EVALUATION OF THE HIGHWAY SAFETY MANUAL CRASH PREDICTION MODEL FOR RURAL TWO-LANE HIGHWAY SEGMENTS IN KANSAS

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ABSTRACT

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While there have been numerous previous studies performed to develop the rural two-lane segment crash prediction models as part of the Highway Safety Manual (HSM), no previous study has been developed to validate the accuracy of the current model for states other than those the model was developed for. To address this gap the Kansas Department of Transportation (KDOT) commissioned this study to analyze both the accuracy and the practicality of using these crash prediction models on Kansas highways before deciding whether or not to implement the models as part of their normal project development process.

To accomplish these goals this dissertation first determined gaps in KDOT data versus data requirements of the HSM. This effort identified an important inconsistency between the Kansas highway system and how the HSM recommends application of the model. Next, the model was calibrated using both the HSM procedure and new procedures that address specific qualities of the Kansas highway system. The calibration procedure derived through this dissertation outperformed the HSM procedure and shows promise as a model for calibration in other jurisdictions. Finally, the accuracy of the crash prediction models for Kansas highways was determined and a calibration procedure was recommended for implementation.

ACKNOWLEDGEMENTS

My appreciation goes to my advisor, Dr. Steven Schrock, who allowed me to explore my own solutions while also providing the guidance necessary to complete this research. The time, effort, and resources he provided were critical through evolution of this dissertation.

The members of my committee deserve thanks for their incredible patience and understanding during the false starts and unexpected turns that finally led to this current topic.

The research assistants with the Transportation Research group were not only critical to the data collection effort but also were incredibly supportive peers. Special thanks go to Deepak Chellamani for developing the random project generator used in this study and to Cheryl Bornheimer for her contributions to the Literature Review chapter and data collection effort. This dissertation may never have been completed without Cheryl's consistent dedication to this research.

I would like to recognize my employer, the Kansas Department of Transportation, for there incredible support of not only my educational goals but of all of my professional development activities.

Finally, and most importantly, I would like to thank my friends and family who have always supported me, encouraged me, and picked up my slack when I had to dedicate time to my studies. My best friend and wife, Emily, was my anchor, my editor, and my head cheerleader and for her I will be forever grateful

for Mama and Momo

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CHAPTER I – INTRODUCTION

Historically project-level decisions on the development of a safe highway were based on either engineering judgment or adherence to accepted national guidance, like A Policy on the Geometric Design of Highways and Streets, commonly known as the Green Book (*1*). These tools have allowed highway designers to produce facilities that have demonstrated an improving safety record in recent decades. However, these tools do not allow for the comparison of the safety performance of dissimilar facilities or roadway attributes. For example, the Green Book details the recommended minimum shoulder width for a freeway facility carrying 20,000 vehicles per day. However, it provides no quantifiable safety benefit of using that shoulder width, nor the cost or benefit of using a narrower or wider shoulder.

To address this gap, researchers have been working for decades to develop Crash Prediction Models (CPMs) that can estimate, and ideally predict the expected safety performance of a highway based on its geometric and traffic control features. Thanks to increases in computer processing technology and efforts at the national level, this method for safety-based decision making in the field of transportation engineering has gained momentum as a procedure for decision-making at the programmatic and project level. The largest step toward that goal was the adoption of the Highway Safety Manual (HSM) in 2010, published by the American Association of State Highway and Transportation Officials (AASHTO). The primary goal of the HSM is to provide a science-based technical approach to quantitative safety analysis.

PROBLEM STATEMENT

Even with the recent publishing of the HSM, and the many research studies used in its development, application of CPMs for making project-level decisions has not been rapidly adopted by the practicing community. One of the reasons for this may be the lack of published studies to validate the effectiveness of CPMs to make project-level decisions.

Previous studies have looked thoroughly at the before-and-after impacts of the improving individual roadway elements. These studies are incredibly valuable and have been used in the development of the HSM. Other studies have looked at the calibration of the CPMs for their specific jurisdiction and some validated a calibrated model on an aggregate level. Unfortunately, these studies have not published results on the accuracy of the model on the project development level. And finally, no study to-date has looked at the HSM CPM in the method most true to its intended application. That is to take data from an existing highway combined with proposed improvements to that highway to accurately predict the future safety performance of that road.

RESEARCH OBJECTIVES

To address this gap in research, this study aims to calibrate and validate the HSM CPM for rural two-lane two-way roadway segments using the Kansas highway system. The HSM CPM equation, shown below, has a calibration factor intended to adjust the model for jurisdiction-specific conditions.

$$N_{predicted} = N_{spfx} \times (CMF_{1x} \times CMF_{2x} \times ... \times CMF_{yx}) \times C_x$$

Where:
$N_{predicted}$ = predicted average crash frequency for a specific year;
N_{spfx} = Safety Performance Function;
CMF_{yx} = Crash Modification Factors; and
C_x = calibration factor to adjust for local conditions.

In addition to the calibration factor, C_x, there are two other elements of the equation, the safety performance function (SPF) and crash modification factors (CMFs). These elements are included to first predict a base number of crashes for a given traffic volume and then adjust the prediction to the specific conditions of the modeled roadway. The HSM provides SPFs and CMFs for rural two-lane roads, rural multilane highways, and urban and suburban arterials. At the time of this research, some parallel research efforts were underway to investigate some SPFs and CMFs specific for Kansas highways. However this research utilizes only the SPFs and CMFs provided with the HSM CPM. For that reason this research can serve as a benchmark to other studies looking to improve the crash prediction accuracy by developing jurisdiction-specific elements.

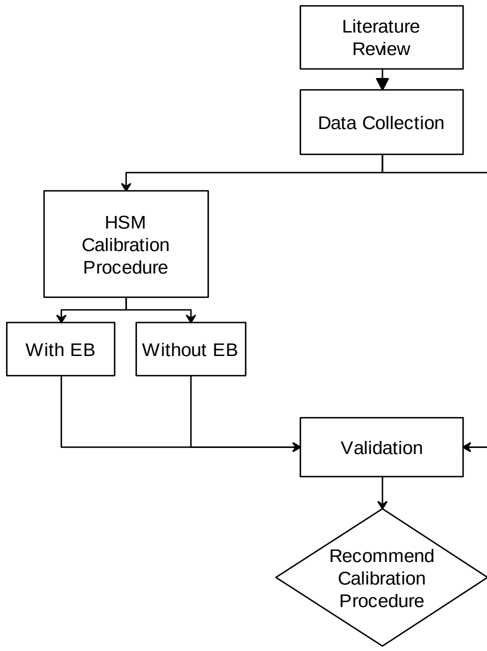
In an effort to use safety modeling effectively to reduce the most severe type of crashes, rural two-lane highways is the most logical place to start. In fact, "[f]orty-one percent of crashes that involve fatalities occur on two-lane rural highways"(*2*). And with approximately 8,600 rural two-lane highway miles, Kansas is one of the most logical places to perform such an analysis.

To account for historical crash data in the future crash prediction the Emperical Bayes, or EB, procedure is recommended by the HSM. Crash predictions can be run with or without the EB procedure but it is recommended when the historical crash data are available. The history and application of the EB procedure is covered in greater detail in Chapter II – Literature Review and Chapter III – Calibration. From this basic understanding of the formula the specific research objectives of this research can be derived:

- Identify locations where HSM definitions or data needs are inconsistent with the Kansas highway system – Chapter III – Data Collection.
- Follow the procedure described in the HSM to develop a calibration value for Kansas highways – Chapter IV – Calibration.
- Investigate alternative calibration procedures that are consistent with the Kansas highway attributes and data availability – Chapter V – Animal Collision.
- Use statistical analysis on constructed projects to determine the accuracy of the different calibration methods and the overall HSM CPM to predict the safety performance of a newly constructed highway – Chapter VI – Validation.

Figure 1 graphically demonstrates the execution of the research objectives.

FIGURE 1 Diagram of Dissertation Research Performed



ACKNOWLEDGEMENTS

The research described herein was funded in part by the Kansas Department of Transportation (KDOT) as part of the K-TRAN research program. KDOT provided this funding in recognition of the current research gap and of the usefulness of an accurate CPM to assist the design process. For this reason the research is almost entirely dedicated to the practical application of the HSM CPM for future KDOT use.

CONTRIBUTION OF RESEARCH

Funding shortfalls and heightened public awareness has led to increased scrutiny of civil works projects, including highway improvements. This has led highway decision makers and practitioners to reevaluate the methods used in designing projects. One gap in the effort for more transparent and cost effective highway engineering is the ability to quantify the safety benefits of specific geometric improvements. Once properly calibrated and validated for an agency, the

CPM will be an excellent tool for evaluating improvement projects, comparing the relative safety performance of design alternatives, and assessing the safety cost-effectiveness of design decisions.

KDOT is currently endorsing practical transportation solutions that promote a departure from set values stated in manuals and encourages engineers to explore the full range of available solutions while considering the cost and safety impacts of the solutions they are investigating. A CPM can prove to be a valuable tool that quantifies safety benefits during the decision-making process and provides additional documentation of the solutions being considered. National case studies have also shown CPMs as valuable tools for use in Road Safety Audits and planning level corridor studies. This research to research two-lane rural roadways for KDOT will also set a base for investigating the implementation of future facility types available in the HSM.

Even if the CPM cannot be proven statistically relevant or efficiently applicable for KDOT project this research will continue the decades-long effort to improve crash prediction capabilities. Portions of the research could be nationally significant and utilized in future editions of the HSM.

ORGANIZATION OF DISSERTATION

This dissertation is organized into seven chapters. Chapter I is an introduction into the background of CPMs along with the need and proposed objectives of this dissertation. Chapter II is a literature review aimed at identifying the primary research that led to the development of the HSM, an in-depth description of the HSM CPM, and an exhaustive screening of the contemporary research which address the application of CPMs by transportation authorities. A description of the many data needs of the HSM CPM and the efforts that were used to collect them can be found in Chapter III. This chapter will cover the data needed to satisfy the SPFs and CMFs. Chapter IV describes efforts to perform the calibration procedure provided in the HSM. The primary product of this chapter will be a calibration value, C_x, for Kansas highways. Based on those results, some alternative calibration techniques specific to Kansas highways are provided in the fifth chapter. All of the worthwhile calibration values and techniques developed in this research are analyzed against a set of validation data in the Chapter VI. Finally, the Chapter VII provides a summary of the research results, conclusions, and recommendations for further research.

Definitions

Throughout this dissertation, the terms “accident”, “collision”, “incident”, and “crash” are used interchangeably. Due to recent industry trends, the HSM utilizes primarily the term “crash”. This dissertation was written in a manner consistent with that practice, but other published reports or forms also use other terms. For this reason, there is some commingling of terms in the dissertation.

The HSM models utilized in this research are for rural two-lane, two-way roads. Since all rural two-lane highways in Kansas are also two-way, the additional “two-way” term is dropped from most references to reduce redundancy. Any references to “rural two-lane” roads are meant to define the same facilitates referenced by the HSM as “rural two-lane, two-way roads”.

The variable, *e*, is found in several different equations in this dissertation. In every case *e* is a constant that equals the base for the natural log, approximately 2.71828.

The terms “segment”, “section”, and “site” are found throughout this dissertation and each represents a distinct portion of a highway. Since the terms are very similar the following definitions are provided:

- A segment represents any part of the highway that is not an intersection. This research covers specifically two-lane rural highway segments because there are different models that address two-lane rural highway intersections.

- A site is a homogenous highway segment. Parts of the CPM that are site-specific analyze characteristics of each site independently and then aggregate the results. When attributes are not defined accurately enough to assign to a particular site a project-specific analysis may be used.

- A section is a group of adjacent sites that are aggregated and analyzed as one element. This term is applied uniquely in this dissertation and most commonly refers to an element in the calibration or validation analysis. A section-specific component is something that is applied uniquely to a calibration or validation section.

CHAPTER II – LITERATURE REVIEW

In Chapter I – Introduction, the HSM CPM equation was presented and its general components were explained. In order to understand the genesis of this equation and its use in contemporary project development, an exhaustive search of literature was performed. The review focuses on three principal areas: the critical research that led to the development of the CPM used in the HSM, a detailed description of the components of the HSM CPMs, and the current state of CPMs as they are applied by transportation authorities. This includes the limited amount of CPM research that has already been performed for Kansas highways. The information gathered through this literature review was used to shape the research performed for application of the HSM CPM for rural two-lane highways in Kansas.

In addition to the CPMs that have been developed to assist in making project-level decisions, there are also tools developed for performing planning-level safety assessments. SafetyAnalyst software is one implementation of methods presented in Part B of the HSM; it focuses on a full network analysis by identifying sites in the system that would benefit the most from safety improvements. Both work using fundamentally similar concepts to predict crashes and find problem areas along highways by using SPFs. A small portion of this literature review is dedicated to highlighting the formation of the planning-level models and the scope of studies initiated by individual transportation authorities to calibrate and utilize these models.

This literature review is not intended to encompass all CPM-related research or all of the research used to develop the HSM CPM. Instead, a summary is provided of the most critical sources that led to the primary development of the HSM CPM, with more extensive coverage of contemporary research of applications of CPMs by transportation authorities. At the end of this chapter is a synopsis of the critical points of the literature review as they relate to this research.

The literature was found using various resources, including the Federal Highway Administration's online database of reports and Transportation Research Board papers both in their online index and from the transportation libraries at the University of Kansas and Kansas Department of Transportation. The access available through these institutions to online resources was invaluable in being able to obtain a scope of literature with both breadth and depth.

DEVELOPMENT OF CRASH PREDICTION MODELS

The HSM was published in 2010 and marked the capstone in decades of research attempting to quantify the relationship between roadway features and driver safety. This portion of the literature review is not meant to be a synthesis of the dozens of core studies that formed the CPMs in the HSM nor the hundreds of auxiliary studies that formed those core studies. Instead it is meant to highlight several pivotal documents that demonstrate the evolution of CPMs from their early inception to their current form.

The Beginning of Predictive Models

The study of predicting the occurrence of crashes on a highway began with the study of how crash types related to roadway features. This was observed by looking at segments of roadway that had lanes and shoulders widened and seeing the reduction in crashes by looking at the before-and-after changes in crashes. The first quantitative model created to predict crashes was included in a study by Zeeger, Maybes, and Deen(*3*). Using data from previous studies in Ohio and Kentucky that studied the relationships between lane and shoulder widening as well as the presence of obstructions along the roadway, the following model was created using a weighted, least-squares fit method:

$$AR = 4.1501(0.8907)^{L}(0.9562)^{S}(1.0026)^{LS}(0.9403)^{P}(1.0040)^{LP}$$

Where:
AR = number of run-off-road and opposite-direction crashes per million vehicle miles;
L = lane width (feet);
S = shoulder width including stabilized and unstabilized components (feet); and
P = stabilized component of the shoulder (feet).

Due to the fact that the data were from only two states and many assumptions were made to allow the creation of the equation, Zeeger et al. recognized that this was only a starting point for predictive models. This equation was intended to estimate only the effect of lane width, shoulder width, and shoulder type on crash frequency. The research recognized that there are many other elements that impact crashes beyond those investigated in this study.

Zeeger et al. continued their study of predictive models, following up their initial predictive model with a more comprehensive study of roadway geometry and its effects on crashes (*4*). This study went more in-depth, looking at data from seven states – Alabama, Michigan, Montana, North Carolina, Utah, Washington, and West Virginia – which provided more variety in geographic characteristics, like terrain type. Zeeger looked closely at the relationships between certain types of crashes and which roadway features would affect them, such as the impact of lane and shoulder widening on run-off-the-road crashes. The model analyzed different combinations of thirty-four variables, including number of railroad crossings, number of intersections, and type of development adjacent to the roadway. After studying the interactions of the variables and deducing which variables correlated well, they found the best-fit equation to be the following:

$$A = 0.0019(ADT)^{0.8824}(0.8786)^{W}(0.9192)^{PA}(0.9316)^{UP}(1.2365)^{H}(0.8822)^{TER_1}(1.3221)^{TER_2}$$

Where:
A = number of crashes per mile per year;
ADT = average daily traffic;
W = lane width (feet);
PA = width of paved shoulder (feet);
UP = width of unpaved shoulder (feet);
H = average roadside hazard rating;
TER_1 = 1 for flat terrain, 0 otherwise; and
TER_2 = 1 for mountainous terrain, 0 otherwise.

The R^2-value for the model was 0.456, meaning that 45.6 percent of crashes in the study were explained by the model. To be some of the first research on predicting crashes, this was a good start, but not ready for practical application.

Development of Safety Performance Functions and Crash Prediction Models

As the relationships between road improvements and the reduction in crashes became clearer and preliminary equations were developed to predict the number of crashes on a roadway with certain geometric characteristics, researchers began to explore and fine-tune these equations to more accurately predict crashes.

Miaou and Lum (*5*) created four different types of models to find the model of best fit to estimate the number of truck crashes along a segment of highway. Of the four models they tried – additive and multiplicative linear regression models and multiplicative Poisson regression with an exponential rate function and a nonexponential rate function – they found the Poisson regression models worked better as crashes are distinct, rare events and the crash counts are nonnegative numbers. The Poisson regression model was also closer to a probability model as compared to the multiple linear regression models. The best fit model is as follows:

$$P(y_i) = \frac{(\lambda_i v_i)^{y_i} e^{-\lambda_i v_i}}{y_i!}$$

Where:

y_i = number of trucks involved in crashes on the highway segment;

$P(y_i)$ = probability that y_i trucks will be involved in crashes;

λ_i = mean crash rate (number of trucks per million truck-miles) on the segment; and

v_i = truck exposure (millions of truck-miles).

λ_i is predicted using the following equation:

$$\lambda_i = 0.0818 + 0.1022x_{1i} + 0.0949x_{2i} + 0.0426x_{3i} + 0.0341x_{4i} - 0.0263x_{5i}$$

Where on the i^{th} section:

x_{1i} = average daily traffic (ADT) per lane (in thousands of vehicles);

x_{2i} = horizontal curvature (in degrees per hundred feet);

x_{3i} = x_{2i} multiplied by horizontal curve length;

x_{4i} = deviation of stabilized outside shoulder width in each direction; and

x_{5i} = percent trucks.

However, the Poisson regression model does not account for overdispersion. This is to be expected considering the relatively simple nature of the Poisson regression model compared to the high variability experienced in crash data. Miaou proposed using the negative binomial regression model to account for overdispersion as it allows for additional variance which can help with variables that are not included when creating the equation. Miaou followed up that study and compared Poisson regression, zero-inflated Poisson (ZIP), and the negative binomial regression statistical methods in continuing his research in predicting truck crashes (*6*). In his investigation, he found that no model proved that it was better than the others and concluded that a Poisson regression can be used to establish the relationship between highway geometrics and crashes. If the Poisson regression is found to have overdispersion, he suggested using either the ZIP or negative binomial regressions.

A different approach was taken by Mountain, Fawaz, and Jarrett (*7*) in the United Kingdom, where they used the Poisson regression, two loglinear models (one with intersections included and the other with intersections separately) and the Empirical Bayes (EB) method to predict the number of crashes along a highway segment. They concluded that the EB method was superior to the predictive models as it appeared to be impartial to estimating crashes at segments considered to be high-risk. A similar study by Persaud(*8*) also looked at the effects of the EB method for predicting crashes on rural, two-way, two-lane roads in Canada. Noting that the EB method accounts not only for the traffic volume and geometric features of a highway, but also accounts for that segment's crash history, he predicted and confirmed that the EB method works well as an addition to an equation formed using negative binomial regression. An indepth description of the EB procedure and how it is applied to crash prediction is provided in Chapter IV – Calibration.

The Modern Crash Prediction Model

Since previous studies established that regression models were the best for predicting crashes, the next step was to determine how best to apply regression models to produce the most accurate crash predictions. Vogt and Bared (*9*) made the first step by creating the base model, or SPF, that would be used in the HSM. They collected roadway geometry, as well as surrounding conditions, from the states of Washington and Minnesota for rural, two-lane, two-way highways. They used the Poisson regression model, negative binomial regression, and an extended negative binomial regression, which breaks segments into homogeneous subsegments. They chose the extended negative binomial regression technique as they preferred how it accounted for overdispersion and worked well with the EB method when past crash data are available. The R^2-value for the extended binomial regression is also consistent with the other models, as can be seen in Table 1. The R^2_P-value used in this research is a refined R^2-value that is the proportion of potentially explainable variation that can be expected from the many different factors. The R^2_K-value used with both forms of negative binomial regression is used by Miaou (*10*) and based on the overdispersion parameter.

TABLE 1 R^2-values for the Different Statistical Methods

Test and R^2 Values	Washington	Minnesota	Combined
Poisson (R^2, R^2_P)	0.7297, 0.8208	0.6279, 0.7716	0.6607, 0.7673
Negative Binomial Regression (R^2, R^2_K)	0.7251, 0.8609	0.6268, 0.8310	0.6669, 0.8354
Extended Negative Binomial Regression (R^2, R^2_K)	0.7246, 0.8575	0.5720, 0.8161	0.6547, 0.8291

When using an equation that will work for both states, either equation determined by negative binomial regression was desirable. They opted for the following equation, created by the extended negative binomial regression as it was created using homogeneous sections:

$$N_{br} = EXPO \times \exp(0.6409 + 0.1388 STATE - 0.0846 LW - 0.0591 SW + 0.0668 RHR + 0.0084 DD)$$
$$(\sum WH_i \exp(0.0450 DEG_i))(\sum WV_j \exp(0.4652 V_j))(\sum WG_k \exp(0.1048 GR_k))$$

Where:
N_{br} = predicted number of crashes along a highway segment;

$EXPO$ = exposure in million vehicle-miles of travel per year = $(ADT)(365)(L)(10^{-6})$;

ADT = average daily traffic volume (veh/day) on highway segment;

L = length of roadway segment (mi);

$STATE$ = which state the segment is in (0 = Minnesota, 1 = Washington);

LW = lane width (ft); average if different in each direction;

SW = shoulder width (ft); average if different in each direction;

RHR = roadside hazard rating; takes values from 1 to 7 and represents how hazardous the roadside can be;

DD = driveway density (driveways per miles) on highway segment;

WH_i = weight factor for the i^{th} horizontal curve in the highway segment; proportion of total highway segment length represented by the portion of the i^{th} horizontal curve that lies in the segment (the weights, WH_i, must sum to 1.0);

DEG_j = degree of curvature for the i^{th} horizontal curve in the highway segment (degrees per 100 ft);

WV_j = weight factor for the j^{th} crest vertical curve in the roadway segment; proportion of total highway segment length represented by the portion of the j^{th} vertical curve that lies in the segment (the weights, WV_j, must sum to 1.0);

V_j = crest vertical curve grade rate for the j^{th} crest vertical curve that lies within the segment in percent change in grade per 100 ft = $|g_{j2}-g_{j1}|/l_j$;

g_{j1}, g_{j2} = highway grades at the beginning and end of the j^{th} vertical curve (percent);

l_j = length of j^{th} vertical curve (in hundreds of feet);

WG_k = weight factor for the k^{th} straight grade segment in the roadway segment; proportion of total highway segment length represented by the portion of the k^{th} straight grade segment that lies in the segment (the weights, WG_k, must sum to 1.0); and

GR_k = absolute value of grade for the k^{th} straight grade on the segment (percent).

To validate the model, a chi-squared test was used with the overdispersion parameter of the model included as well as looking at the mean absolute deviation (MAD) and the mean absolute scaled deviation (MASD). MAD and MASD are statiscial measures that look at the average magnitude of variability of prediction. The measures are beneficial because they utilize absolute values, which prevent positive and negative errors from canceling each other out.

Refining the Crash Prediction Model

Estimates of safety based on statistical models, like that used by Vogt and Bared (*9*), can be a very accurate method for predicting expected crashes. However, statistical models can show inverse or disproportionate weighting of variables that are not consistent with engineering principles. This can often be caused by variables serving as surrogates for other factors. In addition, the statistical models do not necessarily show a cause and effect relationship, only a correlation. In order to more accurately account for the impact of various highway elements on safety, additional scrutiny of the model was needed.

To address this deficiency in the Vogt and Bared (*9*) base model, Harwood et al. (*11*) supplemented it with information from before-and-after studies, estimates from expert judgment and estimates from historical data. In this study, Harwood et al. (*11*) gathered an expert panel to refine the crash modification factors (CMFs) developed by Hughes and Vogt(*9*). Separate expert panels were used to address CFS for segments and intersections. The panel used their expert judgment along with published and unpublished research to evaluate a list of all the possible features that were known to impact safety and select a list of the most important features for which CMFs could be developed. The final list of CMFs for roadway segments developed by Harwood et al. (*11*) are:

- Lane Width;
- Shoulder Width;
- Shoulder Type;
- Horizontal Curve;
    - Length;
    - Radius;
    - Presence or absence of spiral transitions;
    - Superelevation;
- Grades;

- Driveway Density;
- Two-way left-turn lanes;
- Passing lanes/short four-lane sections; and
- Roadside design.

This expert panel process was critiqued by Washington, Lord and Persaud (*12*). This critique pointed out ways that the expert panel process used by Harwood et al. (*11*) could be improved, including having experts work independently. However, there was no definitive answer as to the accuracy and precision of the results of an expert panel process.

In addition to developing many of the CMFs published in the HSM, Harwood et al. (*11*) also developed the framework used in the HSM for applying the crash prediction model and using the EB procedure.

Once the list of CMFs was finalized, the following base conditions were developed and applied to the model dveloped by Vogt and Bared (*9*). These are the same base conditions used in the HSM (*13*) for rural, two-lane, two-way roads:

- Lane width (LW) = 12 feet;
- Shoulder width (SW) = 6 feet;
- Roadside hazard rating (RHR) = 3;
- Driveway density (DD) = 5 driveways per mile;
- Horizontal curvature (DEG) = none;
- Vertical curvature (V) = none; and
- Absolute grade level = 0 percent.

This creates the following base equation which is nearly identical to the rural two-lane SPF used in the HSM(*13*):

$$N_{\text{spf rs}} = AADT \times L \times 365 \times 10^{-6} \times e^{-0.4865}$$

Where:
AADT = Average annual daily traffic; and

L = length (mi).

During creation of the HSM, the model was recalibrated using some additional CMFs not considered by Harwood et al. (*11*), which resulted in a slightly different exponent between this equation and the one published in the HSM.

THE HIGHWAY SAFETY MANUAL

This section of the literature review is dedicated entirely to understanding the rural two-lane highway CPM utilized in the HSM (*13*). All of the information in this section is either taken directly, or indirectly, from the HSM. Therefore, although repeated citations will not be used, it should be assumed that all the information in this section is taken from the HSM (*13*) unless otherwise noted.

The HSM is an AASHTO accepted document that is the culmination of decades of research. The primary goal of HSM is to provide a science-based technical approach to quantitative safety analysis. Part C of the HSM is dedicated to methods for quantitatively estimating crash frequency for roadway networks, facilities, and individual sites. Currently, there are prediction methods for three different types of facilities (Rural Two-Lane Two-Way Roads, Rural Multilane Highways, and Urban and Suburban Arterials). In addition to Part C, there are three other parts of the HSM, each addressing other aspects of highway safety. The other parts in the HSM relate to Part C in the following ways.

Part A – describes key concepts for understanding crashes and crash modeling, including SPFs and CMFs.

Part B – provides higher level concepts that give guidance for agencies on how to monitor, improve, and maintain their facilities. Crash prediction modeling is one tool presented in Part B. More information about this planning-level modeling is covered later in the literature review.

Part D – covers all of the CMFs available for consideration when implementing appropriate counter measures. The appropriate CMFs from Part D are already incorporated in Part C.

Since this research focuses on only rural two-lane two-way roads, it is critical to understand how the HSM defines these facilities. Rural, for use in the HSM, is based on the FHWA guidelines which classify the opposing urban areas as within boundaries with population greater than 5,000 persons. Two-lane two-way roads include those with center two-way left-turn lanes, climbing lanes, passing lanes, and/or short four-lane segments (up to two miles in length) provided for passing opportunities.

Predictive Model Procedure

The predictive model for individual sites in all facility types utilize the same basic equation for predicting the number of crashes and the same 18-step procedure for utilizing those equations. Predicting crashes for a facility or network is then the summation of predicted crashes for each individual site. The base equation is:

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

Where:

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

N_{spfx} = 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.

Generally $N_{predicted}$ is calculated via SPFs, CMFs, and a Calibration factor (C_x). The SPFs are site type specific calculations based on the base condition for each site type. SPFs are based on a negative binomial distribution which is preferable in modeling crashes since they tend to be highly variable. To adjust from base conditions to the site specific conditions in the rural two-lane model, there are twelve CMFs for highway segments and four CMFs for intersections.

Finally, the calibration factor is used to account for jurisdictional differences in crash rates and recording.

$N_{predicted}$ is entirely based on the geometric design, traffic control, and traffic volume for that site. For instances where analysis is being done of an existing facility, $N_{predicted}$ is combined with the observed crash frequency, $N_{observed}$, to yield the average expected crash frequency for a site, $N_{expected}$. The benefit of this is to remove biases related to regression-of-the-mean inherent in trying to predict crashes based solely on historic crash data.

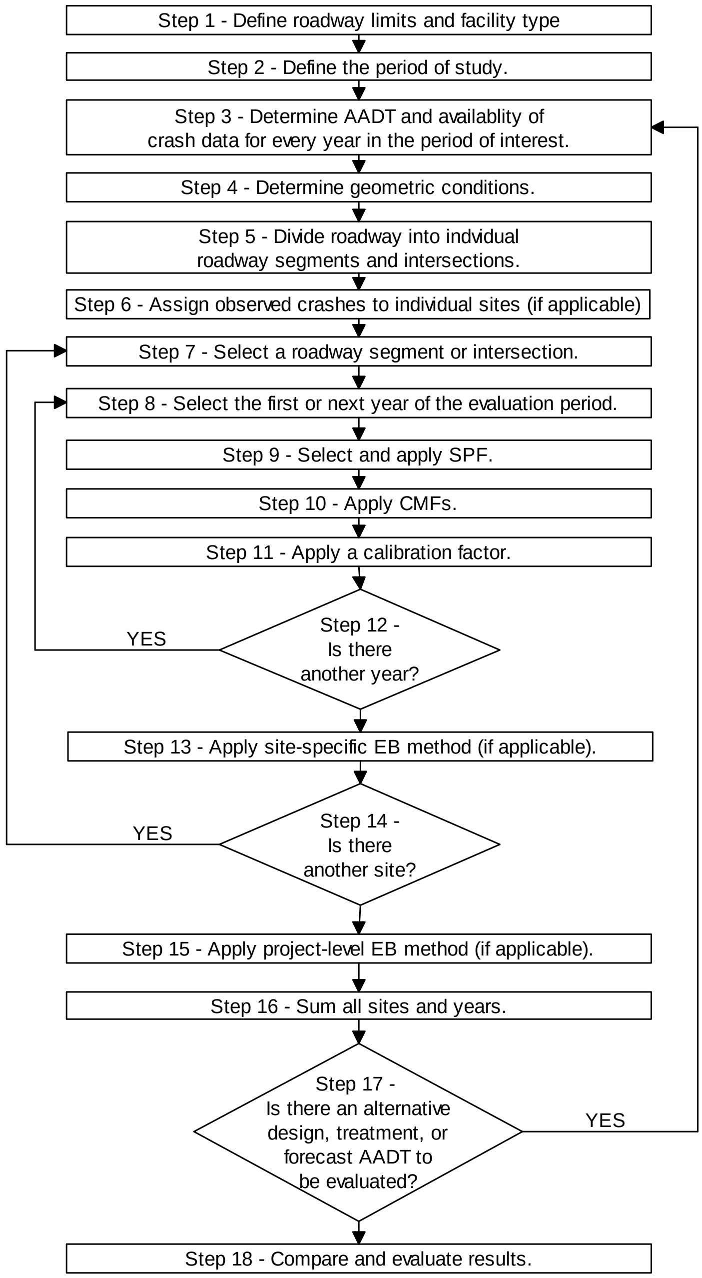
Figure 2 illustrates the HSM 18-step procedure for crash prediction

Step 1 – Define the limits of the roadway and facility types in the study network, facility, or site for which the expected average crash frequency, severity, and collision types are to be estimated.

These analyses are either performed on a single site or a network of facilities which are a collection of individual sites. The sites that can be analyzed using the HSM methodology for two-lane rural highways are:

- Undivided roadway segment;
- 3-legged intersection with minor leg stop control;
- 4-legged intersection with minor leg stop control; and
- 4-legged signalized intersection.

FIGURE 2 HSM Crash Prediction Procedure



Step 2 – Define the period of interest.

The predictive method can be run on both past periods (based on observed AADTs) and future periods (based on predicted AADTs). Determination for the specific period of interest will be influenced by the amount of crash data, geometric data, and traffic volumes available.

Step 3 – For the study period, determine the availability of annual traffic volumes and, for an existing roadway network, the availability of observed crash data to determine whether the EB method is applicable.

AADT is the sole input for the SPFs and some of the CMFs. Therefore, the AADTs for all the years being considered must be provided from measured, estimated, or forecasted data. In addition, at least two years of reliable crash data are required when using the EB method. If the EB method is used, AADT values must be provided for every year that crash data are available.

Step 4 – Determine geometric design features, traffic control features, and site characteristics for all sites in the study network.

For roadway segments, the following data are utilized:

- Length of segment (miles);
- AADT (vehicles per day);
- Lane width (feet);
- Shoulder width (feet);
- Shoulder type (paved/gravel/composite/turf);
- Presence or absence of horizontal curve (curve/tangent). For curved sections:
  - Length of horizontal curve (miles);
  - Radius of horizontal curve (feet);
  - Presence of spiral curve transition; and
  - Superelevation of curve and maximum superelevation used according to jurisdictional policy.
- Grade (percent), measured from PVI to PVI;
- Driveway Density (driveways per mile);
- Presence of centerline rumble strips;
- Presence of a passing lane;
- Presence of a short four-lane section;
- Presence of two-way left-turn lane;
- Roadside hazard rating;

- Presence of roadway segment lighting; and
- Presence of automated speed enforcement.

Step 5 – Divide the roadway network or facility under consideration into individual homogeneous segments and intersections, which are referred to as sites.

Use data collected in previous steps to develop homogeneous sites. Roadway segment lengths should be limited to no less than 0.10 mile and begin and end at either the center of an intersection or where the geometric design or traffic control features of a roadway segment change. Intersections are defined as the junction of two or more roadway segments.

Step 6 – Assign observed crashes to individual sites (*if applicable*).

This step only applies if the EB method is being applied. Crashes that occur at an intersection or are related to an intersection should be attributed to that intersection. Crashes that occur between intersections should be attributed to that particular segment unless coded as an intersection-related crash in the crash report.

Step 7 – Select the first or next individual site in the study network. If there are no more sites to be evaluated, go to Step 15.

Step 8 – For the selected site, select the first or next year in the period of interest. If there are no more years to be evaluated for that site, proceed to step 15.

Steps 8 through 14 are repeated for each site in the study and for each year in the study period.

Step 9 – For the selected site, determine and apply the appropriate SPF for the site's facility type and traffic control features.

For rural two-lane roadways there is one SPF equation for segments and three SPFs for various intersection types. SPFs calculate the predicted average crash rate frequency based on the AADT volumes determined in Step 3. Results of the SPF equation are assigned crash severity and collision type based on either the default distribution or user developed distribution.

Step 10 – Multiply the result obtained in Step 9 by the appropriate CMFs to adjust the estimated crash frequency for base conditions to the site specific geometric design and traffic control.

CMF are used to adjust the average crash rate frequency to the specific conditions of each site. There are limitations regarding the use of CMFs including that care should be taken when more than three CMFs are applied.

*Step 11 - Multiply the result obtained in Step 10 by the appropriate calibration factor***.**

Calibration factors (*Cr* for roadway segments or *Ci* for intersections) are used to account for jurisdictional differences.

Step 12 – If there is another year to be evaluated in the study period for the selected site, return to Step 8. Otherwise, proceed to Step 13.

Step 13 – Apply site-specific EB Method (*if applicable*).

The EB Method uses the existing crash data and an overdispersion parameter, calculated with the SPF, to calibrate the predicted number of crashes using site specific history.

Step 14 – If there is another site to be evaluated, return to step 7, otherwise, proceed to Step 15.

Step 15 – Apply the project level EB method (*if the site-specific EB Method is not applicable*).

Step 16 – Sum all sites and years in the study to estimate total crashes or average crash frequency for the network.

$$N_{total} = \sum_{\text{all roadway segments, all years}} N_{rs} + \sum_{\text{all intersections, all years}} N_{\text{int}}$$

Where:

N_{total} = total expected number of crashes within the roadway limits of the study for all years in the period of interest. Or, the sum of the expected average crash frequency for each year for each site within the defined roadway limits within the study period;

N_{rs} = expected average crash frequency for a roadway segment using the predictive method for one year; and

N_{int} = expected average crash frequency for an intersection using the predictive method for one year.

This equation represents the total expected number of crashes estimated to occur during the study period.

$$N_{\text{total average}} = \frac{N_{total}}{n}$$

Where:

$N_{\textit{total average}}$ = total expected average crash frequency estimated to occur within the defined roadway limits during the study period; and

n = number of years in the study period.

This equation estimates the total expected average crash frequency within the network or facility limits during the study period.

Step 17 – Determine if there is an alternative design, treatment, or forecasted AADT to be evaluated.

Step 18 – Evaluate and compare results.

Results of the predictive method can have many uses including screening alternatives and evaluating countermeasures both before and after implementation.

Safety Performance Functions

SPFs are regression equations that calculate the dependant variable, predicted crash frequency, based on independent variables. There are separate SPFs for roadway segments and all three intersection types. The independent variables for segments are roadway segment length and AADT. The independent variables for intersection are major and minor leg AADT. Due to the range of data used to develop these equations, there is an AADT range for which the equations can be used. There are also overdispersion parameters (k) that are calculated or given with each

SPF. These parameters are used for calibration with the EB method. The SPF and overdispersion parameter equation for each of rural two-lane segments is listed below along with the acceptable AADT range.

$$N_{\mathrm{spf\,rs}} = AADT \times L \times 365 \times 10^{-6} \times e^{(-0.312)}$$

Where:

$N_{spf\ rs}$ = estimated total crash frequency for roadway segment base conditions;

$AADT$ = average annual daily traffic volume (vehicles per day), Range from 0 to 17,800; and

L = length of roadway segment (miles).

$$k = \frac{0.236}{L}$$

Where:

k = overdispersion parameter; and

L = length of roadway segment.

SPFs have been developed for a set of base conditions in specific representative test states. In lieu of these equations, agencies may choose to develop jurisdiction-specific SPFs. These SPFs must be developed using the same base conditions and be based on statistically sound studies. The base conditions for segments are:

- Lane width – 12 feet;
- Shoulder width – 6 feet;
- Roadside hazard rating – 3;
- Driveway density – 5 driveways per mile;
- Horizontal curvature – none;
- Vertical curvature – none;
- Grade – level (0 percent);
- Centerline rumble strips – none;

- Passing lanes – none;
- Two-way left turn lanes – none;
- Lighting – none; and
- Automated speed enforcement – none.

The crash prediction results are distributed into crash severity and type by applying pre-developed global distributions to the results of the SPF. Use and calibration of crash type distributions is discussed in greater depth in Chapter IV – Calibration.

Crash Modification Factors

Generally CMFs account for the specific geometric conditions of a location by adjusting the crash prediction yielded by the SPF. For rural two-lane highways, there are twelve CMFs for segments and four CMFs for intersections. All of the CMFs for segments are described below with their associated equations and constraints.

CMF_{1r} – Lane Width

This CMF calculates the safety impact of lane width on the segment AADT. It is based on the work of Zegeer et al. (*14*) and Griffin and Mak (*15*). The equations for the CMF are displayed in Table 2.

TABLE 2 CMF for Lane Width on Roadway Segments (*CMF_{ra}*)

	AADT (veh/day)		
Lane Width	<400	400 to 2000	>2000
9-ft or less	1.05	1.05+2.81x10-4(*AADT*-400)	1.5
10-ft	1.02	1.02+1.75x10-4(*AADT*-400)	1.3
11-ft	1.01	1.01+2.5x10-5(*AADT*-400)	1.05
12-ft or more	1	1	1

$$CMF_{1r} = \left(CMF_{ra} - 1.0\right) \times p_{ra} + 1.0$$

Where:

CMF_{1r} = Crash Modification Factor for the effect of lane width on total crashes;

CMF_{ra} = Crash Modification Factor for the effect of lane width on related crashes (i.e. single-vehicle run-off-the-road and multiple-vehicle head-on, opposite-direction sideswipe, and same-direction sideswipe crashes);

P_{ra} = proportion of total crashes constituted by related crashes.

If the lane widths for opposing directions are different, the CMF for each direction should be calculated and averaged for use on the segment. The proportional factor (p_{ra}) is used to account for the assumption that only single-vehicle run-off-the-road, multiple vehicle head-on, opposite direction sideswipe, and same direction sideswipe crashes are relevant to lane width. The value for p_{ra} is 0.574 (57.4 percent) based on the default distribution. A value should be calculated based on the agency's determined crash distribution to enhance the accuracy of this CMF.

CMF_{2r} – Shoulder Width and Type

The CMF for Shoulder Width and Type is comprised of the separate CMF values for shoulder width (CMF_{wra}) and shoulder type (CMF_{tra}). These equations are also based on Zegeer et al. [4, 14]. The equations necessary to calculate this CMF are displayed in Table 3 and Table 4.

TABLE 3 CMF for Shoulder Width on Roadway Segments (CMF_{wra})

	AADT (veh/day)		
Shoulder Width	<400	400 to 2000	>2000
0-ft	1.1	1.10+2.5x10-4(*AADT*-400)	1.5
2-ft	1.07	1.07+1.43x10-4(*AADT*-400)	1.3
4-ft	1.02	1.02+8.125x10-5(*AADT*-400)	1.15
6-ft	1	1	1
8-ft or more	0.98	0.98-6.875x10-5(*AADT*-400)	0.87

TABLE 4 CMF for Shoulder Types and Shoulder Widths on Roadway Segments (CMF_{tra})

	Shoulder width (ft)						
Shoulder Type	0	1	2	3	4	6	8
Paved	1	1	1	1	1	1	1
Gravel	1	1	1.01	1.01	1.01	1.02	1.02
Composite	1	1.01	1.02	1.02	1.03	1.04	1.06
Turf	1	1.01	1.03	1.04	1.05	1.08	1.11

Note: The values for composite shoulders represent a 50/50 paved/turf shoulder width

$$CMF_{2r} = \left(CMF_{wra} \times CMF_{ra} - 1.0\right) \times p_{ra} + 1.0$$

Where:

CMF_{2r} = Crash Modification Factor for the effect of shoulder width and type on total crashes;

CMF_{wra} = Crash Modification Factor for related crashes (i.e. single-vehicle run-off-the-road and multiple-vehicle head-on, opposite-direction sideswipe, and same-direction sideswipe crashes);

CMF_{ra} = Crash Modification Factor for related crashes based on shoulder type; and

p_{ra} = proportion of total crashes constituted by related crashes.

If shoulder width and type are not consistent for opposing directions, the CMF for each direction should be calculated and averaged for use on the segment. Since shoulder width and type influence the same crash types as lane width, the same p_{ra} factor is used to better correlate the CMF results to local conditions.

CMF_{3r} – Horizontal Curves: Length, Radius, and Presence or Absence of Spiral Transitions

This CMF accounts for the different crash rates experienced on curved segments versus tangent ones. This CMF is based on Zeeger et al. (*16*). The equation for this CMF is:

$$CMF_{3r} = \frac{\left(1.55 \times L_c\right) + \left(\dfrac{80.2}{R}\right) - \left(0.012 \times S\right)}{\left(1.55 \times L_c\right)}$$

Where,

CMF_{3r} = Crash Modification Factor for the effect of horizontal alignment on total crashes;

L_c = length of horizontal curve (miles) which includes spiral transitions, if present;

R = radius of curvature (feet); and

S = 1 if the spiral transition curve is present; 0 if spiral transition curve is not present; 0.5 if a spiral transition curve is present at one but not both ends of the horizontal curve.

The minimum curve length and radius that should be used for this calculation is 100 ft. If the actual curve length or radius is less than 100 ft then 100 ft should be used. Since the base condition for this CMF is a tangent (CMF=1) no value less than 1.00 should be used. If a value less than 1.00 is calculated it should be replaced with 1.00.

CMF_{4r} – Horizontal Curves: Superelevation

This CMF is used to account for crashes attributed to variance of road curves' superelevation versus the value recommended by the AASHTO Green Book (*1*). To determine the recommended value, an agency's policy on superelevation rate should be used. A curve's superelevation variance must be greater than 0.01 before an impact to crash rates is considered. The general functional form for this CMF is based on Zeeger et al. (*16-17*). The equations for this CMF are:

$$CMF_{4r} = 1.00 \text{ for } SV<1.0$$

$$CMF_{4r} = 1.00 + 6\times(SV\text{-}0.01) \text{ for } 0.01\leq SV<0.02$$

$$CMF_{4r} = 1.06 + 3\times(SV\text{-}0.02) \text{ for } SV\geq 0.02$$

Where:

CMF_{4r} = Crash Modification Factor for the effect of superelevation variance on total crashes; and

SV = superelevation variance (ft/ft), which represents the superelevation recommended by the AASHTO Green Book minus the actual superelevation of the curve.

Curves that meet or exceed the recommended AASHTO Green Book value are given the value 1.0 for this CMF.

CMF_{5r} – Grades

This CMF is used to account for the effects of the vertical grade of a roadway on the predicted crash rate. The grades are measured for the entire length between consecutive vertical points of intersection (VPIs). This CMF is based on analysis performed by Miaou (*18*). Table 5 gives the CMF values for various road grades.

TABLE 5 CMF for Grades (*CMF_{5r}*)

Approximate Grade (percent)		
Level Grade (≤3percent)	Moderate Terrain (3 percent<grade≤6 percent)	Steep Terrain (>6 percent)
1.00	1.10	1.16

The CMF can also be represented as 2 percent increase per percent grade.

CMF_{6r} – Driveway Density

This CMF is used to account for the impact of access control on predicted crash rates. Driveway density and AADT are used to calculate this CMF, derived from the work of Muskaug (*19*). The equation for this CMF is:

$$CMF_{6r} = \frac{0.322 + DD \times \left[0.05 - 0.005 \times \ln\left(AADT\right)\right]}{0.322 + 5 \times \left[0.05 - 0.005 \times \ln\left(AADT\right)\right]}$$

Where:

CMF_{6r} = Crash Modification Factor for the effect of driveway density on total crashes;

$AADT$ = average annual daily traffic volume of the roadway being evaluated (vehicles per day); and

DD = driveway density considering driveways on both sides of the highway (driveways/mile).

Only driveways that experience daily traffic should be considered when calculating the driveway density.

CMF_{7r} – Centerline Rumble Strips

This CMF is used to represent the anticipated reduction in crashes due to the presence of a centerline rumble strip. A 21% reduction of head-on and opposite-direction sideswipe crashes can be anticipated with addition of a centerline rumble strip. It is then recommended to assume that this same benefit can be applied to reduction of one-half of run-off-road crashes. This would account for crashes reduced in left side departures. Given the default crash distributions, this would result in a CMF equal to 0.94. A jurisdiction-specific value should be calculated using the jurisdiction distributions. A centerline turn lane negates this benefit and a CMF of 1.0 should be used.

CMF_{8r} – Passing Lanes

This CMF is developed to account for both a conventional one-lane passing/climbing lane and short four-lane sections. Assuming a passing/climbing lane is warranted, a CMF of 0.75 for both directions of traffic can be anticipated. This CMF is valid from the beginning of the upstream taper to the end of the downstream taper. For short four-lane sections, a CMF of 0.65 can be anticipated. This applies for the length of a segment that has a four-lane cross section provided for limited passing opportunity. The passing lane CMF is based on the work of Harwood and St.John (*20*), Rinde (*21*), and Nettleblad (*22*). The four-lane section CMF is based on the work of Harwood and St. John.

CMF_{9r} – Two-Way Left-Turn Lanes

This CMF captures the safety benefit of a two-way left-turn lane (TWLTL) on two-lane rural roadways. The equation for this CMF is:

$$CMF_{9r} = 1.0 - \left(0.7 \times p_{dwy} \times p_{LT/D}\right)$$

Where:
CMF_{9r} = Crash Modification Factor for the effect of two-way left-turn lanes on total crashes;
p_{dwy} = driveway-related crashes as a proportion of total crashes; and
$p_{LT/D}$ = left-turn crashes susceptible to correction by a TWLTL as a proportion of driveway-related crashes (estimated at 0.5).

$$P_{dwy} = \frac{\left(0.0047 \times DD\right) + \left(0.0024 x DD^{(2)}\right)}{1.199 + \left(0.0047 \times DD\right) + \left(0.0024 \times DD^{(2)}\right)}$$

Where:

DD = driveway density considering driveways on both sides of the highway (driveways/mile).

The base condition for CMF_{9r} of 1.0 assumes that no TWLTL exists. This same value should be used if driveway density is less than five per mile.

CMF_{10r} – Roadside Design

Roadside safety is modeled in the HSM predictive method by using the Zegeer et al. (*14*) developed roadside hazard rating. The base condition assumes a roadside hazard rating of 3. The equation for this CMF is:

$$CMF_{10r} = \frac{e^{\left(-0.6869+0.0668 \times RHR\right)}}{e^{\left(-0.4865\right)}}$$

Where:

CMF_{10r} = Crash Modification Factor for the effect of roadside design; and

RHR = Roadside Hazard Rating (1-7 scale).

CMF_{11r} – Lighting

This CMF estimates the safety benefit of adding lighting to a roadway segment. The absence of lighting is the base condition. The equation for this CMF is:

$$CMF_{11r} = 1.0 - \left[\left(1.0 - 0.72 \times p_{inr} - 0.83 \times p_{pnr}\right) \times p_{nr}\right]$$

Where:

CMF_{11r} = Crash Modification Factor for the effect of lighting on total crashes;

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;

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

Default values for p_{inr}, p_{pnr}, and p_{nr} are provided in the following table. Jurisdiction-specific values should be calculated where data are available.

TABLE 6 CMF_{11r} Default Values

p_{inr}	p_{pnr}	p_{nr}
0.382	0.618	0.37

CMF_{12r} – Automated Speed Enforcement

When automated speed enforcement is applied to a highway segment by means of a permanently installed fixed camera or where camera presence is unknown to the driver, a CMF of 0.93 is applied. This is based on research showing that such enforcement reduces all injury crashes by 17 percent. It also assumes the base distribution that injury and fatality crashes make up 43 percent of all crashes. Since no information about the effect of automated speed enforcement on non-injury crashes is known, a conservative assumption is made that it has no effect.

The HSM recognizes one important limitation of the use of CMFs in the CPM. Because the CPM treats the effects of individual geometric design and traffic control features as independent of one another, it ignores potential interactions between them. It is likely that such interactions exist, and ideally, they should be accounted for in the CPM. Because these interactions are not well understood, the HSM recommends caution when using results that utilize multiple CMFs because they may overestimate the collective safety benefit of all the elements.

Calibration Procedure

Even though the HSM is now published, the base equation, or SPF, given does not necessarily work well for every state or region as data from only two states were used in the model development. The HSM strongly recommends first calibrating the model. While calibrating the CPM should provide satisfactory results, more reliable estimates for a given jurisdiction may be obtained by developing a jurisdiction-specific SPF. There are five steps listed in the HSM to correctly calibrate a model; the first step is to decide which type of roadway to perform the calibration on, such as a two-way, two-lane rural highway or three-leg urban signalized intersection. The second step is to select sites to perform the calibration, with a minimum sample size of 30 to 50 sites and total of at least 100 crashes or more per year. They also suggest randomly choosing sites to prevent choosing only sites with a large number of crashes. Recent research by Banihashemi (*23*) recommends that, at least for their test state, a calibration should contain at least 150 crashes per year to have the appropriate confidence level in the calibration value. Once the sites are established, the next step is to collect the total crash frequency for the years chosen to observe and obtain the site characteristics. Table 8, in Chapter III – Data Collection, provides a list of the desired site characteristics. The fourth step is to use the predictive equations without a calibration factor or the EB method to get the expected crash frequency for the sites for the correct number of years. The final step is to compute the calibration factor using the following equation:

$$Cr = \frac{\sum_{all\,sites} observed\ crashes}{\sum_{all\,sites} predicted\ crashes}$$

Since the SPF for two-lane rural roadways is a linear equation, the calibration factor is used to change the relative impact of AADT on predicted crashes for a given jurisdiction. If the calibration value is greater than one, then the AADT will have more weight on the total predicted crashes. Similarly, if the calibration value is less than one, the AADT will have less weight on the predicted crashes. The calibration of the rural two-lane CPM is one of the thrusts of this research and is, therefore, described in greater detail throughout this dissertation.

CONTEMPORARY RESEARCH

During the creation of the HSM, developers produced and distributed drafts of the document. While there are some minor variations between the final versions and these draft versions, the substance is nearly identical. Thanks to the availability of these draft manuals, there is already a good deal of research that has been performed on the HSM even though it was only published in 2010. The following section aims to present a cross section of contemporary research both on efforts to calibrate and utilize the HSM and also on alternative CPMs developed for other transportation authorities.

Highway Safety Manual Calibration

The calibration process described for the HSM has been performed and documented by a small number of entities already. The first study looking at calibrating the CPM for two-lane rural highway segments was performed in 2006 by Sun et al. (*24*) for highways in Louisiana. The CPM used here is nearly identical to the one currently found in the HSM. The biggest difference is that the HSM has additional CMFs for rumble strips, lighting, and automated speed enforcement that were added subsequent to this research. In addition, the calibration procedure called for in the draft HSM and applied here differs from the one in the published HSM. The prime difference is that this procedure calls for a stratification of calibration factors based on traffic volume. The factors are then averaged together for application.

The study by Sun et al. (*24*) utilized the same basic definition for rural two-lane highways. Due to lack of data, default values were used for several of the CMFs. The values provided for some of the data are not consistent with those experienced in Kansas. Ultimately through these data and calibration methodology, a calibration value of 1.63 was determined for the Louisiana highway system.

In addition to the calibration component, the Louisiana study also performs a validation of the CPM, which includes using the calibration factor and the EB procedure. The study shows the accuracy of the model when utilizing the calibration, in terms of percent difference between the observed and predicted crashes. The accuracy of the calibrated model, without utilizing the EB procedure, is 5.22 percent difference. When the EB procedure is added, then accuracy is improved to 3.06 percent difference. It is worth noting that the equation for the EB procedure provided in this dissertation is different than the method shown in the published HSM and it is unclear if they were using observed crashes from the same period being predicted. Also, these accuracies are provided for the aggregate of all the segments modeled in the validation study and do not show the individual segment accuracy in definable values.

In 2009 Martinelli, La Torre, and Vadi (*25*) performed the calibration procedure on segments for a network of rural secondary roads in Italy. This study utilized a slightly older version of the CPM than is currently available in the HSM and the same draft calibration procedure used in the Louisiana study (*24*). Due to the lack of data, default values were used for several of the CMFs. The bulk of the analysis performed was looking at different ways to aggregate the crash prediction results and methods of calibration to determine if any procedure proved especially valuable. The primary finding was that applying a weighted average of crashes over the length of a segment performed better than using a ratio of densities or raw crashes. However, the current calibration procedure varies from the one utilized in these studies. An additional key finding is that "a constant value for the calibration coefficient is not a suitable option for a valid model transferability(*25*)."

In 2011 Xie et al.(*26*) performed a calibration of each of the three types of roadway facility considered by the HSM for the Oregon highway system. For rural, two-lane, two-way roads, their final calibration factor was found to be 0.74, using data from 2004-2006. They speculated it may be under 1.0 due to fewer property damage only (PDO) crashes being reported in Oregon, as those types of crashes are not required to be reported to authorities. They also found that accumulating the data was time consuming. A gap in their research was that they did not validate the newly created calibration factors. Therefore, although they followed the steps given in the HSM, they did not go back to show how accurate the calibrated model was for predicting crashes.

One unique aspect of the Oregon study (*26*) is that they went through the effort of developing jurisdiction-specific crash distributions to replace the default values provided by the HSM. Their analysis showed that, on an aggregate level, using the jurisdiction specific distributions did not significantly impact the results as compared to using the HSM default values. This analysis did not include a quantification of this impact at the project level. It is also worth noting that, of the statistics provided, the Oregon-specific values did not vary notably from the default values provided in the HSM. Therefore, it is not surprising that no significant impact was found by using the Oregon-specific values in place of the default values.

Banihashemi compared calibrating the CPM to creating two new SPFs for the state of Washington(*23*).

$$N_{spf\text{-}1\text{-}rs} = 0.91705 \times AADT \times L \times 365 \times 10^{-6}$$
$$N_{spf\text{-}2\text{-}rs} = 0.5782 \times AADT^{1.05} \times L \times 365 \times 10^{-6}$$

The first equation had the same general form as the rural two-lane SPF found in the HSM. The equation had a similar form except the *AADT* is raised to the power of 1.05. Four new CMFs were also produced for lane width, shoulder width, curve radius, and vertical grade which were used with the new SPFs. In this study, it was found that the calibration for Washington state worked just as well as either of the new models, although the newer models may be preferred if more CMFs were created specifically for the state. However, since the original SPF was created using Washington and Minnesota data, the fact that it worked just as well as new SPFs is not entirely surprising. Similar to a number of previous studies, the models studied by Banihashemi (*23*) assumed default values for a number of the CMFs due to data limitations.

Other Crash Prediction Models

Some transportation officials have taken the same principles used to develop the CPMs in the HSM and developed CPMs for their specific jurisdiction. For example Mayora, Manzo, and Orive (*27*) developed a CPM for two-lane rural road segments on the Spanish National Network. The final version of their CPM contained some similar variables to the HSM version, including vertical grade and access density. However, some variables were different, including reduction in design speed between adjacent segment and sight distance.

The most robust work to develop jurisdiction-specific CPMs has been performed for the Texas DOT. This included a six-year program for "(1) the development of safety design guidelines and evaluation tools to be used by TxDOT designers, and (2) the production of a plan for the incorporation of these guidelines and tools in the planning and design stages of the project development process (*28*).” The end product of this effort was the Roadways Safety Design Workbook (*28*) which includes safety prediction models for several facility types:

- Freeways;
- Rural highways (two and four lane);
- Urban and suburban arterials;
- Interchange ramps and frontage roads;
- Rural intersections; and
- Urban intersections.

The procedure used by TxDOT for rural highways is similar to that developed by Harwood et al.(*11*) with the primary exception that the TxDOT procedure predicts injury (plus fatal) crash frequency, as opposed to total crash frequency. Similar to the HSM procedure, the TxDOT procedure has base conditions for a base model and then a series of CMFs to consider the individual attributes for a segment or intersection.

One relevant difference between the HSM and TxDOT procedures was found in the development of TxDOT’s interchange ramp CPMs. Instead of creating a new CPM for interchange ramps, Lord and Bonneson (*29*) looked at calibrating existing SPFs for ramps based on Texas data. One of the unique elements of this research is that it utilized a disaggregate approach based on the area type, ramp type, and ramp configuration. It was proposed in the research that this method would better fit the Texas data if certain attributes had a disproportionate affect on crashes than the state from which the original model was derived. However, no comparison could be found between the relative accuracy of a single calibration versus the disaggregate calibration.

New research, released by Ibrahim and Sayed (*30*) in 2011, proposed the use of reliability-based risk measures to improve the performance of SPFs. Specifically, this research compared SPFs developed using typical negative binomial regression to ones using probability of non-compliance (P_{nc}) for horizontal curve locations on the Trans-Canada Highway. The comparison showed that the model for total crashes using P_{nc} outperformed the model without and was 10 percent significant using the likelihood reliability test. While this type of reliability measurement in highway safety shows promise, this research was limited to horizontal curves. Additional research is needed to confirm these findings and to investigate probability distributions of the design inputs as well as correlations between the variables (*30*).

KANSAS CRASH PREDICTION RESEARCH

Safety of the highway system is a paramount issue to KDOT. To improve the safety of its highway system, KDOT has commissioned numerous studies to address safety. Three of those contemporary studies address crash prediction on rural two-lane highway segments.

KDOT, like many other transportation organizations, has looked to research for more efficient ways to screen its robust system inventories and crash data for identifying relationships between highway features and safety. In 2009, Najjar and Mandavilli (*31*) used Artificial Neural Networks (ANN) to attempt to identify these relationships for Kansas highways. Their research covered the six major types of roadway network in Kansas: rural Kansas Turnpike Authority (KTA), rural two-lane, rural expressway, rural freeway, urban freeway, and urban expressway. The models evaluated not only the total crash rate but also the fatal, injury, and severe injury crash rates. For rural two-lane highways, Najjar and Mandavilli (*31*) identified eight different variables that were shown to impact crashes:

- Section length;
- Surface width;
- Route class;
- Shoulder width (outside);
- Shoulder type (outside);
- Average ADT;
- Average percent of heavy trucks; and
- Average speed limit.

The ANN models produced by Najjar and Mandavilli (*31*) were measured against training, testing, and validation data sets. The overall rural two-lane model produced a Coefficient of Determination Factor (R^2) of 0.4655. The total crash rate model would be the most similar to the HSM model being investigated with this research. The R^2-value for the total crash rate ANN model was 0.1728.

The research developed by Najjar and Mandavilli (*31*) reported to be the "first in the nation to utilize the ANN mining approach to extract new and reliable traffic-crash correlations from historical databases." As such, it potentially provides a good framework for future applications of this methodology. However, some of the specific results for rural two-lane highways in Kansas seem inconsistent with engineering judgment, other research, and current practice. One such result was the safety performance of similar width shoulders with different pavement types. Due to these practical limitations the ANN model has not been implemented into practice by KDOT.

The only significant research done, to date, on animal crashes on highways in Kansas was performed by Meyer in 2006, as part of a research program sponsored by KDOT. The study, Assessing the Effectiveness of Deer Warning Signs (*32*), used multiple layer regression, logistic regression, and Principal Component Analysis to model the safety effectiveness of deer warning signs based on before-and-after data where signs had been installed. While this analysis did not produce a viable model to help predict the safety benefit of installing deer signs or being able to prioritize segments for installation of signs, there were several important statistical findings (*32*):

- The absence of the variable "presence of deer warning sign" suggests that there is little or no relationship between deer warning signs and crash rate.
- The most significant parameter was the amount of surrounding area that was wooded. Most likely, the amount of wooded area was acting in this data as a surrogate for deer population.
- The sole direct measure of deer population (harvest density) was only available at an extremely coarse geographical resolution for this application.

- Other than percent wooded area, the other parameters identified as having a significant influence on crash rate were traffic volume and speed, sight distance (indirectly implied by the curvature ratio and side slope), and clear width.

With the current guidance on how to perform statically accurate before-and-after studies, it is possible that a model could be developed to better quantify factors impacting deer crashes. However, the findings of this research are still valid and can help to inform future consideration on the nature of animal crashes in Kansas.

The lack of measurable statistical benefit from the use of deer crossing signs was supported by a 2005 study, performed by Knapp (*33*), that synthesized available research on the safety benefits of deer crash countermeasures. This research summary showed that only exclusionary fencing and wildlife crossings showed positive safety analysis results for reducing deer-vehicle crashes.

In 2010, Rhys et al. (*34*) performed a before-and-after analysis of the safety benefits of adding a centerline rumble strip to two different rural two-lane highways in Kansas. Utilizing the EB method, this study showed an 85 percent reduction in the targeted crash types, head-on and opposite sideswipe. They also showed a 33 percent reduction in total crashes. It is worth noting that this study defined total crashes as excluding animal crashes. The findings of this study state that "it can be assumed that overall results found in Kansas are comparable to results found by other states (*34*)." It is somewhat difficult to compare these results to the HSM because the CMF for centerline rumble strips also applies to one-half of run-off-the-road crashes. However, the value given for reduction of target crashes for the centerline CMF is 0.79 (21 percent reduction). Therefore, it is safe to say that the study by Rhys et al. (*34*) demonstrated a larger safety benefit for centerline rumble strips than what is shown in the HSM.

One additional noteworthy finding of the Rhys et al. (*34*) study was the creation of SPFs for roads similar to the two test sections analyzed. This was developed to isolate the safety benefit of the rumble strips. The equation they developed for similar rural two-way highways is:

$$ACC = e^{\beta_0} \times e^{(AADT_{before} \times \beta_1)}$$

Where:

ACC = expected number of crashes (per mile per year) in a section with the same characteristics to the section of interest;

$AADT_{before}$ = average AADT for the before period;

β_0 = -1.4019 (section A), -1.2229 (section B); and

β_1 = 0.0004 (section A), 0.0007 (section B).

An overdispersion factor was also calculated for the equation. It equaled -0.0793 for section A and -0.1475 for section B. The two sections cited in this report, A and B, reference the two different sections that were studied for crash reduction due to addition of a centerline rumble strip. Highways with similar traffic volumes, road geometry, and crash history were used to develop an SPF for each roadway type.

SAFETYANALYST

SafetyAnalyst is similar to the CPM from Part B of the HSM in that it uses a SPF but uses less geometric data and looks at a whole network with several different tools. These tools identify sites that could benefit from safety improvements, diagnose possible reasons for the safety problems, suggest what improvements could be made and at what cost, prioritize which sites could benefit most with regard to cost estimates, and can perform before-and-after evaluations. To perform these analyses, the primary data needed includes the following:

- Segment length;
- Area type (rural/urban);
- Number of lanes;
- Median type;
- Access control; and
- Traffic volume.

The base model for SafetyAnalyst is then the following:

$$Crashes = e^{a} \times AADT^{b} \times SL$$

Where:

Crashes = predicted crashes per year;

AADT = average annual daily traffic (vehicles/day);

SL = segment length (miles); and

a and b = regression parameters.

It can also be adjusted with a calibration factor that should be evaluated on a yearly basis and a proportion factor if looking at only certain types of crashes.

In supportive efforts, a number of states have also published research regarding their individual efforts to develop accurate methods for predicting crashes for network analysis. Many of these states have focused their research on development and calibration of SPFs used in SafetyAnalyst for their particular state, including Virginia (*35*) and Louisiana (*36*).

Research by Lyon et al. (*37*) recognized that there are some fundamental issues with statistical analysis of road safety. These include "site-selection bias, lack of experimental control of confounding variables, relatively small effects of some predictor variables, large crash variability, and omitted variable bias (*37*)." However, this research also recognized that given the limitations of the current state of practice of safety analysis, the HSM approach for predicting rural intersection crashes is "sound and defensible" (*37*). This is the same approach used for modeling segment crashes for the CPMs.

Based on the network qualities and data availability, certain jurisdictions have chosen to deviate from the SafetyAnaylst method. In research performed by Qin and Wellner (*38*), jurisdiction-specific equations were developed for South Dakota. Direct comparison is difficult because this research developed equations for different roadway classifications than are presented in the HSM. One interesting finding is that the equations for South Dakota use some variables not found in the HSM, including percent trucks, vertical curve density, speed limit, and municipal funding category.

A similar study performed in Italy (*39*) developed jurisdiction-specific equations that used variables similar to those found in the HSM. Two primary differences are that the Italian equations predict only injury crashes and also use mean speed as a variable.

Kononov and Allery (*40*), of the Colorado Department of Transportation, developed a concept called Level of Safety Service (LOSS). LOSS is a screening model that compares the performance of similar roadways to determine problematic sections that have appreciably worse safety performance. This method uses SPFs to describe the overall performance of group of similar road segments. A particular segment's LOSS is then measured as the deviation from that SPF.

SUMMARY

Through review of the literature that led to the development of the HSM and subsequent studies that address applications of the HSM, several key points can be found that will direct this research effort to calibrate and validate the HSM CPM for rural two-lane roadways on Kansas highways.

- There is research that suggests there are superior methods for predicting crashes beyond what is available in the HSM for two-lane rural highways. However, the HSM methods utilize some of the most thorough and well established methods and data for their development. Plus, there are questions as to whether a state agency that had the money to invest in the development of its own CPMs would significantly improve its ability to predict crashes.

- When utilizing the HSM CPM, several research studies have shown that a single calibration factor may not be powerful enough to accurately predict safety performance. Therefore, a more dynamic method of calibration should be considered.

- None of the research analyzed utilized a definition for two-lane rural highway beyond the basic definition found in the HSM. Specifically, the definition of rural was universally applied as any stretch of highway outside of a city with a population greater than 5,000 people.

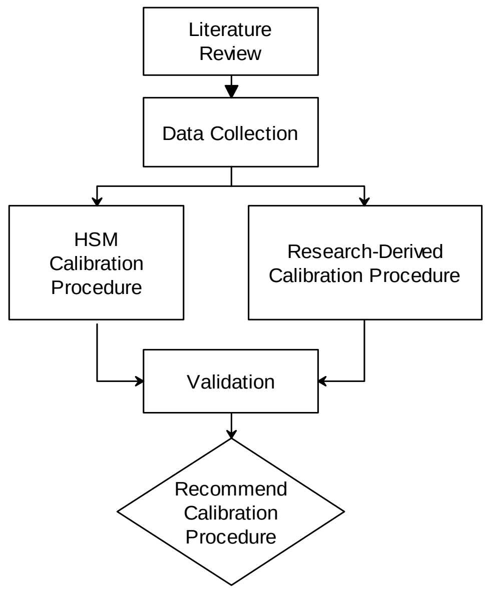
- None of the research analyzed captured CPM performance in a manner that is most consistent with proposed applications for KDOT design projects. While many of the studies used to develop the components of the HSM utilize before-and-after studies, all of the studies that looked at the full HSM CPM for segments analyzed unchanged sections of highway during their study period. These studies demonstrate the general accuracy of the HSM CPM, but fail to capture some important factors like over-prediction of safety benefits by multiplying multiple CMFs together. The needed practical performance of the HSM is to be able to predict what the future performance of a highway section will be once improvements are made.

- Most previous efforts to calibrate and validate the HSM CPMs have utilized the default assumptions for roadway features that were not known. No research was found on the HSM that included all of the variables necessary for fully utilizing the CPM. Also, previous research typically focused on the aggregate accuracy of the CPM as opposed to looking at the accuracy of the individual study sections.

- Research specific to Kansas has led to no validated method for predicting crashes. However, past studies did produce some valuable findings that were referenced during the development of this study.

These conclusions helped shape the direction of this research. One of the primary changes was that instead of focusing solely on the HSM calibration procedure, other methods of calibrating the CPM were also investigated. The literature review also reinforced the value of performing the validation step in a manner that is most consistent with how the HSM CPM is intended for use in practice. Figure 3 displays the evolution of the research plan after completion of the Literature Review.

FIGURE 3 Diagram of Dissertation Research Performed – Literature Review



CHAPTER III – DATA COLLECTION

The collection of data for the calibration of segments was an evolving process. This chapter will cover all the different data elements that were collected for the calibration of segments along with the source of that data and the collection procedure. The framework for the use of much of these data is presented in the Literature Review. However, there are additional discussions in the following chapters that more explicitly demonstrate the need for each of these different data elements.

CANSYS DATABASE

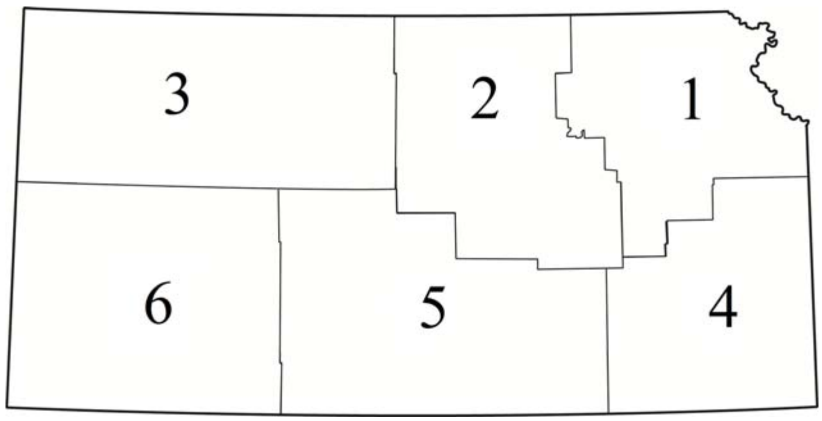
The CANSYS database is the primary repository of roadway feature data at KDOT. A variety of data elements ranging from pavement quality to traffic volume to shoulder width are available through CANSYS. The database is maintained by KDOT planning staff and the various data elements are each collected at varying intervals and by different sources. Individual data elements, especially those addressing roadway features, have the potential to be inconsistent with existing field conditions or missing specific roadway elements. For this reason the CANSYS database was primarily used for higher level analyses including network screening and trend evaluation. Other, more accurate sources for roadway features data were primarily used for the in-depth analyses including the model calibration and validation.

Data from the entire state system was obtained for the study. Generally the database is sorted by route name and county so that every mile is accounted for and there is no double counting of segments. Forty-five specific fields were chosen from the myriad of total fields that were available. A list of all 46 fields can be found in Appendix A. The following is a list of the primary data fields that were used with a brief discussion of how they were used.

District & County

There are 105 counties in Kansas. KDOT also has its own geographic division of the state starting at the highest level of district, for which there are six in the state. Figure 4 depicts the six KDOT geographic districts. For this study, the fields of 'District' and 'County' were used primarily to ensure proper distribution of data geographically throughout the state.

FIGURE 4 Map of KDOT Geographic Districts



Begin/End Mile Post & Segment Length

Every highway route on the Kansas system has a milepost system generally that runs south to north for odd numbered routes and west to east for even routes. There is a state-route and county-route milepost system used by KDOT. The two systems vary depending on where the zero milepost is started, either at the state line or county line. The data selected for this study utilized the county-route milepost system. This required some data to be converted from the state-route milepost value.

Begin and end mileposts were developed by the system for every homogenous segment. Most commonly, the segment ends were defined by an intersection or a crash report. Using the begin and end milepost, the system then calculated a length for each segment. This segment length was primarily used in analyses that consider the total length of highway miles associated with certain highway attributes (i.e. system miles with traffic volume between 200 and 300 vehicles per day).

Intersection

The intersection field simply represents the presence of an intersection with the highway. This field was very accurate for the state-to-state route intersections, but the other intersection types were inconsistently recorded.

Lane Class & City Code

The field 'Lane Class' identifies the type of facility that is present. Values for this field range from undivided two-lane to divided eight-lane. The segments that were not undivided two-lane segments, were filtered out for this study. The remaining segments were considered unqualified as two-lane rural highways. This definition is slightly over-stringent because the HSM model allows for the consideration of sections with a two-way-left turn lane or short four-lane sections. Any bias caused by this exclusion is considered extremely small because these sections represent a very small amount of the overall Kansas highway system and the variance in performance of these types of facility from strictly two-lane sections is nominal.

The field 'City Code' identifies the location of a specific highway segment relative to an urban area boundary. There is only one value for this field, 999, representing a rural segment. A null value in this field represents a segment that is within an urban boundary. The FHWA definition of urban is used: a city with a population of 5,000 or more. More discussion on how these two fields are used is presented below.

Accident ID

The CANSYS database also contains a field identifying the location and specific identification number of each crash report. While the CANSYS database does not contain any specific information about the crash, it does assign a route, county, and milepost to each crash. This was used to coordinate the attributes of a highway segment with each crash. More information about the specific crash attributes is presented below.

CRASH REPORT DATABASE

KDOT maintains a database of all crash reports filed for incidents on the Kansas highway system. This database is coded in accordance with the Kansas Motor Vehicle Accident Report (KDOT Form 850A). A copy of the 2009 version of this form can be found in Appendix B. A report is filled out for every incident that the Kansas Highway Patrol (KHP) participates. Unlike some other states, all crashes are supposed to be reported, no matter the level of damage. For this study, every crash report filed for the years 2005-2007 were gathered. When performing the calibration, the HSM recommends a period of three to five years be utilized. Shorter periods than three years are subject to high variability due to the randomness of crashes. Longer periods than five years are subject to introduction of bias due changes in reporting standards or the physical changes to the roadway features. The length of period selected should correspond with the frequency with which the model is recalibrated.

In the crash report database, each report is assigned a specific crash identification number. Then the individual attributes of a specific incident are assigned to that identification number. There is a wealth of information contained in the Kansas Motor Vehicle Accident Report. For this study, several fields were primarily used. The following is a list of those fields with a brief description about how each field was used.

Location of Crash

There are several fields within the crash report itself that are used to represent where a crash took place. These include the county milepost and the distance from a named intersection. Because the incident responders do not typically have precise positioning equipment to determine the specific milepost of an incident, this value can have some inaccuracies. For this reason, all of the crashes used in the calibration and validation analyses were verified with the proximity to a named intersection to verify the location of the crash relative to the highway section being analyzed.

Accident Class

This field identifies the type of crash that occurred. The most common types include animal collision, overturned, or collision with a motor vehicle in-transport or fixed object. For the collisions with other elements, the crash report also provides additional fields which more accurately identify the specific object hit or the nature of the collision.

Accident Location

This field identifies the type of facility where the incident occurred, and includes values for 'intersection' and 'intersection-related' crashes. All of the crashes identified to either of these locations were considered intersection crashes for purposes of modeling in the HSM. The remaining crashes were considered segment crashes. This field also contains a value for crashes that occurred at the access to a parking lot or a driveway.

Accident Severity

These crash reports contain only three types of crash severity: fatality, injury, or property damage only (PDO). Multiple vehicle crashes can have different severity levels for each vehicle involved in the crash. For purposes of this study, each crash was assigned to the most severe level experienced by any vehicle involved.

Light Condition

Light condition values are necessary for replacement of some of the HSM default values. Description of how these data were used for development of those replacement values is presented in Chapter IV – Calibration.

COMBINED DATABASE

The CANSYS data and crash data are kept in separate databases by KDOT and, therefore, were provided as separate elements. Since a major element of this study required analyzing segments by both roadway feature and accident type, the two databases were merged. This was completed by linking the accident ID number from the CANSYS database with the accident ID number for each crash. This was primarily completed with some functionality available in Microsoft Excel. However, some manual manipulation of the data was necessary for crashes that contained non-numeric characters. The primary function of this merged database was to segregate the two-lane rural segments from the remainder of the Kansas highway system. While fundamentally this screening seems simple, with the data provided there was a significant issue that arose dealing with the definition of rural.

Definition of Rural

One of the most fundamental challenges of this study was defining the word "rural" as it applied to the CPM. Since this HSM model only addresses two-lane rural highways, it was critical to determine what constituted a rural highway. The HSM uses the FHWA definition, which is that a rural section is any segment outside of a city with a population of 5,000 people or more. In Kansas, there are 41 cities with population of 5,000 or greater. According to the HSM, every highway mile that does not go through one of those 41 cities is considered rural.

Initial screening of data for this study was performed using this definition. Any segment not associated with the value of 999 (rural) in the city code field was eliminated from consideration with this research. The remaining data were then used to perform the high level analyses including replacement of default values and overall system trends. This definition for rural was also used when the original random highway segments were generated for use in developing the calibration factors.

During the data mining for the calibration procedure described below, an inconsistency was discovered in the application of the HSM definition of rural for Kansas highways. Some of the random highway segments that were generated for analysis contained portions that went through cities with populations under 5,000 people. The typical sections for the highways in these cities were two-lane, or short four-lane, so they would otherwise qualify for analysis using the HSM model. However, the other features of the highway were not consistent with the two-lane rural model. Some sections included curb and gutter, storm sewer, on-street parking, sidewalks, and downtown-style development. These sections, which qualified under the HSM model definition, could not accurately be modeled using the rural two-lane model. For this reason, the definition of "rural" for application on Kansas highways was modified to exclude segments going through cities of any population. This is a significant finding because at the time of this research Kansas contained roughly 587 cities with a population under 5,000, and nearly all of them were served directly by a highway. All calibration and validation segments were modified to exclude any section that passed through any city.

The result of this modified definition created an inconsistency in the statewide data analyzed versus how the HSM model was originally proposed for Kansas highways. There was no value available in the CANSYS database for a highway that passed through any city of any size. Ultimately, all of the default values and overall system trend analyses presented in this research were based on the data inclusive of cities of population under 5,000. For this reason they do carry some bias relative to the application of the HSM model to only segments outside any cities. However, results ultimately showed that the change in default values had little to no effect on the overall calibration results achieved. Additionally, any equations or models developed from overall statewide trends were then either supplemented with additional data that excluded cities of any size or validated against highway segments outside cities of any size.

OTHER DATA SOURCES

In the instance where roadway feature data were required that were not available through the CANSYS database, other sources of information were consulted.

Existing Plans

Performing the HSM model required data elements and data accuracy that were not available in the CANSYS database. To address this gap, existing highway construction plans were gathered to provide the supplementary information. KDOT's construction strip maps were consulted to determine the most recent highway grading project that had been performed on a specific segment of highway. The existing plans were retrieved from the KDOT archives, typically from microfilm. Since newer projects often overlapped segments of older projects, additional effort was needed to combine the elements of each project to develop a proper model of the existing highway. The existing plan features were compared to other data sources to validate that more recent grading had not taken place over that segment.

KDOT Videolog

At the time of this research, KDOT maintained a digital database of images of the entire state highway system. Every mile of the state was photographed, logged, matched to GPS data, and updated every three years. The image is taken roughly every 264 feet by the Videolog vehicle.

Via an online interface, users can then see these images linked to the milepost where the photo was taken.

Aerial Photography

In some instances, there were data needed that fell outside the limits of the existing plans and the Videolog. To address this gap, aerial photography was utilized. The aerial photography was typically provided using Google© products including Google Maps© and Google Earth©. The resolution of the maps is not particularly high, but for segments the aerial photography was primarily used to detect the presence of entrances, which does not require a high level of resolution.

MQA Random Segment Generator

As part of a KDOT sponsored research project, Review and Analysis of the Kansas Department of Transportation Maintenance Quality Assurance Program (*41*), the University of Kansas developed a random segment generator to help with the Maintenance Quality Assurance (MQA) program. For this study, a modified version of that generator was developed. The generator for this study was populated by the same data used for the MQA program. The primary difference is that this generator allowed the user to vary the length of the random segment. While any method can be used to randomly select segments for performing the model calibration, this generator looked at the entire Kansas highway system and adjusted for proper highway termini. Two negatives of the generator are that it required manual screening of two-lane rural sections and provides the data in state milepost. Since the other KDOT sources generate data in county milepost, the data had to be converted. This was accomplished by manually reviewing a state milepost to county milepost conversion chart and changing the values.

KDOT Traffic Maps

Only traffic data for 2007 were provided with the CANSYS database. To supplement these data and provide a more accurate model, additional years of traffic data were gathered. Historic KDOT traffic flow maps were consulted for traffic data in years other than 2007. The AADTs were inputted into the model corresponding to the year the traffic count was taken.

CALIBRATION MODEL DATA

Replacement of Default Values

The raw data necessary to develop replacement distributions for the HSM default values can all be found in the crash reports. The combined CANSYS/crash report database was used to screen only the two-lane rural crashes. Some interpretation of the standard crash report database fields was needed to categorize the collision types into similar categories as are provided by the HSM. A key is provided in Appendix C of this dissertation to describe the translation used for this research.

Calibration of Model

Since there were no existing highway segments that had been modeled for the HSM, it was determined that the use of randomly selected highway segments would provide the least biased calibration factor. Ten-mile long sections were selected because they were long enough so they would likely extend through multiple projects but short enough that a reasonable number of sections would satisfy the minimum criteria for number of crashes. Fifty random ten-mile sections were generated using a modified version of the program developed to choose random highway segments for KDOT's MQA program. Nine of the sections were removed from future consideration because they had elements that violated the HSM two-lane rural model parameters. These violations included sections that were in urban areas and some four-lane sections. The combined CANSYS/crash database was then referenced to determine how many crashes occurred within each ten-mile segment. Crashes were divided between intersection crashes and segment crashes. A list of these remaining 41 segments can be found in Appendix D.

It was determined that just going through the list of random sections until the minimum number of crashes was reached would bias the data set to sections with high crash frequency. To address this potential bias, a statistical analysis of crash frequency on KDOT highway segments was performed from the remaining 41 sections. The mean number of crashes for the 41 sections was 18; the standard deviation was 15. These values are for the full three-year period that crash data were collected.

It was decided to use a conservative value for the number of sections that would be evaluated to develop the calibration value. Therefore, the calculation to determine the necessary number of sections was based on two standard deviations from the mean to produce 100 crashes per year. *Assuming a normal distribution of crashes per ten-mile section, it was estimated that 19 ten-mile sections were necessary for roadway segment data collection.*

The list of 41 ten-mile sections from above was again used to select the 19 sections that would be carried forward to perform the calibration procedure. Some bias was intentionally added to the section selection to assure a geographic distribution throughout the state. To accomplish this geographic distribution, a minimum of three sections were selected from each of KDOT's six geographic districts. Sections were chosen from the top of the randomly generated list until each district had at least three sections. The list of the sections that were finally selected is shown in Table 7.

TABLE 7 Calibration Sections

Section #	Route	District	County of First Section	County Milepost		County of Second Section	County Milepost	
				Begin	End		Begin	End
1	K-25	6	Grant	23.78	24.7	Kearny	0	9.08
2	US-400	5	Greenwood	6.59	16.59			
3	K-4	6	Lane	12.97	22.97			
4	K-150	2	Marion	6.7	8.01	Chase	0	8.49
5	K-25	6	Kearny	32.48	39.03	Wichita	0	3.45
6	K-177	2	Chase	32.35	33.08	Morris	0	9.28
7	K-25	6	Kearny (Part 1)	12.88	16.15	Kearny (Part 2)	16.95	23.68
8	US-59	4	Labette	14.16	24.16			
9	US-169	4	Neosho (Part 1)	1.96	6.96	Neosho (Part 2)	8.27	13.27
10	K-181	3	Smith	2.4	12.4			
11	US-160	5	Cowley (E/W)	12.4	22.4			
12	K-2	5	Harper (E/W)	10.23	17.23	Harper (N/S)	18.07	21.07
13	US-83	3	Logan	19.12	29.12			
14	US-36	3	Smith	2.78	12.78			
15	K-99	1	Wabaunsee	31.01	41.01			
16	US-400	4	Labette	22.56	25.55	Cherokee	0	7.015
17	US-36	2	Republic	17.97	27.97			
18	US-75	1	Brown	0	10			
19	K-116	1	Atchison	0.99	10.99			

Some sections traversed county lines, and some sections had gaps in them because the randomly generated section had a city within its boundaries. In those cases, the city section was omitted and the limits of the section were extended to achieve a ten-mile section.

Once the sections are determined, there were specific data needed to perform the modeling. Table 8 lists the different data elements and their respective needs.

TABLE 8 Roadway Segment Calibration Data Needs

	Data Need		
Data Element	Required	Desirable	Default Assumption
Segment length	X		Need actual data
Average annual daily traffic (AADT)	X		Need actual data
Lengths of horizontal curves and tangents	X		Need actual data
Radii of horizontal curves	X		Need actual data
Presence of spiral transition for horizontal curves		X	Base default on agency design policy
Superelevation variance for horizontal curves		X	No superelevation variance
Percent grade		X	Base default on terrain
Lane width	X		Need actual data
Shoulder type	X		Need actual data
Shoulder width	X		Need actual data
Presence of lighting		X	Assume no lighting
Driveway density		X	Assume 5 driveways per mile
Presence of passing lane		X	Assume not present
Presence of short four-lane section		X	Assume not present
Presence of center two-way left-turn lane	X		Need actual data
Presence of center rumble strip		X	Base default on agency design policy
Roadside hazard rating		X	Assume roadside hazard rating = 3
Use of automated speed enforcement		X	Base default on current practice

Because KDOT statewide databases did not contain all of the required or desirable data, existing plans and other sources were consulted. Other sources included aerial photography and KDOT's Videolog. Table 9 contains a list of what specific elements were tapped to retrieve each of the specific data elements.

TABLE 9 Data Sources

Data Element	Data Source
Segment length	Developed in IHSDM
Average annual daily traffic	CANSYS/Historical maps
Lengths of horizontal curves and tangents	Existing plans
Radii of horizontal curves	Existing plans
Presence of spiral transition for horizontal curves	Existing plans
Superelevation variance for horizontal curves	Existing plans
Percent grade	Existing plans
Lane width	Existing plans / CANSYS
Shoulder type	Existing plans / CANSYS
Shoulder width	Existing plans / CANSYS
Presence of lighting	Videolog
Driveway density	Videolog / Aerial photography
Presence of passing lane	Existing plans / CANSYS
Presence of short four-lane section	Existing plans / CANSYS
Presence of center two-way left-turn lane	Existing plans / CANSYS
Presence of center rumble strip	Videolog
Roadside hazard rating	Videolog / CANSYS
Use of automated speed enforcement	None

Segment Length

One advantage of using the IHSDM software to model the predicted crashes is the determination of segment length. The user inputs the station at which the different elements change and the software automatically develops homogeneous segments based on those data. The software then calculates the length of each of the homogeneous segments.

AADT

As described above, the CANSYS database provided the 2007 AADT for each of the sections. The AADT did vary across many of the ten-mile sections. The breaks for the differing AADTs were converted from the milepost given in the database to a station that corresponded with the IHSDM input.

Since the AADT values also varied over the analysis period, additional AADTs were gathered for years 2005 and 2006. These AADTs were taken from historical traffic count maps and assigned stationing that corresponded to the ones taken from the CANSYS database.

Horizontal Alignment

The CANSYS database does not keep sufficient horizontal alignment information to meet the HSM needs. This includes the values for:

- Lengths of horizontal curves and tangents;
- Radii of horizontal curves;
- Presence of spiral transition for horizontal curves; and
- Superelevation variance for horizontal curves.

In order to retrieve this information for each of the 19 selected segments, the plans for the original highway grading were retrieved. This required researching and cross referencing several KDOT sources. The list of the selected sections with the individual project numbers and construction year can be found in Appendix E of this dissertation. When reviewing this list, it is worth noting that many of the sections were constructed under different route numbers than they currently carry. Therefore, even though the route number listed on the plans may be different than the route analyzed for this study they are the same section of roadway.

The existing plans contained all of the necessary horizontal alignment information. It was assumed that the current horizontal alignment is the same as the original grading. The only element that would likely deteriorate over time is the superelevation. As additional pavement overlays are placed, it can be difficult to maintain the existing plan superelevation. However, no better information was available than the original plans to estimate the existing superelevation.

Percent Grade

The percent grade information was also not contained in the CANSYS database. These data were also retrieved from the existing plans. Most of the plans explicitly stated the grade, but in some instances the grade needed to be approximated from the existing profile in the plans.

Cross Section Elements

The CANSYS database does contain information on cross section elements including:

- Lane width;
- Shoulder type;
- Shoulder width;
- Presence of passing lane;
- Presence of short four-lane section; and
- Presence of center two-way left-turn lane.

These elements were compared to the typical sections contained in the existing plans. Any time there was a discrepancy between database and the existing plans, then the KDOT Videolog or aerial photography were consulted.

Roadside Hazard Rating (*RHR*)

The CANSYS database does have values for the roadside foreslope. This information was supplemented with data collected from the KDOT Videlog. The reference information in the HSM and IHSDM were consulted for interpreting the RHR for the given attributes of a segment. It was originally hypothesized that retrieval of this particular element would be most difficult because existing databases do not carry this information and individual interpretation is needed along the entire length of the project being analyzed. Due to the relative flat and consistent nature of Kansas highways, the RHR value did not vary much either along a project or between different projects. Therefore, it was determined that directing resources to develop a surrogate for this value in the HSM would not be efficient.

Automated Speed Enforcement

At the time of this research, it was not the practice to use automated speed enforcement on Kansas Highways. For this reason, no automated speed enforcement was considered on any of the sections analyzed.

Other Elements

Three items needed or desired for the model were not available either in the CANSYS database or in the existing plans. The three elements are:

- Presence of lighting;
- Driveway density; and
- Presence of center rumble strip.

The presence of these three elements was determined using both the KDOT Videolog and aerial photography. No calibration sections were found to contain either lighting or centerline rumble strips. Driveway density was determined for each of the calibration sections analyzed. However, since driveways receiving only occasional use such as field entrances were not considered as part of the HSM, very few segments had greater than five driveways per mile. This led to almost all of the sections being assigned the default minimum value of five driveways per mile.

Summary

In additional to the above-listed elements, the crash locations and severity were also gathered from the crash database. Once the data for all of the sections were gathered, it was translated into plan stations and entered into the IHSDM. The input values for the 19 calibration sections can be found in Appendix F. An example of an output from an IHSDM model from the calibration sections is available in Appendix G.

After all the data were collected and inputted into the IHSDM, it was verified that the 19 ten-mile segments met the minimum number of sites, 30 to 50, for a valid calibration set. It was also verified that that the 19 segments totaled 437 observed crashes over a three-year period (146 crashes per year), meeting the minimum criteria of number of crashes.

VALIDATION MODEL DATA

For segments, the necessary data for modeling the validation projects were identical to the data necessary for modeling the calibration projects. Therefore, all of the same sources and techniques for gathering data for the calibration projects were used on the validation projects. The sole difference between the calibration data set and the validation data set was the method by which projects were selected. Appendix H contains a list of the inputs used for the validation projects. A sample output from a validation project can be found in Appendix I.

Project Selection

The primary function that the HSM crash prediction model could serve for KDOT is to assess the predicted safety benefits of highways being considered as part of a reconstruction project. For that reason, it was determined that random selection of Kansas highways was not appropriate for the segments to be validated. Instead, segments were selected that corresponded to a reconstruction project that was performed between 1999 and 2003. This timeframe allowed sufficient data after the project was constructed to compare the predicted versus observed crash performance. Selection of segments that experienced a geometric improvement project would also properly assess the model's ability to use existing crash data on the unimproved system to predict safety performance on the future improved section. This is more consistent with KDOT practice than analyzing segments that are static over time.

To achieve the desired project pool, a query was performed on KDOT's project management system (WinCPMS). All projects with the program category of "Modernization—Safety & Shoulder Improvements" were returned. This list was then manually screened for only two-lane rural highways over 2.5 miles in length. Ten projects were then selected from the list in the order they were provided from the query. To provide a mixed geographical representation, bias was added to this selection to ensure that at least one project was selected from each of KDOT's six districts. Some final modifications were done within the limits of the ten selected projects to remove any sections that passed through a city. Table 10 contains a list of the validation projects/sections that were selected for analysis.

TABLE 10 Validation Projects

Section	Project Number	Route	County	District	County Milepost	
					Begin	End
1	K-5393-01	K-383	Norton	3	0	13.618
2	K-5384-01	US-50	Chase	2	20.671	28.486
3	K-5745-01	US-56	Marion	2	32.051	39.815
4	K-5767-01	US-77	Butler	5	0	12.713
5	K-5391-01	US-283	Ness	6	13.944	30.202
6	K-5761-01	US-73	Atchison	1	0	4.142
7	K-5757-01	K-47	Wilson	4	5.573	7.747
8	K-5741-01	US-36	Rawlins	3	28.472	36.393
9	K-5749-01	K-156	Barton	5	18.61	35.81
10	K-5743-01	US-50	Hamilton	6	17.217	28.498

Crash Data

Because only crash data for 2005-2007 were obtained originally, supplemental crash data were needed to properly analyze the validation projects. To be consistent with anticipated future practices, data were requested for the three years prior to the project construction. These crashes were used for the EB procedure. Crashes were then requested through 2009, which were the most recent crash data available at the time of the study. These data were analyzed to compare the accuracy of the model prediction. The year(s) the project were under construction were removed from study to eliminate any bias related to traffic traveling through construction or travelers adjusting to new, unfamiliar roadway features. Even if construction was completed in the middle of the year, only full years were dropped to avoid biasing the data with seasonal impacts on crash frequency. Table 11 contains a list of the validation projects with the associated years of crash data that were used.

TABLE 11 Validation Projects, Years for Crash Analysis

				Years for crash data	
Section	Project Number	Notice to proceed	Completion date	Before	After
1	K-5393-01	9/21/1999	6/15/2001	1996-1998	2002-2009
2	K-5384-01	4/26/1999	4/15/2000	1996-1998	2001-2009
3	K-5745-01	7/23/2001	4/1/2003	1998-2000	2004-2009
4	K-5767-01	1/27/2003	1/3/2005	2000-2002	2006-2009
5	K-5391-01	2/9/1999	11/2/1999	1996-1998	2000-2009
6	K-5761-01	3/6/2001	11/4/2004	1998-2000	2005-2009
7	K-5757-01	2/23/2000	12/7/2001	1997-1999	2002-2009
8	K-5741-01	1/2/2001	8/9/2002	1998-2000	2003-2009
9	K-5749-01	5/24/2000	9/18/2001	1997-1999	2002-2009
10	K-5743-01	8/28/2000	12/8/2001	1997-1999	2002-2009

SUMMARY

Some of the greatest value of this research is related to the manner and accuracy with which data were collected.

- All of the data, both required and desirable, were collected for all of the calibration and validation sections. Since no default values were utilized, this study examined the full capacity of the HSM CPM for rural two-lane highways.

- Validation sections were selected in a manner that was most consistent with how the HSM CPMs would be utilized in practice.

- Application of the HSM for Kansas rural highways will account for only segments that do not go through a city of any size. This is a level of screening not previously considered in any other study. It is more limiting than the HSM definition, which follows the FHWA definition of segments outside a city of population 5,000 or greater.

These findings, while important, did not create further evolution of the research plan beyond what was established from Chapter II – Literature Review.

CHAPTER IV – CALIBRATION

The HSM recognizes that the base formulas and default values originally used to develop the crash prediction models may not be applicable for every jurisdiction or state (*13*). For that reason, Appendix A of Part C of the HSM describes calibration procedures that can be used to help provide results that are meaningful and accurate for each jurisdiction. It is a primary goal of this research to determine the appropriate calibration for KDOT projects and to develop a procedure by which these calibrations can be perpetuated in the future or be used for crash prediction models beyond just the two-lane rural highway model.

The HSM proposes three methods that can be performed periodically at an administrative level and applied to future iterations of the model. These methods are to replace selected default values of the models, to develop calibrations for the SPFs provided by the HSM, and to develop jurisdiction-specific SPFs. Each of these three methods can use the entire state highway system as a jurisdiction or develop smaller jurisdictions if particular geographic areas of the state perform differently than other areas.

The first step of the calibration performed with this research was to replace the selected default values of the models. In doing so, analysis of the crash characteristics determined if there were any geographic areas of the state that demonstrated different crash characteristics. The next step in the research was to follow the model calibration procedure either on a statewide basis or by selected jurisdictions. Development of jurisdiction-specific SPFs was beyond the scope of this research due to the intensive amount of work needed to complete such an effort. If the accuracy obtained by calibrating the existing SPFs does not meet agency expectations, then KDOT will know that the development of jurisdiction-specific SPFs may be performed to attempt to improve the prediction accuracy.

In addition to the administrative-level calibrations listed above, the HSM also recommends a project-specific calibration that may be performed for each individual analysis. This calibration entails using the EB procedure to combine predicted and observed crash frequencies. With the help of the IHSDM, this procedure was relatively easy to perform if site-specific crash data were available, which it was for Kansas highways. As part of the validation step, all sections modeled had results developed both with and without using the EB procedure. This analysis will determine what additional accuracy is brought by use of the EB procedure. The results of this analysis are provided in Chapter VI – Validation.

REPLACEMENT OF SELECTED DEFAULT VALUES

The HSM states that replacement of selected default values is recommended but not necessary to achieve satisfactory results. If the replacement values were going to be calculated, it was recommended to do so before performing the other calibrations. Since the data necessary to perform this calibration procedure were available through statewide databases, it was performed first. In addition, the data necessary for this procedure could be segregated by county or by district and, therefore, provide insight as to any regions within the state that displayed different crash characteristics.

The HSM recommends replacement of only certain default values for two-lane rural highway segments, which are shown in table 12.

TABLE 12 Default Items That May Be Calibrated to Local Conditions

Table or Equation Number	Data Element or Distribution That May Be Calibrated to Local Conditions
Table 10-3	Crash severity by facility type for roadway segments
Table 10-4	Collision type by facility type for roadway segments
Equation 10-18	Driveway-related crashes as a portion of total crashes (pdwy)
Table 10-12	Nighttime crashes as a proportion of total crashes by severity level

Experimental Design

The Kansas Motor Vehicle Accident Report (KDOT Form 850A) listed crash severity, collision type, whether the crash was intersection-related or not, what type of traffic control was present, and light conditions. The Kansas Motor Vehicle Accident Report also had a driveway-related crash location called, “Access to Parking Lot / Driveway.” This was used to develop a KDOT-specific value to be used in Equation 10-18. Thanks to the detail of data available, KDOT specific values were able to be calculated for the all of the recommended segment tables and equations with little modification needed to the basic report data provided.

Some interpretation of the Kansas Motor Vehicle Accident Report fields was needed to categorize the collision types into similar categories as those provided by the HSM. A key is provided in Appendix C of this dissertation to describe the translation used for this study.

Results

Crash Severity, HSM Table 10-3

The first exhibit that was developed for KDOT-specific jurisdiction was Table 10-3 from the HSM, Default Distribution for Crash Severity Level on Rural Two-Lane, Two-Way Roadway Segments. This distribution was developed by analyzing all crashes in the data set that were not intersection or intersection-related. Each crash was counted only once and was attributed to the highest severity level. So, if a crash had both incapacitating injuries and non-incapacitating injuries, it was only counted as incapacitating. Table 13 contains both the KDOT calculated and HSM default distributions for crash severity level.

TABLE 13 Crash Severity Level on Rural Two-Lane Roadway Segments

	KDOT		HSM
Crash Severity Level	Count	Percent	Percent
Fatal	270	1.5	1.3
Incapacitating (disabled) injuries	495	2.7	5.4
Non-incapacitating injuries	1574	8.7	10.9
Possible injury	966	5.3	14.5
Total fatal and injury	3305	18.3	32.1
Property damage only	14791	81.7	67.9
Total	18096	100.0	100.0

Collision Type, HSM Table 10-4

The second exhibit that was developed for KDOT-specific jurisdiction was HSM Table 10-4, Default Distribution by Collision Type for Specific Crash Severity Levels on Rural Two-Lane, Two-Way Roadway Segments. For this exhibit, the same crashes used for HSM Table 10-3 were used, but were further broken down by collision type. Once the crashes were distributed into Property Damage Only (PDO) and Total Fatal and Injury (F&I), the crashes were assigned using the collision types available in the Kansas Motor Vehicle Accident Report. Table 14 shows the distribution of collisions for Kansas rural two-lane highways.

TABLE 14 Collision Type Distribution for Kansas Rural Two-Lane Highways

Collision Type	F&I		PDO		Total Crashes	
	County	Percent	Count	Percent	Count	Percent
Collision with animal	345	10.4	10320	69.8	10665	58.9
Collision with pedestrian	22	0.7	0	0.0	22	0.1
Collision with cyclist	13	0.4	0	0.0	13	0.1
Overturned	893	27.0	559	3.8	1452	8.0
Ran off road	481	14.5	754	5.1	1235	6.8
Collision with legally parked vehicle	13	0.4	89	0.6	102	0.6
Collision with railway train	5	0.2	0	0.0	5	0.0
Collision with fixed object	644	19.5	1312	8.9	1956	10.8
Collision with other object	13	0.4	138	0.9	151	0.8
Other non-collision	64	1.9	300	2.0	364	2.0
Total single vehicle	2493	75.4	13472	91.1	15965	88.2
Angle collision	192	5.8	221	1.5	413	2.3
Head-on collision	167	5.0	27	0.2	194	1.1
Rear-end collision	266	8.0	471	3.2	737	4.1
Sideswipe: opposite direction	135	4.1	187	1.3	322	1.8
Sideswipe: same direction	36	1.1	203	1.4	239	1.3
Backed into	6	0.2	92	0.6	98	0.5
Other	11	0.3	113	0.8	124	0.7
Unknown	2	0.1	2	0.0	4	0.0
Total multiple-vehicle collisions	815	24.6	1316	8.9	2131	11.8

Since the collision types available in the Kansas Motor Vehicle Accident Report did not match those provided in the HSM, some additional sorting was necessary in order to compare the values. In the single vehicle crashes, collisions with legally parked vehicles, fixed objects, and other objects were assigned to "Ran Off Road." Because all of these elements exist outside the normal roadway, it can be assumed a departure from the roadway was necessary in order to collide with them. "Collisions with Railway Train" was combined with "Other Non-Collision" under the heading "Other Single Vehicle Crash." Similarly in the Multiple-Vehicle Crashes, the "Backed Into" and "Unknown" collision types were assigned to the "Other" category. After performing this sorting, a collision type distribution was developed for KDOT data to replace HSM Table 10-4. Table 15 contains both the KDOT calculated values and the default HSM values for contrast.

TABLE 15 Collision Type Distribution Values for KDOT and HSM

Collision Type	KDOT F&I	KDOT PDO	KDOT Total	HSM F&I	HSM PDO	HSM Total
Single-Vehicle Collisions						
Collision with animal	10.4%	69.8%	58.9%	3.8%	18.4%	12.1%
Collision with cyclist	0.7%	0.0%	0.1%	0.4%	0.1%	0.2%
Collision with pedestrian	0.4%	0.0%	0.1%	0.7%	0.1%	0.3%
Overturned	27.0%	3.8%	8.0%	3.7%	1.5%	2.5%
Ran Off Road	34.8%	15.5%	19.0%	54.5%	50.5%	52.1%
Other single-vehicle	2.1%	2.0%	2.1%	0.7%	2.9%	2.1%
Total single vehicle	75.4%	91.1%	88.2%	63.8%	73.5%	69.3%
Multiple-Vehicle Collisions						
Angle collision	5.8%	1.5%	2.3%	10.1%	7.2%	8.5%
Head-on collision	5.0%	0.2%	1.1%	3.4%	0.3%	1.6%
Rear-end collision	8.0%	3.2%	4.1%	16.5%	12.2%	14.2%
Sideswipe collision	5.2%	2.7%	3.1%	3.8%	3.8%	3.7%
Other multiple-vehicle	0.6%	1.3%	1.2%	2.6%	3.0%	2.7%
Total multiple-vehicle collisions	24.6%	8.9%	11.8%	36.2%	26.3%	30.7%

Driveway Related Crashes, HSM Equation 10-18

HSM Equation 10-18 allows for replacement of a jurisdiction-specific value for the percentage of driveway-related crashes as a portion of total crashes. There were a total of 18,096 segment crashes. According to the crash data, 284 of them were driveway or parking lot related. That yielded a proportion of p_{dwy} equal to 0.016.

Nighttime Crash Proportions, HSM Table 10-12

The third and final table of default values for segments is Table 10-12, Nighttime Crash Proportions for Unlighted Roadway Segments. Kansas Motor Vehicle Accident Report had five different values for light conditions:

- Daylight;
- Dawn;
- Dusk;
- Dark: street lights on;
- Dark: no street lights; and
- Unknown.

Crashes marked as "Unknown" represent a very small portion of the total crashes and may have been caused by failure to document the light condition or arriving at an crash site after the crash had occurred. For purposes of determining the proportions necessary for Table 10-12, the crashes labeled as either "Dark: street lights on" or "Unknown" were removed from in the count of total crashes. Crashes for dawn and dusk were assigned to the light condition. The crashes in each category are shown in Table 16.

TABLE 16 Crash Distribution by Light Condition

Light Condition	PDO	F&I	Total
Unknown	36	7	43
Dark (lights on)	1147	231	1378
Light	7311	2792	10103
Dark (no lights)	7914	1172	9086
Total minus Unkown minus Dark (lights on)	15225	3964	19189

From these data, the replacement values were developed for HSM Table 10-12 and are shown in Table 17 along with the HSM default values for contrast.

TABLE 17 Nighttime Crashes as a Portion of Total Crashes by Severity Level

	p_{inr}	p_{pnr}	p_{nr}
KDOT	0.207	0.793	0.47
HSM	0.382	0.618	0.37

Where:

p_{inr} = proportion of total nighttime crashes for unlighted roadway segments that involve a fatility 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

Analysis

Collision Type

Analysis of the first replaced distribution shows that KDOT crashes are typically less severe than those provided in the default jurisdiction. The default distribution had 32.1percent of crashes result in fatality or injury. KDOT crashes had only 18.3 percent of crashes that result in fatality or injury. These values could show that KDOT highways were more forgiving than the default states. However, this difference could also be attributed to different reporting standards for crashes in the two states[i], or it could be due to the high percentage of animal collisions described below. Only 3.2 percent of animal collisions on two-lane rural highways in Kansas result in an injury or fatality.

Analysis of the second distribution, regarding collision types, is the most telling regarding how the nature of crashes on Kansas highways could impact how those crashes are modeled. On Kansas highways, 58.9 percent of segment crashes were collisions with animals. This is compared to only 12.1 percent of crashes in the default distribution. This is significant first because the KDOT value is almost five times the default value. It is also significant because animal collision crashes account for a majority of crashes on Kansas two-lane rural highway segments.

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[i] The HSM provided a default crash distribution for highway segments that was based on data from the state of Washington for the period from 2002 to 2006. These distributions were different than the distributions of the data used during the original development of the crash prediction model, found in Prediction of the Expected Safety Performance of Rural Two-Lane Highways (42). For this study, it was determined that there was value in comparing results of this research to both distributions. However, for Table 10-3 in the HSM, it was determined the values given were actually from the Prediction of the Expected Safety Performance of Rural Two-Lane Highways (42) study and not the Washington data as cited in the manual. This discrepancy has been brought to AASHTO's attention and will be addressed in future versions of the manual.

To get a better understanding of the impact of collision type distribution on the crash prediction model, Table 18 contains a comparison of the Kansas distribution with the HSM default and the distribution developed in Prediction of the Expected Safety Performance of Rural Two-Lane Highways (11). This study is the original study from which the HSM's SPF for highway segments was developed.

TABLE 18 Collision Distribution Comparison

Collision Type	Kansas	Washington Minnesota (42)	HSM Default
Single-Vehicle Collisions			
Collision with animal	58.9%	30.9%	12.1%
Collision with cyclist	0.1%	0.5%	0.2%
Collision with pedestrian	0.1%	0.3%	0.3%
Overturned	8.0%	2.3%	2.5%
Ran Off Road	6.8%	28.8%	52.1%
Other single-vehicle	2.0%	3.6%	2.1%
Total single vehicle	88.2%	66.3%	69.3%
Multiple-Vehicle Collisions			
Angle collision	2.3%	3.9%	8.5%
Head-on collision	1.1%	1.9%	1.6%
Rear-end collision	4.1%	13.9%	14.2%
Sideswipe collision	1.8%	9.8%	3.7%
Other multiple-vehicle	0.7%	4.1%	2.7%
Total multiple-vehicle collisions	11.8%	33.7%	30.7%

While the original study showed a percentage of animal collisions 2.5 times higher than the default in the HSM, it was still nearly half of the rate for Kansas highways. The ability to model these animal collisions has a major impact on crash prediction on KDOT highways. Therefore, this issue will be examined in further depth in Chapter V – Animal Collision. One impact this skewed distribution may have is that the p_{ra} value calculated for CMF 1 and CMF 2 is different between the KDOT and default distributions. Specifically, the default p_{ra} value was 57.4 percent while the KDOT p_{ra} value was 23.2 percent. The impact of this difference is quantified below, in Table 20.

The distributions were also calculated by district to determine if there were any geographic trends in collision type that would signal that more specific geographic dissection of the distributions was warranted versus using a single statewide distribution. Table 19 contains the collision type distribution by KDOT district.

TABLE 19 Collision Type Distribution by KDOT District

	KDOT District					
Collision Type	1	2	3	4	5	6
Collision with animal	52.7%	65.0%	65.3%	56.2%	66.3%	44.2%
Collision with pedestrian	0.1%	0.2%	0.1%	0.1%	0.1%	0.3%
Collision with cyclist	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Overturned	7.8%	7.2%	10.0%	7.2%	6.1%	15.1%
Ran Off Road	9.0%	6.3%	5.7%	7.8%	4.3%	7.3%
Collision with legally parked vehicle	0.5%	0.5%	0.7%	0.4%	0.6%	1.0%
Collision with railway train	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%
Collision with fixed object	14.3%	9.9%	8.5%	12.1%	8.3%	9.1%
Collision with other object	0.7%	0.8%	0.5%	1.1%	0.8%	1.1%
Other non-collision	1.8%	1.7%	1.2%	1.9%	2.5%	3.3%
Total single-vehicle crashes	86.9%	91.9%	92.0%	86.8%	89.0%	81.6%
Angle collision	2.3%	1.9%	2.1%	3.0%	1.8%	2.5%
Head-on collision	1.0%	0.6%	0.8%	1.0%	1.2%	2.4%
Rear-end collision	5.3%	2.6%	2.6%	4.6%	3.3%	5.9%
Sideswipe: opposite direction	1.9%	1.1%	0.9%	2.0%	1.5%	4.0%
Sideswipe: same direction	1.1%	1.2%	1.0%	1.4%	1.4%	2.1%
Backed into	0.4%	0.5%	0.4%	0.5%	0.7%	0.6%
Other	0.9%	0.2%	0.2%	0.7%	1.0%	1.0%
Unknown	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Total multiple-vehicle collisions	13.1%	8.1%	8.0%	13.2%	11.0%	18.4%

Based on these data, it appeared the distribution of crashes by collision type is fairly consistent across the different regions of Kansas. The most glaring differences are that District 6 had a noticeably lower rate of animal crashes and a higher rate of overturned vehicles. The issue of the frequency of animal crashes will be addressed in Chapter V – Animal Collision. The difference in overturned vehicles may be worth investigating from an overall standpoint but does not warrant a separate calibration in the HSM.

Nighttime Crashes

Analysis of KDOT highways distribution for nighttime driving crashes on segments showed that Kansas had a slightly higher rate of crashes occurring at night versus the default value. Table 17 also shows that the severity of nighttime crashes was consistent with the overall system rate. Specifically, 20.7 percent of unlighted nighttime crashes were fatal or injury as compared to 18.3 percent for the whole system. Any differences in this distribution would have no impact on the overall study outcomes since none of the highways analyzed for the calibration or validation were lighted.

MODEL CALIBRATION PROCEDURE

Experimental Design

According to the HSM for rural two-lane highway crash prediction, four different 'C' factors are utilized and can be recalculated for a specific jurisdiction. One 'C' factor address segments, and three 'C' factors cover the three distinct intersection types: three-leg with minor stop control, four-leg with minor stop control, and four-leg signalized intersection. While the procedure described is the same for segments and intersections, only the segment calibrations were completed as part of this research.

The purpose of the 'C' factors is to account for jurisdictional differences in climate, driver populations, animal populations, crash reporting thresholds, and crash reporting system procedures. The factors are based on a ratio of observed crashes for a particular site versus the predicted crashes for that same site. The HSM suggests developing different calibration factors within a given jurisdiction if there is a significant variation in climate or topography.

Calculating the calibration factors in the HSM involves a five-step process. Step 1 is to identify the facility types to be calibrated. This research investigated solely rural two-lane two-way segments. Step 2 is to select sites for calibration of the methodology for each facility type. Step 3 is to obtain data for each facility type applicable to a specific calibration period. Steps 2 and 3 are closely linked because the selection of facilities is tied to the ease of collecting data for those facilities. Since no formal stratification is needed in calibration, the HSM suggests selecting sites in a manner that makes data collection for Step 3 as efficient as possible. If no significant data collection advantage is obtained by direct selection of the sites, then it is desirable that the sites are chosen from random selection. The only firm guidance given for Step 2 is that the calibration data set should include 30 to 50 sites that experience a total of at least 100 crashes per year.

Step 4 of the calibration process is to apply the crash prediction methodology to predict the total crashes for all of the selected sections. The predictions should be run without using the calibration factor and without using the EB procedure. However, as called for in the HSM, the default distributions calculated above were substituted before running the models.

The final step in the process is to compute the calibration factor. The computation is performed separately for each calibration factor using the equation:

$$C_r \left(\text{or } C_i\right) = \frac{\sum_{\text{all sites}} \text{observed crashes}}{\sum_{\text{all sites}} \text{predicted crashes}}$$

Results

The collection of data to cover Steps 1, 2, and 3 are covered previously in Chapter III – Data Collection. To complete Step 4, the data gathered for each of the 19 calibration sections were placed in the IHSDM. Per the guidance in the HSM, the models were run with the KDOT specific values for the crash distribution. To quantify the impact of changing the distributions, the calibration sections were run through the model with both the default and KDOT specific distributions. Table 20 shows the number of predicted crashes for each of the calibration sections using the different distributions.

TABLE 20 Predicted Crashes with Using KDOT and HSM Collision Distributions

Section	HSM Default	KDOT	Percent Difference
1	13.27	12.26	8.24%
2	28.74	30.12	-4.58%
3	3.81	3.76	1.33%
4	10.13	9.86	2.74%
5	3.96	3.83	3.39%
6	7.18	6.8	5.59%
7	8.54	8.05	6.09%
8	25.95	26.54	-2.22%
9	25.75	26.98	-4.56%
10	3.08	2.99	3.01%
11	18.08	17.01	6.29%
12	15.73	14.86	5.85%
13	15.68	14.46	8.44%
14	13.12	13.3	-1.35%
15	25.8	25.24	2.22%
16	30.58	32.05	-4.59%
17	10.46	10.53	-0.66%
18	28.85	30.24	-4.60%
19	7.77	7.38	5.28%
Total	296.48	296.26	0.07%

The change in distributions caused as much as an 8.4 percent change in any given section but created only a 0.07 percent overall change in the predicted number of crashes. This analysis is valuable because no previous research has shown the project-level impact of using a jurisdiction-specific distribution. On the aggregate, even though the KDOT- specific distribution results will be used, it will not impact the final calibration value calculated. This is consistent with the findings of previous research (*26*).

Because of the relative uniform nature of Kansas highways and because none of the previous analyses indicated that additional geographic dissection of the state was necessary, the primary focus was to develop one calibration factor for the entire state. The following is a list of the results of modeling the selected 19 ten-mile sections showing the predicted number of crashes, with KDOT-specific values used, and the observed number of crashes. The two values were then used to develop the ratio of observed crashes to predicted crashes for each section (OP Ratio). The OP Ratio is effectively the calculated calibration factor for each individual calibration section. The OP Ratio of the total observed and predicted crashes is the same as the calibration value as defined in the HSM. The term OP Ratio is used to distinguish if an individual calibration section or the total statewide data is being used. For sections with values greater than one the model under predicted the number of crashes. Inversely, sections with OP ratios less than one over predicted the number of crashes. In addition to the crash values, the composite AADT over the study period and KDOT district were provided in Table 21. These data were used to further analyze the calibration results.

TABLE 21 Crash Prediction Results for Calibration Sections

Section	District	AADT	Predicted	Observed	OP Ratio
1	6	1457	12.26	18	1.47
2	5	4389	30.12	26	0.86
3	6	459	3.76	3	0.80
4	2	1388	9.86	8	0.81
5	6	497	3.83	3	0.78
6	2	778	6.80	9	1.32
7	6	1000	8.05	9	1.12
8	4	3498	26.54	42	1.58
9	4	3921	26.98	36	1.33
10	3	406	2.99	3	1.00
11	5	2140	17.01	28	1.65
12	5	1925	14.86	35	2.36
13	3	1941	14.46	12	0.83
14	3	1704	13.30	24	1.80
15	1	3038	25.24	58	2.30
16	4	4365	32.05	36	1.12
17	2	1337	10.53	34	3.23
18	1	4030	30.24	35	1.16
19	1	795	7.38	18	2.44
Total			296.26	437	1.48

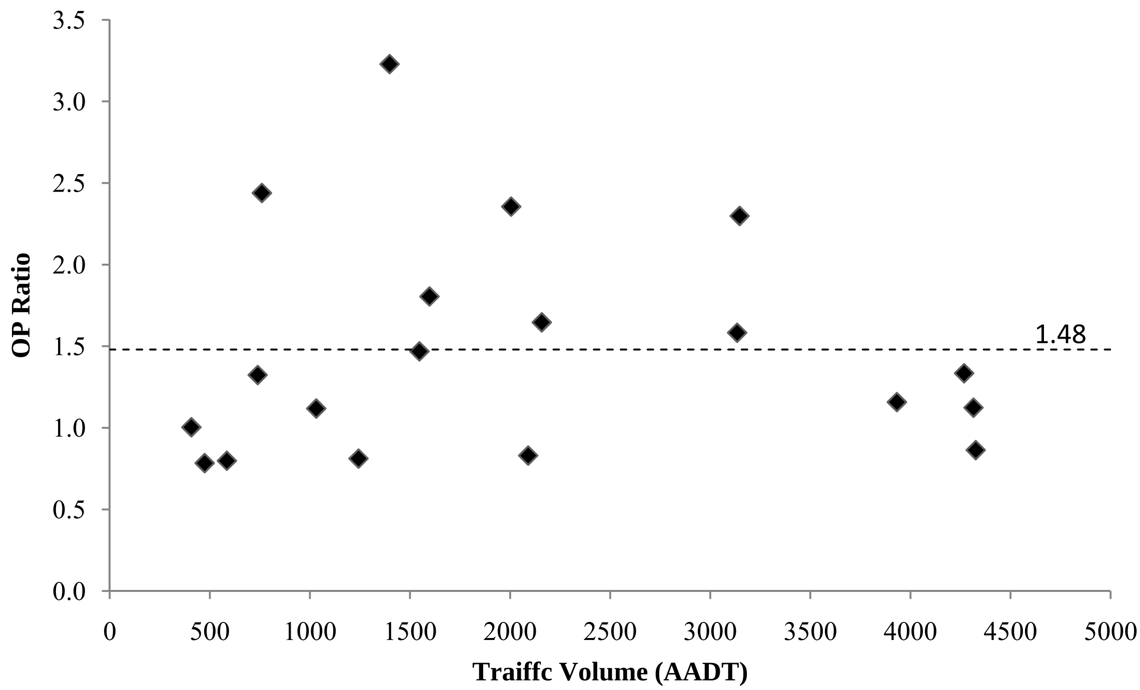
Analysis

A basic statistical analysis of the OP Ratios was performed and showed that the average of the OP Ratios was 1.47; the standard deviation was 0.68. The overall calibration value of 1.48 and the average of the OP Ratios, 1.48, were extremely close and demonstrated that no individual segment with a high number of crashes disproportionately weighed on the results. However, the fact that the standard deviation of OP ratios was nearly half of the calibration factor indicated that there may be some weakness in the value of this single statewide calibration value. The size of the calibration value and the distance from 1.00 have no reflection on the model accuracy. The value only quantifies the relationship of traffic volume and segment length to crash rate for Kansas highways.

To check the validity of the calibration, the data were screened for outliers that could contribute disproportionably to final results. The data for section 17 was an outlier because the OP Ratio for that segment is 3.23, 118% higher than the average calibration. All of the other values are within 65% of the average calibration. The average and standard deviation were recalculated with the data for section 17 removed. The total calibration factor for that set was 1.41; the average of the OP Ratios was 1.37; the standard deviation of the OP ratios was 0.55. Clearly, removing section 17 from the data improves the tightness of the fit of the data but only changes the overall calibration from 1.48 to 1.41. The difference of 0.07 was less than 15 percent of the standard deviation of the OP Ratios. For this reason, the data for section 17 remained in the data set and a statewide calibration of 1.48 will be carried forward.

Additional scrutiny was given to determine if there was any tendency in the sections that yielded lower calibration values versus those that yield higher calibration values. The first tendency addressed was the correlation of the OP Ratio of a section to the composite AADT of that section. While AADT is already considered by the model, the hypothesis of this investigation was that low-volume and high-volume roads perform differently. Figure 5 shows a graph of this relationship of OP Ratio and traffic volume.

FIGURE 5 Traffic Volume versus OP Ratio



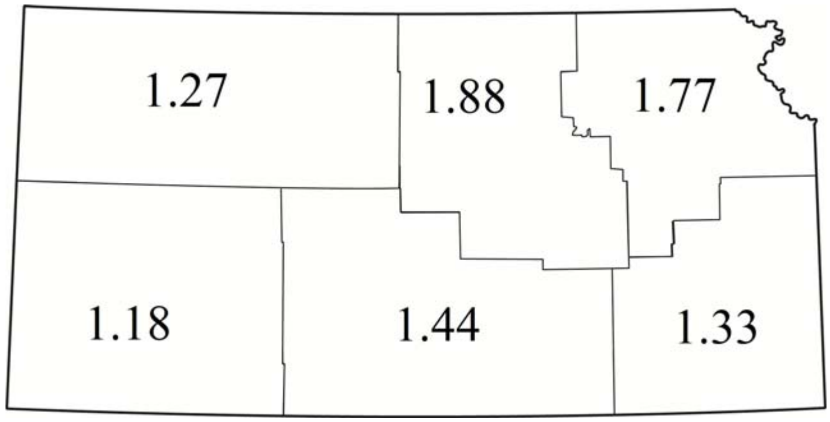
Based on Figure 5, there does not appear to be any relationship between traffic volume and the OP Ratios of the calibration sections.

Even though the collision type analysis did not reveal any geographic tendencies, it was still worth investigating if any geographic tendencies were revealed by the OP Ratio calculated for each section. To accomplish this comparison, the individual sections were grouped by district, as shown in Table 22 and Figure 6.

TABLE 22 OP Ratio by KDOT District

District	Total Predicted	Total Observed	OP Ratio
1	62.86	111	1.77
2	27.19	51	1.88
3	30.75	39	1.27
4	85.57	114	1.33
5	61.99	89	1.44
6	27.9	33	1.18
Total	296.26	437	1.48

FIGURE 6   Map of OP Ratio by KDOT District



There was some consistency of model performance when the calibration sections were grouped geogrpahically by district. However, the number of observed crashes in any of districts barely reached one-third of the 100 crashes per year prescribed by the HSM. To address the shortfall and strengthen this geographic analysis, the districts were paired together by combining adjoining districts with similar OP Ratios. The two westernmost Distrcts, 3 and 6, had the two lowest OP Ratios so they were paired together. These also corresponded to the two least densely populated districts and were both dominated by rural land use. The two highest OP Ratios belonged to the districts in the north central and northeast regions of the state, Districts 1 and 2. The population density and travel demand in these areas of the state were also very simiar. The middle calibrations belonged to the southeast and southcentral Disctricts, 4 and 5. Again, these districts generally had similar geographic and population distributions in their rural sections. After pairing the calibration results by district, the following results were found, as shown in Table 23. The average OP Ratio and standard deviation were calculated using all of the individual calibration sections assigned to that District.

TABLE 23   OP Ratio by Paired District

Districts	Total Predicted	Total Observed	OP Ratio for District Pair	Average OP Ratio	Standard Deviation
1 & 2	90.05	162	1.8	1.73	0.93
3 & 6	58.65	72	1.23	1.13	0.39
4 & 5	147.56	203	1.38	1.48	0.52
Total	296.26	437	1.48	1.47	0.68

Overall, the grouping of sections to develop separate geographic calibrations did not appear to improve the tightness of the data. For the District 1 and 2 area, the standard deviation of the calibration values got worse. Only the District 3 and 6 area improved, but that was also the area with the lowest sample size. For the purposes of this study, no geographic tendencies seemed to be beneficial for use with the HSM calibration procedure in Kansas, so they were not considered further. There may be promise in future studies addressing calibration by geography within the state. More flexible boundaries may need to be considered beyond the district boundaries.

For additional comparison, calibration values that were calculated for other states using the HSM two-lane rural highway model were obtained and shown in Table 24. The calibration for Washington State was obtained from unpublished documentation (42). The values for Oregon (*26*) and Louisiana (24) were both derived from studies described in Chapter II – Literature Review.

TABLE 24 Calibration Value Comparison

State	Years	Calibration
Kansas	2005-2007	1.48
Washington	2002-2006	1.19
Oregon	2004-2006	0.74
Louisiana	1999-2001	1.63

Instead of determining the calibration factors for the default SPF, some agencies may choose to use their own data to develop a jurisdiction-specific SPF. These SPFs must be developed using a statistically valid methodology and conform to the HSM predictive method. To accomplish this, the HSM provides some guidelines for developing SPFs. A statistical technique like negative binomial regression is encouraged to account for overdispersion typically found in crash data. An overdispersion factor would need to be determined so the EB method can later be applied to the SPF. The jurisdiction-specific SPF should include the effects for mainline and sideroad AADT and have a function in which crash frequency is directly proportional to segment length. Finally, the jurisdiction-specific SPF should use the same base conditions as the default SPF used in the model. To accomplish this, two types of data sets can be used. The SPFs can be developed either from only data that represent the base condition or data from a broader set of conditions, but relate the results back to the base condition using the appropriate CMFs. No guidance is given related to the sample size necessary to develop a jurisdiction-specific SPF. Such work is beyond this study but should be considered in future research.

It is worth noting that the HSM recommends recalibrating the model at a frequency equal to the number of years of crash data used. Based on the data collected for this research, it is recommended that the calibration factors be recalculated for Kansas highways once crash data are available for years 2008 – 2010.

EB PROCEDURE

The HSM promotes use of the EB method to improve the accuracy of crash predictions by combining the results of the predictive model with observed crash data. This method can help to address the random nature of crashes and the negative effect of crash spikes on prediction. This phenomenon is called regression-to-the-mean in statistics. The EB method can be used to predict the crashes on a highway that is not being improved. If the highway is being improved, then the scope of the improvements needs to be considered. The EB method should not be used on projects where new alignments are being considered, the number of through lanes are changing, or that have intersections planned for major reconfiguration. If a project varies in scope, it is acceptable to only apply the EB method to relatively unaffected segments.

If using the EB method, it is desirable if at least two years of crash data are available on the roadway. Crashes assigned to a particular segment or intersection are preferable. However, if specific crash locations are not known, crashes can be assigned across the entire section being modeled. These two variations of the EB procedure are called the site specific and project level procedure, respectively.

Site Specific EB Procedure

Once the data are obtained, the following equation is used to apply the site specific EB procedure:

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

$$w = \frac{1}{1 + k \times \left(\sum_{\text{all study years}} N_{\text{predicted}} \right)}$$

Where:

$N_{expected}$ = estimate of expected average crash frequency for the study period;

$N_{predicted}$ = predictive model estimate of average crash frequency predicted for the study period under the given condition;

$N_{observed}$ = observed crash frequency at the site over the study period;

w = weighted adjustment to be placed on the predictive model estimate; and

k = overdispersion parameter of the associated SPF used to estimate $N_{predicted}$.

The equations provide for weighting of the predicted and observed crash values based on the overdispersion parameter associated with the SPF used to predict the number of crashes. Because of this factor, more weight is put on the predicted number of crashes when the overdispersion parameter for the prediction is lower. Conversely, more weight is put on the observed number of crashes when the overdispersion parameter is higher. The equation for weighting the crashes also considers the number of predicted crashes. As the number of predicted crashes increase, the weight on predicted crashes decrease. “This might seem counterintuitive at first. However, this implies that for longer sites and for longer study periods, there are more opportunities for crashes to occur. Thus, the observed crash history is likely to be more meaningful and the model prediction less important”(*13*).

Project Level EB Procedure

The project-level EB procedure utilizes a different set of equations because the overdispersion of different segments in a project are not related. Additionally, it cannot be assumed that crash frequency of the different sites across a project are statistically correlated. For this reason, a more complex EB method was developed to figure the expected number of crashes. This method calculates the number of crashes assuming both statistical independence (r = 0) and perfect correlation (r = 1). The two values are then averaged to develop the expected average crash frequency. Because the project level EB procedure is more complex and less accurate, the site-specific EB procedure is preferred and used in this study. The project-level EB procedure was dropped from further consideration.

In order to forecast the number of crashes for a future period, differences in traffic volume, duration of study, and design features that effect CMFs must all be considered between the before and after conditions; the following equation does this.

$$N_f = N_p\left(\frac{N_{bf}}{N_{bp}}\right)\left(\frac{CMF_{1f}}{CMF_{1p}}\right)\left(\frac{CMF_{2f}}{CMF_{2p}}\right)\cdots\left(\frac{CMF_{nf}}{CMF_{np}}\right)$$

Where:

N_f = expected average crash frequency during the future time period for which crashes are being forecast for the segment or intersection in question (i.e., the after period);

N_p = expected average crash frequency for the past time period for which observed crash history data were available (i.e., the before period);

N_{bf} = number of crashes forecast by the SPF using the future AADT data, the specified nominal values for geometric parameters, and—in case of a roadway segment—the actual length of the segment; and

N_{bp} = number of crashes forecast by the SPF using the past AADT data, the specified nominal values for geometric parameters, and—in case of a roadway segment—the actual length of the segment;

CMF_{nf} = value of the nth CMF for the geometric conditions planned for the future (i.e., proposed) design; and

CMF_{np} = value of the nth CMF for the geometric conditions for the past (i.e., existing) design.

The *Nbf* and *Nbp* term are used to account for changes in the traffic volume and study period.

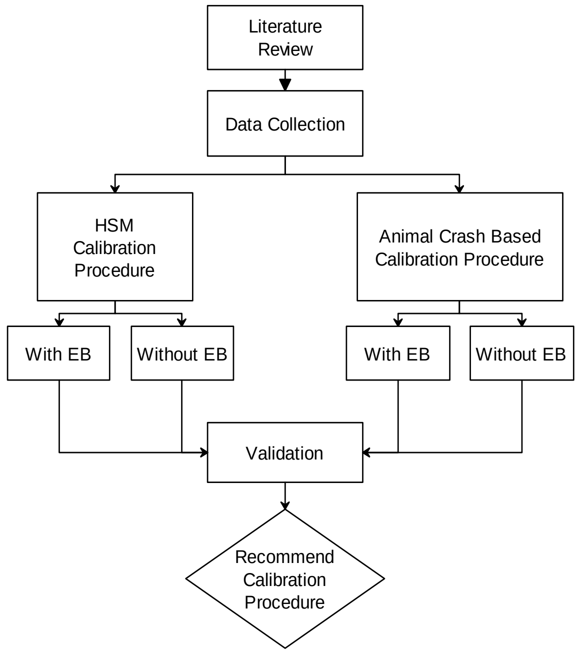
Since the EB procedure is meant to be performed on sections with before and after crash data and with the calibration factor being utilized for the model, the EB procedure will not be performed on these calibration sections. Instead it will be performed on the validation projects and evaluated in Chapter VI – Validation.

SUMMARY

For this study, the first parts of the segment calibration procedures were performed for the two-lane rural highway crash prediction model of the HSM, as prescribed in Appendix A of Part C. A number of different derivations of the model were considered, but ultimately development and use of a single statewide crash distribution and calibration factor produced the most consistent results. Therefore, the distributions given above for the HSM Tables 10-3, 10-4, and 10-12 and Equation 10-18 were recommended for implementation by KDOT. A statewide calibration factor of 1.48 was carried forward and evaluated in Chapter VI – Validation. Because the standard deviations of the OP Ratios calculated for the individual calibration sections were so high, there was concern with the accuracy of the model when only a single statewide calibration factor was used. The EB procedure can help improve the accuracy of the model. The accuracy of the model using a single statewide calibration and the improvement brought by the EB procedure will be determined in Chapter VI – Validation.

An additional finding from this section was the weight of animal crashes for two-lane rural highways in Kansas. For this reason, animal crashes became the focus for the previously contemplated research derived calibration procedure. The research plan was refined to account for these findings, as displayed in Figure 7.

FIGURE 7 Diagram of Dissertation Research Performed - Calibration



Also worth noting is that the lower volume roads and resulting lower total crashes on Kansas highways resulted in the need for more length of highway to be modeled to achieve the 100 crash per year threshold prescribed by the HSM. The effort necessary to gather data for 19 ten-mile sections is documented in Chapter III – Data Collection. This effort would be multiplied if future studies determine that smaller geographic regions for calibration are preferred.

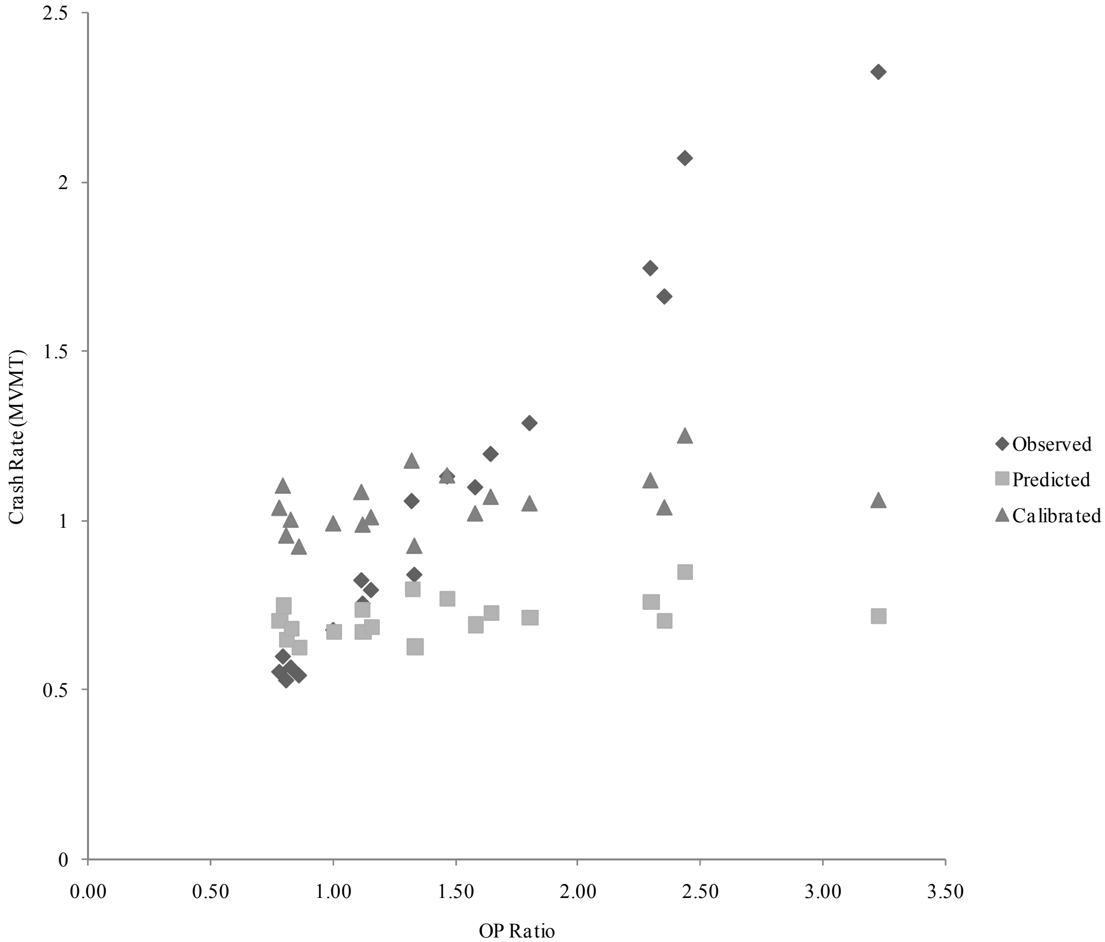
CHAPTER V – ANIMAL COLLISION

One major research discovery found while performing the segment calibration procedure was the discrepancy between the percent of animal crashes experienced on Kansas highways as compared to the HSM default distribution. Specifically, 58.9 percent of crashes on two-lane rural highway segments in Kansas were animal collisions. This compares to 30.9 percent for the original study used to develop the HSM SPFs and 12.1 percent for the HSM default distribution. Not only was the discrepancy between the values large, but so is the influence of the value for Kansas. Because nearly 60 percent of two-lane rural segment crashes are due to animal collisions, it was resoundingly the most frequent cause of crashes on these facilities. The next highest cause was overturned vehicles, which account for 8.0 percent of Kansas two-lane rural highway segment crashes. Because of the significance of animal collisions on two-lane rural highway segments, special attention was warranted to investigate the impact of these types of crashes on the crash prediction model. Several different approaches were investigated for special ways to account for animal crashes in crash prediction on Kansas highways.

To construct a new calibration procedure that accounts for animal crashes, one of the key findings from Chapter II – Literature Review was heavily utilized. Specifically, several research studies have shown that a single calibration factor may not be powerful enough to accurately predict safety performance. To verify that this was consistent with Kansas data, Figure 6 was developed to demonstrate the nature of model calibration using a single factor.

By its root equation, the calibration procedure provided in the HSM is aimed at producing a total number of predicted crashes that is close to the total number of actual crashes. Figure 8 depicts the results from the 19 calibration sections. The x-axis shows OP ratio, or the number of observed crashes divided by the number of predicted crashes for a particular section. The 19 data points correspond to each of the 19 calibration sections and do not vary, along the x-axis, depending on the method of crash estimation used. The y-axis is the accompanying crash rate for that section given in crashes per MVMT. Three different crash rates were used, observed, predicted (un-calibrated) and calibrated (predicted using a single statewide calibration value).

FIGURE 8 OP Ratio versus Crash Rate for Calibration Sections

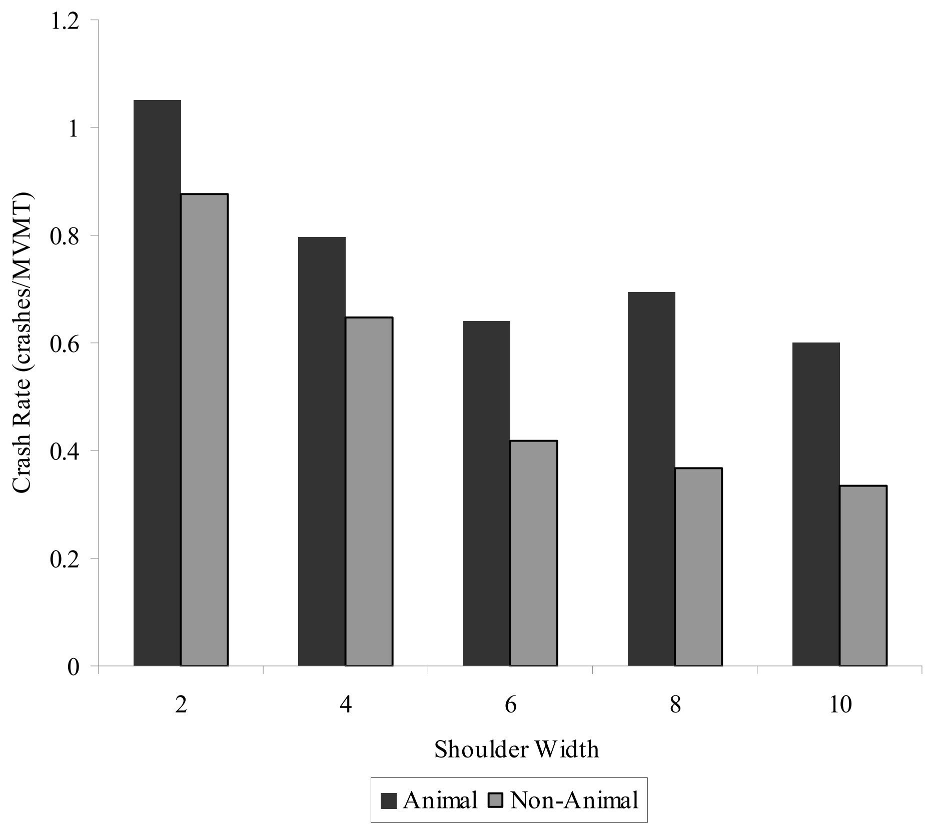


The observed crashes follow a diagonal line showing that sections with a higher rate of observed crashes also had a higher calibration factor. By contrast, the predicted number crashes are nearly straight across showing an almost constant crash rate for each of the 19 sections even after the CMFs are applied. Once the statewide calibration is applied, the predicted crashes move to the weighted center of the observed crashes but still show an almost constant rate.

Therefore, it can reasonably be expected that the total number of predicted crashes for a group of sections will be close to the total number of observed crashes. However, unless the observed crash rate happens to be near the average crash rate it is unlikely that the predicted number of crashes will be accurate for a given section.

Once it was established that a dynamic calibration procedure could help improve the model accuracy it had to be determined how best to structure this procedure. As documented in Chapter II – Literature Review, research on Kansas highways found that geometric features impacted animal crashes (*32*). Figure 9 was developed to demonstrate that this finding is consistent with the data used for this dissertation. Specifically, Figure 9 shows the crash rate for animal and non-animal segment crashes on rural two-lane highways based on the shoulder width of that segment. Shoulder width was used because research has shown (*13*) that wider shoulders generally produce a safety benefit.

FIGURE 9 Shoulder Width versus Crash Rate



Based on this Figure 9, it was interpreted that animal crashes generally performed similarly to non-animal crashes relative to shoulder width. Moreover, shoulder width was a good metric for assessing all of the design criteria for a section of Kansas highway. It has typically been KDOT practice to bring all of the design elements up to standard at the same time. Therefore, routes with wider shoulders typically exhibit roadside features, horizontal alignment, and vertical alignment consistent with higher design speeds and full AASHTO Green Book (*1*) standards.

The finding that geometric features affect both animal and non-animal crashes strengthens the concept that adjusting the calibration procedure should be able to produce more accurate prediction results. Two primary methods for accounting for animal crashes in the calibration procedure are considered in this chapter.

CALIBRATION WITHOUT ANIMAL COLLISIONS

Experimental Design

While it was established in the introduction that roadway geometrics impact both animal and non-animal crashes, it is unknown if it impacts them both equally. Therefore, the first calibration procedure developed looked at a separate calibration for animal collisions versus all other crash types. One justification for this approach was the comparison of the distribution of non-animal collisions for KDOT against the HSM default and the original study from which the HSM was developed. Table 25 shows the overall distribution of crashes sorted into animal collisions, single vehicle (non-animal collisions), and total multiple vehicle crashes:

TABLE 25 Animal Focused Crash Distributions

Collision Type	Kansas	Harwood et al. (42)	HSM Default
Collision with animal	58.9%	30.9%	12.1%
Single vehicle (non-animal)	29.3%	35.4%	57.2%
Total multiple vehicle collisions	11.8%	33.7%	30.7%

Clearly the distributions of these crash types vary greatly between the three different samples. A second distribution of crashes was developed that looked at the relationship of crash types with animal crashes excluded. Table 26 is a distribution of non-animal crashes by single vehicle or multiple vehicle.

TABLE 26 Non-Animal Crash Distributions

Non-Animal Collision Type	Kansas	Harwood et al. (42)	HSM Default
Single Vehicle (Non-Animal)	71.29%	51.23%	65.07%
Total Multiple Vehicle Collisions	28.71%	48.77%	34.93%

The values for the different samples do still vary, but are much closer without the animal crashes skewing the distributions. Based on this improved relationship, it was hypothesized that calibrating the non-animal crashes separately should improve the accuracy of the model for these types of crashes.

Results

The same procedure and data set used for developing the statewide calibration was used to develop a non-animal calibration factor, as shown in Table 27.

TABLE 27 Non-Animal Calibration Factor

		Observed			
Section	Predicted	Total	Animal	Non-Animal	Non-Animal OP Ratio
1	12.26	18	12	6	0.489
2	30.12	26	17	9	0.299
3	3.76	3	1	2	0.532
4	9.86	8	3	5	0.507
5	3.83	3	2	1	0.261
6	6.8	9	3	6	0.882
7	8.05	9	3	6	0.745
8	26.54	42	25	17	0.641
9	26.98	36	23	13	0.482
10	2.99	3	2	1	0.334
11	17.01	28	20	8	0.47
12	14.86	35	25	10	0.673
13	14.46	12	5	7	0.484
14	13.3	24	20	4	0.301
15	25.24	58	28	30	1.189
16	32.05	36	22	14	0.437
17	10.53	34	32	2	0.19
18	30.24	35	18	17	0.562
19	7.38	18	11	7	0.949
Total	296.26	437	272	165	0.557

After modeling the 19 calibration sections and comparing them to the non-animal crashes, a calibration value of 0.557 was developed.

Analysis

To test whether the non-animal calibration provided a better accuracy than the statewide calibration, both factors were applied to the predicted values for the calibration projects and compared to the observed number of crashes. While this method did not provide an independent analysis of the accuracy of the two calibration factors, it provided an initial comparison to evaluate the different calibration methods. The raw values for predicted and observed crashes using both a total and non-animal calibration are shown in Table 28.

TABLE 28 Total and Non-Animal Crash Prediction Values

	Predicted			Observed	
Section	No Calibration	Total Calibration	Non-Animal Calibration	Total	Non-Animal
1	12.26	18.08	6.83	18	6
2	30.12	44.43	16.78	26	9
3	3.76	5.55	2.09	3	2
4	9.86	14.54	5.49	8	5
5	3.83	5.65	2.13	3	1
6	6.8	10.03	3.79	9	6
7	8.05	11.87	4.48	9	6
8	26.54	39.15	14.78	42	17
9	26.98	39.8	15.03	36	13
10	2.99	4.41	1.67	3	1
11	17.01	25.09	9.47	28	8
12	14.86	21.92	8.28	35	10
13	14.46	21.33	8.05	12	7
14	13.3	19.62	7.41	24	4
15	25.24	37.23	14.06	58	30
16	32.05	47.27	17.85	36	14
17	10.53	15.53	5.87	34	2
18	30.24	44.6	16.84	35	17
19	7.38	10.89	4.11	18	7

The differences between the predicted and actual crashes for each segment were determined for both the total calibration and the non-animal only calibration. The total of the absolute value of the differences for all 19 segments for the total calibration was 139.1 crashes. This compared to 53.3 crashes for the non-animal only calibration. However, total crash difference was a poor metric for comparison since there are over double the number of total crashes than non-animal crashes. When the absolute value of the percent-difference was calculated, the statewide calibration had an average percent-difference of only 40.3 percent as compared to 44.1 percent for the non-animal calibration. Based on this analysis, it was determined that modeling only non-animal crashes would not likely improve the model accuracy. Based on this analysis, the non-animal calibration method was dropped from further consideration in this study.

VARIABLE CALIBRATION VALUES

The effort to develop another calibration procedure based on animal crashes led to a deeper investigation into the nature of animal crashes within Kansas. This investigation showed that even within the state the rate of animal crashes fluctuated dramatically. The statewide crash data for 2005 to 2007 were analyzed to determine the rate of animal crashes for 104 of the 105 counties in Kansas. Wyandotte County has no rural two-lane highway miles, so it was not evaluated.

First, the frequency of animal crashes per county was calculated to evaluate the variance of animal crash rates across the state. The full data and results can be found in Appendix J. The county animal distribution varied from as low as 24.3 percent in Haskell County to as high as 86.8 percent in Jewell County. The mean distribution of animal crashes was 56.6 percent. The median distribution of animal crashes was 57.7 percent. A graph of the distribution of animal crashes from lowest to highest, is shown in Figure 10.

FIGURE 10 Distribution of Animal Crash Rate per County as Percent

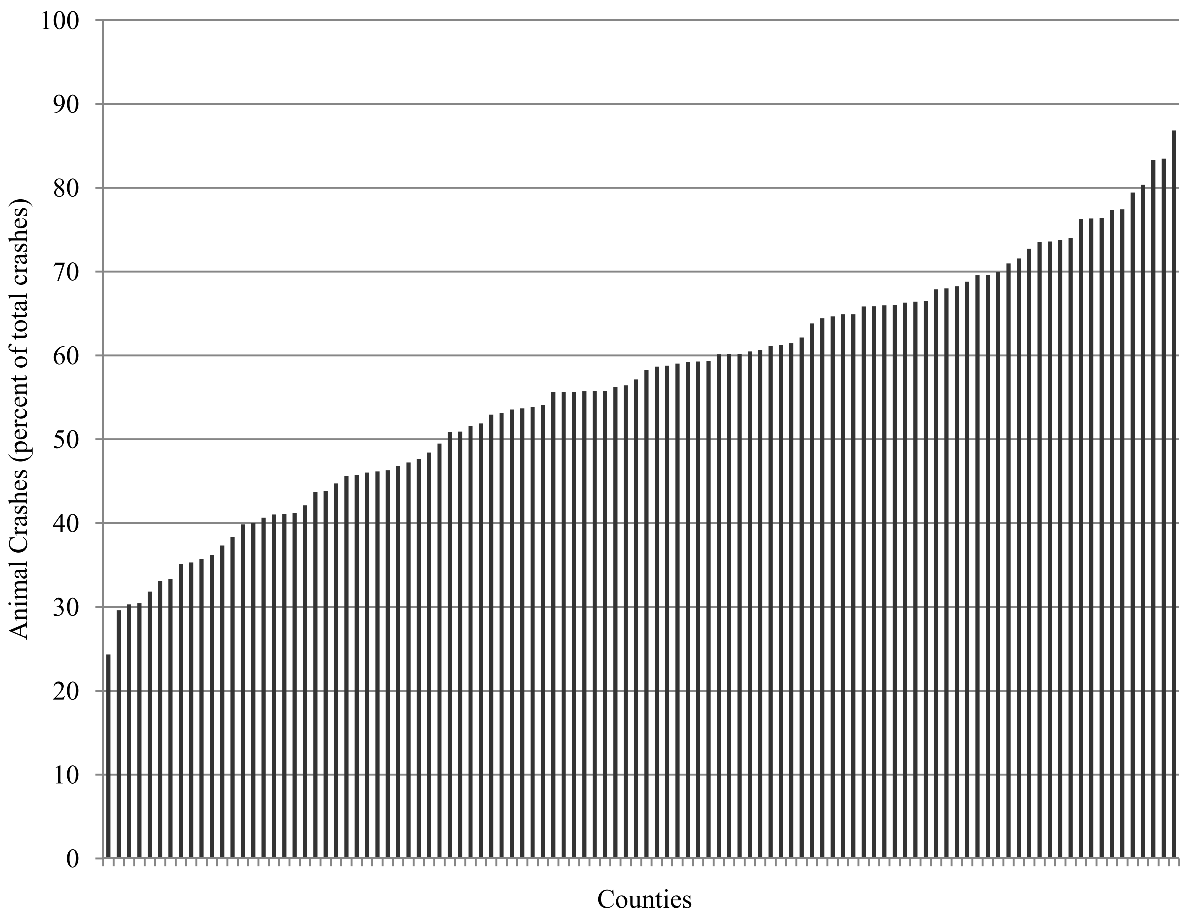


Figure 10 is a graph of all the counties in Kansas with rural two-lane highway sections graphed in order of the percent of animal crashes that occurred on rural two-lane highways in that county. It showed that there is a fairly linear progression of distribution of animal crashes across the counties without any noticeable pockets or anomalies. Next, the distribution of animal crashes was mapped for the state, as shown in Figure 11.

FIGURE 11 Map of Percent of Crashes Involving Animals for Two-Lane Rural Highways by County

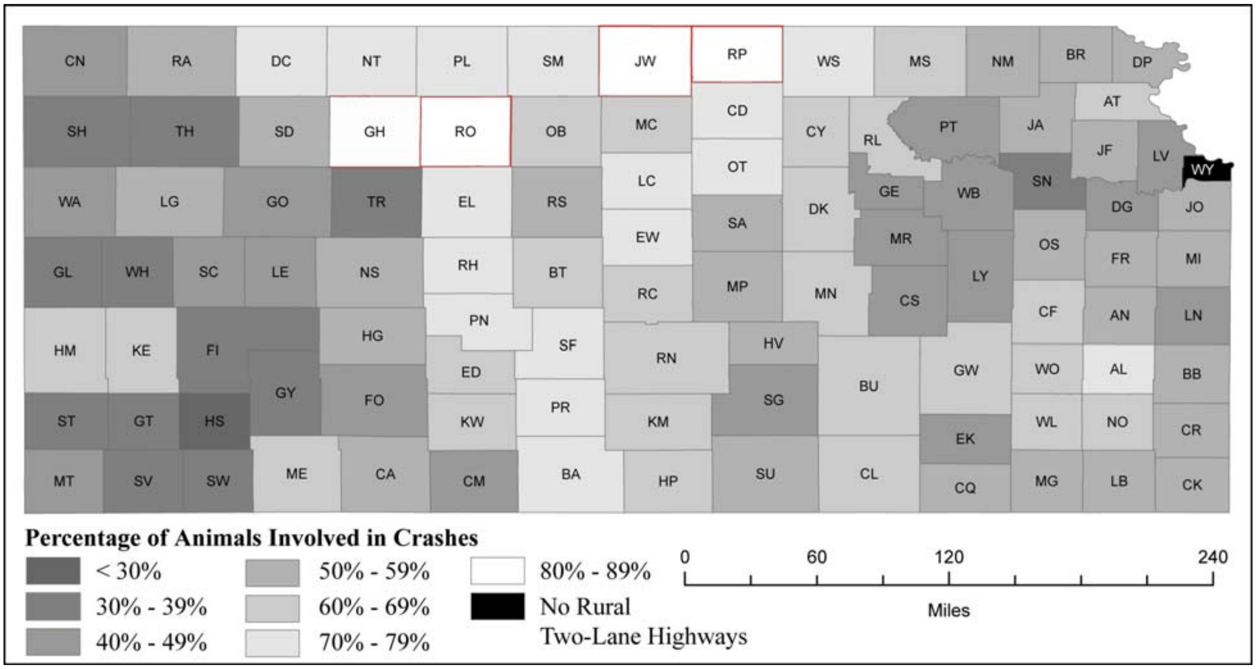


Figure 11 showed some trends for counties with higher percentages of animal crashes through the central portion of the state, especially the north central. The southeast portion of the state also has some pockets of counties with high percentages of animal crashes. Since these higher areas of the state also tend to have more topographic relief than the other portions, the differences could be because the counties have fewer non-animal crashes. In an effort to normalize the data, the rates of animal crashes were determined. The highest rate was Republic County with 1.92 animal crashes per MVMT. The lowest rate was again Haskell County with 0.10 animal crashes per MVMT. The mean rate was 0.685 animal crashes per MVMT and the median was 0.625 animal crashes per MVMT. Figure 12 is a graph of the animal crash rate by county from lowest to highest.

FIGURE 12   Distribution of Animal Crashes by County as Rate

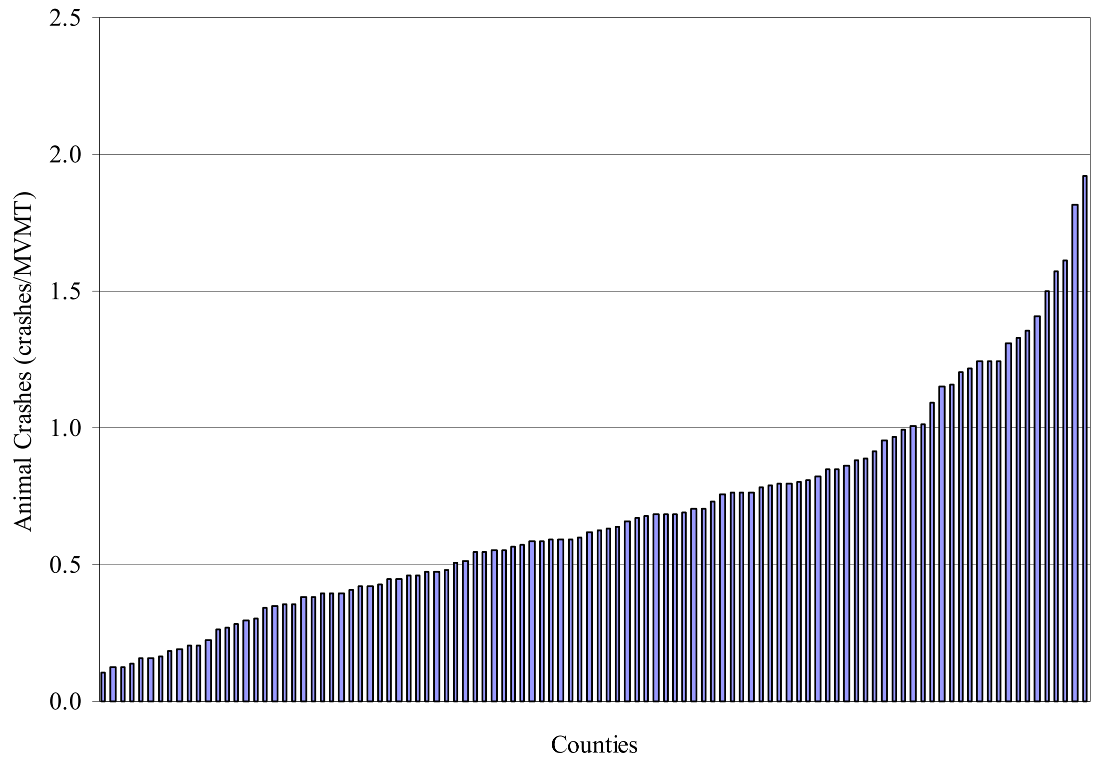


Figure 12 is a graph of all the counties in Kansas with rural two-lane highway sections graphed in order of the animal crash rate that occured on rural two-lane highways in that county. Evaluation of this Figure 10 showed a fairly linear trend from the lowest rate to approximately 0.9 animal crashes per MVMT. The rate then increases at an increased rate for the counties with the highest animal crash rates. Again the counties were mapped but this time according to the rate of animal crashes as opposed to the percent of animal crashes, as shown in Figure 13.

FIGURE 13 Map of Animal Crash Rates for Two-Lane Rural Highways by County

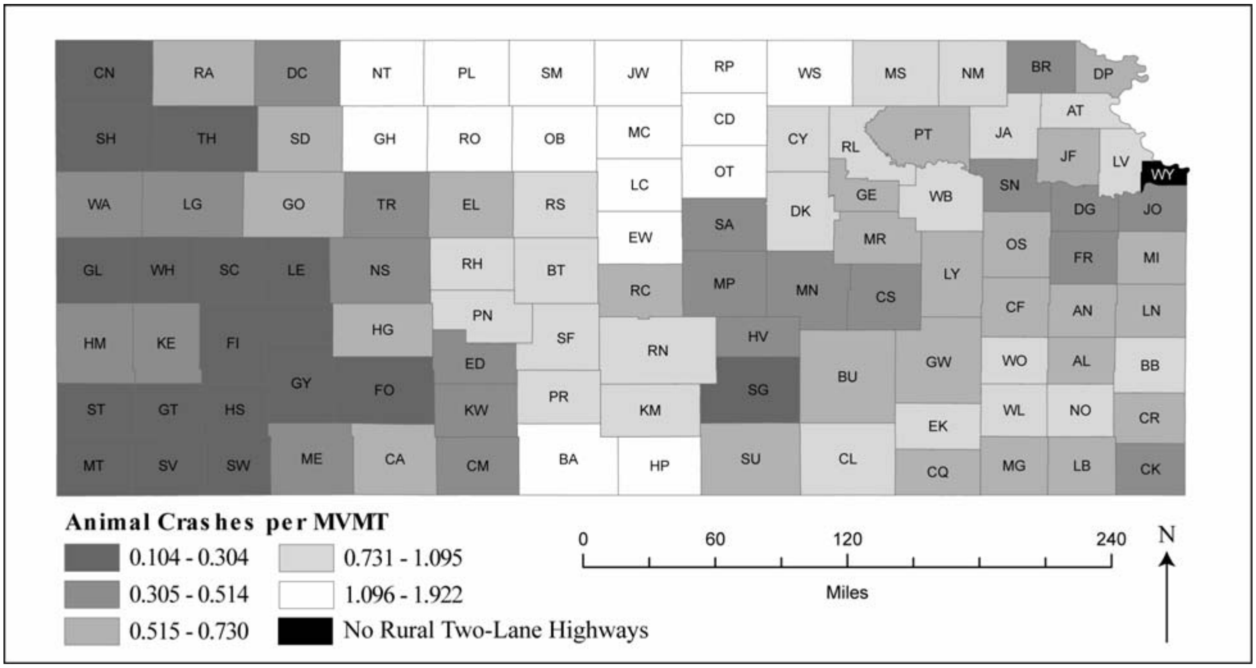


Figure 13 shows similar trends to the Figure 12, but generally improves the grouping of areas with low, medium, and high animal crash rates. Based on this analysis, it was determined that the study should investigate whether regional calibration factors could be developed based on the percent of animal crashes.

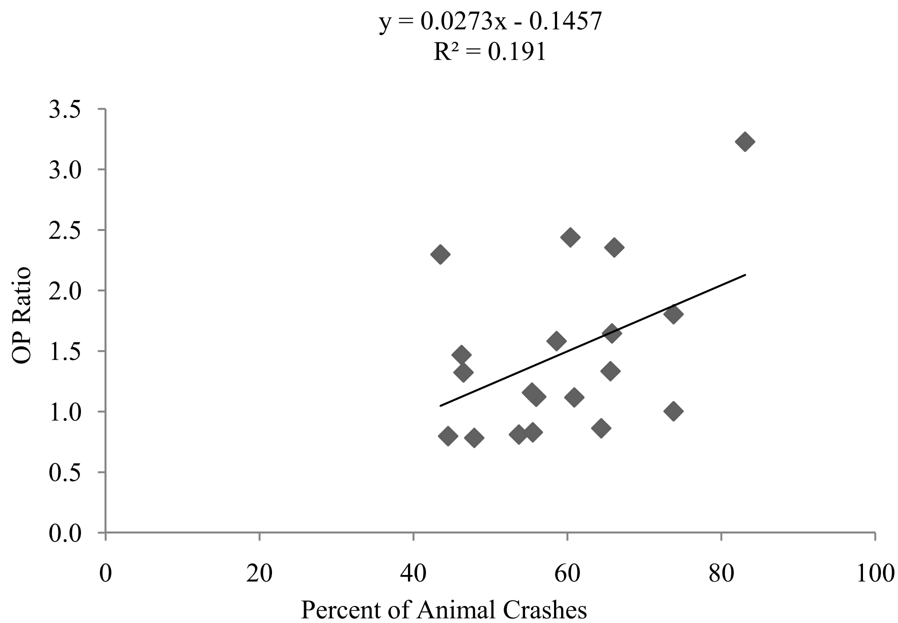
Experimental Design

As described in Chapter IV – Calibration, calibration using district boundaries was already investigated and ruled out as a method for improving the accuracy of the model. This decision was supported by the animal crash distribution maps that show a number of districts with a high variance in the percent and rate of animal crashes. Because the trends in animal crashes often spill across district boundaries, additional scrutiny was performed to determine if there was value in calibrating by groups of counties or other more refined boundaries. Similar to the above animal crash analysis, the same data from the calibration procedure were used for developing and evaluating a calibration based on more refined geographic boundaries.

Results

Any consideration of grouping counties together by percent or rate of animal crashes would be based on the theory that counties with similar animal crash characteristics would perform similarly in the model. To investigate this theory, the individual OP Ratios calculated for the 19 calibration sections were graphed based on the animal crash characteristics of the county they were located. Figure 14 shows the relationship of individual OP Ratios versus percent of animal crashes in the host county. Five of the 19 calibration segments cross through two different counties. For those segments, an average percent animal crash was developed for the segment.

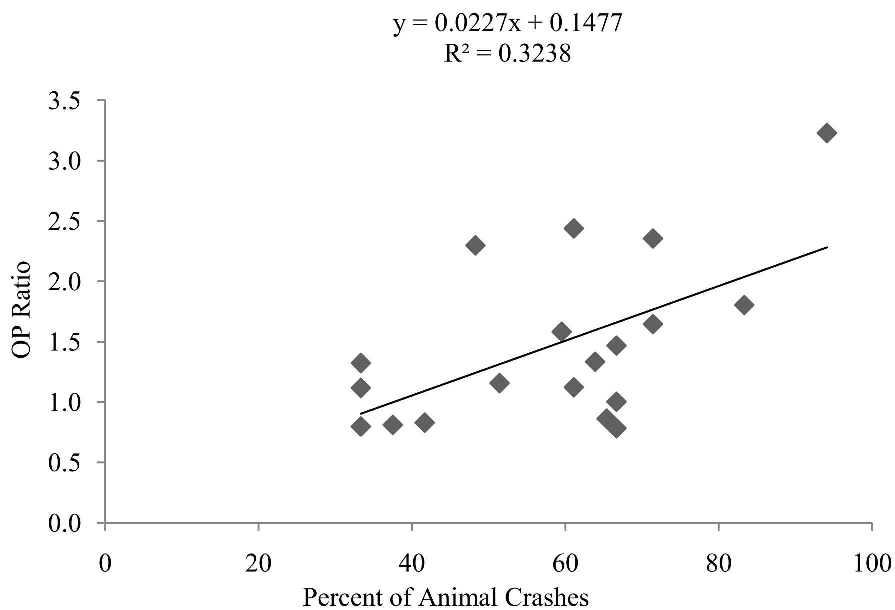
FIGURE 14 Percent of Animal Crashes for County versus OP Ratio



A linear trendline was added to the scattered data and an R^2-value calculated to determine if there was any relationship in the data. The linear trend returned an R-squared value of 0.191, which indicates a poor correlation. Furthermore the scatter does not show any bunching or grouping of points that would indicate similar performance of sections based on percent animal crashes.

Due to the size of the counties, it was likely that there was fluctuation of the percent of animal crashes within a given county. For this reason, an additional examination was performed and the percent of animal crashes was determined for each individual project. A similar graph was developed that plots the individual OP Ratios against the percent of animal crashes in that section as shown in Figure 15.

FIGURE 15 Percent of Animal Crashes for Section versus OP Ratio

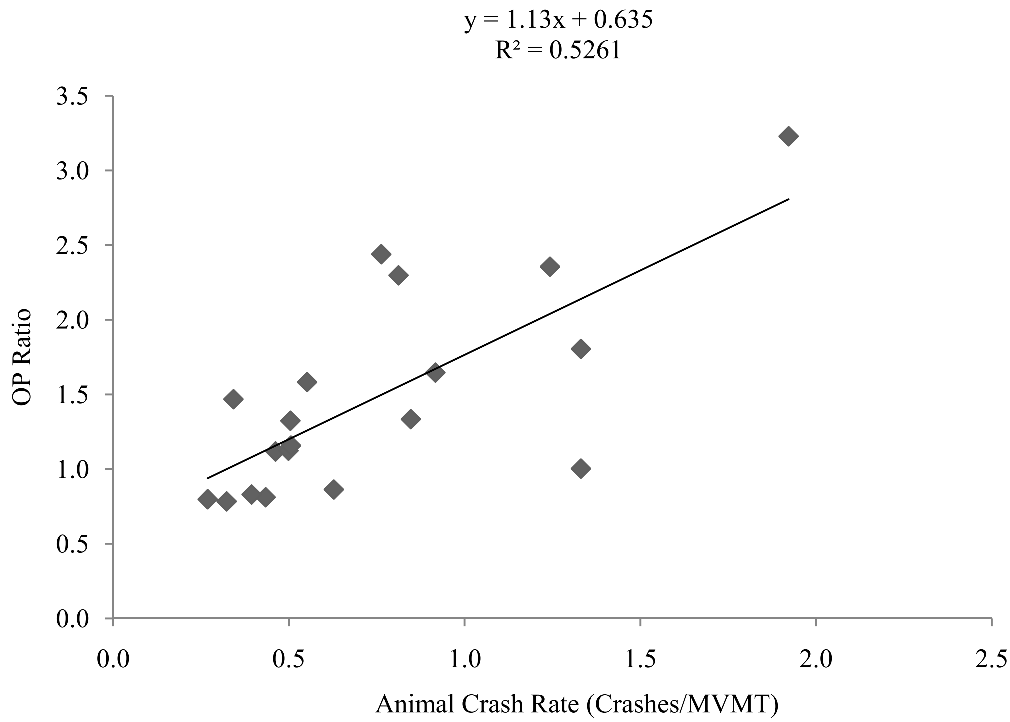


A similar analysis was performed on this scatter of data. By using the percent animal crashes for the specific segment, the linear relationship has improved. These data provided an R^2-value of 0.324, which denotes some adherence with a linear trend. Figure 15 also shows some grouping of data points that would denote that development of specific calibration values by range of values could be valuable.

In the maps of the animal crashes (Figures 11 and 13), the change from percent animal crash to animal crash rate showed some smoothing of the regional anomalies. Based on this improvement, a similar analysis to Figures 14 and 15 was performed. However, instead the percent animal crashes were replaced with the animal crash rate. Figure 16 shows the individual OP Ratios charted against the animal crash rate for the county in which the section was found.

Similar to the graph of percent animal crashes, the calibration sections that traverse two counties were converted to a blended rate.

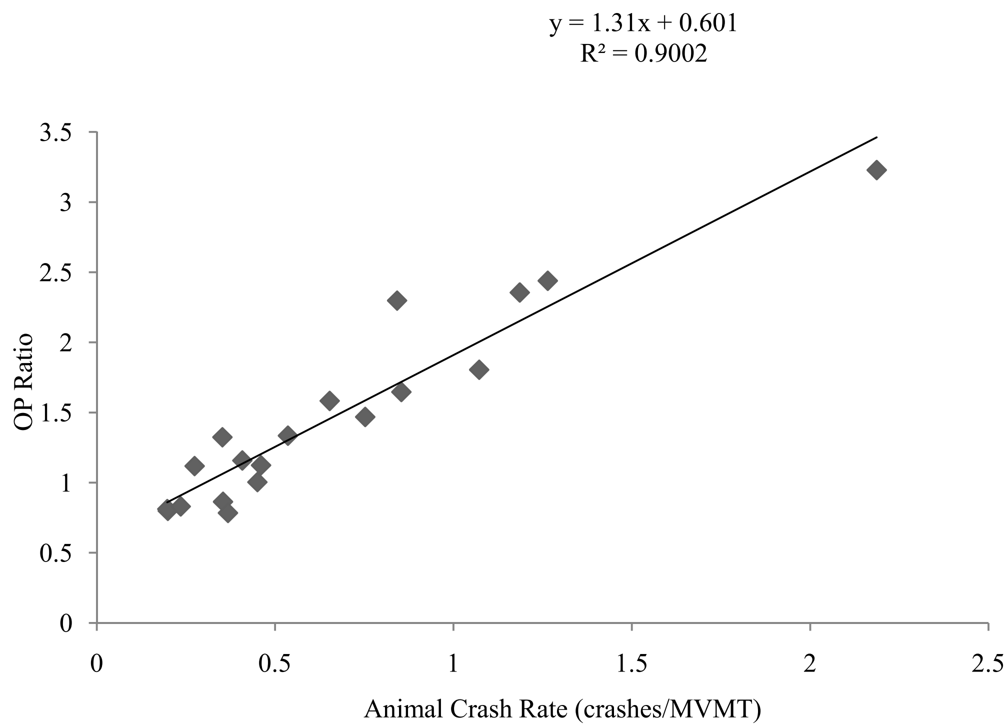
FIGURE 16 Animal Crash Rate versus OP Ratio for County



As expected, Figure 16 shows a significant improvement over the similar analysis for percent of animal crashes. The R^2-value for Figure 16 was 0.526, an improvement over the previous relationships. Visually, this graph is clearly demonstrating a linear trend in the data.

In the previous analyses, improvement was found when moving from percent animal crashes to animal crash rate and from overall county statistics to corridor-specific statistics. Therefore, it would hold that the tightest tendency should be found in a graph of individual calibration crash rate versus individual OP Ratios. Figure 17 is the graph of this relationship.

FIGURE 17 Animal Crash Rate versus OP Ratio for Section



As predicted, this relationship shows the tightest linear correlation. This analysis yielded a very definitive linear trend with an R^2-value of 0.900.

Based on their strong linear correlations, the equations for developing the calibration factor by county animal crash rate and individual section animal crash rate was carried forward for further analysis. The equation for the county-specific calibration based on animal crash rate, from Figure 16, is:

$$C_{county} = 1.13 \times ACR_{county} + 0.635$$

Where:

C_{County} = Calibration factor for a county; and

ACR_{county} = Deer crash rate for a county.

The equation for the section-specific calibration based on animal crash rate, from Figure 17, is:

$$C_{section} = 1.31 \times ACR_{section} + 0.601$$

Where:

$C_{section}$ = Calibration factor for a segment;

$ACR_{section}$ = Deer crash rate for a segment.

Analysis

Similar to the previous analysis in this chapter, the initial analysis of the effectiveness of calculating a section's calibration factor by animal crash rate utilized the data collected for the calibration sections. While testing the effectiveness of an equation using the same data used to derive the equation is not an independent assessment, it is meant as just a first step in the measurement of the effectiveness of the equation. To perform this analysis, a section-specific calibration factor was developed for each of the 19 calibration sections using both of the previously developed equations. The accuracy of each equation was then compared based on the relative improvement in the accuracy of the predicted crashes as compared to use of a statewide calibration factor. Table 29 shows the impact of using the animal crash rate by county to calculate the calibration factor for each of the 19 calibration sections.

TABLE 29 Predicted Calibration Sections Using *Ccounty*

Section	Observed	C_{County}	Predicted	Absolute Difference	Absolute Percent Difference
1	18	1.022	12.53	5.47	30.42%
2	26	1.344	40.49	14.49	55.73%
3	3	0.939	3.53	0.53	17.63%
4	8	1.125	11.09	3.09	38.66%
5	3	1	3.83	0.83	27.61%
6	9	1.205	8.19	0.81	8.98%
7	9	1.157	9.31	0.31	3.46%
8	42	1.258	33.4	8.6	20.48%
9	36	1.592	42.94	6.94	19.29%
10	3	2.139	6.39	3.39	113.15%
11	28	1.671	28.42	0.42	1.50%
12	35	2.039	30.3	4.7	13.42%
13	12	1.08	15.61	3.61	30.12%
14	24	2.139	28.44	4.44	18.52%
15	58	1.552	39.18	18.82	32.45%
16	36	1.198	38.41	2.41	6.70%
17	34	2.806	29.55	4.45	13.08%
18	35	1.206	36.48	1.48	4.23%
19	18	1.497	11.05	6.95	38.63%

The total of the absolute value of the differences using this method was 91.8 as compared to 139.1 using the total calibration value established in Chapter IV – Calibration. This method has an average of the absolute value of the percent difference between the predicted and absolute value of 26.0 percent as compared to 40.3 percent using the statewide calibration.

Next, a similar analysis was performed using the equation to calculate the calibration factor using the animal crash rate for the section being analyzed. Table 30 shows the results of using that equation for the 19 calibration segments.

TABLE 30 Predicted Calibration Sections Using *Csection*

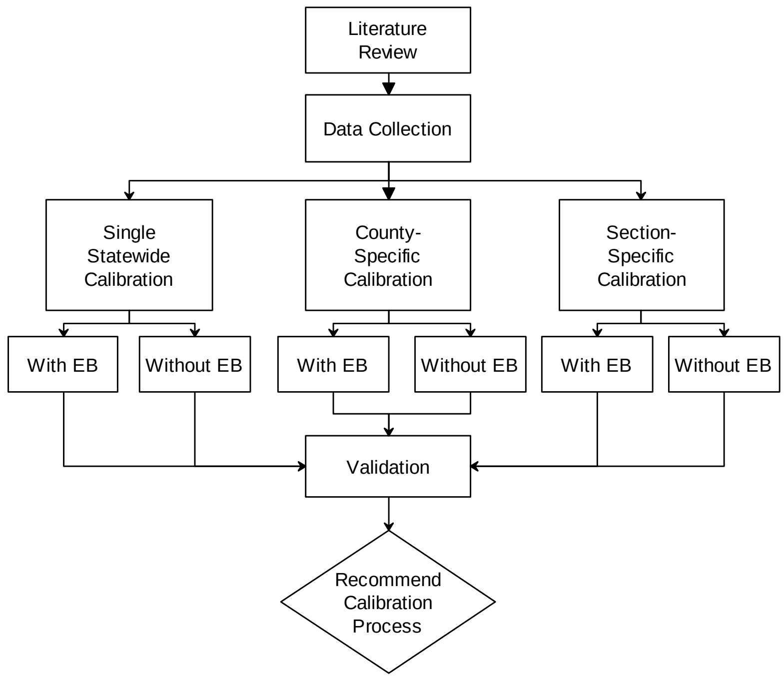
Section	Observed	Section Animal Crash Rate	$C_{section}$	Predicted	Absolute Difference	Absolute Percent Difference
1	18	0.75	1.59	19.44	1.44	8.01%
2	26	0.35	1.06	32.06	6.06	23.29%
3	3	0.20	0.86	3.24	0.24	8.00%
4	8	0.20	0.86	8.48	0.48	5.96%
5	3	0.37	1.08	4.15	1.15	38.19%
6	9	0.35	1.06	7.22	1.78	19.76%
7	9	0.27	0.96	7.73	1.27	14.14%
8	42	0.65	1.46	38.63	3.37	8.03%
9	36	0.54	1.30	35.13	0.87	2.41%
10	3	0.45	1.19	3.56	0.56	18.64%
11	28	0.85	1.72	29.23	1.23	4.39%
12	35	1.19	2.15	31.99	3.01	8.60%
13	12	0.24	0.91	13.15	1.15	9.56%
14	24	1.07	2.00	26.65	2.65	11.05%
15	58	0.84	1.70	42.98	15.02	25.90%
16	36	0.46	1.20	38.57	2.57	7.15%
17	34	2.19	3.46	36.46	2.46	7.23%
18	35	0.41	1.14	34.33	0.67	1.93%
19	18	1.26	2.26	16.65	1.35	7.53%

The total of the absolute value of the differences using *Csection* was 47.3 crashes as compared to 139.1 crashes using the statewide calibration value. This project-specific calibration had an average of the absolute value of the percent difference between the predicted and absolute value of 12.1 percent as compared to 40.3 percent using the statewide calibration.

SUMMARY

This chapter looked at the impact of animal collisions on crash prediction modeling for highways in Kansas. The first method investigated the potential to calibrate the existing HSM model to look at only non-animal crashes. This method showed no improved accuracy over the use of a single statewide calibration and would still require a new way to model animal collisions. The second method investigated using variable calibration values based on several different factors related to animal crashes. The most promising of the factors evaluated was the use of the animal crash rate for either a full county or a specific section of roadway to calculate a variable calibration factor for that section being studied. The two equations for the variable calibration value were carried forward and evaluated in Chapter VI – Validation. Figure 18 depicts the evolution of the research model after inclusion of the findings from Chapter V – Animal Collision.

FIGURE 18 Diagram of Dissertation Research Performed – Animal Calibration



These findings are consistent with the major findings of the previous study performed on deer crashes in Kansas (*32*):

- The absence of the variable "presence of deer warning sign" suggested that there is little or no relationship between deer warning signs and crash rate.

- The most significant parameter was the amount of surrounding area that was wooded. Most likely, the amount of wooded area was acting in these data as a surrogate for deer population.

- The only direct measure of deer population (harvest density) was available at an extremely coarse geographical resolution for this application.

- Other than the percent wooded area, the other parameters identified as having a significant influence on crash rate were traffic volume and speed, sight distance (indirectly implied by the curvature ratio and side slope), and clear width.

Specifically, these research findings agree with earlier research that geometric features impact both animal crashes and non-animal crashes. In Meyer's study, percent wooded area was being used as a surrogate measure for deer population. Similarly, for this dissertation the animal crash rate was used as a surrogate for exposure to animal crashes. That is to say that counties and highway sections with higher deer crash rates likely have higher deer crash exposure. That value should then remain relatively constant during the study period.

CHAPTER VI – VALIDATION

The primary goal of the validation section was to evaluate the accuracy of the HSM CPM relative to implementation for design-level highway improvement projects. That is to say, when analyzing a specific roadway segment, how well does the model predict the future crash rate depending on the countermeasures that are being implemented? Previous studies have analyzed the model relative to unchanged sections, as this study looked at the calibration sections, but no previous study has done a before-and-after analysis to validate the model. Ultimately the aim of the HSM is to produce a crash prediction model that is accurate enough to be implemented for design of highway sections.

In addition to the overall model accuracy, this validation study also examined the relative accuracy of several different methods for calibrating the model. In the previous chapters several different calibration procedures were analyzed, and their theoretical impact on the HSM crash prediction model was determined. The three most promising methods analyzed were:

- A single statewide calibration;
- A county-specific calibration determined by frequency of deer crashes; and
- A section-specific calibration determined by frequency of deer crashes.

The single statewide calibration was developed using the methodology given in the HSM. The other two methods were developed through this research, and both show a high theoretical improvement in the accuracy of the model. The section-specific calibration showed a very high theoretical improvement, however, the analysis performed on the calibration sections did not show if deer crash rates before an improvement were good predictors for deer crash rates after an improvement.

In addition to the three calibration procedures, the validation study also examined the impact on the model accuracy of using the EB procedure. This procedure allows the model to consider the location-specific crash history of a roadway prior to an improvement as a way to better predict crashes after an improvement.

EXPERIMENTAL DESIGN

The selection of projects and collection of data for the validation analysis are described in detail in Chapter III – Data Collection. Each of the ten validation sections that were selected were entered into the IHSDM for analysis. Within the IHSDM, each of the sections were analyzed to determine the number of total predicted crashes. This was performed for each of the different combinations of calibration procedure and EB procedure possible. A total of 51 crash predictions were generated to cover all of the different possible calibration combinations.

Default Crash Distributions

As described in Chapter IV – Calibration, the HSM and IHSDM allow replacement of some default crash distributions with distributions calculated for a specific jurisdiction. For the validation analysis, the statewide replacement distributions developed in Chapter IV – Calibration were used if they impacted the overall number of predicted segment crashes. The specific values are:

- p_{ra};
- p_{inr};
- p_{prn}; and
- p_{nr}.

The values for $p_{LT/D}$ and p_{dwy} were not used because none of the validation sections had a two-way left turn lane. The default crash distributions were not entered for this analysis because they did not impact the model's prediction for total crashes. Distributions were applied to the total predicted crashes to develop the predicted crashes by type.

Statewide Calibration

The statewide calibration factor of 1.48, developed in Chapter IV – Calibration, was applied to all ten of the validation sections.

County-Specific Calibration

As detailed in Chapter V – Animal Collision, an equation was developed to calculate the calibration factor for a specific county based on its countywide rate for animal crashes. The equation for calculating this calibration factor is:

$$C_{county} = 1.13 \times ACR_{county} + 0.635$$

Where,

C_{county} = Calibration factor for a county; and

ACR_{county} = Deer crash rate for a county.

Since each of the ten validation sections was in a unique county, this equation was applied for each of the sections. Table 31 shows list of the validation sections with their respective C_{county} value.

TABLE 31 C_{county} Values for Validation Sections

Section	Project Number	Route	County	ACR_{county}	C_{county}
1	K-5393-01	K-383	Norton	1.245	2.041
2	K-5384-01	US-50	Chase	0.354	1.035
3	K-5745-01	US-56	Marion	0.514	1.215
4	K-5767-01	US-77	Butler	0.592	1.304
5	K-5391-01	US-283	Ness	0.483	1.18
6	K-5761-01	US-73	Atchison	0.763	1.497
7	K-5757-01	K-47	Wilson	0.765	1.499
8	K-5741-01	US-36	Rawlins	0.575	1.284
9	K-5749-01	K-156	Barton	0.793	1.531
10	K-5743-01	US-50	Hamilton	0.397	1.083

To facilitate the different C_{county} values in the IHSDM, a separate calibration data set had to be created in the IHSDM Administration Tool for each validation project.

Section-Specific Calibration

Similar to the county-specific calibration, in Chapter V – Animal Collision an equation was developed to calculate the calibration factor for a specific section based on its animal crash rate calculated for that specific section. The equation is:

$$C_{section} = 1.31 \times ACR_{section} + 0.601$$

Where:

$C_{section}$ = Calibration factor for a section; and

$ACR_{section}$ = Deer crash rate for a section.

Since each of the ten validation sections had a unique crash history, the equation was applied for each of the sections. Table 32 shows a list of the validation sections with their respective $C_{section}$ value. The number of animal crashes comes from the before analysis period which is specific three year span for each validation section.

TABLE 32 $\mathbf{C_{section}}$ Values for Validation Sections

Section	Project Number	Route	AADT	Animal Crashes	Miles	$ACR_{section}$	$C_{section}$
1	K-5393-01	K-383	847	17	13.62	1.346	2.363
2	K-5384-01	US-50	4983	13	7.54	0.316	1.015
3	K-5745-01	US-56	1893	6	7.76	0.373	1.089
4	K-5767-01	US-77	3078	32	12.71	0.747	1.579
5	K-5391-01	US-283	1297	14	16.26	0.606	1.394
6	K-5761-01	US-73	2433	27	4.14	2.447	3.803
7	K-5757-01	K-47	1190	1	2.17	0.353	1.063
8	K-5741-01	US-36	868	5	7.92	0.664	1.471
9	K-5749-01	K-156	2582	56	17.2	1.152	2.108
10	K-5743-01	US-50	2571	30	11.28	0.945	1.837

The IHSDM does not have a simple mechanism to implement a dynamic calibration like this. Therefore, a calibration dataset had to be developed in the IHSDM administrative tools for each validation project to account for the different $C_{section}$ values.

EB Procedure

The EB procedure, as described in Chapter IV – Calibration, allowed for additional calibration of the crash prediction model results based on the crash history of a section being analyzed. Functionality built into the IHSDM was used to apply the EB procedure to validation sections. In order to utilize this functionality, the existing roadway features had to be modeled in the

IHSDM in addition to the proposed features. Since the specific crash locations were known for the section crash histories, the site-specific EB procedure was used.

One caveat of using the EB procedure was that the existing roadway must be similar to the proposed roadway. Sections where the proposed improvements will substantially change the roadway alignment cannot utilize the EB procedure. Based on this criterion, three of the ten validation sections were not analyzed using the EB procedure. These sections were:

- Section 3 – US-56 in Marion County;
- Section 6 – US-73 in Atchison County; and
- Section 8 – US-36 in Rawlins County.

For the seven remaining sections, the EB procedure was applied to all three of the calibration procedures being considered. This created a total of six different crash predictions for each of the sections eligible for the EB procedure and three different crash predictions for each of the sections that are not eligible.

RESULTS

No EB Calibration

The first analysis performed was to run all ten validation sections through the IHSDM crash prediction model without utilizing the EB procedure. The results of that modeling are shown in Tables 33, 34, and 35.

Statewide Calibration

The results from running the validation sections through the IHSDM using a statewide calibration value without the EB calibration are shown in Table 33.

TABLE 33 Statewide Calibration Validation Results without EB Procedure

Section	Project Number	Route	Years Evaluated	Crashes Observed	Crashes Predicted	Percent Difference
1	K-5393-01	K-383	2002-2009	62	37.75	39.1%
2	K-5384-01	US-50	2001-2009	78	119.71	53.5%
3	K-5745-01	US-56	2004-2009	25	29.72	18.9%
4	K-5767-01	US-77	2006-2009	74	49.63	32.9%
5	K-5391-01	US-283	2000-2009	71	66.31	6.6%
6	K-5761-01	US-73	2005-2009	24	23.28	3.0%
7	K-5757-01	K-47	2002-2009	18	8.75	51.4%
8	K-5741-01	US-36	2003-2009	15	19.37	29.1%
9	K-5749-01	K-156	2002-2009	174	146.7	15.7%
10	K-5743-01	US-50	2002-2009	69	62.82	9.0%
Total				610	564.04	7.5%

Since each section was constructed in a different year, each section had a different corresponding beginning for the crash prediction evaluation. Since 2009 was the most recent crash data available at the time the study was performed, this was a common final year of analysis for each section. The resulting range of years evaluated for each section is shown with the model results. In addition, the actual number of crashes occurring, or "observed," during the evaluation period is listed along with the total number of crashes predicted. To show the relative accuracy of the prediction model, a calculation is provided showing the percent difference between the number of crashes predicted and observed. This value is shown as absolute value because the model both over-predicts and under-predicts the number of crashes. By using the absolute value it prevents these values from canceling each other out when summed.

County-Specific Calibration

The results from running the validation sections through the IHSDM using the county-specific calibration method without the EB calibration are shown in Table 34.

TABLE 34 County-Specific Calibration Validation Results without EB Procedure

Section	Project Number	Route	Years Evaluated	Crashes		Percent Difference	Improvement
				Observed	Predicted		
1	K-5393-01	K-383	2002-2009	62	52.24	15.7%	23.4%
2	K-5384-01	US-50	2001-2009	78	84	7.7%	45.8%
3	K-5745-01	US-56	2004-2009	25	24.48	2.1%	16.8%
4	K-5767-01	US-77	2006-2009	74	43.88	40.7%	-7.8%
5	K-5391-01	US-283	2000-2009	71	53.05	25.3%	-18.7%
6	K-5761-01	US-73	2005-2009	24	23.62	1.6%	1.4%
7	K-5757-01	K-47	2002-2009	18	8.89	50.6%	0.8%
8	K-5741-01	US-36	2003-2009	15	16.86	12.4%	16.7%
9	K-5749-01	K-156	2002-2009	174	152.26	12.5%	3.2%
10	K-5743-01	US-50	2002-2009	69	46.13	33.1%	-24.2%
Total				610	505.41	17.15%	-9.61%

Similar data are displayed in Table 34 as shown in Table 33 for the results using a single statewide calibration. An additional column is provided showing the relative improvement of using the county-specific calibration as opposed to the statewide calibration. A negative value in this column shows a section where the county-specific calibration predicted crashes less accurately than the statewide calibration.

Section-Specific Calibration

The results from running the validation sections through the IHSDM using the segment-specific calibration method without the EB calibration are shown in Table 35.

TABLE 35 Section-Specific Calibration Validation Results without EB Procedure

Section	Project Number	Route	Years Evaluated	Crashes		Percent Difference	Improvement
				Observed	Predicted		
1	K-5393-01	K-383	2002-2009	62	60.48	2.5%	36.7%
2	K-5384-01	US-50	2001-2009	78	82.38	5.6%	47.9%
3	K-5745-01	US-56	2004-2009	25	21.94	12.2%	6.6%
4	K-5767-01	US-77	2006-2009	74	53.13	28.2%	4.7%
5	K-5391-01	US-283	2000-2009	71	62.67	11.7%	-5.1%
6	K-5761-01	US-73	2005-2009	24	60.02	150.1%	-147.1%
7	K-5757-01	K-47	2002-2009	18	6.31	64.9%	-13.6%
8	K-5741-01	US-36	2003-2009	15	19.32	28.8%	0.3%
9	K-5749-01	K-156	2002-2009	174	209.65	20.5%	-4.8%
10	K-5743-01	US-50	2002-2009	69	78.24	13.4%	-4.4%
Total				610	654.14	-7.2%	0.3%

With EB Calibration

Next, the IHSDM crash prediction model was performed on the seven sections that qualify for utilizing the EB procedure. The results are shown in Table 36, 37 and 38.

Statewide Calibration

The results from running the validation sections through the IHSDM using a statewide calibration value with the EB calibration are shown in Table 36.

TABLE 36 Statewide Calibration Validation Results with EB Procedure

Section	Project Number	Route	Years Evaluated	Crashes Observed	Crashes Predicted	Percent Difference
1	K-5393-01	K-383	2002-2009	62	41.67	32.79%
2	K-5384-01	US-50	2001-2009	78	102.18	31.00%
4	K-5767-01	US-77	2006-2009	74	66.07	10.72%
5	K-5391-01	US-283	2000-2009	71	63.52	10.54%
7	K-5757-01	K-47	2002-2009	18	6.98	61.22%
9	K-5749-01	K-156	2002-2009	174	180.12	3.52%
10	K-5743-01	US-50	2002-2009	69	71.25	3.26%
Sub-Total				546	531.79	2.60%
3	K-5745-01	US-56	2004-2009	25	29.72	18.88%
6	K-5761-01	US-73	2005-2009	24	23.28	3.00%
8	K-5741-01	US-36	2003-2009	15	19.37	29.13%
Total				610	604.16	0.96%

The results from the three sections where the EB procedure could not be performed were also given in Table 36. They are shown with the values from the model without the EB so that a similar comparison of all ten sections could be made for each of the different calibration procedures.

County-Specific Calibration

The results from running the validation sections through the IHSDM using the county-specific calibration method with the EB calibration are shown in Table 37.

TABLE 37 County-Specific Calibration Validation Results with EB Procedure

Section	Project Number	Route	Years Evaluated	Crashes		Percent Difference	Improvement
				Observed	Predicted		
1	K-5393-01	K-383	2002-2009	62	53.99	12.92%	19.87%
2	K-5384-01	US-50	2001-2009	78	86.18	10.49%	20.51%
4	K-5767-01	US-77	2006-2009	74	61.54	16.84%	-6.12%
5	K-5391-01	US-283	2000-2009	71	53.93	24.04%	-13.51%
7	K-5757-01	K-47	2002-2009	18	7.05	60.83%	0.39%
9	K-5749-01	K-156	2002-2009	174	183.79	5.63%	-2.11%
10	K-5743-01	US-50	2002-2009	69	58.21	15.64%	-12.38%
Sub-Total				546	504.69	7.57%	-4.96%
3	K-5745-01	US-56	2004-2009	25	24.48	2.08%	16.80%
6	K-5761-01	US-73	2005-2009	24	23.62	1.58%	1.42%
8	K-5741-01	US-36	2003-2009	15	16.86	12.40%	16.73%
Total				610	569.65	6.61%	-5.66%

The improvements given in Table 37 were relative to the results from the crash prediction model for the statewide calibration factor utilizing the EB procedure.

Section-Specific Calibration

The results from running the validation sections through the IHSDM using the segment-specific calibration method with the EB calibration are shown in Table 38.

TABLE 38 Section-Specific Calibration Validation Results without EB Procedure

Section	Project Number	Route	Years Evaluated	Crashes		Percent Difference	Improvement
				Observed	Predicted		
1	K-5393-01	K-383	2002-2009	62	60.32	2.71%	30.08%
2	K-5384-01	US-50	2001-2009	78	85.3	9.36%	21.64%
4	K-5767-01	US-77	2006-2009	74	68.61	7.28%	3.43%
5	K-5391-01	US-283	2000-2009	71	61	14.08%	-3.55%
7	K-5757-01	K-47	2002-2009	18	5.55	69.17%	-7.94%
9	K-5749-01	K-156	2002-2009	174	215.52	23.86%	-20.34%
10	K-5743-01	US-50	2002-2009	69	81.14	17.59%	-14.33%
Sub-Total				546	577.44	5.76%	-3.16%
3	K-5745-01	US-56	2004-2009	25	21.94	12.24%	6.64%
6	K-5761-01	US-73	2005-2009	24	60.02	150.08%	-147.08%
8	K-5741-01	US-36	2003-2009	15	19.32	28.80%	0.33%
Total				610	678.72	-11.27%	-10.31%

Summary

Table 39 and 40 summarize the data for the different combinations of calibration procedure. Table 39 shows a summary of the raw results. The highlighted cells are the sections where the EB procedure could not be utilized, and the non-EB results are carried over.

TABLE 39 Validation Results Summary in Crashes

			Crashes Predicted					
			No EB			Yes EB		
Section	Years Evaluated	Crashes Observed	Statewide	County	Section	Statewide	County	Section
1	2002-2009	62	37.75	52.24	60.48	41.67	53.99	60.32
2	2001-2009	78	119.71	84	82.38	102.18	86.18	85.3
3	2004-2009	25	29.72	24.48	21.94	29.72	24.48	21.94
4	2006-2009	74	49.63	43.88	53.13	66.07	61.54	68.61
5	2000-2009	71	66.31	53.05	62.67	63.52	53.93	61
6	2005-2009	24	23.28	23.62	60.02	23.28	23.62	60.02
7	2002-2009	18	8.75	8.89	6.31	6.98	7.05	5.55
8	2003-2009	15	19.37	16.86	19.32	19.37	16.86	19.32
9	2002-2009	174	146.7	152.26	209.65	180.12	183.79	215.52
10	2002-2009	69	62.82	46.13	78.24	71.25	58.21	81.14
Total		610	564.04	505.41	654.14	604.16	569.65	678.72

Table 40 summarizes the percent difference for each of the ten validation sections. In addition to the percent difference of the total predicted crashes are the average and median of the percent difference values.

TABLE 40 Validation Results Summary in Percent Difference

		Crashes Predicted (Percent Difference)					
		No EB			Yes EB		
Section	Years Evaluated	Statewide	County	Section	Statewide	County	Section
1	2002-2009	39.11%	15.74%	2.45%	32.79%	12.92%	2.71%
2	2001-2009	53.47%	7.69%	5.62%	31.00%	10.49%	9.36%
3	2004-2009	18.88%	2.08%	12.24%	18.88%	2.08%	12.24%
4	2006-2009	32.93%	40.70%	28.20%	10.72%	16.84%	7.28%
5	2000-2009	6.61%	25.28%	11.73%	10.54%	24.04%	14.08%
6	2005-2009	3.00%	1.58%	150.08%	3.00%	1.58%	150.08%
7	2002-2009	51.39%	50.61%	64.94%	61.22%	60.83%	69.17%
8	2003-2009	29.13%	12.40%	28.80%	29.13%	12.40%	28.80%
9	2002-2009	15.69%	12.49%	20.49%	3.52%	5.63%	23.86%
10	2002-2009	8.96%	33.14%	13.39%	3.26%	15.64%	17.59%
Average		25.92%	20.17%	33.79%	20.41%	16.24%	33.52%
Median		24.01%	14.12%	16.94%	14.80%	12.66%	15.84%
Total		7.53%	17.15%	-7.24%	2.60%	7.57%	5.76%

ANALYSIS

The alternate methods of calibration each had different benefits and costs and will be evaluated individually based on their performance.

Section-Specific Calibration

The crash predictions developed using this calibration method deviated most from the observed crashes when compared to the other calibration procedures evaluated. The average percent difference in the predicted versus experienced crashes for these ten validation sections was 33.8 percent. A primary contributor to this was section six, where the section-specific calibration predicted a value that was 150 percent different than the expected. This compared to the other two calibration procedures which were no more than 3 percent off.

In addition, the section-specific calibration was the only method that was not improved by using the EB procedure. This was likely due to the fact that the EB procedure and section-specific calibration each used previous crash data on a section as a means for improving the prediction on that section.

This combination of results leads to the conclusion that the section-specific calibration was overly sensitive to existing crash data and did not provide an additional benefit beyond what is provided by the EB procedure. For these reasons, the section-specific calibration was dropped from future consideration for implementation.

Outlier Data

Visual analysis of the validation data shows that validation section seven appeared to be an outlier because the accuracy of the crash prediction consistently deviated from the performance of the other sections for all of the calibration methods considered. Further analysis of the data for this section showed that this 2.2-mile highway section yielded an average of less than one crash per year before the improvements were made and over two crashes per year after the improvements. The traffic volumes after the improvement were approximately 10 to 25 percent higher than the before volumes as compared to the annual crash rate increased 3.4 times. Therefore the increase traffic volumes does not account for the spike in crash rate.

One data anomaly that that might explain this raise in crash rate was that the traffic volume maps that were used to derive the traffic data did not account for traffic for a route used as a detour for other routes that are under construction. K-GATE (KDOT's GIS database) was used to determine if there were any projects adjacent to this section that would have used it as a detour route during the study period. K-GATE revealed no routes that would have been closed during the analysis period and used this section as a detour. Lacking a clear reason to remove this section, it was kept for further analysis.

EB Procedure

The site-specific EB procedure almost universally improved the accuracy of the crash prediction for the remaining two calibration procedures. For the seven sections eligible for the EB procedure, five were improved for the statewide calibration method, and five were improved for the county-specific calibration. The improvement in percent-difference using the EB procedure was as high as 23.9 percent while the highest decrease in percent-difference was 10.2 percent, and that section had some other anomalies discussed above. On average, the site-specific EB procedure improved the crash prediction accuracy by 5.5 percent using the statewide calibration and 3.9 percent using the county-specific calibration. Therefore, it was recommended that the site-specific EB procedure be used when the data are available.

County-Specific Calibration

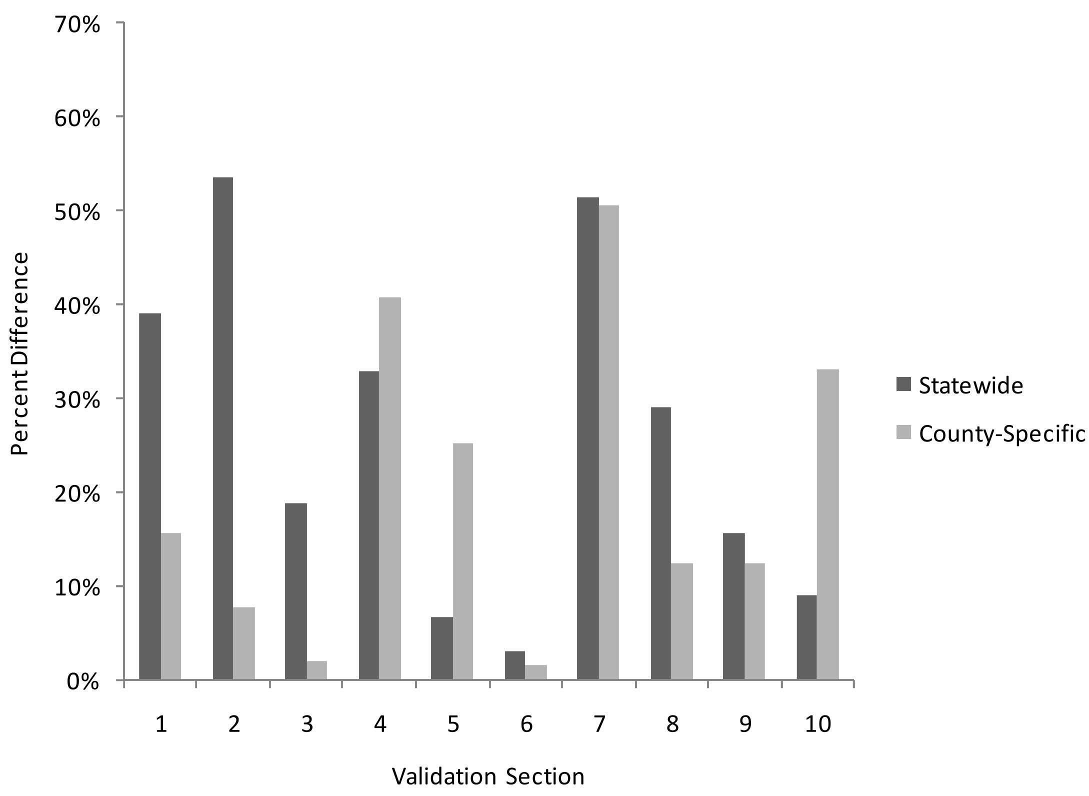
Total Crashes

The final calibration method to be assessed was the county-specific calibration. When looking at the total crashes for all ten sections averaged together, the statewide calibration performed better than the county-specific calibration. Specifically, with no EB procedure, the statewide calibration had a percent difference of 7.5 percent for the total crashes where the county specific calibration was 17.2 percent. Both methods improved when using the EB procedure to 2.6 percent and 7.6 percent respectively.

Cumulative Section Crashes

As previously demonstrated in Figure 8, the nature of the single statewide calibration is to produce a total predicted value that is close to the total predicted observed. However, even though the single statewide calibration produces a better estimate of total crashes, the county-specific method may produce the highest overall accuracy when looking at the individual sections analyzed. To address this, the analysis was extended to look at the cumulative section accuracy in addition to the accuracy of the total crashes. Figure 19 displays the accuracy of each of the ten validation sections with no EB procedure for both the statewide and county-specific calibration procedure.

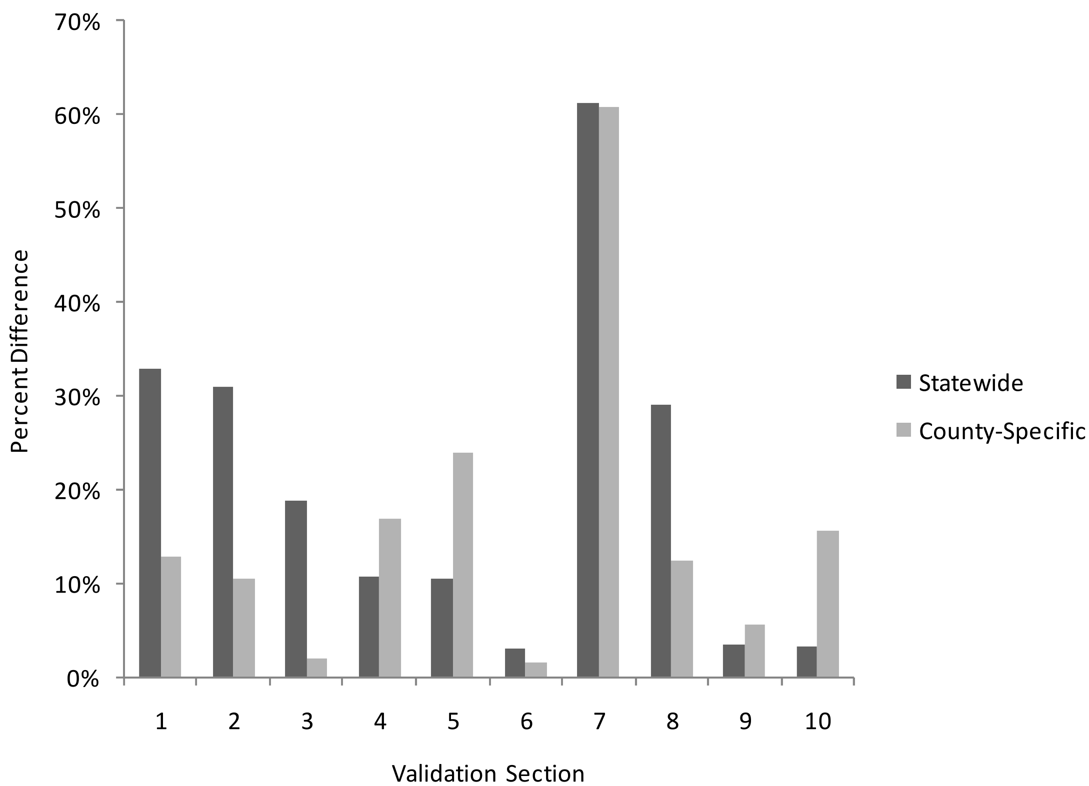
FIGURE 19 Validation Results with No EB Procedure in Percent Difference



The county-specific method improved the accuracy of the model for four of the ten sections. Three of the ten sections showed less accurate results with the county-specific method, and three were relatively unchanged. And as previously described, the average percent-difference for the county-specific calibration sections was 5.7 percent more accurate than using the statewide calibration. This compares to the average percent-difference of all of the sections, using the county-specific calibration of 20.2 percent.

Figure 20 displays the accuracy of each of the ten validation sections with the EB procedure for both the statewide and county-specific calibration procedure. To verify that the county-specific calibration still performed well when the EB procedure was used, the graph was repeated using the seven validation sections for which the EB procedure was valid. For sections 3, 6, and 8, where the EB procedure was not valid, the non-EB values were utilized.

FIGURE 20 Validation Results with the EB Procedure in Percent Difference



This graph most closely represents the way that the model would be used in practice, since the sections where the EB procedure was valid, are using that method, and when the EB procedure was not valid the non-EB values were used. The sections all performed similarly to the non-EB iterations with four improved, three reduced, and three with relatively no change in accuracy.

Again the number and weight of the improvements led to better overall accuracy using the county-specific method. The average percent-difference for the county-specific calibration sections is 4.2 percent more accurate than using the statewide calibration. This is a significant improvement considering that the average percent-difference for all of the sections, using the county-specific calibration, was 16.2 percent.

Statistical Measures

To test whether the model accurately predicts crashes in a statistically significant way, the paired t-test was used. The test was run on each of the two calibration procedures and with and without the EB procedure, creating four calibration procedure combinations. The predicted values from each section and each calibration combination were compared against the observed crashes for that section. A 90 percent significance level was used to evaluate the model accuracy. A two-tailed analysis was used because there was only concern with the relative accuracy and not whether the predictions were high or low. The null hypothesis was that there was no difference between the predicted and actual crash values represented in this model as a mean population difference equal to zero. Based on these parameters and nine degrees of freedom, the null hypothesis would be rejected if the calculated t-value is less than -1.833 or higher than 1.833 (43).

For this statistical analysis, the validation results were normalized by converting the predicted and observed crashes to a rate, in crashes per mile per year. This was done to avoid a longer section or a section with more years analyzed skewing the data. This normalization was not performed for the above percent-difference analysis because the percent-difference calculations are all made within the same section. The percent-difference within a section of the raw crash values and the rate values were the same. A summary of these rate values can be found in Appendix K.

Table 41 shows the four different calibration method combinations along with their respective results from the paired t-test.

TABLE 41 Paired T-Test Results

Calibration Procedure	EB	T-Value	P-Value
Statewide	No	0.602	0.562
County-Specific	No	0.85	0.417
Statewide	Yes	0.587	0.572
County-Specific	Yes	0.183	0.859

P-values were also calculated using the GraphPad Software website (44). Based on these values, the null hypothesis cannot be rejected for any of the calibration method combinations. Therefore, with a 90 percent confidence interval, we cannot reject the null hypothesis that there is no difference between the predicted and actual crash values for any of these four calibration combinations.

SUMMARY

For the validation of the HSM crash prediction model, three different calibration procedures were considered: statewide, county-specific, and section-specific. While the section-specific proved the most promising originally, it was determined that some of the fundamental assumptions used to develop this procedure broke down when using before data. Because the section-specific calibration did not hold up in the validation, it was dropped from consideration. The remaining two methods both demonstrated a relatively high accuracy for prediction modeling and are considered valid methods. Because the single statewide calibration did not provide a large enough range of predicted crashes, the county-specific calibration is recommended to be utilized for modeling crashes on Kansas rural two-lane highways.

The location-specific EB procedure was applied to all of the calibration methods and consistently provided to improve the accuracy of the model. While this procedure was not necessary to achieve an acceptable accuracy, it is recommended that the location-specific EB procedure be applied whenever practical.

This research demonstrated that CMFs alone, or in conjunction with a single statewide calibration factor, do not provide an adequate range of predicted crash rates to account for the different observed crash rates experienced on Kansas highways. Future research should:

- Continue to investigate if there are other methods that can provide accurate prediction results with greater consistency. These methods could include adjustment of the CMFs for Kansas or another calibration procedure.
- Determine if this same county-specific calibration can be applied to other crash prediction models, including the rural multi-lane, urban/suburban, or intersection model.

CHAPTER VII – CONCLUSION AND RECOMMENDATIONS

After completion of this research and analysis of the research results, several major findings were brought to the forefront. Some of these findings were consistent with the expectations previous to the study commencing, while some were developed through the evolution of the research. The research conclusions are organized into data collection, calibration, and validation as these are the main tasks performed in the research and correspond to the primary activities that future practitioners of the HSM will perform.

DATA COLLECTION

The data collection portion of the research was by far the greatest effort undertaken in this study. This was certainly complicated by the fact that KDOT databases had relatively few values that corresponded to the HSM data needs. Moreover, some of the data fields were not maintained to an accuracy that was sufficient for this study. Due to these limitations, several sources had to be consulted to provide the adequate data. While the HSM does allow for default values, finding values for all the fields was consistent with how the CPM would be applied at the project level.

Prior to beginning the research it was believed that certain fields, including RHR, would be especially difficult to develop since no existing KDOT resource provides this data. However, once the data collection effort had been performed it was found that no particular data element was appreciably harder to find than any other. The most time consuming effort to develop the models was, by far, translating all the different data sources to a single station reference. Due to the dynamic nature of some data, including the mileposts themselves, several different sources had to be consulted to accurately tie attributes to one another. If utilized for future design projects, this effort should be mitigated since a field survey should capture most of the geometric features and develop a primary alignment for reference.

Definition of Rural

The primary finding of the data collection effort, relative to application of the HSM to other jurisdictions, was the fundamental issue of what roadway sections were covered by the model.

During this research it was discovered that the definition of rural used by the HSM was inconsistent with application to highways going though cities with a population less than 5000. Based on this discrepancy, application of the HSM for Kansas rural highways only accounted for segments that do not go through a city of any size. While this definition may be overly restrictive, it allowed for a more consistent analysis until further study can be performed.

Neither this discrepancy nor this level of screening was previously considered in any other published study uncovered during this research. It was unclear from the review of literature if other states that have researched the model did not have highways that went through small cities with urban characteristics or if the impacts of these areas were considered negligible.

CALIBRATION

HSM Procedure

Performing the calibration procedure prescribed by the HSM was relatively straightforward. Unfortunately, the effort necessary to meet the minimum needs described by the manual was time consuming. It required modeling 19 ten-mile sections to develop just a single statewide calibration that met these minimum requirements. Analysis of the calibration sections showed that even with a single statewide calibration, the CMFs did not provide an adequate range of predicted crash rates to account for the different actual crash rates that were observed across these sections.

A preliminary analysis was performed to determine if calibration using the HSM procedure on smaller geographic sections would improve the accuracy of the model. While this analysis was limited, it did not show promise at the largest existing geographic division in KDOT, the district level. There may be future promise in utilizing ever smaller or more refined distributions using the HSM procedure, but available resources may be limiting given the significant data collection needs.

An additional element discovered while performing the calibration procedure was the impact of using the jurisdiction-specific crash distributions on the CPM. The calibration sections were analyzed using both the default and Kansas-specific distributions. The results showed that the prediction for each 10-mile section could vary as much as 8.4 percent and included both over-predictions and under-predictions when compared to the default. For use in calculating a calibration value, the aggregate difference was only 0.1 percent. This showed that while use of the jurisdiction-specific distributions may not greatly impact the calibration value, it can impact the results of crash prediction for a given section.

Alternative Procedure

Due to the limitations of the HSM calibration procedure, an alternative calibration procedure was sought. This effort focused on animal crashes due to their prevalence on Kansas rural two-lane highways. Several methods were investigated, but ultimately only two were carried further for future research. Both methods used the sections analyzed with the HSM procedure to discover tendencies in the calibration factor versus animal crash rates. While this procedure varied from what is prescribed in the HSM, it was consistent with the goal of the calibration procedure, to account for jurisdiction-specific attributes not already accounted for the in the CPM. In addition, this procedure was consistent with previous research. For Kansas, the animal crashes were an important variable, but other jurisdictions could use the Kansas procedure as a model to consider any significant crash generator in their jurisdiction.

VALIDATION

The goal of the validation section was to analyze the HSM CPM in a way that is most consistent with the way the CPM would be practically applied by KDOT and report the model accuracy accordingly. To that end, the site selection and data collection for validation focused on before-and-after analysis of sections that were reconstructed. In addition, the average accuracy of individual sections was considered in addition to the accuracy of the total crashes predicted. These values develop a baseline that state transportation authorities, including KDOT, can use to establish the expected performance of the HSM CPM.

EB Procedure

Not surprisingly the site-specific EB method of calibration consistently showed improvement in the accuracy of the CPM. Since KDOT keeps relatively accurate crash records with crashes tied to specific mile posts, the EB method should be utilized on all future application of the HSM CPM for rural two-lane highways.

Calibration Procedure

Three different calibrations, or calibration procedures, were carried forward for analysis in the validation portion of this research. The section-specific calibration was analyzed and removed leaving only the single statewide calibration value and the alternative county-specific calibration procedure. While both methods were shown to be reliable, the county-specific calibration procedure outperformed the single statewide value for accuracy of prediction.

FUTURE RESEARCH EFFORTS

In the process of filling some gaps in the existing research of the HSM CPM for rural two-lane roadways, this study also exposed some new areas that should be addressed by future researchers.

National Research

- The most significant finding of this research, relative to national application of the HSM CPM, is the fundamental definition of what sections qualify as rural. Those looking to apply the HSM CPM in the future could benefit from determination of the impact of this finding on previous studies and/or from confirmation of this discrepancy in other jurisdictions.

- Similarly future research could benefit from identifying how highways through small towns should be modeled. Specifically, it should be determined if modifications can be made to the rural two-lane model so these road can be analyzed, or do these roads perform in a way that is more consistent with the urban/suburban arterial model. It is also unknown if the higher crash rates along these relatively short sections of highway can skew analysis that groups them with rural sections that have no portion through a city.

- Since the alternative method for calibrating the HSM CPM improved the accuracy of the CPM for Kansas, it should be considered for use by other jurisdictions. This method could prove especially helpful for jurisdictions that have a significant cause of crashes that is not considered by the HSM CPM and is not related to the roadway geometry or traffic control.

Kansas Research

- To assist with future research in crash prediction on rural two-lane highways, KDOT should consider adding a field to the CANSYS database to determine if a section of highway goes through a city of any size.

- The calibration values developed with this research are only good for three years after the last year of data analyzed, 2007. Therefore, a new calibration value should be developed when the 2008-2010 crash data are available for Kansas. Since the IHSDM input files were prepared, the recalibration should be much simpler.

- The accuracy of the CPM, even when calibrated, was not as high as desired. Therefore, future research in Kansas should look at taking the next calibration step and develop jurisdiction-specific SPFs for Kansas highways.

- Investigate development of a KDOT-specific SPF to replace the default SPF.

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APPENDIX A – ORIGINAL DATA FIELDS FROM CANSYS

- RSE_DISTRICT
  - KDOT District, 1-6
- RSE_COUNTY
  - Kansas County, numbered by alphabetical order by county, 1-105
- FROM_LRS
  - LRS is the Linear Reference System used for internal highway system tracking.
- TO_LRS
  - LRS is the Linear Reference System used for internal highway system tracking.
- NE_GROUP
  - NE is the Number Element field used for internal highway system tracking.
- BOUND_GROUP
  - The bound group field is a code used for internal cataloging of the highway system.
- FROM_SECT
  - The section field is used for internal highway system tracking.
- TO_SECT
  - The section field is used for internal highway system tracking.
- RSE_BEGIN_DESCR
  - Written description of the beginning of the LRS Section
- RSE_END_DESCR
  - Text description of the end of the LRS Section
- BEGIN_COUNTY_MP
  - County milepost of the beginning of the LRS Section
- END_COUNTY_MP
  - County milepost of the end of the LRS Section
- NE_LENGTH
  - Length of the LRS section (miles), END_COUNTY_MP - BEGIN_COUNTY_MP
- NMS_MRG_JOB_ID
- NMS_MRG_SECTION_ID
- SECT_NETWORK_DIRECTION
  - Direction of highway, Eastbound (EB) or Northbound (NB)
- SECT_NE_SUB_TYPE
  - This field indicates whether the route is divided (D) or undivided (U)
- SECT_ROUTE
  - The section field is used for internal highway system tracking.
- INTR_INTRSCTN_NAME
  - Name of intersecting roadway, field was found to be incomplete
- INTR_ON_STATE_NONSTATE
  - Type of intersecting roadway, State highway (S) or other roadway (N)
- INTR_TFO_IND
  - TFO Indicator
- INTR_INTRSCTN_DESC

    - Text description of interesting roadway
- INTR_LEFT_TURN_LN
    - Type of left turn lane, values below, field was found to be incomplete
        - 0 - N/A, rural section, not permitted, or no intersections exist on section.
        - 1 - Turns permitted, mult. exclusive turning lanes exist.   No through
        - 2 - Turns permitted, cont. exclusive turn lane. (Chicken Ln) No through.
        - 3 - Turns Permitted, single exclusive turn lane.
        - 4 - Turns permitted, no exclusive turn lane.
        - 5 - No turn permitted during peak period.
- INTR_RIGHT_TURN_LANE
    - Type of right turn lane, values same as left turn lane, field was found to be incomplete
- INTR_NMBR_LGS
    - Number of total legs in intersection, field was found to be incomplete
- INTR_INTERSECTION_CONTROL
    - Type of intersection control, values below, field was found to be incomplete
        - 0 - N/A, rural section
        - 1 - Signal, uncoordinated fixed time
        - 2 - Signal, traffic actuated
        - 3 - Signal, progressive (cordinated signal through several intersections)
        - 4 - Stop sign
        - 5 - Other or No control
        - 6 - Roundabout
        - 7 - Interchange
- INTR_INTRSCTN_ID
    - ID number individual to each intersection in system
- LNCL_LNCL_CLS_ID
    - Lane Class, values below
        - 1 - 2LU - Two lane, undivided.
        - 10 - 1L1 - One lane, one way.
        - 11 - 2L1 - Two lane, one way.
        - 12 - 3L1 - Three lane, one way.
        - 13 - 4L1 - Four lane, one way.
        - 14 - 2LD - Two lane, divided
        - 2 - 4LU - Four lane, undivided.
        - 3 - 4LD - Four lane, divided.
        - 4 - 6LU - Six lane, undivided.
        - 5 - 6LD - Six lane, divided.
        - 6 - 8LU - Eight lane, undivided.
        - 7 - 8LD - Eight lane, divided.
        - 8 - 3L - Three lane.
        - 9 - 5L - Five lane.
- UAB_CITY_CODE
    - Urban area code, Rural (999)
- A007_AADT_CNT
    - 2007 AADT Value

- SHLD_SHOR_SHLDR_ID
  - Type of right shoulder
    - 1 - None - Non-State shoulder code
    - 10 - ASSC - ABS with B.S.T. and curb and gutter
    - 11 - BC - Bituminous base.
    - 12 - BCGU - Bituminous base and gutter
    - 13 - BCCG - Bituminous base curb and gutter
    - 14 - GUTT - Gutter
    - 15 - GUTU - Gutter and turf
    - 16 - GUAS - Gutter and ABS
    - 17 - GASS - Gutter and ABS (with B.S.T.)
    - 18 - GUBC - Gutter and bituminous base
    - 19 - CG - Curb and gutter
    - 2 - TURF - Turf.
    - 20 - CGTU - Curb and gutter and turf
    - 21 - CGAS - Curb and gutter and ABS
    - 22 - CASS - Curb and gutter and ABS (with B.S.T.)
    - 23 - CGBC - Curb and gutter and bituminous base
    - 24 - SEAG - Seeded aggregate base.
    - 25 - AISM - Agg. 1 with CACL2 (3R), LT 6".
    - 26 - CGMT - Mountable village curb and gutter
    - 27 - PCCBO - PCCP Shoulder w/ Bituminous Overlay
    - 28 - WEDG - Wedge <= 2' aggregate/bituminous filler.
    - 29 - PCC - Portland cement concrete shoulder.
    - 3 - TUGU - Turf and gutter
    - 30 - AC - Asphaltic concrete shoulder.
    - 31 - 1'BT - One foot bituminous with remainder turf.
    - 32 - 2'BT - Two feet bituminous with remainder turf.
    - 33 - 3'BT - Three feet bituminous with remainder turf.
    - 34 - 4'BT - Four feet bituminous with remainder turf.
    - 35 - 5'BT - Five feet bituminous with remainder turf.
    - 36 - 6'BT - Six feet bituminous with remainder turf.
    - 37 - 7'BT - Seven feet bituminous with remainder turf.
    - 38 - 8'BT - Eight feet bituminous with remainder turf.
    - 4 - TUCG - Turf and curb and gutter
    - 41 - 1'BA - One foot bituminous with remainder aggregate.
    - 42 - 2'BA - Two feet bituminous with remainder aggregate.
    - 43 - 3'BA - Three feet bituminous with remainder aggregate.
    - 44 - 4'BA - Four feet bituminous with remainder aggregate.
    - 45 - 5'BA - Five feet bituminous with remainder aggregate.
    - 46 - 6'BA - Six feet bituminous with remainder aggregate.
    - 47 - 7'BA - Seven feet bituminous with remainder aggregate.
    - 48 - 8'BA - Eight feet bituminous with remainder aggregate.
    - 5 - AS - Aggregate base stabilized, (CACL2), full design thickness.
    - 51 - 1'AT - One foot aggregate with remainder turf.
    - 52 - 2'AT - Two feet aggregate with remainder

- 53 - 3'AT - Three feet aggregate with remainder
- 54 - 4'AT - Four feet aggregate with remainder
- 55 - 5'AT - Five feet aggregate with remainder
- 56 - 6'AT - Six feet aggregate with remainder
- 57 - 7'AT - Seven feet aggregate with remainder
- 58 - 8'AT - Eight feet aggregate with remainder
- 6 - ASGU - Aggregate base stabilized and
- 60 - 3'CA - Three feet PCC with remainder
- 68 - PCA1C - PCCP with remainder AS1C
- 7 - ASCG - Aggregate base stabilized and
- 70 - PCBT - PCCP remainder bituminous.
- 71 - STABILIZED - Non-State code for Stabilized
- 72 - COMBINATION - Non-State code for
- 8 - ASSE - ABS with B.S.T.
- 9 - ASSG - ABS with B.S.T. and gutter

- SHLD_SHOR_SHLDR_WDTH
  - Width of right shoulder (meters)
- SHLD_SHOL_SHLDR_ID
  - Left shoulder type
    - Coding same as right shoulder type
- SHLD_SHOL_SHLDR_WDTH
  - Width of left shoulder (meters)
- LANE_LN1R_LN_ID
  - Type of first right lane, values below
    - 1 - THRU - Through lane
    - 10 - CREEPER - Creeper lane (grade associated)
    - 11 - DEAD - Dead lane for special situations
    - 12 - CONT LEFT TURN - Continuous left turn lane
    - 13 - CUT PARA PRK- Cut parallel parking (approx. 5 ft)
    - 14 - CUT DIAG PRK - Cut diagonal parking (approx. 17 ft)
    - 3 - LEFT TURN - Left turn lane
    - 4 - RIGHT TURN - Right turn lane
    - 5 - PASSING - Passing lane IAW "New Guideline" construction
    - 6 - ACCEL/DECEL -Acceleration lane
    - 7 - PARALLEL PRK - Parallel parking (approx. 8 FEET)
    - 8 - DIAGONAL PRK - Diagonal parking (approx. 17 feet)
    - 9 - CENTER PRK - Center parking
- LANE_LN1R_LN_WDTH
  - Width of first right lane (meters)
- LANE_LN2R_LN_ID
  - Type of second right lane (if present), values same as first right lane
- LANE_LN2R_LN_WDTH
  - Width of second right lane (if present) (meters)
- LANE_LN1L_LN_ID
  - Type of first left lane, values same as first right lane
- LANE_LN1L_LN_WDTH

- Width of first left lane (meters)
- LANE_LN2L_LN_ID
  - Type of second left lane (if present), values same as first right lane
- LANE_LN2L_LN_WDTH
  - Width of second left lane (if present) (meters)
- ACCL_SMRY_ACC_ID
  - Accident ID number, distinct for each reported accident
- ACCL_SMRY_ACC_TYPE_ID
  - Accident type
    - 1 - F - Includes a fatality.
    - 2 - D - No fatalities, highest severity is disabling injury.
    - 3 - N - No fatalities, highest severity is non-incapacitating injury.
    - 4 - I - No fatalities, highest severity is possible injury.
    - 5 - P - No fatalities or injuries, property damage only.
- ACCL_SMRY_ACC_DT
  - Date of accident

APPENDIX B – 2009 KANSAS MOTOR VEHICLE ACCIDENT REPORT

KDOT FORM 850A REV 1-2009

Kansas Motor Vehicle Accident Report

KDOT Form 850A Rev 1-2009

Investigating Department	Reviewed by	Local Case No.	Page of /	☐ Amended Report
Investigating Officer Name	Badge Number	County	City Name	☐ DUI ☐ Hit & Run

Milepost	Block No	Dir Pfx	On Road Name	Road Type	Dir Sfx	SpdLmt	Date of Accident (mm/dd/yyyy)	Time Occur.	Day
From Dist	Ft/Mi	From Dir ○ FROM ○ AT	Dir Pfx	Reference or At Road Name	Road Type	Dir Sfx	SpdLmt	Date Notified (mm/dd/yyyy)	Time Notif. / Day

○ Fatal
○ Injury
○ PDO >=$1,000
○ PDO < $1,000
☐ Private Property

Narrative: Describe each traffic unit's pre-crash movement and direction of travel

Date Arrived (mm/dd/yyyy) | Time Arriv. | Day

Latitude (AOI)

Longitude (AOI)

Photos by

KDOT? ☐	Object 1 Damaged & Nature of Damage (show in diagram)	Owner Street Address					Personal Phone
Owner Last Name	First Name	Middle Name	City	State	Zip		Work Phone

KDOT? ☐	Object 2 Damaged & Nature of Damage (show in diagram)	Owner Street Address					Personal Phone
Owner Last Name	First Name	Middle Name	City	State	Zip		Work Phone

WORK ZONE TYPE

O / A
- ○ ○ 00 None Apply
- ○ ○ 01 Construction Zone -
- ○ ○ 02 Maintenance Zone -
- ○ ○ 03 Utility Zone -
- ○ ○ 99 Unknown

KDOT? ☐

- LOCATION IN WORK ZONE (AOI)

- ○ 01 Before first warning sign
- ○ 02 Advance warning area
- ○ 03 Transition area
- ○ 04 Activity area
- ○ 05 Termination area
- ○ 99 Unknown

ONLY CHECK ONE BOX PER CATEGORY UNLESS SPECIFIED OTHERWISE

LIGHT CONDITIONS

- ○ 01 Daylight
- ○ 02 Dawn
- ○ 03 Dusk
- ○ 04 Dark: street lights on
- ○ 05 Dark: no street lights
- ○ 99 Unknown

ADVERSE WEATHER CONDITIONS

- ○ 00 No adverse conditions
- ○ 01 Rain, mist, drizzle
- ○ 02 Sleet, hail
- ○ 03 Snow
- ○ 04 Fog
- ○ 05 Smoke
- ○ 06 Strong wind
- ○ 07 Blowing dust, sand, etc.
- ○ 08 Freezing rain, mist, drizzle
- ○ 14 Rain & fog
- ○ 16 Rain & wind
- ○ 24 Sleet & fog
- ○ 36 Snow & wind
- ○ 88 Other: ______
- ○ 99 Unknown

SURFACE TYPE

O / A
- ○ ○ 01 Concrete
- ○ ○ 02 Blacktop (Asphalt)
- ○ ○ 03 Gravel
- ○ ○ 04 Dirt
- ○ ○ 05 Brick
- ○ ○ 88 Other: ______
- ○ ○ 99 Unknown

SURFACE CONDITIONS

O / A
- ○ ○ 01 Dry
- ○ ○ 02 Wet
- ○ ○ 03 Snow
- ○ ○ 04 Ice
- ○ ○ 05 Mud/dirt/sand
- ○ ○ 06 Debris (oil, etc.)
- ○ ○ 07 Standing/ moving water
- ○ ○ 08 Slush
- ○ ○ 88 Other: ______
- ○ ○ 99 Unknown

ACC. LOCATION

(of 1st Harmful Event)

ON ROADWAY: (within travel lanes)
- ○ 11 Non-intersection
- ○ 12 Intersection +
- ○ 13 Intersection-related +
- ○ 14 Access to Parking lot/Drvwy
- ○ 15 Interchange Area +
- ○ 16 On Crossover
- ○ 17 Toll Plaza

OFF ROADWAY:
- ○ 20 Shoulder
- ○ 21 Roadside (not shoulder)
- ○ 22 Median
- ○ 23 Parking lot or Rest area
- ○ 88 Other: ______
- ○ 99 Unknown

+INTERSECTION TYPE

- ○ 01 Four-way intersection
- ○ 02 Five-way or more
- ○ 03 T - intersection
- ○ 04 Y - intersection
- ○ 05 L - intersection
- ○ 06 Roundabout
- ○ 07 Traffic Circle
- ○ 08 Part of an interchange
- ○ 99 Unknown

(See Manual for Definitions)

ROAD SPECIAL FEATURES (up to 3)

- ☐ 00 None
- ☐ 01 Bridge ______
- ☐ 02 Bridge Overhead
- ☐ 03 Railroad Bridge
- ☐ 04 RRXING ______
- ☐ 05 Interchange
- ☐ 06 Ramp
- ☐ 99 Unknown

ACCIDENT CLASS

(mark 1 box per side)

1st Harmful Event		Most Harmful Event
○	00 Other non-collision	○
○	01 Overturned/Rollover	○
	COLLISION WITH:	
○	02 Pedestrian	○
○	03 Motor vehicle in-transport*	○
○	04 Legally Parked Vehicle	○
○	05 Railway train	○
○	06 Pedal cyclist	○
○	07 Animal Type: ______	○
○	08 Fixed object**	○
○	09 Other object: ______	○
○	99 Unknown	○

**FIXED OBJECT TYPE

(mark 1 box per side if applicable)

1st Harmful Event		Most Harmful Event
○	01 Bridge structure	○
○	02 Bridge rail	○
○	03 Crash cush./Impact attenuator	○
○	04 Divider, median barrier	○
○	05 Overhead sign support	○
○	06 Utility devices: pole,meter,etc	○
○	07 Other post or pole	○
○	08 Building	○
○	09 Guardrail	○
○	10 Sign post	○
○	11 Culvert	○
○	12 Curb	○
○	13 Fence/Gate	○
○	14 Hydrant	○
○	15 Barricade	○
○	16 Mailbox	○
○	17 Ditch	○
○	18 Embankment	○
○	19 Wall	○
○	20 Tree	○
○	21 RRXING fixtures	○
○	88 Other: ______	○
○	99 Unknown	○

- WORK ZONE CATEGORY

- ○ 01 Lane closure
- ○ 02 Lane shift / crossover
- ○ 03 Work on shoulder / median
- ○ 04 Intermittent or moving vehicle
- ○ 88 Other: ______
- ○ 99 Unknown

*COLLISION WITH VEHICLE

(mark 1 box per side if applicable)

1st Harmful Event		Most Harmful Event
○	01 Head on	○
○	02 Rear end	○
○	03 Angle - side impact	○
○	04 Sideswipe: opposite direction	○
○	05 Sideswipe: Same direction	○
○	06 Backed into	○
○	88 Other: ______	○
○	99 Unknown	○

TRAFFIC CONTROLS

(On / At Road) O/A

Type Present | OK/NF

- 00 None
- 01 Officer, flagger
- 02 Traffic signal
- 03 Stop sign
- 04 Flasher
- 05 Yield sign
- 06 RR gates / signal
- 07 RR crossing signs
- 08 No passing zone
- 09 Center/Edge lines
- 10 Warning signs
- 11 School zone signs
- 12 Parking lines
- 88 Other: ______
- 99 Unknown

1	1	1
2	2	2
3	3	3
4	4	4
5	5	5

Accident Diagram 850A continued	SPECIAL EVENT	SPECIAL DATA	Local Case No.	Page of /

ROADWAY NUMBER OF LANES

O / A
- O O 01 One
- O O 02 Two
- O O 03 Three
- O O 04 Four to Six
- O O 05 Seven or more
- O O 88 Other: ____________
- O O 99 Unknown

ROAD CHARACTER

O / A
- O O 01 Straight & Level
- O O 02 Straight on grade/slope
- O O 03 Straight on hillcrest
- O O 04 Curved & level
- O O 05 Curved on grade/slope
- O O 06 Curved on hillcrest
- O O 88 Other: ____________
- O O 99 Unknown

SPECIAL JURISDICTION

- O 00 Normal Jurisdiction (Not Special)
- O 01 National Park Service
- O 02 Military
- O 03 Indian Reservation
- O 04 College / University Campus
- O 05 Other Federal property
- O 88 Other: ____________
- O 99 Unknown

A basic diagram is required for all state reportable accidents showing movements, direction, and positions of all traffic units in relationship to the trafficway. Identify (label) the street(s) and traffic unit(s) along with the area of impact (AOI) where possible. Refer to vehicles and pedestrians by unique numbers assigned in this report.

Indicate North Direction

Draw scene as observed or recreate per statements and evidence available

Note: The above line scale is 1"=20'; 5 feet squares. If another scale is used, please specify.

Occupants & Vehicles
KDOT Form 850B Rev. 1-2009

DRIVER & PASSENGER INFORMATION
(record pedestrians on supplemental form 854)

Investigating Officer / Badge No.	Local Case No.	Page of
		/

TU#	VIOLATIONS CHARGED	CITATION#	TU#	VIOLATIONS CHARGED (More violations in narrative ☐)	CITATION#

OFFICER'S OPINION OF APPARENT CONTRIBUTING CIRCUMSTANCES - ENTER AS MANY AS APPLY TO THIS ACCIDENT (FACTOR TYPE, TU#, CC CODE)

Unit # / Seat Type	DRIVER Last Name / DRIVER First Name	Middle Name / Date of Birth	DRIVER ADDRESS (Number, Street, Suffix, etc.) / City State Zip	Personal Phone Number / Work Phone Number	Gender / Age	SE Used / Eject/Trap	Inj Severity / Eject Path	Transpt Unit / Extrication?
TU		MN	New address? ☐	Personal				
ST		DOB		Work				☐
TU		MN	New address? ☐	Personal				
ST		DOB		Work				☐

TRAFFIC UNIT# (01, 03, N3, X3, etc)

DL State	Driver's License Number	DL Class	Driving for Employer?	CDL?
			☐	☐

DR LICENSE COMPLY
- ○ 00 Not licensed
- ○ 01 Valid License
- ○ 02 Suspended
- ○ 03 Revoked
- ○ 04 Expired
- ○ 05 Cancld or Denied
- ○ 06 Disqualified
- ○ 07 Restricted
- ○ 99 Unknown

RESTRICT COMPLY

Restrictions? Y ○ N ○

Driver's Lic Restrictions		Complied? Y	N
1		○	○
2		○	○
3		○	○
4		○	○

COMMERCIAL ENDORSEMENTS
- ☐ Z - None
- ☐ T - Double/Triple Trailer
- ☐ P - Passenger Vehicle
- ☐ N - Tank Vehicle
- ☐ H - Placarded Haz. Material
- ☐ X - Combination Tank/HazMat
- ☐ S - School Bus
- ☐ U - Unknown

SUBSTANCE USE (mark all that apply)
- ☐ AP - Alcohol ingested
- ☐ AC - Alcohol contributed
- ☐ DP - Illegal drugs ingested
- ☐ DC - Illegal drugs contributed
- ☐ MP - Medication ingested
- ☐ MC - Medication contributed

METHOD OF DETERMINATION (mark all that apply)

ALCOHOL		DRUGS
☐	00 No evidence of impairment	☐
☐	01 Evidential Test (Breath,Blood,etc)	☐
☐	02 Preliminary Breath Test PBT	☐
☐	03 Behavioral Tests: HGN, walk-and-turn, one leg stand, etc.	☐
☐	04 Passive Alcohol Sensor (detects alcohol from driver's mouth)	☐
☐	05 Observed (Odor, staggering, slurred speech, etc)	☐
☐	06 Other (e.g. saliva test)	☐

IMPAIRMENT TEST (mark all that apply)
- ☐ NG - No Test given
- ☐ TR - Test Refused (Alcohol/Drug)
- ☐ PT - Prelim Positive Test (PBT)
- ☐ TG - Evidentiary Test given
- ☐ RP - Results pending

ALCOHOL

☐ Evidentiary Breath	☐ Eye Fluid
0.____	0.____
☐ Blood (BAC)	☐ Other
0.____	0.____

☐ Drug screen result ○ Pos ○ Neg

TRAFFIC UNIT# (02, 04, N2, X4, etc)

DL State	Driver's License Number	DL Class	Driving for Employer?	CDL?
			☐	☐

DR LICENSE COMPLY
- ○ 00 Not licensed
- ○ 01 Valid License
- ○ 02 Suspended
- ○ 03 Revoked
- ○ 04 Expired
- ○ 05 Cancld or Denied
- ○ 06 Disqualified
- ○ 07 Restricted
- ○ 99 Unknown

RESTRICT COMPLY

Restrictions? Y ○ N ○

Driver's Lic Restrictions		Complied? Y	N
1		○	○
2		○	○
3		○	○
4		○	○

COMMERCIAL ENDORSEMENTS
- ☐ Z - None
- ☐ T - Double/Triple Trailer
- ☐ P - Passenger Vehicle
- ☐ N - Tank Vehicle
- ☐ H - Placarded Haz. Material
- ☐ X - Combination Tank/HazMat
- ☐ S - School Bus
- ☐ U - Unknown

SUBSTANCE USE (mark all that apply)
- ☐ AP - Alcohol ingested
- ☐ AC - Alcohol contributed
- ☐ DP - Illegal drugs ingested
- ☐ DC - Illegal drugs contributed
- ☐ MP - Medication ingested
- ☐ MC - Medication contributed

METHOD OF DETERMINATION (mark all that apply)

ALCOHOL		DRUGS
☐	00 No evidence of impairment	☐
☐	01 Evidential Test (Breath,Blood,etc)	☐
☐	02 Preliminary Breath Test PBT	☐
☐	03 Behavioral Tests: HGN, walk-and-turn, one leg stand, etc.	☐
☐	04 Passive Alcohol Sensor (detects alcohol from driver's mouth)	☐
☐	05 Observed (Odor, staggering, slurred speech, etc)	☐
☐	06 Other (e.g. saliva test)	☐

IMPAIRMENT TEST (mark all that apply)
- ☐ NG - No Test given
- ☐ TR - Test Refused (Alcohol/Drug)
- ☐ PT - Prelim Positive Test (PBT)
- ☐ TG - Evidentiary Test given
- ☐ RP - Results pending

ALCOHOL

☐ Evidentiary Breath	☐ Eye Fluid
0.____	0.____
☐ Blood (BAC)	☐ Other
0.____	0.____

☐ Drug screen result ○ Pos ○ Neg

Unit # / Seat Type	PASSENGER Last Name / PASSENGER First Name	Middle Name / Date of Birth	PASSENGER ADDRESS (Number, Street, Sfx, etc.) / City State Zip	Personal Phone Number / Work Phone Number	Gender / Age	SE Used / Eject/Trap	Inj Severity / Eject Path	Transpt Unit / Extrication?
TU		MN	New address? ☐	Personal				
ST		DOB		Work				☐
TU		MN	New address? ☐	Personal				
ST		DOB		Work				☐
TU		MN	New address? ☐	Personal				
ST		DOB		Work				☐
TU		MN	New address? ☐	Personal				
ST		DOB		Work				☐

Transport Unit ___	EMS Time Notified	Injured taken by:	Transport Unit ___	EMS Time Notified	Injured taken by:
EMS Arrived	EMS Time@Hosp	Injured taken to:	EMS Arrived	EMS Time@Hosp	Injured taken to:

Transport Units: A, B, C, ..., N

Occupants & Vehicles
850B Continued

VEHICLE# (01, 03, N3, X3, etc) | SPECIAL DATA

OWNER Last Name ("Same" if Driver)	OWNER First Name	Middle Name

OWNER ADDRESS (Number, Street) New address? ☐	Personal Phone

CITY	ST	ZIP	Work Phone

COLOR	YEAR	MAKE	MODEL	BODY STYLE	ST

LICENSE PLATE #	County	Exp YR	Removed by:	MC CCs

VEHICLE IDENTIFICATION NUMBER	Dir of Travel	# Occupants

Insurance Company	Policy Number

SPECIAL CONDITIONS FOR TRAFFIC UNITS | Odometer | Fire? ☐

☐ 1 Hit & Run ☐ 2 Non-Contact ☐ 3 Stolen ☐ 7 Towed away due to damage
☐ 4 Legally Parked ☐ 5 Pursued by LE ☐ 6 Driverless

VEHICLE BODY TYPE

- ○ 01 Automobile
- ○ 02 Motorcycle
- ○ 03 Motor scooter or Moped
- ○ 04 Van
- ○ 05 Pickup truck <10,001 lbs
- ○ 06 Sport utility veh - SUV
- ○ 07 Camper or RV
- ○ 08 Farm machinery
- ○ 09 All-terrain vehicle - ATV

LARGE / HEAVY VEHICLE (GCVWR over 10,000lbs)

- ○ 10 Single heavy truck >10,000 lbs
- ○ 11 Truck & trailer(s)
- ○ 12 Tractor-trailer(s)
- ○ 13 Cross country bus
- ○ 14 School bus
- ○ 15 Transit (city) bus
- ○ 16 Other bus
- ○ 25 Train
- ○ 88 Other: ____
- ○ 99 Unknown

Calculated speed at impact

Bus Seat Capacity ____

○ Fuel ○ Hybrid ○ Electric

VEHICLE USE

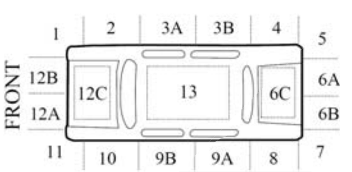
- ○ 01 No special use
- ○ 02 Taxi / Limo
- ○ 03 School bus
- ○ 04 Other bus
- ○ 05 Military
- ○ 06 Police
- ○ 07 Ambulance
- ○ 08 Fire
- ○ 09 Mail/Parcel
- ○ 99 Unknown

VEHICLE DAMAGE

- ○ 00 None
- ○ 01 Damage (minor)
- ○ 02 Functional
- ○ 03 Disabling
- ○ 04 Destroyed
- ○ 88 Other: ____
- ○ 99 Unknown

DAMAGE LOCATION AREA

First Impact ____ Major Impact ____



- ☐ 14 Undercarriage
- ☐ 15 Windshield
- ☐ 16 Other windows
- ☐ 99 Unknown
- ☐ 17 Entire vehicle damaged
- ☐ 88 Other: ____

Trailer? ○ Present ○ Damaged

VEH. MANU. BEFORE UNSTAB. SIT.

- ○ 01 Straight/ following road
- ○ 02 Left Turn
- ○ 03 Right Turn
- ○ 04 U Turn
- ○ 05 Passing
- ○ 06 Changing lanes
- ○ 07 Avoidance man.
- ○ 08 Merging
- ○ 09 Parking
- ○ 10 Backing
- ○ 11 Stopped awaiting turn
- ○ 12 Stopped in traf
- ○ 13 Illegally parked
- ○ 14 Disabled in roadway
- ○ 15 Slowing or stopping
- ○ 16 Negotiating a curve
- ○ 88 Other: ____
- ○ 99 Unknown

VEHICLE SEQUENCE OF EVENTS (List up to 4 per unit in the order of occurence)

1 ____ 2 ____ 3 ____ 4 ____ ☐ The exact sequence is unknown

NON-COLLISION

- 01 Ran off road right
- 02 Ran off road left
- 03 Crossed centerline
- 04 Overturn/Rollover
- 05 Crossed median
- 06 Fell/Jumped from veh
- 07 Thrown or falling object
- 08 Cargo loss or shift
- 09 Equipment failure (tire, brakes, etc.)
- 10 Downhill runaway
- 11 Trailer swing
- 12 Seperation of units
- 13 Jackknife
- 14 Fire
- 15 Explosion
- 16 Immersion in water
- 88 Other event: ____
- 98 Unknown non-coll.

COLLISION WITH

- 21 Pedestrian
- 22 Motor veh in-transport
- 23 Legally Parked Vehicle
- 24 Train
- 25 Pedal cycle (bike, etc)
- 26 Animal
- 27 Fixed Object
- 28 Other moveable object ____
- 99 Unknown object

VEHICLE# (02, 04, N2, X4, etc) | SPECIAL DATA | Local Case No. | Page / of

OWNER Last Name ("Same" if Driver)	OWNER First Name	Middle Name

OWNER ADDRESS (Number, Street) New address? ☐	Personal Phone

CITY	ST	ZIP	Work Phone

COLOR	YEAR	MAKE	MODEL	BODY STYLE	ST

LICENSE PLATE #	County	Exp YR	Removed by:	MC CCs

VEHICLE IDENTIFICATION NUMBER	Dir of Travel	# Occupants

Insurance Company	Policy Number

SPECIAL CONDITIONS FOR TRAFFIC UNITS | Odometer | Fire? ☐

☐ 1 Hit & Run ☐ 2 Non-Contact ☐ 3 Stolen ☐ 7 Towed away due to damage
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- ○ 03 Motor scooter or Moped
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- ○ 05 Pickup truck <10,001 lbs
- ○ 06 Sport utility veh - SUV
- ○ 07 Camper or RV
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LARGE / HEAVY VEHICLE (GCVWR over 10,000lbs)

- ○ 10 Single heavy truck >10,000 lbs
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- ○ 12 Tractor-trailer(s)
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- ○ 14 School bus
- ○ 15 Transit (city) bus
- ○ 16 Other bus
- ○ 25 Train
- ○ 88 Other: ____
- ○ 99 Unknown

Calculated speed at impact

Bus Seat Capacity ____

○ Fuel ○ Hybrid ○ Electric

VEHICLE USE

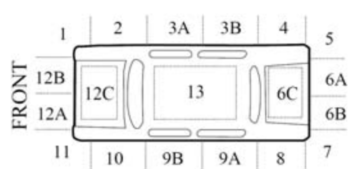
- ○ 01 No special use
- ○ 02 Taxi / Limo
- ○ 03 School bus
- ○ 04 Other bus
- ○ 05 Military
- ○ 06 Police
- ○ 07 Ambulance
- ○ 08 Fire
- ○ 09 Mail/Parcel
- ○ 99 Unknown

VEHICLE DAMAGE

- ○ 00 None
- ○ 01 Damage (minor)
- ○ 02 Functional
- ○ 03 Disabling
- ○ 04 Destroyed
- ○ 88 Other: ____
- ○ 99 Unknown

DAMAGE LOCATION AREA

First Impact ____ Major Impact ____



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- ☐ 15 Windshield
- ☐ 16 Other windows
- ☐ 99 Unknown
- ☐ 17 Entire vehicle damaged
- ☐ 88 Other: ____

Trailer? ○ Present ○ Damaged

VEH. MANU. BEFORE UNSTAB. SIT.

- ○ 01 Straight/ following road
- ○ 02 Left Turn
- ○ 03 Right Turn
- ○ 04 U Turn
- ○ 05 Passing
- ○ 06 Changing lanes
- ○ 07 Avoidance man.
- ○ 08 Merging
- ○ 09 Parking
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- ○ 88 Other: ____
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- 04 Overturn/Rollover
- 05 Crossed median
- 06 Fell/Jumped from veh
- 07 Thrown or falling object
- 08 Cargo loss or shift
- 09 Equipment failure (tire, brakes, etc.)
- 10 Downhill runaway
- 11 Trailer swing
- 12 Seperation of units
- 13 Jackknife
- 14 Fire
- 15 Explosion
- 16 Immersion in water
- 88 Other event: ____
- 98 Unknown non-coll.

COLLISION WITH

- 21 Pedestrian
- 22 Motor veh in-transport
- 23 Legally Parked Vehicle
- 24 Train
- 25 Pedal cycle (bike, etc)
- 26 Animal
- 27 Fixed Object
- 28 Other moveable object ____
- 99 Unknown object

Accident Narrative KDOT Form 851 Rev. 1-2009	**Officer Observations** **Description of Events**	**Witness Statements** **Additional Information**	Investigating Officer / Badge No.	Local Case No.	Page of /

Accident Narrative 851 Continued	**Officer Observations** **Witness Statements** **Description of Events** **Additional Information**	Local Case No.	Page of /

☐ Completed Post Crash Inspection

HEAVY VEHICLE & HAZMAT Supplement

KDOT Form 852 Rev. 1-2009

INFORMATION ON HEAVY VEHICLES / BUSES / HAZARDOUS MATERIALS

Investigating Officer / Badge No.

Local Case No.

MOTOR CARRIER INFORMATION

☐ TU #

Carrier Name

Carrier Street Address (P.O. Box only if no street address)

City

State

Zip

Phone

Carrier Country

CARRIER IDENTIFICATION NUMBER(S)

USDOT#

MC/MX#

☐ NONE

CARRIER TYPE

- 0 - Intrastate
- 1 - Interstate
- 2 - Not in Commerce - Other Truck or Bus
- 3 - Not in Commerce - Government Veh
- 4 - Other / Not Specified

AT THE TIME OF CRASH, THIS VEHICLE WAS:

- 01 Operating on a trafficway open to the public (In-Transport)
- 02 Parked on or off the trafficway
- 88 Other: ______
- 99 Unknown

GVWR/GCWR

- 01 10,000 lbs or less
- 02 10,001-26,000 lbs
- 03 More than 26,000 lbs
- 99 Unknown

ACTUAL WEIGHT ______ lbs

SOURCE OF CARRIER NAME

- 01 Side of vehicle
- 02 Shipping papers or manifest
- 03 Driver
- 04 Logbook

PERMITS (Issuer and Permit Number)

1. ______ ______
2. ______ ______
3. ______ ______

VEHICLE INFORMATION

TRAILER DIMENSIONS

	WIDTH (in)	LENGTH (ft)
Trailer 1		
Trailer 2		
Trailer 3		

TRAILER(s) DAMAGED?

- ☐ None
- ☐ Trailer 1
- ☐ Trailer 2
- ☐ Trailer 3

OVERSIZED LOAD

- ☐ Height
- ☐ Weight
- ☐ Width

HAZMAT / ROADWAY INFORMATION

HAZARDOUS MATERIALS INVOLVEMENT

Did the vehicle have a Hazardous Materials Placard? Yes ○ No ○

If Yes, Include The Following Information From The Placard:

HazMat 4-digit # from the diamond center box: ______

HazMat Class # from the bottom of diamond: ______

HazMat Weight (lbs) ______

Was HazMat released (spilled) from THIS vehicle's cargo? Yes ○ No ○

TRUCK AND TRAILER TOTALS

Vehicle Length (include trailer(s)) ______ ft No. of Trailers ______ No. of Axles ______

TRAILER 1 - IDENTIFICATION NUMBER

TRAILER 2 - IDENTIFICATION NUMBER

TRAILER 3 - IDENTIFICATION NUMBER

ON-ROAD LANE TYPE

- 00 Two-way traffic - Undivided roadway
- 01 One-way traffic - Undivided roadway
- 02 Two-way traffic - Median strip w/o barrier
- 03 Two-way traffic - Median strip w/ barrier
- 04 Two-way traffic - Undivided with a continuous left turn lane
- 99 Unknown

VEHICLE ACCESS CONTROL TO ROADWAYS

- 00 No access control (Unlimited access - Roads with no interchanges)
- 01 Partial access control (mix of interchanges and "at-grade" intersections)
- 02 Full access control (entry/exit only by interchange ramps)
- 99 Unknown

SEE BACK OF THIS FORM FOR EXAMPLES OF VEHICLE CONFIGURATIONS AND CARGO TYPES

VEHICLE CONFIGURATION

- 00 Bus 9-15 passengers, including driver
- 01 Bus more than 15 passengers
- 02 Single-unit truck (2-axles)
- 03 Single-unit truck (3 or more axles)
- 04 Single-unit truck with trailer(s)
- 05 Truck Tractor only (bobtail)
- 06 Truck Tractor and semi-trailer
- 07 Truck Tractor and two trailers
- 08 Truck Tractor and three trailers
- 09 Heavy truck > 10,000 lbs cannot classify
- 10 Vehicles less than 10,000 lbs carrying hazardous materials
- 88 Other: ______
- 99 Unknown

CAB TYPE

- 01 Cab behind engine
- 02 Cab over engine
- 99 Unknown

CARGO BODY TYPE

- 00 Not applicable/No cargo body
- 01 Van or Enclosed box
- 02 Hopper (e.g. Grain, Chips, Gravel)
- 03 Cargo tank (liquid, powder, etc)
- 04 Flatbed
- 05 Dump
- 06 Concrete mixer
- 07 Vehicle transporter
- 08 Garbage or refuse
- 09 Bus 9-15 people, including driver
- 10 Bus more than 15 people
- 11 Pole
- 12 Vehicle towing another motor vehicle
- 13 Intermodal chassis
- 14 Logging
- 88 Other: ______
- 99 Unknown

CARGO TYPE

- 00 None
- 01 Drive away or Tow away
- 02 Explosives
- 03 Animals: farm or other
- 04 Farm products
- 05 Gases
- 06 General freight (packages)
- 07 Heavy machinery, objects
- 08 Household goods
- 09 Liquids (bulk)
- 10 Logs, poles, lumber
- 11 Metal (coils, sheets, etc)
- 12 Mobile / Modular home
- 13 Motor vehicles
- 14 Refrigerated foods
- 15 Solids (bulk)
- 16 Rock, sand, gravel, salt
- 17 Other food products
- 18 Plastic products
- 19 People
- 20 Garbage / refuse
- 21 Pavement mixture: concrete, asphalt, etc.
- 88 Other: ______
- 99 Unknown

SPECIAL DATA

REPORTING CRITERIA FOR HEAVY VEHICLES AND/OR HAZARDOUS MATERIALS

COMPLETE THIS SUPPLEMENT FOR EACH OF THE FOLLOWING VEHICLES INVOLVED WHERE AT LEAST ONE MOTOR VEHICLE IN-TRANSPORT WAS ON A TRAFFICWAY OPEN TO THE PUBLIC:

>10,000 lbs Any truck having a gross vehicle weight rating (GVWR) of more than 10,000 pounds or a gross combination weight rating (GCWR) over 10,000 pounds used on public trafficways, OR...

BUS Any motor vehicle with seats to transport nine (9) or more people, including the driver OR...

HAZMAT Any vehicle, regardless of weight, carrying placardable hazardous materials or displaying a hazardous materials placard.

AND

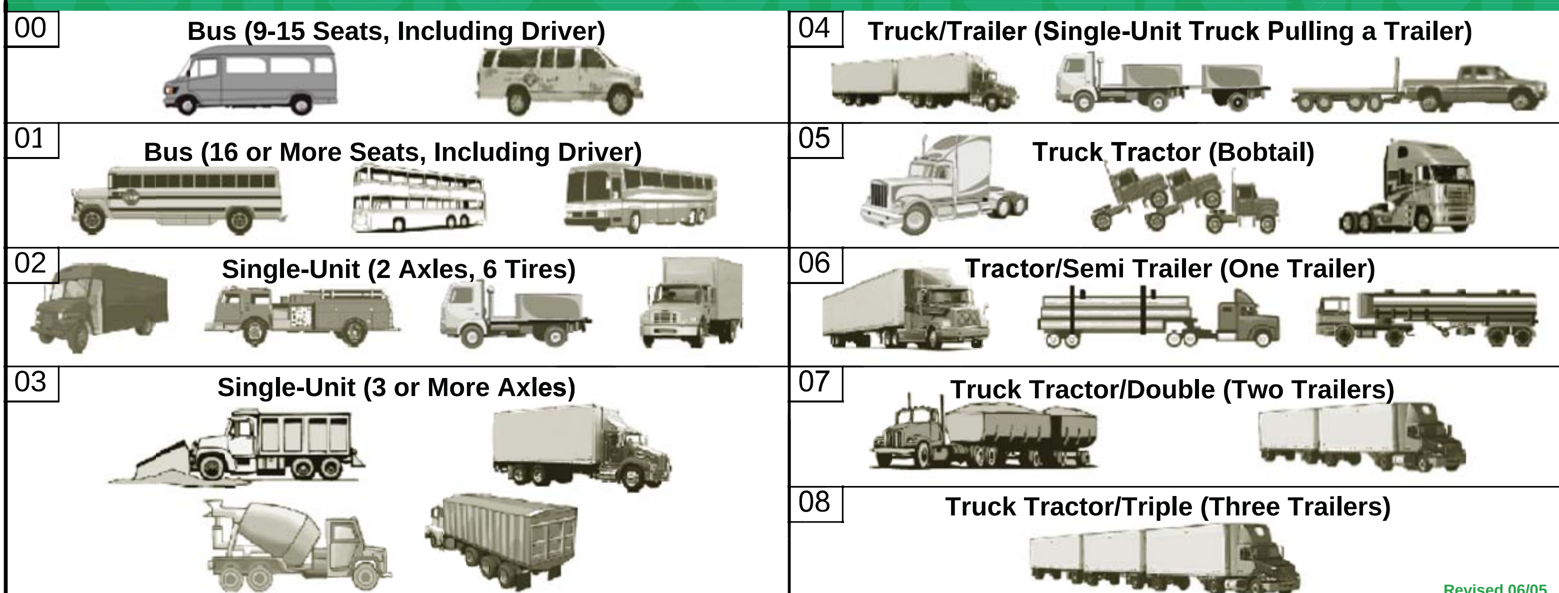
IF THIS ACCIDENT INCLUDES:

A FATALITY: Any person(s) killed in or outside of any vehicle (truck, bus, car, etc.) involved in the crash or who dies within 30 days of the crash as a result of an injury sustained in the crash, OR...

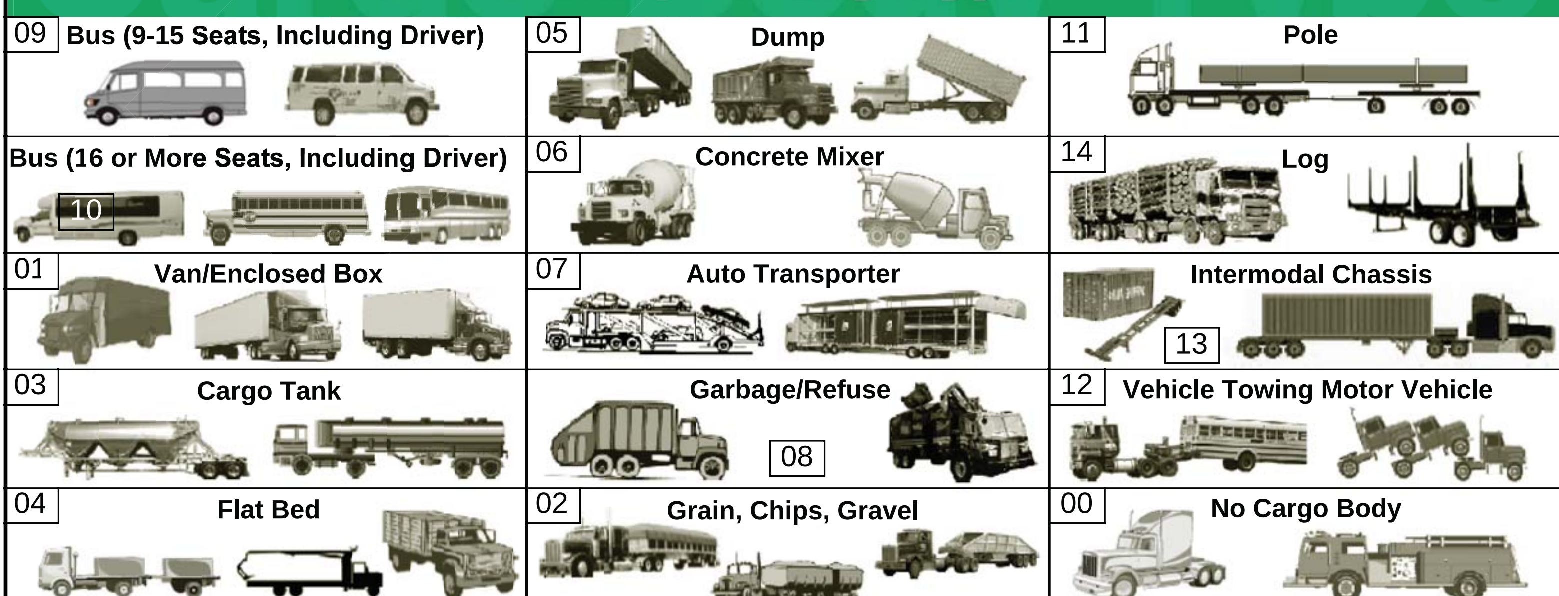
AN INJURY: Any person(s) injured as a result of the crash who immediately receives medical treatment away from the crash scene, OR...

TOW-AWAY: Any motor vehicle (truck combination, bus, car, etc.) disabled as a result of the crash and transported away from the scene by a tow truck or other vehicle.

Vehicle Configuration



Cargo Body Type



Passengers & Pedestrians KDOT Form 854 Rev. 1-2009	LIST ADDITIONAL PASSENGERS BY TRAFFIC UNIT	Investigating Officer / Badge No.	Local Case No.	Page of /

Unit # Seat Type	PASSENGER Last Name PASSENGER First Name	Middle Name Date of Birth	PASSENGER ADDRESS (Number, Street, Sfx, etc.) City State Zip	Personal Phone Number Work Phone Number	Gender Age	SE Used Eject/Trap	Inj Severity Eject Path	Transpt Unit Extrication?
TU		MN	New address? ☐	Personal				
ST		DOB		Work				☐
TU		MN	New address? ☐	Personal				
ST		DOB		Work				☐
TU		MN	New address? ☐	Personal				
ST		DOB		Work				☐
TU		MN	New address? ☐	Personal				
ST		DOB		Work				☐
TU		MN	New address? ☐	Personal				
ST		DOB		Work				☐
TU		MN	New address? ☐	Personal				
ST		DOB		Work				☐
TU		MN	New address? ☐	Personal				
ST		DOB		Work				☐
TU		MN	New address? ☐	Personal				
ST		DOB		Work				☐
TU		MN	New address? ☐	Personal				
ST		DOB		Work				☐
TU		MN	New address? ☐	Personal				
ST		DOB		Work				☐
TU		MN	New address? ☐	Personal				
ST		DOB		Work				☐
TU		MN	New address? ☐	Personal				
ST		DOB		Work				☐
TU		MN	New address? ☐	Personal				
ST		DOB		Work				☐
TU		MN	New address? ☐	Personal				
ST		DOB		Work				☐
TU		MN	New address? ☐	Personal				
ST		DOB		Work				☐
TU		MN	New address? ☐	Personal				
ST		DOB		Work				☐

Transport Unit ____	EMS Time Notified	Injured taken by:	**Transport Unit** ____	EMS Time Notified	Injured taken by:
EMS Arrived	EMS Time@Hosp	Injured taken to:	EMS Arrived	EMS Time@Hosp	Injured taken to:
Transport Unit ____	EMS Time Notified	Injured taken by:	**Transport Unit** ____	EMS Time Notified	Injured taken by:
EMS Arrived	EMS Time@Hosp	Injured taken to:	EMS Arrived	EMS Time@Hosp	Injured taken to:

Transport Units: A, B, C, ..., N

Passengers & Pedestrians
854 continued

PEDESTRIAN INFORMATION

Investigating Officer / Badge No.	Local Case No.	Page of
		/

Unit # / Ped Type	PEDESTRIAN Last Name / PEDESTRIAN First Name	Middle Name / Date of Birth	PEDESTRIAN ADDRESS (Number, Street, Sfx, etc.) / City State Zip	Personal Phone Number / Work Phone Number	Gender / Age	SE Used / Eject/Trap	Inj Severity / Eject Path	Transpt Unit / Extrication?
TU		MN	New address? ☐	Personal				
PT		DOB		Work				☐
TU		MN	New address? ☐	Personal				
PT		DOB		Work				☐

Transport Unit ___	EMS Time Notified	Injured taken by:	Transport Unit ___	EMS Time Notified	Injured taken by:
EMS Arrived	EMS Time@Hosp	Injured taken to:	EMS Arrived	EMS Time@Hosp	Injured taken to:

TU#	DirTrvl	DL State	Driver's License Number	Special Data	TU#	DirTrvl	DL State	Driver's License Number	Special Data

PEDESTRIAN ROADWAY LOCATION BEFORE IMPACT

- ○ 00 NOT in roadway (driving lanes)

IN or AT INTERSECTION
- ○ 01 In crosswalk or bikeway
- ○ 02 NOT in crosswalk or bikeway
- ○ 03 In intersection without a crosswalk or bikeway

NOT IN or AT INTERSECTION
- ○ 11 In crosswalk or bikeway
- ○ 12 NOT in crosswalk or bikeway
- ○ 13 In area without a crosswalk or bikeway

- ○ 88 Other: ________________
- ○ 99 Unknown

OTHER PEDESTRIAN LOCATION (Not in Driving Lanes)

- ○ 01 Within a work zone
- ○ 02 In median (not shoulder)
- ○ 03 On Island
- ○ 04 Road shoulder (not ditch or median)
- ○ 05 Roadside (not on shoulder)
- ○ 06 Sidewalk
- ○ 07 Outside trafficway
- ○ 08 Driveway access crosswalk
- ○ 09 Dedicated bike lane
- ○ 10 Shared-use path or trails
- ○ 11 Inside building
- ○ 12 In legally parked vehicle
- ○ 88 Other: ________________
- ○ 99 Unknown

PEDESTRIAN ACTION BEFORE CRASH

- ○ 01 Walking / cycling to or from school
- ○ 02 Approaching or leaving bus
- ○ 03 Approaching or leaving vehicle
- ○ 04 Working (not on vehicle)
- ○ 05 Working on vehicle
- ○ 06 Pushing motor vehicle
- ○ 07 Standing, sitting, or lying
- ○ 08 Playing, running, walking
- ○ 09 Cycling
- ○ 10 Entering or crossing
- ○ 88 Other: ________________
- ○ 99 Unknown

PEDESTRIAN OBEDIENCE TO TRAFFIC SIGNAL

- ○ 00 No pedestrian signal
- ○ 01 Obeyed pedestrian signal
- ○ 02 Disobeyed pedestrian signal
- ○ 03 Ped signal malfunction
- ○ 04 Not applicable
- ○ 99 Unknown

SUBSTANCE USE
(mark all that apply)

- ☐ AP - Alcohol ingested
- ☐ AC - Alcohol contributed
- ☐ DP - Illegal drugs ingested
- ☐ DC - Illegal drugs contributed
- ☐ MP - Medication ingested
- ☐ MC - Medication contributed

METHOD OF DETERMINATION
(mark all that apply)

ALCOHOL		DRUGS
☐	00 No evidence of impairment	☐
☐	01 Evidential Test (Breath,Blood,etc)	☐
☐	02 Preliminary Breath Test PBT	☐
☐	03 Behavioral Tests: HGN, walk-and-turn, one leg stand, etc.	☐
☐	04 Passive Alcohol Sensor (detects alcohol from driver's mouth)	
☐	05 Observed (Odor, staggering, slurred speech, etc)	☐
☐	06 Other (e.g. saliva test)	☐

IMPAIRMENT TEST
(mark all that apply)

- ☐ NG - No Test given
- ☐ TR - Test Refused (Alcohol/Drug)
- ☐ PT - Prelim Positive Test (PBT)
- ☐ TG - Evidentiary Test given
- ☐ RP - Results pending

ALCOHOL

☐ Evidentiary Breath 0.____	☐ Eye Fluid 0.____
☐ Blood (BAC) 0.____	☐ Other 0.____

☐ Drug screen ○ Pos ○ Neg

PEDESTRIAN ROADWAY LOCATION BEFORE IMPACT

- ○ 00 NOT in roadway (driving lanes)

IN or AT INTERSECTION
- ○ 01 In crosswalk or bikeway
- ○ 02 NOT in crosswalk or bikeway
- ○ 03 In intersection without a crosswalk or bikeway

NOT IN or AT INTERSECTION
- ○ 11 In crosswalk or bikeway
- ○ 12 NOT in crosswalk or bikeway
- ○ 13 In area without a crosswalk or bikeway

- ○ 88 Other: ________________
- ○ 99 Unknown

OTHER PEDESTRIAN LOCATION (Not in Driving Lanes)

- ○ 01 Within a work zone
- ○ 02 In median (not shoulder)
- ○ 03 On Island
- ○ 04 Road shoulder (not ditch or median)
- ○ 05 Roadside (not on shoulder)
- ○ 06 Sidewalk
- ○ 07 Outside trafficway
- ○ 08 Driveway access crosswalk
- ○ 09 Dedicated bike lane
- ○ 10 Shared-use path or trails
- ○ 11 Inside building
- ○ 12 In legally parked vehicle
- ○ 88 Other: ________________
- ○ 99 Unknown

PEDESTRIAN ACTION BEFORE CRASH

- ○ 01 Walking / cycling to or from school
- ○ 02 Approaching or leaving bus
- ○ 03 Approaching or leaving vehicle
- ○ 04 Working (not on vehicle)
- ○ 05 Working on vehicle
- ○ 06 Pushing motor vehicle
- ○ 07 Standing, sitting, or lying
- ○ 08 Playing, running, walking
- ○ 09 Cycling
- ○ 10 Entering or crossing
- ○ 88 Other: ________________
- ○ 99 Unknown

PEDESTRIAN OBEDIENCE TO TRAFFIC SIGNAL

- ○ 00 No pedestrian signal
- ○ 01 Obeyed pedestrian signal
- ○ 02 Disobeyed pedestrian signal
- ○ 03 Ped signal malfunction
- ○ 04 Not applicable
- ○ 99 Unknown

SUBSTANCE USE
(mark all that apply)

- ☐ AP - Alcohol ingested
- ☐ AC - Alcohol contributed
- ☐ DP - Illegal drugs ingested
- ☐ DC - Illegal drugs contributed
- ☐ MP - Medication ingested
- ☐ MC - Medication contributed

METHOD OF DETERMINATION
(mark all that apply)

ALCOHOL		DRUGS
☐	00 No evidence of impairment	☐
☐	01 Evidential Test (Breath,Blood,etc)	☐
☐	02 Preliminary Breath Test PBT	☐
☐	03 Behavioral Tests: HGN, walk-and-turn, one leg stand, etc.	☐
☐	04 Passive Alcohol Sensor (detects alcohol from driver's mouth)	
☐	05 Observed (Odor, staggering, slurred speech, etc)	☐
☐	06 Other (e.g. saliva test)	☐

IMPAIRMENT TEST
(mark all that apply)

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- ☐ TR - Test Refused (Alcohol/Drug)
- ☐ PT - Prelim Positive Test (PBT)
- ☐ TG - Evidentiary Test given
- ☐ RP - Results pending

ALCOHOL

☐ Evidentiary Breath 0.____	☐ Eye Fluid 0.____
☐ Blood (BAC) 0.____	☐ Other 0.____

☐ Drug screen ○ Pos ○ Neg

Transport Units: A, B, C, ..., N

Accident Code Sheet KDOT Form 855 Rev. 1-2009	CONTRIBUTING CIRCUMSTANCES (LIST IN ORDER OF SIGNIFICANCE)

Example: |D1|42|OR|02 Interpretation: Driver 1 made an improper turn on icy or slushy roadway

DRIVER CCs (D + TU# = D1)

00 No driver contributing circumstance evident

DRIVER CONDITION AT THE TIME OF CRASH

01 Under the influence of illegal Drugs
02 Under the influence of Alcohol
03 Under the influence of medication
04 Ill or Medical condition
05 Fell asleep or fatigued
06 Emotional: Angry, depressed, upset, impatient, etc.

DRIVER DISTRACTED BY

20 Mobile (cell) phone
21 Other electronic devices
22 Other distraction in or on vehicle
23 An item or action NOT in or on vehicle
24 Inattention (general sense)

DRIVER ACTIONS AT THE TIME OF CRASH

30 Failed to yield the right of way
31 Disregarded traffic signs, signals, or markings
32 Red light running (disregarded traffic signal)
33 Followed too closely
34 Exceeded posted speed limit
35 Too fast for conditions
36 Impeding or Too slow for traffic
37 Avoidance or Evasive action
38 Over correction / Over steering
39 Reckless / Careless driving
40 Aggressive / Antagonistic driving
41 Improper lane change
42 Made improper turn
43 Improper backing
44 Improper passing
45 Improper or No turn signal
46 Improper parking
47 Wrong side or wrong way
48 Did not comply with license restrictions

ENVIRONMENT (code E, no TU#)

01 Animal: domestic or wild

WEATHER RELATED

02 Rain, mist, or drizzle
03 Sleet, hail, or freezing rain
04 Falling or Blowing snow
05 Strong winds
06 Fog, smoke, or smog
07 Blowing sand, soil, or dirt
08 Reduced visibility due to cloudy skies

VISION OBSTRUCTIONS

15 Building, vehicles, object made by humans
16 Vegetation: trees, shrubs, etc.
17 Glare from sun, headlights, or other lights

PEDESTRIAN CCs (P + TU# = P1)

00 No pedestrian contributing circumstance evident

NON-MOTORIST CONDITION AT THE TIME OF CRASH

01 Under the influence of illegal drugs
02 Under the influence of Alcohol
03 Under the influence of medication
04 Ill or Medical condition
05 Fell asleep or fatigued
06 Emotional: Angry, depressed, upset, impatient, etc.

NON-MOTORIST DISTRACTED BY

15 Mobile (cell) phone
16 Other electronic devices
17 Inattention (general sense)

NON-MOTORIST ACTIONS AT THE TIME OF CRASH

25 Failed to yield the right of way
26 Disregarded traffic control signs, signals, officer, etc.
27 Improper crossing
28 In Roadway (standing, lying, etc)
29 Darting
30 Wrong side of roadway
31 Not visible (dark clothing)
32 Pedal cycle violation(s)

VEHICLE CCs (V + TU# = V1)

PROBLEMS WITH OR LOSS OF...

01 Brakes
02 Tires
03 Wheel(s)
13 Mirrors
14 Unattended or driverless in motion
15 Unattended or driverless not in motion
04 Trailer coupling, hitch, or safety chains
05 Cargo
06 Window or windshield; ice on windshield, tinting, etc
07 Wipers
08 Lights: Front (head), tail, signals, etc
09 Steering
10 Power Train: engine, driveshaft, transmission, differential
11 Exhaust
12 Suspension

ROAD CCs (On/At) (code OR or AR, no TU#)

01 Wet surface, standing or moving water
02 Icy or slushy
03 Snow accumulation or snow packed
04 Debris or obstruction
05 Road construction or maintenance
06 Ruts, holes, bumps
07 Traffic control device inoperative or missing
08 Shoulders: none, low, soft, or high
09 Worn, travel-polished surface

Codes 88 and 99 apply to Other and Unknown

Accident Code Sheet

KDOT Form 855 Rev. 1-2009

SEAT TYPES, SAFETY EQUIPMENT, INJURY SEVERITY, DRIVER'S LICENSE CODES, ETC.

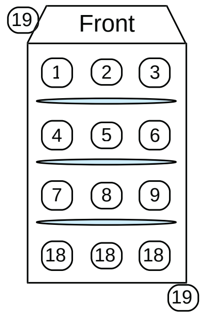
VARIOUS CODE LISTS

OCCUPANT SEAT POSITION

FRONT ROW
- 01 Driver
- 02 Center
- 03 Right

SECOND ROW
- 04 Left
- 05 Center
- 06 Right

THIRD ROW
- 07 Left
- 08 Center
- 09 Right



- 10 Motorcycle passenger
- 11 Extra person on driver's seat or lap
- 12-17 Extra person on passenger lap
- 18 Other seat position IN vehicle
- 19 Other position ON or Outside vehicle
- 27 Enclosed cargo area
- 28 Unenclosed cargo area (pickup bed, etc)
- 29 Sleeper section of truck cab
- 30 Trailing unit (auto, boat, camper)
- 99 Unknown position IN or On vehicle

PEDESTRIAN TYPES (non-motorist)

- 21 Walking, standing, running, etc
- 22 Pedal cyclist
- 23 Rider of animal
- 24 Occupant of animal-drawn vehicle
- 25 In vehicle NOT IN TRANSPORT (legally parked veh)
- 26 Machine operator or passenger (Working Vehicles... ...snow plows, emergency veh, paving machines, etc)
- 88 Other
- 99 Unknown

TRAIN OCCUPANT SEAT TYPES

- 31 Train crew (list all in control whether injured or not)
- 32 Train passengers (list if injured)

GENDER

- M Male
- F Female
- U Unknown

SAFETY EQUIPMENT USE

- S Shoulder & Lap belt
- X Shoulder belt only
- L Lap belt only
- I Infant seat/restraint system (rear facing)
- C Child seat/restraint system (front facing)
- T "Booster" seat/restraint system (see manual)

- P Airbag deployed only (Passive system)
- R Airbag deployed - Shoulder & Lap belt
- J Airbag deployed - Shoulder belt only
- W Airbag deployed - Lap belt only
- F Airbag deployed - Infant seat (rear facing)
- D Airbag deployed - Child seat (front facing)
- K Airbag deployed - "Booster" seat

- B Both Motorcyclist helmet & eye protection
- E Motorcyclist eye protection
- H Motorcyclist helmet

- Q Pedestrian helmet or protective pads
- V Reflective clothing

- N None used
- U Unknown

EJECTED / TRAPPED

- N Not ejected or trapped
- E Ejected (totally)
- P Partially ejected
- T Trapped in vehicle
- U Unknown

INJURY SEVERITY

- N Not injured
- P Possible injury (complaint of pain)
- I Injury - not incapacitating
- D Injury - incapacitating (disabling)
- F Fatal injury
- U Unknown

EJECTION PATH

- 01 Side door
- 02 Side window
- 03 Windshield
- 04 Back window
- 05 Back door/Tailgate
- 06 Roof - sunroof/convertible top down)
- 07 Roof - convertible top up
- 08 Other path (pickup bed)
- 99 Unknown

ANIMAL TYPES

- 01 Deer
- 02 Other wild animal: bobcat, coyote, etc
- 03 Cow
- 04 Other domestic animal: cat, dog, etc
- 05 Horse

KS LIC CLASS

(see manual)

- A - GCWR>26,000
- B - GVWR>26,000
- C - GVWR<26,001
- M - Motorcycle
- (Class+) P - Permit
- ID - Identification #
- U - Unknown

KANSAS LICENSE RESTRICTIONS

- B Corrective lenses
- C Mechanical aid (devices)
- D Prosthetic aid (devices)
- E Automatic Transmission
- F Outside mirror
- G Daylight only
- H Employment only
- I Limited - Other
- K Intrastate only
- L Without Air-brakes
- M No CDL - A Bus
- N No CDL - A/B Bus
- O No Tractor-Trailer
- J01 Outside business area
- J02 Under Age Sixteen
- J03 No Freeway driving
- J04 25 Mi. from Home
- J05 Within City Limits
- J06 Licensed Driver Front Seat
- J07 Moped
- J08 Seasonal CDL
- J09 Farm Permit
- U Unknown

HAZARDOUS MATERIAL CLASS CODES

- 1 Explosives
- 2 Gases
- 3 Flammable/combustible liquid
- 4 Flammable/combustible solid
- 5 Oxidizers & organic peroxides
- 6 Poisonous/infectious substance
- 7 Radioactive material
- 8 Corrosive material
- 9 Misc. HazMat

APPENDIX C - TRANLATION KEY FOR KANSAS ACCIDENT CODES TO HSM COLLISION TYPES

Because the Kansas Motor Vehcile Accident Report contains both Accident Location and Accident Class which correspond tothis chart Collision Type in some hirearchy needed to be developed to determine specifically where a certain crash would be accounted.

Collision Type	**Translation Key**
Collision with animal	Accident Class = 07 AND Acc. Location ≠ 21
Collision with pedestrian	All Accdient Class = 02
Collision with cyclist	All Accident Class = 06
Overturned	All Accident Class = 01
Ran Off Road	Acc. Location = 21 AND Accident Class ≠ 01, 02, 05, or 06
Collision with Legally Parked Vehicle	Accident Class = 04 AND Acc. Location ≠ 21
Collision with Railway Train	All Accident Class = 05
Collision with Fixed Object	Accident Class = 08 AND Acc. Location ≠ 21
Collision with Other Object	Accident Class = 09 AND Acc. Location ≠ 21
Other Non-Collision	Accident Class = 10 or 88 and AND Acc. Location ≠ 21
Angle Collision	Accident Class = 03 AND Collision with Vehicle = 03
Head-on Collision	Accident Class = 03 AND Collision with Vehicle = 01
Rear-end Collision	Accident Class = 03 AND Collision with Vehicle = 02
Sideswipe: Opposite Direction	Accident Class = 03 AND Collision with Vehicle = 04
Sideswipe: Same Direction	Accident Class = 03 AND Collision with Vehicle = 05
Backed Into	Accident Class = 03 AND Collision with Vehicle = 06
Other	Accident Class = 03 AND Collision with Vehicle = 88
Unknown	Accident Class = 03 AND Collision with Vehicle = 99

APPENDIX D - ORIGINAL OUTPUT FROM RANDOM SECTION SELECTOR WITH CRASH DATA

							Crashes					Crashes		Total Crashes	
Route	District	Start SMP	End SMP	1st County	Start CMP	End CMP	Intersection	Segment	2nd County	Start CMP	End CMP	Intersection	Segment	Intersection	Segment
K-25	6	57.5	67.5	Grant	23.78	24.70	0	0	Kearny	0.00	9.08	0	18	0	18
K-4	2	257.8	267.8	Morris	20.86	30.97	0	7						0	7
US-400	5	326.2	336.2	Greenwood	6.59	16.59	7	26						7	26
K-4	6	24.9	34.9	Lane	12.97	22.97	0	3						0	3
K-150	2	6.7	16.7	Marion	6.70	8.01	0	0	Chase	0.00	8.49	0	8	0	8
K-25	6	90.9	100.9	Kearny	32.48	39.03	0	3	Wichita	0.00	3.45	0	0	0	3
K-177	2	54.7	64.7	Chase	32.35	33.08	0	1	Morris	0.00	9.28	0	8	0	9
K-254	6	71.3	81.3	Kearny	12.88	22.88	4	11						4	11
US-59	4	14	24	Labette	14.00	24.00	11	40						11	40
US-81	2	200.5	210.5	Cloud	18.40	24.05	0	0	Republic	0.00	4.34	0	8	0	8
US-169	4	33.2	43.2	Neosho	3.85	13.85	7	33						7	33
K-181	3	58.3	68.3	Smith	2.40	12.40	0	3						0	3
K-23	6	64.4	74.4	Gray	24.80	34.80	1	4						1	4
K-96	6	103.8	113.8	Ness	5.61	15.61	1	9						1	9
US-160	5	317.5	327.5	Cowley	7.85	18.29	3	24						3	24
US-169	4	49.3	59.3	Neosho	19.95	24.96	0	9	Allen	0.00	4.98	1	21	1	30
K-2	5	27.4	37.4	Harper	11.07	21.07	6	45						6	45
US-281	5	128.8	138.8	Barton	31.99	34.03	0	2	Russell	0.00	7.97	2	18	2	20
K-156	5	134.2	144.2	Barton	24.43	34.43	2	54						2	54
US-283	6	91.3	101.3	Hodgeman	22.08	24.17	0	2	Ness	0.00	7.92	0	2	0	4
US-400	4	410.3	420.3	Labette	22.56	25.55	2	14	Cherokee	0.00	7.02	3	22	5	36
US-83	3	146.9	156.9	Logan	22.65	31.11	0	7	Thomas	0.00	1.54	1	2	1	9
US-36	3	165.3	175.3	Smith	2.92	12.92	1	24						1	24
US-81	2	154.3	164.3	Saline	21.31	24.62	0	0	Ottawa	0.00	6.69	0	0	0	0
K-31	1	14	24	Osage	3.91	13.91	2	3						2	3
US-24	1	364.2	374.2	Shawnee	18.52	25.91	0	0	Jefferson	0.00	2.61	0	0	0	0
US-400	4	410.7	420.7	Labette	22.96	25.55	2	11	Cherokee	0.00	7.40	3	23	5	34
US-160	6	93.2	103.2	Seward	14.23	20.87	0	0	Meade	0.00	3.36	0	1	0	1
K-99	1	170.1	180.1	Wabaunsee	37.58	41.01	3	11	Pottawatomie	0.00	6.57	12	31	15	42
US-75	1	130.2	140.2	Osage	17.00	27.00	5	44						5	44
K-42	5	34.7	44.7	Kingman	20.80	30.80	2	20						2	20
US-50	5	282.4	292.4	Harvey	28.84	33.67	3	17	Marion	0.00	5.16	2	14	5	31
K-116	1	10.5	20.5	Atchison	0.99	10.99	1	18						1	18
US-24	3	130	140	Graham	26.69	30.57	0	9	Rooks	0.00	5.75	1	16	1	25
K-96	5	265	275	Sedgwick	1.04	11.04	0	0						0	0
K-99	4	40.5	50.5	Elk	17.16	21.72	0	1	Greenwood	0.00	5.44	2	5	2	6
K-99	1	183.1	193.1	Pottawatomie	9.57	19.57	6	27						6	27
K-31	4	58.5	68.5	Coffey	5.80	8.00	1	0	Anderson	0.00	7.80	0	5	1	5
K-4	6	72.5	82.5	Rush	0.37	10.37	3	10						3	10
US-183	3	149.9	159.9	Ellis	8.66	18.66	3	20						3	20
K-68	4	24	34	Franklin	11.58	21.58	11	26						11	26

APPENDIX E - KDOT PROJECTS ASSOCIATED WITH CALIBRATION SECTIONS

Section #	Route	Year	Project	Year	Project	Year	Project	Year	Project	Year	Project
1	K-25	1938	25-34-FA 544C	1938	25-47 FA 544B(1)						
2	US-400	1994	96-37 K-3292-01	1995	96-37 K-3293-01						
3	K-4	1940	4-51 FAS 143A(1)	1945	4-51 FAS 143B(1)						
4	K-150	2001	150-9 K-5769-01	2001	150-57 K-6777-01						
5	K-25	1958	25-47 S130(3)	1934	25-6 NRWP 47-3	1936	25-6 FA 492G	1936	25-7 FA 492F		
6	K-177	1955	13-9 S 1167(2)	1951	13-9 F 057-1(2)	1951	13-64 F 057-1(1)	1936	13-6 434		
7	K-25	1938	25-47 FA 544-5(1)	1956	25-47 F 013-1(3)	1941	25-47 F 013-1(6)	2004	25-47 K-8015-01	1935	25-6 NRH 492-C
		2000	25-47 K-6864-01	1934	26-5 NRWP 472	1935	25-6 NRH 492D	1934	25-6 NRWP 473		
8	US-59	1946	59-50 F 2(13)	(1)	Ozark Trail Highway (C)	1938	59-50 FAGH 2C	1959	59-50 F 067-1(9)	1958	59-50 F 067-1(12)
		1957	59-50 F-FG 067-1(6)	1938	59-50 FA 2C						
9	US-169	1997	169-67 K-5387-01	2002	169-67 K-6379-01						
10	K-181	1946	181-92 S 211(3)	1946	181-92 S 211(1)						
11	US-160	1938	160-18 FA 237F	1938	160-18 FA 237B	1983	160-18 K-0210-01	1946	160-18 S 136(3)		
12	K-2	1939	14-39 FA 361B(2)	1967	2-36 F 012-1(2)	1958	14-39 F 037-1(B)				
13	US-83	1932	93-13 NRH 247-A	1997	83-55 K-5388-01	1932	83-13 NRH 247-F	1964	70-97 I-70-1(12)36		
14	US-36	1924	212 A&B	1952	36-92 F 092-2(2)	1983	39-92 K-1783-01	1951	36-92 F 092-2(1)		
15	K-99	1932	11-20 243D	1931	11-21 243C	1952	99-99 ER 35	1988	99-99 K-2658-01	1988	99-99 K-2616-01
16	US-400	1940	160-50 FA-214B(3)	1984	160-50 K-0499-01	1995	160-50 K-4896-01	1940	160-11 FA 570-A(1)	1940	160-11 FA 570B(1)
		1986	160-11 K-2044-01								
17	US-36	1941	36-79 FA 211D(1)	1951	39-79 F 092-3(1)						
18	US-75	1955	75-7 F 063-4(5)	1953	75-7 F 063-4(3)	1950	75-7 F 548(3)				
19	K-116	1936	WPSO 540B	1984	116-3 K-0116-01	1938	116-3 FAS 540B(2)				

(1) No year provided on plan set

APPENDIX F - CALIBRATION SECTION INPUTS

Section	Route	County
1A	K-25	Grant

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (ft)	Superelevation (%)	Adverse	Design Speed (mph)
1	2U	4.1	13+204.100	13,200.00	2.5	2005: 1,320; 2006: 1,300; 2007: 1,450	12	12	1.97	1.97	0.03	1	2	FALSE	0	FALSE	FALSE	FALSE				
2	2U	13+204.100	13+996.100	792	0.15		12	12	1.97	1.97	0.08	1	3	FALSE	0	FALSE	FALSE	FALSE				
3	2U	13+996.100	15+844.100	1,848.00	0.35		12	12	1.97	1.97	0.14	1	2	FALSE	0	FALSE	FALSE	FALSE				
4	2U	15+844.100	16+000.000	155.9	0.0295		12	12	1.97	1.97	0.12	1	3	FALSE	0	FALSE	FALSE	FALSE				
5	2U	16+000.000	16+311.140	311.14	0.0589	2005: 1,320; 2006: 1,630; 2007: 1,600	12	12	1.97	1.97	0.12	1	3	FALSE	0	FALSE	FALSE	FALSE				
6	2U	16+311.140	21+096.330	4,785.19	0.9063		12	12	1.97	1.97	0.12	1	3	FALSE	0	FALSE	FALSE	FALSE	6,366.26	1.6	TRUE	65
7	2U	21+096.330	47+946.500	26,850.17	5.0853		12	12	1.97	1.97	0.43	1	3	FALSE	0	FALSE	FALSE	FALSE				

Section	Route	County
1B	K-25	Kearny

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (ft)	Superelevation (%)	Adverse	Design Speed (mph)
1	2U	11+011.000	15+868.600	4,857.60	0.92	2005: 1,370; 2006: 1,350; 2007: 1,450	11.52	11.52	3.94	3.94	0.56	1	2	FALSE	0	FALSE	FALSE	FALSE				

Section	Route	County
2	US-400	Greenwood

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (ft)	Superelevation (%)	Adverse	Design Speed (mph)
1	2U	49+295.200	53+212.960	3,917.76	0.742	2005: 4,570; 2006: 4,490; 2007: 4,250	12	12	8.09	9.84	2.94	1	1	FALSE	0	FALSE	FALSE	FALSE				
2	2U	53+212.960	57+473.180	4,260.22	0.8069		12	12	9.84	9.84	0.67	1	1	FALSE	0	FALSE	FALSE	FALSE				
3	2U	57+473.180	60+210.360	2,737.18	0.5184		12	12	9.84	9.84	2	1	1	FALSE	0	FALSE	FALSE	FALSE	11,459.16	1.6	TRUE	65
4	2U	60+210.360	62+130.880	1,920.52	0.3637		12	12	9.84	9.84	0.66	1	1	FALSE	0	FALSE	FALSE	FALSE				
5	2U	62+130.880	94+656.810	32,525.93	6.1602	2005: 4,420; 2006: 4,340; 2007: 4,360	12	12	9.84	9.84	2.22	1	1	FALSE	0	FALSE	FALSE	FALSE				
6	2U	94+656.810	95+152.000	495.19	0.0938		12	12	9.84	9.84	0.3	1	1	FALSE	0	FALSE	FALSE	FALSE	11,459.16	1.6	TRUE	65
7	2U	95+152.000	95+737.630	585.63	0.1109	2005: 4,420; 2006: 4,340; 2007: 4,220	12	12	9.84	9.84	0.3	1	1	FALSE	0	FALSE	FALSE	FALSE	11,459.16	1.6	TRUE	65
8	2U	95+737.630	99+624.160	3,886.53	0.7361		12	12	9.84	9.84	0.3	1	1	FALSE	0	FALSE	FALSE	FALSE				
9	2U	99+624.160	100+404.110	779.95	0.1477	2005: 4,420; 2006: 4,340; 2007: 4,520	12	12	9.84	9.84	0.81	1	1	FALSE	0	FALSE	FALSE	FALSE				
10	2U	100+404.110	102+095.200	1,691.09	0.3203		12	12	9.84	9.84	0.81	1	1	FALSE	0	FALSE	FALSE	FALSE	7,639.44	3	FALSE	65

Section	Route	County
3	K-4	Lane

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (ft)	Superelevation (%)	Adverse	Design Speed (mph)
1	2U	7+180.480	9+673.000	2,492.52	0.4721	2005: 500; 2006: 490; 2007: 670	12	12	5.91	5.91	0	1	3	FALSE	0	FALSE	FALSE	FALSE				
2	2U	9+673.000	33+827.080	24,154.08	4.5746	2005: 370; 2006: 365; 2007: 590	12	12	5.91	5.91	0.41	1	3	FALSE	0	FALSE	FALSE	FALSE				
3	2U	33+827.080	36+234.370	2,407.29	0.4559		12	12	5.91	5.91	0.26	1	3	FALSE	0	FALSE	FALSE	FALSE	7,162.03	1.6	TRUE	65
4	2U	36+234.370	40+552.500	4,318.13	0.8178		12	12	5.91	5.91	0.11	1	3	FALSE	0	FALSE	FALSE	FALSE				
5	2U	40+552.500	41+874.490	1,321.99	0.2504		12	12	5.91	5.91	0.42	1	3	FALSE	0	FALSE	FALSE	FALSE	8,594.48	1.6	TRUE	65
6	2U	41+874.490	43+105.900	1,231.41	0.2332		12	12	5.91	5.91	0.42	1	3	FALSE	0	FALSE	FALSE	FALSE				
7	2U	43+105.900	43+401.400	295.5	0.056		12	12	5.91	5.91	0	1	3	FALSE	0	FALSE	FALSE	FALSE	8,594.42	1.6	TRUE	65
8	2U	43+401.400	44+053.360	651.96	0.1235	2005: 450; 2006: 440; 2007: 550	12	12	5.91	5.91	0	1	3	FALSE	0	FALSE	FALSE	FALSE	8,594.42	1.6	TRUE	65
9	2U	44+053.360	59+980.480	15,927.12	3.0165		12	12	5.91	5.91	0.2	1	3	FALSE	0	FALSE	FALSE	FALSE				

Section	Route	County
4A	K-150	Marion

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (ft)	Superelevation (%)	Adverse	Design Speed (mph)
1	2U	32+808.399	37+706.470	4,898.07	0.9277	2005: 1,360; 2006: 1,370; 2007: 1,330	12	12	4.92	4.92	0.74	1	1	FALSE	0	FALSE	FALSE	FALSE				
2	2U	37+706.470	43+843.600	6,137.13	1.1623		12	12	4.92	4.92	0.42	1	1	FALSE	0	FALSE	FALSE	FALSE				

3	2U	43+843.600	45+005.200	1,161.60	0.22	2005: 1,460; 2006: 1,470; 2007: 1,210	12	12	4.92	4.92	0.42	1	3	FALSE	0	FALSE	FALSE	FALSE
4	2U	45+005.200	46+589.200	1,584.00	0.3		12	12	4.92	4.92	0.42	1	1	FALSE	0	FALSE	FALSE	FALSE
5	2U	46+589.200	48+331.600	1,742.40	0.33		12	12	4.92	4.92	0.42	1	3	FALSE	0	FALSE	FALSE	FALSE
6	2U	48+331.600	68+712.400	20,380.80	3.86		12	12	4.92	4.92	0.84	1	1	FALSE	0	FALSE	FALSE	FALSE
7	2U	68+712.400	71+299.600	2,587.20	0.49		12	12	4.92	4.92	1.83	1	3	FALSE	0	FALSE	FALSE	FALSE
8	2U	71+299.600	77+635.600	6,336.00	1.2		12	12	4.92	4.92	1.83	1	1	FALSE	0	FALSE	FALSE	FALSE

Section	Route	County
4B	K-150	Chase

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (ft)	Superelevation (%)	Adverse	Design Speed (mph)
1	2U	57+386.830	64+303.628	6,916.80	1.31	2005: 1,390; 2006: 1,650; 2007: 1,330	12	12	4.92	4.92	0.8	1	1	FALSE	0	FALSE	FALSE	FALSE				

Section	Route	County
5A	K-25	Kearny

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (ft)	Superelevation (%)	Adverse	Design Speed (mph)
1	2U	85+140.500	112+069.980	26,929.48	5.1003	2005: 505; 2006: 495; 2007: 440	12	12	3.94	3.94	1.02	1	2	FALSE	0	FALSE	FALSE	FALSE				
2	2U	112+069.980	119+724.500	7,654.52	1.4497	2005: 445; 2006: 435; 2007: 515	12	12	3.94	3.94	0.15	1	2	FALSE	0	FALSE	FALSE	FALSE				

Section	Route	County
5B	K-25	Wichita

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (ft)	Superelevation (%)	Adverse	Design Speed (mph)
1	2U	2+000.000	5+388.210	3,388.21	0.6417	2005: 550; 2006: 540; 2007: 515	11	11	2.95	2.95	0	1	2	FALSE	0	FALSE	FALSE	FALSE				
2	2U	5+388.210	8+389.940	3,001.73	0.5685		11	11	2.95	2.95	0.24	1	2	FALSE	0	FALSE	FALSE	FALSE	1,910.08	5.2	FALSE	65
3	2U	8+389.940	20+216.000	11,826.06	2.2398		11	11	2.95	2.95	0.29	1	2	FALSE	0	FALSE	FALSE	FALSE				

Section	Route	County
6A	K-177	Chase

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (ft)	Superelevation (%)	Adverse	Design Speed (mph)
1	2U	45+617.740	45+676.070	58.33	0.011	2005: 825; 2006: 910; 2007: 825	12	12	1.97	1.97	0.6	1	3	FALSE	0	FALSE	FALSE	FALSE				
2	2U	45+676.070	46+309.400	633.33	0.12		12	12	1.97	1.97	0.6	1	3	FALSE	0	FALSE	FALSE	FALSE	11,459.19	1.6	TRUE	65
3	2U	46+309.400	49+472.140	3,162.74	0.599		12	12	1.97	1.97	0.52	1	3	FALSE	0	FALSE	FALSE	FALSE				

Section	Route	County
6B	K-177	Morris

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (ft)	Superelevation (%)	Adverse	Design Speed (mph)
1	2U	6+079.470	8+955.460	2,875.99	0.5447	2005: 700; 2006: 825; 2007: 690	12	12	0.98	0.98	1.54	1	2	FALSE	0	FALSE	FALSE	FALSE				
2	2U	8+955.460	15+361.710	6,406.25	1.2133		12	12	0.98	0.98	0.46	1	2	FALSE	0	FALSE	FALSE	FALSE	8,594.37	1.6	TRUE	60
3	2U	15+361.710	21+502.710	6,141.00	1.1631		12	12	0.98	0.98	1.12	1	2	FALSE	0	FALSE	FALSE	FALSE				
4	2U	21+502.710	23+239.470	1,736.76	0.3289		12	12	0.98	0.98	0.92	1	2	FALSE	0	FALSE	FALSE	FALSE	7,639.44	1.6	TRUE	60
5	2U	23+239.470	23+873.070	633.6	0.12		12	12	0.98	0.98	0.1	1	3	FALSE	0	FALSE	FALSE	FALSE	7,639.44	1.6	TRUE	60
6	2U	23+873.070	24+542.710	669.64	0.1268		12	12	0.98	0.98	3.56	1	2	FALSE	0	FALSE	FALSE	FALSE	7,639.44	1.6	TRUE	60
7	2U	24+542.710	26+330.210	1,787.50	0.3385		12	12	0.98	0.98	3.56	1	2	FALSE	0	FALSE	FALSE	FALSE				
8	2U	26+330.210	27+406.040	1,075.83	0.2038		12	12	0.98	0.98	3.56	1	2	FALSE	0	FALSE	FALSE	FALSE	5,729.58	1.6	TRUE	60
9	2U	27+406.040	27+771.010	364.97	0.0691		12	12	0.98	0.98	2	1	2	FALSE	0	FALSE	FALSE	FALSE				
10	2U	27+771.010	29+233.510	1,462.50	0.277		12	12	0.98	0.98	2	1	2	FALSE	0	FALSE	FALSE	FALSE	2,864.79	4	TRUE	60
11	2U	29+233.510	29+311.470	77.96	0.0148		12	12	0.98	0.98	1.76	1	2	FALSE	0	FALSE	FALSE	FALSE				
12	2U	29+311.470	30+367.470	1,056.00	0.2		12	12	0.98	0.98	2.08	1	3	FALSE	0	FALSE	FALSE	FALSE				
13	2U	30+367.470	34+889.890	4,522.42	0.8565		12	12	0.98	0.98	2.28	1	2	FALSE	0	FALSE	FALSE	FALSE				
14	2U	34+889.890	35+225.070	335.18	0.0635		12	12	0.98	0.98	0.92	1	2	FALSE	0	FALSE	FALSE	FALSE	3,819.89	4	TRUE	60
15	2U	35+225.070	36+175.470	950.4	0.18		12	12	0.98	0.98	5.98	1	3	FALSE	0	FALSE	FALSE	FALSE	3,819.89	4	TRUE	60
16	2U	36+175.470	36+745.450	569.98	0.108		12	12	0.98	0.98	5.98	1	2	FALSE	0	FALSE	FALSE	FALSE	3,819.89	4	TRUE	60
17	2U	36+745.450	40+610.670	3,865.22	0.732		12	12	0.98	0.98	0	1	2	FALSE	0	FALSE	FALSE	FALSE				
18	2U	40+610.670	40+799.900	189.23	0.0358		12	12	0.98	0.98	4.36	1	3	FALSE	0	FALSE	FALSE	FALSE				
19	2U	40+799.900	50+959.470	10,159.57	1.9242	2005: 900; 2006: 840; 2007: 825	12	12	0.98	0.98	4.34	1	3	FALSE	0	FALSE	FALSE	FALSE				
20	2U	50+959.470	52+385.070	1,425.60	0.27		12	12	0.98	0.98	3.52	1	4	FALSE	0	FALSE	FALSE	FALSE				
21	2U	52+385.070	55+077.870	2,692.80	0.51		12	12	0.98	0.98	4.09	1	3	FALSE	0	FALSE	FALSE	FALSE				

Section	Route	County	Part
7A	K-25	Kearny	1

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (ft)	Superelevation (%)	Adverse	Design Speed (mph)
1	2U	65+947.490	66+332.610	385.12	0.0729	2005: 1,320; 2006: 1,300; 2007: 1,820	12	12	1.97	1.97	2.15	1	2	FALSE	0	FALSE	FALSE	FALSE	5,280.79	2	TRUE	65
2	2U	66+332.610	76+628.350	10,295.74	1.95		12	12	1.97	1.97	2.15	1	2	FALSE	0	FALSE	FALSE	FALSE				
3	2U	76+628.350	76+930.303	301.95	0.0572		12	12	1.97	1.97	0	1	2	FALSE	0	FALSE	FALSE	FALSE	21,486.00	2	TRUE	65
4	2U	76+930.303	77+665.850	735.55	0.1393	2005: 1,320; 2006: 1,300; 2007: 1,880	12	12	1.97	1.97	0	1	2	FALSE	0	FALSE	FALSE	FALSE	21,486.00	2	TRUE	65
5	2U	77+665.850	79+333.850	1,668.00	0.3159		12	12	1.97	1.97	0.8	1	2	FALSE	0	FALSE	FALSE	FALSE				
6	2U	79+333.850	80+225.180	891.33	0.1688		12	12	1.97	1.97	0.8	1	2	FALSE	0	FALSE	FALSE	FALSE	2,291.80	6	FALSE	65
7	2U	80+225.180	81+581.000	1,355.82	0.2568		12	12	1.97	1.97	0.2	1	2	FALSE	0	FALSE	FALSE	FALSE				
8	2U	81+581.000	82+641.924	1,060.92	0.2009		12	12	1.97	1.97	0.04	1	2	FALSE	0	FALSE	FALSE	FALSE	1,432.70	3.1	FALSE	65
9	2U	82+641.924	83+153.170	511.25	0.0968	2005: 2,350; 2006: 2,310; 2007: 2,630	12	12	1.97	1.97	0.04	1	2	FALSE	0	FALSE	FALSE	FALSE	1,432.70	3.1	FALSE	65
10	2U	83+153.170	83+197.250	44.08	0.0084		12	12	1.97	1.97	0.08	1.2	2	FALSE	0	FALSE	FALSE	FALSE	1,432.70	3.1	FALSE	65

Section	Route	County	Part
7B	K-25	Kearny	2

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (ft)	Superelevation (%)	Adverse	Design Speed (mph)
1	2U	1+010.000	2+699.600	1,689.60	0.32	2005: 800; 2006: 785; 2007: 945	12	12	12	12	0.15	1	2	FALSE	0	FALSE	FALSE	FALSE				
2	2U	2+699.600	2+863.280	163.68	0.031		12	12	12	12	0.31	1	2	FALSE	0	FALSE	FALSE	FALSE				
3	2U	2+863.280	3+463.460	600.18	0.1137		12	12	12	12	0.31	1	2	FALSE	0	FALSE	FALSE	FALSE				
4	2U	3+463.460	3+686.960	223.5	0.0423		12	12	12	12	0.97	1	2	FALSE	0	FALSE	FALSE	FALSE	21,486.00	2	TRUE	65
5	2U	3+686.960	4+036.720	349.76	0.0662		12	12	3.94	3.94	0.97	1	2	FALSE	0	FALSE	FALSE	FALSE	21,486.00	2	TRUE	65
6	2U	4+036.720	4+890.090	853.37	0.1616		12	12	3.94	3.94	3.77	1	2	FALSE	0	FALSE	FALSE	FALSE				
7	2U	4+890.090	6+687.770	1,797.68	0.3405		12	12	3.94	3.94	3.77	1	2	FALSE	0	FALSE	FALSE	FALSE	3,691.00	6	FALSE	65
8	2U	6+687.770	17+282.960	10,595.19	2.0067		12	12	3.94	3.94	0.28	1	2	FALSE	0	FALSE	FALSE	FALSE				
9	2U	17+282.960	36+544.400	19,261.44	3.648	2005: 800; 2006: 785; 2007: 420	12	12	3.94	3.94	0.92	1	2	FALSE	0	FALSE	FALSE	FALSE				

Section	Route	County	Part
8A	US-59	Labette	1

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (ft)	Superelevation (%)	Adverse	Design Speed (mph)
1	2U	1+466.500	6+576.350	5,109.85	0.9678	2005: 3,090; 2006: 3,030; 2007: 3,070	12	12	7.87	7.87	1	1	2	FALSE	0	FALSE	FALSE	FALSE				
2	2U	6+576.350	7+376.350	800	0.1515		12	12	7.87	7.87	1.08	1	2	FALSE	0	FALSE	FALSE	FALSE	44,506.00	1.5	TRUE	65
3	2U	7+376.350	8+196.240	819.89	0.1553		12	12	7.87	7.87	1.09	1	2	FALSE	0	FALSE	FALSE	FALSE				
4	2U	8+196.240	9+524.620	1,328.38	0.2516		12	12	7.87	7.87	1.09	1	2	FALSE	0	FALSE	FALSE	FALSE				
5	2U	9+524.620	11+390.640	1,866.02	0.3534		12	12	7.87	7.87	0.23	1	4	FALSE	0	FALSE	FALSE	FALSE				
6	2U	11+390.640	11+501.280	110.64	0.021		12	12	7.87	7.87	1.12	1	2	FALSE	0	FALSE	FALSE	FALSE				
7	2U	11+501.280	12+524.780	1,023.50	0.1938		12	12	7.87	7.87	1.12	1	2	FALSE	0	FALSE	FALSE	FALSE	1,145.93	10.4	FALSE	65
8	2U	12+524.780	12+821.520	296.74	0.0562		12	12	7.87	7.87	1.12	1	2	FALSE	0	FALSE	FALSE	FALSE				
9	2U	12+821.520	14+798.750	1,977.23	0.3745	2005: 3,100; 2006-2007: 3,040	12	12	7.87	7.87	1.12	1	2	FALSE	0	FALSE	FALSE	FALSE				
10	2U	14+798.750	16+372.080	1,573.33	0.298		12	12	7.87	7.87	0.18	1	2	FALSE	0	FALSE	FALSE	FALSE	5,729.65	1.5	TRUE	65
11	2U	16+372.080	16+512.240	140.16	0.0266		12	12	7.87	7.87	0.38	1	2	FALSE	0	FALSE	FALSE	FALSE				

Section	Route	County	Part
8B	US-59	Labette	2

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (ft)	Superelevation (%)	Adverse	Design Speed (mph)
1	2U	6+682.880	8+765.400	2,082.52	0.3944	2005: 3,830; 2006: 3,760; 2007: 3,110	12	12	9.84	9.84	0.4	1	2	FALSE	0	FALSE	FALSE	FALSE				
2	2U	8+765.400	9+675.740	910.34	0.1724		12	12	9.84	9.84	0.4	1	2	FALSE	0	FALSE	FALSE	FALSE	8,594.37	2	FALSE	65
3	2U	9+675.740	16+442.450	6,766.71	1.2816		12	12	9.84	9.84	0.4	1	2	FALSE	0	FALSE	FALSE	FALSE				
4	2U	16+442.450	17+342.430	899.98	0.1704		12	12	9.84	9.84	0.39	1	2	FALSE	0	FALSE	FALSE	FALSE	17,188.74	1.5	TRUE	65
5	2U	17+342.430	20+021.160	2,678.73	0.5073		12	12	9.84	9.84	0.39	1	2	FALSE	0	FALSE	FALSE	FALSE				
6	2U	20+021.160	20+946.160	925	0.1752		12	12	9.84	9.84	0.36	1	2	FALSE	0	FALSE	FALSE	FALSE	23,647.90	1.5	TRUE	65
7	2U	20+946.160	21+723.040	776.88	0.1471		12	12	9.84	9.84	0.36	1	2	FALSE	0	FALSE	FALSE	FALSE				
8	2U	21+723.040	24+885.760	3,162.72	0.599	2005: 3,200; 2006: 3,140; 2007: 2,920	12	12	9.84	9.84	0.2	1	2	FALSE	0	FALSE	FALSE	FALSE				
9	2U	24+885.760	25+829.510	943.75	0.1787		12	12	9.84	9.84	0.04	1	2	FALSE	0	FALSE	FALSE	FALSE	21,485.90	1.5	TRUE	65
10	2U	25+829.510	30+728.650	4,899.14	0.9279		12	12	9.84	9.84	0.04	1	2	FALSE	0	FALSE	FALSE	FALSE				
11	2U	30+728.650	31+655.560	926.91	0.1756		12	12	9.84	9.84	1.28	1	2	FALSE	0	FALSE	FALSE	FALSE	21,489.50	1.5	TRUE	65
12	2U	31+655.560	32+797.090	1,141.53	0.2162		12	12	9.84	9.84	0.16	1	2	FALSE	0	FALSE	FALSE	FALSE				
13	2U	32+797.090	33+296.340	499.25	0.0946		12	12	9.84	9.84	0.16	1	2	FALSE	0	FALSE	FALSE	FALSE	28,648.25	1.5	TRUE	65

Section	Route	County	Part

Section	Route	County	Part
8C	US-59	Labette	3

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (ft)	Superelevation (%)	Adverse	Design Speed (mph)
1	2U	935	5+799.570	4,864.57	0.9213	2005: 4,949;	12	12	9.84	9.84	0	1	2	FALSE	0	FALSE	FALSE	FALSE				
2	2U	5+799.570	6+678.140	878.57	0.1664	2006: 4,850;	12	12	9.84	9.84	0.3	1	2	FALSE	0	FALSE	FALSE	FALSE	24,555.35	2	TRUE	65
3	2U	6+678.140	12+075.800	5,397.66	1.0223	2007: 3,460	12	12	9.84	9.84	0.3	1	2	FALSE	0	FALSE	FALSE	FALSE				

Section	Route	County	Part
9A	US-169	Neosho	1

Segment Number	Type	Start Location	End Location	Length (m)	Length (mi)	AADT	Left Lane Width (m)	Right Lane Width (m)	Left Shoulder Width (m)	Right Shoulder Width (m)	Grade (%)	Driveway Density (driveways/km)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (m)	Superelevation (%)	Adverse	Design Speed (km/h)
1	2U	22+600.000	22+899.863	299.86	0.1863		3.7	3.7	3	3	0.4	1	1	FALSE	0	FALSE	FALSE	FALSE				
2	2U	22+899.863	23+074.482	174.62	0.1085		3.7	3.7	3	3	0.09	1	1	FALSE	0	FALSE	FALSE	FALSE	2,000.00	3	FALSE	110
3	2U	23+074.482	23+186.453	111.97	0.0696		3.7	3.7	3	3	0.57	1	1	FALSE	0	FALSE	FALSE	FALSE				
4	2U	23+186.453	23+361.072	174.62	0.1085	2005: 3,920;	3.7	3.7	3	3	0.57	1	1	FALSE	0	FALSE	FALSE	FALSE	2,000.00	3	FALSE	110
5	2U	23+361.072	25+050.267	1,689.20	1.0496	2006: 3,940;	3.7	3.7	3	3	0.57	1	1	FALSE	0	FALSE	FALSE	FALSE				
6	2U	25+050.267	25+275.306	225.04	0.1398	2007: 4,220	3.7	3.7	3	3	0.52	1	1	FALSE	0	FALSE	FALSE	FALSE	2,000.00	3	FALSE	110
7	2U	25+275.306	25+462.248	186.94	0.1162		3.7	3.7	3	3	0.52	1	1	FALSE	0	FALSE	FALSE	FALSE				
8	2U	25+462.248	25+687.326	225.08	0.1399		3.7	3.7	3	3	0.52	1	1	FALSE	0	FALSE	FALSE	FALSE	2,000.00	3	FALSE	110
9	2U	25+687.326	25+940.570	253.24	0.1574		3.7	3.7	3	3	0.52	1	1	FALSE	0	FALSE	FALSE	FALSE				
10	2U	25+940.570	25+943.570	3	0.0019		3.7	3.7	3	3	0.52	1	1	FALSE	0	FALSE	FALSE	FALSE				
11	2U	25+943.570	26+326.447	382.88	0.2379		3.7	3.7	3	3	0.52	1	1	FALSE	0	FALSE	FALSE	FALSE				
12	2U	26+326.447	26+588.457	262.01	0.1628	2005: 4,180;	3.7	3.7	3	3	0.52	1	1	FALSE	0	FALSE	FALSE	FALSE	2,000.00	3	FALSE	110
13	2U	26+588.457	26+680.401	91.94	0.0571	2006: 4,110;	3.7	3.7	3	3	0.33	1	1	FALSE	0	FALSE	FALSE	FALSE				
14	2U	26+680.401	26+942.451	262.05	0.1628	2007: 4,680	3.7	3.7	3	3	0.33	1	1	FALSE	0	FALSE	FALSE	FALSE	2,000.00	3	FALSE	110
15	2U	26+942.451	30+646.700	3,704.25	2.3017		3.7	3.7	3	3	0.94	1	1	FALSE	0	FALSE	FALSE	FALSE				

Section	Route	County	Part
9B	US-169	Neosho	2

Segment Number	Type	Start Location	End Location	Length (m)	Length (mi)	AADT	Left Lane Width (m)	Right Lane Width (m)	Left Shoulder Width (m)	Right Shoulder Width (m)	Grade (%)	Driveway Density (driveways/km)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (m)	Superelevation (%)	Adverse	Design Speed (km/h)
1	2U	12+453.300	16+080.581	3,627.28	2.2539	2005: 3,470;	3.7	3.7	3	3	0.12	1	1	FALSE	0	FALSE	FALSE	FALSE				
2	2U	16+080.581	16+936.751	856.17	0.532	2006: 3,410;	3.7	3.7	3	3	0.78	1	1	FALSE	0	FALSE	FALSE	FALSE	3,492.77	1.6	TRUE	110
3	2U	16+936.751	17+495.507	558.76	0.3472	2007: 3,990	3.7	3.7	3	3	2.27	1	1	FALSE	0	FALSE	FALSE	FALSE				
4	2U	17+495.507	17+758.580	263.07	0.1635		3.7	3.7	3	3	0.47	1	1	FALSE	0	FALSE	FALSE	FALSE	1,746.40	3.4	FALSE	110
5	2U	17+758.580	17+912.064	153.48	0.0954	2005: 3,470; 2006: 3,410;	3.7	3.7	3	3	0.56	1	1	FALSE	0	FALSE	FALSE	FALSE	1,746.40	3.4	FALSE	110
6	2U	17+912.064	20+500.000	2,587.94	1.6081	2007: 4,160	3.7	3.7	3	3	0.56	1	1	FALSE	0	FALSE	FALSE	FALSE				

Section	Route	County
10	K-181	Smith

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (ft)	Superelevation (%)	Adverse	Design Speed (mph)
1	2U	35+964.000	39+132.000	3,168.00	0.6	2005: 595; 2006: 585; 2007: 500	12	12	2.95	2.95	2.52	1	1	FALSE	0	FALSE	FALSE	FALSE				
2	2U	39+132.000	40+452.000	1,320.00	0.25	2005: 450; 2006: 445; 2007: 390	12	12	2.95	2.95	1.01	1	1	FALSE	0	FALSE	FALSE	FALSE				
3	2U	40+452.000	42+682.300	2,230.30	0.4224		12	12	2.95	2.95	4.24	1	1	FALSE	0	FALSE	FALSE	FALSE				
4	2U	42+682.300	44+349.000	1,666.70	0.3157		12	12	2.95	2.95	1	1	1	FALSE	0	FALSE	FALSE	FALSE	5,723.65	2.1	FALSE	65
5	2U	44+349.000	45+340.800	991.8	0.1878		12	12	2.95	2.95	0.18	1	1	FALSE	0	FALSE	FALSE	FALSE				
6	2U	45+340.800	47+987.500	2,646.70	0.5013	2005: 395;	12	12	2.95	2.95	2.86	1	1	FALSE	0	FALSE	FALSE	FALSE	5,729.65	2.1	FALSE	65
7	2U	47+987.500	58+829.000	10,841.50	2.0533	2006: 390;	12	12	2.95	2.95	3.1	1	1	FALSE	0	FALSE	FALSE	FALSE				
8	2U	58+829.000	59+975.700	1,146.70	0.2172	2007: 400	12	12	2.95	2.95	1.08	1	1	FALSE	0	FALSE	FALSE	FALSE	5,729.65	2.1	FALSE	65
9	2U	59+975.700	67+342.500	7,366.80	1.3952		12	12	2.95	2.95	1.92	1	1	FALSE	0	FALSE	FALSE	FALSE				
10	2U	67+342.500	68+882.500	1,540.00	0.2917		12	12	2.95	2.95	0.78	1	1	FALSE	0	FALSE	FALSE	FALSE	3,819.83	4.2	FALSE	65
11	2U	68+882.500	88+764.000	19,881.50	3.7654		12	12	2.95	2.95	0	1	1	FALSE	0	FALSE	FALSE	FALSE				

Section	Route	County	Part
11A	US-160	Cowley	1

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (ft)	Superelevation (%)	Adverse	Design Speed (mph)
1	2U	11+731.880	12+808.640	1,076.76	0.2039	2005: 3,630;	12	12	4	4	1.73	1	2	FALSE	0	FALSE	FALSE	FALSE				
2	2U	12+808.640	13+751.000	942.36	0.1785	2006: 3,650;	12	12	4	4	1.73	1	2	FALSE	0	FALSE	FALSE	FALSE	42,971.80	1.6	TRUE	65
3	2U	13+751.000	18+749.400	4,998.40	0.9467	2007: 3,640	12	12	4	4	0.28	1	2	FALSE	0	FALSE	FALSE	FALSE				

4	2U	18+749.400	21+259.480	2,510.08	0.4754		12	12	4	4	1.24	1	2	FALSE	0	FALSE	FALSE	FALSE				
5	2U	21+259.480	22+089.480	830	0.1572	2005: 3,190;	12	12	4	4	2.39	1	2	FALSE	0	FALSE	FALSE	FALSE	17,188.80	1.6	TRUE	65
6	2U	22+089.480	22+641.790	552.31	0.1046	2006: 2,810;	12	12	4	4	0.39	1	2	FALSE	0	FALSE	FALSE	FALSE				
7	2U	22+641.790	23+455.580	813.79	0.1541	2007: 2,790	12	12	4	4	0.39	1	2	FALSE	0	FALSE	FALSE	FALSE	11,854.30	1.6	TRUE	65
8	2U	23+455.580	29+310.000	5,854.42	1.1088		12	12	4	4	2.16	1	2	FALSE	0	FALSE	FALSE	FALSE				
9	2U	29+310.000	37+151.060	7,841.06	1.485		12	12	4	4	0	1	2	FALSE	0	FALSE	FALSE	FALSE				
10	2U	37+151.060	37+976.060	825	0.1562	2005: 1,650;	12	12	4	4	0.95	1	2	FALSE	0	FALSE	FALSE	FALSE	42,971.80	1.6	TRUE	65
11	2U	37+976.060	55+169.750	17,193.69	3.2564	2006: 1,680;	12	12	4	4	1.55	1	2	FALSE	0	FALSE	FALSE	FALSE				
12	2U	55+169.750	55+984.040	814.29	0.1542	2007: 1,670	12	12	4	4	0.65	1	2	FALSE	0	FALSE	FALSE	FALSE	100,267.20	1.6	TRUE	65
13	2U	55+984.040	60+991.800	5,007.76	0.9484		12	12	4	4	0.25	1	2	FALSE	0	FALSE	FALSE	FALSE				
14	2U	60+991.800	61+046.190	54.39	0.0103	2005: 955; 2006: 1,090; 2007: 1,080	12	12	2	2	1.54	1	2	FALSE	0	FALSE	FALSE	FALSE				

Section	Route	County	Part
11B	US-160	Cowley	2

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement
1	2U	1+000.000	4+485.690	3,485.69	0.6602	2005: 955; 2006: 1,090; 2007: 1,080	12	12	2	2	0.84	1	3	FALSE	0	FALSE	FALSE	FALSE

Section	Route	County	Part
12A	K-2	Harper	1

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (ft)	Superelevation (%)	Adverse	Design Speed (mph)
1	2U	53+960.000	71+061.920	17,101.92	3.239	2005: 485; 2006: 605; 2007: 600	12	12	2	2	1.14	1	2	FALSE	0	FALSE	FALSE	FALSE				
2	2U	71+061.920	5+505.000(1)	4,443.08	0.8415		12	12	2	2	1.08	1	2	FALSE	0	FALSE	FALSE	FALSE				
3	2U	5+505.000(1)	6+119.790(1)	614.79	0.1164		12	12	2	2	0.44	1	2	FALSE	0	FALSE	FALSE	FALSE	22,918.31	1.6	TRUE	65
4	2U	6+119.790(1)	7+626.610(1)	1,506.82	0.2854	2005: 1,840;	12	12	2	2	0.44	1	2	FALSE	0	FALSE	FALSE	FALSE				
5	2U	7+626.610(1)	8+471.950(1)	845.34	0.1601	2006: 1,990;	12	12	2	2	1.53	1	2	FALSE	0	FALSE	FALSE	FALSE	19,098.59	1.6	TRUE	65
6	2U	8+471.950(1)	10+369.440(1)	1,897.49	0.3594	2007: 1,980	12	12	2	2	0.6	1	2	FALSE	0	FALSE	FALSE	FALSE				
7	2U	10+369.440(1)	81+394.510(2)	1,027.00	0.1945		12	12	2	2	0.12	1	2	FALSE	0	FALSE	FALSE	FALSE	57,295.78	1.6	TRUE	65
8	2U	81+394.510(2)	90+918.070(2)	9,523.56	1.8037		12	12	2	2	0.12	1	2	FALSE	0	FALSE	FALSE	FALSE				

Section	Route	County	Part
12B	K-2	Harper	2

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement
1	2U	5+776.880	6+225.680	448.8	0.085	2005: 3,890; 2006: 3,920; 2007: 3,900	12	12	10	10	0	1	2	FALSE	0	FALSE	FALSE	FALSE
2	2U	6+225.680	21+616.880	15,391.20	2.915	2005: 3,440; 2006: 3,340; 2007: 3,320	12	12	10	10	0	1	2	FALSE	0	FALSE	FALSE	FALSE

Section	Route	County
13	US-83	Logan

Segment Number	Type	Start Location	End Location	Length (m)	Length (mi)	AADT	Left Lane Width (m)	Right Lane Width (m)	Left Shoulder Width (m)	Right Shoulder Width (m)	Grade (%)	Driveway Density (driveways/km)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement
1	2U	17+916.045	19+404.690	1,488.64	0.925	2005: 1,505;	3	3	2.4	2.4	0.54	2	1	FALSE	0	FALSE	FALSE	FALSE
2	2U	19+404.690	25+962.770	6,558.08	4.075	2006: 1,540;	3	3	3	3	1.41	2	1	FALSE	0	FALSE	FALSE	FALSE
3	2U	25+962.770	34+009.485	8,046.72	5	2007: 1,600	3	3	3	3	1.22	2	1	FALSE	0	FALSE	FALSE	FALSE

Section	Route	County
14	US-36	Smith

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (ft)	Superelevation (%)	Adverse	Design Speed (mph)
1	2U	6+600.000	8+032.200	1,432.20	0.2712	2005: 1,830;	12	12	7.8	7.8	0.78	1	2	FALSE	0	FALSE	FALSE	FALSE				
2	2U	8+032.200	8+965.530	933.33	0.1768	2006: 1,700;	12	12	7.8	7.8	2.78	1	2	FALSE	0	FALSE	FALSE	FALSE	6,138.90	1.6	TRUE	65
3	2U	8+965.530	13+231.900	4,266.37	0.808	2007: 1,500	12	12	7.8	7.8	2.86	1	2	FALSE	0	FALSE	FALSE	FALSE				
4	2U	13+231.900	28+728.700	15,496.80	2.935	2005: 1,640; 2006: 1,620; 2007: 1,460	12	12	7.8	7.8	3.34	1	2	FALSE	0	FALSE	FALSE	FALSE				

5	2U	28+728.700	33+237.820	4,509.12	0.854	2005: 1,810; 2006: 1,790; 2007: 1,620	12	12	7.8	7.8	1.1	1	2	FALSE	0	FALSE	FALSE	FALSE				
6	2U	33+237.820	49+848.700	16,610.88	3.146	2005: 1,780; 2006: 1,760; 2007: 1,660	12	12	7.8	7.8	0.46	1	2	FALSE	0	FALSE	FALSE	FALSE				
7	2U	49+848.700	59+400.000	9,551.30	1.809	2005: 1,920; 2006: 1,900; 2007: 1,780	12	12	7.8	7.8	3.88	1	2	FALSE	0	FALSE	FALSE	FALSE				

Section	Route	County
15	K-99	Wabunsee

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (ft)	Superelevation (%)	Adverse	Design Speed (mph)
1	2U	7+148.700	10+670.500	3,521.80	0.667	2005: 2,260; 2006: 2,150; 2007: 2,080	12	12	6	6	2.55	1	3	FALSE	0	FALSE	FALSE	FALSE				
2	2U	10+670.500	11+953.550	1,283.05	0.243	2005: 3,420; 2006: 3,200; 2007: 3,620	12	12	6	6	2.88	1	3	FALSE	0	FALSE	FALSE	FALSE				
3	2U	11+953.550	23+823.110	11,869.56	2.248	2005: 2,820; 2006: 3,000; 2007: 3,090	12	12	6	6	6	1	3	FALSE	0	FALSE	FALSE	FALSE				
4	2U	23+823.110	28+863.600	5,040.49	0.9546	2005: 3,090; 2006: 2,780; 2007: 2,980	12	12	6	6	0.89	1	3	FALSE	0	FALSE	FALSE	FALSE				
5	2U	28+863.600	29+501.900	638.3	0.1209		12	12	6	6	6	1	3	FALSE	0	FALSE	FALSE	FALSE	1,432.50	7.3	FALSE	65
6	2U	29+501.900	32+504.400	3,002.50	0.5687		12	12	6	6	0.41	1	3	FALSE	0	FALSE	FALSE	FALSE				
7	2U	32+504.400	33+280.700	776.3	0.147		12	12	6	6	2.71	1	3	FALSE	0	FALSE	FALSE	FALSE	1,432.50	7.3	FALSE	65
8	2U	33+280.700	33+598.200	317.5	0.0601		12	12	6	6	2.93	1	3	FALSE	0	FALSE	FALSE	FALSE				
9	2U	33+598.200	34+451.100	852.9	0.1615		12	12	6	6	2.93	1	3	FALSE	0	FALSE	FALSE	FALSE	1,632.70	7.3	FALSE	65
10	2U	34+451.100	39+277.500	4,826.40	0.9141		12	12	6	6	2.93	1	3	FALSE	0	FALSE	FALSE	FALSE				
11	2U	39+277.500	39+872.100	594.6	0.1126		12	12	6	6	6	1	3	FALSE	0	FALSE	FALSE	FALSE	1,432.50	7.3	FALSE	65
12	2U	39+872.100	43+380.430	3,508.33	0.6645	2005: 3,130; 2006: 3,090; 2007: 3,420	12	12	6	6	0.91	1	3	FALSE	0	FALSE	FALSE	FALSE				
13	2U	43+380.430	48+022.000	4,641.57	0.8791		12	12	6	6	2.05	1	3	FALSE	0	FALSE	FALSE	FALSE				
14	2U	48+022.000	48+850.570	828.57	0.1569		12	12	6	6	2.05	1	2	FALSE	0	FALSE	FALSE	FALSE				
15	2U	48+850.570	51+142.110	2,291.54	0.434		12	12	6	6	0	1	2	FALSE	0	FALSE	FALSE	FALSE				
16	2U	51+142.110	56+390.480	5,248.37	0.994	2005: 3,350; 2006: 3,310; 2007: 3,670	12	12	6	6	0	1	2	FALSE	0	FALSE	FALSE	FALSE				
17	2U	56+390.480	56+679.180	288.7	0.0547	2005: 3,350; 2006: 3,310; 2007: 3,820	12	12	6	6	0	1	2	FALSE	0	FALSE	FALSE	FALSE				
18	2U	56+679.180	57+506.680	827.5	0.1567		12	12	6	6	0	1	2	FALSE	0	FALSE	FALSE	FALSE	17,188.80	1.6	TRUE	65
19	2U	57+506.680	58+788.480	1,281.80	0.2428		12	12	6	6	0	1	2	FALSE	0	FALSE	FALSE	FALSE				
20	2U	58+788.480	59+121.780	333.3	0.0631		12	12	6	6	0.66	1	2	FALSE	0	FALSE	FALSE	FALSE	1,719.12	1.6	TRUE	65
21	2U	59+121.780	59+500.000	378.22	0.0716		12	12	6	6	0.66	1	2	FALSE	0	FALSE	FALSE	FALSE				

Section	Route	County
16A	US-400	Labette

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (ft)	Superelevation (%)	Adverse	Design Speed (mph)
1	2U	14+940.970	15+130.000	189.03	0.0358	2005: 4,640; 2006: 5,030; 2007: 5,000	12	12	8.86	8.86	0.2	1	2	FALSE	0	FALSE	FALSE	FALSE				
2	2U	15+130.000	16+192.000	1,062.00	0.2011		12	12	8.86	8.86	0.2	1	2	FALSE	0	FALSE	FALSE	FALSE				
3	2U	16+192.000	16+389.280	197.28	0.0374		12	12	8.86	8.86	1	1	2	FALSE	0	FALSE	FALSE	FALSE				
4	2U	16+389.280	16+810.530	421.25	0.0798		12	12	8.86	8.86	1	1	2	FALSE	0	FALSE	FALSE	FALSE	5,729.58	4	FALSE	65
5	2U	16+810.530	17+138.470	327.94	0.0621		12	12	8.86	8.86	0	1	2	FALSE	0	FALSE	FALSE	FALSE				
6	2U	17+138.470	17+565.050	426.58	0.0808		12	12	8.86	8.86	0	1	2	FALSE	0	FALSE	FALSE	FALSE	5,729.58	4	FALSE	65
7	2U	17+565.050	24+293.450	6,728.40	1.2743		12	12	8.86	8.86	0.26	1	2	FALSE	0	FALSE	FALSE	FALSE				
8	2U	24+293.450	24+708.260	414.81	0.0786		12	12	8.86	8.86	0.44	1	2	FALSE	0	FALSE	FALSE	FALSE	2,729.58	4	FALSE	65
9	2U	24+708.260	27+155.550(1)	2,449.88	0.464		12	12	8.86	8.86	0	1	2	FALSE	0	FALSE	FALSE	FALSE				
10	2U	27+155.550(1)	27+565.550(1)	410	0.0776		12	12	8.86	8.86	0.71	1	2	FALSE	0	FALSE	FALSE	FALSE	34,377.47	1.6	TRUE	65

Section	Route	County
16B	US-400	Cherokee

Seg. No.	Type	Start Location	End Location	Length (ft)	Length(mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (ft)	Superelevation (%)	Adverse	Design Speed (mph)
1	2U	3+525.000	3+935.180	410.18	0.0777	2005: 3,930; 2006: 4,280; 2007: 4,250	12	12	10	10	1.34	1	2	FALSE	0	FALSE	FALSE	FALSE	34,377.50	1.6	TRUE	65
2	2U	3+935.180	6+005.050	2,069.87	0.392		12	12	10	10	1.34	1	2	FALSE	0	FALSE	FALSE	FALSE				
3	2U	6+005.050	6+885.050	880	0.1667		12	12	10	10	0	1	2	FALSE	0	FALSE	FALSE	FALSE	22,918.30	1.6	TRUE	65
4	2U	6+885.050	14+032.260	7,147.21	1.3536		12	12	10	10	0	1	2	FALSE	0	FALSE	FALSE	FALSE				

5	2U	14+032.260	24+597.540	10,565.28	2.001	2005: 3,940; 2006: 4,290; 2007: 4,260	12	12	10	10	0.8	1	2	FALSE	0	FALSE	FALSE	FALSE				
6	2U	24+597.540	40+310.820	15,713.28	2.976	2005: 3,980; 2006: 4,320; 2007: 4,290	12	12	10	10	0.67	1	2	FALSE	0	FALSE	FALSE	FALSE				
7	2U	40+310.820	43+753.380	3,442.56	0.652	2005: 4,050; 2006: 4,710; 2007: 4,680	12	12	10	10	0	1	2	FALSE	0	FALSE	FALSE	FALSE				

Section	Route	County
17	US-36	Republic

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (ft)	Superelevation (%)	Adverse	Design Speed (mph)
1	2U	15+525.600	20+277.600	4,752.00	0.9	2005: 1,770; 2006: 1,750; 2007: 1,830	12	12	7.87	7.87	1.79	1	3	FALSE	0	FALSE	FALSE	FALSE				
2	2U	20+277.600	23+345.000	3,067.40	0.581	2005: 1,360; 2006: 1,340; 2007: 1,460	12	12	7.87	7.87	0.17	1	3	FALSE	0	FALSE	FALSE	FALSE				
3	2U	23+345.000	24+055.000	710	0.1345		12	12	7.87	7.87	0.86	1	3	FALSE	0	FALSE	FALSE	FALSE	39,377.00	1.6	TRUE	65
4	2U	24+055.000	53+600.000	29,545.00	5.5956		12	12	7.87	7.87	0.86	1	3	FALSE	0	FALSE	FALSE	FALSE				
5	2U	53+600.000	54+597.600	997.6	0.1889		12	12	7.87	7.87	1.61	1	2	FALSE	0	FALSE	FALSE	FALSE				
6	2U	54+597.600	68+325.600	13,728.00	2.6	2005: 1,030; 2006: 1,020; 2007: 1,120	12	12	7.87	7.87	1.61	1	2	FALSE	0	FALSE	FALSE	FALSE				

Section	Route	County
18	US-75	Brown

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement
1	2U	1+000.000	6+295.840	5,295.84	1.003	2005: 4,920; 2006: 4,860; 2007: 4,820	12	12	8.86	8.86	1.33	1	2	FALSE	0	FALSE	FALSE	FALSE
2	2U	6+295.840	22+135.840	15,840.00	3	2005: 4,260; 2006: 4,210; 2007: 4,370	12	12	8.86	8.86	3.95	1	2	FALSE	0	FALSE	FALSE	FALSE
3	2U	22+135.840	37+975.840	15,840.00	3	2005: 3,740; 2006: 3,690; 2007: 3,380	12	12	8.86	8.86	1.16	1	2	FALSE	0	FALSE	FALSE	FALSE
4	2U	37+975.840	53+800.000	15,824.16	2.997	2005: 3,700; 2006: 4,330; 2007: 3,750	12	12	8.86	8.86	0.42	1	2	FALSE	0	FALSE	FALSE	FALSE

Section	Route	County
19	K-116	Atchison

Segment Number	Type	Start Location	End Location	Length (ft)	Length (mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (ft)	Superelevation (%)	Adverse	Design Speed (mph)
1	2U	5+227.200	7+023.600	1,796.40	0.3402	2005: 1,040; 2006: 1,030; 2007: 715	12	12	1.96	1.96	0.17	1	3	FALSE	0	FALSE	FALSE	FALSE				
2	2U	7+023.600	7+449.200	425.6	0.0806		12	12	1.96	1.96	0.17	1	3	FALSE	0	FALSE	FALSE	FALSE	637.29	8.3	FALSE	55
3	2U	7+449.200	7+907.800	458.6	0.0869		12	12	1.96	1.96	0.17	1	3	FALSE	0	FALSE	FALSE	FALSE				
4	2U	7+907.800	8+342.800	435	0.0824		12	12	1.96	1.96	0.17	1	3	FALSE	0	FALSE	FALSE	FALSE	697.28	8.3	FALSE	55
5	2U	8+342.800	9+000.000	657.2	0.1245		12	12	1.96	1.96	1.45	1	3	FALSE	0	FALSE	FALSE	FALSE				
6	2U	9+000.000	9+999.300	999.3	0.1893		12	12	1.96	1.96	0.3	5	3	FALSE	0	FALSE	FALSE	FALSE				
7	2U	9+999.300	10+560.000	560.7	0.1062		12	12	1.96	1.96	1.04	5	3	FALSE	0	FALSE	FALSE	FALSE	1,146.28	8.3	FALSE	55
8	2U	10+560.000	10+639.500	79.5	0.0151	2005: 780; 2006: 770; 2007: 755	12	12	1.96	1.96	3.98	5	3	FALSE	0	FALSE	FALSE	FALSE	1,146.28	8.3	FALSE	55
9	2U	10+639.500	11+048.700	409.2	0.0775		12	12	1.96	1.96	3.98	5	3	FALSE	0	FALSE	FALSE	FALSE				
10	2U	11+048.700	11+684.700	636	0.1204		12	12	1.96	1.96	3.98	5	3	FALSE	0	FALSE	FALSE	FALSE	1,146.28	8.3	FALSE	55
11	2U	11+684.700	12+000.000	315.3	0.0597		12	12	1.96	1.96	3.98	5	3	FALSE	0	FALSE	FALSE	FALSE				
12	2U	12+000.000	25+919.520	13,919.52	2.6363		12	12	1.96	1.96	3.98	1	3	FALSE	0	FALSE	FALSE	FALSE				
13	2U	25+919.520	58+027.200	32,107.68	6.081	2005: 795; 2006: 785; 2007: 775	12	12	1.96	1.96	5.5	1	3	FALSE	0	FALSE	FALSE	FALSE				

APPENDIX G – SAMPLE CALIBRATION SECTION IHSDM OUTPUT

Interactive Highway Safety Design Model

Crash Prediction Evaluation Report

July 5, 2011

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Report Overview

Report Generated: Jul 5, 2011 6:43 AM
Report Template: System: Multi-Page [System] (mlcpm2, Apr 5, 2011 10:29 AM)

Evaluation Date: Mon Sep 06 10:51:04 CDT 2010
IHSDM Version: v6.0.0 (Jul 15, 2010)
Crash Prediction Module: v2.2.0 (Jun 29, 2010)

User Name: Howard Lubliner
Organization Name: KDOT
Phone: 785-760-4611
E-Mail: howardl@ksdot.org

Project Title: (3) K-4 Lane
Project Comment: Created using wizard
Project Unit System: U.S. Customary

Highway Title: K-4
Highway Comment: Created Thu Jan 21 15:39:46 CST 2010
Highway Version: 1

Evaluation Title: Evaluation 5
Evaluation Comment: Created Mon Sep 06 10:50:09 CDT 2010
Minimum Station: 7+180.480
Maximum Station: 59+980.480
Policy for Superelevation: AASHTO 2004 U.S. Customary
Calibration/Distribution: Default configuration
Model/CMF: Default configuration
Empirical-Bayes Analysis: None
First Year of Analysis: 2005
Last Year of Analysis: 2007

Section 1 Evaluation

Section: Section 1
Evaluation Start Location: 7+180.480
Evaluation End Location: 59+980.480
Area Type: Rural
Functional Class: Arterial
Type of Alignment: Undivided, Two Lane
Model Category: Rural, Two Lane

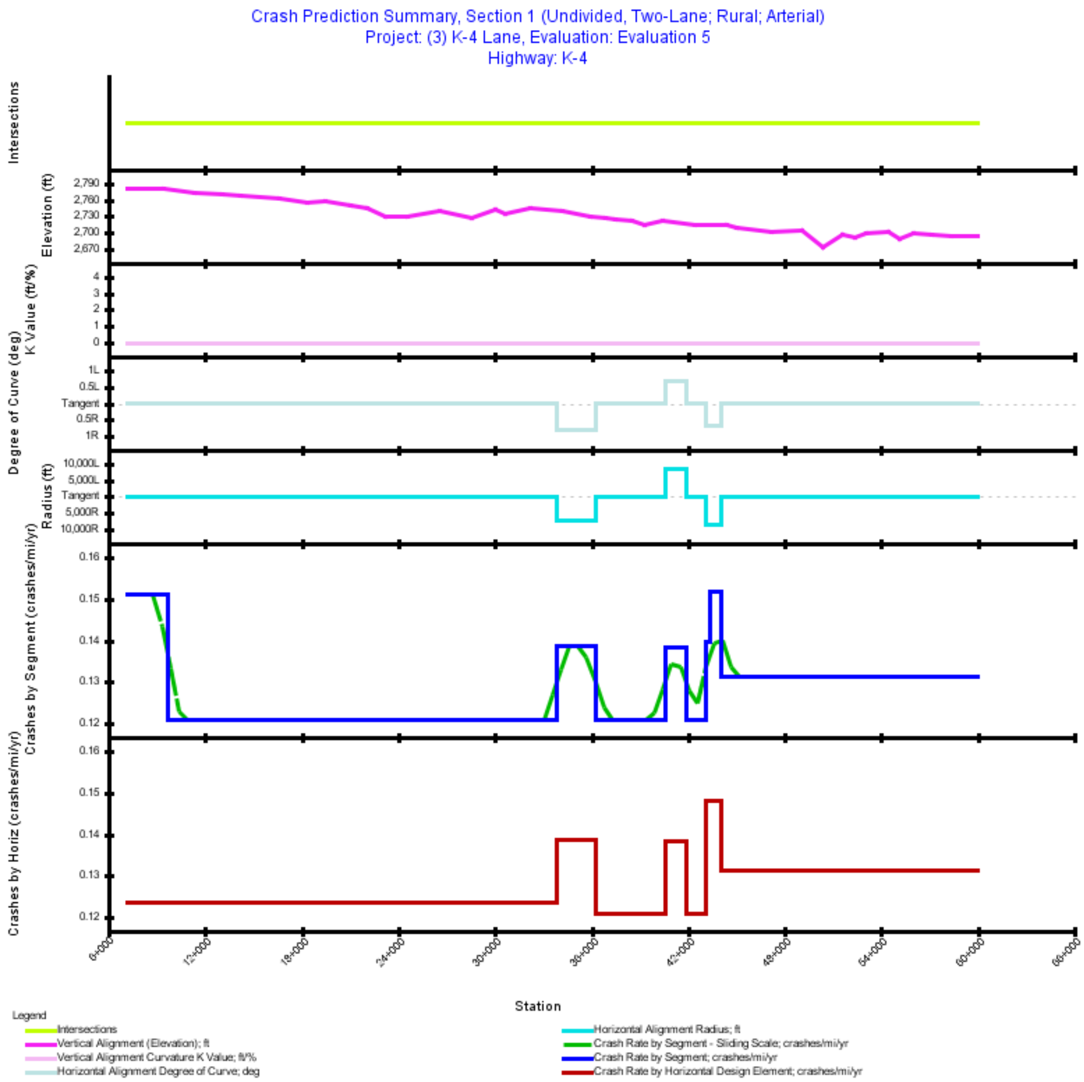

Figure 1. Crash Prediction Summary (Section 1)

Table 1. Evaluation Highway - Homogeneous Segments (Section 1)

Seg. No.	Type	Start Location	End Location	Length (ft)	Length(mi)	AADT	Left Lane Width (ft)	Right Lane Width (ft)	Left Shoulder Width (ft)	Right Shoulder Width (ft)	Grade (%)	Driveway Density (driveways/mi)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (ft)	Superelevation (%)	Adverse	Design Speed (mph)
1	2U	7+180.480	9+673.000	2,492.52	0.4721	2005: 500; 2006: 490; 2007: 670	12.00	12.00	5.91	5.91	0.00	1.0	3	false	0	false	false	false				
2	2U	9+673.000	33+827.080	24,154.08	4.5746	2005: 370; 2006: 365; 2007: 590	12.00	12.00	5.91	5.91	0.41	1.0	3	false	0	false	false	false				
3	2U	33+827.080	36+234.370	2,407.29	0.4559	2005: 370; 2006: 365; 2007: 590	12.00	12.00	5.91	5.91	0.26	1.0	3	false	0	false	false	false	7,162.03	1.6	true	65
4	2U	36+234.370	40+552.500	4,318.13	0.8178	2005: 370; 2006: 365; 2007: 590	12.00	12.00	5.91	5.91	0.11	1.0	3	false	0	false	false	false				
5	2U	40+552.500	41+874.490	1,321.99	0.2504	2005: 370; 2006: 365; 2007: 590	12.00	12.00	5.91	5.91	0.42	1.0	3	false	0	false	false	false	8,594.48	1.6	true	65
6	2U	41+874.490	43+105.900	1,231.41	0.2332	2005: 370; 2006: 365; 2007: 590	12.00	12.00	5.91	5.91	0.42	1.0	3	false	0	false	false	false				
7	2U	43+105.900	43+401.400	295.50	0.0560	2005: 370; 2006: 365; 2007: 590	12.00	12.00	5.91	5.91	0.00	1.0	3	false	0	false	false	false	8,594.42	1.6	true	65
8	2U	43+401.400	44+053.360	651.96	0.1235	2005: 450; 2006: 440; 2007: 550	12.00	12.00	5.91	5.91	0.00	1.0	3	false	0	false	false	false	8,594.42	1.6	true	65
9	2U	44+053.360	59+980.480	15,927.12	3.0165	2005: 450; 2006: 440; 2007: 550	12.00	12.00	5.91	5.91	0.20	1.0	3	false	0	false	false	false				

Table 2. Expected Crash Rates and Frequencies (Section 1)

First Year of Analysis	2005
Last Year of Analysis	2007
Evaluated Length (mi)	10.0000
Average Future Road AADT (vpd)	459
Expected Crashes	
Total Crashes	3.81
Fatal and Injury Crashes	1.22
Fatal and Serious Injury Crashes	0.67
Property-Damage-Only Crashes	2.59
Percent of Total Expected Crashes	
Percent Fatal and Injury Crashes (%)	32
Percent Fatal and Serious Injury Crashes (%)	18
Percent Property-Damage-Only Crashes (%)	68
Expected Crash Rate	
Crash Rate (crashes/mi/yr)	0.1271
Fatal and Injury Crash Rate (crashes/mi/yr)	0.0408
Fatal and Serious Injury Crash Rate (crashes/mi/yr)	0.0224
Property-Damage-Only Crash Rate (crashes/mi/yr)	0.0863
Expected Travel Crash Rate	
Total Travel (million veh-mi)	5.03
Travel Crash Rate (crashes/million veh-mi)	0.76
Travel Fatal and Injury Crash Rate (crashes/million veh-mi)	0.24
Travel Fatal and Serious Injury Crash Rate (crashes/million veh-mi)	0.13
Travel Property-Damage-Only Crash Rate (crashes/million veh-mi)	0.52

Table 3. Expected Crash Frequencies and Rates by Highway Segment (Section 1)

Start Location	End Location	Length (mi)	Expected No. Crashes for Evaluation Period	Crash Rate (crashes/mi/yr)	Travel Crash Rate (crashes/million veh-mi)
7+180.480	9+673.000	0.4721	0.21	0.1513	0.75
9+673.000	33+827.080	4.5746	1.66	0.1207	0.75
33+827.080	36+234.370	0.4559	0.19	0.1388	0.86
36+234.370	40+552.500	0.8178	0.30	0.1207	0.75
40+552.500	41+874.490	0.2504	0.10	0.1384	0.86
41+874.490	43+105.900	0.2332	0.08	0.1207	0.75
43+105.900	43+401.400	0.0560	0.02	0.1397	0.87
43+401.400	44+053.360	0.1235	0.06	0.1519	0.87
44+053.360	59+980.480	3.0165	1.19	0.1312	0.75

Table 4. Expected Crash Frequencies and Rates by Horizontal Design Element (Section 1)

Title	Start Location	End Location	Length (mi)	Expected No. Crashes for Evaluation Period	Crash Rate (crashes/mi/yr)	Travel Crash Rate (crashes/million veh-mi)
Tangent	7+180.480	33+827.080	5.0467	1.87	0.1236	0.75
Curve 1	33+827.080	36+234.370	0.4559	0.19	0.1388	0.86
Tangent	36+234.370	40+552.500	0.8178	0.30	0.1207	0.75
Curve 2	40+552.500	41+874.490	0.2504	0.10	0.1384	0.86
Tangent	41+874.490	43+105.900	0.2332	0.08	0.1207	0.75
Curve 3	43+105.900	44+053.360	0.1794	0.08	0.1481	0.87
Tangent	44+053.360	59+980.480	3.0165	1.19	0.1312	0.75

Table 5. Expected Crash Type Distribution (Section 1)

Element Type	Crash Type	Fatal and Serious Injury		Property Damage Only		Total	
		Crashes	Crashes (%)	Crashes	Crashes (%)	Crashes	Crashes (%)
Highway Segment	Collision with Animal	0.05	1.2	0.48	12.5	0.46	12.1
Highway Segment	Collision with Bicycle	0.00	0.1	0.00	0.1	0.01	0.2
Highway Segment	Other Single-vehicle Collision	0.01	0.2	0.08	2.0	0.08	2.1
Highway Segment	Overturned	0.04	1.2	0.04	1.0	0.10	2.5
Highway Segment	Collision with Pedestrian	0.01	0.2	0.00	0.1	0.01	0.3
Highway Segment	Run Off Road	0.67	17.5	1.31	34.3	1.99	52.1
Highway Segment	Single Vehicle Crashes	0.78	20.5	1.90	49.9	2.64	69.3
Highway Segment	Angle Collision	0.12	3.2	0.19	4.9	0.32	8.5
Highway Segment	Head-on Collision	0.04	1.1	0.01	0.2	0.06	1.6
Highway Segment	Other Multiple-vehicle Collision	0.03	0.8	0.08	2.0	0.10	2.7
Highway Segment	Rear-end Collision	0.20	5.3	0.32	8.3	0.54	14.2
Highway Segment	Sideswipe	0.05	1.2	0.10	2.6	0.14	3.7
Highway Segment	Multiple Vehicle Crashes	0.44	11.7	0.69	18.0	1.17	30.7
Highway Segment	Total Highway Segment Crashes	1.23	32.2	2.59	67.9	3.81	100.0
	Total Crashes	1.23	32.2	2.59	67.9	3.81	100.0

Note:*Fatal and Injury Crashes* and *Property Damage Only Crashes* do not necessarily sum up to *Total Crashes* because the distribution of these three crashes had been derived independently.

APPENDIX H - VALIDATION SECTION INPUTS

Section	Project Number	Route	Before/After
1	K-5393-01	K-383	Before

Segment Number	Type	Start Location	End Location	Length (m)	Length (mi)	AADT	Left Lane Width (m)	Right Lane Width (m)	Left Shoulder Width (m)	Right Shoulder Width (m)	Grade (%)	Driveway Density (driveways/km)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (m)	Superelevation (%)	Adverse	Design Speed (km/h)
1	2U	11+403.500	11+449.321	45.82	0.0285	1996-1998: 765	3.7	3.7	2.41	2.41	1.95	5	1	FALSE	0	FALSE	FALSE	FALSE				
2	2U	11+449.321	11+804.160	354.84	0.2205		3.7	3.7	2.41	2.41	1.95	5	1	FALSE	0	FALSE	FALSE	FALSE	1,496.92	3.9	FALSE	110
3	2U	11+804.160	11+856.338	52.18	0.0324		3.7	3.7	2.41	2.41	2.21	5	1	FALSE	0	FALSE	FALSE	FALSE	1,496.92	3.9	FALSE	110
4	2U	11+856.338	12+206.420	350.08	0.2175		3.7	3.7	2.41	2.41	2.21	5	1	FALSE	0	FALSE	FALSE	FALSE				
5	2U	12+206.420	12+492.891	286.47	0.178	1996-1998: 915	3.7	3.7	2.41	2.41	2.1	5	1	FALSE	0	FALSE	FALSE	FALSE				
6	2U	12+492.891	12+983.420	490.53	0.3048		3.7	3.7	2.41	2.41	2.78	5	1	FALSE	0	FALSE	FALSE	FALSE	873.23	6.2	FALSE	110
7	2U	12+983.420	13+400.000	416.58	0.2588		3.7	3.7	2.41	2.41	0	5	1	FALSE	0	FALSE	FALSE	FALSE				
8	2U	13+400.000	15+222.037	1,822.04	1.1322		3.7	3.7	2.41	2.41	0.42	2.1	1	FALSE	0	FALSE	FALSE	FALSE				
9	2U	15+222.037	15+695.543	473.51	0.2942		3.7	3.7	2.41	2.41	1.19	2.1	1	FALSE	0	FALSE	FALSE	FALSE	2,328.52	2.6	FALSE	110
10	2U	15+695.543	18+031.709	2,336.17	1.4516		3.7	3.7	2.41	2.41	1.19	2.1	1	FALSE	0	FALSE	FALSE	FALSE				
11	2U	18+031.709	18+270.287	238.58	0.1482		3.7	3.7	2.41	2.41	0.57	2.1	1	FALSE	0	FALSE	FALSE	FALSE	1,746.40	3	FALSE	110
12	2U	18+270.287	19+680.510	1,410.22	0.8763		3.7	3.7	2.41	2.41	0.57	2.1	1	FALSE	0	FALSE	FALSE	FALSE				
13	2U	19+680.510	20+624.763	944.25	0.5867		3.7	3.7	2.41	2.41	0	2.1	1	FALSE	0	FALSE	FALSE	FALSE				
14	2U	20+624.763	21+131.467	506.7	0.3148		3.7	3.7	2.41	2.41	0	2.1	1	FALSE	0	FALSE	FALSE	FALSE	1,746.40	3	FALSE	110
15	2U	21+131.467	23+193.290	2,061.82	1.2812		3.7	3.7	2.41	2.41	0.85	2.1	1	FALSE	0	FALSE	FALSE	FALSE				
16	2U	23+193.290	23+456.307	263.02	0.1634		3.7	3.7	2.41	2.41	0.6	2.1	1	FALSE	0	FALSE	FALSE	FALSE	26,195.68	1.6	TRUE	110
17	2U	23+456.307	23+821.652	365.34	0.227		3.7	3.7	2.41	2.41	0.13	2.1	1	FALSE	0	FALSE	FALSE	FALSE				
18	2U	23+821.652	24+070.953	249.3	0.1549		3.7	3.7	2.41	2.41	0.13	2.1	1	FALSE	0	FALSE	FALSE	FALSE	26,195.68	1.6	TRUE	110
19	2U	24+070.953	24+227.555	156.6	0.0973		3.7	3.7	2.41	2.41	0.13	2.1	1	FALSE	0	FALSE	FALSE	FALSE				
20	2U	24+227.555	24+641.616	414.06	0.2573		3.7	3.7	2.41	2.41	0.19	2.1	1	FALSE	0	FALSE	FALSE	FALSE	1,190.75	4.7	FALSE	110
21	2U	24+641.616	25+666.470	1,024.85	0.6368		3.7	3.7	2.41	2.41	0.22	2.1	1	FALSE	0	FALSE	FALSE	FALSE				
22	2U	25+666.470	26+078.843	412.37	0.2562		3.7	3.7	2.41	2.41	0.38	2.1	1	FALSE	0	FALSE	FALSE	FALSE	873.23	6.2	FALSE	110
23	2U	26+078.843	27+105.950	1,027.11	0.6382		3.7	3.7	2.41	2.41	1.19	2.1	1	FALSE	0	FALSE	FALSE	FALSE				
24	2U	27+105.950	27+290.000	184.05	0.1144		3.7	3.7	2.41	2.41	0.09	2.1	1	FALSE	0	FALSE	FALSE	FALSE	638	7.5	FALSE	110
25	2U	27+290.000	27+458.720	168.72	0.1048		3.7	3.7	3.9	3.9	0.09	2.1	3	FALSE	0	FALSE	FALSE	FALSE	638	7.5	FALSE	110
26	2U	27+458.720	28+009.643	550.92	0.3423	1996-1998: 680	3.7	3.7	3.9	3.9	0.09	2.1	3	FALSE	0	FALSE	FALSE	FALSE	638	7.5	FALSE	110
27	2U	28+009.643	28+502.441	492.8	0.3062		3.7	3.7	3.9	3.9	1.01	2.1	3	FALSE	0	FALSE	FALSE	FALSE				
28	2U	28+502.441	28+626.367	123.93	0.077		3.7	3.7	3.9	3.9	0	2.1	3	FALSE	0	FALSE	FALSE	FALSE	2,328.52	2.6	FALSE	110
29	2U	28+626.367	29+273.000	646.63	0.4018		3.7	3.7	3.9	3.9	0	2.1	3	FALSE	0	FALSE	FALSE	FALSE				
30	2U	29+273.000	30+837.092	1,564.09	0.9719		3.7	3.7	2.4	2.4	3.23	2.1	1	FALSE	0	FALSE	FALSE	FALSE				
31	2U	30+837.092	31+094.648	257.56	0.16		3.7	3.7	2.4	2.4	0.49	2.1	1	FALSE	0	FALSE	FALSE	FALSE	11,642.53	1.6	TRUE	110
32	2U	31+094.648	33+315.667	2,221.02	1.3801		3.7	3.7	2.4	2.4	0.49	2.1	1	FALSE	0	FALSE	FALSE	FALSE				

Section	Project Number	Route	Before/After
1	K-5393-01	K-383	After

Segment Number	Type	Start Location	End Location	Length (m)	Length (mi)	AADT	Left Lane Width (m)	Right Lane Width (m)	Left Shoulder Width (m)	Right Shoulder Width (m)	Grade (%)	Driveway Density (driveways/km)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (m)	Superelevation (%)	Adverse	Design Speed (km/h)
1	2U	11+403.500	11+449.321	45.82	0.0285	2002: 839; 2003: 876; 2004: 913; 2005: 950; 2006: 940;	3.7	3.7	2.41	2.41	1.95	5	1	FALSE	0	FALSE	FALSE	FALSE				
2	2U	11+449.321	11+804.160	354.84	0.2205		3.7	3.7	2.41	2.41	1.95	5	1	FALSE	0	FALSE	FALSE	FALSE	1,496.92	3.9	FALSE	110
3	2U	11+804.160	11+856.338	52.18	0.0324	2002: 839; 2003: 876; 2004: 913; 2005: 950; 2006: 940;	3.7	3.7	2.41	2.41	2.21	5	1	FALSE	0	FALSE	FALSE	FALSE	1,496.92	3.9	FALSE	110
4	2U	11+856.338	12+206.420	350.08	0.2175		3.7	3.7	2.41	2.41	2.21	5	1	FALSE	0	FALSE	FALSE	FALSE				
5	2U	12+206.420	12+492.891	286.47	0.178	2002: 925; 2003: 930; 2004: 935; 2005: 940; 2006: 930; 2007-2009: 870	3.7	3.7	2.41	2.41	2.1	5	1	FALSE	0	FALSE	FALSE	FALSE				
6	2U	12+492.891	12+983.420	490.53	0.3048		3.7	3.7	2.41	2.41	2.78	5	1	FALSE	0	FALSE	FALSE	FALSE	873.23	6.2	FALSE	110
7	2U	12+983.420	13+400.000	416.58	0.2588		3.7	3.7	2.41	2.41	0	5	1	FALSE	0	FALSE	FALSE	FALSE				
8	2U	13+400.000	15+222.037	1,822.04	1.1322		3.7	3.7	2.41	2.41	0.42	2.1	1	FALSE	0	FALSE	FALSE	FALSE				
9	2U	15+222.037	15+695.543	473.51	0.2942		3.7	3.7	2.41	2.41	1.19	2.1	1	FALSE	0	FALSE	FALSE	FALSE	2,328.52	2.6	FALSE	110
10	2U	15+695.543	18+031.709	2,336.17	1.4516		3.7	3.7	2.41	2.41	1.19	2.1	1	FALSE	0	FALSE	FALSE	FALSE				
11	2U	18+031.709	18+270.287	238.58	0.1482		3.7	3.7	2.41	2.41	0.57	2.1	1	FALSE	0	FALSE	FALSE	FALSE	1,746.40	3.5	FALSE	110
12	2U	18+270.287	19+680.510	1,410.22	0.8763		3.7	3.7	2.41	2.41	0.57	2.1	1	FALSE	0	FALSE	FALSE	FALSE				
13	2U	19+680.510	20+624.763	944.25	0.5867	2002: 949; 2003: 966; 2004: 983; 2005: 1,000; 2006: 930; 2007-2009: 945	3.7	3.7	2.41	2.41	0	2.1	1	FALSE	0	FALSE	FALSE	FALSE				
14	2U	20+624.763	21+131.467	506.7	0.3148		3.7	3.7	2.41	2.41	0	2.1	1	FALSE	0	FALSE	FALSE	FALSE	1,746.40	3.5	FALSE	110
15	2U	21+131.467	23+193.290	2,061.82	1.2812		3.7	3.7	2.41	2.41	0.85	2.1	1	FALSE	0	FALSE	FALSE	FALSE				
16	2U	23+193.290	23+456.307	263.02	0.1634		3.7	3.7	2.41	2.41	0.6	2.1	1	FALSE	0	FALSE	FALSE	FALSE	26,195.68	1.6	TRUE	110
17	2U	23+456.307	23+821.652	365.34	0.227		3.7	3.7	2.41	2.41	0.13	2.1	1	FALSE	0	FALSE	FALSE	FALSE				
18	2U	23+821.652	24+070.953	249.3	0.1549		3.7	3.7	2.41	2.41	0.13	2.1	1	FALSE	0	FALSE	FALSE	FALSE	26,195.68	1.6	TRUE	110
19	2U	24+070.953	24+227.555	156.6	0.0973		3.7	3.7	2.41	2.41	0.13	2.1	1	FALSE	0	FALSE	FALSE	FALSE				
20	2U	24+227.555	24+641.616	414.06	0.2573		3.7	3.7	2.41	2.41	0.19	2.1	1	FALSE	0	FALSE	FALSE	FALSE	1,190.75	4.7	FALSE	110
21	2U	24+641.616	25+666.470	1,024.85	0.6368		3.7	3.7	2.41	2.41	0.22	2.1	1	FALSE	0	FALSE	FALSE	FALSE				
22	2U	25+666.470	26+078.843	412.37	0.2562		3.7	3.7	2.41	2.41	0.38	2.1	1	FALSE	0	FALSE	FALSE	FALSE	873.23	6.2	FALSE	110
23	2U	26+078.843	27+105.950	1,027.11	0.6382		3.7	3.7	2.41	2.41	1.19	2.1	1	FALSE	0	FALSE	FALSE	FALSE				
24	2U	27+105.950	27+290.000	184.05	0.1144		3.7	3.7	2.41	2.41	0.09	2.1	1	FALSE	0	FALSE	FALSE	FALSE	638	7.5	FALSE	110
25	2U	27+290.000	27+458.720	168.72	0.1048		3.7	3.7	3.9	3.9	0.09	2.1	3	FALSE	0	FALSE	FALSE	FALSE	638	7.5	FALSE	110
26	2U	27+458.720	28+009.643	550.92	0.3423		3.7	3.7	3.9	3.9	0.09	2.1	3	FALSE	0	FALSE	FALSE	FALSE	638	7.5	FALSE	110
27	2U	28+009.643	28+502.441	492.8	0.3062		3.7	3.7	3.9	3.9	1.01	2.1	3	FALSE	0	FALSE	FALSE	FALSE				

28	2U	28+502.441	28+626.367	123.93	0.077	2002: 872; 2003: 968; 2004: 1,064; 2005: 1,160; 2006: 1,150; 2007-2009: 965	3.7	3.7	3.9	3.9	0	2.1	3	FALSE	0	FALSE	FALSE	FALSE	2,328.52	2.6	FALSE	110
29	2U	28+626.367	29+273.000	646.63	0.4018		3.7	3.7	3.9	3.9	0	2.1	3	FALSE	0	FALSE	FALSE	FALSE				
30	2U	29+273.000	30+837.092	1,564.09	0.9719		3.7	3.7	2.4	2.4	3.23	2.1	1	FALSE	0	FALSE	FALSE	FALSE				
31	2U	30+837.092	31+094.648	257.56	0.16		3.7	3.7	2.4	2.4	0.49	2.1	1	FALSE	0	FALSE	FALSE	FALSE	11,642.53	1.6	TRUE	110
32	2U	31+094.648	33+315.700	2,221.05	1.3801		3.7	3.7	2.4	2.4	0.49	2.1	1	FALSE	0	FALSE	FALSE	FALSE				

Section	Project Number	Route	Before/After
2	K-5384-01	US-50	Before

Segment Number	Type	Start Location	End Location	Length (m)	Length (mi)	AADT	Left Lane Width (m)	Right Lane Width (m)	Left Shoulder Width (m)	Right Shoulder Width (m)	Grade (%)	Driveway Density (driveways/km)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (m)	Superelevation (%)	Adverse	Design Speed (km/h)
1	2U	10+801.901	11+882.000	1,080.10	0.6711	1996-1998: 4,770	3.7	3.7	3	3	4	1.1	2	FALSE	0	FALSE	FALSE	FALSE				
2	2U	11+882.000	12+094.249	212.25	0.1319	1996-1998: 4,995	3.7	3.7	3	3	0.54	1.1	2	FALSE	0	FALSE	FALSE	FALSE				
3	2U	12+094.249	12+996.907	902.66	0.5609		3.7	3.7	3	3	0.54	1.1	2	FALSE	0	FALSE	FALSE	FALSE	1,746.38	3	FALSE	100
4	2U	12+996.907	14+023.324	1,026.42	0.6378		3.7	3.7	3	3	1.8	1.1	2	FALSE	0	FALSE	FALSE	FALSE				
5	2U	14+023.324	14+846.776	823.45	0.5117		3.7	3.7	3	3	3.49	1.1	2	FALSE	0	FALSE	FALSE	FALSE	1,746.38	2.7	FALSE	100
6	2U	14+846.776	16+651.791	1,805.02	1.1216		3.7	3.7	3	3	0.54	1.1	2	FALSE	0	FALSE	FALSE	FALSE				
7	2U	16+651.791	16+861.781	209.99	0.1305		3.7	3.7	3	3	3.79	1.1	2	FALSE	0	FALSE	FALSE	FALSE	4,762.85	1.6	TRUE	100
8	2U	16+861.781	18+590.063	1,728.28	1.0739		3.7	3.7	3	3	1	1.1	2	FALSE	0	FALSE	FALSE	FALSE				
9	2U	18+590.063	18+905.870	315.81	0.1962		3.7	3.7	3	3	1.58	1.1	2	FALSE	0	FALSE	FALSE	FALSE	34,927.58	1.6	TRUE	100
10	2U	18+905.870	20+820.818	1,914.95	1.1899		3.7	3.7	3	3	1.66	1.1	2	FALSE	0	FALSE	FALSE	FALSE				
11	2U	20+820.818	21+139.194	318.38	0.1978		3.7	3.7	3	3	1.14	1.1	2	FALSE	0	FALSE	FALSE	FALSE	5,821.26	1.6	TRUE	100
12	2U	21+139.194	22+871.123	1,731.93	1.0762		3.7	3.7	3	3	1.11	1.1	2	FALSE	0	FALSE	FALSE	FALSE				
13	2U	22+871.123	23+044.244	173.12	0.1076		3.7	3.7	3	3	0	1.1	2	FALSE	0	FALSE	FALSE	FALSE	1,493.17	3	FALSE	100

Section	Project Number	Route	Before/After
2	K-5384-01	US-50	After

Segment Number	Type	Start Location	End Location	Length (m)	Length (mi)	AADT	Left Lane Width (m)	Right Lane Width (m)	Left Shoulder Width (m)	Right Shoulder Width (m)	Grade (%)	Driveway Density (driveways/km)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (m)	Superelevation (%)	Adverse	Design Speed (km/h)
1	2U	10+801.901	11+882.000	1,080.10	0.6711	2001: 4,810; 2002: 4,850; 2003: 4,890; 2004: 4,930; 2005-2006: 4,970; 2007-2009: 4,880	3.7	3.7	3	3	4	1.1	1	TRUE	0	FALSE	FALSE	FALSE				
2	2U	11+882.000	12+094.249	212.25	0.1319	2001: 5,122; 2002: 5,249; 2003: 5,376; 2004: 5,503; 2005: 5,630; 2006: 5,560; 2007-2009: 5,550	3.7	3.7	3	3	0.54	1.1	1	TRUE	0	FALSE	FALSE	FALSE				
3	2U	12+094.249	12+996.907	902.66	0.5609		3.7	3.7	3	3	0.54	1.1	1	TRUE	0	FALSE	FALSE	FALSE	1,746.38	3	FALSE	100
4	2U	12+996.907	14+023.324	1,026.42	0.6378		3.7	3.7	3	3	1.8	1.1	1	TRUE	0	FALSE	FALSE	FALSE				
5	2U	14+023.324	14+846.776	823.45	0.5117		3.7	3.7	3	3	3.49	1.1	1	TRUE	0	FALSE	FALSE	FALSE	1,746.38	3	FALSE	100
6	2U	14+846.776	16+651.791	1,805.02	1.1216		3.7	3.7	3	3	0.54	1.1	1	TRUE	0	FALSE	FALSE	FALSE				
7	2U	16+651.791	16+861.781	209.99	0.1305		3.7	3.7	3	3	3.79	1.1	1	TRUE	0	FALSE	FALSE	FALSE	4,762.85	1.6	TRUE	100
8	2U	16+861.781	18+590.063	1,728.28	1.0739		3.7	3.7	3	3	1	1.1	1	TRUE	0	FALSE	FALSE	FALSE				
9	2U	18+590.063	18+905.870	315.81	0.1962		3.7	3.7	3	3	1.58	1.1	1	TRUE	0	FALSE	FALSE	FALSE	34,927.58	1.6	TRUE	100
10	2U	18+905.870	20+820.818	1,914.95	1.1899		3.7	3.7	3	3	1.66	1.1	1	TRUE	0	FALSE	FALSE	FALSE				
11	2U	20+820.818	21+139.194	318.38	0.1978		3.7	3.7	3	3	1.14	1.1	1	TRUE	0	FALSE	FALSE	FALSE	5,821.26	1.6	TRUE	100
12	2U	21+139.194	22+871.123	1,731.93	1.0762		3.7	3.7	3	3	1.11	1.1	1	TRUE	0	FALSE	FALSE	FALSE				
13	2U	22+871.123	23+044.277	173.15	0.1076		3.7	3.7	3	3	0	1.1	1	TRUE	0	FALSE	FALSE	FALSE	1,493.17	3.4	FALSE	100

Section	Project Number	Route	Before/After
3	K-5745-01	US-56	After

Segment Number	Type	Start Location	End Location	Length (m)	Length (mi)	AADT	Left Lane Width (m)	Right Lane Width (m)	Left Shoulder Width (m)	Right Shoulder Width (m)	Grade (%)	Driveway Density (driveways/km)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (m)	Superelevation (%)	Adverse	Design Speed (km/h)
1	2U	11+386.368	11+484.356	97.99	0.0609	2004: 1,768; 2005: 1,740; 2006: 1,720; 2007-2009: 1,730	3.7	3.7	3	3	1.14	1.1	1	FALSE	0	FALSE	FALSE	FALSE				
2	2U	11+484.356	11+799.558	315.2	0.1959		3.7	3.7	3	3	1.14	1.1	1	FALSE	0	FALSE	FALSE	FALSE	5,000.00	1.6	TRUE	110
3	2U	11+799.558	11+963.225	163.67	0.1017		3.7	3.7	3	3	0.74	1.1	1	FALSE	0	FALSE	FALSE	FALSE				
4	2U	11+963.225	12+437.616	474.39	0.2948		3.7	3.7	3	3	0.74	1.1	1	FALSE	0	FALSE	FALSE	FALSE	5,000.00	1.6	TRUE	110
5	2U	12+437.616	13+181.098	743.48	0.462		3.7	3.7	3	3	0	1.1	1	FALSE	0	FALSE	FALSE	FALSE				
6	2U	13+181.098	13+623.078	441.98	0.2746		3.7	3.7	3	3	0.31	1.1	1	FALSE	0	FALSE	FALSE	FALSE	5,000.00	1.6	TRUE	110
7	2U	13+623.078	14+326.378	703.3	0.437		3.7	3.7	3	3	0.22	1.1	1	FALSE	0	FALSE	FALSE	FALSE				
8	2U	14+326.378	14+684.510	358.13	0.2225		3.7	3.7	3	3	0.9	1.1	1	FALSE	0	FALSE	FALSE	FALSE	5,000.00	1.6	TRUE	110
9	2U	14+684.510	16+068.361	1,383.85	0.8599		3.7	3.7	3	3	0.29	1.1	1	FALSE	0	FALSE	FALSE	FALSE				
10	2U	16+068.361	16+349.189	280.83	0.1745		3.7	3.7	3	3	0.53	1.1	1	FALSE	0	FALSE	FALSE	FALSE	5,000.00	1.6	TRUE	110
11	2U	16+349.189	17+263.547	914.36	0.5682		3.7	3.7	3	3	0.39	1.1	1	FALSE	0	FALSE	FALSE	FALSE				
12	2U	17+263.547	17+747.847	484.3	0.3009		3.7	3.7	3	3	0.26	1.1	1	FALSE	0	FALSE	FALSE	FALSE	1,200.00	4.7	FALSE	110
13	2U	17+747.847	19+136.950	1,389.10	0.8632		3.7	3.7	3	3	0.26	1.1	1	FALSE	0	FALSE	FALSE	FALSE				
14	2U	19+136.950	19+388.665	251.72	0.1564	2004: 1,827; 2005: 1,830; 2006: 1,810; 2007-2009: 1,610	3.7	3.7	3	3	0	1.1	1	FALSE	0	FALSE	FALSE	FALSE				
15	2U	19+388.665	19+864.546	475.88	0.2957		3.7	3.7	3	3	0	1.1	1	FALSE	0	FALSE	FALSE	FALSE	1,200.00	4.7	FALSE	110
16	2U	19+864.546	22+399.521	2,534.98	1.5752		3.7	3.7	3	3	1	1.1	1	FALSE	0	FALSE	FALSE	FALSE				
17	2U	22+399.521	22+841.594	442.07	0.2747	2004: 2,152; 2005: 2,160; 2006: 2,130; 2007-2009: 2,770	3.7	3.7	3	3	0.82	1.1	1	FALSE	0	FALSE	FALSE	FALSE				
18	2U	22+841.594	23+055.203	213.61	0.1327		3.7	3.7	3	3	0.82	1.1	1	FALSE	0	FALSE	FALSE	FALSE	5,000.00	1.6	TRUE	110
19	2U	23+055.203	23+983.407	928.2	0.5768		3.7	3.7	3	3	0.82	1.1	1	FALSE	0	FALSE	FALSE	FALSE				

Section	Project Number	Route	Before/After
4	K-5767-01	US-77	Before

Segment Number	Type	Start Location	End Location	Length (m)	Length (mi)	AADT	Left Lane Width (m)	Right Lane Width (m)	Left Shoulder Width (m)	Right Shoulder Width (m)	Grade (%)	Driveway Density (driveways/km)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (m)	Superelevation (%)	Adverse	Design Speed (km/h)
1	2U	10+380.488	10+382.000	1.51	0.0009	2000: 2,430; 2001: 2,370; 2002: 2,310	3.7	3.7	3	3	0.36	1.3	2	FALSE	0	FALSE	FALSE	FALSE				
2	2U	10+382.000	10+771.427	389.43	0.242		3.7	3.7	3	3	0.36	1.3	2	FALSE	0	FALSE	FALSE	FALSE	4,250.00	1.6	TRUE	110
3	2U	10+771.427	10+834.801	63.37	0.0394		3.7	3.7	3	3	1.09	1.3	2	FALSE	0	FALSE	FALSE	FALSE				
4	2U	10+834.801	11+184.935	350.13	0.2176		3.7	3.7	3	3	1.09	1.3	2	FALSE	0	FALSE	FALSE	FALSE	4,250.00	1.6	TRUE	110
5	2U	11+184.935	11+694.231	509.3	0.3165		3.7	3.7	3	3	1.09	1.3	2	FALSE	0	FALSE	FALSE	FALSE				
6	2U	11+694.231	11+998.204	303.97	0.1889		3.7	3.7	3	3	2.85	1.3	2	FALSE	0	FALSE	FALSE	FALSE	2,910.00	2.1	FALSE	110
7	2U	11+998.204	12+009.094	10.89	0.0068		3.7	3.7	3	3	2.85	1.3	2	FALSE	0	FALSE	FALSE	FALSE				
8	2U	12+009.094	12+134.440	125.35	0.0779	2000: 2,410; 2001: 2,368; 2002: 2,326	3.7	3.7	3	3	2.85	1.3	2	FALSE	0	FALSE	FALSE	FALSE				
9	2U	12+134.440	12+631.360	496.92	0.3088		3.7	3.7	3	3	0.3	1.3	2	FALSE	0	FALSE	FALSE	FALSE	2,380.00	2.5	FALSE	110
10	2U	12+631.360	12+770.223	138.86	0.0863		3.7	3.7	3	3	0.3	1.3	2	FALSE	0	FALSE	FALSE	FALSE				
11	2U	12+770.223	13+073.448	303.22	0.1884		3.7	3.7	3	3	2.43	1.3	2	FALSE	0	FALSE	FALSE	FALSE	2,910.00	2.1	FALSE	110
12	2U	13+073.448	13+886.100	812.65	0.505		3.7	3.7	3	3	1.04	1.3	2	FALSE	0	FALSE	FALSE	FALSE				
13	2U	13+886.100	14+453.396	567.3	0.3525		3.7	3.7	3	3	0.07	1.3	2	FALSE	0	FALSE	FALSE	FALSE	1,750.00	3.5	FALSE	110
14	2U	14+453.396	15+311.468	858.07	0.5332		3.7	3.7	3	3	0.07	1.3	2	FALSE	0	FALSE	FALSE	FALSE				
15	2U	15+311.468	17+723.997	2,412.53	1.4991	2000: 2,975; 2001: 2,986; 2002: 2,997	3.7	3.7	3	3	0.2	1.3	2	FALSE	0	FALSE	FALSE	FALSE				
16	2U	17+723.997	18+028.854	304.86	0.1894		3.7	3.7	3	3	0.64	1.3	2	FALSE	0	FALSE	FALSE	FALSE	1,745.00	3.5	FALSE	110
17	2U	18+028.854	19+830.341	1,801.49	1.1194		3.7	3.7	3	3	0.6	1.3	2	FALSE	0	FALSE	FALSE	FALSE				
18	2U	19+830.341	20+711.374	881.03	0.5474		3.7	3.7	3	3	1.78	1.3	2	FALSE	0	FALSE	FALSE	FALSE	1,745.00	3.5	FALSE	110
19	2U	20+711.374	22+180.148	1,468.77	0.9126		3.7	3.7	3	3	0.82	1.3	2	FALSE	0	FALSE	FALSE	FALSE				
20	2U	22+180.148	29+890.849	7,710.70	4.7912	2000: 3,485; 2001: 3,494; 2002: 3,503	3.7	3.7	3	3	0.82	1.3	2	FALSE	0	FALSE	FALSE	FALSE				
21	2U	29+890.849	30+136.585	245.74	0.1527		3.7	3.7	3	3	1.35	1.3	2	FALSE	0	FALSE	FALSE	FALSE	19,495.00	1.6	TRUE	110
22	2U	30+136.585	30+239.743	103.16	0.0641		3.7	3.7	3	3	2.26	1.3	2	FALSE	0	FALSE	FALSE	FALSE				
23	2U	30+239.743	30+839.406	599.66	0.3726	2000: 4,215; 2001: 4,248; 2002: 4,281	3.7	3.7	3	3	2.26	1.3	2	FALSE	0	FALSE	FALSE	FALSE				

Section	Project Number	Route	Before/After
4	K-5767-01	US-77	After

Segment Number	Type	Start Location	End Location	Length (m)	Length (mi)	AADT	Left Lane Width (m)	Right Lane Width (m)	Left Shoulder Width (m)	Right Shoulder Width (m)	Grade (%)	Driveway Density (driveways/km)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (m)	Superelevation (%)	Adverse	Design Speed (km/h)
1	2U	10+380.488	10+382.000	1.51	0.0009	2006: 2,090; 2007-2009: 2,080	3.7	3.7	3	3	0.36	1.3	1	FALSE	0	FALSE	FALSE	FALSE				
2	2U	10+382.000	10+771.427	389.43	0.242		3.7	3.7	3	3	0.36	1.3	1	FALSE	0	FALSE	FALSE	FALSE	4,250.00	1.6	TRUE	110
3	2U	10+771.427	10+834.801	63.37	0.0394		3.7	3.7	3	3	1.09	1.3	1	FALSE	0	FALSE	FALSE	FALSE				
4	2U	10+834.801	11+184.935	350.13	0.2176		3.7	3.7	3	3	1.09	1.3	1	FALSE	0	FALSE	FALSE	FALSE	4,250.00	1.6	TRUE	110
5	2U	11+184.935	11+694.231	509.3	0.3165		3.7	3.7	3	3	1.09	1.3	1	FALSE	0	FALSE	FALSE	FALSE				
6	2U	11+694.231	11+998.204	303.97	0.1889		3.7	3.7	3	3	2.85	1.3	1	FALSE	0	FALSE	FALSE	FALSE	2,910.00	2.1	FALSE	110
7	2U	11+998.204	12+009.094	10.89	0.0068		3.7	3.7	3	3	2.85	1.3	1	FALSE	0	FALSE	FALSE	FALSE				
8	2U	12+009.094	12+134.440	125.35	0.0779	2006: 2,430; 2007-2009: 2,420	3.7	3.7	3	3	2.85	1.3	1	FALSE	0	FALSE	FALSE	FALSE				
9	2U	12+134.440	12+631.360	496.92	0.3088		3.7	3.7	3	3	0.3	1.3	1	FALSE	0	FALSE	FALSE	FALSE	2,380.00	2.5	FALSE	110
10	2U	12+631.360	12+770.223	138.86	0.0863		3.7	3.7	3	3	0.3	1.3	1	FALSE	0	FALSE	FALSE	FALSE				
11	2U	12+770.223	13+073.448	303.22	0.1884		3.7	3.7	3	3	2.43	1.3	1	FALSE	0	FALSE	FALSE	FALSE	2,910.00	2.1	FALSE	110
12	2U	13+073.448	13+886.100	812.65	0.505		3.7	3.7	3	3	1.04	1.3	1	FALSE	0	FALSE	FALSE	FALSE				
13	2U	13+886.100	14+453.396	567.3	0.3525		3.7	3.7	3	3	0.07	1.3	1	FALSE	0	FALSE	FALSE	FALSE	1,750.00	3.5	FALSE	110
14	2U	14+453.396	15+311.468	858.07	0.5332		3.7	3.7	3	3	0.07	1.3	1	FALSE	0	FALSE	FALSE	FALSE				
15	2U	15+311.468	17+723.997	2,412.53	1.4991	2006: 2,830; 2007-2009: 2,810	3.7	3.7	3	3	0.2	1.3	1	FALSE	0	FALSE	FALSE	FALSE				
16	2U	17+723.997	18+028.854	304.86	0.1894		3.7	3.7	3	3	0.64	1.3	1	FALSE	0	FALSE	FALSE	FALSE	1,745.00	3.5	FALSE	110
17	2U	18+028.854	19+830.341	1,801.49	1.1194		3.7	3.7	3	3	0.6	1.3	1	FALSE	0	FALSE	FALSE	FALSE				
18	2U	19+830.341	20+711.374	881.03	0.5474		3.7	3.7	3	3	1.78	1.3	1	FALSE	0	FALSE	FALSE	FALSE	1,745.00	3.5	FALSE	110
19	2U	20+711.374	22+180.148	1,468.77	0.9126		3.7	3.7	3	3	0.82	1.3	1	FALSE	0	FALSE	FALSE	FALSE				
20	2U	22+180.148	29+890.849	7,710.70	4.7912	2006: 3,260; 2007-2009: 3,240	3.7	3.7	3	3	0.82	1.3	1	FALSE	0	FALSE	FALSE	FALSE				
21	2U	29+890.849	30+136.585	245.74	0.1527		3.7	3.7	3	3	1.35	1.3	1	FALSE	0	FALSE	FALSE	FALSE	19,495.00	1.6	TRUE	110
22	2U	30+136.585	30+239.743	103.16	0.0641		3.7	3.7	3	3	2.26	1.3	1	FALSE	0	FALSE	FALSE	FALSE				
23	2U	30+239.743	30+839.439	599.7	0.3726	2006: 3,960; 2007-2009: 3,940	3.7	3.7	3	3	2.26	1.3	1	FALSE	0	FALSE	FALSE	FALSE				

Section	Project Number	Route	Before/After
5	K-5391-01	US-283	Before

Segment Number	Type	Start Location	End Location	Length (m)	Length (mi)	AADT	Left Lane Width (m)	Right Lane Width (m)	Left Shoulder Width (m)	Right Shoulder Width (m)	Grade (%)	Driveway Density (driveways/km)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (m)	Superelevation (%)	Adverse	Design Speed (km/h)
1	2U	10+660.404	10+668.323	7.92	0.0049	1996-1998: 1,515	3.7	3.7	0	0	1.66	1.2	3	FALSE	0	FALSE	FALSE	FALSE				
2	2U	10+668.323	11+260.008	591.68	0.3677		3.7	3.7	0	0	1.66	1.2	3	FALSE	0	FALSE	FALSE	FALSE	873.19	5.5	FALSE	100
3	2U	11+260.008	11+485.556	225.55	0.1402		3.7	3.7	0	0	0	1.2	3	FALSE	0	FALSE	FALSE	FALSE				
4	2U	11+485.556	12+073.474	587.92	0.3653		3.7	3.7	0	0	0.49	1.2	3	FALSE	0	FALSE	FALSE	FALSE	873.19	5.5	FALSE	100
5	2U	12+073.474	25+406.823	#######	8.285		3.7	3.7	0	0	0.46	1.2	3	FALSE	0	FALSE	FALSE	FALSE				
6	2U	25+406.823	26+667.471	1,260.65	0.7833		3.7	3.7	0	0	0.67	1.2	3	FALSE	0	FALSE	FALSE	FALSE				

Segment Number	Type	Start Location	End Location	Length (m)	Length (mi)	AADT	Left Lane Width (m)	Right Lane Width (m)	Left Shoulder Width (m)	Right Shoulder Width (m)	Grade (%)	Driveway Density (driveways/km)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (m)	Superelevation (%)	Adverse	Design Speed (km/h)
7	2U	26+667.471	26+922.021	254.55	0.1582	1996-1998: 1,120	3.7	3.7	0	0	0.54	1.2	3	FALSE	0	FALSE	FALSE	FALSE	8,731.04	1.6	TRUE	100
8	2U	26+922.021	30+072.311	3,150.29	1.9575		3.7	3.7	0	0	0.54	1.2	3	FALSE	0	FALSE	FALSE	FALSE				
9	2U	30+072.311	36+824.467	6,752.16	4.1956	1996-1998: 945	3.7	3.7	0	0	0.23	1.2	3	FALSE	0	FALSE	FALSE	FALSE				

Section	Project Number	Route	Before/After
5	K-5391-01	US-283	After

Segment Number	Type	Start Location	End Location	Length (m)	Length (mi)	AADT	Left Lane Width (m)	Right Lane Width (m)	Left Shoulder Width (m)	Right Shoulder Width (m)	Grade (%)	Driveway Density (driveways/km)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (m)	Superelevation (%)	Adverse	Design Speed (km/h)
1	2U	10+660.404	10+668.323	7.92	0.0049	2000: 1,515; 2001: 1,442; 2002: 1,369; 2003: 1,296; 2004: 1,223; 2005: 1,150; 2006: 1,290; 2007-2009: 1,280	3.7	3.7	1.8	1.8	1.66	1.2	1	FALSE	0	FALSE	FALSE	FALSE				
2	2U	10+668.323	11+260.008	591.68	0.3677		3.7	3.7	1.8	1.8	1.66	1.2	1	FALSE	0	FALSE	FALSE	FALSE	873.19	6	FALSE	100
3	2U	11+260.008	11+485.556	225.55	0.1402		3.7	3.7	1.8	1.8	0	1.2	1	FALSE	0	FALSE	FALSE	FALSE				
4	2U	11+485.556	12+073.474	587.92	0.3653		3.7	3.7	1.8	1.8	0.49	1.2	1	FALSE	0	FALSE	FALSE	FALSE	873.19	6	FALSE	100
5	2U	12+073.474	25+406.823	#######	8.285		3.7	3.7	1.8	1.8	0.46	1.2	1	FALSE	0	FALSE	FALSE	FALSE				
6	2U	25+406.823	26+667.471	1,260.65	0.7833	2000: 1,120; 2001: 1,096; 2002: 1,072; 2003: 1,048; 2004: 1,024; 2005: 1,000; 2006: 1,110; 2007-2009: 1,100	3.7	3.7	1.8	1.8	0.67	1.2	1	FALSE	0	FALSE	FALSE	FALSE				
7	2U	26+667.471	26+922.021	254.55	0.1582		3.7	3.7	1.8	1.8	0.54	1.2	1	FALSE	0	FALSE	FALSE	FALSE	8,731.04	1.6	TRUE	100
8	2U	26+922.021	30+072.311	3,150.29	1.9575		3.7	3.7	1.8	1.8	0.54	1.2	1	FALSE	0	FALSE	FALSE	FALSE				
9	2U	30+072.311	36+824.500	6,752.19	4.1956	2000: 945; 2001: 922; 2002: 899; 2003: 876; 2004: 853; 2005: 830; 2006: 875; 2007-2009: 870	3.7	3.7	1.8	1.8	0.23	1.2	1	FALSE	0	FALSE	FALSE	FALSE				

Section	Project Number	Route	Before/After
6	K-5761-01	US-73	After

Segment Number	Type	Start Location	End Location	Length (m)	Length (mi)	AADT	Left Lane Width (m)	Right Lane Width (m)	Left Shoulder Width (m)	Right Shoulder Width (m)	Grade (%)	Driveway Density (driveways/km)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (m)	Superelevation (%)	Adverse	Design Speed (km/h)
1	2U	13+824.887	14+240.207	415.32	0.2581	2005: 2,770; 2006: 3,060; 2007-2009: 2,920	3	3	3	3	0.45	1	1	FALSE	0	FALSE	FALSE	FALSE	900	6	FALSE	110
2	2U	14+240.207	14+852.040	611.83	0.3802		3	3	3	3	0.45	1	1	FALSE	0	FALSE	FALSE	FALSE				
3	2U	14+852.040	14+886.660	34.62	0.0215	2005: 3,100; 2006: 3,060; 2007-2009: 3,020	3	3	3	3	0.76	1	1	FALSE	0	FALSE	FALSE	FALSE				
4	2U	14+886.660	15+445.828	559.17	0.3474		3	3	3	3	0.76	1	1	FALSE	0	FALSE	FALSE	FALSE	1,200.00	4.7	FALSE	110
5	2U	15+445.828	16+247.000	801.17	0.4978		3	3	3	3	1.04	1	1	FALSE	0	FALSE	FALSE	FALSE				
6	2U	16+247.000	17+143.995	897	0.5574		3	3	3	3	1.04	1	1	FALSE	0	FALSE	FALSE	FALSE	900	6	FALSE	110
7	2U	17+143.995	17+735.267	591.27	0.3674		3	3	3	3	0.98	1	1	FALSE	0	FALSE	FALSE	FALSE				
8	2U	17+735.267	17+850.750	115.48	0.0718		3	3	3	3	0.98	1	1	FALSE	0	FALSE	FALSE	FALSE	900	6	FALSE	110
9	2U	17+850.750	18+006.283	155.53	0.0966		3	3	3	3	0.98	1	1	FALSE	0	FALSE	FALSE	FALSE				
10	2U	18+006.283	18+239.787	233.5	0.1451		3	3	3	3	0.98	1	1	FALSE	0	FALSE	FALSE	FALSE	900	6	FALSE	110
11	2U	18+239.787	19+345.440	1,105.65	0.687		3	3	3	3	2.38	1	1	FALSE	0	FALSE	FALSE	FALSE				
12	2U	19+345.440	19+725.452	380.01	0.2361	2005: 2,780; 2006: 2,740; 2007-2009: 2,990	3	3	3	3	1.39	1	1	FALSE	0	FALSE	FALSE	FALSE				
13	2U	19+725.452	19+755.136	29.68	0.0184		3	3	3	3	3.47	1	1	FALSE	0	FALSE	FALSE	FALSE	5,000.00	1.6	TRUE	110
14	2U	19+755.136	20+073.608	318.47	0.1979		3	3	3	3	3.47	1	1	FALSE	0	FALSE	FALSE	FALSE				
15	2U	20+073.608	20+490.131	416.52	0.2588		3	3	3	3	3.47	1	1	FALSE	0	FALSE	FALSE	FALSE	772.35	6.7	FALSE	110

Section	Project Number	Route	Before/After
7	K-5757-01	K-47	Before

Segment Number	Type	Start Location	End Location	Length (m)	Length (mi)	AADT	Left Lane Width (m)	Right Lane Width (m)	Left Shoulder Width (m)	Right Shoulder Width (m)	Grade (%)	Driveway Density (driveways/km)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (m)	Superelevation (%)	Adverse	Design Speed (km/h)
1	2U	10+300.000	10+486.574	186.57	0.1159	1997-1999: 1,240	3.7	3.7	1.2	1.2	0.25	1.6	3	FALSE	0	FALSE	FALSE	FALSE				
2	2U	10+486.574	10+849.392	362.82	0.2254		3.7	3.7	1.2	1.2	2.12	1.6	3	FALSE	0	FALSE	FALSE	FALSE	1,750.00	2	FALSE	110
3	2U	10+849.392	11+125.017	275.62	0.1713		3.7	3.7	1.2	1.2	1.45	1.6	3	FALSE	0	FALSE	FALSE	FALSE				
4	2U	11+125.017	11+550.000	424.98	0.2641		3.7	3.7	1.2	1.2	1	1.6	3	FALSE	0	FALSE	FALSE	FALSE	1,395.00	3.8	FALSE	110
5	2U	11+550.000	11+672.217	122.22	0.0759		3.7	3.7	1.2	1.2	1	1.6	4	FALSE	0	FALSE	FALSE	FALSE	1,395.00	3.8	FALSE	110
6	2U	11+672.217	11+867.330	195.11	0.1212		3.7	3.7	1.2	1.2	1	1.6	4	FALSE	0	FALSE	FALSE	FALSE				
7	2U	11+867.330	11+886.060	18.73	0.0116		3.7	3.7	1.2	1.2	6.5	1.6	4	FALSE	0	FALSE	FALSE	FALSE				
8	2U	11+886.060	12+100.000	213.94	0.1329	1997-1999: 1,190	3.7	3.7	1.2	1.2	6.5	1.6	4	FALSE	0	FALSE	FALSE	FALSE				
9	2U	12+100.000	12+242.948	142.95	0.0888		3.7	3.7	1.2	1.2	6.5	1.6	3	FALSE	0	FALSE	FALSE	FALSE				
10	2U	12+242.948	12+576.060	333.11	0.207		3.7	3.7	1.2	1.2	6.5	1.6	3	FALSE	0	FALSE	FALSE	FALSE	3,492.74	1.6	TRUE	110
11	2U	12+576.060	12+806.640	230.58	0.1433	1997-1999: 2,495	3.7	3.7	1.2	1.2	0	1.6	3	FALSE	0	FALSE	FALSE	FALSE	3,492.74	1.6	TRUE	110
12	2U	12+806.640	13+800.008	993.37	0.6172		3.7	3.7	1.2	1.2	1.35	1.6	3	FALSE	0	FALSE	FALSE	FALSE				

Section	Project Number	Route	Before/After
7	K-5757-01	K-47	After

Segment Number	Type	Start Location	End Location	Length (m)	Length (mi)	AADT	Left Lane Width (m)	Right Lane Width (m)	Left Shoulder Width (m)	Right Shoulder Width (m)	Grade (%)	Driveway Density (driveways/km)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (m)	Superelevation (%)	Adverse	Design Speed (km/h)
1	2U	10+300.000	10+486.574	186.57	0.1159	2002: 1,304; 2003: 1,336; 2004: 1,368; 2005: 1,400; 2006: 1,360; 2007-2009: 1,350	3.7	3.7	3	3	0.25	1.6	1	FALSE	0	FALSE	FALSE	FALSE				
2	2U	10+486.574	10+849.392	362.82	0.2254		3.7	3.7	3	3	2.12	1.6	1	FALSE	0	FALSE	FALSE	FALSE	1,750.00	3.5	FALSE	110
3	2U	10+849.392	11+125.017	275.62	0.1713		3.7	3.7	3	3	1.45	1.6	1	FALSE	0	FALSE	FALSE	FALSE				
4	2U	11+125.017	11+240.000	114.98	0.0714		3.7	3.7	3	3	1	1.6	1	FALSE	0	FALSE	FALSE	FALSE	1,395.00	4.2	FALSE	110
5	2U	11+240.000	11+500.000	260	0.1616		3.7	3.7	3	3	1	1.6	1	FALSE	0	FALSE	FALSE	FALSE	1,395.00	4.2	FALSE	110
6	2U	11+500.000	11+672.217	172.22	0.107		3.7	3.7	3	3	1	1.6	1	FALSE	1	FALSE	FALSE	FALSE	1,395.00	4.2	FALSE	110
7	2U	11+672.217	11+867.330	195.11	0.1212		3.7	3.7	3	3	1	1.6	1	FALSE	1	FALSE	FALSE	FALSE				

8	2U	11+867.330	11+886.060	18.73	0.0116	2002: 1,318; 2003: 1,382; 2004: 1,446; 2005: 1,510; 2006: 1,330; 2007-2009: 1,370	3.7	3.7	3	3	5.15	1.6	1	FALSE	1	FALSE	FALSE	FALSE				
9	2U	11+886.060	12+010.000	123.94	0.077		3.7	3.7	3	3	5.15	1.6	1	FALSE	1	FALSE	FALSE	FALSE				
10	2U	12+010.000	12+090.000	80	0.0497		3.7	3.7	3	3	5.15	1.6	1	FALSE	0	FALSE	FALSE	FALSE				
11	2U	12+090.000	12+265.482	175.48	0.109		3.7	3.7	3	3	5.15	1.6	1	FALSE	0	FALSE	FALSE	FALSE				
12	2U	12+265.482	12+576.060	310.58	0.193		3.7	3.7	3	3	5.15	1.6	1	FALSE	0	FALSE	FALSE	FALSE	3,715.00	1.6	TRUE	110
13	2U	12+576.060	12+865.046	288.99	0.1796	2002: 2,101; 2003: 1,904; 2004: 1,707; 2005: 1,510; 2006: 1,330; 2007-2009: 1,320	3.7	3.7	3	3	0	1.6	1	FALSE	0	FALSE	FALSE	FALSE	3,715.00	1.6	TRUE	110
14	2U	12+865.046	13+300.608	435.56	0.2706		3.7	3.7	3	3	1.35	1.6	1	FALSE	0	FALSE	FALSE	FALSE				
15	2U	13+300.608	13+500.570	199.96	0.1242		3.7	3.7	3	3	0	1.6	1	FALSE	0	FALSE	FALSE	FALSE	14,610.00	1.6	TRUE	110
16	2U	13+500.570	13+700.669	200.1	0.1243		3.7	3.7	3	3	1.38	1.6	1	FALSE	0	FALSE	FALSE	FALSE	14,620.00	1.6	TRUE	110
17	2U	13+700.669	13+800.000	99.33	0.0617		3.7	3.7	3	3	0.08	1.6	1	FALSE	0	FALSE	FALSE	FALSE				

Section	Project Number	Route	Before/After
8	K-5741-01	US-36	After

Segment Number	Type	Start Location	End Location	Length (m)	Length (mi)	AADT	Left Lane Width (m)	Right Lane Width (m)	Left Shoulder Width (m)	Right Shoulder Width (m)	Grade (%)	Driveway Density (driveways/km)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (m)	Superelev ation (%)	Adverse	Design Speed (km/h)
1	2U	10+534.985	11+065.369	530.38	0.3296	2003: 1,158; 2004: 1,079; 2005: 1,000; 2006: 990; 2007-2009: 1,060	3.7	3.7	2.4	2.4	1.15	1	1	FALSE	0	FALSE	FALSE	FALSE				
2	2U	11+065.369	11+936.034	870.66	0.541		3.7	3.7	2.4	2.4	4	1	1	FALSE	0	FALSE	FALSE	FALSE	5,000.00	1.6	TRUE	110
3	2U	11+936.034	12+431.625	495.59	0.308		3.7	3.7	2.4	2.4	4	1	1	FALSE	0	FALSE	FALSE	FALSE				
4	2U	12+431.625	12+995.609	563.98	0.3504		3.7	3.7	2.4	2.4	0.7	1	1	FALSE	0	FALSE	FALSE	FALSE	5,000.00	1.6	TRUE	110
5	2U	12+995.609	15+779.800	2,784.19	1.73		3.7	3.7	2.4	2.4	0.7	1	1	FALSE	0	FALSE	FALSE	FALSE				
6	2U	15+779.800	16+157.121	377.32	0.2345		3.7	3.7	2.4	2.4	1.3	1	1	FALSE	0	FALSE	FALSE	FALSE	900	6	FALSE	110
7	2U	16+157.121	17+274.918	1,117.80	0.6946		3.7	3.7	2.4	2.4	1.3	1	1	FALSE	0	FALSE	FALSE	FALSE				
8	2U	17+274.918	19+610.179	2,335.26	1.4511	2003: 1,016; 2004: 963; 2005: 910; 2006: 900; 2007-2009: 760	3.7	3.7	2.4	2.4	2.35	1	1	FALSE	0	FALSE	FALSE	FALSE				
9	2U	19+610.179	20+220.874	610.7	0.3795		3.7	3.7	2.4	2.4	1.75	1	1	FALSE	0	FALSE	FALSE	FALSE	1,400.00	4.1	FALSE	110
10	2U	20+220.874	20+746.307	525.43	0.3265		3.7	3.7	2.4	2.4	1.62	1	1	FALSE	0	FALSE	FALSE	FALSE				
11	2U	20+746.307	21+002.136	255.83	0.159		3.7	3.7	2.4	2.4	1.62	1	1	FALSE	0	FALSE	FALSE	FALSE	10,478.27	1.6	TRUE	110
12	2U	21+002.136	22+458.191	1,456.06	0.9048		3.7	3.7	2.4	2.4	1.62	1	1	FALSE	0	FALSE	FALSE	FALSE				
13	2U	22+458.191	22+850.860	392.67	0.244		3.7	3.7	2.4	2.4	0.8	1	1	FALSE	0	FALSE	FALSE	FALSE	5,000.00	1.6	TRUE	110
14	2U	22+850.860	22+907.406	56.55	0.0351		3.7	3.7	2.4	2.4	1.22	1	1	FALSE	0	FALSE	FALSE	FALSE				
15	2U	22+907.406	23+281.710	374.3	0.2326		3.7	3.7	2.4	2.4	1.22	1	1	FALSE	0	FALSE	FALSE	FALSE	5,000.00	1.6	TRUE	110

Section	Project Number	Route	Before/After
9	K-5749-01	K-156	Before

Segment Number	Type	Start Location	End Location	Length (m)	Length (mi)	AADT	Left Lane Width (m)	Right Lane Width (m)	Left Shoulder Width (m)	Right Shoulder Width (m)	Grade (%)	Driveway Density (driveways/km)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (m)	Superelev ation (%)	Adverse	Design Speed (km/h)
1	2U	10+000.000	14+055.304	4,055.30	2.5198	1997-1999: 2,550	3	3	0.9	0.9	0	1.5	3	FALSE	0	FALSE	FALSE	FALSE				
2	2U	14+055.304	14+305.139	249.84	0.1552		3	3	0.9	0.9	0.65	1.5	3	FALSE	0	FALSE	FALSE	FALSE	5,239.14	1.6	TRUE	110
3	2U	14+305.139	15+310.835	1,005.70	0.6249		3	3	0.9	0.9	1.2	1.5	3	FALSE	0	FALSE	FALSE	FALSE				
4	2U	15+310.835	16+698.259	1,387.42	0.8621	1997-1999: 2,675	3	3	0.9	0.9	0	1.5	3	FALSE	0	FALSE	FALSE	FALSE				
5	2U	16+698.259	16+951.730	253.47	0.1575		3	3	0.9	0.9	0.2	1.5	3	FALSE	0	FALSE	FALSE	FALSE	4,365.95	1.6	TRUE	110
6	2U	16+951.730	18+845.900	1,894.17	1.177		3	3	0.9	0.9	1.09	1.5	3	FALSE	0	FALSE	FALSE	FALSE				
7	2U	18+845.900	19+618.341	772.44	0.48		3	3	0.9	0.9	0.25	1.5	3	FALSE	0	FALSE	FALSE	FALSE	1,397.13	2	FALSE	110
8	2U	19+618.341	22+113.469	2,495.13	1.5504		3	3	0.9	0.9	0	1.5	3	FALSE	0	FALSE	FALSE	FALSE				
9	2U	22+113.469	22+447.941	334.47	0.2078		3	3	0.9	0.9	0	1.5	3	FALSE	0	FALSE	FALSE	FALSE	1,746.40	2	FALSE	110
10	2U	22+447.941	26+582.681	4,134.74	2.5692		3	3	0.9	0.9	0	1.5	3	FALSE	0	FALSE	FALSE	FALSE				
11	2U	26+582.681	29+121.587	2,538.91	1.5776	1997-1999: 2,810	3	3	0.9	0.9	0.4	1.5	3	FALSE	0	FALSE	FALSE	FALSE				
12	2U	29+121.587	29+762.839	641.25	0.3985		3	3	0.9	0.9	0.1	1.5	3	FALSE	0	FALSE	FALSE	FALSE	3,492.77	1.6	TRUE	110
13	2U	29+762.839	31+072.750	1,309.91	0.8139		3	3	0.9	0.9	1	1.5	3	FALSE	0	FALSE	FALSE	FALSE				
14	2U	31+072.750	31+174.965	102.22	0.0635	1997-1999: 2,370	3	3	0.9	0.9	0.78	1.5	3	FALSE	0	FALSE	FALSE	FALSE				
15	2U	31+174.965	31+732.360	557.4	0.3464		3	3	0.9	0.9	0.78	1.5	3	FALSE	0	FALSE	FALSE	FALSE	1,746.38	2	FALSE	110
16	2U	31+732.360	33+098.322	1,365.96	0.8488		3	3	0.9	0.9	0.17	1.5	3	FALSE	0	FALSE	FALSE	FALSE				
17	2U	33+098.322	33+749.148	650.83	0.4044		3	3	0.9	0.9	0.46	1.5	3	FALSE	0	FALSE	FALSE	FALSE	1,746.38	3	FALSE	110
18	2U	33+749.148	34+565.027	815.88	0.507		3	3	0.9	0.9	0.56	1.5	3	FALSE	0	FALSE	FALSE	FALSE				
19	2U	34+565.027	34+686.509	121.48	0.0755	1997-1999: 2,205	3	3	0.9	0.9	2.21	1.5	3	FALSE	0	FALSE	FALSE	FALSE				
20	2U	34+686.509	34+947.096	260.59	0.1619		3	3	0.9	0.9	2.21	1.5	3	FALSE	0	FALSE	FALSE	FALSE	1,746.38	2	FALSE	110
21	2U	34+947.096	37+736.009	2,788.91	1.733		3	3	0.9	0.9	2.21	1.5	3	FALSE	0	FALSE	FALSE	FALSE				

Section	Project Number	Route	Before/After
9	K-5749-01	K-156	After

Segment Number	Type	Start Location	End Location	Length (m)	Length (mi)	AADT	Left Lane Width (m)	Right Lane Width (m)	Left Shoulder Width (m)	Right Shoulder Width (m)	Grade (%)	Driveway Density (driveways/km)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (m)	Superelev ation (%)	Adverse	Design Speed (km/h)
1	2U	10+000.000	14+055.304	4,055.30	2.5198	2002: 2,434; 2003: 2,376; 2004: 2,318; 2005: 2,260; 2006: 2,830; 2007-2009: 2,810	3	3	3	3	0	1.5	2	FALSE	0	FALSE	FALSE	FALSE				
2	2U	14+055.304	14+305.139	249.84	0.1552		3	3	3	3	0.65	1.5	2	FALSE	0	FALSE	FALSE	FALSE	5,239.14	1.6	TRUE	110
3	2U	14+305.139	15+310.835	1,005.70	0.6249		3	3	3	3	1.2	1.5	2	FALSE	0	FALSE	FALSE	FALSE				
4	2U	15+310.835	16+698.259	1,387.42	0.8621	2002: 2,661; 2003: 2,654; 2004: 2,647; 2005: 2,640; 2006: 3,020; 2007-2009: 3,000	3	3	3	3	0	1.5	2	FALSE	0	FALSE	FALSE	FALSE				
5	2U	16+698.259	16+951.730	253.47	0.1575		3	3	3	3	0.2	1.5	2	FALSE	0	FALSE	FALSE	FALSE	4,365.95	1.6	TRUE	110
6	2U	16+951.730	18+845.900	1,894.17	1.177		3	3	3	3	1.09	1.5	2	FALSE	0	FALSE	FALSE	FALSE				
7	2U	18+845.900	19+618.341	772.44	0.48		3	3	3	3	0.25	1.5	2	FALSE	0	FALSE	FALSE	FALSE	1,397.13	4.1	FALSE	110
8	2U	19+618.341	22+113.469	2,495.13	1.5504		3	3	3	3	0	1.5	2	FALSE	0	FALSE	FALSE	FALSE				
9	2U	22+113.469	22+447.941	334.47	0.2078		3	3	3	3	0	1.5	2	FALSE	0	FALSE	FALSE	FALSE	1,746.40	3.5	FALSE	110

10	2U	22+447.941	26+582.681	4,134.74	2.5692		3	3	3	3	0	1.5	2	FALSE	0	FALSE	FALSE	FALSE				
11	2U	26+582.681	29+121.587	2,538.91	1.5776	2002: 2,834; 2003: 2,846; 2004: 2,858; 2005: 2,870; 2006: 3,340; 2007-2009: 3,320	3	3	3	3	0.4	1.5	2	FALSE	0	FALSE	FALSE	FALSE				
12	2U	29+121.587	29+762.839	641.25	0.3985		3	3	3	3	0.1	1.5	2	FALSE	0	FALSE	FALSE	FALSE	3,492.77	1.6	TRUE	110
13	2U	29+762.839	31+072.750	1,309.91	0.8139		3	3	3	3	1	1.5	2	FALSE	0	FALSE	FALSE	FALSE				
14	2U	31+072.750	31+174.965	102.22	0.0635	2002: 2,398; 2003: 2,412; 2004: 2,426; 2005: 2,440; 2006: 2,560; 2007-2009: 2,550	3	3	3	3	0.78	1.5	2	FALSE	0	FALSE	FALSE	FALSE				
15	2U	31+174.965	31+732.360	557.4	0.3464		3	3	3	3	0.78	1.5	2	FALSE	0	FALSE	FALSE	FALSE	1,746.38	3.5	FALSE	110
16	2U	31+732.360	33+098.322	1,365.96	0.8488		3	3	3	3	0.17	1.5	2	FALSE	0	FALSE	FALSE	FALSE				
17	2U	33+098.322	33+749.148	650.83	0.4044		3	3	3	3	0.46	1.5	2	FALSE	0	FALSE	FALSE	FALSE	1,746.38	3.5	FALSE	110
18	2U	33+749.148	34+565.027	815.88	0.507		3	3	3	3	0.56	1.5	2	FALSE	0	FALSE	FALSE	FALSE				
19	2U	34+565.027	34+686.509	121.48	0.0755	2002: 2,259; 2003: 2,286; 2004: 2,313; 2005: 2,340; 2006: 2,700; 2007-2009: 2,680	3	3	3	3	2.21	1.5	2	FALSE	0	FALSE	FALSE	FALSE				
20	2U	34+686.509	34+947.096	260.59	0.1619		3	3	3	3	2.21	1.5	2	FALSE	0	FALSE	FALSE	FALSE	1,746.38	3.5	FALSE	110
21	2U	34+947.096	37+736.042	2,788.95	1.733		3	3	3	3	2.21	1.5	2	FALSE	0	FALSE	FALSE	FALSE				

Section	Project Number	Route	Before/After
10	K-5743-01	US-50	Before

Segment Number	Type	Start Location	End Location	Length (m)	Length (mi)	AADT	Left Lane Width (m)	Right Lane Width (m)	Left Shoulder Width (m)	Right Shoulder Width (m)	Grade (%)	Driveway Density (driveways/km)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (m)	Superelevation (%)	Adverse	Design Speed (km/h)
1	2U	1+074.889	1+091.440	16.55	0.0103	1997-1999: 3,040	3.7	3.7	3	3	0.05	0.5	1	FALSE	0	FALSE	FALSE	FALSE				
2	2U	1+091.440	1+731.520	640.08	0.3977		3.7	3.7	3	3	0.05	0.5	1	FALSE	0	FALSE	FALSE	FALSE	2,911.00	1.6	TRUE	110
3	2U	1+731.520	1+793.571	62.05	0.0386		3.7	3.7	3	3	0.14	0.5	1	FALSE	0	FALSE	FALSE	FALSE				
4	2U	1+793.571	2+096.000	302.43	0.1879		3.7	3.7	3	3	0.14	0.5	1	FALSE	0	FALSE	FALSE	FALSE	1,164.28	4.5	FALSE	110
5	2U	2+096.000	2+802.910	706.91	0.4392		3.7	3.7	3	3	0.14	0.5	1	FALSE	0	FALSE	FALSE	FALSE				
6	2U	2+802.910	15+663.312	#######	7.9911	1997-1999: 2,525	3.7	3.7	3	3	0.08	0.5	1	FALSE	0	FALSE	FALSE	FALSE				
7	2U	15+663.312	16+106.796	443.48	0.2756		3.7	3.7	3	3	0.14	0.5	1	FALSE	0	FALSE	FALSE	FALSE	1,746.40	3	FALSE	110
8	2U	16+106.796	18+269.513	2,162.72	1.3438		3.7	3.7	3	3	0.14	0.5	1	FALSE	0	FALSE	FALSE	FALSE				
9	2U	18+269.513	18+583.476	313.96	0.1951		3.7	3.7	3	3	0.52	0.5	1	FALSE	0	FALSE	FALSE	FALSE	10,478.26	1.6	TRUE	110
10	2U	18+583.476	18+789.039	205.56	0.1277		3.7	3.7	3	3	4.15	0.5	1	FALSE	0	FALSE	FALSE	FALSE				
11	2U	18+789.039	19+288.518	499.48	0.3104		3.7	3.7	3	3	4.15	0.5	1	FALSE	0	FALSE	FALSE	FALSE	17,463.76	1.6	TRUE	110

Section	Project Number	Route	Before/After
10	K-5743-01	US-50	After

Segment Number	Type	Start Location	End Location	Length (m)	Length (mi)	AADT	Left Lane Width (m)	Right Lane Width (m)	Left Shoulder Width (m)	Right Shoulder Width (m)	Grade (%)	Driveway Density (driveways/km)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (m)	Superelevation (%)	Adverse	Design Speed (km/h)
1	2U	1+074.889	1+091.440	16.55	0.0103	2002: 2,812; 2003: 2,698; 2004: 2,584; 2005: 2,470; 2006: 2,540; 2007-2009: 2,500	3.35	3.35	3	3	0.05	0.5	1	FALSE	0	FALSE	FALSE	FALSE				
2	2U	1+091.440	1+731.520	640.08	0.3977		3.35	3.35	3	3	0.05	0.5	1	FALSE	0	FALSE	FALSE	FALSE	2,911.00	1.6	TRUE	110
3	2U	1+731.520	1+793.571	62.05	0.0386		3.35	3.35	3	3	0.14	0.5	1	FALSE	0	FALSE	FALSE	FALSE				
4	2U	1+793.571	2+096.000	302.43	0.1879		3.35	3.35	3	3	0.14	0.5	1	FALSE	0	FALSE	FALSE	FALSE	1,164.28	4	FALSE	110
5	2U	2+096.000	2+802.910	706.91	0.4392		3.35	3.35	3	3	0.14	0.5	1	FALSE	0	FALSE	FALSE	FALSE				
6	2U	2+802.910	15+663.312	#######	7.9911	2002: 2,267; 2003: 2,138; 2004: 2,009; 2005: 1,880; 2006: 1,860; 2007-2009: 1,830	3.35	3.35	3	3	0.08	0.5	1	FALSE	0	FALSE	FALSE	FALSE				
7	2U	15+663.312	16+106.796	443.48	0.2756		3.35	3.35	3	3	0.14	0.5	1	FALSE	0	FALSE	FALSE	FALSE	1,746.40	3	FALSE	110
8	2U	16+106.796	18+269.513	2,162.72	1.3438		3.35	3.35	3	3	0.14	0.5	1	FALSE	0	FALSE	FALSE	FALSE				
9	2U	18+269.513	18+583.476	313.96	0.1951		3.35	3.35	3	3	0.52	0.5	1	FALSE	0	FALSE	FALSE	FALSE	10,478.26	1.6	TRUE	110
10	2U	18+583.476	18+657.723	74.25	0.0461		3.35	3.35	3	3	4.15	0.5	1	FALSE	0	FALSE	FALSE	FALSE				
11	2U	18+657.723	18+761.893	104.17	0.0647		3.35	3.35	3	3	4.15	0.5	1	FALSE	0	FALSE	FALSE	FALSE	5,000.00	1.6	TRUE	110
12	2U	18+761.893	18+927.965	166.07	0.1032		3.35	3.35	3	3	4.15	0.5	1	FALSE	0	FALSE	FALSE	FALSE				
13	2U	18+927.965	19+228.510	300.54	0.1868		3.35	3.35	3	3	4.15	0.5	1	FALSE	0	FALSE	FALSE	FALSE	5,000.00	1.6	TRUE	110
14	2U	19+228.510	19+288.510	60	0.0373		3.35	3.35	0	0	2.42	0.5	1	FALSE	0	FALSE	FALSE	FALSE	5,000.00	1.6	TRUE	110

APPENDIX I – SAMPLE VALIDATION SECTION IHSDM OUTPUT

Interactive Highway Safety Design Model

Crash Prediction Evaluation Report

July 5, 2011

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Report Overview

Report Generated: Jul 5, 2011 6:44 AM
Report Template: System: Multi-Page [System] (mlcpm2, Apr 5, 2011 10:29 AM)

Evaluation Date: Sun Mar 27 23:57:36 CDT 2011
IHSDM Version: v6.0.0 (Jul 15, 2010)
Crash Prediction Module: v2.2.0 (Jun 29, 2010)

User Name: Howard Lubliner
Organization Name: KDOT
Phone: 785-760-4611
E-Mail: howardl@ksdot.org

Project Title: Val - Chase US-50
Project Comment: Created Mon May 24 13:45:02 CDT 2010
Project Unit System: Metric

Highway Title: US-50
Highway Comment: Copied from US-50 (v1)
Highway Version: 1

Evaluation Title: SW Yes EB
Evaluation Comment: Created Sun Mar 27 23:56:46 CDT 2011
Minimum Station: 10+801.901
Maximum Station: 23+044.277
Policy for Superelevation: AASHTO 2004 Metric
Calibration/Distribution: Kansas State Wide
Model/CMF: Default configuration
Empirical-Bayes Analysis: Site-Specific
Highway with Crash History: Old US-50
Highway with Crash History Comment: Copied from US-50 (v1)
Highway with Crash History Version: 1
First Year of Analysis: 2001
Last Year of Analysis: 2009

Section 1 Evaluation

Section: Section 1
Evaluation Start Location: 10+801.901
Evaluation End Location: 23+044.277
Area Type: Rural
Functional Class: Arterial
Type of Alignment: Undivided, Two Lane
Model Category: Rural, Two Lane

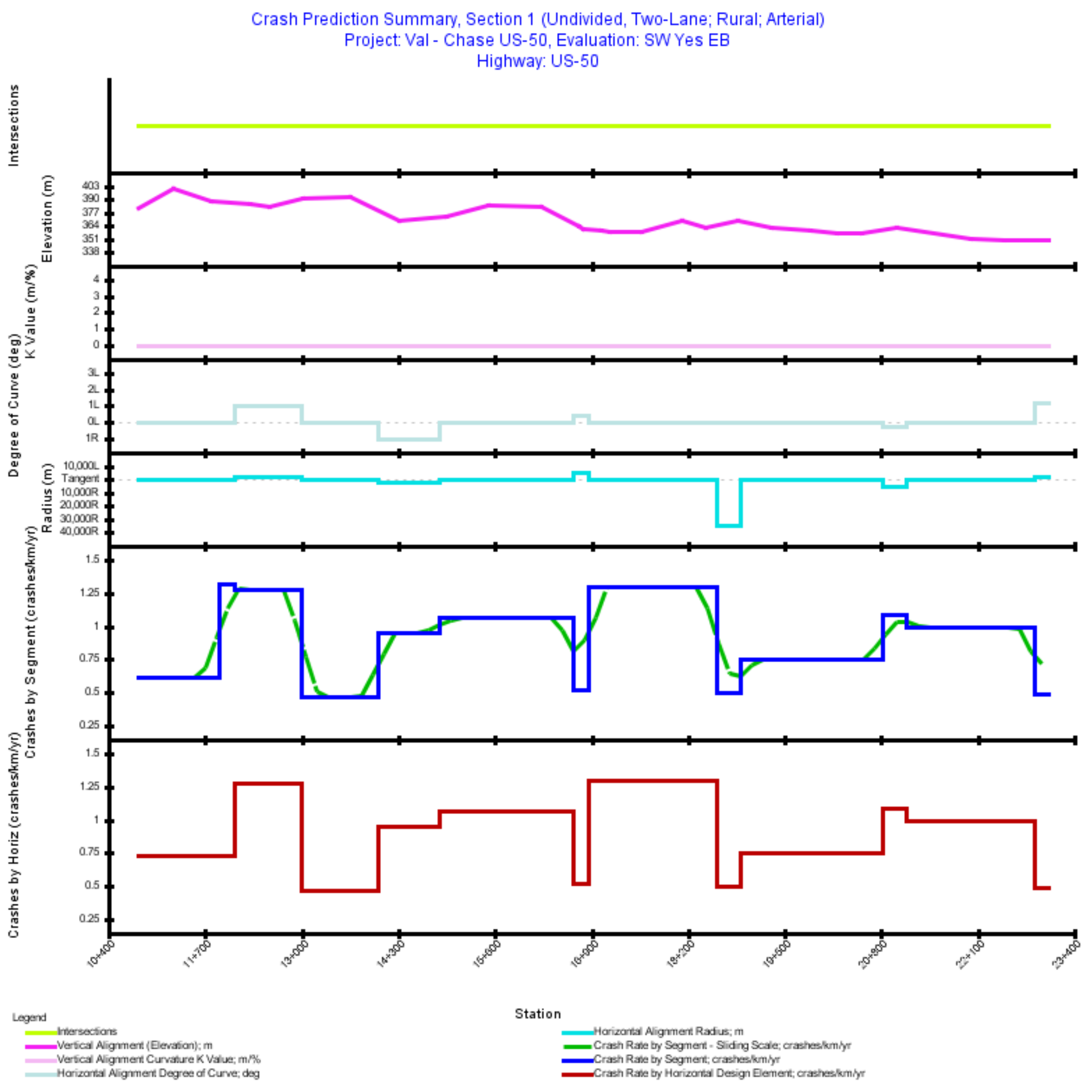

Figure 1. Crash Prediction Summary (Section 1)

Table 1. Observed Crash Summary (Section 1)

Year	Total Crashes	FI Crashes	FI no/C Crashes	PDO Crashes
1996	11	2	0	9
1997	10	1	0	9
1998	10	2	0	8
All Years	31	5	0	26

Table 2. Evaluation Highway - Homogeneous Segments (Section 1)

Seg. No.	Type	Start Location	End Location	Length (m)	Length(mi)	AADT	Left Lane Width (m)	Right Lane Width (m)	Left Shoulder Width (m)	Right Shoulder Width (m)	Grade (%)	Driveway Density (driveways/km)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (m)	Superelevation (%)	Adverse	Design Speed (km/h)
1	2U	10+801.901	11+882.000	1,080.10	0.6711	2001: 4,810; 2002: 4,850; 2003: 4,890; 2004: 4,930; 2005-2006: 4,970; 2007-2009: 4,880	3.70	3.70	3.00	3.00	4.00	1.1	1	true	0	false	false	false				
2	2U	11+882.000	12+094.249	212.25	0.1319	2001: 5,122; 2002: 5,249; 2003: 5,376; 2004: 5,503; 2005: 5,630; 2006: 5,560; 2007-2009: 5,550	3.70	3.70	3.00	3.00	0.54	1.1	1	true	0	false	false	false				
3	2U	12+094.249	12+996.907	902.66	0.5609	2001: 5,122; 2002: 5,249; 2003: 5,376; 2004: 5,503; 2005: 5,630; 2006: 5,560; 2007-2009: 5,550	3.70	3.70	3.00	3.00	0.54	1.1	1	true	0	false	false	false	1,746.38	3.0	false	100
4	2U	12+996.907	14+023.324	1,026.42	0.6378	2001: 5,122; 2002: 5,249; 2003: 5,376; 2004: 5,503; 2005: 5,630; 2006: 5,560; 2007-2009: 5,550	3.70	3.70	3.00	3.00	1.80	1.1	1	true	0	false	false	false				
5	2U	14+023.324	14+846.776	823.45	0.5117	2001: 5,122; 2002: 5,249; 2003: 5,376; 2004: 5,503; 2005: 5,630; 2006: 5,560; 2007-2009: 5,550	3.70	3.70	3.00	3.00	3.49	1.1	1	true	0	false	false	false	1,746.38	3.0	false	100
6	2U	14+846.776	16+651.791	1,805.02	1.1216	2001: 5,122; 2002: 5,249; 2003: 5,376; 2004: 5,503; 2005: 5,630; 2006: 5,560; 2007-2009: 5,550	3.70	3.70	3.00	3.00	0.54	1.1	1	true	0	false	false	false				
7	2U	16+651.791	16+861.781	209.99	0.1305	2001: 5,122; 2002: 5,249; 2003: 5,376; 2004: 5,503; 2005: 5,630; 2006: 5,560; 2007-2009: 5,550	3.70	3.70	3.00	3.00	3.79	1.1	1	true	0	false	false	false	4,762.85	1.6	true	100
8	2U	16+861.781	18+590.063	1,728.28	1.0739	2001: 5,122; 2002: 5,249; 2003: 5,376; 2004: 5,503; 2005: 5,630; 2006: 5,560; 2007-2009: 5,550	3.70	3.70	3.00	3.00	1.00	1.1	1	true	0	false	false	false				
9	2U	18+590.063	18+905.870	315.81	0.1962	2001: 5,122; 2002: 5,249; 2003: 5,376; 2004: 5,503; 2005: 5,630; 2006: 5,560; 2007-2009: 5,550	3.70	3.70	3.00	3.00	1.58	1.1	1	true	0	false	false	false	34,927.58	1.6	true	100
10	2U	18+905.870	20+820.818	1,914.95	1.1899	2001: 5,122; 2002: 5,249; 2003: 5,376; 2004: 5,503; 2005: 5,630; 2006: 5,560; 2007-2009: 5,550	3.70	3.70	3.00	3.00	1.66	1.1	1	true	0	false	false	false				
11	2U	20+820.818	21+139.194	318.38	0.1978	2001: 5,122; 2002: 5,249; 2003: 5,376; 2004: 5,503; 2005: 5,630; 2006: 5,560; 2007-2009: 5,550	3.70	3.70	3.00	3.00	1.14	1.1	1	true	0	false	false	false	5,821.26	1.6	true	100
12	2U	21+139.194	22+871.123	1,731.93	1.0762	2001: 5,122; 2002: 5,249; 2003: 5,376; 2004: 5,503; 2005: 5,630; 2006: 5,560; 2007-2009: 5,550	3.70	3.70	3.00	3.00	1.11	1.1	1	true	0	false	false	false				
13	2U	22+871.123	23+044.277	173.15	0.1076	2001: 5,122; 2002: 5,249; 2003: 5,376; 2004: 5,503; 2005: 5,630; 2006: 5,560; 2007-2009: 5,550	3.70	3.70	3.00	3.00	0.00	1.1	1	true	0	false	false	false	1,493.17	3.4	false	100

Table 3. Crash History Highway - Homogeneous Segments (Section 1)

Seg. No.	Type	Start Location	End Location	Length (m)	Length(mi)	AADT	Left Lane Width (m)	Right Lane Width (m)	Left Shoulder Width (m)	Right Shoulder Width (m)	Grade (%)	Driveway Density (driveways/km)	Hazard Rating	Centerline Rumble Strip	Passing Lanes	TWLT Lane	Lighting	Automated Speed Enforcement	Radius (m)	Superelevation (%)	Adverse	Design Speed (km/h)
1	2U	10+801.901	11+882.000	1,080.10	0.6711	1996-1998: 4,770	3.70	3.70	3.00	3.00	4.00	1.1	2	false	0	false	false	false				
2	2U	11+882.000	12+094.249	212.25	0.1319	1996-1998: 4,995	3.70	3.70	3.00	3.00	0.54	1.1	2	false	0	false	false	false				
3	2U	12+094.249	12+996.907	902.66	0.5609	1996-1998: 4,995	3.70	3.70	3.00	3.00	0.54	1.1	2	false	0	false	false	false	1,746.38	3.0	false	100
4	2U	12+996.907	14+023.324	1,026.42	0.6378	1996-1998: 4,995	3.70	3.70	3.00	3.00	1.80	1.1	2	false	0	false	false	false				
5	2U	14+023.324	14+846.776	823.45	0.5117	1996-1998: 4,995	3.70	3.70	3.00	3.00	3.49	1.1	2	false	0	false	false	false	1,746.38	2.7	false	100
6	2U	14+846.776	16+651.791	1,805.02	1.1216	1996-1998: 4,995	3.70	3.70	3.00	3.00	0.54	1.1	2	false	0	false	false	false				
7	2U	16+651.791	16+861.781	209.99	0.1305	1996-1998: 4,995	3.70	3.70	3.00	3.00	3.79	1.1	2	false	0	false	false	false	4,762.85	1.6	true	100
8	2U	16+861.781	18+590.063	1,728.28	1.0739	1996-1998: 4,995	3.70	3.70	3.00	3.00	1.00	1.1	2	false	0	false	false	false				
9	2U	18+590.063	18+905.870	315.81	0.1962	1996-1998: 4,995	3.70	3.70	3.00	3.00	1.58	1.1	2	false	0	false	false	false	34,927.58	1.6	true	100
10	2U	18+905.870	20+820.818	1,914.95	1.1899	1996-1998: 4,995	3.70	3.70	3.00	3.00	1.66	1.1	2	false	0	false	false	false				
11	2U	20+820.818	21+139.194	318.38	0.1978	1996-1998: 4,995	3.70	3.70	3.00	3.00	1.14	1.1	2	false	0	false	false	false	5,821.26	1.6	true	100
12	2U	21+139.194	22+871.123	1,731.93	1.0762	1996-1998: 4,995	3.70	3.70	3.00	3.00	1.11	1.1	2	false	0	false	false	false				
13	2U	22+871.123	23+044.244	173.12	0.1076	1996-1998: 4,995	3.70	3.70	3.00	3.00	0.00	1.1	2	false	0	false	false	false	1,493.17	3.0	false	100

Table 4. Expected Crash Rates and Frequencies (Section 1)

First Year of Analysis	2001
Last Year of Analysis	2009
Evaluated Length (km)	12.2424
Average Future Road AADT (vpd)	5,405
Expected Crashes	
Total Crashes	102.18
Fatal and Injury Crashes	19.59
Fatal and Serious Injury Crashes	15.44
Property-Damage-Only Crashes	82.59
Percent of Total Expected Crashes	
Percent Fatal and Injury Crashes (%)	19
Percent Fatal and Serious Injury Crashes (%)	15
Percent Property-Damage-Only Crashes (%)	81
Expected Crash Rate	
Crash Rate (crashes/km/yr)	0.9274
Fatal and Injury Crash Rate (crashes/km/yr)	0.1778
Fatal and Serious Injury Crash Rate (crashes/km/yr)	0.1402
Property-Damage-Only Crash Rate (crashes/km/yr)	0.7496
Expected Travel Crash Rate	
Total Travel (million veh-km)	217.37
Travel Crash Rate (crashes/million veh-km)	0.47
Travel Fatal and Injury Crash Rate (crashes/million veh-km)	0.09
Travel Fatal and Serious Injury Crash Rate (crashes/million veh-km)	0.07
Travel Property-Damage-Only Crash Rate (crashes/million veh-km)	0.38

Table 5. Expected Crash Frequencies and Rates by Highway Segment (Section 1)

Start Location	End Location	Length (km)	Expected No. Crashes for Evaluation Period	Crash Rate (crashes/km/yr)	Travel Crash Rate (crashes/million veh-km)
10+801.901	11+882.000	1.0801	5.94	0.6107	0.34
11+882.000	12+094.249	0.2122	2.51	1.3124	0.66
12+094.249	12+996.907	0.9027	10.33	1.2713	0.64
12+996.907	14+023.324	1.0264	4.35	0.4705	0.24
14+023.324	14+846.776	0.8235	7.04	0.9493	0.48
14+846.776	16+651.791	1.8050	17.29	1.0645	0.54
16+651.791	16+861.781	0.2100	0.98	0.5160	0.26
16+861.781	18+590.063	1.7283	20.18	1.2977	0.65
18+590.063	18+905.870	0.3158	1.40	0.4921	0.25
18+905.870	20+820.818	1.9149	12.93	0.7505	0.38
20+820.818	21+139.194	0.3184	3.11	1.0843	0.54
21+139.194	22+871.123	1.7319	15.38	0.9864	0.50
22+871.123	23+044.277	0.1732	0.76	0.4898	0.25

Table 6. Expected Crash Frequencies and Rates by Horizontal Design Element (Section 1)

Title	Start Location	End Location	Length (km)	Expected No. Crashes for Evaluation Period	Crash Rate (crashes/km/yr)	Travel Crash Rate (crashes/million veh-km)
Tangent	10+801.901	12+094.249	1.2923	8.44	0.7259	0.39
Curve 1	12+094.249	12+996.907	0.9027	10.33	1.2713	0.64
Tangent	12+996.907	14+023.324	1.0264	4.35	0.4705	0.24
Curve 2	14+023.324	14+846.776	0.8235	7.04	0.9493	0.48
Tangent	14+846.776	16+651.791	1.8050	17.29	1.0645	0.54
Curve 3	16+651.791	16+861.781	0.2100	0.98	0.5160	0.26
Tangent	16+861.781	18+590.063	1.7283	20.18	1.2977	0.65
Curve 4	18+590.063	18+905.870	0.3158	1.40	0.4921	0.25
Tangent	18+905.870	20+820.818	1.9149	12.93	0.7505	0.38
Curve 5	20+820.818	21+139.194	0.3184	3.11	1.0843	0.54
Tangent	21+139.194	22+871.123	1.7319	15.38	0.9864	0.50
Curve 6	22+871.123	23+044.277	0.1732	0.76	0.4898	0.25

Table 7. Expected Crash Type Distribution (Section 1)

Element Type	Crash Type	Fatal and Serious Injury		Property Damage Only		Total	
		Crashes	Crashes (%)	Crashes	Crashes (%)	Crashes	Crashes (%)
Highway Segment	Collision with Animal	0.74	0.7	15.20	14.9	12.36	12.1
Highway Segment	Collision with Bicycle	0.08	0.1	0.08	0.1	0.20	0.2
Highway Segment	Other Single-vehicle Collision	0.14	0.1	2.40	2.3	2.15	2.1
Highway Segment	Overturned	0.72	0.7	1.24	1.2	2.56	2.5
Highway Segment	Collision with Pedestrian	0.14	0.1	0.08	0.1	0.31	0.3
Highway Segment	Run Off Road	10.68	10.4	41.71	40.8	53.24	52.1
Highway Segment	Single Vehicle Crashes	12.50	12.2	60.71	59.4	70.81	69.3
Highway Segment	Angle Collision	1.98	1.9	5.95	5.8	8.69	8.5
Highway Segment	Head-on Collision	0.67	0.7	0.25	0.2	1.64	1.6
Highway Segment	Other Multiple-vehicle Collision	0.51	0.5	2.48	2.4	2.76	2.7
Highway Segment	Rear-end Collision	3.23	3.2	10.08	9.9	14.51	14.2
Highway Segment	Sideswipe	0.74	0.7	3.14	3.1	3.78	3.7
Highway Segment	Multiple Vehicle Crashes	7.13	7.0	21.89	21.4	31.37	30.7
Highway Segment	Total Highway Segment Crashes	19.63	19.2	82.59	80.8	102.18	100.0
	Total Crashes	19.63	19.2	82.59	80.8	102.18	100.0

Note:*Fatal and Injury Crashes* and *Property Damage Only Crashes* do not necessarily sum up to *Total Crashes* because the distribution of these three crashes had been derived independently.

APPENDIX J - ANNIMAL CRASH STATISTICS BY COUNTY

CountyName	Total Crashes	Intersection Related Crashes	Total Animal Crashes	Intersection Animal Crashes	Segment Animal Crashes (%)	Vehicle Miles in County	Segment Animal Crashes (crashes/MVMT)
Allen	180	17	115	1	69.9%	152487	0.683
Anderson	255	36	114	1	51.6%	186769	0.553
Atchison	245	29	136	5	60.6%	156790	0.763
Barber	218	9	166	0	79.4%	96309	1.574
Barton	436	37	268	3	66.4%	305077	0.793
Bourbon	236	28	122	5	56.3%	134216	0.796
Brown	284	34	141	2	55.6%	250892	0.506
Butler	293	40	159	6	60.5%	235905	0.592
Chase	140	11	59	0	45.7%	152107	0.354
Chautauqua	122	11	62	3	53.2%	84855	0.635
Cherokee	621	141	268	11	53.5%	526659	0.446
Cheyenne	53	6	25	3	46.8%	71046	0.283
Clark	107	6	57	0	56.4%	92261	0.564
Clay	184	20	113	4	66.5%	112473	0.885
Cloud	214	15	156	4	76.4%	85994	1.614
Coffey	174	26	103	2	68.2%	133513	0.691
Comanche	42	4	16	0	42.1%	33986	0.430
Cowley	396	40	244	9	66.0%	233960	0.917
Crawford	355	53	188	9	59.3%	238463	0.686
Decatur	63	10	39	0	73.6%	86687	0.411
Dickinson	233	25	137	2	64.9%	129306	0.953
Doniphan	157	13	87	2	59.0%	113467	0.684
Douglas	303	53	117	3	45.6%	246429	0.422
Edwards	87	4	51	0	61.4%	103546	0.450
Elk	126	9	48	0	41.0%	50809	0.863
Ellis	101	9	64	0	69.6%	107255	0.545
Ellsworth	245	28	158	4	71.0%	121903	1.154
Finney	193	24	50	0	29.6%	277613	0.164
Ford	175	12	77	0	47.2%	345451	0.204
Franklin	252	40	111	1	51.9%	212137	0.474
Geary	207	20	78	2	40.6%	98872	0.702
Gove	35	5	12	0	40.0%	20158	0.544
Graham	128	7	101	0	83.5%	61431	1.501
Grant	75	9	21	0	31.8%	85968	0.223
Gray	86	11	29	1	37.3%	203690	0.126
Greeley	51	5	15	1	30.4%	48443	0.264
Greenwood	289	22	174	2	64.4%	250104	0.628
Hamilton	63	6	37	0	64.9%	85100	0.397
Harper	305	29	186	3	66.3%	134478	1.243
Harvey	153	18	73	0	54.1%	187786	0.355
Haskell	98	24	18	0	24.3%	158734	0.104
Hodgeman	81	6	45	1	58.7%	67433	0.596
Jackson	259	50	125	1	59.3%	141157	0.802
Jefferson	562	109	266	14	55.6%	315316	0.730
Jewell	176	9	148	3	86.8%	72863	1.817
Johnson	34	8	14	0	53.8%	26882	0.476
Kearny	102	12	55	0	61.1%	108827	0.462
Kingman	265	15	172	0	68.8%	158394	0.992
Kiowa	130	22	66	1	60.2%	150929	0.393
Labette	353	57	177	3	58.8%	287708	0.552
Lane	43	5	18	1	44.7%	57803	0.269
Leavenworth	423	71	170	8	46.0%	196132	0.754
Lincoln	103	1	75	0	73.5%	56952	1.203
Linn	291	40	105	5	39.8%	147006	0.621
Logan	78	8	40	1	55.7%	90313	0.394
Lyon	222	19	93	4	43.8%	139351	0.583
Marion	262	27	146	0	62.1%	259382	0.514
Marshall	438	64	235	6	61.2%	205905	1.016
McPherson	238	44	98	2	49.5%	227906	0.385
Meade	110	5	67	0	63.8%	132325	0.462

CountyName	Total Crashes	Intersection Related Crashes	Total Animal Crashes	Intersection Animal Crashes	Segment Animal Crashes (%)	Vehicle Miles in County	Segment Animal Crashes (crashes/MVMT)
Miami	209	35	101	4	55.7%	130653	0.678
Mitchell	230	22	142	5	65.9%	102558	1.220
Montgomery	514	70	251	4	55.6%	383324	0.588
Morris	222	29	93	1	47.7%	128289	0.655
Morton	33	7	12	0	46.2%	53872	0.203
Nemaha	215	9	120	0	58.3%	138651	0.790
Neosho	365	40	217	3	65.8%	230623	0.847
Ness	98	3	51	0	53.7%	96438	0.483
Norton	247	22	164	3	71.6%	118064	1.245
Osage	407	61	177	1	50.9%	271656	0.592
Osborne	151	18	91	5	64.7%	67770	1.159
Ottawa	110	11	72	0	72.7%	52847	1.244
Pawnee	222	28	137	2	69.6%	157210	0.784
Phillips	269	25	184	4	73.8%	121176	1.357
Pottawatamie	342	59	141	4	48.4%	198856	0.629
Pratt	252	18	183	2	77.4%	216146	0.765
Rawlins	73	5	36	0	52.9%	57191	0.575
Reno	427	49	263	6	68.0%	276368	0.849
Republic	150	6	122	2	83.3%	57014	1.922
Rice	220	29	129	3	66.0%	163930	0.702
Riley	357	56	184	3	60.1%	200597	0.824
Rooks	241	22	181	5	80.4%	122839	1.308
Rush	188	19	132	3	76.3%	116889	1.008
Russell	172	25	88	4	57.1%	70057	1.095
Saline	66	11	28	0	50.9%	67196	0.381
Scott	70	14	25	2	41.1%	130320	0.161
Sedgwick	75	21	28	3	46.3%	75174	0.304
Seward	117	18	30	0	30.3%	196045	0.140
Shawnee	174	26	50	1	33.1%	131348	0.341
Sheridan	110	7	62	1	59.2%	83270	0.669
Sherman	27	10	6	0	35.3%	43544	0.126
Smith	192	15	135	4	74.0%	89884	1.331
Stafford	188	15	134	2	76.3%	124257	0.970
Stanton	35	7	11	1	35.7%	58632	0.156
Stevens	75	15	23	0	38.3%	110321	0.190
Sumner	423	43	215	3	55.8%	325664	0.595
Thomas	110	14	33	1	33.3%	97638	0.299
Trego	52	5	17	0	36.2%	44444	0.349
Wabaunsee	208	25	83	3	43.7%	89992	0.812
Wallace	59	8	23	2	41.2%	45691	0.420
Washington	265	17	198	6	77.4%	124758	1.405
Wichita	51	14	14	1	35.1%	64416	0.184
Wilson	318	37	173	4	60.1%	201730	0.765
Woodson	147	10	94	1	67.9%	96097	0.884
Wyandotte	(1)	(1)	(1)	(1)	(1)	(1)	(1)

(1) Wyandotte County has no rural two-lane miles

APPENDIX K - VALIDATION RESULTS IN CRASH RATE

Without Emperical Bayes Procedure

							Crashes Observed		Crashes Predicted			
									Statewide Calibration		County-Specific Calibration	
Section #	Project #	Route	AADT	Miles	# of Years	Years	Crashes	crashes/mile/year	Crashes	crashes/mile/year	Crashes	crashes/mile/year
1	K-5393-01	K-383	955	13.618	8	2002-2009	62	0.569	37.75	0.396	52.24	0.548
2	K-5384-01	US-50	5405	7.60706	9	2001-2009	78	1.139	119.71	1.967	84	1.380
3	K-5745-01	US-56	1822	7.827437	6	2004-2009	25	0.532	29.72	0.700	24.48	0.576
4	K-5767-01	US-77	2896	12.7126	4	2006-2009	74	1.455	49.63	0.991	43.88	0.876
5	K-5391-01	US-283	1159	16.25762	10	2000-2009	71	0.437	66.31	0.457	53.05	0.365
6	K-5761-01	US-73	3000	4.141591	5	2005-2009	24	1.159	23.28	1.808	23.62	1.835
7	K-5757-01	K-47	1434	2.174799	8	2002-2009	18	1.035	8.75	0.503	8.89	0.511
8	K-5741-01	US-36	968	7.920448	7	2003-2009	15	0.271	19.37	0.528	16.86	0.460
9	K-5749-01	K-156	2741	17.23438	8	2002-2009	174	1.262	146.7	1.216	152.26	1.262
10	K-5743-01	US-50	2014	11.31742	8	2002-2009	69	0.762	62.82	0.793	46.13	0.582

With Emperical Bayes Procedure

							Crashes Observed		Crashes Predicted			
									Statewide Calibration		County-Specific Calibration	
Section #	Project #	Route	AADT	Miles	# of Years	Years	Crashes	crashes/mile/year	Crashes	crashes/mile/year	Crashes	crashes/mile/year
1	K-5393-01	K-383	955	13.618	8	2002-2009	62	0.569	41.67	0.382	53.99	0.496
2	K-5384-01	US-50	5405	7.60706	9	2001-2009	78	1.139	102.18	1.492	86.18	1.259
3	K-5745-01	US-56	1822	7.827437	6	2004-2009	25	0.532	29.72	0.633	24.48	0.521
4	K-5767-01	US-77	2896	12.7126	4	2006-2009	74	1.455	66.07	1.299	61.54	1.210
5	K-5391-01	US-283	1159	16.25762	10	2000-2009	71	0.437	63.52	0.391	53.93	0.332
6	K-5761-01	US-73	3000	4.141591	5	2005-2009	24	1.159	23.28	1.124	23.62	1.141
7	K-5757-01	K-47	1434	2.174799	8	2002-2009	18	1.035	6.98	0.401	7.05	0.405
8	K-5741-01	US-36	968	7.920448	7	2003-2009	15	0.271	19.37	0.349	16.86	0.304
9	K-5749-01	K-156	2741	17.23438	8	2002-2009	174	1.262	180.12	1.306	183.79	1.333
10	K-5743-01	US-50	2014	11.31742	8	2002-2009	69	0.762	71.25	0.787	58.21	0.643