Highway-Rail Grade Crossing Safety Challenges for Shared Operations

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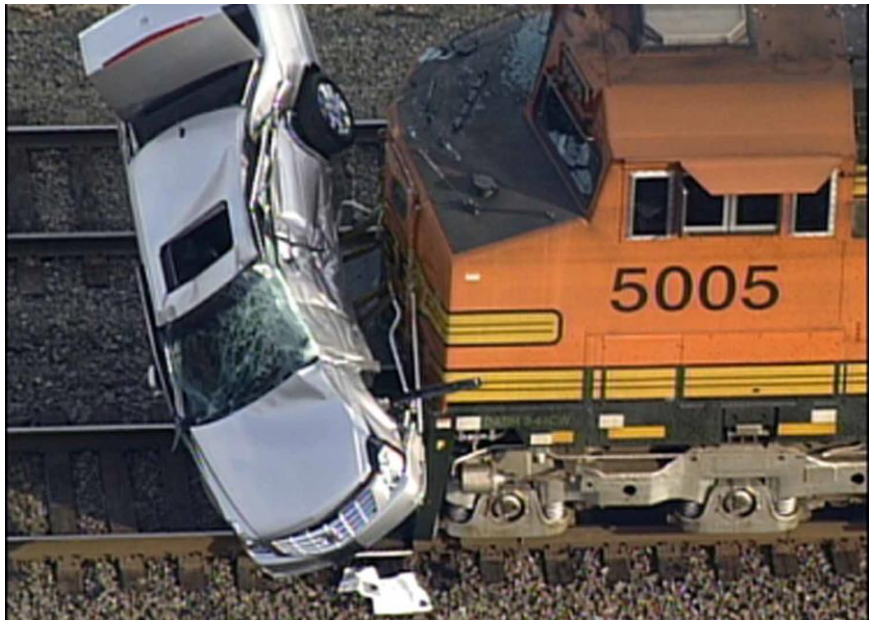
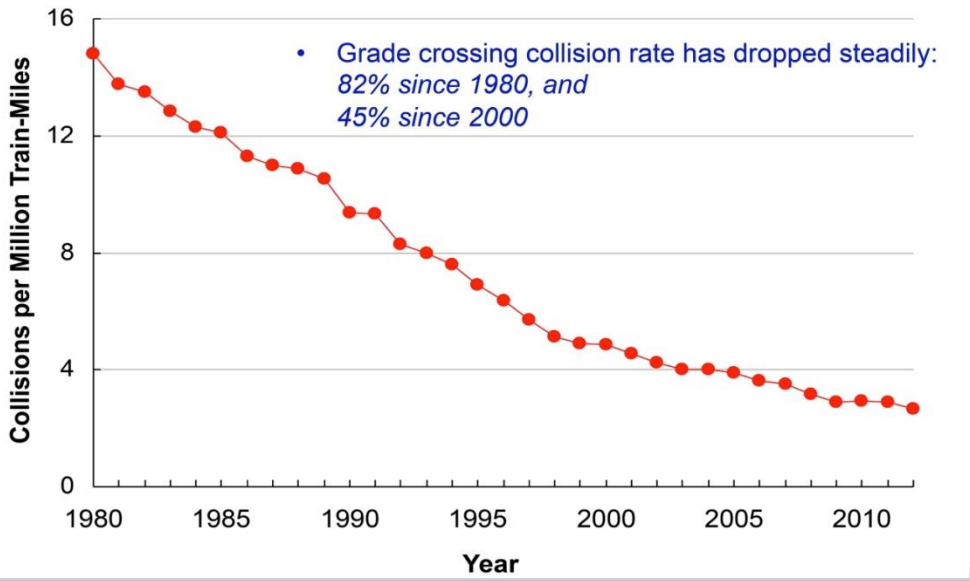
Outline

- Research Goals
- Level Crossing Derailment Risk Model Development
- Prospective Model and Identification of Proxy Variables
- Derailment Likelihood Calculator
- Incorporating Consequence Data
- Future Work

Level Crossings

- Trains pose a risk to motor vehicles at level crossings
  - Substantial research on reducing risk to highway users
  - Improved warning systems, driver education, and other actions have substantially reduced incidents over the past 30 years





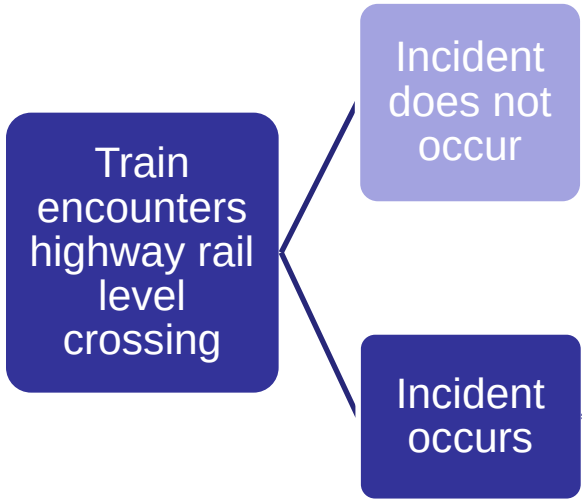
But there is another side to the story…

- What risks do level crossing collisions pose to *trains*?
- The answer to this question is not well understood

Research Goals

- Understanding derailment risk to trains due to level crossings has several important implications
  - Passenger train safety
  - Freight train safety
  - Dangerous goods
  - Time and financial cost
- A model to predict derailment probability due to level crossing incidents will help us understand this risk

Risk Model Development



- A train approaches a hig
- Either a collision will occ collision will not occur
- The probability of a collis level crossing can be cal of factors
- Considerable research h prediction models on the
- USDOT Accident Predic others

- Development of derailment risk model is the focus of this research
- Two derailment risk models will be developed: passenger and freight
- Hypothesis: Passenger and freight trains behave differently in a collision and therefore have different probabilities of derailment

- For passenger trains, consequence metric is number of casualties
- For freight trains, consequence metric could be financial cost, train crew casualties, hazardous materials release
  - Likelihood of hazmat release has been researched extensively

Probability of a derailment occurring given an incident has occurred

Regression Model Variables

Variable	Definition	Variable Type	Range of Values
VEHSPD	**Highway Vehicle Speed** (mph)	Continuous	Range*: 0-105 mph Average *: 10.50 mph Standard Deviation*: 13.57
TRNSPD	**Train Speed** (mph)	Continuous	Range*: 0-80 mph Average*: 31.45 mph Standard Deviation*: 15.58
LGVEH	**Large Highway Vehicle Involved?**	Binary (Yes or No)	N if no; Y if yes
TRNSTK	**Incident Type** **Train Struck Vehicle** **Vehicle Struck Train**	Binary	VST if highway user struck train; TSV if train struck highway user

Freight Train Model

- For incidents where the train strikes the vehicle

$$p_{TSV} = \frac{1}{e^{-x_{TSV}+1}}$$

$$x_{TSV} = -7.1789 + \begin{cases} 0, & LGVEH = Y \\ -1.8687, & LGVEH = N \end{cases} + 0.0166\, TRNSPD$$

- For incidents where the vehicle strikes the train

$$p_{VST} = \frac{1}{e^{-x_{VST}+1}}$$

$$x_{VST} = -6.4039 + \begin{cases} 0, & LGVEH = Y \\ -1.5044, & LGVEH = N \end{cases} + 0.00101\, VEHSPD^2$$

- Where TRNSPD = train speed, VEHSPD = highway vehicle speed and LGVEH indicates the highway vehicle was a truck
- We can combine these using prior probabilities to give an overall level crossing derailment model

$$p_{\,derailment} = 0.80\, p_{TSV} + 0.20\, p_{VST}$$

Summary of model development

- Train strikes vehicle, *the probability of derailment given an incident*, $p(D|I)$ increases:
  - As train speed increases
  - If a large highway vehicle such as a semi-truck is involved
- Vehicle strikes train, $p(D|I)$ increases:
  - As vehicle speed increases
  - If a large highway vehicle such as a semi-truck is involved
- Model predicts likelihood of a particular collision resulting in a derailment
- Goal is to develop predictive model of level crossing characteristics that affect risk of derailment
  - Identify proxy variables for level crossing risk model parameters

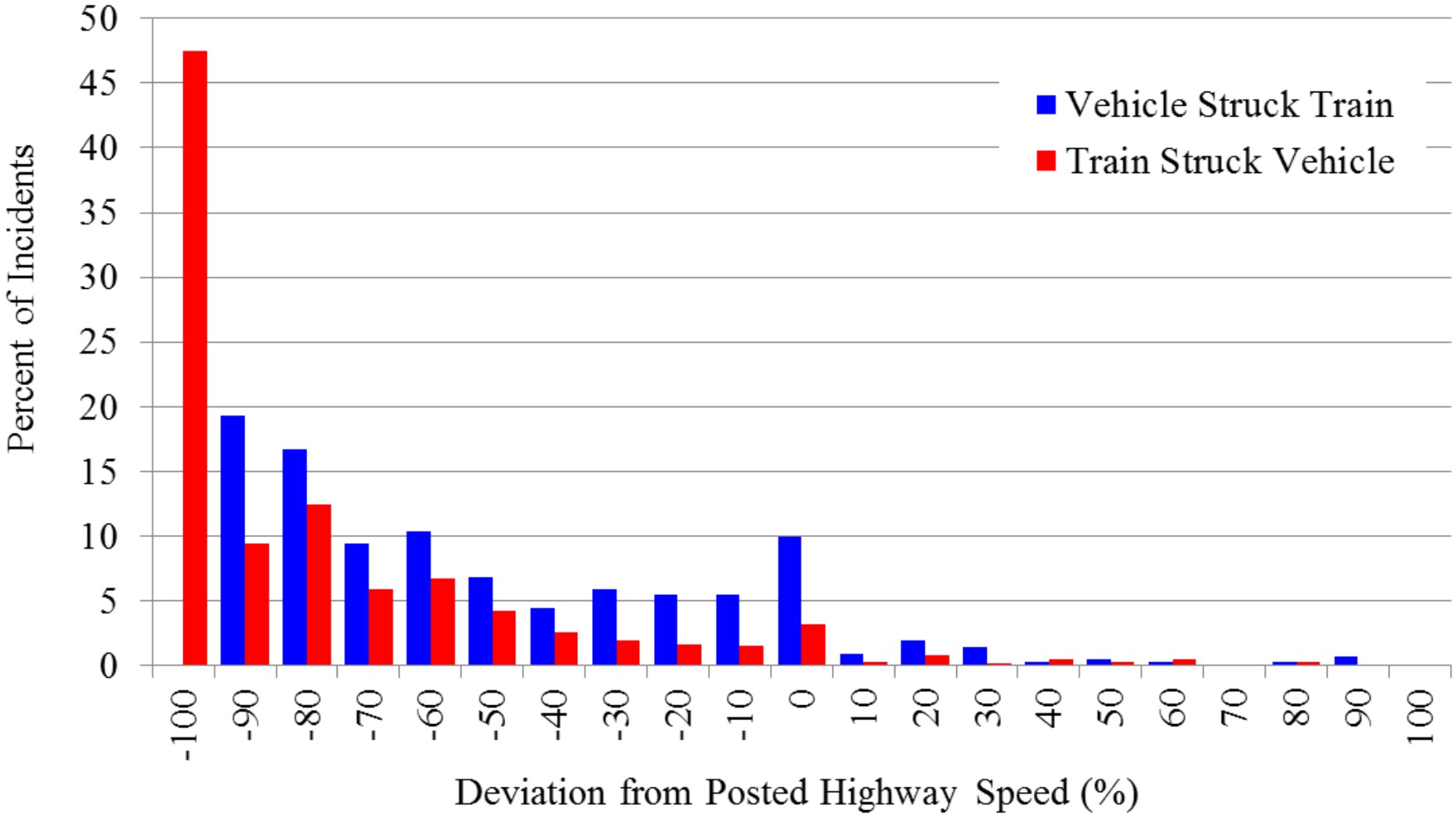
Proxy Variables for Predictive Model

Incident-Specific Variable	Crossing-Specific Variable
Vehicle Speed	Posted Speed Limit
Train Speed	Timetable Speed
Large Vehicle Involvement	Percent Truck Traffic Annual Average Daily Traffic (AADT)

- **Different approach for incident type**
  - Many human and design factors influence incident type
  - Assumed a fixed ratio based on historical data
    - 79.95% TSV
    - 20.15% VST

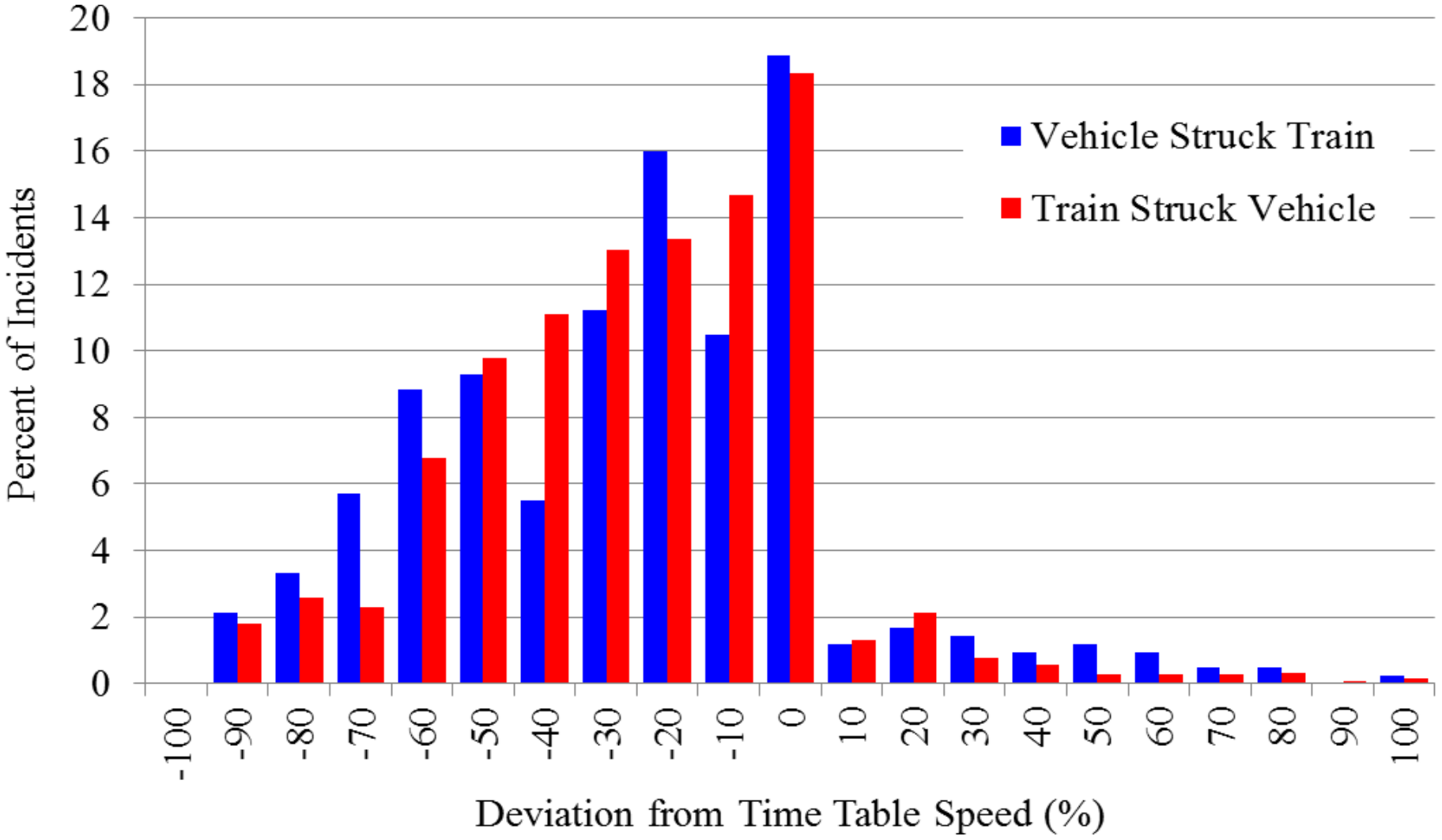
Highway Vehicle Speed

$$PDHSL = \frac{VS - HSL}{HSL}$$

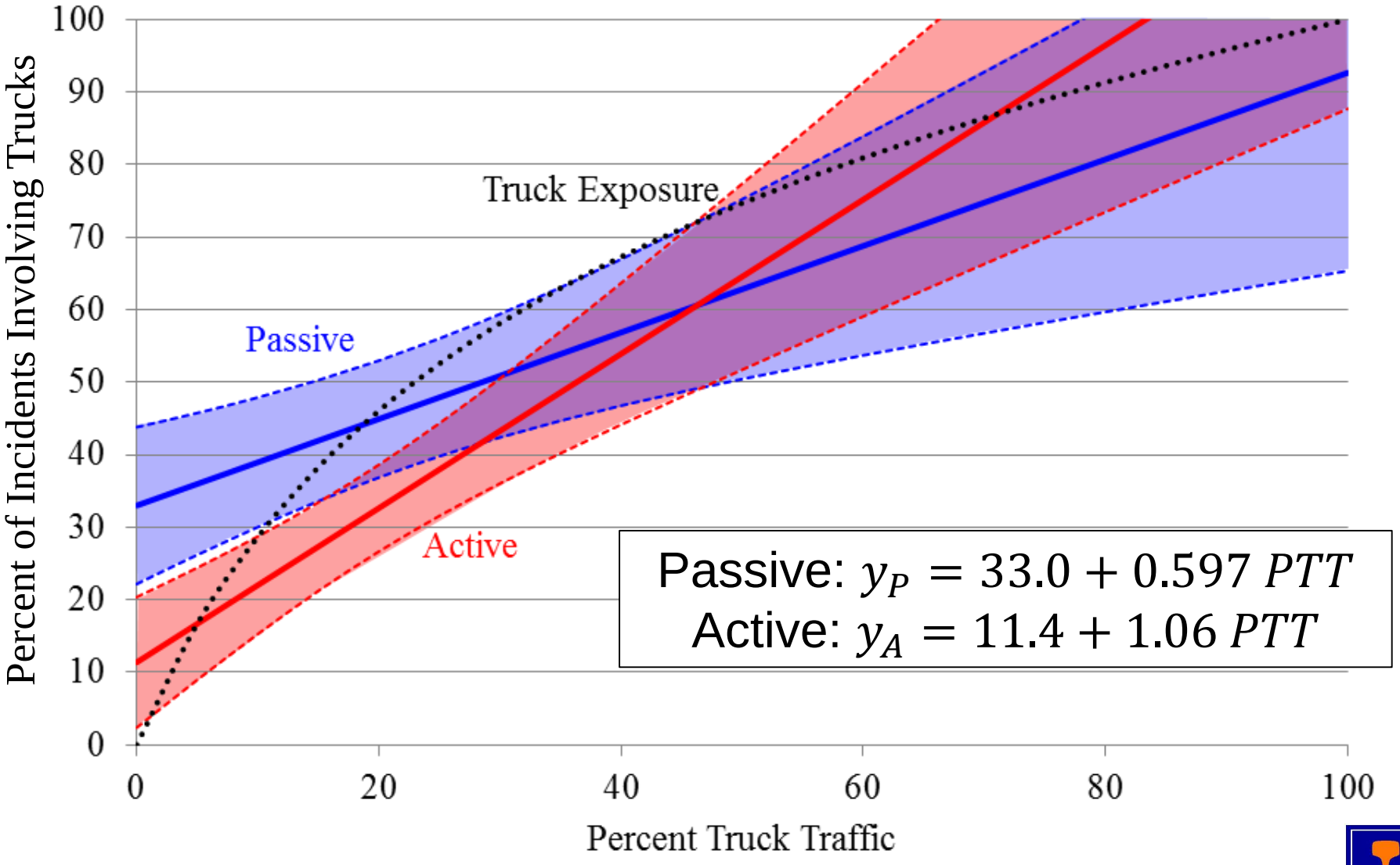


Train Speed

$$PDTTS = \frac{TS - TTS}{TTS}$$



Percent Truck Traffic



Derailment Likelihood Calculator

P(D|I) Calculator

Enter Crossing Factors

Posted Highway Speed Limit*	35	mph
Timetable Speed*	45	mph
* values must be greater than 0		
Level Crossing Type	Other Active	
Percent Truck Traffic	8	(0-100)

Results

Probability of Derailment	0.000380

- Using crossing characteristics, we can calculate an average conditional probability of derailment based on every possible incident scenario
- A “calculator” was developed using Microsoft Excel
- Combined with an incident likelihood model such as the U.S. DOT Accident Prediction Model, this can be used to rank level crossings for improvement

Incorporating Consequence Data

- Prioritization of crossing upgrades should also account for relative likelihood and severity of different level crossing incidents:
  - Non-derailment incident consequence:
    - *highway user casualties*
    - *delay and disruption of service*
  - Derailment incident consequence:
    - *crew casualties, (and/or passenger casualties)*
    - *extensive infrastructure and rolling stock damage*
    - *extended delay and disruption of service*
    - *dangerous goods release*

Derailment Likelihood Example

Crossing	Crossing Classification	Value			Ranking		
		f(I)	p(D|I)	p(D)	f(I)	p(D|I)	p(D)
G	Rural Collector	0.0143	0.00268	3.8E-05	1	1	1
A	Rural Collector	0.0105	0.00041	4.3E-06	2	4	3
E	Rural Collector	0.0099	0.00036	3.6E-06	3	5	4
B	Rural Local Road	0.0092	0.00027	2.5E-06	4	6	6
C	Rural Local Road	0.0061	0.00139	8.5E-06	5	2	2
F	Rural Local Road	0.0057	0.00057	3.3E-06	6	3	5
D	Rural Local Road	0.0022	0.00021	4.6E-07	7	7	7

$$p(D) = f(I) \times p(D|I)$$

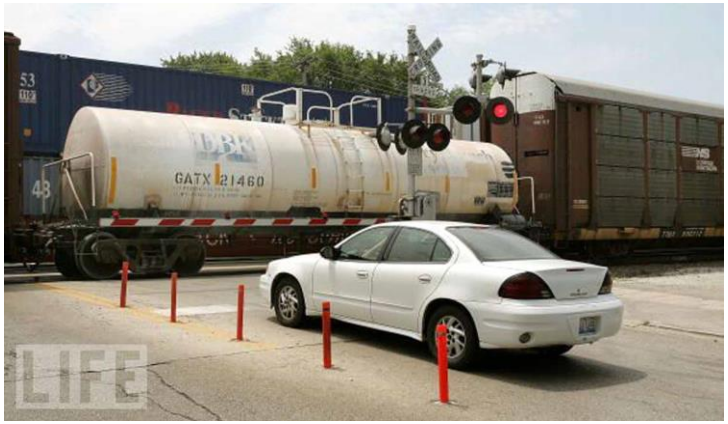
Incorporating Consequence Data

Characteristic	Rural Crossing	Urban Crossing
Warning Device Type	Active	Active
AADT	1,800	29,900
Percent Truck Traffic	10%	6%
Population Density	20 ppl/mi^2	25,000 ppl/mi^2
Projected Casualties in HM Release	25 casualties	31,250 casualties
f(I)	**0.010317**	**0.036942**
p(D|I) (Derailment Calculator)	**0.001668**	**0.000310**

- Rural Crossing: 450 times more likely to experience a highway user casualty than a casualty caused by HM release
- Urban Crossing: Two (2) times more likely to experience a highway user casualty than a casualty caused by HM release

Future Work

- Incorporate consequences of level crossing incidents and derailments into level crossing prioritization model
- Develop analogous model for passenger train risk
- Incorporate these models into the larger risk management framework
    - Implications for shared corridor operations?
    - Routing decisions for dangerous goods trains?



Summary

- Developed a statistical model of freight train derailments due to level crossing incidents
- Identified critical predictors of derailment likelihood
- Developed a prospective model to assess risk of crossings with various key conditions
- Preliminary consideration of how to incorporate consequences into the risk model

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Thank you!
Questions?

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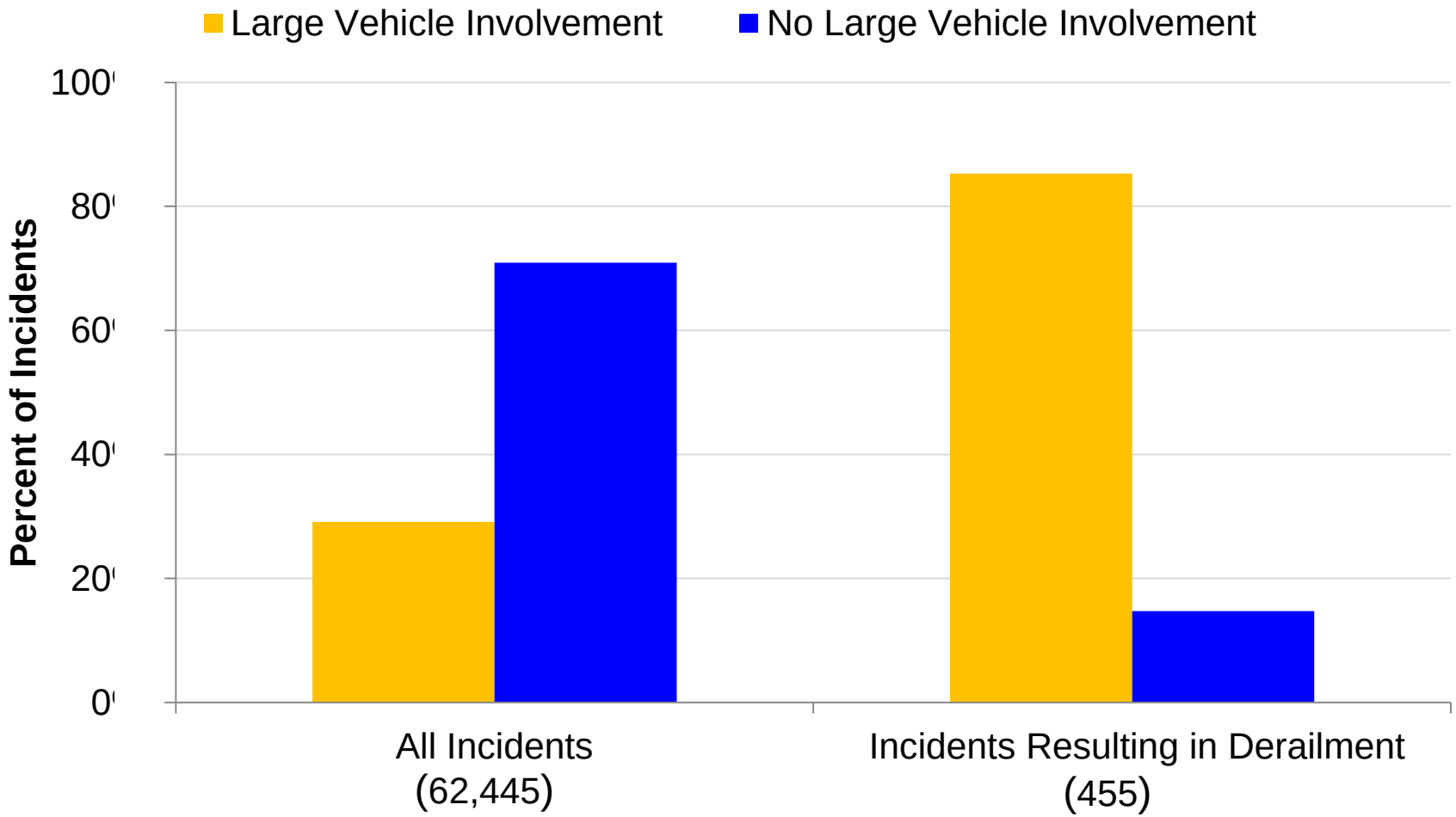
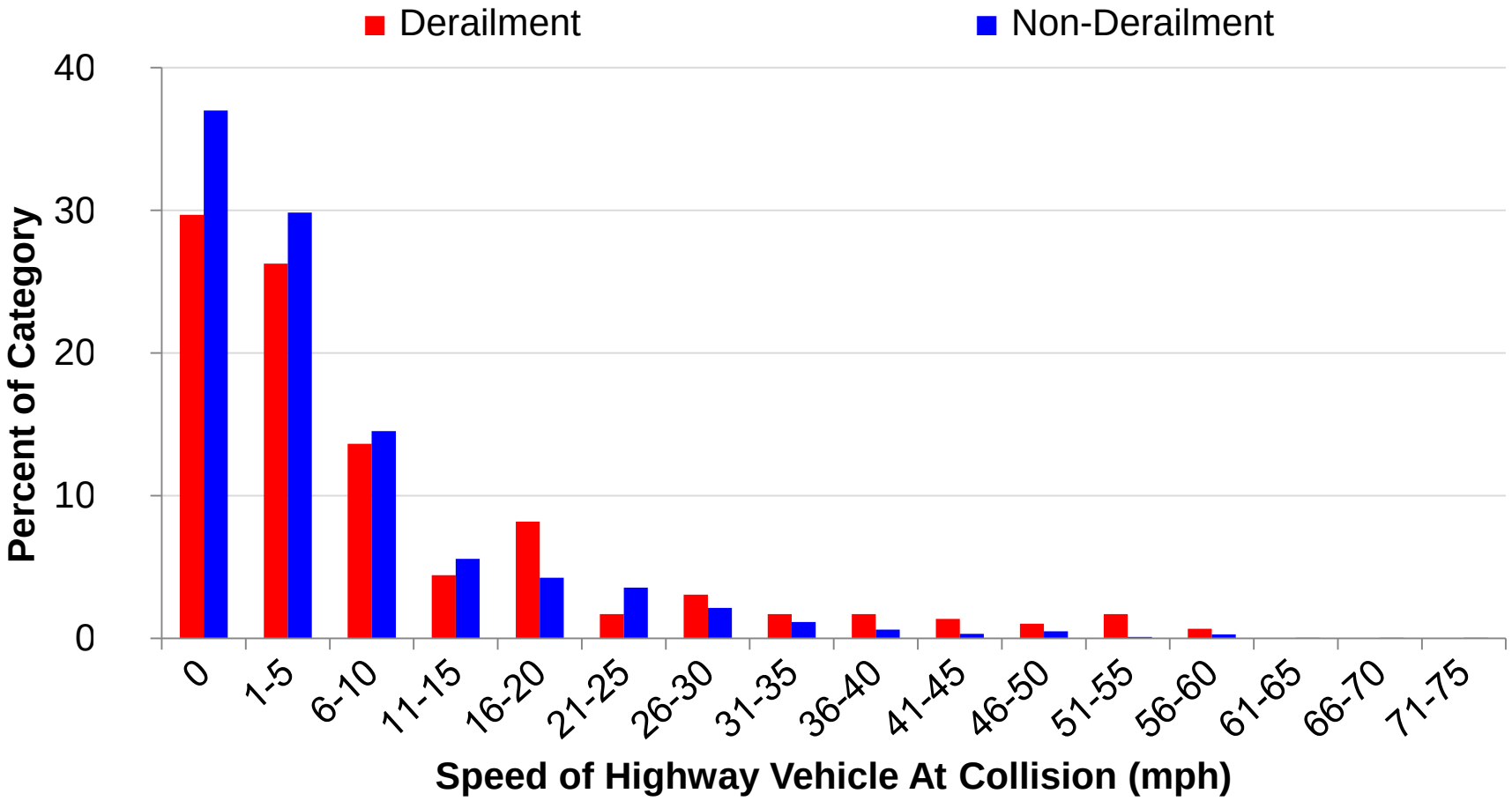
Appendix

Incidents Occurring at Grade Crossings on Mainline Track - 1991 to 2010



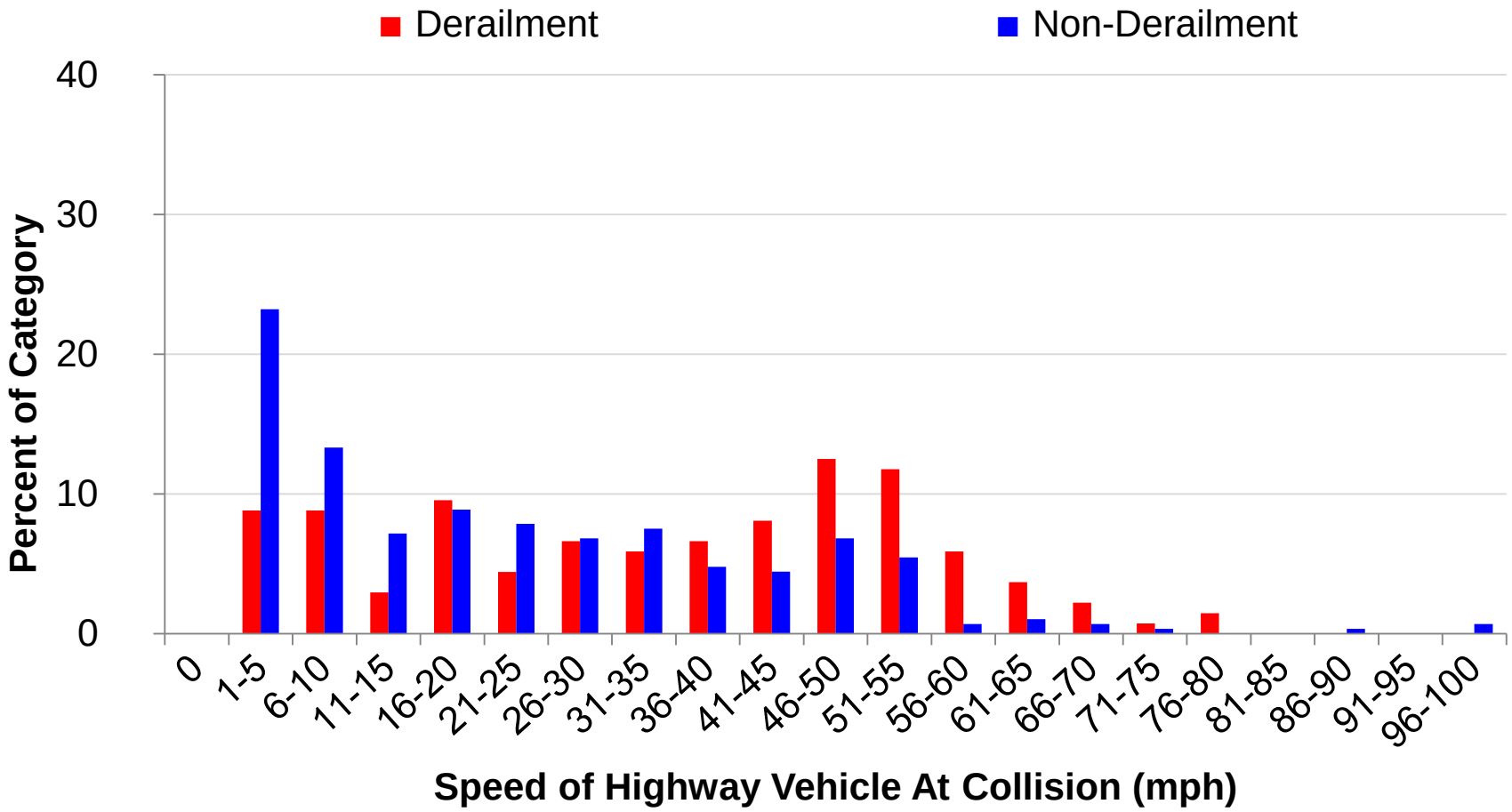
Trains involved in a grade crossing collision with a truck are disproportionately more likely to derail.

Speed at Collision of Highway Users Involved in Grade Crossing Incidents – Train Striking Vehicle. 1991-2010



Derailments are more likely to occur at higher vehicle speeds when the train strikes the vehicle.

Speed at Collision of Highway Users Involved in Grade Crossing Incidents – Vehicle Striking Train, 1991-2010



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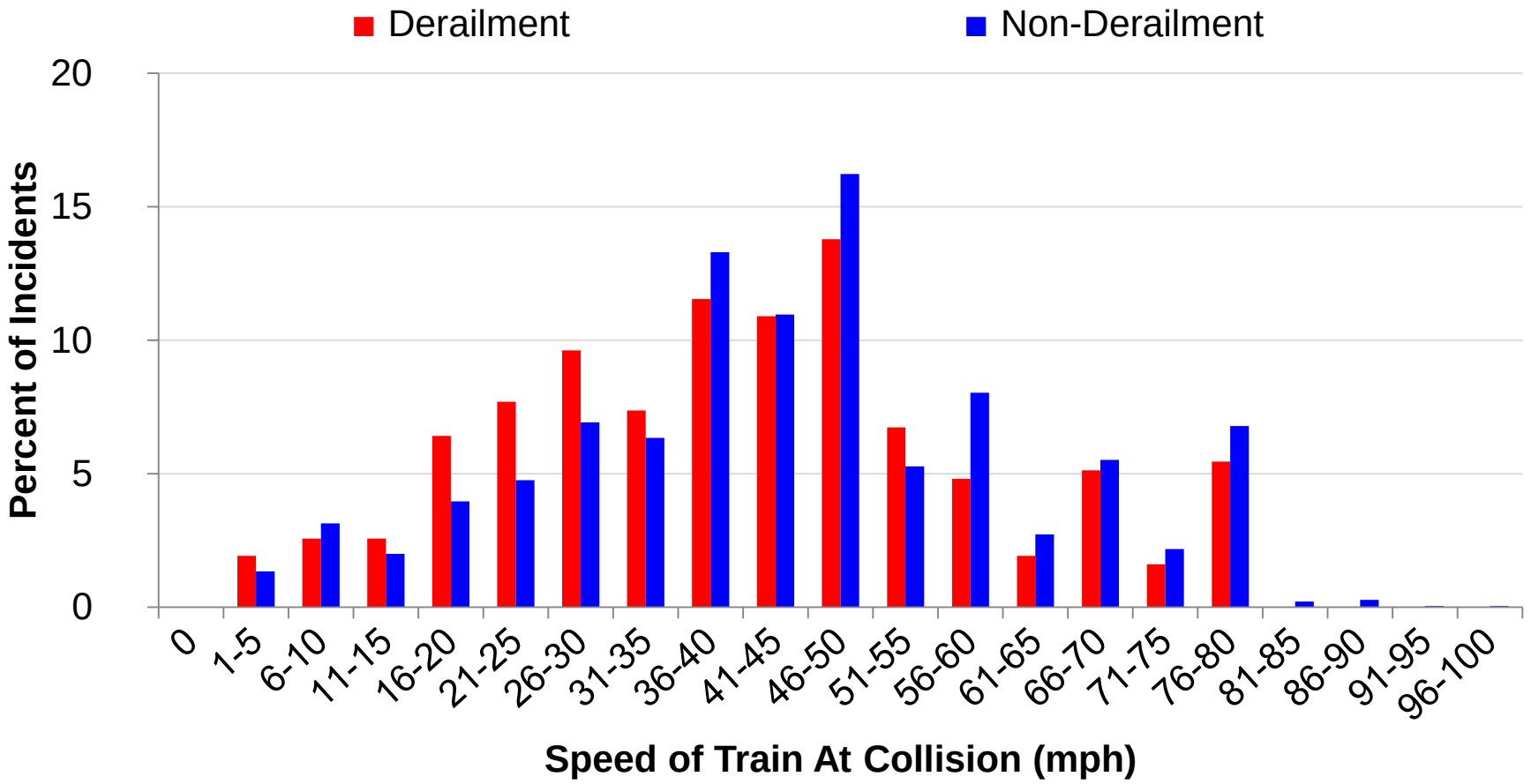
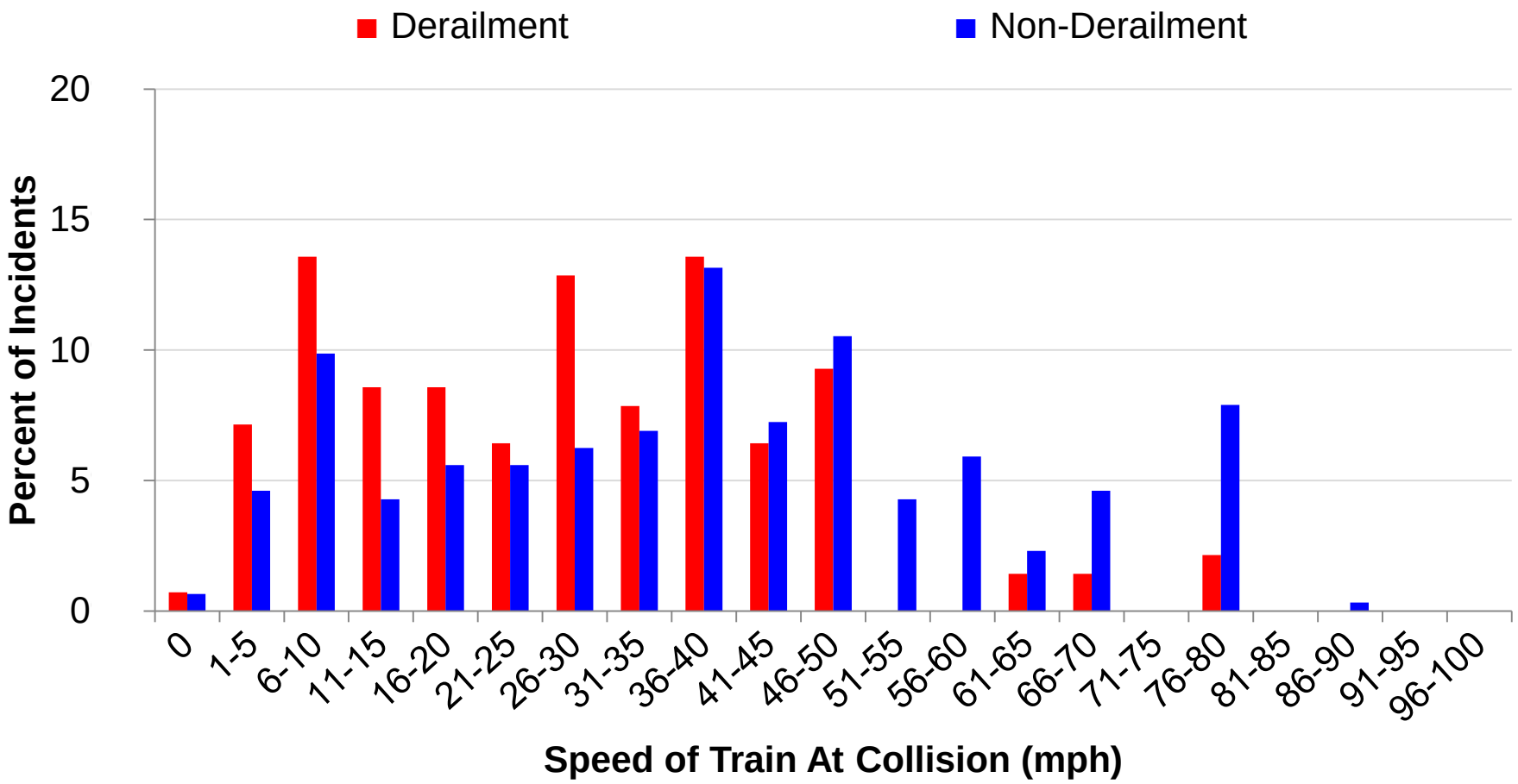


Derailments are more likely to occur at lower train speeds when the train strikes the vehicle.

Speed at Collision of Trains Involved in Grade Crossing Incidents – Vehicle Striking Train, 1991-2010



Derailments are more likely to occur at lower train speeds when the vehicle strikes the train.