Guidelines for Designing Bridge Piers and Abutments for Vehicle Collisions (9-4973-1)

Crash Risk Analysis

by

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Outline

- Data Collection Process
- Characteristics of the Data
- Crash Risk Analysis
- Example Applications
- Comparison between TX and MN
- Summary

Data Collection

Texas:

Crash Data:

- Collected from Department of Public Safety (DPS) for the years 1998-2001.
- Contained information about crash location, crash type, crash time, vehicle type, causing factors, etc.

Network Data:

- Collected using RHINO and Texas Reference Marker (TRM), databases managed by the Texas Department of Transportation (TxDOT).
- Only segments that are defined as interstates, state and US highway main lanes were considered.

Bridge Location Data:

- Collected from TxDOT Transportation Planning and Programming Division.

Data Collection

Minnesota:

Crash and Network Data:

- Collected from Federal Highway Administration's (FHWA) Highway Safety Information System (HSIS) for the years 2002-2006.
- Contained information about crash location, crash type, crash time, vehicle type, causing factors, etc.
- Only segments that are defined as interstates, state and US highway main lanes were considered.

Bridge Location Data:

- Collected from Minnesota Department of Transportation (MnDOT).

Data Characteristics

- Highway sections were separated into divided and undivided segments.
- Separate analysis was also carried out for horizontal curves and tangent sections in Texas.

Undivided segments:

Variable	Texas	Minnesota
Years	1998-2001	2002-2006
Number of sites	350	54
Average segment length (mile)	0.75	0.49
Average bridge density (bridges/mile)	3.91	12.1
Average Shoulder Width (ft)	5.81	6.14
Average lane width (ft)	12.23	12.37
Average Truck AADT	928	673
Total ROR crashes	640	3
Total HBP crashes	7	2

Data Characteristics

Divided segments:

Variable	Texas	Minnesota
Years	1998-2001	2002-2006
Number of sites	2,486	552
Average segment length (mile)	1.15	1.006
Average bridge density (bridges/mile)	4.07	12.33
Average right shoulder width (ft)	9.54	9.05
Average lane width (ft)	12.01	12.23
Average Truck AADT	6,696	3346
Total ROR crashes	32,326	421
Total HBP crashes	159	28

Crash Probability

Probability of a heavy vehicle to runoff the road:

P_{T_ROR} = the number of truck ROR crashes / the number of opportunities

Where,

Number of opportunities= TAADT*365*Y

Probability of a heavy vehicle to hit a bridge pier after running off the road:

P_{HBP/T_ROR} = the number of trucks hitting a bridge pier / the number of Trucks ROR crashes

Probability of a heavy vehicle to hit a bridge:

$P_{HBP} = P_{HBP/T\_ROR} * P_{T\_ROR}$

Annual Frequency the bridge pier is hit is given as:

$$AF = TAADT * P_{HBP} * 365$$

Crash Probability

Crash Probability Analysis (Texas Data)

Variables	Undivided	Divided
Number of Sites	350	2486
Total Length (miles)	264.2	2862.9
ROR Crashes (4-year)	640	32326
Hit Bridge Pier Crashes (4-year)	7	159
Opportunities	$4.742*10^{8}$	$2.43*10^{10}$
P_{T_ROR}	**$2.21*10^{-6}$**	**$1.79*10^{-6}$**
P_{HBP/T_ROR}	0.011	0.005
P_{HBP}	**$2.42*10^{-8}$**	**$8.83*10^{-9}$**

Crash Probability

Crash Probability Analysis on Tangent Sections and Horizontal Curves (Texas Data)

	Undivided		Divided	
Variables	Tangents	Curves	Tangents	Curves
Number of Sites	156	25	912	540
Total Length (miles)	64.2	6.9	707.8	161.4
ROR crashes (4yrs)	203	24	8664	3468
Hit bridge pier crashes (4yrs)	2	0	46	49
Opportunities	$2.094*10^{8}$	$3.259*10^{7}$	$8.936*10^{9}$	$5.498*10^{9}$
P_{T_ROR}	**$2.209*10^{-6}$**	**$4.156*10^{-6}$**	**$1.897*10^{-6}$**	**$2.545*10^{-6}$**
P_{HBP/T_ROR}	0.00985	--	0.00531	0.0141
P_{HBP}	**$2.176*10^{-8}$**	--	**$1.007*10^{-8}$**	**$3.596*10^{-8}$**

Crash Probability

Crash Probability Analysis (Minnesota Data)

Variables	Undivided	Divided
Number of Sites	54	552
Total Length (miles)	26.8	555.3
ROR Crashes (5-year)	3	421
Hit Bridge Pier Crashes (5-year)	2	28
Opportunities	$6.637*10^{7}$	$2.697*10^{9}$
P_{T_ROR}	$2.03*10^{-8}$	$3.29*10^{-7}$
P_{HBP/T_ROR}	0.67	0.067
P_{HBP}	$1.35*10^{-8}$	$2.19*10^{-8}$

Regression Analysis

Negative Binomial distribution

The number of crashes 'Y_i' for a particular i^{th} site when conditional on its mean is Poisson distributed and independent over all sites and time periods

$$Y_{it} | \lambda_{it} \sim Po(\lambda_{it})$$

The mean of the crashes is structured as

$$\lambda_{it} = \mu_{it} \exp(\varepsilon_{it})$$

Where μ_{it} is the function of covariates f (X, β),

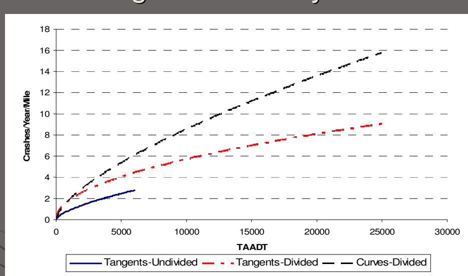
$\beta = \beta_0 .....\beta_k$ are the vector of regression coefficients, and

X's are the vector of traffic flow and site specific covariates

$$\exp(\varepsilon_{it}) | \alpha \sim gamma\ (1/\alpha, 1/\alpha)$$

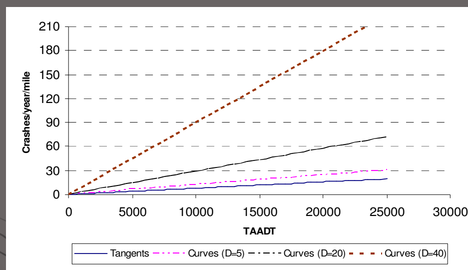
$$\alpha \sim gamma\ (a, b)$$

Regression Analysis



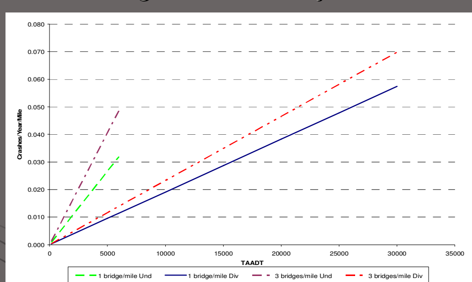
Relationship between Truck ROR Crashes and TAADT on Tangent Sections and Horizontal Curves (Texas Data)

Regression Analysis



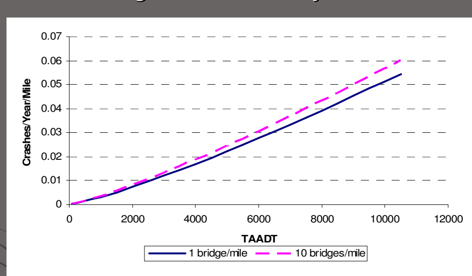
Relationship between ROR Crashes and TAADT with the Change in Degree of Curvature on Divided Segments (Texas Data)

Regression Analysis



Relationship between Truck Hitting Bridge Pier Crashes and TAADT (Texas Data)

Regression Analysis



Relationship between Truck Hitting Bridge Pier Crashes and TAADT (Minnesota Data)

Practical Application- 1

A new bridge is planned to be constructed on I-10. The TAADT on this highway is 6000 vehicles per day. The designer is interested in finding the frequency of the bridge to be hit by a heavy vehicle.

Using the values found in Table 5.17, the probability for a truck to hit bridge pier (P_{HBP}) on a divided highway is estimated to be 8.83*10-9.

The annual frequency (AF) the bridge pier is hit can be calculated as:

$$AF = TAADT \times P_{HBP} \times 365$$

$$AF = 6000 \times 8.83 \times 10^{-9} \times 365 = 0.0161$$

The bridge may be hit about once every 62 years.

Practical Application- 2

Due to a train derailment, a bridge spanning on the top of that railway has been damaged. The heavy trucks are diverted to an adjacent highway. This alternative route is 10 mile long undivided highway with an average of 2 bridges/mile. The existing heavy truck traffic is 7000 vehicles/day and because of re-routing, another 5000 heavy trucks will be added to it. One bridge pier has been hit over the last five years on this route. The designer is interested in finding the frequency of the hit bridge pier crash by a heavy vehicle.

Step 1: Calculate the crash risk on the alternative route with existing traffic

Using equation (5) and table 5.23, the expected hit bridge crashes is given as:

$$\mu_i = \frac{F_i \times L_i \times 365}{1,000,000} \beta_0 e^{\sum_{i=1}^{n} x_i \beta_i}$$

$$\hat{\mu} = \frac{19000 \times 10 \times 365}{1,000,000} e^{-4.437} \times e^{0.210*2} = 1.25$$

The predicted frequency of a heavy truck to hit a bridge pier is given as 1.25*0.14= 0.175 crashes/year

Practical Application- 2

Step 2: Calculate the Empirical Bayes (EB) estimate with the existing traffic

Using equation (7), the EB estimate is given as:

$$\hat{\hat{\mu}}_{it} = (1 - \omega_{it}) y_{it} + \omega_{it} \hat{\mu}_{it}$$

The weight factor is given as follows:

$$\omega_{it} = 1/(1 + \alpha \times \hat{\mu}_{it})$$

$$\omega_{it} = 1/(1 + (0.175 \times 1/0.122)) = 0.139$$

Over the last five years, the predicted crashes would be 0.175*5= 0.875

The EB estimate for hit bridge crashes over the last five years is:

$$\hat{\hat{\mu}}_{it} = (1 - 0.139) * 1 + 0.139 \times 0.875 = 0.983$$

Thus the EB estimate is 0.983/5= 0.197 crashes/year.

Practical Application- 2

Step 3: Calculate the EB estimate on the alternative route with the new and existing traffic

The EB estimate for heavy truck hit bridge pier crashes in the next year is given as:

$$\hat{\mu}_{it} = \frac{12000}{7000} \times 0.197 = 0.34$$

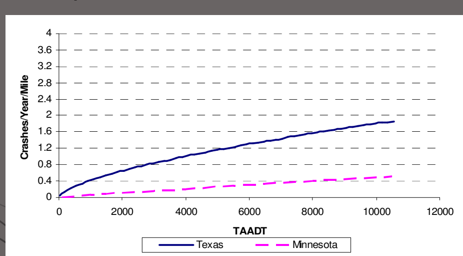
Thus, we can expect a hit bridge pier crash by heavy truck in the next three years on this route.

Comparison between TX and MN

Crash Probability Analysis (Divided Roads)

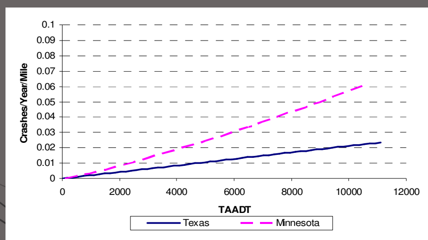
Variables	Texas	Minnesota
Number of Sites	2486	552
Total Length (miles)	2862.9	555.3
ROR Crashes (4-year)	5323	421
Hit Bridge Pier Crashes (4-year)	30	28
Opportunities	$8.33*10^{9}$	$2.697*10^{9}$
P_{T_ROR}	**$5.24*10^{-7}$**	**$3.29*10^{-7}$**
P_{HBP/T_ROR}	0.0056	0.067
P_{HBP}	**$2.93*10^{-9}$**	**$2.19*10^{-8}$**

Comparison between TX and MN



Relationship between Truck ROR Crashes and TAADT on Divided Roads

Comparison between TX and MN



Relationship between Truck Hitting Bridge Pier Crashes and TAADT on Divided Roads with 3 Bridges per Mile

Summary

- Crash risk analysis using Texas data showed that the undivided segments have higher risk for a truck to hit bridge pier than for divided segments.
- Horizontal curves have higher risk of having heavy vehicle running off the road and hit bridge pier crashes than the tangent sections.
- Crash risk analysis showed that the probability for a heavy vehicle to run-off-the-road is higher in Texas than in Minnesota.
- Crash risk analysis also showed that the probability for the heavy vehicle to hit a bridge pier is higher in Minnesota than in Texas.

THANK YOU

Questions???