Improving Safety Performance Function Model Fit Using Exploratory Regression Techniques

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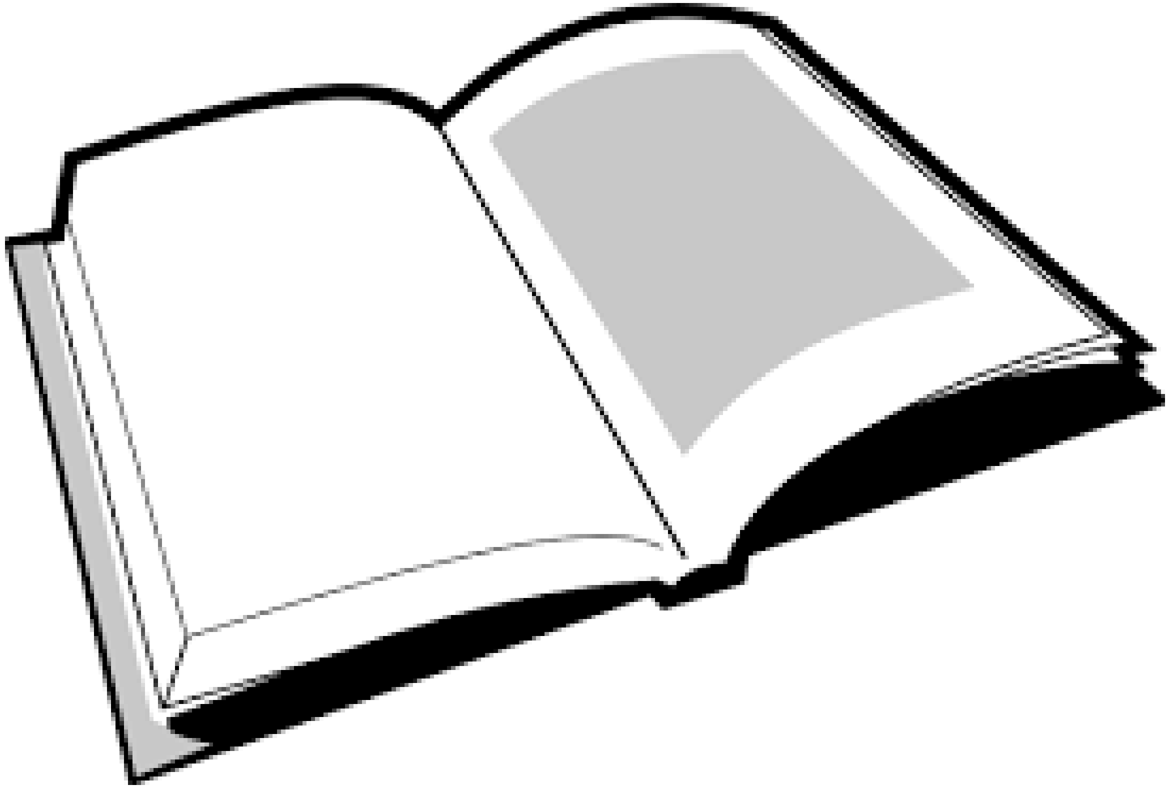
Presentation Outline

- ✓ **Background**
- ✓ **Motivation of the research**
- ✓ **Data Preparation**
- ✓ **Model Development and Results**
- ✓ **Recommendations**

Background



The Highway Safety Manual Approach

* In Kentucky, Potential for Safety Improvement (PSI) is referred to as Excess Expected Crashes (EEC)

$$\boldsymbol{EEC = SPF\ Predicted\ Crashes\ -\ EB\ Estimated\ Crashes}$$

Safety Performance Functions

- Negative Binomial Regression

$$SPF\ predicted\ crashes\ (N_{SPF}) = e^{\alpha} * Length * AADT^{\beta}$$

$$Variance = N_{SPF} + \frac{N_{SPF}^2}{\theta}$$

Here,

α, β = Regression parameters

θ = Inverse overdispersion parameter (1/k)

Base Conditions and Adjustment Factors

- **Base conditions:** Typically, the most frequently encountered geometric attributes
- **Adjustment Factors:** Used to adjust SPF crashes when any segment's geometric attributes are different from the SPF's base conditions.
- **Sources:**
  - ➢The Highway Safety Manual
  - ➢CMF Clearinghouse

$$\textbf{Adjusted SPF Crashes} = SPF\ Crashes\ for\ base\ condition * AF_1 * AF_2 * AF_3 * \cdots$$

Empirical Bayes (EB) Estimate

- Accounts for the regression-to-the-mean bias.
- **EB Expected Crashes** =
  $weight * SPF\ predicted\ crashes + (1 - weight) * observed\ on\ that\ site$

$$weight = \frac{1}{1 + \frac{N_{SPF}/Length}{\theta}}$$

Motivation of the research

Problem Statement

More Base Conditions
Less OVB
Better GOFs

No Base Conditions
Less OVB
Worse GOFs

More AFs

No AFs

Specific SPF

Generic SPF

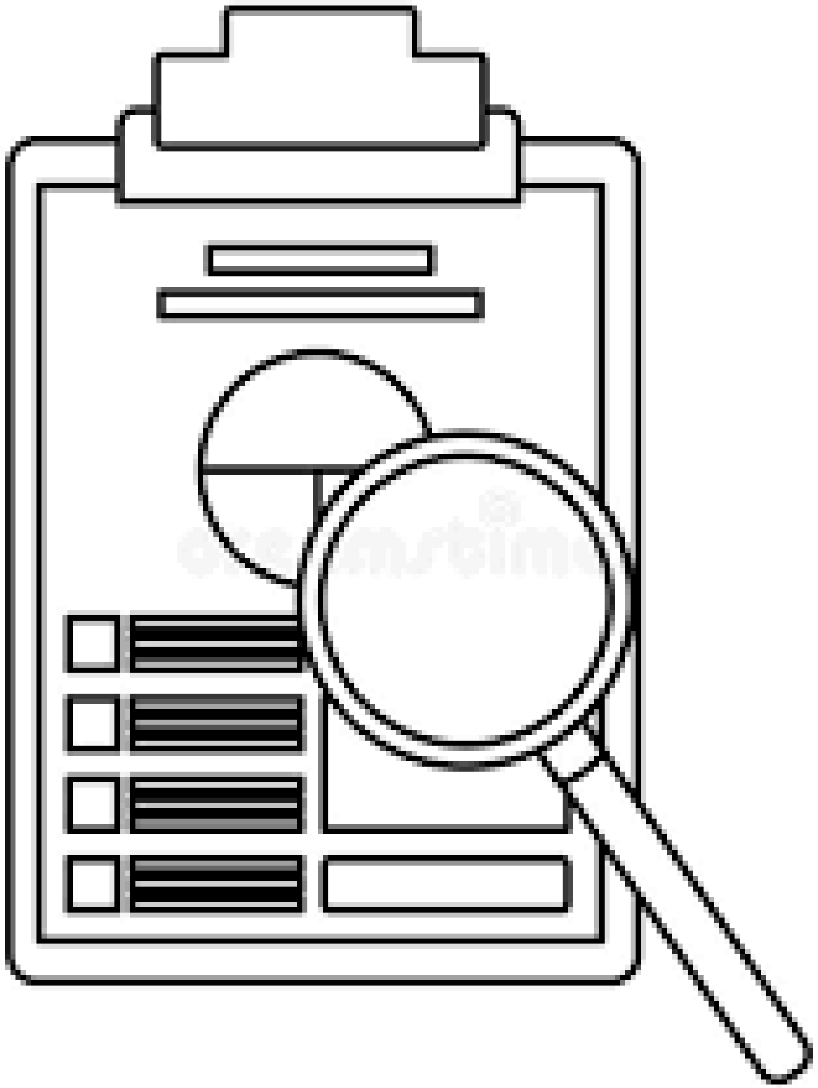
OVB = Omitted Variable Bias
GOF = Goodness-of-fit measures

Goal of the research

Explores the tradeoffs between SPF quality and network coverage by

- Expanding the range of base conditions
- Exploring alternate form of SPF

Data Preparation



Data Source

Roadway Data **(Rural two-lane)**

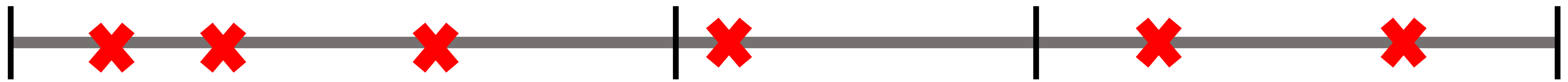
- Source: Highway Information System (HIS)

Crash Data **(KABCO)**

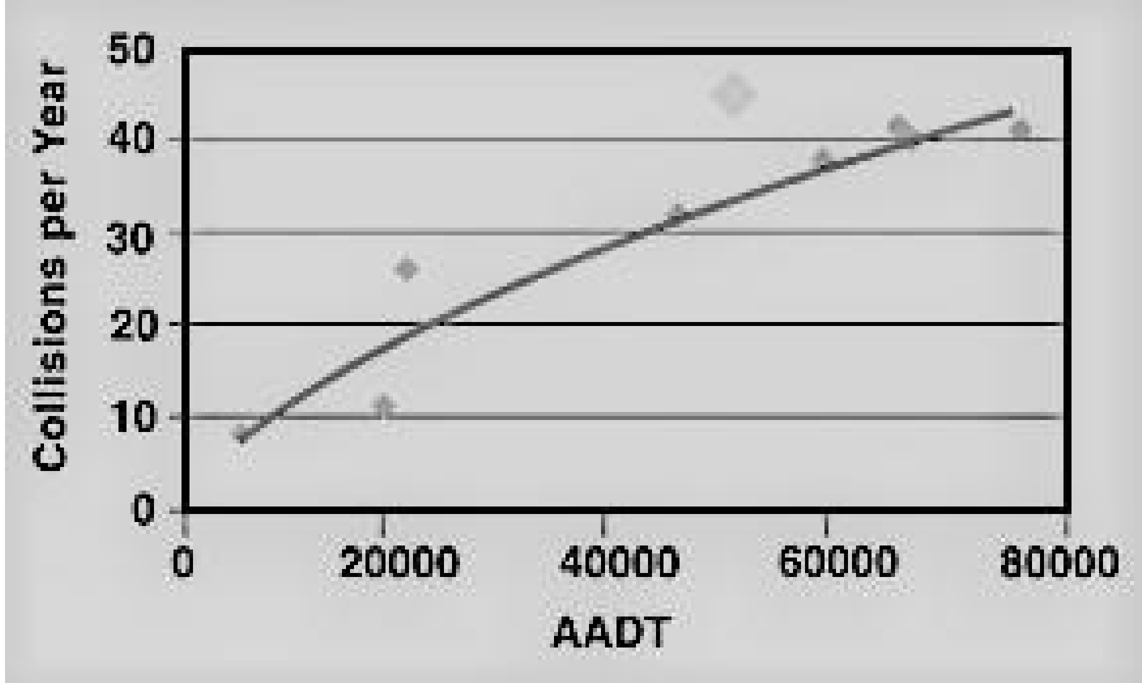
- Source: Kentucky State Police (KSP)
- Base year: 2013-2017

Segmentation and crash match

Criteria	Conditions
• AADT • Lane Width • Shoulder Width • Vertical Curve	• Minimum Segment Length = 0.05 mi • AADT>0 • No intersection or ramp



SPF Development and Results



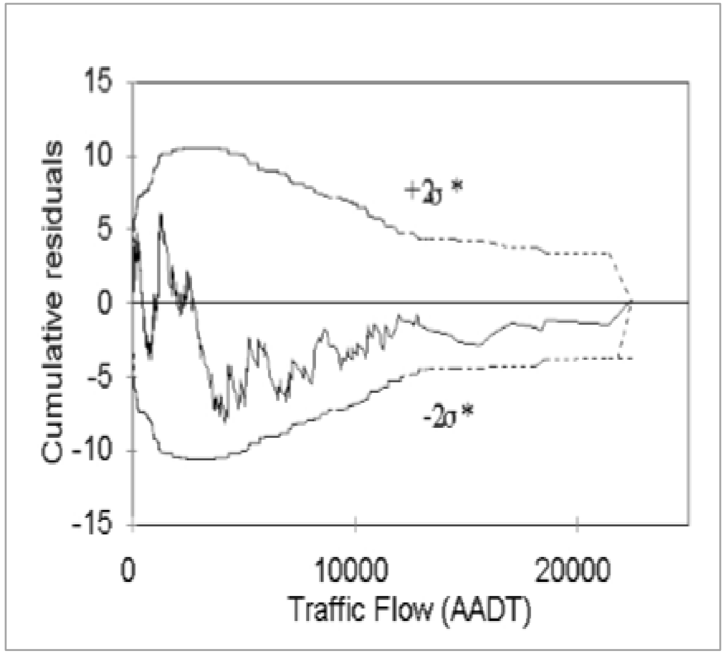
SPF Development

$$\boldsymbol{SPF\ crash\ estimate = e^{\alpha} * Length * AADT^{\beta}}$$

- Used an automation tool named "**SPF-R**", a script in RStudio: http://github.com/irkgreen/SPF-R

Assessing SPFs using CURE Plots

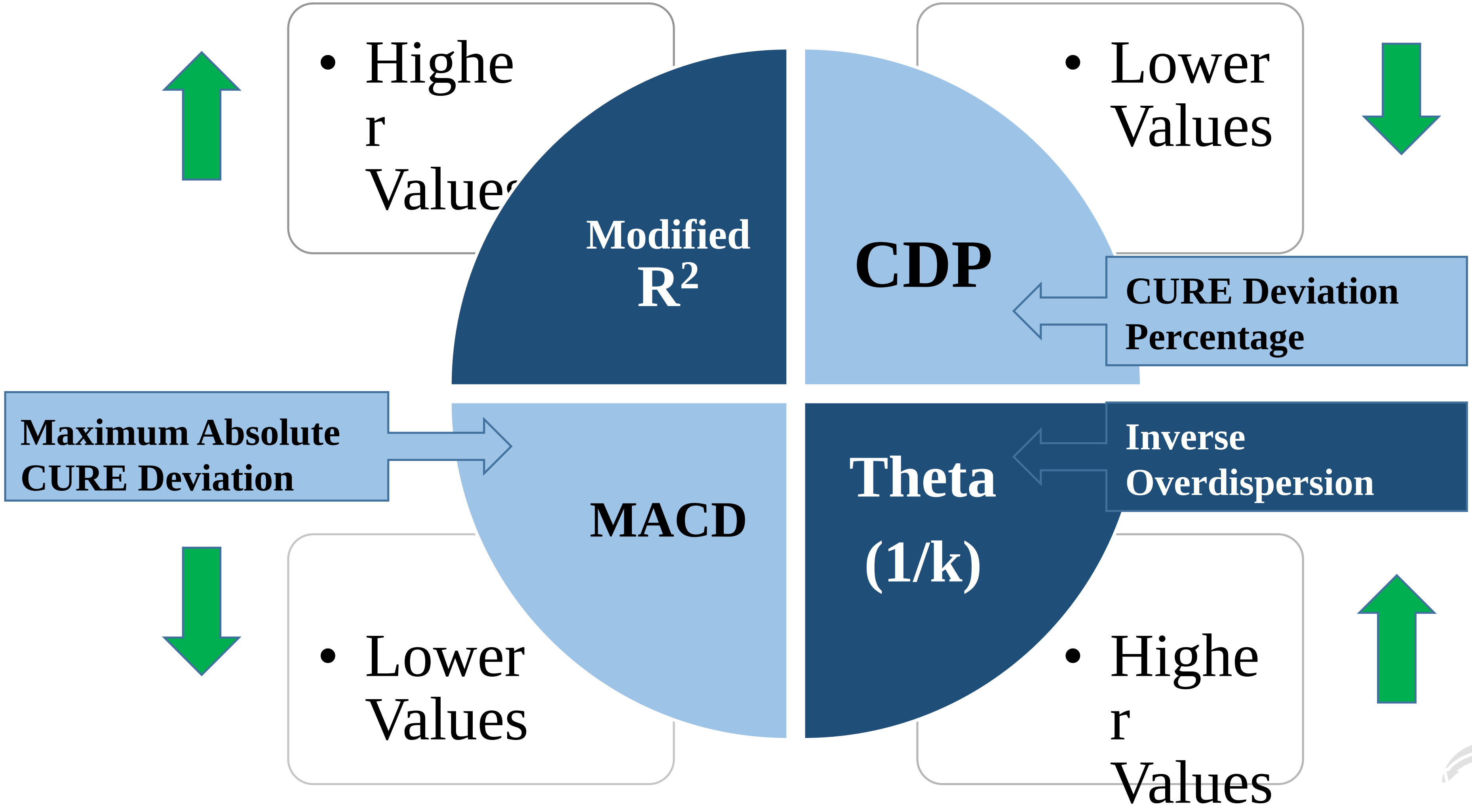
- Plots cumulative residual vs explanatory variable (e.g. AADT).
- Expected to oscillate around X-axis.
- Expected to stay within two standard deviations.
- Free of large vertical jumps
- Minimum upward or downward drifting.



Example CURE Plot with ±2σ confidence limits*

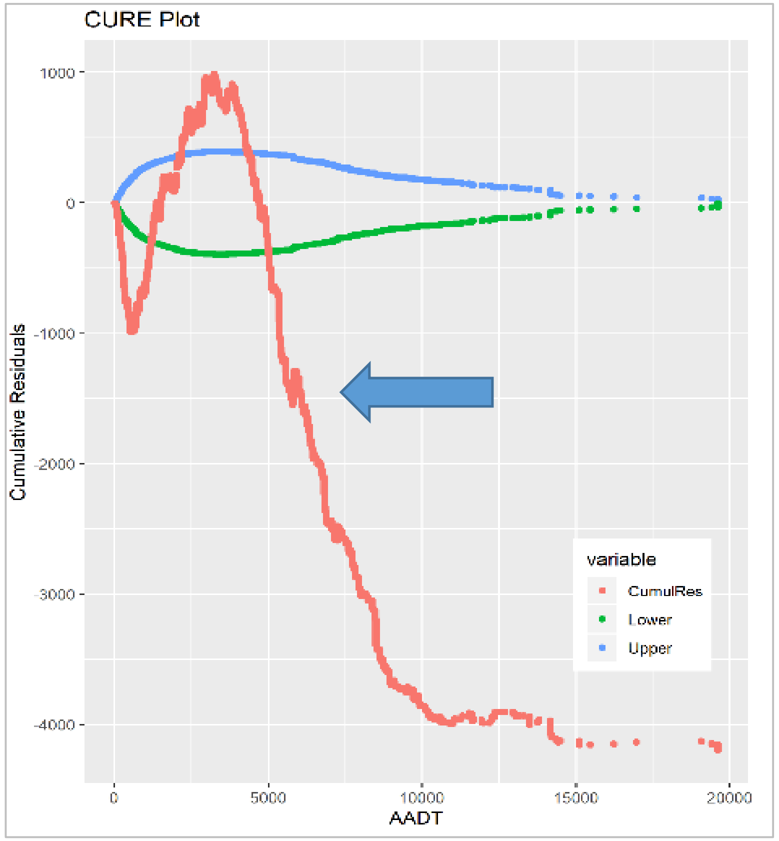
* Source: Hauer, E., Bamfo, J., 1997. Two tools for finding what function links the dependent variable to the explanatory variables, in: Proceedings of the ICTCT 1997 Conference, Lund, Sweden

Goodness-of-Fit Measures



Generic vs. Specific SPF

No base conditions



Lane Width = 9 ft
Shoulder Width = 3 ft
Grade Class = A

GR = A (0-0.4% grade)

Proposed Improvements

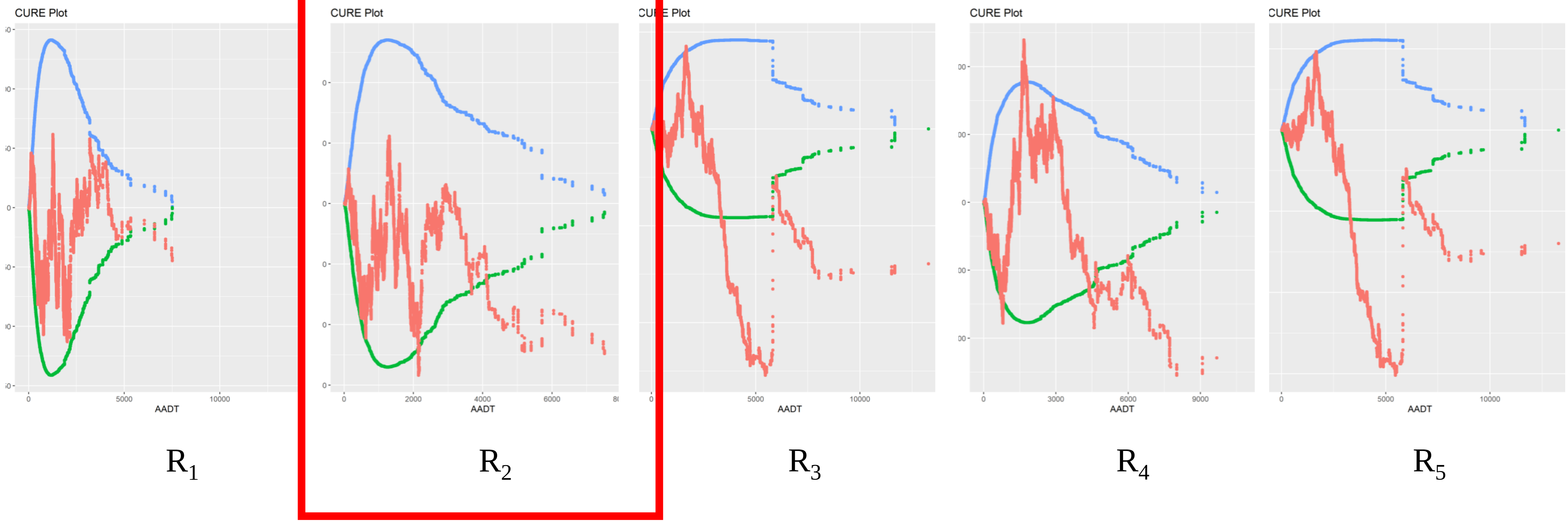
Expanding the range of base conditions

Exploring SPFs with additional explanatory variables

Expanding the range of base conditions

Models	Base Conditions		
	Lane Width	Shoulder Width	Curve
R1	9	0-3	A, B
R2	9	3-6	A, B
R3	9-13	3	A, B
R4	8-10	3	A, B
R5	9-12	3	A

CURE Plots



R1 R2 R3 R4 R5

Goodness-of-fit Measures

Models	CDP	MACD	Modified R^2	Theta
Generic	86.0	5582.9	0.26	1.163
Specific	0.6	101.0	0.65	2.230
R1	4.5	112.9	0.59	1.950
R2	**2.0**	**141.9**	**0.60**	**2.094**
R3	6.0	635.8	0.35	1.607
R4	12.0	254.7	0.55	1.873
R5	37.8	297.1	0.52	1.800

SPFs with additional explanatory variables

Model	Variable added	Model form
V1	Lane Width (LW)	$Y = L * e^{a} AADT^{b1} * e^{LW*b2}$
V2	Shoulder Width (SW)	$Y = L * e^{a} AADT^{b1} * e^{SW*b2}$
V3	Roadway Width (LW+SW)	$Y = L * e^{a} AADT^{b1} * e^{(LW+SW)*b2}$
V4	LW, SW	$Y = L * e^{a} AADT^{b1} * e^{LW*b2} * e^{SW*b3}$
V5	LW, SW, LW*SW (Interaction term)	$Y = L * e^{a} AADT^{b1} * e^{LW*b2} * e^{SW*b3} * e^{LW*SW*b4}$

SPFs with additional explanatory variables (cont.)

Model	Variable added	Model form
V6*	Degree of Curvature (CUDEG)	$Y = L * e^{a} * AADT^{b1} * (2 * CUDEG)^{b_2} * (\frac{CUDEG}{5730 * L})^{b3}$
V7*	LW, SW, CUDEG	$Y = L * e^{a} * AADT^{b1} * e^{LW*b2} * e^{SW*b3} * (2 * CUDEG)^{b_4} * (\frac{CUDEG}{5730*L})^{b5}$

* **Reference:** Bauer, K. M., and D. W. Harwood. Safety Effects of Horizontal Curve and Grade Combinations on Rural Two-Lane Highways. *Transportation Research Record*, Vol. 2398, No. 1, 2013, pp. 37–49. https://doi.org/10.3141/2398-05
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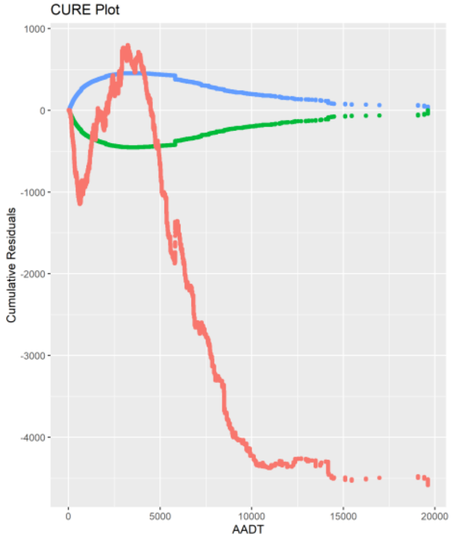
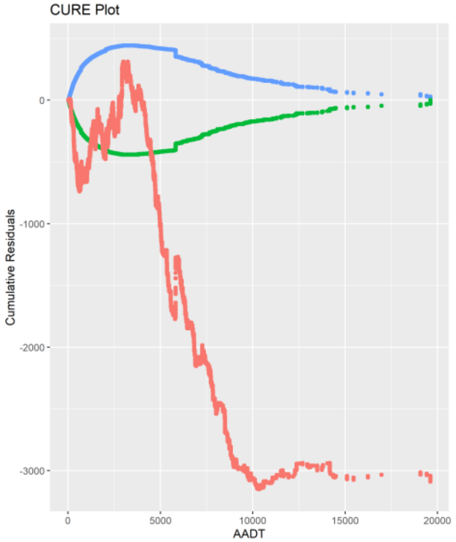
CURE Plots



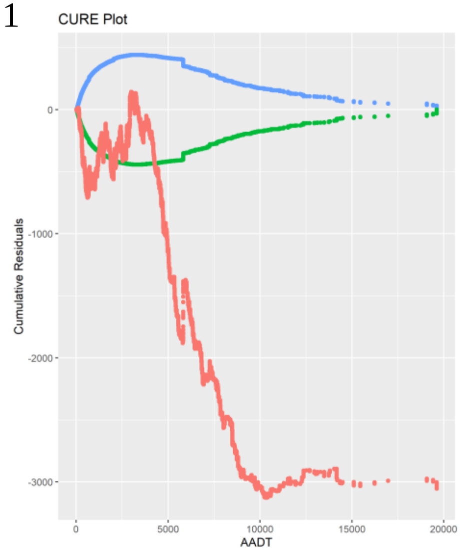
V_1



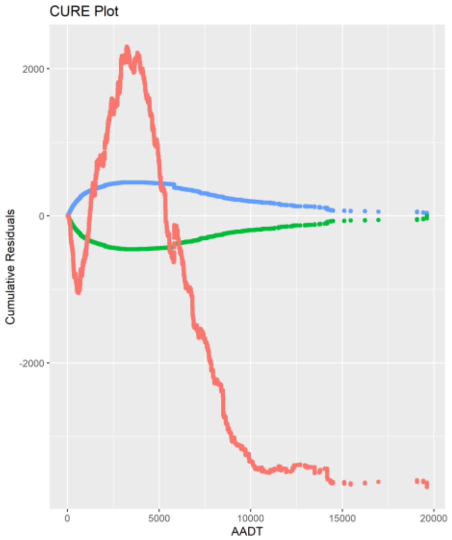
V_2

V_3

V_4



V_5



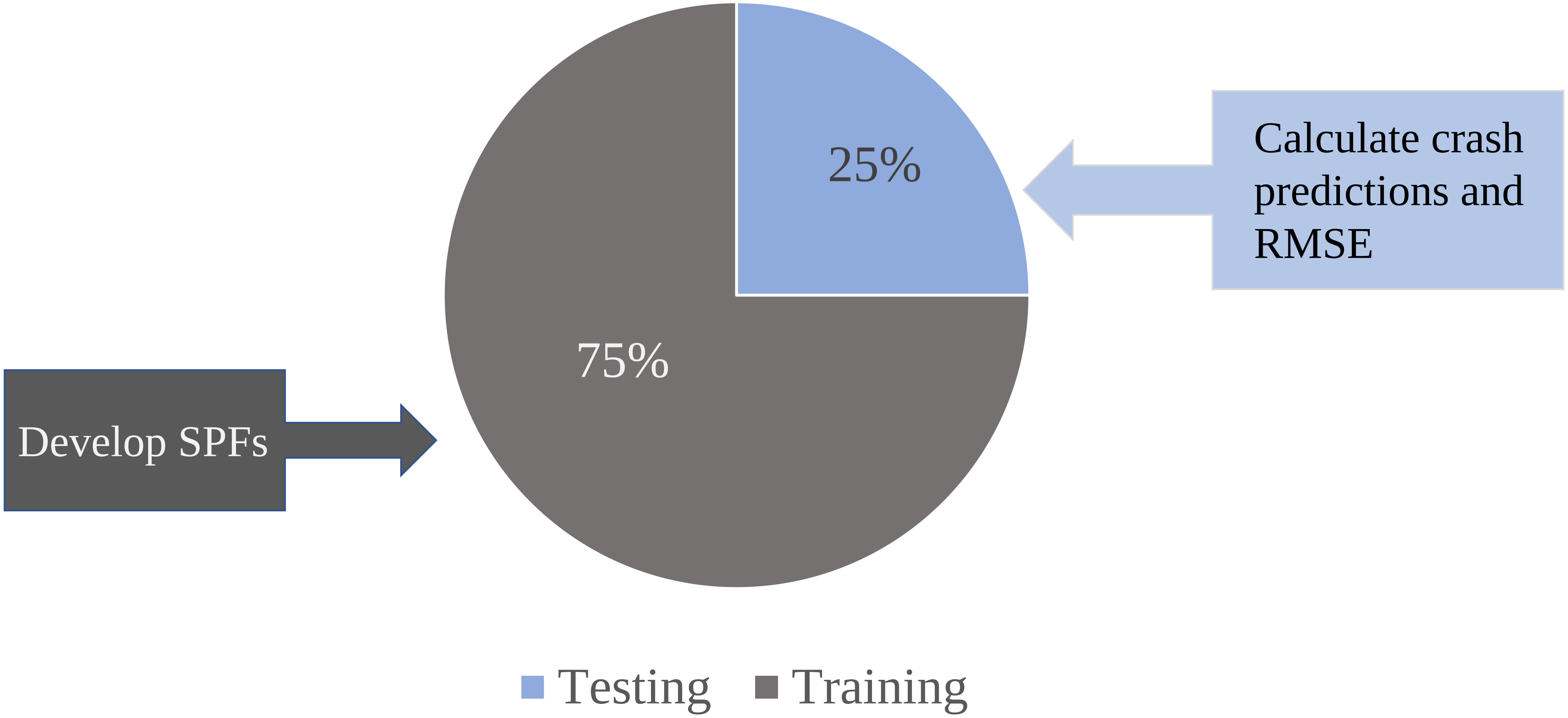
V_6

V_7

Goodness-of-fit Measures

Models	CDP	MACD	Modified R^2	Theta
Generic	86.0	5582.9	0.26	1.163
Specific	0.6	101.0	0.65	2.230
V1	76.6	4583.8	0.30	1.206
V2	64.7	3148.8	0.35	1.279
V3	65.1	3177.5	0.35	1.278
V4	64.9	3136.5	0.35	1.281
V5	65.6	3128.4	0.35	1.284
V6	90.0	3687.5	0.29	1.239
V7	63.4	1628.1	0.37	1.358

Cross Validation



Cross Validation Metric: Root Mean Square Error

Models	RMSE
Generic	1.27
Specific	0.94
R2	1.1
V7	1.15

Recommendation

Recommendations

SPFs with Base Conditions (specific/Range)	SPFs with explanatory variables ✓
• Better fit and predictive power • Still dependent on the availability of AFs	• Shows improvement in model fit and predictions compared to the generic model • Independent of any need for adjustments

Questions?

or

Comments?

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