Kentucky Transportation Cabinet

Kentucky's Network Screening Process

SAFETY DATA CASE STUDY

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16. Abstract

This purpose of this case study is to describe Kentucky's network screening methodology for all State-owned roads, as well as local roads classified as a collector street or above. The Kentucky Transportation Cabinet's (KYTC) Highway Safety Improvement Program requires a data-driven process to identify sites with a potential safety need and prioritize projects. The KYTC partnered with the University of Kentucky's Kentucky Transportation Center (KTC) to develop a network screening approach to prioritize locations statewide to be targeted for future safety improvement projects. This network screening approach addresses five focus areas: 1) Roadway Departure Corridors, 2) Cable Barrier, 3) High Friction Surface Treatment (HFST) Segments, 4) HFST Ramps, and 5) Intersections. The KTC analyzed statewide enterprise road, traffic, and crash data to develop safety performance functions (SPFs) that predict crashes on all facilities encompassed by each focus area. The KTC used cumulative residual (CURE) plots to assess SPF model performance and identify outliers or issues inherent in the dataset that lead to worse model fit. The CURE plot approach also underscores the importance of thoughtful and homogenous site segmentation for improved performance and meaningful network screening results. This network screening methodology applies a State-specific approach to rank locations based on higher-than-expected crashes and associated crash costs.

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Acronyms

Acronym	Description
AADT	annual average daily traffic
AASHTO	American Association of State Highway and Transportation Officials
CURE	cumulative residuals
CMF	crash modification factor
EB	Empirical-Bayes
EEC	Excess Expected Crashes
FHWA	Federal Highway Administration
HFST	High Friction Surface Treatment
HIS	Highway Information System
HSIP	Highway Safety Improvement Program
HSM	Highway Safety Manual
KTC	Kentucky Transportation Center
KYTC	Kentucky Transportation Cabinet
LOSS	level of service of safety
RwD	roadway departure
SPF	Safety Performance Function
SPF-R	Safety Performance Function – R
TED	Transportation Enterprise Database

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Executive Summary

This purpose of this case study is to describe Kentucky's network screening methodology for all State-owned roads, as well as local roads classified as a collector street or above. The Kentucky Transportation Cabinet's (KYTC) Highway Safety Improvement Program requires a data-driven process to identify sites with a potential safety need and prioritize projects. The KYTC partnered with the University of Kentucky's Kentucky Transportation Center (KTC) to develop a network screening approach to prioritize locations statewide to be targeted for future safety improvement projects. This network screening approach addresses five focus areas: 1) Roadway Departure Corridors, 2) Cable Barrier, 3) High Friction Surface Treatment (HFST) Segments, 4) HFST Ramps, and 5) Intersections. The KTC analyzed statewide enterprise road, traffic, and crash data to develop safety performance functions (SPFs) that predict crashes on all facilities encompassed by each focus area. The KTC used cumulative residual (CURE) plots to assess SPF model performance and identify outliers or issues inherent in the dataset that lead to worse model fit. The CURE plot approach also underscores the importance of thoughtful and homogenous site segmentation for improved performance and meaningful network screening results. This network screening methodology applies a State-specific approach to rank locations based on higher-than-expected crashes and associated crash costs.

Introduction

The Transportation Research Board's Safety Performance Analysis (ACS20) User Liaison Subcommittee has an on-going initiative focused on practical application of the American Association of State Highway and Transportation Officials (AASHTO) Highway Safety Manual (HSM) (i.e., "using the HSM in the real world"). FHWA also administers the HSM Implementation Pooled Fund, which includes 22 States focused on projects to help further HSM implementation. Development of HSM case studies will assist practitioners in performing data-driven safety analysis using the advanced methods described in the HSM. The primary purpose of the HSM case studies is to highlight noteworthy applications of HSM methods, focus on common challenges, and feature agencies that overcame those challenges. These case studies serve as a source of lessons learned and noteworthy practices to help guide practitioners applying the HSM.

Background, Purpose, and Need

This purpose of this case study is to describe Kentucky's network screening methodology for all State-owned roads, as well as local roads classified as a collector street or above. The Kentucky Transportation Cabinet's (KYTC's) Highway Safety Improvement Program (HSIP) requires a data-driven process to identify sites with a potential safety need and prioritize projects. According to the First Edition of the HSM (2010):

> "Network screening is a process for reviewing a transportation network to identify and rank sites from most likely to least likely to realize a reduction in crash frequency with implementation of a countermeasure" (p. 4-1).

The KYTC partnered with the University of Kentucky's Kentucky Transportation Center (KTC) to develop a network screening approach to prioritize locations statewide to be targeted for future safety improvement projects. This methodology applies a State-specific approach to rank locations based on higher-than-expected crashes and associated crash costs.

Project Description

- **Sponsoring agency(ies):** Kentucky Transportation Cabinet's Highway Safety Improvement Program Team.
- **Project location:** All State-owned roads and any locally-owned roads functionally classified as a collector street or above.
- **Area and Facility type(s):** Rural two-lane, two-way roads; urban and rural freeways; ramps; and intersections.
- **Project status:** Completed annually.

Safety Performance Analysis

This section provides an overview of Kentucky's analysis methods, assumptions, and results. Chapter 4 of the First Edition of the HSM contains general guidance on network screening techniques and considerations.

Analysis Overview

Critical first steps to the network screening process include establishing a focus for the analysis, delineating the network to be screened, and identifying reference populations. Kentucky established five focus areas, each with their own specific networks and reference populations, for its network screening approach.

Table 1. KYTC network screening focus areas.

Focus Area	Key Characteristics
Roadway Departure (RwD) Corridors	▸ Rural ▸ 2-lane ▸ Posted speed limit of 50 miles per hour and above ▸ RwD crashes only
Cable Barrier	▸ Urban and rural ▸ Interstates and parkways with applicable space for installing cable barrier (i.e. no existing barrier and median suitable for cable) ▸ Median crossover crashes only
High Friction Surface Treatment (HFST) Segments	▸ Urban and rural ▸ Wet pavement RwD crashes only ▸ 8 roadway classes.
HFST Ramps	▸ All ramps ▸ Wet pavement RwD crashes only
Intersections	▸ Urban and rural ▸ All crashes within intersection buffer area ▸ This is based on a pre-specified proximity to the crossing route, and it will vary if another adjacent intersection falls within the specified buffer distance ▸ 36 intersection classes

The KYTC houses the State's traffic (e.g., annual average daily traffic – AADT) and roadway data in the Highway Information System (HIS). The KYTC obtains crash data, maintained by the Kentucky State Police, and integrates it in the agency's Transportation Enterprise Database (TED) which stores traffic and other performance monitoring data. The KTC receives annual extracts of both databases and stores these data in its own internal database, "BILL." KTC analysts summarize the crash data according to the KABCO crash-severity scale.

The KABCO scale refers to the most severe injury of a person involved with a crash:

- **K:** Fatal crash
- **A:** Suspected serious injury
- **B:** Suspected minor injury
- **C:** Possible injury
- **O:** No injury

To create the appropriate network for each analysis, the KTC divides segments and intersections into their relevant groups or "populations" of similar locations. The KTC developed State-specific safety performance functions (SPFs) for each of the KYTC's five focus areas (e.g., RwD corridors) to predict K and A; B; C; and O severity crash frequency at relevant sites. Since these are State-specific SPFs, they do not require calibration to effectively apply to the Kentucky context.

Analysis Details

First, analysts developed SPFs based on the most recent available crash and AADT data. If AADT data were not available for a specific site, the KTC applied traffic estimates to facilitate the use of SPFs. These locations were typically locally-owned roads, and the KTC used county-level estimates for these facilities (i.e., local roads in a specific county all share the same value). To validate each SPF model, analysts use cumulative residual (CURE) plots and other metrics to evaluate and improve the SPF development process each year. The KTC created populations of homogenous roadway segments and intersections based on the appropriate focus area, and the analysis emphasized the importance of homogenous segmentation of the roadway inventory. As an example, figures 1 and 2 show CURE plots of an SPF based on two different levels of segmentation. CURE plots are a common method of assessing model fit and the appropriateness of variables in SPF development. A satisfactory CURE plot should have two overall characteristics (Srinivasan and Bauer, 2013):

1. Residuals should gently oscillate around zero on the y-axis of the plot
    - Drifting up indicates the SPF is underpredicting crashes
    - Drifting down indicates the SPF is overpredicting crashes
2. Plotted values should stay within the two standard deviation bounds

Figure 1 plots a model with homogeneity defined only as rural two-lane roads. Figure 2 illustrates a model with much stricter segmentation criteria, and it only includes rural two-lane road segments with no median, a shoulder width of 2 feet, a lane width of 9 feet, no vertical or horizontal curvature, and an AADT of less than 500 vehicles per day.

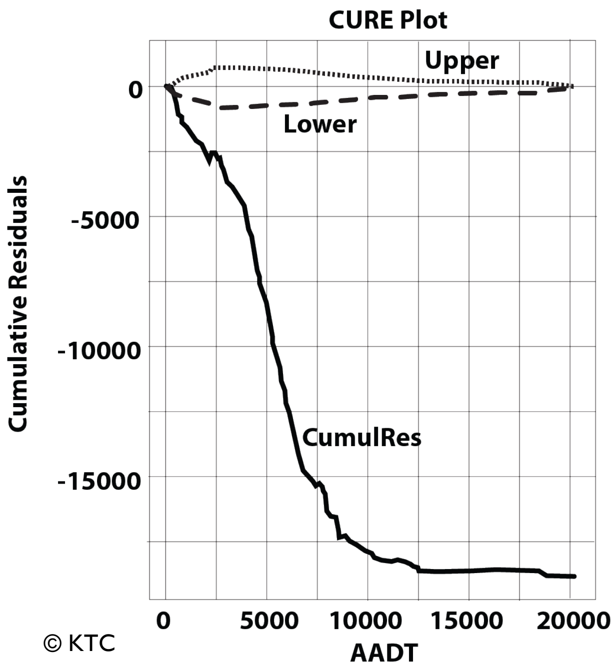

Figure 1. Graphic. CURE plot – more heterogenous segmentation.

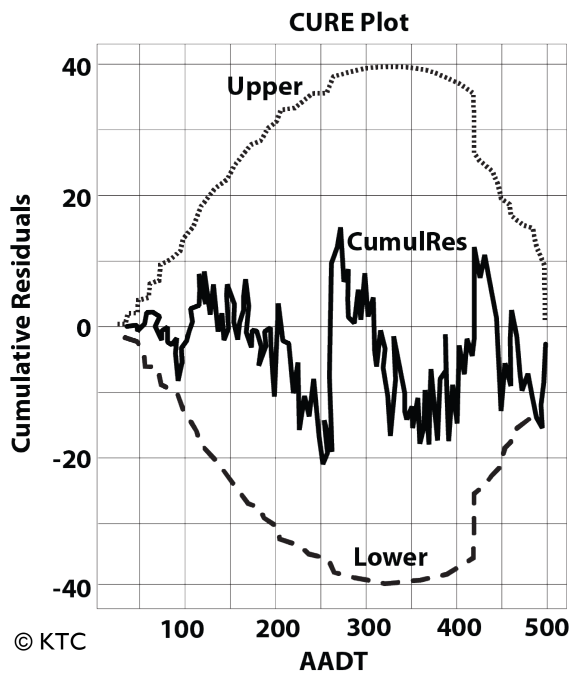

Figure 2. Graphic. CURE plot – more homogenous segmentation.

Analysts developed SPFs using an open source statistical package, Safety Performance Function – R (SPF-R), for K and A; B; C; and O crash severity types using five years of crash data from the Kentucky State Police. R is an open source statistical package with its own programming language and available for download. The SPF-R can be downloaded for use by anyone from [FHWA's Roadway Safety Data Program Toolbox].

Kentucky uses the Empirical-Bayes (EB) method to account for regression-to-the-mean bias by combining predictions from the SPF with observed crash data. KTC computed new metrics, the excess expected crashes (EEC) and the level of service of safety (LOSS), by comparing the expected crash frequency obtained from the EB method with observed crash frequency. Figure 3 Illustrates an example of how the EB method is used to compare observed crashes to predicted crashes and calculate the EEC.

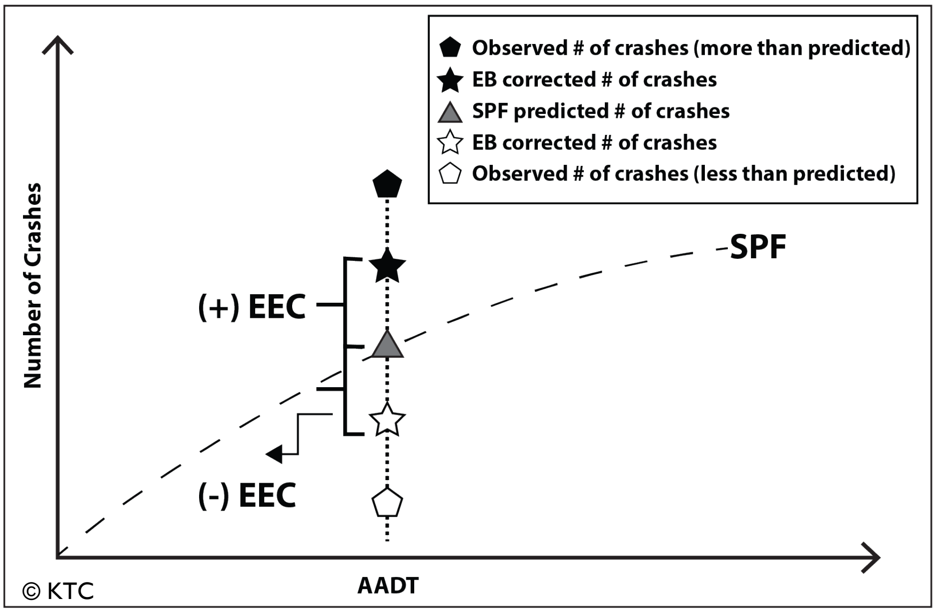

Figure 3. Graphic. Diagram illustrating EEC relative to the SPF prediction.

Once the KTC finalizes the SPFs, KYTC then incorporates average crash costs, per crash severity level, to arrive at a figure referred to as the "Cost of EECs." This value represents the theoretical comprehensive crash costs the public bears because of the excessive crashes. The KYTC prioritizes a list of sites in each focus area for potential improvement according to the Cost of EECs metric.

Results

KTC updates the SPFs annually, and the results of the analysis, primarily the Cost of EECs metric, help "sort and prioritize locations where countermeasures are most identify and rank sites from most likely to least likely to realize a reduction in crash frequency with implementation of a countermeasure" (AASHTO, 2010, p. 4-1). In practice, these rankings help determine how $30-40 million of annual HSIP funding should be spent across Kentucky's network of roadway segments and intersections. Leadership at KYTC has noted that these results are quite valuable in making better investment decisions with their safety improvement projects.

Additional Resources

In addition to the HSM, several FHWA resources contributed to this research and development:

- *SPF Development Guide: Developing Jurisdiction-Specific SPFs* (Srinivasan and Bauer, 2013)
- *The Calibrator: An SPF Calibration and Assessment Tool User Guide* (Lyon et al., 2016)
- *SPF Decision Guide: SPF Calibration vs SPF Development* (Srinivasan et al., 2013)

The FHWA's *Crash Costs for Highway Safety Analysis* document also provides national guidance and a supporting tool for crash cost development (Harmon et al., 2018). The following documents outline components of the State's data development and analysis approach:

- *A Methodology to Prioritize the Locations of Cable Barrier Installations in Kentucky* (Green and Fields, 2015)
- *Spatial Database for Intersections* (Green et al., 2016)
- *Automating Safety Performance Function Development to Improve Regression Models* (Green et al., 2018)

Challenges

The Kentucky analysis comes with many of the same caveats that apply to many States. The availability and quality of some data presented challenges to the analysis. Many local roads in Kentucky do not have reliable (or any) AADT records available. This required analysts to rely on county-level traffic estimates. Additionally, there is some degree of uncertainty regarding the accuracy of crash-location data. The Kentucky Traffic Records Advisory Committee is aware of this concern and is in the process of investigating it further.

Limitations of the HSM Method and Solutions

A typical challenge associated with network screening involves outlier observations and locations that are substantially different from average conditions. The KTC noted that some intersections and segments did not match the baseline conditions that were used to develop the SPFs for each facility type. The KYTC and KTC applied adjustments factors to the extent possible. However, KTC could not effectively apply adjustment factors to every outlier segment or intersection. One common issue involves highways which experienced a change in their route designation (i.e., a highway route became a bypass or business route). In these instances, crash data might indicate that crashes occurred on the original highway route, but the milepoint location is incompatible with the new route designation. This resulted in incomplete or inaccurate crash data for certain routes. Locations based on latitude and longitude coordinates could somewhat overcome this limitation, but it adds necessary processing time and is not a guarantee of accuracy. The KTC identified some of these systemic issues and outliers during its CURE-plot review. Outliers created large changes in the CURE plots (figure 4), and analysts could remove these observations from the model to generate better model fit and SPF performance (figure 5).

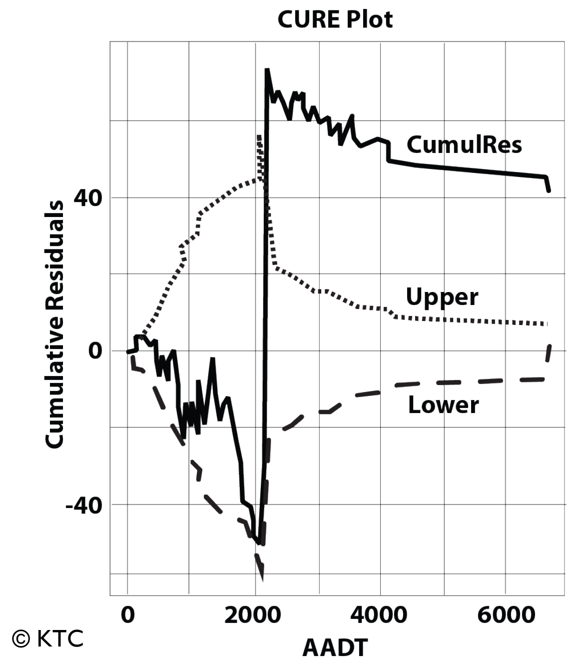

Figure 4. Graphic. CURE plot with a significant outlier around 2,000 AADT.

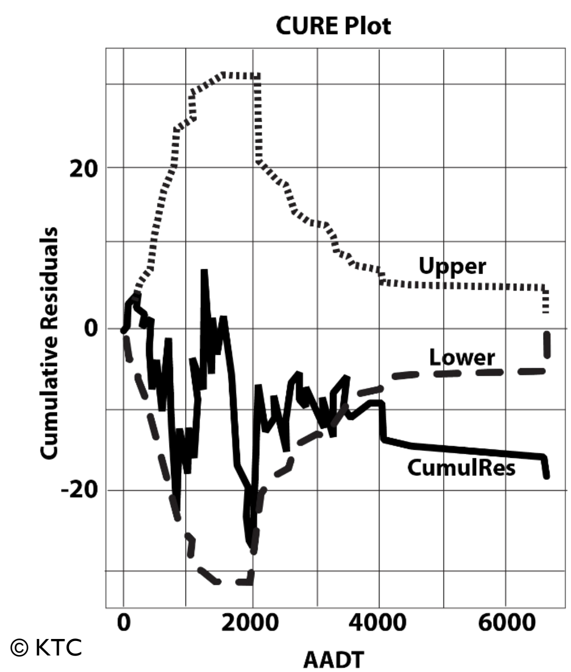

Figure 5. Graphic. CURE plot with the significant outlier removed.

Conclusions and Lessons Learned

The KYTC needed a data-driven method for prioritizing locations for safety-improvement projects to meet HSIP requirements. Through a university partnership, KYTC was able to develop SPFs for five different focus areas that span urban and rural roadway segments and intersections. These advanced, predictive methods account for regression-to-the-mean bias, compare expected crashes with observed crashes to determine excess crashes, and create a metric for finding locations that presented the greatest cost to the public associated with excess crashes.

In addition to the emphasis of specific focus areas and reference populations in Kentucky, the KTC and KYTC project team noted the importance of consistent, accurate data, as well as the appropriateness of careful site delineation and homogeneity. Thoughtful consideration of network segmentation was an important part of Kentucky's success. Future iterations of this method can be improved by having more complete or better-quality data (e.g., traffic volumes on local roads) for the purposes of SPF development.

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