Estimating Crash Risk Using Naturalistic Driving Study Data

Feng Guo, Ph.D.
Virginia Tech Transportation Institute
Department of Statistics
Virginia Tech

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Estimating Crash Risk: Outline

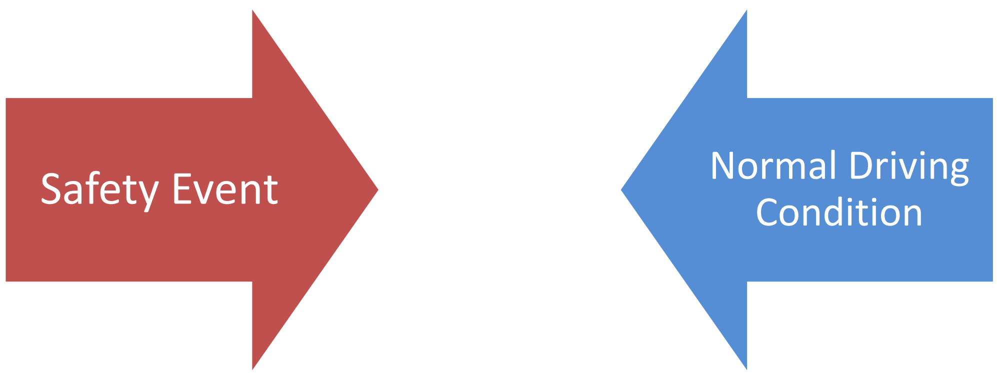
- Overview
- Case-cohort and case-crossover approaches: results and lessons learned
- Near-crashes as crash surrogates for risk assessment purpose

Naturalistic Driving versus Crash Database

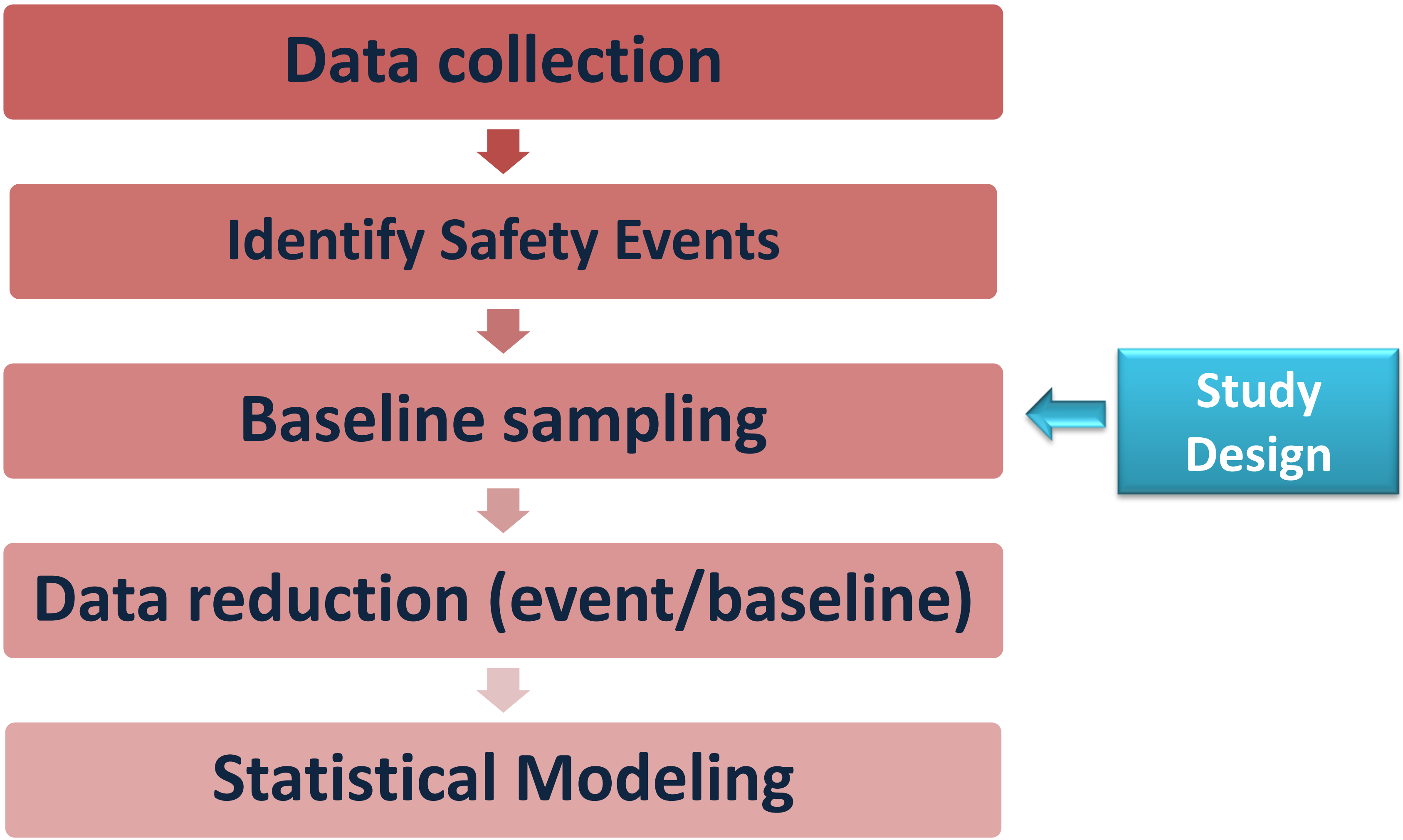
	Crash Database	Naturalistic driving data
Sample population	All drivers: limited selection bias	Participants only: selection bias
Source	Police report: small proportion of actual accidents	Data collection system: all safety events
Information source	Driver/witness statements, retrospective: information bias	High resolution video and instrument recording
Driver behavior	Limited/unreliable information	Accurate/detailed information through data reduction

Risk Assessment

- Presence of a factor at crash ≠ Risk
- Comparing exposure status for safety events and for normal driving conditions.
- Naturalistic driving data provides detailed and accurate exposure information

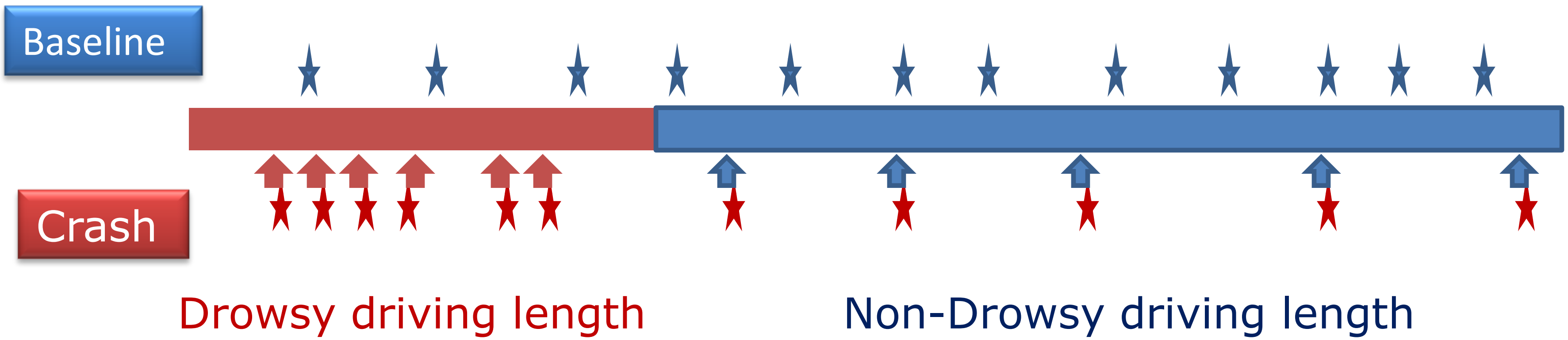


Modeling Crash Likelihood Framework

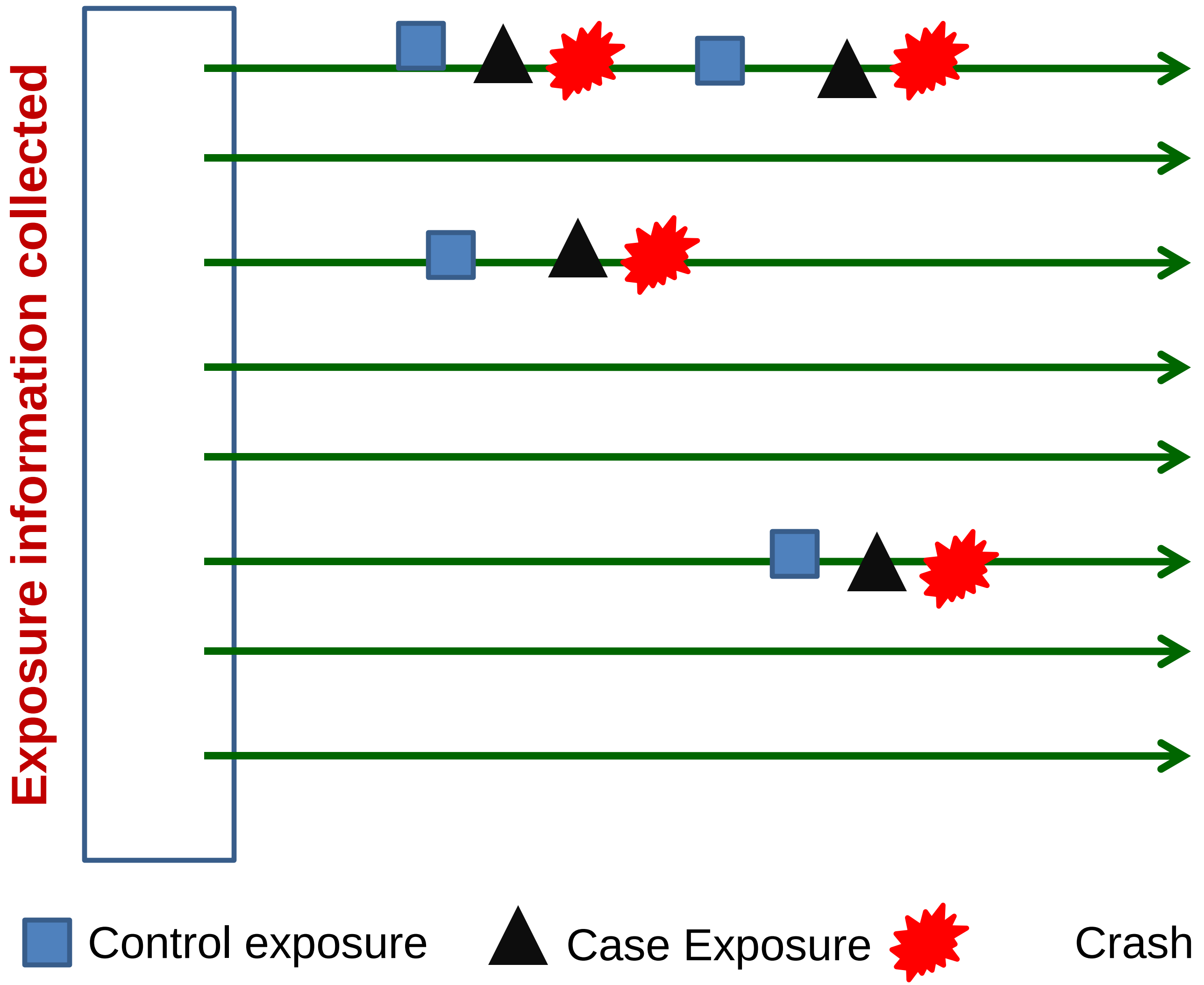


Modeling 100-Car: Case-Cohort Approach

- Sample short (6 second) epochs from the videos
- Sampling Scheme: Random sampling stratified by vehicle travel time
- Independent of crash/near-crash



Case-Crossover



Sample exposure immediate before crashes

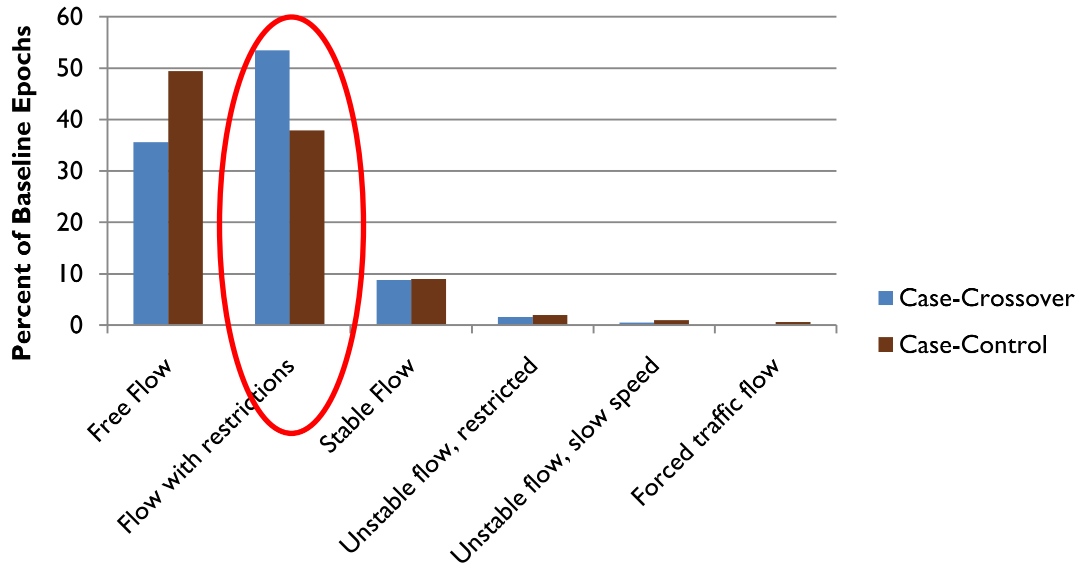
Sample exposure for time interval some period before crash

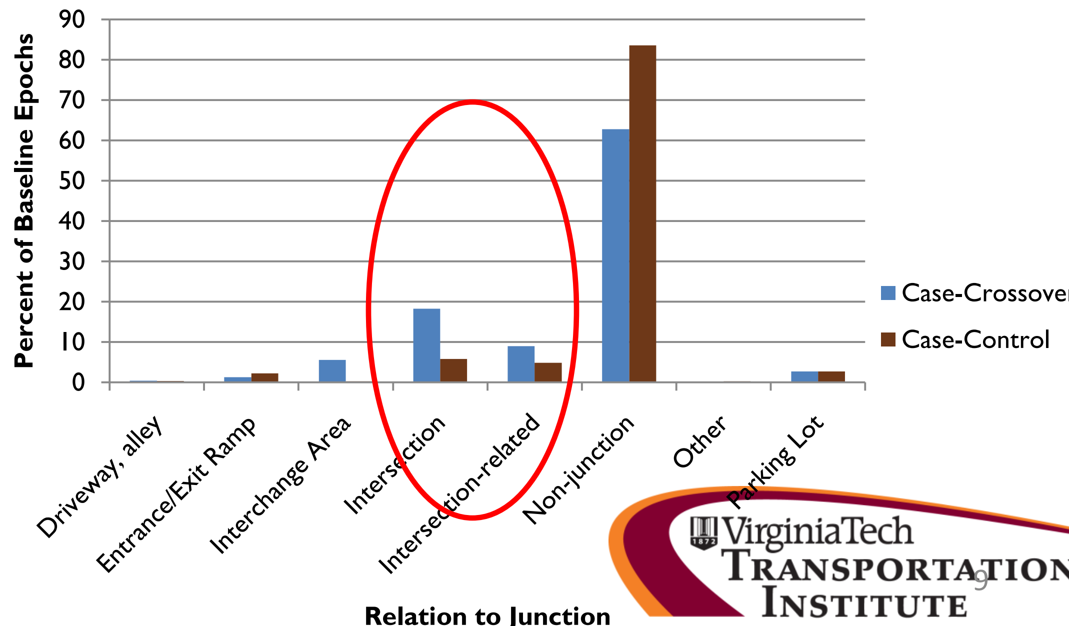
Matched Factors

- Driver ID
- Day of week (weekday versus weekend)
- Time of day (± 2 hours)
- Same GPS Location (± 100 Meters OR match to relation to junction)
- Must occur *prior to* crash/near-crash occurrence.

- Goal: 15 baselines for every crash/near-crash event.

Differences between the Case-Crossover and Case-Control





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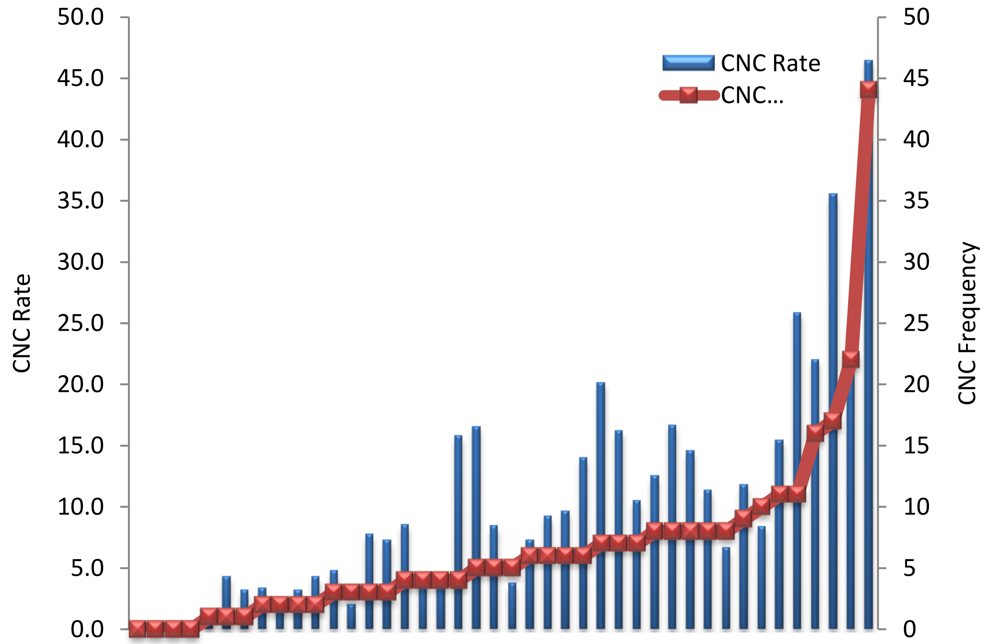
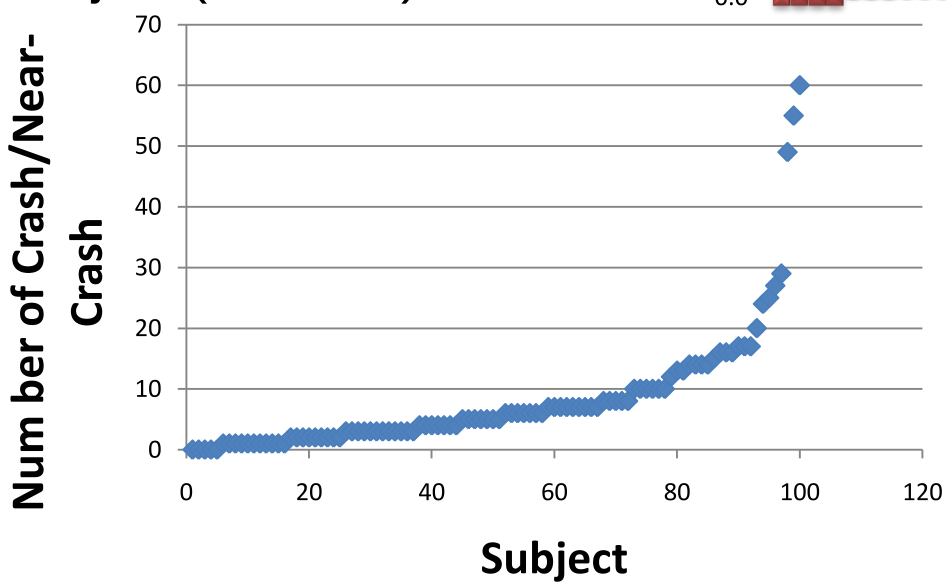
Individual Variation: Good Driver, Bad Driver

Teen driver crash/near crash rate



Number of safety events by subject (100-Car)



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Case-Cohort: Generalized Mixed Effect Model

Model specification

$$y_i = \begin{cases} 1 & Crash \\ 0 & No\ Crash \end{cases}$$

$$y_i \sim Binomial(1, p_i)$$

$$\log\left(\frac{p_{ij}}{1-p_{ij}}\right) = \mathbf{X}_{ij}\boldsymbol{\beta} + \mathbf{Z}_{ij}\boldsymbol{\alpha}_i$$

where p_i is the probability of crash for *i*th observation
X_{1i} is the 1st covariate for event *i*;
β's are the regression parameters
$\boldsymbol{\alpha}_i$ is the driver specific random effect

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Case-Crossover: Conditional Logistic Regression

Let p_{ij} be the probability of crash/near-crash for *jth* observation in *ith* matched set.

Define

$$Y_{ij} = \begin{cases} 1 & \text{if the jth observation in ith matched set is a crash /near} - \text{crash.} \\ 0 & \text{if the jth observation in ith matched set is a baseline.} \end{cases}$$

The matched sampling mechanism leads to:

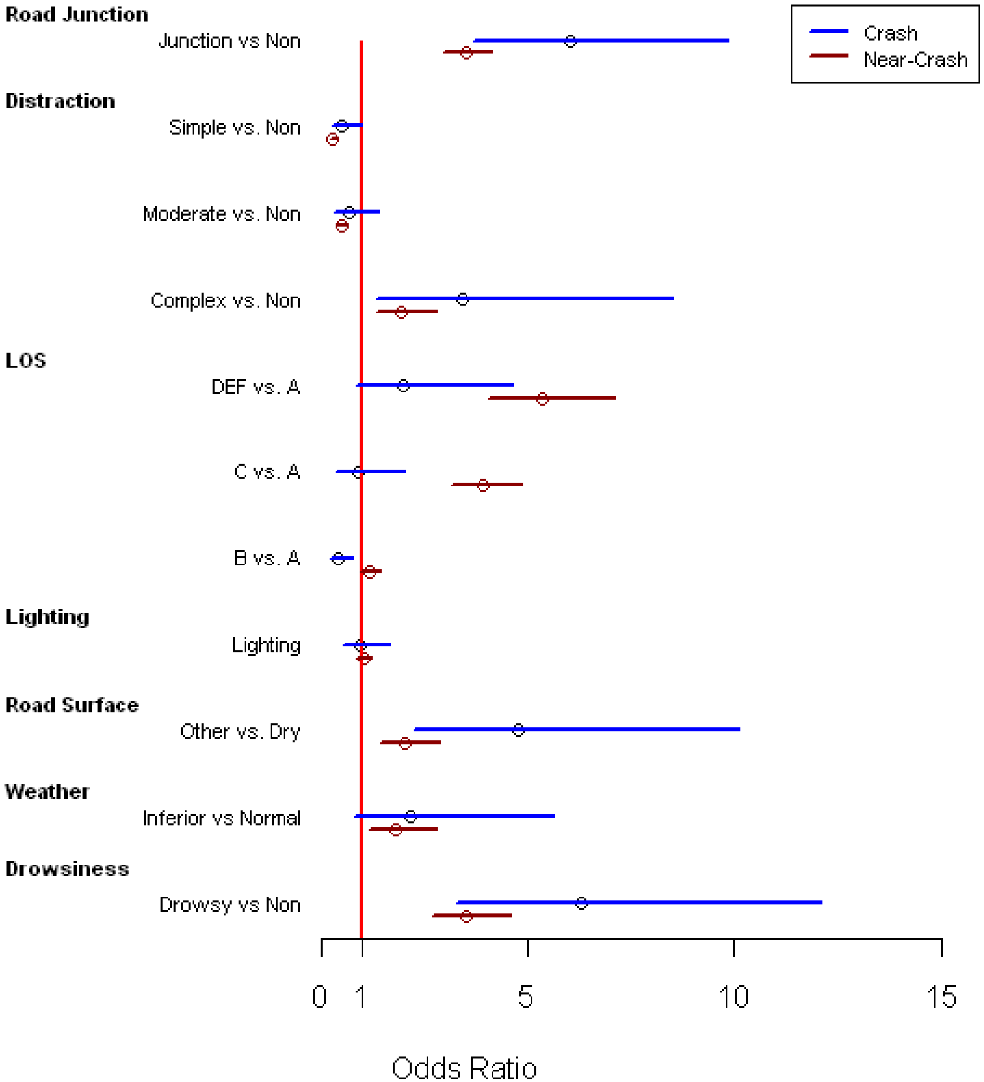
$$\sum_j Y_{ij} = 1$$

$$\text{logit}\left(p_{ij} \middle| \textstyle\sum_j Y_{ij} = 1\right) = \beta * \text{drowsy}_{ij},$$

In this model exp (β) is the estimated OR.

Case-Cohort: Crash Risk

- Drowsiness increases crash risk by 6 times
- Complex secondary task increase the risk by 3 times
- Crashes are more likely to happened in roadway junction areas (6-fold increase)
- Crashes are 5 times more likely to happened on wet, snowy, or muddy road surface.



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Comparing Secondary Task Engagement OR for Case-Crossover versus Case-Control

Distraction	Case Cross-over Odds Ratio	95% Odds Ratio Confidence Limits		Case-Control Odds Ratios	95% Odds Ratio Confidence Limits	
Simple	0.8	0.62	1.05	1.2	0.88	1.57
Moderate	**1.3**	**1.00**	**1.70**	**2.1**	**1.62**	**2.72**
Complex	**2.1**	**1.19**	**3.58**	**3.1**	**1.72**	**5.47**

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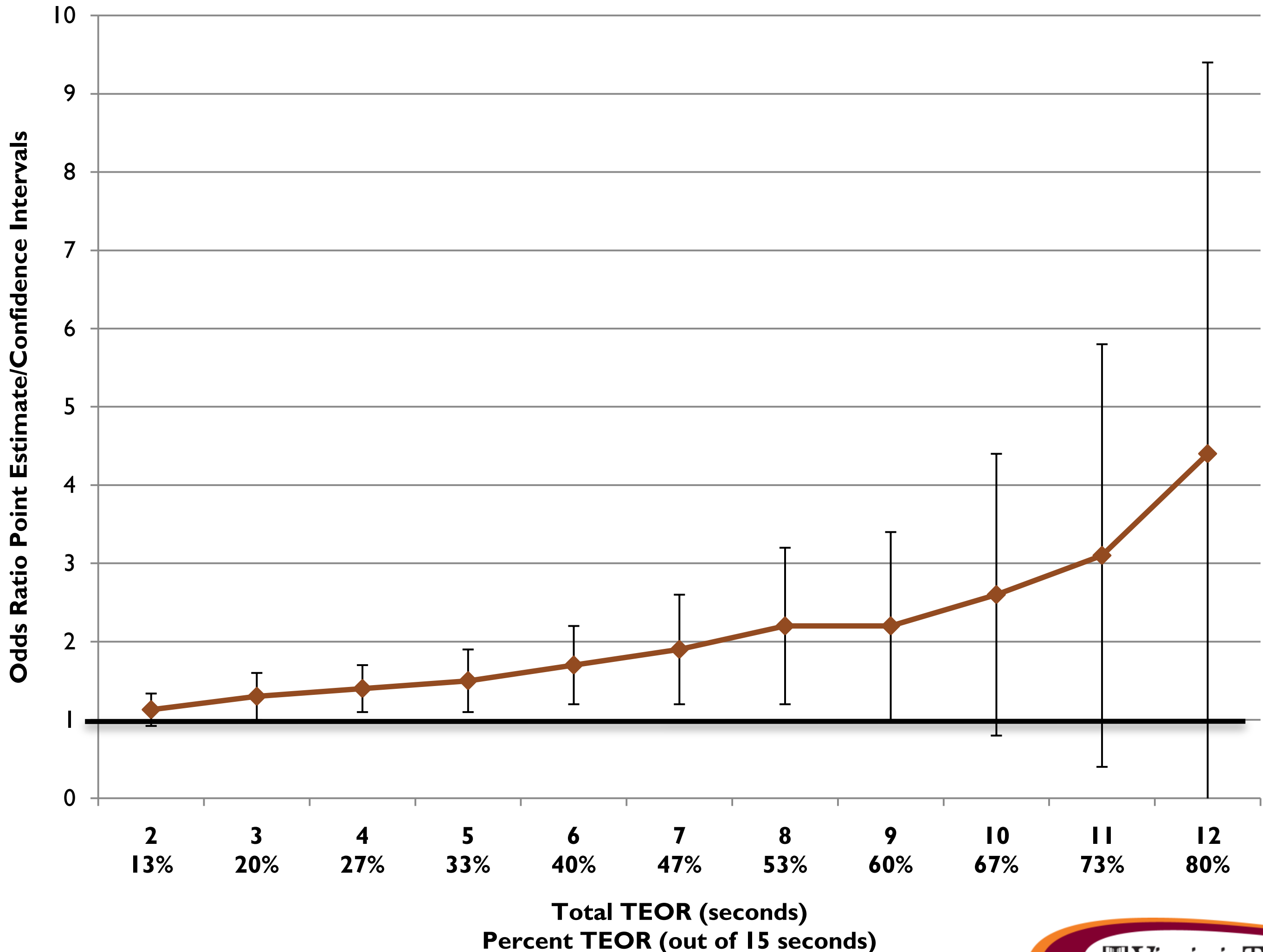
Crash Risk Increase Monotonically with Total Eyes Off Forward Roadway



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Comparison of Case-Cohort and Case-Crossover

- Case-Cohort: Greater generalizability to not only driver behavior but also environmental and roadway risk assessment.
- Case-Cohort: Simpler to conduct and less resource intensive.
- Case-Crossover: Greater precision as potential confounding factors are controlled through baseline sampling.

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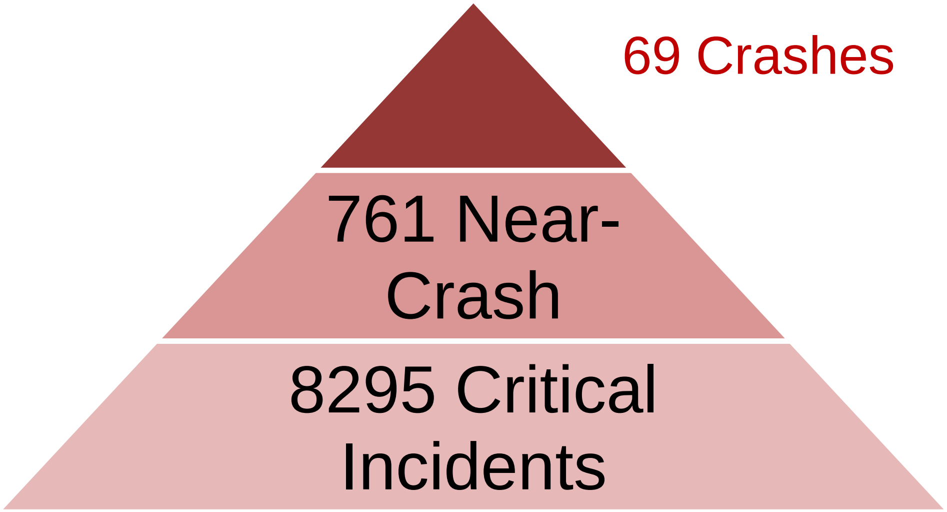
Can Near-Crashes Serve as Crash Surrogates?

- They are different by definition!

- It depends on the purpose the study.
  - This analysis focuses on the impacts for risk assessment purpose.

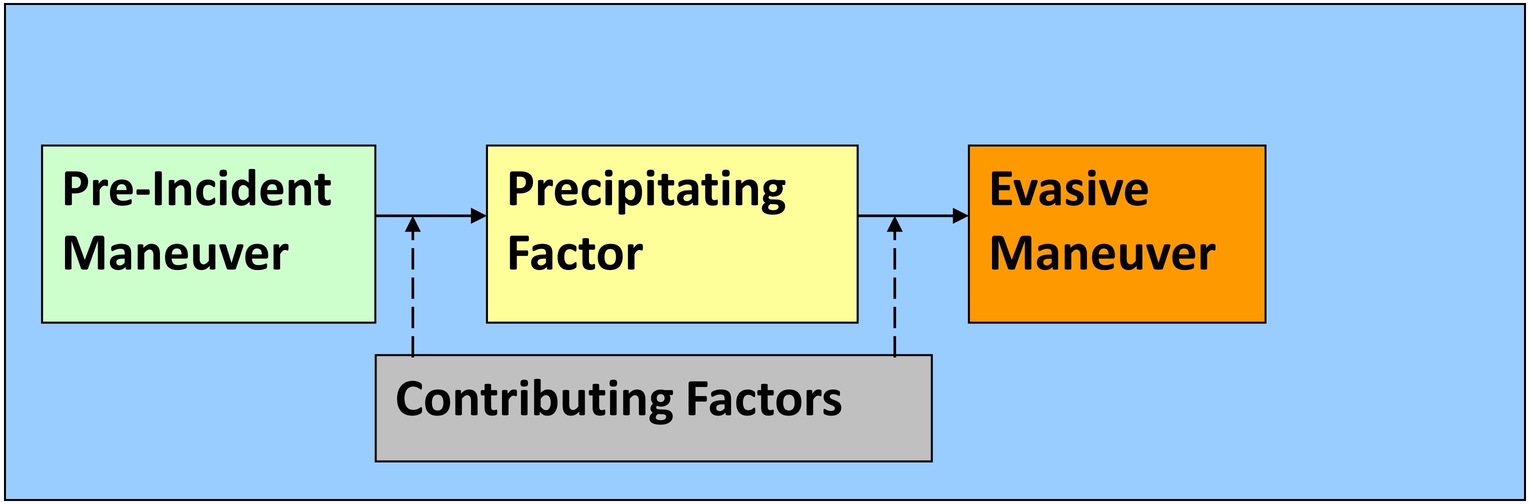
Crash Surrogate



- Less-severe events happen more frequently than severe events
- Severe events can be reduced by reducing less sever events

1. The causal mechanism for surrogates (near-crashes) and crashes are the same or similar.
2. There is a strong association between the frequency of surrogate measures and crashes under different settings.

Driver Reaction on Crash and Near-crash



All Conflict Types | **Conflict with Leading Vehicle**

i	Crash	Near-Crash		Crash	Near-Crash
Reaction	45	723	Reaction	5	377
No-Reaction	23	37	No reaction	9	0
Perc. Reaction	**66%**	**95%**	Perc. Reaction	**36%**	**100%**

Frequency Relationship

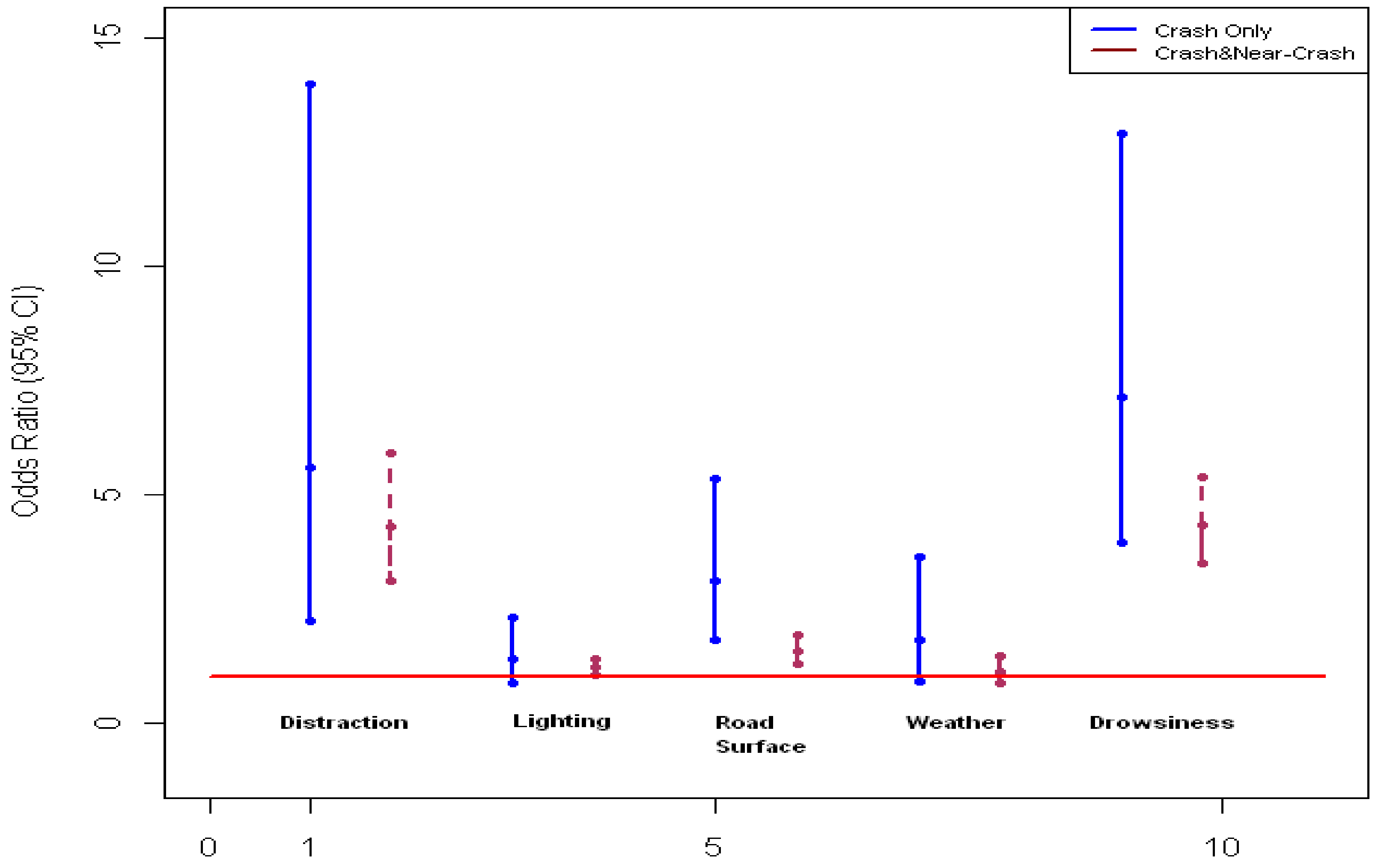
	Constant Crash to Near-Crash Ratio		Measure for Association	
Factors	p-value	Significant	R-squared	Adjusted R^2
Gender	0.26	NO	NA	NA
Age Group	0.23	NO	**0.91**	**0.87**
Level of Service (LOS)	<0.001	YES	**0.5 (0.72*)**	**0.33 (0.45*)**
Lighting Conditions	0.414	NO	**0.97**	**0.95**
Road Alignment	0.02	YES	**0.99**	**0.99**
Road Surface Condition	0.02	YES	**0.99**	**0.99**
Weather	0.32	NO	**0.99**	**0.99**

$$y_i \sim Poisson(\lambda_i)$$

$$\log(\lambda_i) = \beta_0 + \beta_1 x_i$$

	Coefficient	***p*-value**
Intercept	-2.31	<.0001
Near-Crash	**0.21**	**<.0001**

Sensitivity Analysis



Surrogate Measure: Summary

- Using crashes plus near-crashes will lead to a conservative but more precise result in risk assessment.
- For smaller studies with an insufficient number of observed crashes, there is a definite benefit to using near-crashes as a crash surrogate.
- Caution should be used when interpreting the results of risk evaluation.