2.890	-2.28
		4U	-3.824	1.178	-3.25
		4D	-7.847	2.608	-3.01
		5T	-4.743	1.565	-3.03
		6D	-9.201	3.013	-3.05
		8D	-7.828	3.093	-2.53
b_{sv1}	AADT on SV crashes	2U55E	0.387	0.124	3.13
		2U55L	0.233	0.149	1.56
		3T	0.487	0.310	1.57
		4U	0.207	0.128	1.62
		4D	0.624	0.274	2.28
		5T	0.315	0.157	2.00
		6D	0.721	0.299	2.42
		8D	0.575	0.304	1.89
b_{com}	Commercial vehicle proportion	All	1.144	0.651	1.76
b_{r1}	Added effect of Superior region	All	-0.163	0.076	-2.15
b_{r2}	Added effect of North region	All	0.000	--	--
b_{r3}	Added effect of Grand region	All	0.170	0.051	3.36
b_{r4}	Added effect of Bay region	All	0.000	--	--
b_{r5}	Added effect of Southwest region	All	0.000	--	--

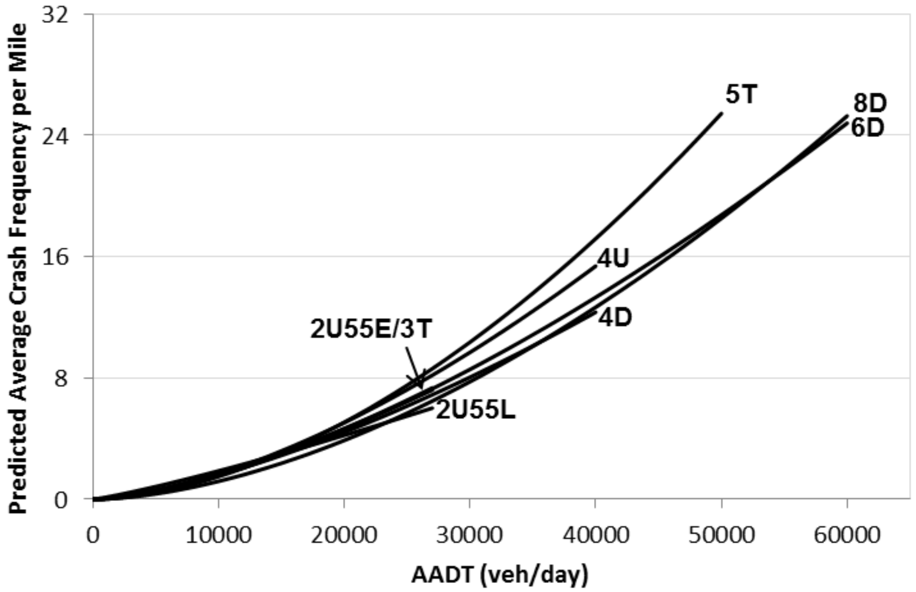
Coefficient	Variable	Type	Value	Std. Dev	t-statistic
b_{r6}	Added effect of University region	All	0.000	--	--
b_{lw}	Lane width	All	-0.026	0.064	-0.40
b_{lsw}	Left shoulder width	4D/6D/8D	-0.022	0.024	-0.91
b_{mw}	Median width	4D/6D/8D	-0.138	0.123	-1.12
b_{dwc}	Commercial driveway density	All	0.014	0.002	9.36
b_{dwi}	Industrial driveway density	All	0.005	0.004	1.14
b_{dwr}	Residential driveway density	All	0.002	0.002	1.00
b_{dwr}	Other type driveway density	All	0.003	0.002	1.98
δ_{mv}	Inverse dispersion parameter for MV crashes	2U55E	1.108	0.262	4.22
		2U55L	1.288	0.266	4.85
		3T	1.012	0.239	4.24
		4U	0.582	0.179	3.26
		4D	1.266	0.214	5.92
		5T	1.184	0.106	11.14
		6D	0.917	0.219	4.19
		8D	0.566	0.154	3.68
δ_{sv}	Inverse dispersion parameter for SV crashes	2U55E	1.455	0.489	2.97
		2U55L	0.887	0.449	1.98
		3T	0.236	0.394	0.60
		4U	0.908	0.361	2.52
		4D	0.792	0.457	1.74
		5T	1.197	0.352	3.40
		6D	0.832	0.594	1.40
		8D	0.636	0.486	1.31
Observations		2057 segments (2U55E=213; 2U55L=271; 3T=237; 4U=239; 4D=373; 5T=440; 6D=119; 8D=165)			

Table 42. Calibrated coefficients for PDO crashes on two-way street segments

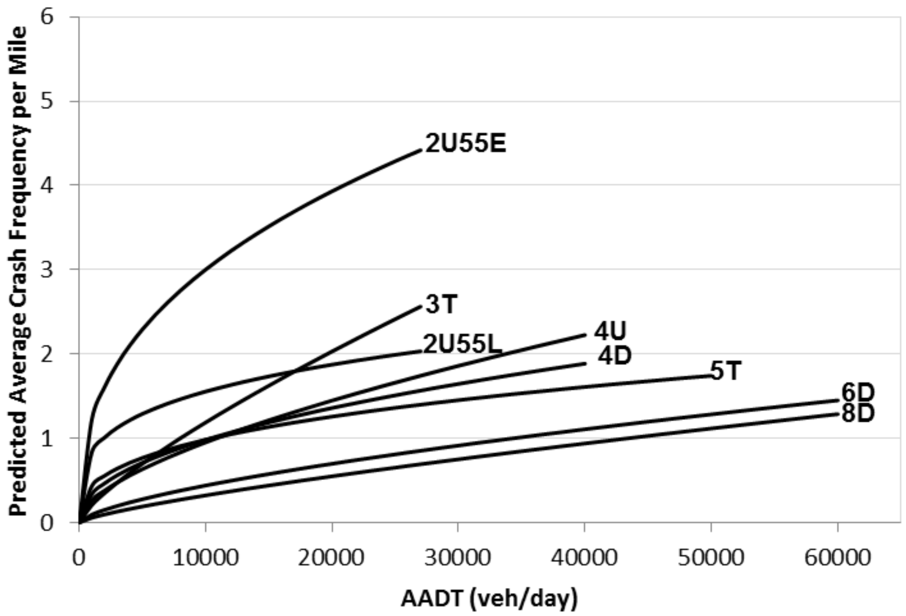
Coefficient	Variable	Type	Value	Std. Dev	t-statistic
b_{mv}	Intercept for MV crashes	2U55E	-13.959	0.975	-14.32
		2U55L	-9.494	0.896	-10.60
		3T	-13.413	1.452	-9.24
		4U	-14.791	0.840	-17.61
		4D	-12.670	1.132	-11.19
		5T	-16.188	0.883	-18.33
		6D	-13.954	1.608	-8.68
		8D	-15.674	1.449	-10.81
b_{mv1}	AADT on MV crashes	2U55E	1.533	0.107	14.28
		2U55L	1.071	0.098	10.90
		3T	1.483	0.155	9.54
		4U	1.638	0.090	18.18
		4D	1.403	0.119	11.81
		5T	1.772	0.089	19.96
		6D	1.543	0.160	9.63
		8D	1.700	0.143	11.89
b_{sv}	Intercept for SV crashes	2U55E	-2.577	0.674	-3.82
		2U55L	-2.206	1.054	-2.09
		3T	-7.311	1.793	-4.08
		4U	-6.360	0.990	-6.43
		4D	-4.249	1.906	-2.23
		5T	-3.536	1.202	-2.94
		6D	-7.017	1.973	-3.56
		8D	-8.981	2.278	-3.94
b_{sv1}	AADT on SV crashes	2U55E	0.389	0.075	5.15
		2U55L	0.274	0.117	2.34
		3T	0.801	0.193	4.15
		4U	0.667	0.106	6.31
		4D	0.445	0.202	2.21
		5T	0.363	0.121	3.00
		6D	0.652	0.197	3.31
		8D	0.822	0.224	3.66
b_{com}	Commercial vehicle proportion	All	1.486	0.546	2.72
b_{r1}	Added effect of Superior region	All	0.000	--	--
b_{r2}	Added effect of North region	All	0.151	0.052	2.92
b_{r3}	Added effect of Grand region	All	0.199	0.041	4.86
b_{r4}	Added effect of Bay region	All	0.000	--	--
b_{r5}	Added effect of Southwest region	All	0.000	--	--

Coefficient	Variable	Type	Value	Std. Dev	t-statistic
b_{r6}	Added effect of University region	All	0.135	0.038	3.53
b_{lw}	Lane width	All	-0.013	0.046	-0.27
b_{lsw}	Left shoulder width	4D/6D/8D	0.036	0.018	1.96
b_{mw}	Median width	4D/6D/8D	-0.254	0.096	-2.63
b_{dwc}	Commercial driveway density	All	0.014	0.001	9.98
b_{dwi}	Industrial driveway density	All	0.009	0.003	2.63
b_{dwr}	Residential driveway density	All	-0.002	0.002	-1.28
b_{dwr}	Other type driveway density	All	0.006	0.001	4.27
δ_{mv}	Inverse dispersion parameter for MV crashes	2U55E	1.020	0.164	6.23
		2U55L	0.798	0.121	6.58
		3T	0.897	0.123	7.28
		4U	0.575	0.101	5.68
		4D	1.348	0.121	11.17
		5T	0.948	0.074	12.83
		6D	0.770	0.151	5.10
		8D	0.794	0.117	6.81
δ_{sv}	Inverse dispersion parameter for SV crashes	2U55E	1.283	0.121	10.60
		2U55L	0.350	0.118	2.95
		3T	0.398	0.126	3.16
		4U	0.937	0.144	6.53
		4D	0.404	0.138	2.93
		5T	0.945	0.110	8.62
		6D	0.611	0.230	2.65
		8D	0.534	0.215	2.49
Observations		2057 segments (2U55E=213; 2U55L=271; 3T=237; 4U=239; 4D=373; 5T=440; 6D=119; 8D=165)			

The relationship between crash frequency (FI plus PDO crashes) and traffic demand for base conditions, as obtained from the calibrated models, is illustrated in Figure 34.



a) Multiple-Vehicle Crashes



b) Single-Vehicle Crashes

Figure 34. Graphical Form of the Segment SPF for Crashes on Two-way Streets

The crash frequency obtained can be multiplied by the proportions in Table 44 to estimate the predicted average multiple-vehicle crash frequency by collision type category.

Table 43. Distribution of multiple-Vehicle crashes by collision type

Manner of Collision	Proportion of Crashes by Severity Level for Specific Segment Types							
	2U55E		2U55L		3T		4U	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Rear-end	0.43	0.47	0.45	0.47	0.52	0.51	0.43	0.37
Head-on	0.13	0.02	0.12	0.05	0.05	0.01	0.07	0.01
Angle	0.15	0.15	0.19	0.14	0.22	0.20	0.22	0.19
Sideswipe-Same	0.06	0.13	0.05	0.16	0.03	0.13	0.05	0.25
Sideswipe-Opposite	0.06	0.06	0.06	0.05	0.04	0.03	0.03	0.03
Other MV	0.16	0.18	0.12	0.17	0.14	0.12	0.19	0.15
	4D		5T		6D		8D	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Rear-end	0.66	0.57	0.42	0.39	0.68	0.55	0.63	0.50
Head-on	0.02	0.01	0.05	0.01	0.01	0.00	0.01	0.00
Angle	0.13	0.09	0.32	0.26	0.15	0.09	0.17	0.12
Sideswipe-Same	0.08	0.23	0.05	0.20	0.07	0.27	0.11	0.28
Sideswipe-Opposite	0.01	0.01	0.03	0.00	0.00	0.01	0.01	0.01
Other MV	0.09	0.09	0.11	0.09	0.09	0.08	0.07	0.09

6.1.2 Vehicle-Pedestrian Crashes

The number of vehicle-pedestrian collisions per year for a segment is estimated as:

$$N_{peds} = N_{bs} \times f_{ped}$$

$N_{bs} =$ predicted average crash frequency of an individual segment (excluding vehicle-pedestrian and vehicle-bicycle collisions);

$N_{peds} =$ predicted average crash frequency of vehicle-pedestrian collisions for a segment;

$f_{ped} =$ pedestrian crash adjustment factor.

The pedestrian crash adjustment factor is estimated by dividing the vehicle-pedestrian crashes by the sum of single-vehicle and multiple-vehicle crashes for each segment type. Table 45 presents the values of f_{ped}. All vehicle-pedestrian collisions are considered to be fatal-and-injury crashes.

Table 44. Pedestrian crash adjustment factors

Segment Type	Total Pedestrian Crashes	Total MV and SV Crashes*	f_{ped}
2U55E	8	5611	0.0014
2U55L	25	3695	0.0068
3T	16	2812	0.0057
4U	38	3004	0.0095
4D	17	6925	0.0025
5T	151	17703	0.0085
6D	29	3810	0.0076
8D	70	31	0.0104

*Excludes pedestrian and bicycle crashes

6.1.3 Vehicle-Bicycle Crashes

The number of vehicle-bicycle collisions per year for a segment is estimated as:

$$N_{bikes} = N_{bs} \times f_{bike}$$

$N_{bs} =$ predicted average crash frequency of an individual segment (excluding vehicle-pedestrian and vehicle-bicycle collisions);
$N_{bikes} =$ predicted average crash frequency of vehicle-bicycle collisions for a segment;
$f_{bike} =$ bicycle crash adjustment factor.

The bicycle crash adjustment factor is estimated by dividing the vehicle-bicycle crashes by the sum of single-vehicle and multiple-vehicle crashes for each segment type. Table 46 presents the values of f_{bike}. The vehicle-bicycle collisions by severity are estimated using the following equation.

$$N_{bikes,fs} = N_{bikes} \times P_{fs}$$
$$N_{bikes,pdo} = N_{bikes} \times \left(1 - P_{fs}\right)$$

$N_{bikei,fi} =$ predicted average fatal and injury crash frequency of vehicle-bicycle collisions for a segment ;
$N_{bikei,pdo} =$ predicted average property damage only crash frequency of vehicle-bicycle collisions for a segment;
$P_{fi} =$ proportion of fatal and injury vehicle-bicycle crashes.

Table 45. Bicycle crash adjustment factors

Segment Type	Bicycle Crashes			Total MV and SV Crashes*	f_{bike}
	Total	Fatal and Injury only	P_{fi}		
2U55E	9	9	1.00	5611	0.0016
2U55L	14	12	0.86	3695	0.0038
3T	26	22	0.85	2812	0.0092
4U	38	28	0.74	3004	0.0095
4D	15	13	0.87	6925	0.0022
5T	103	89	0.86	17703	0.0058
6D	25	23	0.92	3810	0.0066
8D	31	28	0.90	31	0.0046

*Excludes pedestrian and bicycle crashes

6.1.4 Crash Modification Factors

The CMFs for geometric design features of segments are presented below. The CMFs are used to adjust the SPF for segments to account for differences between the base conditions and the local site conditions. Several CMFs were calibrated in conjunction with the SPFs. These were calibrated using the FI crash data because of known issues with the PDO crash data, such as underreporting. If the coefficient used in the CMFs was not significant or when the data was not available, CMFs were adopted from previous research. Collectively, CMFs describe the relationship between various geometric factors and crash frequency. Many of the CMFs found in the literature were typically derived from (and applied to) the combination of multiple-vehicle and single-vehicle crashes. That is, one CMF is used to indicate the influence of a specified geometric feature on total crashes. In contrast, the models developed for this project include several CMFs that are calibrated for a specific crash type.

CMF_{lw}- Lane Width. The estimated coefficient that is used in the lane width CMF is statistically insignificant but it is similar to the one found in Lord et al. Thus, the CMF is adopted from the work of Lord et al [57]. The base condition for this CMF is a 12-ft lane width. The lane width used in this CMF is an average for all through lanes on the segment. This CMF applies to both MV and SV segment crashes (not including vehicle-pedestrian and vehicle-bicycle crashes). The lane width CMF is described using the following equation:

$$CMF_{lw} = e^{-0.0219(W_l-12)}$$

CMF_{lsw}- Left Shoulder Width. The base condition for this CMF is a 1.0-ft inside shoulder width and it is applicable to divided roadway segments only. The shoulder width used in this CMF is an average of two roadbeds on the segment. This CMF applies to both MV and SV segment crashes (not including vehicle-pedestrian and vehicle-bicycle crashes).

$$CMF_{lsw} = e^{-0.022(W_{lsw}-1.0)}$$

CMF_{rsw}- Right Shoulder Width. Although efforts are made in this study to develop a right shoulder width CMF, a meaningful CMF could not be developed. The outside shoulder width CMF from the work from Lord et al. was adopted and is described in the below equation [57]. The base condition for this CMF was a 1.5-ft outside shoulder width. The shoulder width used in this CMF is an average of two roadbeds on the segment. This CMF applies to both MV and SV segment crashes (not including vehicle-pedestrian and vehicle-bicycle crashes).

$$CMF_{rsw} = e^{-0.0285(W_{rsw}-1.5)}$$

where,

$W_{rsw} =$ average right shoulder width, ft.

CMF_{mw}- Median Width. The estimated coefficient that is used in the median width CMF is statistically insignificant and therefore the CMF from the work of Bonneson and Pratt was adopted [58]. The base condition for this CMF was a 16-ft median width for restrictive medians and a 12-ft median width for nonrestrictive medians. Restrictive medians can include raised-curb or depressed medians. This CMF applies to both MV and SV segment crashes (not including vehicle-pedestrian and vehicle-bicycle crashes).

For restrictive medians: $CMF_{mw} = e^{-0.041(\sqrt{W_m}-\sqrt{16})}$

For nonrestrictive medians: $CMF_{mw} = e^{-0.0255(W_m-12)}$

CMF_{pk}- On-street Parking. This CMF is adopted from the HSM and is applicable to two-way roadway segments with five or fewer lanes. The base condition for this CMF is the absence of on-street parking on the roadway segment. The CMF for on-street parking is determined using the following equation.

$$CMF_{pk} = 1 + p_{pk} \times (f_{pk} - 1.0)$$

Where,

f_{pk} = factor from Table 47;

p_{pk} = proportion of curb length with on-street parking = (0.5 L_{pk}/L);

L_{pk} = sum of curb length with on-street parking for both sides of the road combined (miles); and

L = length of roadway segment (miles).

The CMF for on-street parking applies to all collision types other than vehicle-pedestrian and vehicle-bicycle. The sum of curb length with on-street parking (L_{pk}) can be determined from field measurements or video log review to verify parking regulations. Estimates can be made by deducting from twice the roadway segment length allowances for intersection widths, crosswalks, and driveway widths.

Table 46. Values of f_{pk} used in determining the CMF for on-street parking

	Type of Parking and Land Use			
	Parallel Parking		**Angle Parking**	
Roadway Segment	**Residential or Other**	**Commercial or Industrial/Institutional**	**Residential or Other**	**Commercial or Industrial/Institutional**
2U	1.465	2.074	3.428	4.853
3T	1.465	2.074	3.428	4.853
4U	1.100	1.709	2.574	3.999
4D	1.100	1.709	2.574	3.999
5T	1.100	1.709	2.574	3.999

CMF_{fo}- Roadside Fixed Objects. The roadside fixed-object CMF is adopted from the work of Lord et al. and is applicable to single-vehicle crashes only [57]. It is described using the following equation.

$$CMF_{fo} = 1.0 + \frac{0.01 D_{fo}}{e^{0.131(O_{fo})}}$$

The base condition for the roadside fixed-object CMF is absence of roadside objects. The change in the roadside fixed-object CMF with an increase in the offset distance for a segment with 50 roadside objects per mile is shown in Table 48.

Table 47. Roadside fixed-object CMF

Offset to Fixed Objects (O_{fo}) (ft)	CMF (Proposed)
0	1.50
2	1.38
5	1.26
10	1.13
15	1.07
20	1.04
25	1.02
30	1.01

CMF_{dw}- Driveways. The driveway CMF is applicable to multiple-vehicle crashes only. Commercial driveways provide access to establishments that serve retail customers. Industrial/institutional driveways serve factories, warehouses, schools, hospitals, churches, offices, public facilities, and other places of employment. Residential driveways serve single- and multiple-family dwellings. Other driveways include field, private, and undefined driveways. The base condition for the driveway CMF is 10 commercial driveways per mile, three industrial driveways per mile, eight residential driveways per mile, and 10 other type driveways per mile. The driveway CMF is described using the following equation.

$$CMF_{dw} = e^{0.014(n_{dwc}-10)} \times e^{0.005(n_{dwi}-3)} \times e^{0.002(n_{dwr}-8)} \times e^{0.003(n_{dwo}-10)}$$

CMF_{lgt}- Lighting. The CMF for lighting is adopted from the HSM and is applicable only to roadway segments with five or fewer lanes. The base condition for lighting is the absence of roadway segment lighting. The CMF is determined using the following equation.

$$CMF_{lgt} = 1.0 - \left(1.0 - 0.72 \times p_{inr} - 0.83 \times p_{pnr}\right)$$

Where,

p_{inr} = proportion of total nighttime crashes for unlighted roadway segments that involve a fatality or injury;

p_{pnr} = proportion of total nighttime crashes for unlighted roadway segments that involve property damage only; and

p_{nr} = proportion of total crashes for unlighted roadway segments that occur at night.

This CMF applies to all collision types other than vehicle-pedestrian and vehicle-bicycle. Table 49 presents default values for the nighttime crash proportions p_{nr}, p_{inr}, and p_{pnr}.

Table 48. Nighttime crash proportions for unlighted roadway segments

Roadway Segment Type	Proportion of Total Nighttime Crashes by Severity Level		Proportion of Crashes that Occur at Night
	FI p_{inr}	PDO p_{pnr}	p_{nr}
2U	0.424	0.576	0.316
3T	0.429	0.571	0.304
4U	0.517	0.483	0.365
4D	0.364	0.636	0.410
5T	0.432	0.568	0.274

CMF_{spd}—Automated Speed Enforcement. The CMF for automated speed enforcement is adopted from the HSM and it applies to all roadway segment types and all collision types (other than vehicle-pedestrian and vehicle-bicycle). Automated speed enforcement systems use video or photographic identification in conjunction with radar or lasers to detect speeding drivers. These systems automatically record vehicle identification information without the need for police officers at the location. The base condition for automated speed enforcement is that it is absent. A CMF of 0.83 for the reduction of all types of FI crashes from implementation of automated speed enforcement is recommended. This CMF is assumed to apply to roadway segments between intersections with fixed camera sites where the camera is always present or where drivers have no way of knowing whether the camera is present or not. No information is available on the effect of automated speed enforcement on noninjury crashes. With the conservative assumption that automated speed enforcement has no effect on noninjury crashes, the value of the CMF for automated speed enforcement would be 0.95.

6.2 Model Development – One-Way Arterial Segments

The following regression model form was used to predict the average crash frequency along an individual roadway segment.

$$N_j = (N_{spfmv} I_{mv} CMF_{pk} CMF_{dw} + N_{spfsv} I_{sv} CMF_{fo}) \times CMF_{rsw}$$

with,

$$N_{spfmv} = n \times L \times e^{b_{mv} + b_{mv1} \ln(AADT) + b_{r1} I_{r1} + b_{r2} I_{r2} + b_{r3} I_{r3} + b_{r4} I_{r4} + b_{r5} I_{r5} + b_{r6} I_{r6}}$$

$$N_{spfsv} = n \times L \times e^{b_{sv}+b_{sv1}\ln(AADT)+b_{r1}I_{r1}+b_{r2}I_{r2}+b_{r3}I_{r3}+b_{r4}I_{r4}+b_{r5}I_{r5}+b_{r6}I_{r6}}$$

$$CMF_{dw} = e^{b_{dwc}(n_{dwc}-10)}$$

where,

$N_j =$ predicted annual average crash frequency for model *j* (*j*=*mv*, *sv*);
$N_{mv} =$ predicted annual average multiple-vehicle crash frequency;
$N_{sv} =$ predicted annual average single-vehicle crash frequency;
$I_{mv} =$ multiple-vehicle crash indicator variable (=1.0 if multiple-vehicle crash data, 0.0 otherwise) ;
$I_{sv} =$ single-vehicle crash indicator variable (=1.0 if single-vehicle crash data, 0.0 otherwise) ;
$n =$ number of years of crash data;
$AADT =$ annual average daily traffic, veh/day;
$I_{r1} =$ Superior region indicator variable (=1.0 if site is in Superior region, 0.0 if it is not);
$I_{r2} =$ North region indicator variable (=1.0 if site is in North region, 0.0 if it is not);
$I_{r3} =$ Grand region indicator variable (=1.0 if site is in Grand region, 0.0 if it is not);
$I_{r4} =$ Bay region indicator variable (=1.0 if site is in Bay region, 0.0 if it is not);
$I_{r5} =$ Southwest region indicator variable (=1.0 if site is in Southwest region, 0.0 if it is not);
$I_{r6} =$ University region indicator variable (=1.0 if site is in University region, 0.0 if it is not);
$CMF_{rsw} =$ right shoulder width crash modification factor;
$CMF_{pk} =$ on-street parking crash modification factor;
$CMF_{fo} =$ roadside fixed objects crash modification factor;
$CMF_{dw} =$ driveway count crash modification factor;
$n_{dwc} =$ commercial driveway density, driveways/mile
$b_i =$ calibration coefficient for variable *i*.

The inverse dispersion parameter, *K* (which is the inverse of the over-dispersion parameter *k*), is allowed to vary with the segment length. The inverse dispersion parameter is calculated using the following equation:

$$K = L \times e^{\delta,j};\ j = mv, sv$$

where,

K = inverse dispersion parameter.
δ = calibration coefficient for inverse dispersion parameter.

The predictive model calibration process consisted of the simultaneous calibration of multiple-vehicle and single-vehicle crash models and CMFs using the aggregate model represented by the equations above. The database assembled for calibration included two replications of the original database. The dependent variable in the first replication was set equal to the multiple-vehicle crashes. The dependent variable in the second replication was set equal to the single-vehicle crashes. Table 50 and Table 51 summarize the modeling results for one-way arterial segments for FI and PDO, respectively.

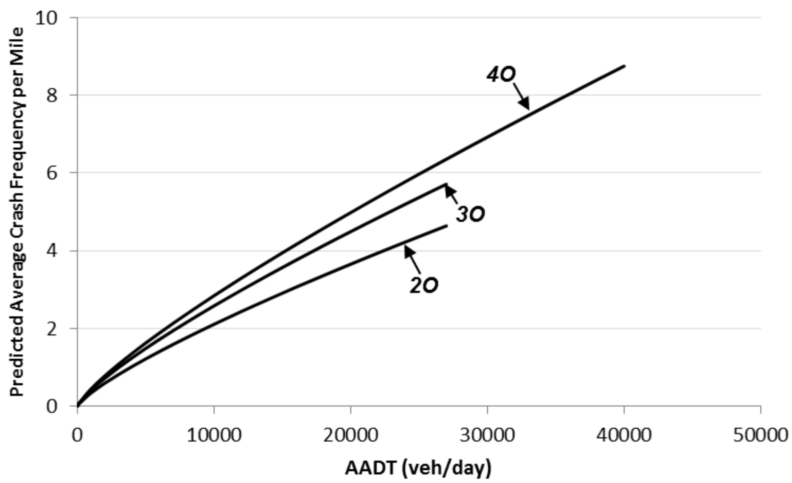
Table 49. Calibrated coefficients for FI crashes on one-way arterials.

Coefficient	**Variable**	**Facility**	**Estimate**	**Std. Error**	**t-statistic**
b_{mv}	Intercept for MV crashes	2O	-10.263	2.878	-3.57
		3O	-9.775	3.024	-3.23
		4O	-9.308	3.126	-2.98
b_{mv1}	AADT on MV crashes	All	0.943	0.321	2.93
b_{sv}	Intercept for SV crashes	2O	-6.460	4.422	-1.46
		3O	-5.094	4.643	-1.10
		4O	-5.094	4.643	-1.10
b_{sv1}	AADT on SV crashes	All	0.332	0.496	0.67
b_{dwc_mj}	Major commercial driveway density on MV crashes	All	0.011	0.006	1.85
b_{r1}	Added effect of Superior region	All	0.000	--	--
b_{r2}	Added effect of North region	All	0.000	--	--
b_{r3}	Added effect of Grand region	All	0.000	--	--
b_{r4}	Added effect of Bay region	All	-0.998	0.287	-3.47
b_{r5}	Added effect of Southwest region	All	0.000	--	--
b_{r6}	Added effect of University region	All	0.000	--	--
δ_{mv}	Inverse dispersion parameter for MV crashes	2O	0.561	1.373	0.41
		3O	3.541	2.787	1.27
		4O	0.792	0.614	1.29
δ_{sv}	Inverse dispersion parameter for SV crashes	2O	4.020	18.045	0.22
		3O	0.459	0.757	0.61
		4O	0.459	0.757	0.61
Observations		181 segments (2O=33; 3O=117; 4O=31)			

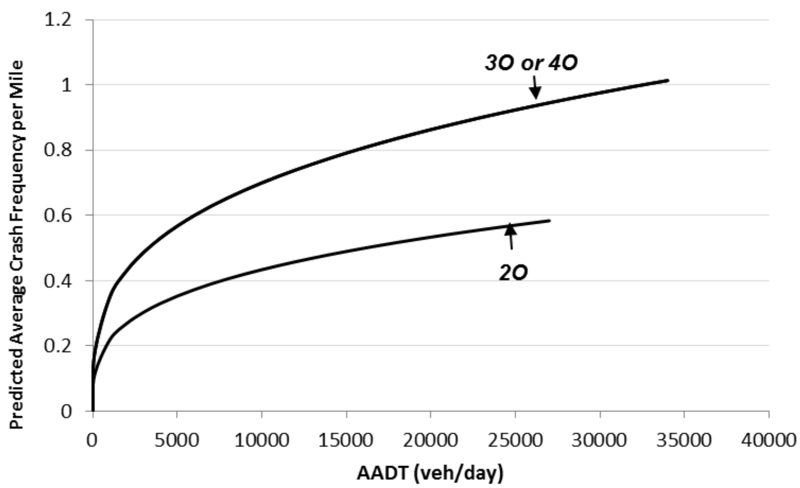
Table 50. Calibrated coefficients for PDO crashes on one-way arterials

Coefficient	Variable	Facility	Estimate	Std. Error	t-statistic
b_{mv}	Intercept for MV crashes	2O	-6.503	1.236	-5.26
		3O	-6.337	1.292	-4.91
		4O	-6.310	1.329	-4.75
b_{mv1}	AADT on MV crashes	All	0.776	0.139	5.60
b_{sv}	Intercept for SV crashes	2O	-3.642	2.477	-1.47
		3O	-3.290	2.608	-1.26
		4O	-3.290	2.608	-1.26
b_{sv1}	AADT on SV crashes	All	0.296	0.280	1.06
b_{dwc_mj}	Major commercial driveway density on MV crashes	All	0.005	0.003	1.38
b_{r1}	Added effect of Superior region	All	0.000	--	--
b_{r2}	Added effect of North region	All	0.000	--	--
b_{r3}	Added effect of Grand region	All	0.000	--	--
b_{r4}	Added effect of Bay region	All	-0.679	0.130	-5.23
b_{r5}	Added effect of Southwest region	All	0.000	--	--
b_{r6}	Added effect of University region	All	0.000	--	--
δ_{mv}	Inverse dispersion parameter for MV crashes	2O	2.381	0.770	3.09
		3O	2.450	0.320	7.65
		4O	1.849	0.452	4.09
δ_{sv}	Inverse dispersion parameter for SV crashes	2O	1.327	1.097	1.21
		3O	0.434	0.284	1.53
		4O	0.434	0.284	1.53
Observations		181 segments (2O=33; 3O=117; 4O=31)			

The relationship between crash frequency (FI plus PDO crashes) and traffic demand for base conditions, as obtained from the calibrated models, is illustrated in Figure 35.



a) Multiple-Vehicle Crashes



b) Single-Vehicle Crashes

Figure 35. Graphical form of the segment SPF for crashes on one-way streets

Table 52 shows the proportion of injury crashes for SV and MV crashes by severity level. The values from this can be multiplied by the output of N_{spfmv} and N_{spfsv} for multi- and single-vehicle crashes, respectively. Note that all one-way segments have a very small sample size. Hence, the proportions should be used with caution.

Table 51. Proportion of injury crashes for single- and multi-vehicle crashes for one-way segments

Severity	2O		3O		4O	
	SV	**MV**	**SV**	**MV**	**SV**	**MV**
Killed (K)	0.00	0.00	0.04	0.00	0.33	0.02
Injury A	0.00	0.00	0.08	0.03	0.00	0.02
Injury B	0.00	0.36	0.36	0.21	0.33	0.14
Injury C	1.00	0.64	0.52	0.76	0.33	0.81

The crash frequency obtained can be multiplied by the proportions in Table 53 to estimate the predicted average multiple-vehicle crash frequency by collision type category.

Table 52. Distribution of multiple-vehicle crashes by collision type

Manner of Collision	Proportion of Crashes by Severity Level for Specific Segment Types					
	2O		**3O**		**4O**	
	FI	**PDO**	**FI**	**PDO**	**FI**	**PDO**
Rear-end	0.45	0.20	0.51	0.28	0.23	0.18
Head-on*	0.00	0.02	0.01	0.00	0.05	0.00
Angle	0.27	0.10	0.19	0.13	0.16	0.20
Sideswipe- Same	0.27	0.52	0.18	0.45	0.44	0.53
Sideswipe-Opposite*	0.00	0.12	0.01	0.01	0.00	0.01
Other MV	0.00	0.03	0.08	0.13	0.12	0.08

*Technically, these crashes should not happen but may occur due to wrong-way driving.

6.2.1 Vehicle-Pedestrian Crashes

The number of vehicle-pedestrian collisions per year for a segment is estimated as:

$$N_{peds} = N_{bs} \times f_{ped}$$

$N_{bs} =$ predicted average crash frequency of an individual segment (excluding vehicle-pedestrian and vehicle-bicycle collisions);

$N_{peds} =$ predicted average crash frequency of vehicle-pedestrian collisions for an segment;

$f_{ped} =$ pedestrian crash adjustment factor.

The pedestrian crash adjustment factor is estimated by dividing the vehicle-pedestrian crashes by the sum of single-vehicle and multiple-vehicle crashes for each segment type. Table 54 presents the values of f_{ped}. All vehicle-pedestrian collisions are considered to be fatal-and-injury crashes.

Table 53. Pedestrian crash adjustment factors

Segment Type	Total Pedestrian Crashes	Total MV and SV Crashes*	f_{ped}
2O	0	204	0.0000
3O	4	676	0.0060
4O	2	368	0.0005

*Excludes pedestrian and bicycle crashes

6.2.2 Vehicle-Bicycle Crashes

The number of vehicle-bicycle collisions per year for a segment is estimated as:

$$N_{bikes} = N_{bs} \times f_{bike}$$

$N_{bs} =$ predicted average crash frequency of an individual segment (excluding vehicle-pedestrian and vehicle-bicycle collisions);
$N_{bikes} =$ predicted average crash frequency of vehicle-bicycle collisions for a segment;
$f_{bike} =$ bicycle crash adjustment factor.

The bicycle crash adjustment factor is estimated by dividing the vehicle-bicycle crashes by the sum of single-vehicle and multiple-vehicle crashes for each segment type. Table 55 presents the values of f_{bike}. The vehicle-bicycle collisions by severity are estimated using the following equation.

$$N_{bikes,fs} = N_{bikei} \times P_{fs}$$
$$N_{bikes,pdo} = N_{bikes} \times \left(1 - P_{fs}\right)$$

Where,

$N_{bikes,fs} =$ predicted average fatal and injury crash frequency of vehicle-bicycle collisions for a segment;
$N_{bikes,pdo} =$ predicted average property damage only crash frequency of vehicle-bicycle collisions for a segment;
$P_{fs} =$ proportion of fatal and injury vehicle-bicycle crashes.

Table 54. Bicycle crash adjustment factors

Segment Type	Bicycle Crashes			Total MV and SV Crashes*	f_{bike}
	Total	Fatal and Injury only	P_{fs}		
2O	5	4	0.80	204	0.0245
3O	7	6	0.88	676	0.0104
4O	3	3	1.00	368	0.0082

*Excludes pedestrian and bicycle crashes

6.2.3 Crash Modification Factors

The CMFs for geometric design features of one-way street roadway segments are presented below. The CMFs are used to adjust the SPF for segments to account for differences between the base conditions and the local site conditions.

CMF_{rsw}- Right Shoulder Width. The sites considered in this study had no right shoulders and so a CMF could not be developed. Recently, Lord et al. found that the right shoulder width has a significant influence on the safety of one-way streets. Thus, the right shoulder width CMF from the work of Lord et al. was adopted in this study [57]. The base condition for this CMF is no shoulders. This CMF applies to both MV and SV segment crashes (not including vehicle-pedestrian and vehicle-bicycle collisions). The right shoulder width CMF is described using the following equation.

$$CMF_{rsw} = \frac{e^{-0.0201(W_{rsw}-4)}}{e^{0.0804}}$$

where,

W_{rsw} = right shoulder width, ft.

CMF_{pk}- On-street Parking. This CMF is adopted from the work of Lord et al [57]. The base condition for this CMF is the absence of on-street parking on the roadway segment and is applicable to multi-vehicle crashes only. The CMF for on-street parking is determined using the following equation.

$$CMF_{pk} = \left(1 + \left(\frac{0.5\ L_{pk_{par}}}{L}\right) \times \left(b_{pk_{par}} - 1.0\right)\right) \times \left(1 + \left(\frac{0.5\ L_{pk_{ang}}}{L}\right) \times (b_{pk_{ang}} - 1.0)\right)$$

where,

$L_{pk_{par}}$	=	sum of curb length with on-street parallel parking for both sides of road combined, mi;
$L_{pk_{ang}}$	=	sum of curb length with on-street angle parking for both sides of road combined, mi; and
b_{pk}	=	factor from Table 56
L	=	length of roadway segment (miles).

Table 55. Values of b_{pk} used in determining the CMF for on-street parking.

	Type of Parking	
Road Type	**Parallel Parking ($b_{pk_{par}}$)**	**Angle Parking ($b_{pk_{ang}}$)**
2O	1.112	4.364
3O	1.359	4.364
4O	1.359	4.364

CMF$_{dw}$- Driveways. The driveway CMF is applicable to multiple-vehicle crashes only. Commercial driveways provide access to establishments that serve retail customers. The base condition for the driveway CMF is 10 commercial driveways per mile. The driveway CMF is described using the following equation.

$$CMF_{dw} = e^{0.011(n_{dwc}-10)}$$

CMF$_{fo}$- Roadside Fixed Objects. The roadside fixed-object CMF is adopted from the work of Lord et al. and is applicable to single-vehicle crashes only [57]. It is described using the following equation.

$$CMF_{fo} = 1.0 + \frac{0.01D_{fo}}{e^{0.0938(O_{fo})}}$$

The base condition for the roadside fixed-object CMF is absence of roadside objects. The change in the roadside fixed-object CMF with the increase in the offset distance for a segment with 50 roadside objects per mile is shown in Table 57.

Table 56. Roadside fixed-object CMF

Offset to Fixed Objects (O_{fo}) (ft)	CMF (Proposed)
0	1.50
2	1.41
5	1.31
10	1.20
15	1.12
20	1.08
25	1.05
30	1.03

6.3 Development of Severity Distribution Functions

This section documents the development of SDFs for two-way arterials. Although efforts were made to develop SDFs for one-way streets as well, meaningful results were not obtained due to the small sample size. For this reason, a fixed proportion by severity is recommended in Table 52. Section 6.3.1 describes the functional form. Section 6.3.2 covers the model development. Section 6.3.3 describes how the models may be used to predict the proportion of crashes by severity level, and Section 6.3.4 summarizes how the models can be used to predict crashes by type.

6.3.1 Functional Form

A SDF is represented by a discrete choice model. In theory, it could be used to predict the proportion of crashes in each of the following severity categories: Fatal = K, Incapacitated injury = A, Non-incapacitated injury = B, or Possible injury = C. The SDF can be used with the safety performance functions to estimate the expected crash frequency for each severity category. It may include various geometric, operation, or traffic variables that would allow the estimated proportion to be specific to an individual segment.

The multinomial logit (MNL) model was used to predict the probability of crash severities. Given the characteristics of the data, the MNL model was the most suitable model for estimating a SDF. A linear function was used to relate the crash severity with the geometric and traffic variables. SAS's NLMIXED procedure was used for the evaluation of the MNL model.

The probability for each crash severity category is given by the following equations:

$$P_K = \frac{e^{V_K}}{1+e^{V_K}+e^{V_A}+e^{V_B}}$$
$$P_A = \frac{e^{V_A}}{1+e^{V_K}+e^{V_A}+e^{V_B}}$$
$$P_B = \frac{e^{V_B}}{1+e^{V_K}+e^{V_A}+e^{V_B}}$$
$$P_C = 1-(P_K+P_A+P_B)$$

where,

P_j = probability of the occurrence of crash severity *j*;

V_j = systematic component of crash severity likelihood for severity *j*.

6.3.2 Modeling Development

The database assembled for calibration included crash severity level as a dependent variable and the geometric and traffic variables of each site as independent variables. Each row (site characteristics) is repeated to the frequency of each severity level. Thus, a segment with 'n' crashes will be repeated 'n' number of times. It should be noted that the segments without injury (including fatal) crashes are not included in the database. The total sample size of the final dataset for model calibration was equal to the total number of injury (plus fatal) crashes in the data. During the model calibration, the "possible injury" category was set as the base scenario with coefficients restricted to zero.

A model for estimating the systematic component of crash severity V_j for two-way arterial segments is described by the following equations.

$$V_K = ASC_K + b_{ter,K} \times I_{ter} + b_{div,K} \times I_{div} + b_{psl,K} \times PSL$$
$$V_A = ASC_A + b_{ter,A} \times I_{ter} + b_{div,A} \times I_{div} + b_{psl,A} \times PSL$$
$$V_B = ASC_B + b_{ter,B} \times I_{ter} + b_{div,B} \times I_{div} + b_{psl,B} \times PSL$$

where,

I_{ter} = terrain indicator variable (=1.0 if level, 0.0 if it is rolling);

I_{div} = divided road indicator variable (=1.0 if divided, 0.0 otherwise);

PSL = posted speed limit on the segment, miles per hour;

ASC_j = alternative specific constant for crash severity *j*; and

$b_{k,j}$ = calibration coefficient for variable *k* and crash severity *j*.

The final form of the regression models is described here, before the discussion of regression analysis results. However, this form reflects the findings from several preliminary regression analyses where alternative model forms were examined. The form that is described represents that which provided the best fit to the data while also having coefficient values that were logical with constructs that were theoretically defensible and properly bounded.

Table 58 summarizes the estimation results of the MNL model. An examination of the coefficient values and their implication on the corresponding crash severity levels are documented in a subsequent section. In general, the sign and magnitude of the regression coefficients in Table 58 are logical and consistent with previous research findings.

Table 57. Parameter estimation for the SDF

Coefficient	Variable	Fatality (K)		Incapacitating injury (A)		Non-Incapacitating injury (B)	
		Value	t-statistic	Value	t-statistic	Value	t-statistic
ASC	Alternative specific constant	-4.930	-7.49	-2.631	-8.28	-1.427	-6.99
b_{ter}	Terrain (1=level; 0=rolling)	-0.656	-2.54	-0.256	-1.69	-0.130	-2.53
b_{div}	Divided road (1=divided; 0=others)	-0.355	-1.99	-0.354	-4.16	-0.130	-2.53
PSL	Posted speed limit, mph	0.042	3.49	0.018	3.28	0.013	3.74
Observations		10,021 crashes (K=173; A=809; B=2,340; C=6,699)					

Note: Possible injury is the base scenario with coefficients restricted at zero.

6.3.3 Predicted Probabilities

This section describes the change in probability of each crash severity for a given change in particular variable.

Terrain. This variable indicates the type of terrain. Approximately 95% of the segments were on level terrain, and the remaining 5% were on rolling terrain. The negative coefficient in Table 58 indicates that the probability of K, A, and B crash severities for the segments on level terrain was lower than the segments on rolling terrain. As seen in Table 59, the likelihood of a fatal and injury crash changes from 34.1% on level terrain to 38.5% on rolling terrain.

Table 58. Crash severity distribution based on terrain type

Road Type	Crash Severity			
	K	**A**	**B**	**C**
Level	1.6%	7.7%	24.8%	65.9%
Rolling	2.8%	9.3%	26.3%	61.5%

Road Type. The effect of road type on crash severity was also considered in the calibrated model. About 33 percent of crashes occurred on divided roads while the remaining crashes occurred on undivided or TWLTL segments. The model coefficients in Table 58 indicated that a crash on a divided road segment is less severe than a crash on either undivided segments or segments with a TWLTL. As seen in Table 60, the likelihood of fatal and severe injury crashes (i.e., K, A, and B) is 31.5 percent on divided segments and 35.7 percent on undivided or TWLTL segments. This was expected because the chance of opposite direction crashes, which are very severe in nature, is reduced on divided segments.

Table 59. Crash severity distribution based on road type.

Road Type	Crash Severity			
	K	**A**	**B**	**C**
2U/3T/4U/5T	1.8%	8.2%	29.0%	61.1%
4D/6D/8D	1.3%	6.5%	27.8%	64.4%

Speed Limit. The speed limit variable indicates the posted speed limit on a particular segment. The speed limit of all segments considered in the SDF model calibration ranged from 25 mph to 70 mph. The average speed limit was 45 mph. The positive sign for a posted speed limit in Table 58 shows that as speed limit increases, the likelihood of a fatal injury also increases. As seen in Table 61, the likelihood of a fatal crash increases from 0.7 percent at 25 mph to 3.7 percent at 70 mph. This is not unexpected because speed limit is highly correlated to crash severity.

Table 60. Crash severity distribution based on posted speed limit.

Posted Speed Limit (mph)	Crash Severity			
	K	**A**	**B**	**C**
25	0.7%	5.8%	20.6%	72.8%
30	0.9%	6.2%	21.6%	71.3%
35	1.0%	6.7%	22.6%	69.7%
40	1.3%	7.2%	23.5%	68.0%
45	1.5%	7.7%	24.5%	66.3%
50	1.8%	8.2%	25.5%	64.5%
55	2.2%	8.7%	26.5%	62.7%
60	2.6%	9.3%	27.4%	60.7%
65	3.1%	9.8%	28.3%	58.7%
70	3.7%	10.4%	29.2%	56.7%

6.3.4 Estimation of Crashes by Type

The predicted average crash frequency obtained can be multiplied by the proportions in Table 62 through Table 69 to estimate the predicted average multiple-vehicle crash frequency by collision type category.

Table 61. Statewide Distribution of Multiple-Vehicle Crashes by Collision Type

Manner of Collision	Statewide Proportion of Multi-Vehicle Crashes by Severity Level for Specific Segment Types															
	2U		3T		4U		5T		4D		6D		8D		One-Way	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Rear-end	0.436	0.468	0.520	0.509	0.433	0.372	0.423	0.392	0.664	0.570	0.679	0.550	0.625	0.504	0.411	0.236
Rear-end Left-turn	0.051	0.029	0.018	0.006	0.075	0.033	0.007	0.007	0.015	0.016	0.008	0.020	0.012	0.012	0.008	0.017
Rear-end Right-turn	0.013	0.012	0.037	0.022	0.008	0.019	0.010	0.014	0.011	0.006	0.011	0.011	0.017	0.011	0.008	0.011
Head-on	0.127	0.016	0.053	0.014	0.072	0.008	0.048	0.011	0.024	0.008	0.006	0.003	0.011	0.004	0.023	0.006
Head-on Left-turn	0.032	0.023	0.066	0.024	0.072	0.030	0.083	0.038	0.007	0.004	0.000	0.001	0.002	0.000	0.000	0.004
Angle	0.173	0.144	0.219	0.199	0.222	0.193	0.322	0.255	0.128	0.086	0.153	0.087	0.173	0.120	0.194	0.141
Sideswipe-Same	0.054	0.146	0.029	0.133	0.054	0.248	0.050	0.202	0.082	0.234	0.090	0.272	0.113	0.277	0.279	0.491
Sideswipe-Opposite	0.064	0.055	0.037	0.028	0.029	0.028	0.018	0.027	0.012	0.012	0.005	0.005	0.005	0.010	0.008	0.015
Other MV	0.050	0.109	0.021	0.065	0.034	0.069	0.038	0.054	0.058	0.064	0.047	0.051	0.042	0.063	0.070	0.078

Table 62. Distribution of Multiple-Vehicle Crashes by Collision Type for Superior Region Segments

Manner of Collision	Superior Proportion of Multi-Vehicle Crashes by Severity Level for Specific Segment Types															
	2U		3T		4U		5T		4D		6D		8D		One-Way	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Rear-end	0.465	0.317	0.000	0.381	0.414	0.250	0.287	0.239	0.476	0.405	0.000	0.000	0.000	0.000	0.000	0.159
Rear-end Left-turn	0.093	0.014	0.000	0.000	0.034	0.063	0.000	0.011	0.000	0.027	0.000	0.000	0.000	0.000	0.000	0.000
Rear-end Right-turn	0.000	0.014	0.000	0.048	0.000	0.038	0.010	0.021	0.024	0.011	0.000	0.000	0.000	0.000	0.000	0.000
Head-on	0.140	0.014	0.000	0.048	0.069	0.013	0.139	0.032	0.024	0.027	0.000	0.000	0.000	0.000	0.000	0.037
Head-on Left-turn	0.023	0.007	0.000	0.000	0.034	0.063	0.050	0.039	0.024	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Angle	0.093	0.151	0.000	0.048	0.310	0.300	0.366	0.256	0.167	0.151	0.000	0.000	0.000	0.000	0.000	0.061
Sideswipe-Same	0.070	0.194	0.000	0.286	0.103	0.213	0.079	0.277	0.095	0.243	0.000	0.000	0.000	0.000	1.000	0.549
Sideswipe-Opposite	0.070	0.043	0.000	0.000	0.000	0.013	0.030	0.049	0.024	0.032	0.000	0.000	0.000	0.000	0.000	0.073
Other MV	0.047	0.245	0.000	0.190	0.034	0.050	0.040	0.077	0.167	0.103	0.000	0.000	0.000	0.000	0.000	0.122

Table 63. Distribution of Multiple-Vehicle Crashes by Collision Type for North Region Segments

Manner of Collision	North Proportion of Multi-Vehicle Crashes by Severity Level for Specific Segment Types															
	2U		3T		4U		5T		4D		6D		8D		One-Way	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Rear-end	0.474	0.430	0.479	0.403	0.439	0.337	0.289	0.251	0.600	0.600	0.000	0.000	0.000	0.000	0.000	0.000
Rear-end Left-turn	0.051	0.068	0.021	0.000	0.088	0.031	0.004	0.011	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rear-end Right-turn	0.013	0.016	0.063	0.036	0.018	0.023	0.009	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Head-on	0.077	0.012	0.042	0.022	0.035	0.004	0.061	0.007	0.100	0.029	0.000	0.000	0.000	0.000	0.000	0.000
Head-on Left-turn	0.026	0.032	0.104	0.022	0.018	0.019	0.105	0.040	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Angle	0.205	0.157	0.167	0.137	0.298	0.245	0.430	0.302	0.000	0.086	0.000	0.000	0.000	0.000	0.000	0.000
Sideswipe-Same	0.051	0.129	0.021	0.252	0.053	0.280	0.048	0.298	0.200	0.171	0.000	0.000	0.000	0.000	0.000	1.000
Sideswipe-Opposite	0.077	0.060	0.083	0.058	0.035	0.015	0.031	0.035	0.000	0.086	0.000	0.000	0.000	0.000	0.000	0.000
Other MV	0.026	0.096	0.021	0.072	0.018	0.046	0.022	0.039	0.000	0.029	0.000	0.000	0.000	0.000	0.000	0.000

Table 64. Distribution of Multiple-Vehicle Crashes by Collision Type for Grand Region Segments

Manner of Collision	Grand Proportion of Multi-Vehicle Crashes by Severity Level for Specific Segment Types															
	2U		3T		4U		5T		4D		6D		8D		One-Way	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Rear-end	0.442	0.416	0.628	0.584	0.404	0.335	0.477	0.403	0.748	0.636	0.760	0.638	0.000	0.400	0.000	0.000
Rear-end Left-turn	0.054	0.045	0.023	0.006	0.074	0.028	0.003	0.006	0.015	0.018	0.000	0.000	0.000	0.000	0.000	0.000
Rear-end Right-turn	0.014	0.011	0.047	0.012	0.011	0.013	0.010	0.013	0.012	0.008	0.000	0.019	0.000	0.000	0.000	0.000
Head-on	0.150	0.011	0.070	0.012	0.032	0.013	0.047	0.010	0.018	0.008	0.000	0.000	0.000	0.000	0.000	0.000
Head-on Left-turn	0.034	0.029	0.047	0.064	0.149	0.041	0.084	0.039	0.006	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Angle	0.150	0.127	0.116	0.162	0.213	0.206	0.270	0.250	0.092	0.072	0.080	0.010	0.000	0.000	0.000	0.000
Sideswipe-Same	0.061	0.186	0.000	0.104	0.043	0.266	0.046	0.196	0.053	0.204	0.080	0.305	0.000	0.600	0.000	0.000
Sideswipe-Opposite	0.054	0.048	0.023	0.012	0.043	0.028	0.020	0.025	0.012	0.007	0.000	0.000	0.000	0.000	0.000	0.000
Other MV	0.041	0.127	0.047	0.046	0.032	0.070	0.042	0.058	0.045	0.046	0.080	0.029	0.000	0.000	0.000	0.000

Table 65. Distribution of Multiple-Vehicle Crashes by Collision Type for Bay Region Segments

Manner of Collision	Bay Proportion of Multi-Vehicle Crashes by Severity Level for Specific Segment Types															
	2U		3T		4U		5T		4D		6D		8D		One-Way	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Rear-end	0.466	0.441	0.550	0.480	0.474	0.357	0.404	0.379	0.522	0.435	0.000	0.000	0.000	0.000	0.417	0.222
Rear-end Left-turn	0.057	0.025	0.000	0.007	0.105	0.053	0.012	0.008	0.000	0.043	0.000	0.333	0.000	0.000	0.000	0.000
Rear-end Right-turn	0.029	0.022	0.025	0.000	0.000	0.030	0.009	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Head-on	0.092	0.019	0.050	0.013	0.105	0.008	0.041	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.083	0.000
Head-on Left-turn	0.046	0.025	0.075	0.007	0.053	0.038	0.077	0.038	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Angle	0.155	0.127	0.225	0.230	0.175	0.229	0.366	0.281	0.261	0.116	0.000	0.333	0.000	0.000	0.250	0.178
Sideswipe-Same	0.052	0.206	0.050	0.125	0.044	0.165	0.047	0.194	0.130	0.290	0.000	0.333	0.000	0.000	0.167	0.533
Sideswipe-Opposite	0.057	0.051	0.025	0.013	0.009	0.049	0.009	0.021	0.043	0.043	0.000	0.000	0.000	0.000	0.083	0.011
Other MV	0.046	0.083	0.000	0.125	0.035	0.071	0.035	0.050	0.043	0.072	0.000	0.000	0.000	0.000	0.000	0.056

Table 66. Distribution of Multiple-Vehicle Crashes by Collision Type for Southwest Region Segments

Manner of Collision	Southwest Proportion of Multi-Vehicle Crashes by Severity Level for Specific Segment Types															
	2U		3T		4U		5T		4D		6D		8D		One-Way	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Rear-end	0.298	0.411	0.473	0.470	0.486	0.427	0.339	0.371	0.409	0.367	1.000	0.400	0.000	0.000	0.462	0.340
Rear-end Left-turn	0.069	0.042	0.044	0.003	0.057	0.037	0.014	0.009	0.023	0.014	0.000	0.000	0.000	0.000	0.000	0.006
Rear-end Right-turn	0.015	0.011	0.055	0.030	0.029	0.017	0.014	0.018	0.023	0.007	0.000	0.000	0.000	0.000	0.000	0.013
Head-on	0.145	0.023	0.066	0.012	0.071	0.012	0.055	0.012	0.091	0.014	0.000	0.000	0.000	0.000	0.000	0.000
Head-on Left-turn	0.031	0.023	0.044	0.027	0.029	0.020	0.079	0.042	0.000	0.007	0.000	0.000	0.000	0.000	0.000	0.006
Angle	0.191	0.156	0.242	0.238	0.229	0.153	0.397	0.245	0.250	0.173	0.000	0.000	0.000	0.000	0.231	0.051
Sideswipe-Same	0.092	0.133	0.022	0.099	0.043	0.207	0.045	0.200	0.068	0.273	0.000	0.400	0.000	0.000	0.231	0.442
Sideswipe-Opposite	0.069	0.071	0.033	0.024	0.029	0.014	0.010	0.026	0.045	0.022	0.000	0.000	0.000	0.000	0.000	0.013
Other MV	0.092	0.130	0.022	0.096	0.029	0.112	0.048	0.077	0.091	0.122	0.000	0.200	0.000	0.000	0.077	0.128

Table 67. Distribution of Multiple-Vehicle Crashes by Collision Type for University Region Segments

Manner of Collision	University Proportion of Multi-Vehicle Crashes by Severity Level for Specific Segment Types															
	2U		3T		4U		5T		4D		6D		8D		One-Way	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Rear-end	0.413	0.524	0.421	0.510	0.410	0.369	0.463	0.448	0.681	0.570	0.676	0.552	0.625	0.504	0.319	0.199
Rear-end Left-turn	0.033	0.014	0.000	0.020	0.090	0.027	0.008	0.006	0.016	0.011	0.009	0.021	0.012	0.012	0.021	0.023
Rear-end Right-turn	0.009	0.009	0.000	0.061	0.000	0.014	0.009	0.013	0.008	0.003	0.012	0.011	0.017	0.011	0.021	0.019
Head-on	0.136	0.012	0.158	0.020	0.100	0.008	0.046	0.011	0.016	0.005	0.007	0.003	0.011	0.004	0.043	0.000
Head-on Left-turn	0.033	0.027	0.000	0.000	0.100	0.049	0.083	0.039	0.008	0.006	0.000	0.001	0.002	0.000	0.000	0.005
Angle	0.207	0.139	0.316	0.245	0.150	0.152	0.284	0.236	0.113	0.079	0.154	0.087	0.173	0.120	0.213	0.194
Sideswipe-Same	0.061	0.134	0.053	0.102	0.070	0.285	0.052	0.172	0.101	0.243	0.091	0.267	0.113	0.277	0.255	0.477
Sideswipe-Opposite	0.056	0.043	0.053	0.020	0.050	0.033	0.016	0.025	0.004	0.009	0.005	0.006	0.005	0.010	0.000	0.009
Other MV	0.052	0.098	0.000	0.020	0.030	0.065	0.039	0.050	0.054	0.073	0.046	0.053	0.042	0.063	0.128	0.074

Table 68. Distribution of Multiple-Vehicle Crashes by Collision Type for Metro Region Segments

Manner of Collision	Metro Proportion of Multi-Vehicle Crashes by Severity Level for Specific Segment Types															
	2U		3T		4U		5T		4D		6D		8D		One-Way	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Rear-end	0.413	0.524	0.421	0.510	0.410	0.369	0.463	0.448	0.681	0.570	0.676	0.552	0.625	0.504	0.319	0.199
Rear-end Left-turn	0.033	0.014	0.000	0.020	0.090	0.027	0.008	0.006	0.016	0.011	0.009	0.021	0.012	0.012	0.021	0.023
Rear-end Right-turn	0.009	0.009	0.000	0.061	0.000	0.014	0.009	0.013	0.008	0.003	0.012	0.011	0.017	0.011	0.021	0.019
Head-on	0.136	0.012	0.158	0.020	0.100	0.008	0.046	0.011	0.016	0.005	0.007	0.003	0.011	0.004	0.043	0.000
Head-on Left-turn	0.033	0.027	0.000	0.000	0.100	0.049	0.083	0.039	0.008	0.006	0.000	0.001	0.002	0.000	0.000	0.005
Angle	0.207	0.139	0.316	0.245	0.150	0.152	0.284	0.236	0.113	0.079	0.154	0.087	0.173	0.120	0.213	0.194
Sideswipe-Same	0.061	0.134	0.053	0.102	0.070	0.285	0.052	0.172	0.101	0.243	0.091	0.267	0.113	0.277	0.255	0.477
Sideswipe-Opposite	0.056	0.043	0.053	0.020	0.050	0.033	0.016	0.025	0.004	0.009	0.005	0.006	0.005	0.010	0.000	0.009
Other MV	0.052	0.098	0.000	0.020	0.030	0.065	0.039	0.050	0.054	0.073	0.046	0.053	0.042	0.063	0.128	0.074

7.0 CALIBRATION, MAINTENANCE, AND USE OF SPFS

7.1 SPF Calibration Overview

When applied to different jurisdictions or over different time periods, SPFs need to be calibrated to reflect differences due to temporal or spatial trends. This calibration is achieved through the estimation of a calibration factor C_x. The recommended crash prediction algorithm takes the following form:

$$N_{predicted} = N_{spf,x} \times (CMF_{1x} \times CMF_{2x} \times \ldots \times CMF_{yx}) \times C_x ,$$

where:

$N_{predicted}$ = predicted average crash frequency for a specific year for a site of type x;

$N_{spf,x}$ = predicted average crash frequency determined for base conditions of the SPF developed for site type x;

CMF_{yx} = Crash modification factors specific to SPF for site type x, and

C_x = calibration factor to adjust SPF for local conditions for site type x.

Calibration capabilities are built into existing software support packages, such as the IHSDM, which includes a calibration utility within its Administration Tool to assist agencies in implementing the calibration procedures described in the HSM. The IHSDM also allows state agencies to develop and implement their own SPFs, in addition to modifying the crash severity and crash type distribution values [59].

7.2 SPF Calibration Procedure

Calibration can be used to account for changes in safety performance over time, which may be reflective of effects outside of the factors included in the SPFs developed as a part of this study. The calibration process is relatively straight-forward and can be applied following the steps outlined in Appendix A from Part C of the *HSM*. This procedure is briefly described on the following pages.

1. Identify the facility type for which the applicable SPF is to be calibrated. For the case of the Michigan specific SPFs documented in this report, eight specific facility types are identified. This study considered undivided (2U, 3T, 4U, 5T), divided (4D, 6D, 8D), and OW roadway segments.
2. Select sites for calibration of the predictive model for each facility type. The *HSM* procedure recommends using 30-50 sites for a given facility type. The *HSM* also recommends that for jurisdictions attempting calibration that do not have enough sites of a particular type to use all sites within that jurisdiction of said type. For calibration purposes, sites should be selected without regard of historical crash experience at, as selecting sites based on crash experience will potentially result in high or low calibration values. The selected sites should represent a total of at least 100 crashes. Sites should be selected so that they are representative of segments for the entire area for which the calibration will be applied but do not need to be stratified by traffic volume or other site characteristics. The *HSM* states that site selection for calibration need only occur once, as the same sites may be used for calibration in subsequent years.
3. Obtain data for each facility type available to a specific calibration period. For annual calibration, one year of data should be used. Crashes of all severity levels should be included in the calibration. The HSM recommends that elements a through j are required for calibration of urban and suburban arterials, while items k through m are desired elements.
    - Observed crashes on each segment
    - Segment length
    - Number of through traffic lanes
    - Presence of median
    - Presence of center TWLTL
    - AADT
    - Number of driveways by land use type
    - Low-speed vs. intermediate or high speed
    - Presence of on-street parking
    - Type of on-street parking
    - Roadside fixed object density
    - Presence of lighting
    - Presence of automated speed enforcement

    For calibration of Michigan-specific models, the following data elements should be acquired in order to perform calibration:
    - Observed crashes on each segment
    - MDOT region of the segment
    - Segment length
    - Lane width
    - Left shoulder width
    - Right shoulder width
    - Median width
    - On-street parking
    - Driveway density
    - Roadside fixed object offset

- Lighting
- Automated speed enforcement

4. Apply the SPF to determine the total predicted average crash frequency for each site during the calibration period as a whole. This is done using the equations in sections 6.0 and 6.1 of this report.
5. Calculate the number of expected fatal and injury multiple-vehicle crashes prior to the application of CMFs, N_{spfmv}
6. Calculate the number of expected fatal and injury single-vehicle crashes prior to the application of CMFs, N_{spfsv}
7. Calculate the CMFs for fatal and injury vehicular crashes, $CMF_1 \times \ldots . \times CMF_p$
8. Sum N_{spfmv} and N_{spfsv}, and apply the CMFs to calculate N_{bi} for fatal and injury crashes
9. Calculate the number of expected PDO multiple-vehicle crashes prior to the application of CMFs, N_{spfmv}
10. Calculate the number of expected PDO single-vehicle crashes prior to the application of CMFs, N_{spfsv}
11. Calculate the CMFs for PDO crashes, $CMF_1 \times \ldots . \times CMF_p$
12. Sum N_{spfmv} and N_{spfsv}, and apply the CMFs to calculate N_{bi} for PDO crashes
13. Add the fatal and injury N_{bi} with the PDO N_{bi} to obtain the predicted total of all automobile-only crashes
14. Apply the pedestrian and bicycle proportions to the total automobile-only N_{bi}, to obtain the predicted number of pedestrian and bicycle involved crashes
15. Add the pedestrian and bicycle crashes to N_{bi} to obtain the predicted amount of total crashes
16. Compute calibration factors to use with each SPF. The purpose of the calibration factor is to scale the SPF to more accurately match the segments it is being used on. If an SPF predicts fewer total crashes than actually occur for the sum of all crashes of the calibration data set, a calibration factor greater than one is required. If the SPF predicts more crashes than actually occur for the calibration year, then a calibration factor less than one is needed to reduce the predicted crashes. The calibration factors for segments of a particular facility type, C_i, are computed with the following equation:

$$C_i = \frac{\Sigma_{observed\ crashes}}{\Sigma_{predicted\ crashes}}$$

7.3 Example Calibration

To illustrate this point, consider the following example: A set of 30 calibration sites experience a total of 100 crashes during the calibration year. The appropriate SPF predicts that the calibration sites should experience 105.099 crashes during the calibration year. The calibration factor of this facility type is calculated by

$$C_i = \frac{100}{105.099} = 0.951$$

This calibration factor can then be applied when predicting crashes for segments of the appropriate facility type. This concept is illustrated in Table 70.

Table 69. Example Calibration

Hypothetical Segment	Hypothetical Observed Crashes	Hypothetical Predicted Crashes	Calibrated Predictions
1	4	2.983	2.839
2	3	3.283	3.124
3	3	2.983	2.839
4	2	3.583	3.409
5	1	3.283	3.124
6	0	3.883	3.695
7	6	4.183	3.980
8	3	3.583	3.409
9	4	3.283	3.124
10	2	3.583	3.409
11	1	3.583	3.409
12	2	3.883	3.695
13	3	2.533	2.410
14	5	4.483	4.266
15	1	2.983	2.839
16	8	3.283	3.124
17	9	3.133	2.981
18	0	3.433	3.267
19	3	2.683	2.553
20	6	4.783	4.551
21	3	4.183	3.980
22	5	4.183	3.980
23	3	3.283	3.124
24	0	3.283	3.124
25	4	3.583	3.409
26	6	4.483	4.266
27	4	2.683	2.553
28	4	2.983	2.839
29	5	3.583	3.409
30	0	3.433	3.267
Total	100	105.099	100
Calibration Factor		0.951	

7.4 Long Term Maintenance and SPF Re-estimation

In the future, MDOT may wish to re-estimate the SPFs developed in this research. In order to accomplish this task, data should be collected and organized as described in Section 3 of this report. Data available in *Safety Analyst* may be sufficient to estimate SPFs when used in conjunction with crash data from the Michigan State Police. In lieu of the discontinuation of the Sufficiency File maintained by MDOT, manual data collection may be necessary if available data sources do not contain geometric data. This research found the following variables to significantly influence crashes within at least one of the segment site types:

- AADT
- Commercial vehicle percent
- Lane width
- Median width
- Right shoulder width
- Posted speed limit
- Driveway density
- Count of schools
- Intersection density
- Crossover density

These characteristics provide a starting point for data collection to re-estimate the SPFs;; however, changes in driver behavior and roadway characteristics may lead to additional characteristics becoming significant in the future. In addition to roadway characteristics, this research found variation in estimated crash frequency between MDOT regions, making the inclusion of MDOT region classification a relevant characteristic. Note that a newly proposed regional scheme is scheduled for implementation by MDOT in the near future.

Once the dataset has been assembled, statistical analysis software must be utilized to estimate the effects of each roadway characteristic on each facility type. Negative binomial models, the standard for SPF development, should be used. A functional form of the model must be identified. Recall that separate models have been developed for single-vehicle and multiple-vehicle crashes at FI and PDO severity levels. For a given severity level, the general equation for the predicted number of crashes is shown below.

$$N_j = (N_{spfmv} I_{mv} + N_{spfsv} I_{sv}) \times CMF_{lw} \times CMF_{lsw} \times CMF_{rsw} \times CMF_{mw} \times CMF_{pk} \times CMF_{fo} \times CMF_{dw} \times CMF_{lgt} \times CMF_{spd}$$

The equation for multiple vehicle and single vehicle crashes based on the natural log of AADT and the MDOT regional indicators are shown below.

$$N_{spfmv} = n \times L \times e^{b_{mv} + b_{mv1} \ln(AADT) + b_{com} \frac{AADT_{com}}{AADT} + b_{r1} I_{r1} + b_{r2} I_{r2} + b_{r3} I_{r3} + b_{r4} I_{r4} + b_{r5} I_{r5} + b_{r6} I_{r6}}$$

$$N_{spfsv} = n \times L \times e^{b_{sv} + b_{sv1} \ln(AADT) + b_{com} \frac{AADT_{com}}{AADT} + b_{r1} I_{r1} + b_{r2} I_{r2} + b_{r3} I_{r3} + b_{r4} I_{r4} + b_{r5} I_{r5} + b_{r6} I_{r6}}$$

Ultimately, the results of the statistical analysis will yield parameter estimates, or coefficients, as well as significance levels and information regarding the accuracy of the parameter estimation. The parameter estimates will serve as the “b” values in the SPF equations, provided they are significant at a 95 percent confidence interval or their inclusion can otherwise be justified using engineering judgement. The equation above illustrates that AADT is generally log-transformed, which has been shown to provide improved fit.

The effects of other roadway characteristics such as lane width or speed limit are accounted for through the creation of CMFs. In Section 3, it was mentioned that the “base” scenario is represented with a CMF of 1.0 for a specific roadway characteristic. Based on engineering judgement, it may be desirable to transform the data collected for any specific roadway feature so that a particular case is used as the base scenario. For example, in this research it was determined that the base condition for the driveway CMF is 10 commercial driveways per mile, three industrial driveways per mile, eight residential driveways per mile, and 10 other type driveways per mile. Therefore, all segments which have the aforementioned number of driveways for each type, would have a CMF of 1.0. The driveway CMF is described using the following equation:

$$CMF_{dw} = e^{0.014(n_{dwc} - 10)} \times e^{0.005(n_{dwi} - 3)} \times e^{0.002(n_{dwr} - 8)} \times e^{0.003(n_{dwo} - 10)}$$

Re-estimation/long-term maintenance of the SPFs will require careful data collection and analysis. The resulting SPFs can only be as good as the data they are based upon. The SPFs presented in this report are the result of extensive data collection and analysis, and ultimately serve as a guideline for the re-estimation of Michigan-specific SPFs in the future.

8.0 CONCLUSIONS

This project involved the development of a uniform, consistent approach that can be applied to estimate the safety performance of urban trunkline segments at an aggregate (i.e., total crash), crash type, and crash severity level. The study results provide important guidance to allow MDOT to make informed decisions when planning and programming safety projects.

This report documents the processes involved in developing safety performance functions (SPFs) and crash modification factors (CMFs) for eight types of arterial roadway segments in Michigan. These tools were developed using a robust database which combined traffic crash, volume, and roadway geometric data. These data were obtained from the following sources:

- Michigan State Police Statewide Crash Database;
- MDOT Sufficiency File;
- MiGDL All Roads File;
- MDOT Driveway File;
- WSU Curve Database;
- WSU Intersection Inventory; and
- Google Earth.

Through the MDOT Sufficiency File and Driveway File, important information on traffic volume, roadway geometric information, speed, and driveway count by type of land use were provided. Additionally, curvature information was extracted through a database created by WSU. Crash information was obtained through the Michigan State Police Crash Database and crashes were linked to each roadway segment through the utilization of a linear referencing system. Crossover information was collected manually using Google Earth and included a count of crossovers as well as type of traffic control. These data were aggregated to develop a comprehensive database of segments including five years of crash, volume, and roadway characteristics for each segment. The final sample was comprised of the following number of locations by site type:

- 489 two-lane undivided (2U) segments;
- 236 three-lane (3T) segments;
- 373 four-lane undivided (4U) segments;
- 439 four-lane divided (4D) segments;
- 239 five-lane (5T) segments;
- 119 six-lane divided (6D) segments;
- 166 eight-lane divided (8D) segments

- 189 One-Way (OW) segments.

After the data were assembled, an exploratory analysis of the data was conducted separately for each segment type to identify general crash trends using Michigan-specific data. The results indicated that a non-linear relationship generally existed between traffic flow and the number of crashes, especially for undivided and one-way segments. With respect to pedestrian and bicycle crashes, it was found that more crashes involving pedestrians or bicyclists occur at lower major road AADT volumes.

In order to provide MDOT with a tool to calculate predicted crash frequency on a particular segment, a series of SPFs were developed. First, the base SPFs from the Highway Safety Manual (HSM) were applied to the Michigan segment data. A calibration exercise illustrated that the models, without calibration, provided inconsistent fit across site types, crash types, and severity levels.

After the calibration exercise, a series of Michigan-specific SPFs were developed. These included a series of simple statewide models, which consider only AADT estimates, as well as regionalized models, which account for differences in traffic, environment, and roadway geometry. In addition to these SPFs, crash type distributions were also developed at a statewide and regional level. While AADT-only SPFs are provided for total, fatal/injury, and property damage only crashes within each of the eight segment types, preliminary models are also provided for pedestrian- and bicycle-involved crashes.

Lastly, more detailed SPFs were estimated that considered traffic volume, speed limits, functional class, and numerous roadway geometric variables such as shoulder and median width; driveway density by land type; intersection and crossover density; and horizontal curvature. These detailed statistical models account for the effects of this wide range of factors, as they provide the greatest degree of accuracy. The models have been calibrated such that they are able to account for the effects of traffic volumes, roadway geometry, regional differences, and other effects.

Within each site type, separate SPFs are also provided to allow for the prediction of vehicle-involved crash frequency (i.e. single- and multi-vehicle crashes), as well as pedestrian- or bicycle-related crashes as a percentage of the vehicular crashes. Distributions are also provided to allow for disaggregation of multi-vehicle crashes into various collision type categories (e.g. rear-end, head-on, angle etc.).

In addition to the SPFs, which were developed for specific base conditions, CMFs were also developed, which can be used to adjust the SPF estimate when the characteristics of a segment are not consistent with the base conditions. Several variables are incorporated in the development of the SPFs and CMFs including AADT, MDOT Region, lane, right and/or left shoulder,median width, on-street parking, driveway density by land use; school count, posted speed limit, and intersection and crossover density. All of the models developed as a part of this project are calibrated such that they can be applied at either the statewide level or within any of MDOT's seven geographic regions.

In addition to the Michigan-specific SPFs and CMFs developed as a part of this study, SDFs were developed which can be used to predict the proportion of injury crashes which result in different injury severity levels. The SDFs can be used with the SPFs to estimate the expected crash frequency for each severity category. The SDFs may include various geometric, operation, and traffic variables that allow the estimated proportion to be specific to an individual segment.

This report also documents a procedure for maintaining and calibrating these SPFs over time. Calibration will allow for MDOT to account for yearly changes in traffic volumes and general trends in crashes over time that are not directly reflected by the predictor variables. As MDOT continues to build its data system, the use of additional geographically-referenced geometric, operational, and traffic control data will allow for further refinements to these analytical tools.

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APPENDIX

Table 70. 2U55L Segment List

2U55L Superior			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
M 26	1175707|5.564|6.268	Douglas Blvd	1476103|0|0.434
US 41	1176203|10.547|12.082	S Suffolk St	1477303|0.513|0.668
Calumet Ave	1176203|12.305|13.148	W Aurora St	1480110|0.137|0.603
US 41	1176203|13.148|14.802	Silver St	1480110|0|0.137
3rd St	1177301|0.447|0.557	W Ludington St	1552105|0.669|0.804
Depot St	1177301|0.557|0.811	Carpenter Ave	1553305|0|0.776
Quincy St	1177509|0.753|1.065	Division St	1563209|2.615|3.491
Quincy St	1177509|1.065|1.346	Division St	1563209|3.491|4.562
Quincy St	1177509|1.346|1.907	County Rd	1563209|4.562|5.66
Canal Rd	1177509|1.907|2.784	Silver St	1563209|5.66|5.931
Pine St	1177509|17.835|18.025	Silver St	1563209|5.931|5.967
Pine St	1177509|18.025|18.222	Jackson St	1564702|0.091|0.295
Pine St	1177509|18.222|18.697	Portage Ave E	1902204|1.052|1.488
US 41	1178404|13.214|14.56	Portage Ave E	1902204|1.488|2.939
College Ave	1178404|15.288|15.615	Portage Ave E	1902204|2.939|3.311
US 41	1178404|7.363|8.124	Tone Rd	3170005|0|4.104
Hecla St	1185203|0.152|0.419	S Mackinac Trl	3170835|0|0.258
M 35	1322610|0.849|2.593	Ashmun St	3170836|17.432|17.625
M 35	1349006|12.677|13.695	Frederick St	3270070|0|0.078
M 35	1349006|13.695|14.769	M 26	3310007|2.998|3.263
M 35	1349006|14.769|15.576	Lake Linden Ave	3310007|3.263|3.702
M 35	1349906|1.486|2.215	Teal Lake Ave	3520187|0|0.526
Ashmun St	1465607|27.211|28.173	Lake Shore Dr	3520776|0|0.791
2U55L North			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
W Washington Ave	1023609|20.236|21.063	M 55	1126103|18.556|18.759
M 32	1023609|21.063|21.363	Sunnyside Dr	1127310|0|2.269
W Washington Ave	1023609|21.363|21.962	Sunnyside Dr	1127310|2.269|2.766
E Chisholm St	1024202|0.117|0.264	M 115	1127810|22.952|23.877
W Chisholm St	1024202|0.264|1.053	Charlevoix Ave	1164305|5.084|5.585
S State Ave	1024309|14.42|14.919	Bay View Rd	1164507|0.013|0.511
S State Ave	1024309|14.919|15.313	Huron Rd	1251607|22.427|23.224
S Gladwin Rd	1053202|8.758|10.075	S James St	215605|0|0.482
N Roscommon Rd	1054905|0|0.721	N Lakeshore Dr	215810|0.901|1.153
M 55	1126103|17.426|18.556	Peninsula Dr	993906|0.312|0.933
-			

2U55L Grand			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
E Washington St	1202910|3.521|4.236	E Fulton St	409005|4.85|5.781
S Greenville Rd	1204902|2.813|3.173	Lake Michigan Dr NW	409105|4.281|4.294
S Lafayette St	1204902|3.173|3.594	W Bluewater Hwy	502809|11.571|11.796
N Lafayette St	1204902|4.17|4.464	W State St	503009|3.722|4.056
Weston St SW	3410389|0|0.121	E State St	503009|4.532|5.041
Grandville Ave SW	3415605|5.5|5.942	W Bluewater Hwy	503406|5.098|5.499
Grandville Ave SW	3415605|5.942|6.482	W Lincoln Ave	503406|5.963|7.302
Belding Rd NE	407607|0.171|2.845	S State Rd	504502|13.121|13.751
Belding Rd NE	407607|2.845|5.388	Northland Dr	524603|14.363|14.679
Franklin St SW	408807|0.063|0.422	S 3rd Ave	525602|0.681|1.091
Oakes St SW	409003|0.191|0.364	Holton Rd	860003|0.408|1.899
W Fulton St	409005|0.353|1.156	Holton Rd	860003|0|0.408
W Fulton St	409005|0|0.353	Holton Rd	860003|3.477|4.31
W Main St SE	409005|19.3|20.358	Water St	860702|0.513|1.1
2U55L Bay			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Peck Rd	1013004|13.393|13.959	E Washington Rd	472110|9.18|9.996
N Dort Hwy	1497008|10.265|10.76	Midland Rd	477106|0|1.776
N Dort Hwy	1497008|11.134|11.284	W Monroe Rd	497604|11.098|11.386
S Dort Hwy	1497008|5.419|5.917	E Monroe Rd	497604|12.623|12.952
S Dort Hwy	1497008|5.917|6.924	N Lapeer Rd	754110|12.73|13.451
S Dort Hwy	1497008|6.924|7.333	N Lapeer Rd	754110|13.451|13.9
S Dort Hwy	1497008|7.333|7.505	E Hotchkiss Rd	765710|3.525|5.241
S Dort Hwy	1497008|7.505|7.938	N Euclid Ave	766409|0.623|2.712
S Dort Hwy	1497008|7.938|8.429	N Euclid Ave	766409|0|0.623
N Dort Hwy	1497008|8.429|8.938	N Tuscola Rd	766609|9.07|9.572
N Dort Hwy	1497008|8.938|9.63	Broadway Ave	767110|2.688|3.134
N Dort Hwy	1497008|9.63|10.265	Broadway Ave	767110|3.134|4.085
N State St	267604|16.234|16.893	Lafayette Ave	767310|0|0.141
Mertz Rd	274805|13.337|13.84	Salzburg Ave	767401|0.556|1.118
W Center Rd	3090057|2.669|4.559	Lafayette Ave	767401|0|0.556
State Park Dr	3090980|0|0.324	Garfield Ave	767404|0.468|1.001
2U55L Southwest			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
S Superior St	1296305|5.996|6.374	Niles Rd	3111292|12.388|12.941
S Superior St	1296305|6.374|6.805	Industrial Rd	3130077|0|1.035
Beadle Lake Rd	1296707|2.423|3.468	West Dr	3130078|0|0.285
Beadle Lake Rd	1296707|3.468|3.906	Michigan Ave E	3130975|1.104|1.626
C Dr N	1297504|0.966|1.119	Michigan Ave E	3130975|1.626|1.895

2U55L Southwest			
Bedford Rd N	1298703|1.281|2.33	S Kalamazoo Ave	3131051|13.321|13.668
Bedford Rd N	1298703|2.33|2.837	Michigan Ave	3131227|0.771|0.929
E Michigan Ave	1301102|2.989|3.515	Olympia Dr	3131227|0.929|2.092
Partello Rd	1301102|3.515|4.135	E Michigan Ave	3750035|1.003|1.591
6 1/2 Mile Rd	1319407|6.652|6.702	E Hoffman St	3750042|7.305|7.903
W Chicago Rd	1361203|0.999|1.579	M 60	3750550|0|0.094
W Chicago Rd	1361203|1.579|2.228	LaGrange St	578110|1.023|1.454
S Lincoln Ave	1362410|0.563|0.803	M 43	578301|0.786|1.085
Main St	1362801|0.305|0.445	M 40	579901|6.545|6.948
E Main St	1362801|1.175|1.243	S Main St	579901|6.948|7.691
N 5th St	1364810|1.864|3.102	N Main St	579901|7.691|8.117
Ferry St	1365209|0.833|1.084	M 62	593502|1.634|1.994
Front St	1365209|0|0.833	Main St	594006|8.859|9.071
Ferry St	1365209|8.206|8.987	Yankee St	594601|0|1.555
Ferry St	1365209|8.987|9.442	Gull Rd	7407|4.396|5.145
Oak St	1365310|0|0.501	Gull Rd	7407|5.145|7.637
E Battle Creek St	1410|0.697|0.963	Gull Rd	7407|7.637|7.881
Main St	228406|0|0.26	Gull Rd	7407|7.881|8.267
Main St	228509|0.969|1.355	Jenner Dr	781803|6.977|7.689
Main St	228509|0|0.969	Grand St	787604|0.662|1.386
Jefferson St	229201|0.125|0.824	M 89	788201|2.452|3.429
E D Ave	23410|2.416|2.48	W Chicago Rd	923007|15.855|16.203
S Washington Ave	3031548|0.576|1.368	S Clay St	924202|2.758|3.059
2U55L University			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
S Dixie Hwy	1227004|0|0.659	Upland Ave	565810|0|0.749
I94 BL	1426706|0|0.347	Dexter St	565810|9.116|9.466
W Michigan Ave	1427301|17.128|18.471	Dexter St	565810|9.466|9.86
W Michigan Ave	1427301|9.688|10.189	Hartel Rd	566510|0.042|0.355
W Michigan Ave	1427707|0|0.107	Hartel Rd	566510|0.355|0.969
E Old M 78	212806|0|0.642	W Lawrence Ave	567304|11.204|11.747
Beck Rd	3300029|0|0.556	N Cochran Ave	567504|18.432|19.223
Hudson Rd	3300901|1.041|1.358	Water St	569007|0.243|0.655
Brooklyn Rd	3381114|0|1.628	Water St	569007|0.655|0.881
N Francis St	3381120|0|0.428	VFW Hwy	569007|0.881|1.759
Ann Arbor Rd	3381751|0.011|1.37	Water St	569007|0|0.243
Industrial Dr	3461030|0|0.399	W Michigan Ave	897207|12.234|12.876
W Ash St	361110|0.219|0.638	W Michigan Ave	897207|12.876|13.203
W Ash St	361110|0.638|0.802	W Michigan Ave	897207|13.203|13.742
E Ash St	361110|0.802|1.517	N West Ave	898201|0.948|1.242

2U55L University			
E Ash St	361110|1.517|2.029	N West Ave	898201|1.243|1.746
W Corunna Ave	3780087|0.207|0.347	Cooper St	901504|1.645|3.052
W Corunna Ave	3780087|0.347|1.052	Cooper Rd	901504|3.052|4.421
W Corunna Ave	3780087|1.052|2.053	E M 36	931604|0|2.135
S Michigan Ave	4104400|0|0.527	E M 36	932308|12.739|14.485
Mason Rd	4104400|1.195|1.553	W M 36	932308|5.824|6.261
N Telegraph Rd	4300001|17.245|18.868	E M 36	932308|7.472|12.241
Beck Rd	518610|0|0.125	M 36	932903|0.1|0.726
Beck St	518703|0|0.504	E Chicago Blvd	947405|16.82|17.462
M 71	553803|1.557|2.395	S Adrian Hwy	948206|9.788|10.959
S Water St	559708|0|0.185	N Adrian Hwy	948504|3.616|4.539
2U55L Metro			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Hoover St	1588008|0.913|2.718	W Auburn Rd	625105|4.161|7.443
Gunston St	1588008|0|0.913	W Auburn Rd	625105|7.443|8.145
Ann Arbor Rd	1604102|2.67|3.171	E Auburn Rd	625105|8.145|10.178
Dixie Hwy	4502633|0|4.456	Ortonville Rd	627809|0.326|0.784
Pointe Tremble Rd	4502633|10.509|11.307	Ortonville Rd	627809|0.784|1.472
Saint Clair River Dr	4502633|12.963|13.547	Main St	814905|3.97|4.348
Saint Clair River Dr	4502633|13.539|14.053	S Main St	817204|0.5|0.922
River Rd	4502633|14.053|16.762	S Main St	817204|0.922|1.322
River Rd	4502633|16.762|17.926	S Main St	817204|1.322|2.486
Dixie Hwy	4502633|4.456|7.196	Gratiot Ave	832010|9.423|10.649
Dyke Rd	4502633|7.196|8.194	Pine Grove Ave	964203|3.125|3.5
Dyke Rd	4502633|8.194|10.509	Pine Grove Ave	964203|3.5|5.043
N Main St	4502782|0.46|1.11	M 25	964608|2.276|2.481
River Rd	4502782|1.11|2.201	Lakeshore Rd	964704|4.372|8.757
River Rd	4502782|2.201|4.586	Fairbanks St	966604|0.188|0.52
River Rd	4502782|4.586|6.326	River Rd	967105|2.787|4.796
River Rd	4502782|6.326|6.756	Busha Hwy	967105|5.41|8.037
Oakland Ave	4502782|6.756|7.021	Busha Hwy	967105|8.037|8.754
Old Dix Toledo Hwy	4718579|0|0.372	-	-

Table 71. 2U55E Segment List

2U55E Superior			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
M 26	1175707|1.448|2.452	M 35	1349906|2.215|3.012
M 26	1175707|8.764|9.97	US 2	1351805|10.911|11.297
M 203	1177509|17.324|17.835	Dixie Hwy	1465607|24.21|27.211
US 41	1178404|11.669|12.319	US 141	1551706|0.862|1.147
US 41	1178404|12.319|13.214	US 141	1551706|0|0.862
US 41	1178404|6.241|7.363	US 2	1551710|0|0.5
US 41	1178404|8.124|11.669	M 553	1561008|16.567|17.672
US 41	1322308|3.239|3.752	US 41	1562009|18.465|19.113
US 41	1322308|3.753|5.213	M 28	1562406|0|3.785
M 35	1322610|2.593|3.763	-	-
2U55E North			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
US 23	1024202|2.954|3.694	US 23	1725704|0|5.63
US 23	1024309|11.094|12.243	N Lakeshore Dr	215810|1.153|2.579
M 32	1079903|8.682|8.982	S Pere Marquette Hwy	217004|8.314|8.959
M 115	1127810|21.743|22.952	M 116	223306|0|0.527
M 115	1127810|25.028|25.542	West Bay Shore Dr	3450711|20.46|20.931
US 31	1153803|2.008|3.569	West Bay Shore Dr	3450711|20.931|25.49
E Parkdale Ave	1153803|7.205|9.104	Old US 131	3830970|4.561|5.803
Caberfae Hwy	1154207|0|1.033	US 31	992204|6.062|6.357
Caberfae Hwy	1154207|1.033|1.49	US 31	992204|6.357|7.345
Caberfae Hwy	1154207|1.49|4.007	US 31	992204|7.345|8.188
Charlevoix Ave	1164305|2.962|4.603	M 37	992703|6.063|7.065
Charlevoix Ave	1164305|4.603|5.084	US 31	994002|6.463|6.763
US 131	1166601|3.224|4.227	M 72	994307|0.4|1.228
Huron Rd	1251607|28.051|30.6	Center Rd	994703|0|3.747
2U55E Grand			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
E Washington St	1202910|4.236|5.203	M 37 NW	423610|10.733|13.92
S Greenville Rd	1204902|6.171|6.672	W Bluewater Hwy	502809|10.306|11.271
River Hill Dr	3702170|0|1.036	Storey Rd	503008|0|1.003
River Hill Dr	3702175|0|0.27	S State Rd	504502|10.959|11.805
Broadmoor Ave SE	407204|1.308|1.607	Northland Dr	524603|17.895|19.533
E Fulton St SE	409005|12.516|12.924	Northland Dr	524603|19.533|20.287
E Fulton St SE	409005|12.924|14.651	19 Mile Rd	525401|2.594|2.957
E Fulton St SE	409005|14.651|17.788	48th St	712309|2.011|3.01
Wilson Ave NW	409008|0|1.528	Warner Ave	712604|1.513|2.5
Wilson Ave NW	409008|1.828|2.233	Lake Michigan Dr	732002|12.293|13.006

2U55E Grand			
Wilson Ave NW	409008|2.233|2.533	Lake Michigan Dr	732002|13.006|13.209
Wilson Ave NW	409008|3.133|5.068	E Savidge St	754007|1.93|3.005
Wilson Ave SW	409008|5.068|5.57	Cleveland St	754007|3.005|3.511
2U55E Bay			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Lakeshore Rd	1015507|0|3.336	N Meridian Rd	3560069|1.294|1.7
Lakeshore Rd	1015507|4.646|5.763	N Meridian Rd	3560069|2.194|4.192
Lakeshore Rd	1015507|5.763|6.699	E Holland Rd	3730053|5.141|5.71
Lakeshore Rd	1015507|7.95|8.259	S Graham Rd	3730210|7.266|8.745
Sheridan Ave	1494001|0.168|0.76	Gera Rd	467707|0|1.526
E Vienna Rd	1494503|10.905|12.661	E Washington Rd	472110|10.836|12.722
N Dort Hwy	1497008|15.319|17.731	N State Rd	494801|7.016|8.017
Clio Rd	1497102|25.027|26.201	W Monroe Rd	497604|7.976|8.983
N State Rd	1501502|12.383|15.129	W Monroe Rd	497604|8.983|9.28
S State Rd	1501502|8.455|9.81	W Monroe Rd	497604|9.28|9.993
E Remus Rd	246401|11.944|12.754	W Monroe Rd	497604|9.993|11.098
E Remus Rd	246401|12.754|13.962	E Lincoln Rd	500608|11.694|12.93
E Caro Rd	267604|18.388|19.709	S River Rd	767110|0.615|2.688
2U55E Southwest			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Columbia Ave W	1296507|0|1.464	Capital Ave NE	3130086|5.039|5.646
Skyline Dr	1296507|1.464|3.754	E Michigan Ave	3130105|1.092|1.736
M 89	1298109|0|0.249	Michigan Ave E	3130975|6.069|6.606
M 66	1301402|10.398|11.493	S Kalamazoo Ave	3131051|11.671|13.321
M 66	1301402|11.493|12.597	M 60	3750037|0|1.719
M 66	1301402|12.597|13.181	LaGrange St	577905|8.41|8.647
Wheatfield Rd	1317710|10.023|10.487	LaGrange St	578110|0|1.023
Wheatfield Rd	1317710|10.487|10.776	M 40	579901|13.163|14.382
M 63	1360705|8.646|10.208	M 40	579901|8.117|9.946
N 5th St	1364810|3.102|4.724	M 40	579901|9.946|11.052
M 139	1366708|0|1.438	M 62	593502|0|0.457
M 139	1366708|1.438|1.838	M 62	593502|2.859|3.203
M 140	1368002|14.665|15.164	M 62	593706|6.423|7.595
M 140	1368002|15.164|15.941	US 12	594006|0.348|1.344
M 140	1368002|15.941|16.366	King Hwy	6906|3.351|5.894
E Augusta Dr	1410|0.963|1.643	E Michigan Ave	6906|5.894|7.712
US 12	232106|15.321|16.576	M 40	781803|6.196|6.977
US 12	232106|18.883|19.383	Grand St	787604|1.386|1.797
M 43	23403|2.668|3.043	Lincoln Rd	788009|1.543|3.145
M 89	23709|0.534|3.052	E Colon Rd	922610|12.425|13.049

2U55E Southwest			
US 131	238202|5.185|5.448	W Chicago Rd	923007|13.52|15.629
M 66	238204|4.26|4.512	E Chicago Rd	923007|19.941|21.569
M 139	3111292|8.01|9.141	M 43	983008|1.652|2.656
M 139	3111292|9.141|10.771	S M 37	983110|0|1.468
Capital Ave NE	3130086|3.426|5.039	-	-
2U55E University			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Memorial Hwy	1223207|4.512|5.74	M 71	553803|0.093|1.557
S Dixie Hwy	1227004|0.659|1.435	M 71	553803|2.395|2.893
S Dixie Hwy	1227004|10.039|12.032	S Cochran Ave	565703|1.778|2.307
S Dixie Hwy	1227004|8.303|9.044	Potterville St	566510|0.969|1.497
S Dixie Hwy	1227004|9.044|10.039	N Hartel Rd	566510|10.269|10.772
E Michigan Ave	1427301|12.55|13.167	Hartel Rd	566510|7.445|8.149
E Michigan Ave	1427301|13.639|14.099	W Lawrence Hwy	567304|10.928|11.204
E Michigan Ave	1427301|14.149|15.109	E Grand Ledge Hwy	567503|13.721|15.362
E Michigan Ave	1427301|15.109|15.409	N Clinton Trl	567504|16.942|17.961
Blue Water Hwy	208909|12.925|13.424	S Clinton Trl	568804|4.355|5.148
Blue Water Hwy	208909|14.931|16.152	Eaton Rapids Rd	897108|0|0.354
S Wright Rd	209001|0|0.432	W Michigan Ave	897201|0|0.458
US 127 BR	209503|17.98|18.411	M 50	898807|0|0.262
Hudson Rd	3300901|1.358|2.181	Brooklyn Rd	899310|2.088|3.656
Hudson Rd	3300901|2.181|3.351	Old US 127 Ramp	899404|0|0.426
Hudson Rd	3300901|3.351|5.169	Spring Arbor Rd	899407|11.737|12.56
E Grand River Ave	3330502|2.537|3.696	E Main St	899407|8.794|11.737
E Grand River Ave	335601|15.649|18.294	Clinton Rd	900409|11.189|12.389
W Dansville Rd	361110|2.029|2.431	Clinton Rd	900409|12.389|14.273
Telegraph Rd	4300001|0.428|1.651	Clinton Rd	900409|14.273|14.598
Telegraph Rd	4300001|1.651|4.941	E Highland Rd	933209|10.265|12.735
N Telegraph Rd	4300001|18.868|19.794	US 223	946402|18.019|18.939
Telegraph Rd	4300001|4.941|6.108	US 223	946402|18.939|19.367
S Telegraph Rd	4300001|8.727|13.351	US 223	946402|19.367|20.772
M 21	551310|13.17|13.576	US 223	946402|21.54|22.037
S M 52	551706|13.031|14.167	US 223	946402|22.037|23.44
N M 52	551706|18.491|18.989	E Monroe Rd	947405|17.462|18.414
N M 52	551706|18.989|20.362	-	-
2U55E Metro			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Ford Rd	1595510|0|1.994	M 53	813706|20.353|20.718
Ford Rd	1595510|1.994|2.986	New Haven Rd	814905|2.707|3.97
Ann Arbor Rd	1604102|0|1.819	Keewahdin Rd	964703|2.067|3.652

2U55E Metro			
Ann Arbor Rd	1604102|1.82|2.67	Kimball Dr	964704|8.757|12.598
Ortonville Rd	627809|2.447|3.177	-	-

Table 72. 3T Segment List

3T Superior			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Calumet Ave	1176203|12.082|12.305	M 35	1349906|1.235|1.486
10th St	1322308|2.557|3.239	Ashmun St	3170836|16.956|17.432
3T North			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
M 32	1023609|18.755|19.224	W Parkdale Ave	1153803|6.369|7.205
W Chisholm St	1024202|1.053|1.811	Bay View Rd	1164507|0.511|1.177
US 23	1024202|2.444|2.954	US 31	1164507|1.177|1.989
S State Ave	1024309|14.063|14.42	US 31	1164507|2.673|3.241
W Main St	1079903|11.123|11.659	US 131	1166601|4.227|4.999
M 32	1079903|11.659|11.926	Huron Rd	1251607|23.224|23.769
M 32	1079903|11.926|12.58	Huron Rd	1251607|23.769|24.218
M 32	1079903|8.682|9.802	Huron Rd	1251607|24.218|24.511
E 38 Rd	1127601|1.273|1.317	Huron Rd	1251607|27.139|28.051
M 115	1127810|23.877|24.173	N Lakeshore Dr	215810|0.158|0.901
M 115	1127810|24.173|24.635	S Pere Marquette Hwy	217004|8.959|9.546
M 115	1127810|24.635|25.028	West Bay Shore Dr	3450711|25.49|26.789
Manistee Hwy	1153803|3.569|4.142	M 37	992703|7.065|8.064
Manistee Hwy	1153803|4.142|4.475	N Garfield Ave	993403|14.76|14.88
3T Grand			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
W Washington St	1202910|2.312|2.986	E Lincoln Ave	503406|7.302|8.28
E Washington St	1202910|2.986|3.247	N State Rd	503510|0.277|0.53
E Washington St	1202910|3.247|3.521	N State Rd	503510|0.53|0.922
S Lafayette St	1204902|3.594|4.17	S State Rd	504502|11.805|12.446
E Fulton St SE	409005|17.788|18.586	S State Rd	504502|12.446|12.741
Wilson Ave NW	409008|1.528|1.828	S State Rd	504502|12.741|13.121
Wilson Ave NW	409008|2.533|3.133	48th St	712309|3.01|3.607
14 Mile Rd NE	410710|3.681|5.085	W Main St	712309|4.374|4.629
Belding Rd	503009|2.622|3.031	W Main St	712309|4.629|4.842
W State St	503009|3.031|3.722	E Main St	712309|4.842|5.002
W State St	503009|4.056|4.532	E Savidge St	754007|0.884|1.46
W Lincoln Ave	503406|5.499|5.763	E Savidge St	754007|1.46|1.93
W Lincoln Ave	503406|5.763|5.963	Holton Rd	860003|1.899|2.831

3T Bay			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Lakeshore Rd	1015507|3.336|4.646	S State St	267604|15.495|16.234
Main St	1015507|6.699|7.264	E Caro Rd	267604|16.893|17.297
Main St	1015507|7.264|7.95	N Meridian Rd	3560069|0.139|1.294
E Vienna Rd	1494503|10.406|10.905	N Meridian Rd	3560069|1.7|2.194
W Vienna St	1494503|9.395|9.755	E Holland Rd	3730053|4.688|5.141
W Vienna St	1494503|9.755|9.904	S Washington Ave	472110|4.359|4.665
E Vienna St	1494503|9.904|10.406	S Washington Ave	472110|4.665|5.08
W High St	246401|13.962|14.464	E Washington Rd	472110|9.996|10.836
W High St	246401|14.464|15.096	East St	474010|8.227|8.83
W High St	246401|15.096|15.475	Wright Ave	496207|0.097|0.963
W High St	246401|15.475|15.977	E Superior St	500608|13.475|14.216
Cleaver Rd	266710|0.463|1.118	E Superior St	500608|14.458|14.784
Ellington St	266710|0|0.463	E Superior St	500608|14.784|14.951
Cleaver Rd	266710|1.118|1.443	N Main St	754110|11.728|12.73
E Frank St	266803|0|0.484	N Lapeer Rd	754110|13.9|14.698
W Caro Rd	267604|14.705|15.495	Westside Saginaw Rd	765710|2.894|3.487
3T Southwest			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
E Dickman Rd	1296303|4.442|4.788	Michigan Ave E	3130975|0.164|0.659
Michigan Ave W	1298109|0.249|1.082	Michigan Ave E	3130975|0.659|1.104
Michigan Ave W	1298109|5.178|6.392	Michigan Ave E	3130975|1.895|2.258
E Michigan Ave	1301102|2.417|2.76	Michigan Ave E	3130975|2.258|3.665
E Michigan Ave	1301102|2.76|2.989	Michigan Ave E	3130975|5.384|6.069
Main St	1319407|7.567|7.886	N Front St	3140026|0.587|1.612
Red Arrow Hwy	1360705|1.121|1.523	M 43	578301|0.609|0.786
Lakeshore Dr	1360705|1.523|2.854	Phillips St	578301|0|0.609
Lakeshore Dr	1360705|2.854|4.37	N Kalamazoo St	579901|11.85|13.163
Lakeshore Dr	1360705|4.37|5.2	M 51	592909|8.382|9.028
Main St	1360705|5.2|5.583	Spruce St	592909|9.028|9.393
W Main St	1363303|0.753|1.566	Main St	592909|9.393|9.896
E Main St	1363303|1.566|1.999	M 62	593502|1.994|2.859
E Main St	1363303|1.999|2.539	E Division St	593706|7.595|8.35
N 5th St	1364810|0.496|1.316	Main St	594006|8.019|8.859
N 5th St	1364810|1.316|1.864	W Michigan Ave	6906|7.712|8.271
Ferry St	1365209|9.442|9.746	E Bridge St	785302|0.855|1.611
Oak St	1365310|0.501|0.714	Monroe St	787604|0.134|0.662
Oak St	1365310|0.714|0.999	N Cedar St	788007|0|0.061
S Main St	1368002|13.763|14.665	Cutler St	788009|0.3|0.962
Main St	228406|0.26|1.402	Lincoln Rd	788009|0.962|1.543

3T Southwest			
Main St	228406|1.402|1.966	M 40	788009|18.024|19.333
US 12	232106|16.576|17.076	M 40	788009|19.333|19.77
US 12	232106|17.631|17.839	Marshall St	788201|0.934|1.732
US 12	232106|17.839|18.35	N Cedar St	788201|0|0.168
E D Ave	23410|2.73|2.969	M 89	788201|1.732|2.452
M 89	23709|0|0.534	Allegan St	788201|12.533|13.194
N Nottawa St	238204|2.74|3.631	Lincoln Rd	788201|8.64|9.233
N Nottawa St	238204|3.631|4.26	Lincoln Rd	788201|9.233|9.872
N Cass St	3111292|0.486|1.167	W Chicago Rd	923007|15.629|15.855
M 139	3111292|1.167|1.978	W Chicago St	923007|17.027|17.872
M 139	3111292|1.978|2.7	E Green St	982909|0.193|0.575
Niles Rd	3111292|10.771|12.388	M 43	983402|0.926|1.5
Capital Ave NE	3130086|2.415|2.91	M 43	983402|1.5|1.894
Capital Ave NE	3130086|2.91|3.426	M 43	983402|1.894|2.294
Jackson St E	3130975|0.094|0.164	N 32nd St	9905|6.149|6.649
3T University			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
W Michigan Ave	1427301|10.189|10.656	S Main St	568804|5.148|5.566
E Michigan Ave	1427301|15.409|16.138	S Main St	568804|5.566|6.072
W Michigan Ave	1427301|16.138|16.802	S Main St	568804|6.072|6.571
W Michigan Ave	1427301|16.802|17.128	Canal St	568804|6.571|7.448
W Grand River Ave	208306|11.517|12.535	W Michigan Ave	897207|13.742|14.148
W Grand River Ave	208306|9.426|11.517	S Meridian Rd	899004|6.516|8.16
W State St	208909|13.424|14.505	Brooklyn Rd	899310|1.8|2.088
E State St	208909|14.505|14.931	Cooper St	901504|0.46|0.583
S Whitmore St	209503|15.896|16.122	Cooper St	901504|0.583|1.645
N Whitmore St	209503|16.122|16.455	Cooper St	901504|0|0.46
W Grand River Ave	335601|3.006|3.997	E M 36	932308|12.241|12.739
W Grand River Ave	335601|8.921|9.341	E M 36	932308|14.485|14.793
W Grand River Ave	335601|9.341|10.58	W Main St	932308|6.261|6.906
N Francis St	3381120|0.428|0.551	E Main St	932308|6.906|7.472
Stockbridge Rd	360401|7.253|8.142	W Grand River Ave	932910|11.234|12.539
Mason Rd	4104400|0.527|1.195	E Grand River Rd	932910|12.539|13.407
N Telegraph Rd	4300001|16.701|17.245	W Highland Rd	933209|0|0.532
W Carleton Rd	515103|2.321|3.742	E Highland Rd	933209|4.315|4.739
Olds St	515103|3.742|4.173	E Highland Rd	933209|4.739|5.027
M 21	551310|12.578|13.17	W Beecher Rd	945708|16.286|16.79
M 21	551310|8.149|8.652	W Beecher Rd	945708|16.79|17.152
S M 52	551706|14.167|15.307	W Beecher Rd	945708|17.152|17.425
S Shiawassee St	551706|15.307|15.804	W Beecher St	945708|17.425|17.799

3T University			
S Shiawassee St	552701|8.355|8.702	W Beecher St	945708|17.799|18.307
E McNeil St	553803|6.315|7.114	US 223	946402|17.27|18.019
S Cochran Ave	565703|2.307|2.806	W Maumee St	946901|0.495|1.099
E Lawrence Ave	566006|0|1.363	W Maumee St	946901|0|0.495
Hartel Rd	566510|8.149|8.446	W Maumee St	946901|1.099|1.838
S Clinton St	566510|8.446|8.941	W Maumee St	946901|1.838|2.032
S Bridge St	566510|9.435|9.577	E Monroe Rd	947405|14.81|15.739
S Bridge St	566510|9.577|9.952	E Church St	948503|0.264|0.406
N Clinton St	566510|9.952|10.269	W Church St	948503|0|0.264
E Saginaw Hwy	567503|15.362|15.652	S Main St	948504|0|0.107
N Cochran Ave	567504|17.961|18.432	S Broad St	948701|0|0.287
3T Metro			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Saint Clair River Dr	4502633|11.853|12.963	S Main St	817204|0|0.5
River Rd	4502633|17.926|18.99	Gratiot Ave	832010|14.831|15.278
Ortonville Rd	627809|3.177|3.849	River Rd	967105|4.796|5.41

Table 73. 4U Segment List

4U Superior			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Front St	1176203|0|0.196	S Lincoln Rd	1349006|16.203|16.946
N Lincoln Dr	1176203|1.831|2.024	4th Ave N	1349906|0.179|1.235
10th Ave	1322308|0.454|0.727	W Cloverland Dr	1476001|0.397|1.136
10th St	1322308|0.727|1.232	E Cloverland Dr	1476001|1.136|2.447
US 41	1322308|0|0.454	US 2	1551710|4.012|4.485
10th St	1322308|1.232|1.984	Carpenter Ave	1553305|1.792|2.043
10th St	1322308|1.984|2.558	Carpenter Ave	1553305|2.043|2.658
M 35	1322610|0|0.849	US 41	1562009|34.856|35.395
S Lincoln Rd	1349006|15.576|16.203	Ashmun St	3170836|16.198|16.956
4U North			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
W Houghton Lake Dr	1052204|11.164|11.957	E Ludington Ave	216003|0.348|0.629
M 55	1052204|2.335|3.019	E Ludington Ave	216003|0.629|0.773
W Houghton Lake Dr	1052204|3.019|5.917	US 10	216003|0.773|1.132
W Houghton Lake Dr	1052204|5.917|11.164	E Traverse Rd	3280081|0.337|1.018
S Otsego Ave	1086304|11.27|11.994	Mitchell St	3830970|1.148|1.661
Cypress St	1153803|4.475|4.913	Mitchell St	3830970|1.661|2.053
Cypress St	1153803|4.913|5.233	Mitchell St	3830970|2.845|3.569
Cypress St	1153803|5.233|6.369	S Division St	992703|13.806|14.663

4U North			
Charlevoix Ave	1164305|5.585|6.336	N Division St	992703|14.663|15.012
US 31	1164507|1.989|2.321	E Front St	993610|3.95|4.694
W Mitchell St	1166601|6.15|6.457	Munson Ave	994002|0|1.047
4U Grand			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
W Washington St	1202910|2.008|2.312	Northland Dr	524603|16.199|16.813
N Lafayette St	1204902|4.464|4.675	Northland Dr	524603|16.813|17.895
N Lafayette St	1204902|4.675|5.182	Maple St	525201|0|0.59
N Lafayette St	1204902|5.182|6.171	S 3rd Ave	525602|0.312|0.681
N Division Ave	3030181|14.623|15.359	W Main St	712309|3.607|4.007
Remembrance Rd NW	3410246|0|0.682	W Main St	712309|4.007|4.374
Chicago Dr SW	3415605|2.833|3.042	Pine St	732409|0|0.175
Chicago Dr SW	3415605|3.042|4.496	M 104	754007|0|0.884
Chicago Dr SW	3415605|4.496|5.5	Apple Ave	857803|0.319|1.235
Taylor Ave NE	405307|0|0.166	Apple Ave	857803|0|0.319
Leonard St NE	405310|0|0.518	Apple Ave	857803|1.235|2.277
W Fulton St	409005|1.156|1.478	Colby St	857910|0.697|1.361
E Fulton St SE	409005|18.586|19.3	Thompson St	859301|0.306|0.536
28th St SW	409008|11.184|11.771	Thompson St	859301|0|0.306
S State Rd	504502|13.751|13.976	Water St	860702|0.078|0.513
4U Bay			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Corunna Rd	1494107|4.942|5.912	E Holland Ave	3730053|2.811|3.18
Corunna Rd	1494107|5.912|7.406	Bay St	460105|0.752|1.241
Corunna Rd	1494107|9.903|11.113	Gratiot Rd	466004|17.886|18.878
Dort Hwy	1497008|0|1.583	Gratiot Ave	466004|18.878|19.5
Dort Hwy	1497008|1.583|2.21	Gratiot Ave	466004|19.5|19.905
N Dort Hwy	1497008|11.284|12.286	S Washington Ave	472110|5.08|5.805
N Dort Hwy	1497008|12.286|13.292	N Main St	494801|8.518|9.025
N Dort Hwy	1497008|13.292|15.319	W Washington Ave	497604|11.386|11.982
Dort Hwy	1497008|2.21|2.967	E Washington Ave	497604|11.982|12.455
S Dort Hwy	1497008|2.967|3.921	E Monroe Rd	497604|12.455|12.623
S Dort Hwy	1497008|3.921|4.919	Tuscola Rd	766609|8.292|8.821
N Saginaw Rd	1497102|20.86|22.93	N Tuscola Rd	766609|8.821|9.07
N Saginaw Rd	1497102|22.93|25.027	S Huron Rd	767610|10.352|14.682
W Court St	1498006|5.138|5.497	S Huron Rd	767610|6.144|8.158
W Court St	1498006|5.497|5.939	S Huron Rd	767610|8.158|9.559
S State Rd	1501502|10.602|11.622	S Huron Rd	767610|9.559|10.352
Veterans Memorial Pkwy	3730025|0|1.084	Eastman Ave	885901|8.902|10.419
Veterans Memorial Pkwy	3730025|1.084|2.029	-	-

4U Southwest			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
S Westnedge Ave	10208|3.821|4.088	W Main St	21502|6.995|8.005
S Westnedge Ave	10208|4.088|4.526	W Main St	21502|8.005|8.572
S Superior St	1296305|6.805|7.127	E D Ave	23410|2.48|2.73
Helmer Rd S	1296603|3.506|4.53	M 66	238008|0.496|1.502
Helmer Rd N	1296603|4.53|4.98	Niles Ave	3111292|13.538|14.102
Columbia Ave E	1297108|5.249|5.812	Niles Ave	3111292|14.102|14.396
N Eaton St	1297402|11.461|11.954	Capital Ave NE	3130086|0.375|1.924
W Dickman Rd	1298108|0|0.553	Austin Ave	3130105|0|1.092
Michigan Ave W	1298109|1.082|1.433	Austin Ave	3130113|0|0.177
Michigan Ave W	1298109|1.433|2.956	Helmer Rd N	3130639|0|0.134
Michigan Ave W	1298109|3.868|5.178	W Michigan Ave	3750035|0|1.003
Bedford Rd N	1298703|0.936|1.281	Phoenix St	578110|2.49|3.107
Bedford Rd N	1298703|0|0.936	M 62	592802|0|0.514
Washington Ave S	1298906|0.68|1.118	King Hwy	6906|0.479|1.273
Helmer Rd N	1300501|0|0.878	Marshall St	788201|0.168|0.934
Michigan Ave	1301102|1.923|2.417	W Allegan St	788201|9.872|10.838
Bedford Rd S	1311108|0|0.897	S Riverview Dr	8403|0|0.339
US 12	1359407|0|2.037	W Chicago St	923007|16.203|17.027
Main St	1360705|5.583|6.178	E Chicago St	923007|17.872|18.396
M 63	1360705|6.178|6.596	Division St	924202|3.059|3.552
N M 63	1360705|6.596|7.224	Division St	924202|3.552|3.734
N M 63	1360705|7.224|7.415	S Broadway St	983008|0.125|0.318
E Main St	1362801|0.69|0.948	N Broadway St	983008|0.508|1.155
E Main St	1363303|2.654|3.036	N Broadway St	983008|1.155|1.652
US 131	15007|2.516|3.532	-	-
4U University			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
S Custer Rd	1223803|18.124|18.404	S Cedar St	362604|1.092|1.302
S Custer Rd	1223803|18.404|18.814	Corunna Ave	3780087|2.053|3.003
S Monroe St	1227004|14.776|14.916	Telegraph Rd	4300001|0|0.428
N Monroe St	1227004|15.158|15.808	N Telegraph Rd	4300001|19.794|21.855
N Monroe St	1227004|16.147|17.116	Telegraph Rd	4300001|27.466|28.567
N Monroe St	1227004|17.116|17.969	N Main St	4603186|1.694|2.187
N Monroe St	1227004|17.969|18.299	N Main St	4603186|2.187|2.858
N Monroe St	1227004|18.299|19.48	W Huron St	4604878|1.397|2.275
W Michigan Ave	1427301|10.656|10.899	E Huron St	4604878|2.666|2.941
W Michigan Ave	1427301|10.899|11.123	W Carleton Rd	515103|0.708|0.928
E Michigan Ave	1427301|11.123|11.274	W Carleton Rd	515103|0.928|1.514
E Michigan Ave	1427301|11.274|11.56	W Carleton Rd	515103|1.514|2.321

4U University			
Washtenaw Ave	1427706|0.391|1.397	W Main St	551310|8.652|9.645
Washtenaw Ave	1427706|1.397|1.985	E Main St	551310|9.828|10.607
Old US 27	209503|1.592|3.123	S Shiawassee St	551706|16.299|17.313
S Broad St	3300901|0.27|1.041	N M 52	551706|17.313|18.491
N Broad St	3300901|0|0.27	S Washington St	554210|4.028|4.209
N Grand River Ave	3330066|0|1.885	E Jefferson St	566510|8.941|9.435
N Grand River Ave	3330066|1.885|3.023	W Lawrence Ave	567304|11.747|11.909
E Grand River Ave	335601|13.321|13.898	W Lawrence Ave	567304|11.909|12.248
W Grand River Ave	335601|13.898|14.712	W Michigan Ave	897207|14.597|15.097
W Grand River Ave	335601|14.712|15.024	W Michigan Ave	897207|15.097|15.421
E Grand River Ave	335601|15.024|15.649	W Grand River Ave	932910|9.898|10.858
E Grand River Ave	335601|2.997|3.006	E Chicago Blvd	947405|16.369|16.625
E Michigan Ave	3381123|0.529|1.315	S Main St	948206|11.963|12.501
E Michigan Ave	3381123|1.315|1.726	N Main St	948504|0.413|1.026
N Cedar St	362604|0.588|1.092	-	-
4U Metro			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Van Dyke St	1577904|0|0.586	S Washington	616604|9.919|10.821
Clark St	1581210|1.352|1.479	N Perry	674007|0.462|1.127
Grand River	4104142|16.056|16.63	N Telegraph Rd	710110|0.232|2.058
S Parker St	4502633|18.99|19.823	N Telegraph Rd	710110|0|0.232
Oakland Ave	4502782|7.021|7.309	23 Mile Rd	807106|17.84|19.08
Oakland Ave	4502782|7.309|7.366	Green St	807106|19.08|20.13
Telegraph Rd	4700038|1.14|1.7	Military St	963509|19.311|19.988
Telegraph Rd	4700038|1.7|2.266	Military St	963509|19.988|20.354
Telegraph Rd	4700038|4.063|4.523	Military St	963509|20.354|20.58
Telegraph Rd	4700038|4.523|5.391	Military St	963509|20.58|21.081
Telegraph Rd	4700038|5.391|6.506	Hancock St	964505|0.558|0.685
Telegraph Rd	4700038|6.506|6.876	Fairbanks St	966604|0.089|0.188
S Fort St	4700047|0.856|1.018	S Riverside Ave	967105|0.983|1.342
Randolph St	4711788|0.262|0.545	N Riverside Ave	967105|1.342|1.636
N Washington	616604|10.821|11.053	N Riverside Ave	967105|1.636|2.787
Lapeer Rd	616604|9.065|9.919	-	-

Table 74. 5T Segment List

5T Superior			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
M 26	1175707|3.48|3.665	US 2	1551710|3.77|4.012
M 26	1175707|3.665|4.247	US 2	1551710|4.485|4.716
Memorial Rd	1175707|4.247|4.746	US 2	1551710|4.716|5.109
Memorial Rd	1175707|4.746|5.104	US 2	1551710|5.109|5.869
10th St	1322308|1.232|1.983	US 2	1551710|5.869|6.876
10th St	1322308|1.983|2.557	US 2	1551710|6.876|8.318
S Lincoln Rd	1349006|16.946|17.227	Carpenter Ave	1553305|0.776|1.025
S Lincoln Rd	1349006|17.227|17.654	Carpenter Ave	1553305|1.025|1.371
N Lincoln Rd	1349006|17.654|17.897	Carpenter Ave	1553305|1.371|1.792
N Lincoln Rd	1349006|17.897|18.726	US 41	1562009|19.113|20.757
N Lincoln Rd	1349006|18.726|18.909	Front St	1562009|20.757|23.364
N Lincoln Rd	1349006|18.909|19.397	US 41	1562009|28.624|30.425
N Lincoln Rd	1349006|19.397|19.616	US 41	1562009|33.745|34.524
US 2	1351805|11.297|11.897	US 41	1562009|34.524|34.856
US 2	1351805|11.897|12.404	US 41	1562009|35.395|36.986
3 Mile Rd	1467209|1.209|1.835	US 41	1562009|36.986|37.585
E Cloverland Dr	1476001|2.447|2.878	US 41	1562009|37.585|38.457
US 2	1476001|2.878|3.548	US 41	1562009|38.457|39.24
US 2	1476001|3.548|4.058	US 41	1562009|39.24|39.93
US 2	1551710|0.877|1.295	US 41	1562009|39.93|40.621
US 2	1551710|1.295|1.751	US 41	1562009|40.621|41.048
US 2	1551710|1.751|2.465	Mackinac Spur	3170836|14.643|15.908
US 2	1551710|2.465|3.222	Ashmun St	3170836|15.908|16.198
US 2	1551710|3.222|3.626	McClellan Ave	3520167|0|1.946
US 2	1551710|3.626|3.77	-	-
5T North			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
M 32	1023609|19.224|20.236	US 10	216003|1.842|2.682
US 23	1024202|1.811|2.142	US 10	216003|2.682|3.377
US 23	1024202|2.142|2.444	US 31	216003|3.377|3.725
US 23	1024309|12.243|13.368	US 31	216003|3.725|4.123
US 23	1024309|13.368|13.727	Mitchell St	3830970|0.876|1.148
S State Ave	1024309|13.727|14.063	Mitchell St	3830970|2.053|2.267
W Main St	1079903|10.609|11.123	Mitchell St	3830970|2.267|2.845
M 32	1079903|9.802|10.609	US 131 BR	3830970|3.569|4.561
S Otsego Ave	1086304|10.276|11.27	US 31	992703|11.668|13.259
S Old 27	1086304|9.117|10.276	US 31	992703|13.259|13.806
E 34 Rd	1131507|11.64|12.676	US 31	992703|8.064|9.062

5T North			
US 31	1164507|2.321|2.673	US 31	992703|9.062|11.668
US 131	1166601|4.999|5.249	E Front St	993610|4.694|5.047
Spring St	1166601|5.249|5.744	US 31	994002|1.047|1.824
Huron Rd	1251607|24.511|25.083	US 31	994002|1.824|2.932
Huron Rd	1251607|25.083|27.139	US 31	994002|2.932|5.662
E Ludington Ave	216003|0.209|0.348	US 31	994002|5.662|6.463
W Ludington Ave	216003|0|0.209	M 72	994307|0|0.4
US 10	216003|1.132|1.842	-	-
5T Grand			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
W Washington St	1202910|1.472|2.008	28th St SE	409008|15.959|16.708
S Division Ave	3030181|13.875|14.246	28th St SE	409008|16.708|17.706
N Division Ave	3030181|14.246|14.623	28th St SE	409008|17.706|18.462
Perry Ave	3540813|2.767|3.816	Wilson Ave SW	409008|6.735|6.907
Perry Ave	3540813|3.816|4.839	28th St SW	409008|6.907|7.621
Lake Michigan Dr	3702045|6.038|7.149	28th St SW	409008|7.621|8.298
Lake Michigan Dr	3702045|7.149|8.927	28th St SW	409008|8.298|8.785
Plainfield Ave NE	405307|3.021|3.821	28th St SW	409008|8.785|9.778
Plainfield Ave NE	405307|3.821|5.677	28th St SW	409008|9.778|10.772
Plainfield Ave NE	405307|5.677|7.206	Lake Michigan Dr NW	409105|0.428|1.01
Broadmoor Ave SE	407204|7.681|7.979	Lake Michigan Dr NW	409105|0|0.428
Broadmoor Ave SE	407204|7.979|8.211	Lake Michigan Dr NW	409105|1.01|1.674
E Beltline Ave SE	407204|8.211|8.694	Lake Michigan Dr NW	409105|1.674|3.43
E Beltline Ave NE	407503|1.704|2.021	Lake Michigan Dr NW	409105|3.43|4.281
Webber Ave NE	407503|2.021|2.66	Alpine Ave NW	423610|2.661|3.254
E Fulton St	409005|10.085|10.349	Alpine Ave NW	423610|3.689|5.199
E Fulton St SE	409005|10.349|11.299	Northland Dr	524603|14.679|15.301
E Fulton St	409005|5.781|6.033	Ironwood Dr	751907|0|1.423
E Fulton St	409005|6.405|7.526	Ironwood Dr	751907|1.423|1.789
28th St SW	409008|10.772|11.184	Apple Ave	857803|2.277|2.748
28th St SE	409008|11.771|12.231	Apple Ave	857803|2.748|3.254
28th St SE	409008|12.231|12.73	Apple Ave	857803|3.254|5.26
28th St SE	409008|12.73|13.695	Apple Ave	857803|5.26|7.145
28th St SE	409008|13.695|14.704	Apple Ave	857803|7.145|8.146
28th St SE	409008|14.704|15.189	Holton Rd	860003|2.831|3.477
28th St SE	409008|15.189|15.959	-	-
5T Bay			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Corunna Rd	1494107|7.406|7.909	Bay Rd	460105|3.749|3.997
Corunna Rd	1494107|7.909|9.091	Bay Rd	460105|3.997|5.74

5T Bay			
Corunna Rd	1494107|9.091|9.471	Rust Ave	460805|1.489|2.433
Corunna Rd	1494107|9.471|9.903	Gratiot Rd	466004|14.638|15.033
W Vienna Rd	1494503|7.813|8.185	Gratiot Rd	466004|15.033|16.011
W Vienna Rd	1494503|8.185|8.919	Gratiot Rd	466004|16.011|16.694
W Vienna Rd	1494503|8.919|9.395	Gratiot Rd	466004|16.694|17.886
S Dort Hwy	1497008|4.919|5.419	S Washington Ave	472110|5.805|6.887
S State Rd	1501502|10.01|10.241	N Washington Ave	472110|6.887|7.16
S State Rd	1501502|10.241|10.602	N Washington Ave	472110|7.16|8.373
S State Rd	1501502|9.81|10.01	N Washington Ave	472110|8.888|9.18
E Pickard St	242308|14.009|14.502	Midland Rd	477106|1.776|3.412
E Pickard St	242308|14.502|14.997	Midland Rd	477106|3.412|5.502
E Pickard Rd	242308|14.997|15.487	Midland Rd	477106|5.502|8.53
E Pickard Rd	242308|15.487|16.017	Midland Rd	477106|8.53|8.976
E Pickard Rd	242308|17.008|18.506	Midland Rd	477106|8.976|10.023
US 127 BR	246704|1.896|2.571	Wright Ave	496207|0.963|1.345
S Mission Rd	246704|2.571|3.578	N Alger Rd	496207|1.345|2.095
S Mission Rd	246704|3.578|4.082	S Lapeer Rd	754110|9.873|10.694
N Mission Rd	246704|4.082|4.587	Washington Ave	767404|1.169|1.629
N Mission Rd	246704|4.587|4.898	S Euclid Ave	767610|2.861|3.86
Center Ave	3090057|0.277|0.936	S Euclid Ave	767610|3.86|4.134
Center Ave	3090057|0.936|1.148	S Euclid Ave	767610|4.134|4.362
Center Ave	3090057|1.148|1.81	N Euclid Ave	767610|4.362|4.862
Center Ave	3090057|1.81|2.669	N Euclid Ave	767610|4.862|5.863
E Holland Rd	3730053|3.18|3.988	N Euclid Ave	767610|5.863|6.144
E Holland Rd	3730053|3.988|4.688	N Madison Ave	768803|1.085|1.225
Bay Rd	460105|1.241|1.744	E Isabella Rd	885110|13.931|14.933
Bay Rd	460105|1.744|2.738	E Isabella Rd	885110|14.933|16.98
Bay Rd	460105|2.738|3.237	Jerome St	885110|18.119|18.355
Bay Rd	460105|3.237|3.749	Eastman Ave	885901|7.777|8.902
5T Southwest			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
S Westnedge Ave	10208|2.773|3.821	W Main St	21502|4.286|5.243
W Dickman Rd	1296303|3.257|3.556	W Main St	21502|5.243|6.032
W Dickman Rd	1296303|3.556|3.905	W Main St	21502|6.032|6.244
E Dickman Rd	1296303|3.905|3.988	W Main St	21502|6.244|6.995
Columbia Ave W	1297108|2.265|2.642	E Michigan Ave	22207|10.739|10.862
Columbia Ave W	1297108|2.642|3.27	E Michigan Ave	22207|10.862|11.106
Columbia Ave W	1297108|3.27|3.662	Stadium Dr	22207|6.388|8.233
Columbia Ave W	1297108|3.662|4.27	Stadium Dr	22207|8.233|8.889
Columbia Ave E	1297108|4.27|4.775	Stadium Dr	22207|8.889|9.428

5T Southwest			
Columbia Ave E	1297108|5.812|7.595	US 12	232106|17.076|17.329
28 Mile Rd	1297402|10.959|11.461	US 12	232106|17.329|17.631
W Dickman Rd	1298108|0.553|1.489	US 12	232106|18.35|18.883
W Dickman Rd	1298108|1.489|2.389	M 66	238008|1.502|2.659
Michigan Ave W	1298109|2.956|3.868	E 48th St	3030234|3.318|4.045
Michigan Ave E	1301102|0.882|1.522	Niles Rd	3111292|12.941|13.538
W Michigan Ave	1301102|1.522|1.923	LaGrange St	578110|1.454|1.959
Red Arrow Hwy	1360705|0.046|1.121	Phillips St	578110|1.959|2.49
S 11th St	1361302|0.986|2.823	M 40	579901|11.052|11.85
S 11th St	1361302|0|0.986	King Hwy	6906|0|0.479
S 11th St	1361302|2.823|3.223	Gull Rd	7407|0.926|1.97
S 11th St	1361302|3.223|3.603	Gull Rd	7407|1.97|2.404
S 11th St	1361302|3.603|4.492	Gull Rd	7407|2.404|2.766
S 12th St	1362708|0|0.137	Gull Rd	7407|2.766|3.251
E Main St	1362801|0.948|1.175	Gull Rd	7407|3.251|4.396
E Main St	1363303|2.539|2.661	Lincoln Ave	783503|5.222|5.654
M 139	1366708|1.838|3.063	M 89	788201|10.838|12.141
Michigan St	1366708|3.063|3.787	M 89	788201|12.341|12.533
Michigan St	1366708|3.787|4.21	E Chicago St	923007|18.396|18.919
E Napier Ave	1367002|3.95|5.114	E Chicago St	923007|18.919|19.34
Division St N	1863703|0.302|0.481	E Chicago St	923007|19.34|19.492
Division St N	1863703|0|0.302	E Chicago St	923007|19.492|19.941
W Main St	21502|3.038|4.286	W State St	983402|0|0.926
5T University			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
S Dixie Hwy	1227004|12.032|13.392	E Saginaw St	341208|6.171|6.79
S Dixie Hwy	1227004|13.392|14.077	Eaton Rapids Rd	352303|0|1.053
S Monroe St	1227004|14.077|14.435	S Martin Luther King Jr Blvd	352303|1.053|1.456
S Monroe St	1227004|14.435|14.776	S Martin Luther King Jr Blvd	352303|1.456|2.707
N Monroe St	1227004|14.916|15.158	S Martin Luther King Jr Blvd	352303|2.707|3.709
N Monroe St	1227004|15.808|16.147	S Martin Luther King Jr Blvd	352303|3.709|4.227
E Michigan Ave	1427301|11.56|12.55	S Cedar St	359606|6.511|7.643
Washtenaw Ave	1427706|1.985|2.795	S Cedar St	359606|7.643|9.639
Washtenaw Ave	1427706|3.429|3.586	N Cedar St	362604|0.448|0.588
Washtenaw Ave	1427706|3.586|4.632	S Telegraph Rd	4300001|13.351|13.651
Washtenaw Ave	1427706|4.632|5.327	S Telegraph Rd	4300001|13.651|14.623
Washtenaw Ave	1427706|5.327|6.437	S Telegraph Rd	4300001|14.623|14.916
W Michigan Ave	1427707|0.107|0.73	S Telegraph Rd	4300001|14.916|15.627
E Michigan Ave	1427804|1.82|2.49	N Telegraph Rd	4300001|15.627|16.38
E Michigan Ave	1427804|2.49|3.408	N Telegraph Rd	4300001|16.38|16.701

5T University			
E Michigan Ave	1427804|3.408|5.177	Jackson Ave	4604878|0.428|0.635
Ecorse Rd	1428108|0.391|1.464	Jackson Ave	4604878|0|0.428
Ecorse Rd	1428108|0|0.391	E Huron St	4604878|2.275|2.666
W Grand River Ave	208306|8.67|9.426	M 21	551310|10.607|12.027
Old US 27	209503|0|1.592	M 21	551310|12.027|12.578
Old US 27	209503|3.638|4	E Main St	551310|9.645|9.828
Old US 27	209503|4|5.838	E Saginaw Hwy	567503|16.154|16.718
N Cedar St	3330526|2.051|2.489	E Saginaw Hwy	567503|16.718|18.11
N East St	3330526|2.489|3.105	E Saginaw Hwy	567503|18.11|19.111
E Michigan Ave	335507|0.168|0.472	E Saginaw Hwy	567503|20.105|21.105
E Grand River Ave	335601|4.721|5.25	E Saginaw Hwy	567503|22.12|23.109
E Grand River Ave	335601|5.25|5.554	N Michigan Rd	568804|16.098|17.158
E Grand River Ave	335601|5.554|6.052	S Michigan Rd	568804|7.448|8.706
W Grand River Ave	335601|6.052|7.09	N West Ave	898201|0.175|0.948
W Grand River Ave	335601|7.09|7.479	W Grand River Ave	932910|10.858|11.234
W Grand River Ave	335601|7.479|8.038	E Grand River Rd	932910|13.407|15.08
W Grand River Ave	335601|8.038|8.921	E Grand River Rd	932910|15.08|15.692
S Cooper St	3381112|0|0.326	E Grand River Rd	932910|15.692|16.572
S Cooper St	3381112|1.003|1.534	E Highland Rd	933209|3.628|4.315
E Michigan Ave	3381123|0|0.529	US 223	946402|20.772|21.278
E Michigan Ave	3381123|1.726|2.34	US 223	946402|21.278|21.54
W Saginaw St	341208|0|0.809	S Main St	948206|10.959|11.738
E Saginaw St	341208|4.995|5.086	S Main St	948206|11.738|11.963
W Saginaw St	341208|5.086|5.634	N Main St	948504|1.026|1.706
W Saginaw St	341208|5.634|6.171	N Adrian Hwy	948504|1.706|3.616
5T Metro			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Michigan Ave	1577103|0|1.209	Telegraph Rd	4700038|3.726|4.063
Michigan Ave	1577103|1.872|3.764	Wyoming Ave	4706472|0|0.147
Michigan Ave	1577103|3.764|4.576	Dix Toledo Hwy	4718578|0.372|0.741
Grand River Ave	1577408|0.718|1.916	Dix Toledo Hwy	4718578|0.741|1.055
Grand River Ave	1577408|1.916|2.745	Dix Toledo Hwy	4718578|0|0.372
Grand River Ave	1577408|2.745|4.654	Lapeer Rd	616604|6.472|6.825
Grand River Ave	1577408|4.654|5.201	S Broadway St	616604|6.825|7.742
Van Dyke St	1577904|0.586|3.906	Ortonville Rd	627809|0|0.326
Van Dyke St	1577904|3.906|4.886	Highland Rd	648906|12.716|14.548
McGraw St	1581903|0|0.076	Highland Rd	648906|14.548|17.826
S Fort St	1585010|0.019|0.74	Highland Rd	648906|17.826|18.54
W Fort St	1585010|0.74|2.408	W Huron St	648906|18.54|19.26
W Fort St	1585010|2.408|3.123	E Highland Rd	648906|5.169|5.722

5T Metro			
W Fort St	1585010|3.123|3.987	E Highland Rd	648906|5.722|6.118
Ford Rd	1595510|10.031|12.024	Highland Rd	648906|8.294|12.716
Ford Rd	1595510|2.986|3.485	Cesar E Chavez Ave	672206|1.237|2.309
Ford Rd	1595510|3.485|5.284	N Perry	674007|1.127|1.64
Ford Rd	1595510|5.284|6.011	N Perry	674007|1.64|3.749
Ford Rd	1595510|6.011|7.049	Lapeer Rd	674007|3.749|3.999
Ford Rd	1595510|7.049|8.045	Dixie Hwy	689103|0.697|1.831
Ford Rd	1595510|8.045|9.291	Dixie Hwy	689103|1.831|2.485
Ford Rd	1595510|9.291|10.031	Dixie Hwy	689103|2.485|6.205
Michigan Ave	1600206|15.523|16.592	Dixie Hwy	689103|6.205|8.609
Plymouth Rd	1604102|12.088|12.339	Groesbeck Hwy	803009|11.199|11.715
Plymouth Rd	1604102|12.339|14.29	N Groesbeck Hwy	803009|11.715|13.106
Ann Arbor Rd	1604102|3.171|3.672	Groesbeck Hwy	803009|13.106|14.098
Ann Arbor Rd	1604102|3.672|4.676	Groesbeck Hwy	803009|7.124|7.662
Ann Arbor Rd	1604102|4.676|5.901	Groesbeck Hwy	803009|7.662|9.512
Ann Arbor Rd	1604102|5.901|6.179	Groesbeck Hwy	803009|9.512|11.199
Ann Arbor Rd	1604102|6.179|7.259	23 Mile Rd	807106|14.084|16.834
Ann Arbor Rd	1604102|7.259|9.333	23 Mile Rd	807106|16.834|17.327
Plymouth Rd	1604102|9.333|12.088	23 Mile Rd	807106|17.327|17.84
Greenfield Rd	1651002|12.223|12.299	N Gratiot Ave	832010|0.912|1.153
Groesbeck Hwy	1817105|0|0.172	N Gratiot Ave	832010|1.153|2.093
Grand River	4104142|14.249|14.464	N Gratiot Ave	832010|2.093|5.508
Grand River	4104142|14.464|15.555	Gratiot Rd	963509|13.92|14.334
Grand River	4104142|15.555|16.056	Gratiot Blvd	963509|14.334|16.573
Grand River	4104142|16.63|17.824	Pine Grove Ave	964203|0.689|1.024
Grand River	4104142|17.824|18.243	Pine Grove Ave	964203|0|0.689
S Rochester Rd	4413538|11.79|12.352	Pine Grove Ave	964203|1.024|1.255
Rochester Rd	4413538|12.352|13.128	Pine Grove Ave	964203|1.255|1.532
N Main	4413538|13.128|13.601	Pine Grove Ave	964203|1.532|1.887
Rochester Rd	4413538|13.601|13.818	Pine Grove Ave	964203|1.887|2.633
S Rochester Rd	4413538|9.051|9.708	Pine Grove Ave	964203|2.633|3.125
S Rochester Rd	4413538|9.708|11.79	M 25	964608|0.268|1.259
Pointe Tremble Rd	4502633|11.307|11.853	M 25	964608|1.259|1.771
Telegraph Rd	4700038|0|1.14	M 25	964608|1.771|2.276
Telegraph Rd	4700038|3.374|3.726	Busha Hwy	967105|8.754|9.426

Table 75. 4D Segment List

4D Superior			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Memorial Rd	1176107|0|0.178	US 2	3210000|0.914|1.293
Townsend Dr	1178404|14.875|15.288	US 2	3210000|0|0.914
US 2	1349006|19.616|20.393	US 2	3210001|0.831|1.326
US 2	1349006|20.393|20.9	US 2	3210001|0|0.831
US 2	1349006|23.341|24.176	US 2	3210001|1.326|2.725
US 2	1349006|24.176|24.665	US 2	3210001|2.725|2.901
US 2	1349006|24.665|26.075	US 2	3210001|2.901|3.971
US 2	1349006|26.075|26.271	US 2	3210001|3.971|5.71
US 2	1349006|26.271|27.323	US 2	3220756|0|0.616
US 2	1349006|27.323|29.061	US 2	3220757|0.164|0.395
W Cloverland Dr	1476001|0|0.397	US 2	3220757|0|0.164
US 2	1551710|0.5|0.665	W Cloverland Dr	3270065|0|0.243
US 2	1551710|0.665|0.877	Townsend Dr	3310874|0.309|0.729
US 2	1551710|11.082|11.681	US 41	3520507|0.666|1.372
S Front St	1562009|23.339|24.04	S Front St	3520507|0|0.666
US 41	1562009|24.04|24.76	US 41	3520507|1.372|1.883
US 41	1562009|24.76|25.204	US 41	3520507|1.883|2.104
US 41	1562009|25.204|25.486	US 41	3520507|2.104|3.187
US 41	1562009|25.486|26.585	US 41	3520507|3.187|3.444
US 41	1562009|26.585|26.833	US 41	3520777|0.808|2.792
US 41	1562009|30.425|31.231	US 41	3520777|0|0.808
US 41	1562009|31.231|33.244	US 41	3520777|2.792|3.316
US 41	1562009|33.244|33.745	-	-
4D North			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
W Grandview Pkwy	3281171|0.576|0.984	W Grandview Pkwy	993209|0.584|0.995
W Grandview Pkwy	3281171|0|0.576	W Grandview Pkwy	993209|0|0.584
E Grandview Pkwy	3281427|0|0.676	E Grandview Pkwy	993209|1.152|1.825
W Ludington Ave	3530728|0|0.361	-	-
4D Grand			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Broadmoor Ave SE	3410033|0|0.939	E Beltline Ave NE	407204|14.229|15.221
Broadmoor Ave SE	3410033|2.441|4.381	E Beltline Ave NE	407204|15.221|16.255
Broadmoor Ave SE	3410033|4.381|6.075	Broadmoor Ave SE	407204|5.977|7.681
E Fulton St	3411823|0|2.564	E Beltline Ave SE	407204|9.209|10.194
E Beltline Ave SE	3412181|0.515|1.501	E Beltline Ave NE	407503|0|1.704
E Beltline Ave SE	3412181|0|0.515	Northland Dr NE	407503|2.66|4.829
E Beltline Ave SE	3412181|1.501|2.609	E Fulton St SE	409005|11.775|12.516

4D Grand			
E Beltline Ave SE	3412181|2.609|3.034	E Fulton St	409005|6.033|6.405
E Beltline Ave NE	3412181|3.034|3.468	E Fulton St	409005|7.526|10.085
E Beltline Ave NE	3412182|0.646|1.643	Alpine Ave NW	423610|5.199|6.699
E Beltline Ave NE	3412182|0|0.646	Alpine Ave NW	423610|6.699|7.704
E Beltline Ave NE	3412182|1.643|2.635	Alpine Ave NW	423610|7.704|9.917
E Beltline Ave NE	3412182|2.635|5.384	M 37 NW	423610|9.917|10.733
E Fulton St	3412399|0|0.296	Northland Dr	524603|15.301|15.818
Alpine Ave NW	3412445|0|1.501	Northland Dr	524603|15.818|16.071
Alpine Ave NW	3412445|1.501|2.505	Northland Dr	524603|16.071|16.199
Alpine Ave NW	3412445|2.505|4.72	US 31	740406|0|1.083
M 37 NW	3412445|4.72|5.53	S US 31	740406|1.083|1.991
Northland Dr NE	3415610|0|2.164	S US 31	740406|1.991|2.605
Northland Dr	3540721|0.517|0.77	S US 31	740406|17.437|17.98
Northland Dr	3540721|0.77|0.898	S US 31	740406|17.98|20.621
Northland Dr	3540721|0|0.517	S US 31	740406|2.605|3.133
M 120	3610261|0|0.865	S Beacon Blvd	740406|20.621|22.154
Shoreline Dr	3611477|0.743|0.992	S US 31	740406|3.133|4.171
Shoreline Dr	3611477|0.992|1.73	S US 31	740406|4.171|5.203
Shoreline Dr	3611477|0|0.743	S US 31	740406|5.203|6.293
Shoreline Dr	3611478|0.682|0.928	Chicago Dr	740803|1.942|2.208
Shoreline Dr	3611478|0.928|1.66	Chicago Dr	740803|2.208|2.838
Shoreline Dr	3611478|0|0.682	Chicago Dr	740803|2.838|4.639
Chicago Dr	3700131|0.17|0.441	I 196 BL	740803|4.639|6.289
Chicago Dr	3700131|0.441|1.053	I 196 BL	740803|6.289|7.467
Chicago Dr	3700131|1.053|2.872	US 31	742605|0|1.082
I 196 BL	3700131|2.872|4.525	N US 31	742605|1.082|1.995
I 196 BL	3700131|4.525|5.717	N US 31	742605|17.43|17.977
Chicago Dr	3701952|0|1.169	N US 31	742605|17.977|20.619
Chicago Dr	3701952|11.015|12.662	N US 31	742605|2.604|3.134
Chicago Dr	3701952|5.591|6.706	S Beacon Blvd	742605|20.619|22.153
Chicago Dr	3701952|6.706|7.959	N US 31	742605|3.134|4.17
Chicago Dr	3701952|7.959|9.097	N US 31	742605|4.17|5.202
Chicago Dr	3701952|9.097|11.015	N US 31	742605|5.202|6.292
Lake Michigan Dr	3702045|0|2.863	Skyline Dr	858204|1.876|2.391
Lake Michigan Dr	3702045|2.863|4.625	Seaway Dr	859613|0|1.325
Lake Michigan Dr	3702045|4.625|6.038	Seaway Dr	859613|1.325|1.921
Lake Michigan Dr	3702046|0|2.862	Seaway Dr	859613|1.921|2.426
Lake Michigan Dr	3702046|2.862|4.624	Seaway Dr	859613|2.426|3.155
Lake Michigan Dr	3702046|4.624|6.039	Seaway Dr	859613|3.155|4.16
Chicago Dr	3702173|0|1.195	Seaway Dr	859613|4.16|5.168

4D Grand			
Chicago Dr	3702173|11.038|12.478	Seaway Dr	859613|5.168|5.613
Chicago Dr	3702173|5.618|6.729	M 120	859701|0|0.246
Chicago Dr	3702173|6.729|7.974	Skyline Dr	859903|1.827|2.396
Chicago Dr	3702173|7.974|9.106	M 120	859906|0|1.096
Chicago Dr	3702173|9.106|11.038	Seaway Dr	859917|0|1.311
Main Ave	3702715|0.101|0.117	Seaway Dr	859917|1.311|1.91
Main Ave	3702715|0|0.101	Seaway Dr	859917|1.91|2.414
Broadmoor Ave SE	407204|1.607|2.534	Seaway Dr	859917|2.414|3.184
E Beltline Ave SE	407204|10.194|11.3	Seaway Dr	859917|3.184|4.186
E Beltline Ave SE	407204|11.3|11.733	Seaway Dr	859917|4.186|5.194
E Beltline Ave NE	407204|13.232|14.229	Seaway Dr	859917|5.194|5.701
4D Bay			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Corunna Rd	1494107|3.438|4.942	Bay Rd	3731356|0|1.004
N Dort Hwy	1497008|10.76|11.134	Bay Rd	460105|5.74|6.742
S Washington Ave	3090038|0|0.043	Stephens St	460805|0.76|1.489
S Washington Ave	3090100|0|0.129	Williams St	460806|0.809|0.939
Westside Saginaw Rd	3090970|0|1.905	Gratiot Rd	466004|12.051|13.038
Dort Hwy	3250363|0|0.382	Gratiot Rd	466004|13.038|14.638
Corunna Rd	3250552|3.438|4.941	Westside Saginaw Rd	765710|0|1.894
Gratiot Rd	3730501|0.179|1.167	S Washington Ave	767404|1.001|1.169
Gratiot Rd	3730501|1.167|2.766	E Thomas St	768604|2.366|3.047
Rust Ave	3731169|0|0.587	M 25	768706|1.141|1.796
4D Southwest			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Skyline Dr	1296303|0|0.372	W Main St	3110096|0.338|0.704
W Dickman Rd	1296303|1.226|1.369	W Pulaski Hwy	3110501|0.648|1.586
W Dickman Rd	1296303|1.369|2.24	W Pulaski Hwy	3110501|1.586|2.874
W Dickman Rd	1296303|2.24|2.75	W Pulaski Hwy	3110501|3.192|4.196
W Dickman Rd	1296303|2.75|3.257	W Pulaski Hwy	3110501|4.196|5.466
E Dickman Rd	1296303|3.988|4.442	W Main St	3110502|0|1.998
Skyline Dr	1297110|0|0.533	S M 63	3111211|0|1.23
W Dickman Rd	1300503|0|0.399	W Dickman Rd	3130900|0.199|0.342
W Dickman Rd	1300702|0|0.224	W Dickman Rd	3130900|0.342|1.212
Michigan Ave E	1301102|0.371|0.882	W Dickman Rd	3130900|1.212|1.724
Michigan Ave E	1301102|0|0.371	W Dickman Rd	3130900|1.724|2.232
E Pulaski Hwy	1359807|21.206|22.12	E Dickman Rd	3130901|0|0.435
E Pulaski Hwy	1359807|22.12|23.431	Michigan Ave E	3130975|10.003|10.367
E Pulaski Hwy	1359807|23.749|24.753	Michigan Ave E	3130975|10.367|10.883
E Pulaski Hwy	1359807|24.753|26.018	M 60	3140000|0.306|2.137

4D Southwest			
N M 63	1360705|7.415|8.646	M 60	3140000|0|0.306
W Main St	1363303|0.344|0.753	M 60	3140000|2.137|3.914
E Main St	1363303|3.043|4.937	S US 131	3390106|0|1.506
S US 131	1915006|0.571|1.449	M 60	594510|0.057|2.164
S US 131	1915006|1.449|2.298	M 60	594510|0|0.057
S US 131	1915006|2.298|3.678	M 60	594510|2.164|3.133
S US 131	1915006|3.678|7.521	M 60	594510|3.133|3.917
N US 131	238202|6.062|6.887	N US 31	798206|2.013|3.413
N US 131	238202|6.887|7.735	N US 31	798206|3.413|4.197
N US 131	238202|7.735|9.106	S US 31	798304|2.29|3.391
N US 131	238202|9.106|12.96	S US 31	798304|3.391|4.159
S Bus US 131	26101|0.082|0.399	N Bus US 131	9308|1.325|1.689
4D University			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
S Custer Rd	1223803|15.84|18.124	Lansing Rd	3231104|2.536|4.129
Washtenaw Ave	1427706|0|0.391	Lansing Rd	3231104|4.129|5.531
E Michigan Ave	1427804|5.177|5.528	Larch	3330067|0|0.319
Ecorse Rd	1428901|0|0.325	E Saginaw St	3330504|0.625|1.024
US 12	1430401|0|0.725	E Saginaw St	3330504|0|0.625
Ecorse Rd	1430401|2.24|2.448	E Saginaw St	3330504|1.024|1.624
US 12	1430402|0|0.818	I 69 BL	3330504|1.624|3.125
E M 153	1431510|0.837|1.553	N Cedar St	3331423|0|0.456
W M 153	1431602|0|1.01	S Cooper St	3381112|0.326|1.003
W M 153	1431602|1.01|1.708	S Cooper St	3381113|0|0.678
I 96 BL	1869707|0|0.762	E Saginaw St	341208|6.79|7.415
Saginaw Hwy	1877204|0.469|0.677	E Saginaw St	341208|7.415|7.873
Saginaw Hwy	1877204|0.677|1.143	E Saginaw St	341208|7.873|8.458
Saginaw Hwy	1877204|0|0.469	I 69 BL	341208|8.458|9.955
Saginaw Hwy	1877206|0.446|0.672	Lansing Rd	355301|0|0.883
Saginaw Hwy	1877206|0.672|1.141	W Highland Rd	4105117|0.45|1.248
Saginaw Hwy	1877206|0|0.446	W Highland Rd	4105117|0|0.45
N Michigan Rd	1925502|6.068|7.398	W Highland Rd	4105117|1.248|2.985
US 127 BR	209503|13.978|14.986	Highland Rd	4105278|0.432|3.477
N Whitmore St	209503|16.455|17.319	S Custer Rd	4300467|0|2.285
US 127 BR	209503|17.319|17.98	E Michigan Ave	4600027|0|0.359
Old US 27	209503|3.123|3.319	E Huron St	4603893|0|0.472
Old US 27	209503|3.319|3.638	E Huron St	4604878|2.941|3.017
US 127 BR	3190811|2.982|3.99	Lansing Rd	566006|10.972|11.579
S Whitmore St	3190812|0|0.309	Lansing Rd	566006|12.371|13.052
US 127 BR	3190813|0.868|1.525	Lansing Rd	566006|13.052|14.644

4D University			
N Whitmore St	3190813|0|0.868	Lansing Rd	566006|14.644|16.049
Old US 27	3190815|0.197|0.516	N Michigan Rd	568804|14.781|16.098
Old US 27	3190815|0|0.197	W Highland Rd	933209|0.532|1.004
Lansing Rd	3231104|0.448|1.059	W Highland Rd	933209|1.004|1.772
Lansing Rd	3231104|0|0.448	W Highland Rd	933209|1.772|3.628
Lansing Rd	3231104|1.059|1.847	Highland Rd	933209|12.735|13.496
Lansing Rd	3231104|1.847|2.536	Highland Rd	933209|13.496|16.318
4D Metro			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Telegraph Rd	1576806|0|0.406	Michigan Ave	4705565|3.335|5.774
Michigan Ave	1577103|4.576|4.881	Randolph St	4707253|0|0.149
Fort St	1592105|0|1.721	Randolph St	4711788|0.126|0.262
Fort St	1592105|1.721|2.755	Woodward Ave	614101|10.163|10.828
Fort St	1592105|2.755|3.959	Woodward Ave	614101|10.828|11.257
Fort St	1592105|3.959|6.179	Lapeer Rd	616604|0.781|2.06
Fort St	1592105|6.179|7.182	M 24	616604|11.053|12.258
Fort St	1592106|0|1.601	Lapeer Rd	616604|2.06|6.472
Fort St	1592106|1.601|2.594	Lapeer Rd	616604|7.742|9.065
Fort St	1592106|2.594|3.801	Lapeer Rd	616605|2.047|6.459
Fort St	1592106|3.801|6.021	Woodward Ave	616808|10.154|10.824
Fort St	1592106|6.021|7.023	Woodward Ave	616808|10.824|11.249
Michigan Ave	1599002|0|0.952	Grand River	633807|0|0.349
Michigan Ave	1599009|0|0.618	Grand River	634904|0|0.393
Michigan Ave	1600206|0.836|1.344	W Highland Rd	648906|0|2.101
Michigan Ave	1600206|0|0.836	W Highland Rd	648906|2.101|3.183
Michigan Ave	1600206|1.344|3.362	E Highland Rd	648906|3.183|5.169
Michigan Ave	1600206|3.362|5.803	E Highland Rd	648906|6.118|8.294
William P Rosso Hwy	4205105|0|0.163	Cesar E Chavez Ave	672206|2.309|2.568
N M 53	4210208|13.241|18.384	Northwestern Hwy	710010|0.123|2.578
N M 53	4210208|18.384|18.883	Northwestern Hwy	710010|0|0.123
N M 53	4210208|18.883|20.358	Northwestern Hwy	710102|0.171|2.573
Cesar E Chavez Ave	4400845|0|0.258	Northwestern Hwy	710102|0|0.171
Lapeer Rd	4410003|0|1.321	S M 53	813706|13.284|16.638
E Highland Rd	4410081|0|2.174	S M 53	813706|16.638|17.538
W Highland Rd	4410120|0|2.102	S M 53	813706|17.538|18.395
W Highland Rd	4410120|2.102|3.183	S M 53	813706|18.395|18.895
E Highland Rd	4410120|3.183|5.165	S M 53	813706|18.895|20.353
M 24	4410277|0|1.203	Busha Hwy	963402|0|0.819
Telegraph Rd	4700038|6.876|7.26	Busha Hwy	963509|16.573|17.42
Michigan Ave	4705565|0|1.18	I 94/Pine Grove Connector	964509|0.381|0.654

4D Metro			
Michigan Ave	4705565|1.18|1.316	I 94/Pine Grove Connector	964510|0.325|0.658
Michigan Ave	4705565|1.316|3.335	-	-

Table 76. 6D Segment List

6D Grand			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Broadmoor Ave SE	3410033|0.939|1.759	N Beacon Blvd	740406|22.154|22.833
Broadmoor Ave SE	3410033|1.759|2.441	N US 31	742605|1.995|2.604
Broadmoor Ave SE	407204|2.534|3.362	N Beacon Blvd	742605|22.153|22.846
Broadmoor Ave SE	407204|3.362|4.087	-	-
6D Bay			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
N Washington Ave	3730515|0|0.496	N Washington Ave	472110|8.373|8.888
6D Southwest			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
W Michigan Ave	22207|9.428|9.762	W Michigan Ave	3392168|0|0.304
6D University			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Ecorse Rd	1430401|0.725|1.366	Michigan Ave	3331425|0|0.492
Ecorse Rd	1430402|0.818|1.428	W Saginaw St	341208|0.809|1.073
Ecorse Rd	1430402|2.196|2.429	S Martin Luther King Jr Blvd	352303|4.227|4.709
W Saginaw St	3330065|0|0.262	S Martin Luther King Jr Blvd	352303|4.709|5.203
W Grand River Ave	3330501|0.066|0.782	S Martin Luther King Jr Blvd	352303|5.708|6.136
S Martin Luther King Jr Blvd	3330522|0.484|0.851	S Cedar St	359606|10.592|10.792
S Martin Luther King Jr Blvd	3330522|0|0.484	N Cedar St	359606|12.266|12.61
S Cedar St	3330526|0.037|0.237	Highland Rd	4105278|0|0.432
N Cedar St	3330526|1.669|2.051	Lansing Rd	566006|11.579|12.371
Michigan Ave	3331424|0.373|0.826	S Martin Luther King Jr Blvd	980401|0.65|1.263
Michigan Ave	3331424|0|0.373	S Martin Luther King Jr Blvd	980401|0|0.129
6D Metro			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
S Telegraph Rd	1576806|0.604|1.599	W Davison St	4702009|0.677|1.055
S Telegraph Rd	1576806|1.599|4.605	E M 8	4702009|0|0.677
N Telegraph Rd	1576806|10.541|11.61	W Davison St	4702010|0.591|0.981
S Telegraph Rd	1576806|5.548|6.418	W M 8	4702010|0|0.591
S Telegraph Rd	1576806|6.418|7.227	Lapeer Rd	616604|0|0.781
S Telegraph Rd	1576806|7.227|7.673	Lapeer Rd	616605|0.819|2.047
S Telegraph Rd	1576806|7.673|8.096	Lapeer Rd	616605|0|0.819
S Telegraph Rd	1576806|8.096|9.549	N I 75 BL	625903|1.304|1.557

6D Metro			
N Telegraph Rd	1576806|9.549|10.541	N I 75 BL	625903|1.557|2.142
W Fort St	1585010|5.456|5.652	S I 75 BL	625912|1.332|1.577
Fort St	1592105|11.041|12.965	S I 75 BL	625912|1.577|2.152
Fort St	1592105|12.965|13.915	W Square Lake Rd	640407|2.64|3.979
Fort St	1592105|13.915|15.245	S Saginaw St	674904|0|0.854
Fort St	1592105|7.182|8.184	Telegraph Rd	710009|4.584|5.092
Fort St	1592105|8.184|8.88	Telegraph Rd	710009|5.092|6.104
Fort St	1592105|8.88|9.422	Telegraph Rd	710009|6.104|6.631
Fort St	1592106|10.894|12.815	Telegraph Rd	710009|7.513|9.686
Fort St	1592106|12.815|13.78	Telegraph Rd	710009|9.686|11.344
S Fort St	1592106|13.78|15.084	Northwestern Hwy	710010|2.578|3.313
S Fort St	1592106|15.084|15.374	Northwestern Hwy	710102|2.573|3.355
Fort St	1592106|7.023|8.026	Northwestern Hwy	710102|3.355|3.835
Fort St	1592106|8.026|8.703	Telegraph Rd	710106|5.091|6.103
N M 39	1592408|0.312|0.498	Telegraph Rd	710106|6.103|6.651
Ford Rd	1595510|14.348|15.427	Telegraph Rd	710106|7.512|9.681
Ford Rd	1924107|0|1.077	Telegraph Rd	710106|9.681|11.33
William P Rosso Hwy	4205580|0|0.572	S Telegraph Rd	710110|3.18|3.595
Gratiot Ave	4208203|0|2.265	S Telegraph Rd	710110|3.595|3.855
Gratiot Ave	4208203|2.265|3.398	Gratiot Ave	804806|0|2.301
Gratiot Ave	4208203|3.398|5.14	Gratiot Ave	804806|2.301|3.433
Van Dyke Ave	4210208|0.214|1.193	Gratiot Ave	804806|3.433|5.176
Van Dyke Ave	4210208|1.193|2.227	Hall Rd	807801|10.291|11.008
Van Dyke Ave	4210208|2.227|3.245	Hall Rd	807801|11.008|11.797
S Saginaw St	4400013|0|0.852	William P Rosso Hwy	807801|11.797|12.534
S M 5	4402005|0|0.945	Hall Rd	807801|7.956|10.291
N M 5	4402006|0|0.951	Van Dyke Ave	813706|0.215|1.193
W Square Lake Rd	4404559|0.203|1.509	Van Dyke Ave	813706|1.193|2.227
S Telegraph Rd	4412692|0.428|0.715	Van Dyke Ave	813706|2.227|3.241
S Telegraph Rd	4412692|0|0.428	Hall Rd	820202|4.969|7.463
Telegraph Rd	4700038|14.111|14.559	Hall Rd	820202|7.463|8.019
Telegraph Rd	4700038|14.559|14.966	Hall Rd	820202|8.019|8.793
N Telegraph Rd	4700038|7.489|8.484	S Broadway St	833209|0|0.164
N Telegraph Rd	4700038|8.484|11.489	I 69 BL	962706|27.79|28.343
S Fort St	4700047|0|0.275	I 69 BL	962902|27.832|28.372

Table 77. 8D Segment List

8D Grand			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Skyline Dr	858204|1.047|1.876	Skyline Dr	859903|1.021|1.827
8D University			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Ecorse Rd	1430401|1.366|2.24	Ecorse Rd	1430402|1.428|2.196
8D Metro			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Telegraph Rd	1576806|0.406|0.604	Michigan Ave	4701012|0|0.305
Telegraph Rd	1576806|11.61|12.613	Vernier Rd	4702102|0|0.999
Telegraph Rd	1576806|12.613|12.988	E Vernier Rd	4702103|0|0.977
Telegraph Rd	1576806|12.988|13.588	Michigan Ave	4704788|0|1.158
Telegraph Rd	1576806|13.588|14.597	Michigan Ave	4704788|1.158|2.486
Telegraph Rd	1576806|14.597|15.095	Michigan Ave	4705565|10.612|11.121
Telegraph Rd	1576806|15.095|16.3	Michigan Ave	4705565|11.121|11.644
Telegraph Rd	1576806|16.3|17.55	Michigan Ave	4705565|11.644|12.683
S Telegraph Rd	1576806|4.605|5.237	Michigan Ave	4705565|12.683|13.705
S Telegraph Rd	1576806|5.237|5.548	Michigan Ave	4705565|13.705|13.954
E Jefferson Ave	1577509|12.652|12.807	Michigan Ave	4705565|13.954|14.692
E Jefferson Ave	1577510|12.642|12.792	Michigan Ave	4705565|14.692|15.139
E Jefferson Ave	1577705|0|0.17	Michigan Ave	4705565|15.139|15.488
E Jefferson Ave	1577706|0|0.167	Michigan Ave	4705565|5.774|6.506
Fort St	1592105|9.422|11.041	Michigan Ave	4705565|6.506|8.199
Fort St	1592106|8.703|9.262	W Michigan Ave	4705565|9.097|10.612
Fort St	1592106|9.262|10.894	N Woodward Ave	614101|0.638|3.655
S M 39	1592407|0.317|0.504	S Woodward Ave	614101|0|0.638
S M 39	1592407|0.504|0.744	Woodward Ave	614101|11.257|11.396
N M 39	1592408|0.498|0.744	Woodward Ave	614101|11.396|13.019
Ford Rd	1595510|15.427|16.956	Woodward Ave	614101|3.655|4.285
Ford Rd	1595510|16.956|17.541	Woodward Ave	614101|4.285|5.989
Ford Rd	1595510|17.541|17.98	Woodward Ave	614101|5.989|7.809
Ford Rd	1595510|17.98|19.277	Woodward Ave	614101|7.809|9.598
Michigan Ave	1600206|10.644|11.152	Woodward Ave	614101|9.598|10.163
Michigan Ave	1600206|11.152|11.675	N Woodward Ave	616808|0.639|3.655
Michigan Ave	1600206|11.675|12.716	S Woodward Ave	616808|0|0.639
Michigan Ave	1600206|12.716|13.736	Woodward Ave	616808|11.249|11.408
Michigan Ave	1600206|13.736|13.985	Woodward Ave	616808|11.408|13.015
Michigan Ave	1600206|13.985|14.726	N Woodward Ave	616808|3.655|4.273
Michigan Ave	1600206|14.726|15.17	Woodward Ave	616808|4.273|5.989
Michigan Ave	1600206|15.17|15.523	Woodward Ave	616808|5.989|7.805

8D Metro			
Michigan Ave	1600206|16.592|17.751	Woodward Ave	616808|7.805|9.597
Michigan Ave	1600206|17.751|19.085	Woodward Ave	616808|9.597|10.154
Michigan Ave	1600206|5.803|6.532	S Woodward Ave	616906|0.753|1.317
Michigan Ave	1600206|6.532|8.227	S Woodward Ave	616906|0|0.753
Michigan Ave	1600206|9.229|10.644	Woodward Ave	622302|0.746|1.314
Grand River Ave	1600604|0.28|1.991	S Woodward Ave	622302|0|0.746
Grand River	1600604|0|0.28	Grand River	633807|0.349|1.625
Grand River Ave	1600604|1.991|2.57	Grand River	634904|0.393|1.644
Grand River Ave	1600604|2.57|3.26	W 8 Mile Rd	640807|0.242|1.732
Grand River Ave	1600605|0.233|1.944	W 8 Mile Rd	640807|0|0.242
Grand River	1600605|0|0.233	W 8 Mile Rd	640807|1.732|2.216
Grand River Ave	1600605|1.944|2.525	W 8 Mile Rd	640807|10.055|11.604
Grand River Ave	1600605|2.525|3.226	W 8 Mile Rd	640807|11.604|12.182
8 Mile Rd	1817406|0.223|1.709	W 8 Mile Rd	640807|2.216|5.212
8 Mile Rd	1817406|0|0.223	W 8 Mile Rd	640807|5.212|6.039
8 Mile Rd	1817406|1.709|2.193	W 8 Mile Rd	640807|6.039|10.055
8 Mile Rd	1817406|10.041|11.583	Telegraph Rd	710009|0|2.041
8 Mile Rd	1817406|11.583|12.161	Telegraph Rd	710009|2.041|3.309
8 Mile Rd	1817406|2.193|5.193	Telegraph Rd	710009|3.309|4.096
8 Mile Rd	1817406|5.193|6.029	Telegraph Rd	710009|4.096|4.584
8 Mile Rd	1817406|6.029|10.041	Telegraph Rd	710009|6.631|7.513
Ford Rd	1924107|1.077|2.6	Northwestern Hwy	710010|3.313|3.835
Ford Rd	1924107|2.6|3.184	Telegraph Rd	710106|0|2.042
Ford Rd	1924107|3.184|3.624	Telegraph Rd	710106|2.042|3.304
Ford Rd	1924107|3.624|4.919	Telegraph Rd	710106|3.304|4.095
Gratiot Ave	4208203|5.14|5.941	Telegraph Rd	710106|4.095|4.582
Gratiot Ave	4208203|5.941|6.864	Telegraph Rd	710106|4.582|5.091
S Gratiot Ave	4208203|6.864|8.52	Telegraph Rd	710106|6.651|7.512
S Gratiot Ave	4208203|8.52|9.691	S Telegraph Rd	710110|3.855|5.525
S M 5	4402005|0.945|1.998	8 Mile Rd	802803|0|2.998
S M 5	4402005|1.998|3.108	8 Mile Rd	802803|2.998|4.126
N M 5	4402006|0.951|2.003	8 Mile Rd	802803|4.126|5.904
N M 5	4402006|2.003|3.114	8 Mile Rd	802803|5.904|7.266
S Telegraph Rd	4412692|0.715|2.348	8 Mile Rd	802803|7.266|7.567
N Telegraph Rd	4700038|11.489|12.121	8 Mile Rd	802804|0|2.999
N Telegraph Rd	4700038|12.121|12.432	8 Mile Rd	802804|2.999|4.136
Telegraph Rd	4700038|12.432|13.302	8 Mile Rd	802804|4.136|5.917
Telegraph Rd	4700038|13.302|14.111	8 Mile Rd	802804|5.917|7.283
Telegraph Rd	4700038|14.966|16.433	8 Mile Rd	802804|7.283|7.597
Telegraph Rd	4700038|16.433|17.424	Gratiot Ave	804806|5.176|6.006

8D Metro			
Telegraph Rd	4700038|17.424|18.494	Gratiot Ave	804806|6.006|6.901
Telegraph Rd	4700038|18.494|19.497	S Gratiot Ave	804806|6.901|9.622
Telegraph Rd	4700038|19.497|19.873	Hall Rd	807801|3.024|4.031
Telegraph Rd	4700038|19.873|20.473	Hall Rd	807801|4.031|6.045
Telegraph Rd	4700038|20.473|21.482	Hall Rd	807801|6.045|7.956
Telegraph Rd	4700038|21.482|21.992	Hall Rd	820202|0.034|1.044
Telegraph Rd	4700038|21.992|23.173	Hall Rd	820202|1.044|3.058
Telegraph Rd	4700038|23.173|24.435	Hall Rd	820202|3.058|4.969
Telegraph Rd	4700038|7.26|7.489	-	-

Table 78. 2O Segment List

2O Superior			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
E Montezuma Ave	1176201|0.269|0.685	Reservation St	1177408|0.056|0.111
Shelden Ave	1176202|0|0.59	Quincy St	1177509|0.075|0.753
Hancock St	1176203|0.196|0.897	-	-
2O North			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
W Washington Ave	1023609|21.962|22.094	S 2nd Ave	1024201|1.222|1.314
S 3rd Ave	1024109|2.473|2.665	-	-
2O Bay			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
State St	459605|0.228|0.585	State St	459605|1.554|2.29
State St	459605|0.585|1.305	N Michigan Ave	477403|5.711|6.019
State St	459605|0|0.228	N Michigan Ave	484406|0|0.156
State St	459605|1.305|1.554	-	-
2O Southwest			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
S Westnedge Ave	10208|5.462|5.782	S Bus US 131	26101|0|0.082
N Westnedge Ave	10208|6.173|6.795	N Park St	9308|0.196|0.814
N Westnedge Ave	10208|6.795|7.237	N Park St	9308|0.814|1.325
2O University			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
W Cross St	1428902|1.777|2.432	-	-
2O Metro			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Weir St	4711432|0|0.13	Electric Ave	963402|1.145|2.085
I 69 BL	962706|28.343|29.353	Electric Ave	963402|2.085|2.76
I 69 BL	962706|29.353|29.745	Military St	963509|17.42|17.712

2O Metro			
I 69 BL	962902|28.372|29.381	Military St	963509|17.712|18.654
I 69 BL	962902|29.381|29.776	Military St	963509|18.654|19.311
Electric Ave	963402|0.819|1.145	-	-

Table 79. 3O Segment List

3O Superior			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
E Montezuma Ave	1176201|0|0.269	-	-
3O Bay			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
W 5th St	1499403|0|0.072	Stephens St	460805|0.381|0.646
W 5th St	1525102|0|0.203	Stephens St	460805|0.646|0.76
E Lyon Rd	3560054|0|1	Williams St	460806|0.498|0.695
Buttles St	3560073|0.114|0.235	Williams St	460806|0.695|0.809
Buttles St	3560073|0.235|0.918	Schaefer St	464303|0|0.179
E Remington St	3730000|0.837|1.513	W Thomas St	768604|1.458|1.659
E Remington St	3730000|1.513|1.951	W Thomas St	768604|1.659|2.366
E Holland Ave	3730053|1.831|2.436	McKinley St	768604|3.047|3.213
E Holland Ave	3730053|2.436|2.811	E Jenny St	768706|0.183|0.384
State St	459605|2.29|2.542	E Jenny St	768706|0.384|1.141
State St	459605|2.542|2.71	7th St	768706|1.796|1.963
Davenport Ave	459610|0.226|1.241	Patrick Rd	884809|0|0.868
Davenport Ave	459610|0|0.226	E Indian St	885605|0.185|0.87
Davenport Ave	459610|1.241|1.499	E Indian St	885605|0.87|0.953
Davenport Ave	459610|1.499|2.488	E Indian St	885605|0|0.185
Davenport Ave	459610|2.488|2.677	Eastman Ave	885901|10.419|10.509
Hill St	460405|0.243|0.492	-	-
3O Southwest			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
S Westnedge Ave	10208|4.526|5.462	Port St	3110096|0.136|0.338
S Westnedge Ave	10208|5.782|5.977	S Park St	5007|0.952|1.278
Ship St	1363303|0.137|0.344	S Park St	5007|0|0.952
S Fair Ave	1364005|0.199|1.006	S Park St	5007|1.278|1.475
S Fair Ave	1364005|0|0.199	W Kalamazoo Ave	7405|0.503|0.628
Martin Luther King Dr	1364007|0.18|1.008	W Kalamazoo Ave	7405|0.628|1.269
Martin Luther King Dr	1364007|0|0.18	W Kalamazoo Ave	7405|0|0.503
W Main St	21502|8.572|8.902	Douglas Ave	7810|0|0.11
W Michigan Ave	22207|10.049|10.739	Michikal St	7907|0|0.289

3O University			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
Washtenaw Ave	1427706|6.437|6.922	S Homer St	340802|0|0.851
N Hamilton St	1428006|0.332|0.514	W Saginaw St	341208|1.073|1.2
N Huron St	1428010|0.421|0.755	W Saginaw St	341208|1.2|1.544
N Grand Ave	1903504|0.655|0.727	W Saginaw St	341208|1.544|1.829
W Saginaw St	3330065|0.262|0.766	W Saginaw St	341208|1.829|2.199
W Oakland Ave	3330065|0.766|1.048	W Saginaw St	341208|2.199|2.353
W Oakland Ave	3330065|1.048|1.429	W Saginaw St	341208|2.353|2.594
W Oakland Ave	3330065|1.429|1.583	E Saginaw St	341208|2.594|2.882
W Oakland Ave	3330065|1.583|1.879	N Winter St	3460110|0|0.103
E Oakland Ave	3330065|2.113|2.212	E Front St	3460528|0.467|0.605
E Oakland Ave	3330065|2.212|2.453	S Martin Luther King Jr Blvd	352303|5.203|5.708
E Oakland Ave	3330065|2.453|2.849	S Cedar St	359606|10.792|10.902
E Oakland Ave	3330065|2.849|3.11	S Cedar St	359606|10.902|11.157
N Larch St	3330526|0.592|1.093	N Cedar St	359606|11.157|11.657
N Larch St	3330526|1.093|1.304	N Cedar St	359606|11.657|11.856
N Larch St	3330526|1.304|1.669	N Cedar St	359606|11.856|12.266
E Grand River Ave	335601|1.777|1.827	S Huron St	4603870|0.215|0.587
S Grand Ave	335809|0.491|0.559	S Huron St	4603870|0.587|1.104
W Louis Glick Hwy	3381121|0|0.616	S Huron St	4603871|0.21|0.558
W Allegan St	339807|0.4|0.758	S Hamilton St	4603871|0.558|1.071
W Allegan St	339807|0.758|1.071	W Washington Ave	900903|0|0.905
W Allegan St	339807|1.071|1.237	N Winter St	948502|0.108|0.312
W Ottawa St	339809|0.506|1.184	N Winter St	948502|0|0.108
W Ottawa St	339809|1.184|1.349	W Front St	949203|0|0.07
N Howard St	340710|0.419|0.873	S Martin Luther King Jr Blvd	980401|0.129|0.65
S Howard St	340710|0|0.419	-	-
3O Metro			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
S Gratiot Ave	4208203|10.302|11.624	N Cass Ave	674803|0.194|0.701
S Gratiot Ave	4208203|11.624|12.18	N Cass Ave	674803|0|0.194
S Gratiot Ave	4208203|12.18|12.476	N Gratiot Ave	832010|0.638|0.912
W Michigan Ave	4705565|8.199|9.097	N Gratiot Ave	832010|0|0.638
University Dr	624301|0.211|0.537	S Broadway St	833209|0.164|0.754
W Woodward Ave	641407|0.102|0.349	N Gratiot Ave	833209|0.754|1.997
E Huron St	648906|21.077|21.175	N Gratiot Ave	833209|1.997|2.034

Table 80. 4O Segment List

4O Bay			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
W Court St	1498006|5.939|6.185	E 5th St	1499403|0.306|0.645
W Court St	1498006|6.185|6.415	Rust Ave	460805|2.433|2.524
E Court St	1498006|6.415|6.761	Sheridan Ave	461709|1.163|1.574
W 5th St	1499403|0.072|0.306	S Warren Ave	461710|0.706|1.004
4O Southwest			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
N Westnedge Ave	10208|5.977|6.173	N Park St	9308|0|0.196
W Michigan Ave	22207|9.924|10.049	-	-
4O University			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
E Oakland Ave	3330065|1.879|2.113	E Louis Glick Hwy	3381121|0.616|0.894
S Larch St	3330526|0.237|0.341	E Saginaw St	341208|2.882|2.977
S Larch St	3330526|0.341|0.592	E Saginaw St	341208|3.327|4.575
E Grand River Ave	335601|1.827|2.476	E Saginaw St	341208|4.575|4.736
E Grand River Ave	335601|2.476|2.671	E Saginaw St	341208|4.736|4.995
E Grand River Ave	335601|2.671|2.921	-	-
4O Metro			
Road Name	PR|BMP|EMP	Road Name	PR|BMP|EMP
E Michigan Ave	1600206|8.227|9.229	E Woodward Ave	672705|0.679|0.759
S Gratiot Ave	4208203|9.691|10.302	E Woodward Ave	672705|0.759|0.95
W Woodward Ave	641407|0.349|0.516	E Woodward Ave	672705|0|0.679
W Woodward Ave	641407|0.516|1.211	E Cass Ave	674803|0.701|1.183
E Huron St	648906|21.175|21.524	-	-