An Empirical Bayes Before and After Safety Evaluation of Safety Edge Treatment in Iowa

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Introduction

Problem: Pavement Edge drop-off

- Pavement edge drop-off is the **vertical difference in elevation between the paved roadway and the adjacent ground.**
- **Serious safety concern** for vehicles that **goes off the track** and in order to immediately remount back on the paved roadway encounters **tire scrubbing effect**.
- **lane departure crashes**, rollovers, head-on collisions, sideswipes, etc.

An Edge Drop-off. Hallmark et al. (2006)

A typical Safety Edge. Source: FHWA.

Solution: Safety Edge

- **A 30 degree fillet** constructed along the outside edge of the paved section of roadway which provides a gradual rather than abrupt transition back to the roadway again.

Problem Statement

- Pavement edge drop-off contribute to **18%** of rural run-off-road **(ROR) crashes**. (Hallmark et. al., 2006).
- **11,000 injuries** and **160 fatalities** are caused **each year** due to unsafe pavement edges in the United States (FHWA, 2010).
- 150 fatal crashes on rural two-lane roads in Georgia (2004) suggested that **55% of the crashes included edge drop off issue** (Georgia, 2004).

Research Tasks

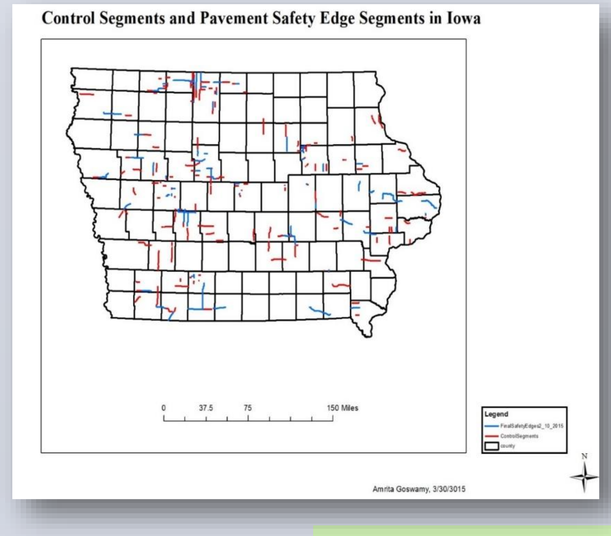
- Identify road segments provided with **Safety Edge in Iowa.**
- Identify **control segments**.
- Conduct a **before and after crash analysis** to evaluate **safety effectiveness** of Safety Edge **treatment.**
- Calculate crash modification factor **(CMF).**

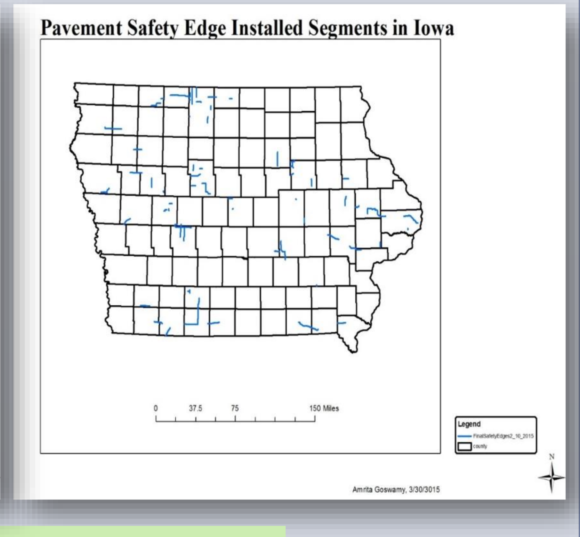
Data Sources and Description

- **Locations** of **Safety Edge** segments (Institute of Transportation and Iowa DOT).
- **Installation Periods** (Institute of Transportation and Iowa DOT).
- Road and traffic characteristics (Geographic Information Management System **(GIMS)**, Iowa DOT.
- **11 years** of crash data (Iowa DOT).
- Crash severity levels (HSIPM, 2010)
  - ✓ Fatal Injury Crashes **(K)**
  - ✓ Disabling Injury Crashes **(A)**
  - ✓ Visible Injury Crashes **(B)**
  - ✓ Possible Injury Crashes **(C)**
  - ✓ Property-Damage-Only **(PDO)**

Data Quality Assurance

- **GIMS** Characteristics **were checked** against information from site visits, aerial imagery, and Google forward roadway view.
- **Contiguous GIMS segments** with homogenous roadway characteristics were **combined**.
- Study was concentrated on **two-lane** rural roadways with **asphalt pavement** material and with speed limits of **45 mph or more**.
- Intersection related crashes were manually selected and deleted.
- All types of **run-off-road** crashes chosen as **target crashes.**





Statistical Method

Development of SPFs

Crash models were developed using **negative binomial regression** modeling that is derived from the Poisson model. Predicted number of crashes per segment per year for before and after periods were calculated from the following form:

$$E_i = L_i * EXP(\beta_0 + \beta_i X_i)$$

Empirical Bayes Method

Reduces regression to the mean effect

Expected before Crashes

$$N_{eb} = w\,(N_{pb}) + (1-w)\,(N_b),\quad w = \frac{1}{(1+\alpha N_{pb})}$$

where, N_{pb} = predicted before crash frequency from SPFs, α = estimated negative binomial model dispersion parameter.

Expected after crashes that would have occurred without the Safety Edge:

$$N_{ea}\,(Expected\ after) = N_{eb}\,(Expected\ before)\,\frac{N_{pa}\,(Predicted\ after)}{N_{pb}\,(Predicted\ before)}$$

Crash Modification Factor (CMF, Θ)

(Persaud et. al., 2001 and Hauer, 1997)

$$Biased\ estimate\ of\ CMF\ (\theta) = \frac{Total\ Observed\ After\ Crashes}{Total\ expected\ after\ crashes}$$

$$Unbiased\ estimate\ of\ CMF\ (\theta) = \frac{Biased\ estimate\ of\ CMF}{1+\left\{\frac{Var\,(Expected\ after)}{(Expected\ after)^2}\right\}}$$

Calculation of Variance of Θ and Standard Error (Persaud et. al., 2001 and Hauer, 1997)

The variance, $Var(\theta) = \theta[\{Var(\sum N_a)/(\sum N_a)^2\} + \{Var(N_{EA})/N_{EA}^2\}]/(1+\{Var(N_{EA})/N_{EA}^2\})$

where, N_a = Observed crash counts during the after period.

Standard error, $S.E.(\theta) = \sqrt{Var(\theta)}$

Safety Performance Functions (SPFs)

Severity Model	Parameter	All Types of Crashes SPFs		
		Estimate (β)	Std. Error	P-Value
KABCO	Intercept	-6.467	0.405	<0.000
	LNAADT	0.705	0.058	<0.000
	Curve	0.707	0.095	<0.000
	Rumbles	-0.249	0.105	<0.010
	ShdWDH>4	-0.472	0.093	<0.000
	α*	1.201	0.183	<0.000
KAB	Intercept	-8.377	0.826	<0.000
	LNAADT	0.795	0.116	<0.000
	Curve	0.601	0.181	<0.000
	ShdWDH>4	-0.549	0.19	<0.004
	α*	4.845	1.242	<0.001
PDO+C	Intercept	-6.497	0.461	<0.000
	LNAADT	0.662	0.066	<0.000
	Curve	0.731	0.11	<0.000
	Rumbles	-0.298	0.123	<0.015
	ShdWDH>4	-0.443	0.107	<0.000
	α*	1.057	0.247	<0.000

Crash Severity	Parameter	Target Crashes SPFs		
		Estimate (β)	Std. Error	P-Value
KABCO	Intercept	-6.771	0.452	<0.000
	LNAADT	0.718	0.064	<0.000
	Curve	0.761	0.099	<0.000
	Rumbles	-0.274	0.110	<0.012
	ShdWDH>4	-0.372	0.101	<0.000
	LaneWDH<12	0.254	0.114	<0.026
	α*	1.266	0.197	<0.000
KAB	Intercept	-8.199	0.874	<0.000
	LNAADT	0.755	0.123	<0.000
	Curve	0.647	0.193	<0.001
	ShdWDH>4	-0.529	0.201	<0.009
	α*	6.009	1.532	<0.001
PDO+C	Intercept	-6.862	0.511	<0.000
	LNAADT	0.681	0.072	<0.000
	Curve	0.779	0.113	<0.000
	Rumbles	-0.313	0.128	<0.015
	ShdWDH>4	-0.326	0.117	<0.005
	LaneWDH<12	0.279	0.130	<0.032
	α*	0.959	0.247	<0.000

Results

All Types of Crashes

	Crashes in the after period		CMF (Θ)	S.E.	95% confidence interval	% Reduction
	Observed	EB estimate				
KABCO	602	695	0.870	0.035	(0.800,0.939)	13.14*
KAB	97	105	0.837	0.085	(0.669,1.000)	16.47*
PDO+C	505	631	0.801	0.036	(0.731,0.871)	19.96*

Target Crashes

	Crashes in the after period		CMF (Θ)	S.E.	95% confidence interval	% Reduction
	Observed	EB estimate				
KABCO	231	260	0.890	0.059	(0.775,1.005)	11.11
KAB	61	69	0.891	0.115	(0.666,1.115)	10.99
PDO+C	170	189	0.901	0.069	(0.765,1.037)	10.02

Conclusion

- **13.4% reduction** for **all types of KABCO** crashes after the construction of Safety Edge.
- **16.5% reduction** for **all types of KAB (fatal, major and minor injury) crashes**.
- **20% reduction** in **all types of possible injury (C) and PDO** crashes.
- Above **results are statistically significant at 95% confidence level**.
- Crash **reduction** for **target crashes** ranged from **10% to 11%** for the three different crash severity levels but **were not statistically significant at 95% confidence level**.

Limitations and Future Studies

- **One third of the total crashes** were **not coded** with any **sequence of events**.
- Problems in selection of target crashes.
- Improvement in **accuracies of GIMS** data may improve results.
- Future studies: effectiveness of Safety Edge on 4-lane roads. CMFs for Safety Edge on PCC pavement.

References

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- *Iowa DOT, Iowa Department of Transportation.*