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

• Grade crossing collision rate has dropped steadily: 82% since 1980, and 45% since 2000
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 highway rail level crossing.
- Either a collision will occur or a collision will not occur.
- The probability of a collision at a level crossing can be calculated based on various factors.
- Considerable research has gone into developing prediction models on the highway safety side, including the USDOT Accident Prediction Model and 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, the consequence metric is the number of casualties.
For freight trains, the consequence metric could be financial cost, train crew casualties, hazardous materials release, and so on.

Probability of a derailment occurring given an incident has occurred:
- Likelihood of hazmat release has been researched extensively.
## Regression Model Variables

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

• For incidents where the train strikes the vehicle

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

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

• For incidents where the vehicle strikes the train

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

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

• 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

<table>
<thead>
<tr>
<th>Incident-Specific Variable</th>
<th>Crossing-Specific Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle Speed</td>
<td>Posted Speed Limit</td>
</tr>
<tr>
<td>Train Speed</td>
<td>Timetable Speed</td>
</tr>
<tr>
<td>Large Vehicle Involvement</td>
<td>Percent Truck Traffic, Annual Average Daily Traffic (AADT)</td>
</tr>
</tbody>
</table>

- **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

\[ PDHSL = \frac{VS - HSL}{HSL} \]

- 0 to 100
- 0 to -100
- 0 to -90
- 0 to -80
- 0 to -70
- 0 to -60
- 0 to -50
- 0 to -40
- 0 to -30
- 0 to -20
- 0 to -10
- 0 to 0
- 0 to 10
- 0 to 20
- 0 to 30
- 0 to 40
- 0 to 50
- 0 to 60
- 0 to 70
- 0 to 80
- 0 to 90
- 0 to 100

Percent of Incidents

Deviation from Posted Highway Speed (%)
Train Speed

\[ PDTTS = \frac{TS - TTS}{TTS} \]

- Blue: Vehicle Struck Train
- Red: Train Struck Vehicle

Percent of Incidents vs. Deviation from Time Table Speed (%)
Percent Truck Traffic

Passive: \( y_P = 33.0 + 0.597 \text{ PTT} \)

Active: \( y_A = 11.4 + 1.06 \text{ PTT} \)
Derailment Likelihood Calculator

P(D|I) Calculator

Enter Crossing Factors

<table>
<thead>
<tr>
<th>Factor</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posted Highway Speed Limit*</td>
<td>35 mph</td>
</tr>
<tr>
<td>Timetable Speed*</td>
<td>45 mph</td>
</tr>
</tbody>
</table>

* values must be greater than 0

<table>
<thead>
<tr>
<th>Factor</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level Crossing Type</td>
<td>Other Active</td>
</tr>
<tr>
<td>Percent Truck Traffic</td>
<td>8 (0-100)</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Crossing</th>
<th>Crossing Classification</th>
<th>Value</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>f(I)</td>
<td>p(D</td>
</tr>
<tr>
<td>G</td>
<td>Rural Collector</td>
<td>0.0143</td>
<td>0.00268</td>
</tr>
<tr>
<td>A</td>
<td>Rural Collector</td>
<td>0.0105</td>
<td>0.00041</td>
</tr>
<tr>
<td>E</td>
<td>Rural Collector</td>
<td>0.0099</td>
<td>0.00036</td>
</tr>
<tr>
<td>B</td>
<td>Rural Local Road</td>
<td>0.0092</td>
<td>0.00027</td>
</tr>
<tr>
<td>C</td>
<td>Rural Local Road</td>
<td>0.0061</td>
<td>0.00139</td>
</tr>
<tr>
<td>F</td>
<td>Rural Local Road</td>
<td>0.0057</td>
<td>0.00057</td>
</tr>
<tr>
<td>D</td>
<td>Rural Local Road</td>
<td>0.0022</td>
<td>0.00021</td>
</tr>
</tbody>
</table>

\[ p(D) = f(I) \times p(D|I) \]
Incorporating Consequence Data

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

- 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
Acknowledgements

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Thank you!
Questions?

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

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