Factors Affecting the Severity of Injuries Sustained in Collisions with Roadside Objects

Presenter: Ashirwad Barnwal
Adviser: Dr. Peter T. Savolainen

Source: clipartbest.com
Overview

- Background
- Research Objective
- Literature Review
- Data Collection
- Data Summary
- Analysis Results
- Conclusion
Background

- Roadway departure crashes have always been a major concern.
- Enhanced vehicle, roadway and roadside designs.
- Reduced propensity for roadside encroachment.
- Fixed object crashes still result in numerous injuries and fatalities.

Source: Insurance Institute for Highway Safety (IIHS)
Research Objective

- Severity of single vehicle fixed object crashes along major interstates in Iowa (I-80 and I-35)
Literature Review

- The Crash Severity Impacts of Fixed Roadside Objects-Holridge et al. (2005)

Traffic barrier crashes: Property damage only
Inclement weather: Less severe crashes
Increasing speed limit: More severe crashes
Literature Review

- Analysis of Roadside Accident Frequency and Severity and Roadside Safety Management - Lee and Mannering (1999)

Road recovery space: Most important factor determining crash severity

Impaired driving/Fatigue: More severe crashes

Roadside data collection: Expensive
Data Collection

Identification of Rural Mainline Interstate Segments
Data Collection

Single Vehicle Fixed Object Crashes along Interstates: 2,606
Data Summary

Distribution of Crash Frequency by Fixed Object Strike

- Guardrail, 1177, 45%
- Ditch/Embankment, 584, 22%
- Other Fixed Objects, 249, 10%
- Bridge Rail/Overpass, 181, 7%
- Curb/Raised Median, 38, 1%
- Tree, 104, 4%
- Sign Post, 98, 4%
- Structure Support, 22, 1%
- Culvert, 43, 2%
- Concrete Barrier, 47, 2%
- Poles, 49, 2%
- Impact Attenuator, 14, 0%
- Other, 213, 8%
## Data Summary

### Distribution of Crash Severity by Fixed Object Strike

<table>
<thead>
<tr>
<th>Fix. Objects \ Severity</th>
<th>K</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>O</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guardrail</td>
<td>1</td>
<td>10</td>
<td>48</td>
<td>85</td>
<td>1033</td>
<td>1177</td>
</tr>
<tr>
<td>Ditch/Embankment</td>
<td>12</td>
<td>22</td>
<td>89</td>
<td>80</td>
<td>381</td>
<td>584</td>
</tr>
<tr>
<td>Other Fixed Objects</td>
<td>12</td>
<td>15</td>
<td>219</td>
<td></td>
<td></td>
<td>249</td>
</tr>
<tr>
<td>Bridge Rail/Overpass</td>
<td></td>
<td>24</td>
<td>131</td>
<td>181</td>
<td></td>
<td>181</td>
</tr>
<tr>
<td>Tree</td>
<td>4</td>
<td>61</td>
<td></td>
<td></td>
<td></td>
<td>104</td>
</tr>
<tr>
<td>Sign Post</td>
<td>4</td>
<td>91</td>
<td></td>
<td></td>
<td></td>
<td>98</td>
</tr>
<tr>
<td>Poles</td>
<td></td>
<td>44</td>
<td></td>
<td></td>
<td></td>
<td>49</td>
</tr>
<tr>
<td>Concrete Barrier</td>
<td></td>
<td>35</td>
<td></td>
<td></td>
<td></td>
<td>47</td>
</tr>
<tr>
<td>Culvert</td>
<td></td>
<td>26</td>
<td></td>
<td></td>
<td></td>
<td>43</td>
</tr>
<tr>
<td>Curb/Raised Median</td>
<td>7</td>
<td>31</td>
<td></td>
<td></td>
<td></td>
<td>38</td>
</tr>
<tr>
<td>Structure Support</td>
<td>4</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td>22</td>
</tr>
<tr>
<td>Impact Attenuator</td>
<td>1</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td>14</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>18</td>
<td>54</td>
<td>200</td>
<td>2074</td>
<td>2606</td>
<td>2606</td>
</tr>
</tbody>
</table>

- **K** represents 1% severity
- **A** represents 2% severity
- **B** represents 8% severity
- **C** represents 10% severity
- **O** represents 79% severity
Data Summary

Variables Considered in the Analysis

- **Light Conditions**
  - Daylight- (1103)
  - Dawn or Dusk- (109)
  - Dark- roadway lighted- (49)
  - Dark- roadway not lighted- (631)

- **Surface Conditions**
  - Dry- (746)
  - Wet- (241)
  - Ice- (487)
  - Snow- (347)
  - Slush- (71)

- **Driver Gender**
  - Male- (1252)
  - Female- (640)

- **Driver Age**
  - First group: < 20
  - In steps of 5 years (e.g.,>= 20 and <= 24)
  - Last group: >= 65

- **Number of Occupants**
  - 1 (1250), 2 (450), 3 (114), 4 (58), 5 (20)

- **Point of Initial Impact**
  - Front- (718)
  - Passenger/Driver Side- Front- (663)
  - Passenger/Driver Side- Middle- (205)
  - Passenger/Driver Side- Rear- (126)
  - Rear- (101)
  - Top- (55)
  - Under-carriage- (24)

Source: Iowa DOT Accident Code Sheet
Data Summary

Variables Considered in the Analysis

- **AADT**
  - Mean: 26,778
  - Std. Dev: 6,676

- **Truck percentage**
  - Mean: 29.66
  - Std. Dev: 6.09

- **Driver Condition**
  - Normal- (1584)
  - Asleep/fainted/fatigued- (212)
  - Under the influence of alcohol/drug/medication- (77)
  - Illness- (19)

- **Terrain**
  - Flat- (1140)
  - Rolling- (714)
  - Hilly- (38)

- **Vehicle Configuration**
  - Passenger car- (896)
  - Pick-up truck- (321)
  - Van- (92)
  - SUV- (294)
  - Single Unit Truck- (50)
  - Truck-trailer/tractor- (214)
  - Tractor/ doubles- (14)
  - Motorcycle- (9)

- **Fixed Object Struck**
  - 11 object types
Data Analysis

Ordered Probability Models

- Ordered probability models are derived by defining an unobserved variable, $z$, that is used as a basis for modeling the ordinal ranking of data.

$$z = \beta X + \varepsilon$$

- Where:
  - $X$ is a vector of variables determining the discrete ordering for observation $n$,
  - $\beta$ is a vector of estimable parameters,
  - $\varepsilon$ is a random disturbance.
Data Analysis

Ordered Probability Models

- Using this equation, observed ordinal data, $y$, for each observation are defined as,
  
  $y = 1$ if $z \leq \mu_0$
  
  $y = 2$ if $\mu_0 < z < \mu_1$
  
  $y = 3$ if $\mu_1 < z < \mu_2$
  
  $y = \ldots$
  
  $y = I$ if $z \geq \mu_{I-1}$,

- where $\mu$ 's are estimable parameters (referred to as thresholds) that define $y$, which corresponds to integer ordering, and $I$ is the highest integer ordered response.
## Data Analysis

### Ordered Probit Model Results

<table>
<thead>
<tr>
<th>Threshold Coefficients</th>
<th>Estimate</th>
<th>Std. Error</th>
<th>t-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>C</td>
<td>-2.351</td>
<td>1.287</td>
</tr>
<tr>
<td>C</td>
<td>B</td>
<td>-1.804</td>
<td>1.287</td>
</tr>
<tr>
<td>B</td>
<td>A</td>
<td>-0.938</td>
<td>1.287</td>
</tr>
<tr>
<td>A</td>
<td>K</td>
<td>-0.143</td>
<td>1.286</td>
</tr>
</tbody>
</table>

### Object Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>Std. Error</th>
<th>t-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bridge-Rail (Baseline)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guardrail</td>
<td>-0.434</td>
<td>0.129</td>
<td>-3.378</td>
</tr>
<tr>
<td>Sign Post</td>
<td>-0.927</td>
<td>0.258</td>
<td>-3.588</td>
</tr>
<tr>
<td>Underpass/Structure Support</td>
<td>0.860</td>
<td>0.301</td>
<td>2.856</td>
</tr>
</tbody>
</table>

### Roadway Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>Std. Error</th>
<th>t-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>LN AADT (Baseline)</td>
<td>-0.288</td>
<td>0.128</td>
<td>-2.257</td>
</tr>
<tr>
<td>Dry (Baseline)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wet</td>
<td>-0.327</td>
<td>0.114</td>
<td>-2.861</td>
</tr>
<tr>
<td>Ice</td>
<td>-0.461</td>
<td>0.097</td>
<td>-4.756</td>
</tr>
<tr>
<td>Snow</td>
<td>-0.487</td>
<td>0.112</td>
<td>-4.350</td>
</tr>
</tbody>
</table>
# Data Analysis

## Ordered Probit Model Results

<table>
<thead>
<tr>
<th>Vehicle Characteristics</th>
<th>Estimate</th>
<th>Std. Error</th>
<th>t-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front Baseline</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passenger/Driver Side- Front</td>
<td>-0.189</td>
<td>0.081</td>
<td>-2.339</td>
</tr>
<tr>
<td>Passenger/Driver Side- Rear</td>
<td>-0.561</td>
<td>0.184</td>
<td>-3.051</td>
</tr>
<tr>
<td>Rear</td>
<td>-0.960</td>
<td>0.254</td>
<td>-3.787</td>
</tr>
<tr>
<td>Top</td>
<td>0.348</td>
<td>0.172</td>
<td>2.016</td>
</tr>
<tr>
<td>Under-Carriage</td>
<td>-0.475</td>
<td>0.286</td>
<td>-1.661</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Single Occupant Baseline</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Occupants</td>
<td>0.309</td>
<td>0.080</td>
<td>3.855</td>
</tr>
<tr>
<td>3 Occupants</td>
<td>0.318</td>
<td>0.140</td>
<td>2.278</td>
</tr>
<tr>
<td>5 Occupants</td>
<td>0.957</td>
<td>0.261</td>
<td>3.673</td>
</tr>
</tbody>
</table>

## Driver Characteristics

<table>
<thead>
<tr>
<th>Normal Baseline</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Asleep/fainted/fatigued</td>
<td>0.332</td>
<td>0.103</td>
<td>3.222</td>
</tr>
<tr>
<td>Alcohol/drug/medication</td>
<td>0.800</td>
<td>0.146</td>
<td>5.478</td>
</tr>
<tr>
<td>Illness</td>
<td>0.724</td>
<td>0.263</td>
<td>2.755</td>
</tr>
</tbody>
</table>
Conclusion

- Underpass/structure support requires more attention and should properly be guarded with impact attenuators.
- More stringent regulations on drunk driving.
- More safety provisions on high occupancy vehicles.
- More rigorous crash test criteria for vehicles.
Comments or Questions?

Ashirwad Barnwal  
Graduate Research Assistant  
Institute for Transportation  
Iowa State University  
(515)-520-4266  
ashirwad@iastate.edu