Unobserved Heterogeneity and Spatial Correlation: Statistical and Econometric Analyses of Heavy-Vehicle Hard Braking and Crash Frequency

Jason Anderson

Portland State University

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Unobserved Heterogeneity and Spatial Correlation: Statistical and Econometric Analyses of Heavy-Vehicle Hard Braking and Crash Frequency by Crash Type

Jason C. Anderson, Ph.D.
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Statistical and Econometric Analyses

How?

Jason C. Anderson, Ph.D.
Post-Doctoral Research Associate
Portland State University
Unobserved Heterogeneity and Spatial Correlation

Why?

Jason C. Anderson, Ph.D.
Post-Doctoral Research Associate
Portland State University
About Me (1/2)
About Me (2/2)

B.S. – Civil Engineering
2009
2014

M.S. – Civil Engineering
2014
2016

Ph.D. – Civil Engineering
2016
2018

Academia
Outline

• Research Motivation
• Background
• Research Contribution
• Data
• Research Methods
• Results
• Summary and Recommendations
• Moving Forward
Outline

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Motivation (1/3)

- **What is Hard Braking?**
  - *A Hard Braking Occurrence is Often Described as an Event That Prompts the “Black Box” to Record an Abrupt Change in Speed (Fried, 2015)*

- **Can Serve as a Proxy for Several Factors**
  - Economically
    - Impacts Overall Gas Mileage ➔ Can Cost Trucking Firms Up to Three Miles Per Gallon
  - Environmentally
    - Increases Pollutants Due to High Fuel Consumption and Particle Emissions From Brake Wear
  - Aggressive Driving Behavior
    - Can Directly Impact Safety, Both for Heavy-Vehicles and All System Users

- **But…**
Motivation (2/3)

• **Such Data for Heavy-Vehicles is Often Difficult to Attain**
  - Public Data Sources (Freight Analysis Framework, Commodity Flow Survey, etc.)
    • Aggregated Picture and Intended Primarily for Commodity Flow Behavior
  - Private Data Sources (FleetSeek, TRANSEARCH, etc.)
    • More Disaggregated Picture, but Still Intended Primarily for Commodity Flow Behavior

• **To Investigate Heavy-Vehicle Hard Braking, Specific Data is Needed**
  - EROAD®
    • Freight Telematics Data
  - Heavy-Vehicle Hard Braking Locations in Oregon

• **Using EROAD® Data, Heavy-Vehicle Hard Braking Locations Are Analyzed**
Motivation (3/3)

- Density Analysis
- Hot Spot Analysis
- Random Parameters Crash Frequency Analysis
- Spatial Lag Crash Frequency Analysis
Outline

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• Widely Known That Stopping Distances for Heavy-Vehicles Are Substantially Longer
  – Worsens When Road Surface Conditions are Wet and Slippery
• Anti-Lock Brake Systems Improve Driver Control
  – Likelihood of Jackknifing, Rear-End Crashes, Fixed-Object Crashes, etc.
• Federal Motor Vehicle Safety Standard Amendment Regarding Air Brake Systems
  – Required That the “Majority of New Heavy-Vehicles Achieve a 30% Reduction in Stopping Distance”
  – “Stop Not In More Than 250 Feet When Loaded to Their Gross Vehicle Weight Rating and Tested at a Speed of 60 mi/hr”
• Reduce Number of Fatalities and Injuries Associated With Heavy-Vehicle Braking
Background (2/3)

Comparison of Stopping Distances at 65 mph

Source: UDOT
1) **(Hard) Braking Literature**
   - (1) Braking Performance, (2) Brake Behavior Modeling, and (3) Naturalistic/Simulator Studies

2) **Heavy-Vehicle Braking Literature**
   - (1) Stopping Distance, (2) Vertical Loads, and (3) Safety Climates

3) **Crash Frequency Analysis**
   - (1) Few Emphasize Heavy-Vehicles, and (2) Focus on Crash Frequency at Intersections, Roadway Segments, or Junctions

- **Uniquely Addresses All Simultaneously**
  - Heavy-Vehicle Hard Braking
  - Explicitly in a Safety Context
    - Crash Frequency and Crash Type
Outline

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Contribution (1/1)

- Utilizes a Previously Unused Freight Data Source
  - Provide a Proof-of-Concept That This Data Can Used by Researchers Moving Forward

- Investigates Heavy-Vehicle Hard Braking in a Safety Context of Users

- Contributes to Methodologies for Transportation Research
  - Spatial Econometrics to Account For Spatial Autocorrelation

- Compares Two Analytical Methods to Determine a Preferred Method When Conducting Data-Driven Analyses
  - Unobserved Heterogeneity or Spatial Autocorrelation?
Outline

- Research Motivation
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- Moving Forward
• Several Datasets Were Used in The Current Analysis
  – EROAD®
  – Hard Braking Locations In Oregon

• Six Month Period
  – 1/01/2017 to 6/25/2017
  – 2,993 Hard Braking Events
• **Comprehensive Crash Database Provided by ODOT**
  – Consisted of all Police- and Self-Reported Crashes from 2011 to 2015
  – Crash File, Vehicle File, and Participant File

• **However…**

• **Due to the Nature of Analysis, Many of the Characteristics in the Crash Data Cannot be Used**
  – For Crash Frequency Analysis, Crashes are Aggregated (Heavy-Vehicle Hard Braking Hot Spots)
  – 10 Crashes at a Heavy-Vehicle Hot Spot ➞ 1 Observation With a New “Frequency” Variable
  – This Procedure Prevents Characteristics Related to the Driver, Crash, Weather, etc., From Being Used

• **Several Additional Datasets Consisting of Exposure-Based Variables Were Merged With Each Year of Crash Data**
Data (3/8)

Lane Width

Surface Width, Type

Shoulder Width, Type

Surface Conditions

Barrier Type

Traffic Volume
<table>
<thead>
<tr>
<th>FHWA Vehicle Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Motorcycles</td>
</tr>
<tr>
<td>2 axles, 2 or 3 tires</td>
</tr>
<tr>
<td>2. Passenger Cars</td>
</tr>
<tr>
<td>2 axles, can have 1- or 2-axle trailers</td>
</tr>
<tr>
<td>3. Pickups, Panel vans</td>
</tr>
<tr>
<td>2 axles, 4-tire single units</td>
</tr>
<tr>
<td>Can have 1 or 2-axle trailers</td>
</tr>
<tr>
<td>4. Buses</td>
</tr>
<tr>
<td>2 or 3 axles, full length</td>
</tr>
<tr>
<td>5. Single Unit 2-Axle Trucks</td>
</tr>
<tr>
<td>2 axles, 6 tires (dual rear tires), single-unit</td>
</tr>
<tr>
<td>6. Single Unit 3-Axle Trucks</td>
</tr>
<tr>
<td>3 axles, single unit</td>
</tr>
<tr>
<td>7. Single Unit 4 or More-Axle Trucks</td>
</tr>
<tr>
<td>4 or more axles, single unit</td>
</tr>
<tr>
<td>8. Single Trailer 3- or 4-Axle Trucks</td>
</tr>
<tr>
<td>3 or 4 axles, single trailer</td>
</tr>
<tr>
<td>9. Single Trailer 5-Axle Trucks</td>
</tr>
<tr>
<td>5 axles, single trailer</td>
</tr>
<tr>
<td>10. Single Trailer 6 or More-Axle Trucks</td>
</tr>
<tr>
<td>6 or more axles, single trailer</td>
</tr>
<tr>
<td>11. Multi-Trailer 5 or Less-Axle Trucks</td>
</tr>
<tr>
<td>5 or less axles, multiple trailers</td>
</tr>
<tr>
<td>12. Multi-Trailer 6-Axle Trucks</td>
</tr>
<tr>
<td>6 axles, multiple trailers</td>
</tr>
<tr>
<td>13. Multi-Trailer 7 or More-Axle Trucks</td>
</tr>
<tr>
<td>7 or more axles, multiple trailers</td>
</tr>
</tbody>
</table>
• **Associate Crashes With Heavy-Vehicle Hard Braking Hot Spots**
  – Spatially Joined to Hard Braking Hot Spots
  – In general, a 250 Feet Buffer is Adopted (Wang et al., 2008; AASHTO, 2010)
  – But, a 250 Feet Buffer to All Crashes and Crash Types Can Result in Statistical Errors During Analysis (AASHTO, 2010)

• **Therefore, Highest Observed Speed (85th Percentile) is Used to Determine Adequate Buffer Area** (Fambro et al., 1997; Dolastsara, 2014)
  – A 500-Foot Buffer Was Then Applied (i.e., Any Crash That Occurred Within 500 Feet of a Hot Spot was Spatially Joined to That Hot Spot)

• **Now, All Data Has Been Merged and the Crash Types That Occurred Most Often Can be Identified** (13,734 Crashes)
Data (6/8)

- Rear-End Crashes (57%)
- Turning Movement Crashes (17%)
- Sideswipe (Overtaking) Crashes (8%)
- Fixed-Object Crashes (8%)
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Methods (1/9)

- Kernel Density Analysis
  - Calculates the Magnitude-per-Unit Area From Point Features (ESRI, 2018)
  - Gain a General Understanding of High Density Hard Braking Areas
  - ArcGIS® is Used to Conduct the Kernel Density Analysis
**Methods (2/9)**

- **Hot Spot Analysis**
  - Utilizes a Getis-Ord $G_i^*$ to Investigate Each Hard Braking Event With the Context of Neighboring Hard Braking Events
  - Produces a $z$-statistic to Determine Statistical Significance ("hot" or "cold")
  - These Hot Spot Locations Are Use for the Crash Frequency Analysis
  - ArcGIS® is Used to Conduct the Hot Spot Analysis
Methods (3/9)

- **Crash Frequency Analysis**
  - Crash Frequencies (i.e., Counts) are Non-Negative Integer Values
  - Data is Not Over- or Under-Dispersion → Poisson Regression

\[
P(y_i) = \frac{e^{-\lambda_i} \lambda_i^{y_i}}{y_i!}
\]

\[
\lambda_i = e^{(\beta X_i)}
\]

<table>
<thead>
<tr>
<th>(P(y_i))</th>
<th>Probability of Heavy-Vehicle Hard Braking Hot Spot (i) Having (y_i) Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\lambda_i)</td>
<td>Poisson Parameter for Heavy-Vehicle Hard Braking Hot Spot (i)</td>
</tr>
</tbody>
</table>

\(X_i\) Vector of Explanatory Variables
\(\beta\) Vector of Estimable Parameters

What Happens if There is Over- or Under-Dispersion (i.e., \(E[y_i] < \text{Var}[y_i]\) or \(E[y_i] > \text{Var}[y_i]\))?
**Crash Frequency Analysis**

- Crash Frequencies (i.e., Counts) are Non-Negative Integer Values
- Data is Over- or Under-Dispersed → Negative Binomial Regression

\[
P(y_i | \varepsilon_i) = \frac{e^{-\lambda_i} \lambda_i^{y_i}}{y_i!}
\]

\[
\lambda_i = e^{(\beta X_i + \varepsilon_i)}
\]

| \(P(y_i | \varepsilon_i)\) | Probability of Heavy-Vehicle Hard Braking Hot Spot \(i\) Having \(y_i\) Crashes |
|--------------------------|--------------------------------------------------------------------------------|
| \(\lambda_i\)           | Poisson Parameter for Heavy-Vehicle Hard Braking Hot Spot \(i\)               |

<table>
<thead>
<tr>
<th>(X_i)</th>
<th>Vector of Explanatory Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\beta)</td>
<td>Vector of Estimable Parameters</td>
</tr>
<tr>
<td>(\varepsilon_i)</td>
<td>Gamma-Distributed Disturbance Term With Mean 1 and Variance (\alpha)</td>
</tr>
</tbody>
</table>

\(\alpha\)
• Variation (i.e., Unobserved Heterogeneity) is Often Present in Most Datasets
  – Variation Within Existing Variables Due to Unobserved Factors
  – Missing Variables

• To Account for This Variation, Extend the Previous Methods to Include Random Parameter Estimation

\[
\lambda_i = e^{(\beta X_i)}
\]

\[
\lambda_i = e^{(\beta X_i + \varepsilon_i)}
\]

\[
\beta_i = \beta + \varphi_i
\]

\[
\lambda_i \mid \varphi_i = e^{(\beta X_i + \varepsilon_i)}
\]

\[
\lambda_i \mid \varphi_i = e^{(\beta X_i)}
\]

\[\varphi_i \text{ Randomly Distributed Term}\]
• Are Heavy-Vehicle Hard Braking Hot Spots Spatially Correlated?
  – Test for Spatial Autocorrelation
    • Moran’s I Statistic
    • Moran’s I Statistic on Model Residuals
  – Determine Number of Nearest Neighbors
    • 1 to $k$-Nearest Neighbors Were to be Assessed
  – Create Spatial Weights Matrix
  – Conduct a Spatial Lag of X Analysis (SLX Model)
Methods (7/9)
Methods (8/9)

3 K-Nearest Neighbors
3 K-Nearest Neighbors for Heavy-Vehicle Hard Braking
Hot Spots and Rear-End Crashes

4 K-Nearest Neighbors
4 K-Nearest Neighbors for Heavy-Vehicle Hard Braking
Hot Spots and Turning Movement Crashes

2 K-Nearest Neighbors
2 K-Nearest Neighbors for Heavy-Vehicle Hard Braking
Hot Spots and Fixed-Object Crashes

5 K-Nearest Neighbors
5 K-Nearest Neighbors for Heavy-Vehicle Hard Braking
Hot Spots and Sideswipe (Overtaking) Crashes
• Spatial Lag of X Model

<table>
<thead>
<tr>
<th>Poisson Model</th>
<th>Negative Binomial Model</th>
<th>Spatial Lag of X Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \lambda_i = e^{(\beta x_i)} )</td>
<td>( \lambda_i = e^{(\beta x_i + \epsilon_i)} )</td>
<td>( \lambda_i = e^{(\beta x_i + W \cdot \beta x_i)} )</td>
</tr>
</tbody>
</table>

- No Disturbance Term
- Addition of Disturbance Term

\( W \) Spatial Weights Matrix
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Results (1/10)

Rear-End

- Over-Dispersed (Mean Less Than Variance)
  - $\alpha = 3.03$, $\theta = 12.95$
- Negative Binomial Model
- 16 Significant Variables
- 9 Normally Distributed Random Parameters

Turning Movement

- Over-Dispersed (Mean Less Than Variance)
  - $\alpha = 5.93$, $\theta = 3.52$
- Negative Binomial Model
- 13 Significant Variables
- 6 Normally Distributed Random Parameters

Fixed-Object

- Equal Mean and Variance
  - $\theta = 1.08$
- Poisson Model
- 11 Significant Variables
- 4 Normally Distributed Random Parameters

Sideswipe (Overtaking)

- Over-Dispersed (Mean Less Than Variance)
  - $\alpha = 15.2$, $\theta = 1.71$
- Negative Binomial
- 10 Significant Variables
- 3 Normally Distributed Random Parameters

\* $\alpha$ = Dispersion Parameter; $\theta$ = Manual Check Using Poisson Estimates
## Summary of Roadway Characteristics by Crash Type

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Rear-End Crashes</th>
<th>Turning Movement Crashes</th>
<th>Fixed-Object Crashes</th>
<th>Sideswipe (Overtaking) Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural Roadway Classifications</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Urban Roadway</td>
<td>–</td>
<td>–</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Low Posted Speed Limits</td>
<td>↓↑</td>
<td>↓</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>High Posted Speed Limits</td>
<td>↓</td>
<td>↓</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Solid Median Barriers</td>
<td>↓↑</td>
<td>–</td>
<td>↑</td>
<td>–</td>
</tr>
<tr>
<td>Jersey Barrier</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>↓↑</td>
</tr>
<tr>
<td>Earth, Grass, or Paved Median</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Width of Roadway (In Feet)</td>
<td>↑↑</td>
<td>↑↑</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Number of Lanes</td>
<td>↓↑</td>
<td>↓</td>
<td>–</td>
<td>↑</td>
</tr>
<tr>
<td>Vertical Geometrics (Grade)</td>
<td>↓↑</td>
<td>–</td>
<td>–</td>
<td>↑</td>
</tr>
<tr>
<td>Horizontal Curve</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>↑</td>
</tr>
<tr>
<td>Straight Segments</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>↓↑</td>
</tr>
<tr>
<td>Lane Width</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Bridge Structure</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Work Zone</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

### Legend
- **↓** Decrease
- **↑** Increase
- **↓↑** Heterogeneous
- **–** Insignificant
## Summary of Intersection and Traffic Control Characteristics by Crash Type

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Rear–End Crashes</th>
<th>Turning Movement Crashes</th>
<th>Fixed–Object Crashes</th>
<th>Sideswipe (Overtaking) Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross Intersections</td>
<td>↓↑</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traffic Signal</td>
<td>↑</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left–Turn Refuge</td>
<td>–</td>
<td>↓↑</td>
<td></td>
<td>↑</td>
</tr>
<tr>
<td>One–Way Street</td>
<td>–</td>
<td></td>
<td></td>
<td>↓</td>
</tr>
</tbody>
</table>

*Legend*
- **↓**: Decrease
- **↑**: Increase
- **↓↑**: Heterogeneous
- **-**: Insignificant

## Summary of Roadway Surface Characteristics by Crash Type

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Rear–End Crashes</th>
<th>Turning Movement Crashes</th>
<th>Fixed–Object Crashes</th>
<th>Sideswipe (Overtaking) Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Good Pavement Condition</td>
<td>–</td>
<td>↓</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Good Pavement Condition</td>
<td>–</td>
<td>–</td>
<td>↑</td>
<td>–</td>
</tr>
<tr>
<td>Asphalt Concrete Surface</td>
<td>–</td>
<td>–</td>
<td>↑</td>
<td>–</td>
</tr>
</tbody>
</table>
## Summary of Traffic Characteristics by Crash Type

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Rear-End Crashes</th>
<th>Turning Movement Crashes</th>
<th>Fixed-Object Crashes</th>
<th>Sideswipe (Overtaking) Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>AADT</td>
<td>↑</td>
<td>↑</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>High HV-AADT</td>
<td>-</td>
<td>↓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Percentage of Heavy-Vehicles</td>
<td>-</td>
<td>-</td>
<td>↓</td>
<td>-</td>
</tr>
<tr>
<td>Class 01 Vehicles</td>
<td>↓</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Class 03 Vehicles</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Class 04 Vehicles</td>
<td>↑</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Class 06 Vehicles</td>
<td>↑</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Class 07 Vehicles</td>
<td>↑</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Class 08 Vehicles</td>
<td>-</td>
<td>↑</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Class 09 Vehicles</td>
<td>-</td>
<td>-</td>
<td>↑</td>
<td>-</td>
</tr>
<tr>
<td>Class 10 Vehicles</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>↑</td>
</tr>
<tr>
<td>Class 12 Vehicles</td>
<td>↑</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Legend**
- **↓** Decrease
- **↑** Increase
- **↑↑** Heterogeneous
- **-** Insignificant
Results (5/10)

Moran I Statistic Standard Deviate $\rightarrow p$-value

<table>
<thead>
<tr>
<th>Moran I Statistic</th>
<th>Standard Deviate</th>
<th>$p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.358</td>
<td></td>
<td>0.000</td>
</tr>
<tr>
<td>5.6997</td>
<td></td>
<td>0.000</td>
</tr>
</tbody>
</table>
Results (6/10)

Moran Scatter Plot (2 K-Nearest Neighbors) for Heavy-Vehicle Hard Braking Hot Spots and Fixed-Object Crashes

Moran Scatter Plot (5 K-Nearest Neighbors) for Heavy-Vehicle Hard Braking Hot Spots and Sideswipe (Overtaking) Crashes

<table>
<thead>
<tr>
<th>Moran I Statistic Standard Deviate</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1932</td>
<td>0.000</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Moran I Statistic Standard Deviate</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.4913</td>
<td>0.000</td>
</tr>
</tbody>
</table>
Results (7/10)

Rear-End

Log-Likelihood = -1,890.23
McFadden Pseudo R-Squared = 0.08

Log-Likelihood = -1,871.00
McFadden Pseudo R-Squared = 0.09
Results (8/10)

Turning Movement

Log–Likelihood = -1,029.19  
McFadden Pseudo R–Squared = 0.11

Log–Likelihood = -1,033.00  
McFadden Pseudo R–Squared = 0.11
Results (9/10)

Fixed-Object

Log-Likelihood = -832.45
McFadden Pseudo R-Squared = 0.18

Log-Likelihood = -821.21
McFadden Pseudo R-Squared = 0.19
Results (10/10)

Sideswipe (Overtaking)

Log-Likelihood = -630.98
Mcfadden Pseudo R-Squared = 0.10

Log-Likelihood = -618.10
Mcfadden Pseudo R-Squared = 0.12
Outline

- Research Motivation
- Background
- Research Contribution
- Data
- Research Methods
- Results
- Summary and Recommendations
- Moving Forward
• Crash Frequencies at Heavy-Vehicle Hard Braking Hot Spots
  – Previously Unused Freight Data Source
  – Several Datasets Were Merged and Used for Analysis
• Rear-End, Turning Movement, and Sideswipe Data Over-Dispersed
  – Fixed-Object Data Met Poisson Assumptions
• 50 Total Significant Variables Across Crash Type Models
  – 22 Are Heterogeneous (Have Random Parameters)
• Two Factors Significant in At Least Three Crash Frequency Models
  – Urban Roadway Classifications
  – Class 12 Vehicles (6-Axle Multi-Trailer Trucks)
  – Some Factors Significant in Two Crash Frequency Models (Roadway Width, High Posted Speed Limits, AADT, Rural Classifications, Solid Medians, Number of Lanes, Grade)
• **Heavy-Vehicle Hard Braking Hot Spots Are Spatially Correlated**  
  – Statistically Significant Moran’s I Statistic  
  – Errors Terms do Have Spatial Autocorrelation

• **A Spatial Lag of X Model is Fit**  
  – Accounts for Spatial Correlation by the Addition of Lagged Variables and a Spatial Weights Matrix

• **Factors Found to Have Direct and Spillover (Indirect) Effects on Crash Frequency by Crash Type**  
  – Significant Direct Effect, But Insignificant Spillover Effect  
  – Insignificant Direct Effect, But Significant Spillover Effect  
  – Insignificant Direct, Significant Spillover Effect, and Opposite Effects

• **Spatial Lag of X Provided Slightly Better Overall Model Fit**  
  – Random Parameters Model Had Superior Predictability Power
Summary/Recommendations (3/5)

• Monitor and Mitigate Hard Braking Events of Heavy-Vehicles
  – Mandate for ELDs (1st Deadline to Comply in Dec. 2017)
  – Trucking Firms Can Put More Emphasis on Hard Braking Mitigation (e.g., Bonus System)
    • Monthly Fuel Incentives
    • New Car Giveaway
    • $25,000 Prize for Driver With Best End-of-Year MPG

• Monitoring and Mitigating Hard Braking is Something All Drivers Can Do
  – If A Driver Can Monitor Hard Braking, They May Be Able to Adapt Their Driving Behavior
  – Smartphone Application, such as GasBuddy
Summary/Recommendations (5/5)

• What Can Oregon DOT Take From This?
  – Investigate Hard Braking Hot Spot Locations
  – Visibility, Lighting, Signage, Poor Pavement Conditions, etc.

• Traffic Signals and Left-Turn Refuges Increase Expected Number of Crashes
  – Focus on Locations of These Traffic Control Devices
  – Signage, Speed Drop Zones, Horizontal Curves, Crests

• Very Good Pavement Conditions Decrease Expected Number of Crashes
  – Prompt Projects to Improve Pavement Conditions

• Can Use Methodological Approach to Predict Crash Frequency
  – Develop a R-Studio Toolbox to Estimate These Models and Predict Crash Frequency
Outline

• Research Motivation
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Moving Forward (1/1)

- Explore EROAD Dataset
- Hard-Braking and Other Safety Metrics
- Spatial Econometrics in Other Contexts
- Algorithm Development
The End

Thank You, Questions?

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