Using Injury Data to Understand Traffic and Vehicle Safety

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Injury Data in Traffic Safety

1. Background
2. Policy
   a. Motorcycle helmet law in Michigan
3. Vehicle design for occupant protection systems
   a. Adaptive restraints and occupant characteristics
   b. Low-mass vehicles
   c. Crash-mitigation in a crash-avoidance world
4. Improved injury response
   a. AACN
Collaborators

- Jonathan Rupp
- Jingwen Hu
- Kathleen Klinich
- Patrick Bowman
- Patrick Carter
- Doug Kononen
The Current Problem

• Motor-vehicle crashes:
  – account for 40% of trauma admission to US hospitals,
  – are the fourth most common cause of non-fatal injuries treated in emergency departments, and
  – are the leading cause of death for people between ages 1-44.

• 33,000 fatalities and 2.2 million injuries each year in road-traffic crashes. (NHTSA, 2011). Likely to increase in coming years, as economy (and travel) recover.

• The annual economic cost of these injuries is estimated at $231 billion.
Primary data sources for injury:

- National Automotive Sampling System—Crashworthiness Data System (NASS-CDS)
  - Include medical diagnosis data, accident investigation, and detailed crash data
  - Small (but nationally weighted) sample

- State police-report data
  - Uses police-reported injury severity (KABCO scale)
  - Data linkage to trauma/hospital needed, encouraged by USDOT, in progress in many states…
Working with Injury Data in Traffic Safety Research

Policy Analysis
Policy Analysis

Helmet law change in Michigan

On April 13, 2012, a modified helmet law went into effect in Michigan allowing motorcyclists 21 and over to choose not to wear a helmet. What was the effect and how is fatality/injury risk affected by helmet use?
## Motorcycle Fatalities and Injuries
**Apr 13-Dec 31**

<table>
<thead>
<tr>
<th>Year(s)</th>
<th>Helmet Use</th>
<th>Fatalities (per year)</th>
<th>Serious Injuries (per year)</th>
<th>Percent Fatal</th>
<th>Percent Serious Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>Yes</td>
<td>97</td>
<td>574</td>
<td>3.2%</td>
<td>19%</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>6</td>
<td>23</td>
<td>7.2%</td>
<td>31%</td>
</tr>
<tr>
<td>2012</td>
<td>Yes</td>
<td>56</td>
<td>390</td>
<td>2.3%</td>
<td>16%</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>55</td>
<td>194</td>
<td>6.5%</td>
<td>23%</td>
</tr>
</tbody>
</table>
Motorcycle Fatalities and Injuries
Apr 13-Dec 31

- Overall fatality rate in 2011 = 3.3%
- Overall fatality rate for 2012 = 3.4%
- Fatality rate was 2.8 times higher for those who didn’t wear helmets in 2012 compared to those who did
### Who Wears Helmets?

<table>
<thead>
<tr>
<th>Driver Drinking</th>
<th>Year(s)</th>
<th>Helmet Use Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver Not Drinking</td>
<td>2008-11</td>
<td>98%</td>
</tr>
<tr>
<td>Driver Not Drinking</td>
<td>2012</td>
<td>76%</td>
</tr>
<tr>
<td>Driver Drinking</td>
<td>2008-11</td>
<td>90%</td>
</tr>
<tr>
<td>Driver Drinking</td>
<td>2012</td>
<td>54%</td>
</tr>
</tbody>
</table>
Separating the Effect of Alcohol from the Effect of the Helmet

How do we figure out what effect the helmet has, separate from risk-taking factors like alcohol use?

Regression models allow us to predict risk of fatality or injury account for alcohol, speed, age, and other factors.
Taking risk-taking factors into account, we find:

- Alcohol more than quadruples the risk of death and nearly triples the risk of serious injury
- After accounting for other risk factors, not wearing a helmet doubles the risk of fatality and increases the risk of serious injury by 60%
- 24 fatalities and 67 serious injuries estimated to have resulted from reduced helmet use after the helmet-law modification
Working with Injury Data in Traffic Safety Research

Vehicle Design
Demographic Changes: Aging of the U.S. Population

Source: US Census Bureau, 2004
Effects of Age on Fatality Rate

Per 100 Million Miles Driven

Source: IIHS (2007), FHWA
Serious Injury Risk by Age in Frontal Crashes

Male, Belted, Driver, BMI=24, Pass Car, 35 mph DV

- Head (OR=4.10)
- Thorax (OR=15.90)
- Abdomen (OR=11.30)
- Spine (OR=5.99)
- UX (OR=2.99)
- LX (OR=3.49)
Load limiting seatbelts

Deformable element in the retractor allows belt to spool out at a fixed force to limit chest loading and chest deformation and thus minimize the potential for thoracic injury.
Obesity Trends* Among U.S. Adults
(*BMI ≥30, or about 30 lbs. overweight for 5’4” person)

• 27% of population or 75M adults are currently obese.

• These estimates are based on self-reported height and weight, actual rates of obesity are higher (best estimate is ~7% higher).
Serious Injury by BMI in Frontal Crashes

Obesity mainly affects injury risk in frontal crashes.

- More mass to stop \( \rightarrow \) higher force to stop occupant.
- Worse belt fit \( \rightarrow \) tougher to apply forces to bony anatomy, especially the pelvis.

35YO, driver, belted, male passenger car, 35 mph \( \Delta V \)

Risk of AIS 3+ Injury (%)

- Abdomen (OR=1.81)
- UX (OR=2.30)
- LX (OR=1.76)
- Spine (OR=8.17)
Parametric Study on Obesity

BMI 25

BMI 40
Future Improvements in Occupant Restraint Technologies

• Inflatable belts (2011 Ford Explorer, Lexus FXL) and 4-point belts
• Adaptive restraints (customize belt forces for individual occupants)
• Ejection mitigation in rollovers (FMVSS 226)
• and many more…
Occupant Protection in Low-Mass Vehicles

• Smaller cars experience more severe crashes than larger cars, on average, in a mixed fleet

• Suppose a low-mass vehicle were equipped with ideal crash avoidance technology, such that it couldn’t cause a crash but could still be hit by other vehicles
  – What would be the overall risk of injury to occupants of the low-mass vehicle?
  – What kinds of injuries would they sustain?
Research Approach

1. Identify crashes that remain for a vehicle that never causes a crash (change in exposure)

2. Identify changes in crash-severity distribution for LMV given a crash (change in risk)
   - Average crash severity increases by 80% for a single low-mass vehicle traveling with the current fleet

3. Estimate change in overall injury incidence in each crash type resulting from combination of decreased involvement and increased risk
Low Mass Vehicle Injury by Crash Type

![Bar chart showing the percent of original crashes by crash direction (front and side) for original and low-mass vehicle categories.](chart.png)
LMV increased severity of remaining crashes

![Graph showing increased risk of head injury in low-mass vehicle (LMV) crashes compared to original crashes. The graph compares the risk of head injury in front and side crash directions between original and low-mass vehicle (LMV) conditions.]
Occupant Protection in a Crash-Avoidance World

- As more vehicles are equipped with forward collision assistance systems (warnings, brake assist or automatic braking), the makeup of frontal collisions will change
  - Some crashes are avoided, others are mitigated
- Currently occupant protection is aimed at the 95th percentile frontal crash severity (~35 mph)

Research Question: How can occupant protection be improved by linking it to information from crash avoidance systems?
Occupant Protection in a Crash-Avoidance World

Integration of Active and Passive Safety

Computational Modeling

Field Data Analysis

Naturalistic Driving Data Analysis
Occupant Protection in a Crash-Avoidance World

• Some crashes will be avoided (ests from 20-40%)

• Crash severity distribution for remaining crashes will shift to lower levels (so most crashes will be milder than current)

• Occupant protection systems “know” when a crash is imminent and can be prepped (e.g., fire pretensioners)

• Systems can also predict impending crash severity, so systems can be optimized (e.g., tune airbag force and timing)
Improved Injury Response
Automatic Collision Notification and the Injury Severity Prediction Algorithm

EDR = Event Data Recorder
A car’s “black box”
Automatic Collision Notification and the Injury Severity Prediction Algorithm

• Used NASS-CDS to predict risk of serious injury given EDR-reportable crash factors
• Algorithm output is continuous (risk from 0-1)
• Cutoff of 0.2 chosen by expert panel and implemented by OnStar
• When serious injury risk >20%, advisor alerts dispatch to high risk of serious injury for faster triage
Automatic Collision Notification and the Injury Severity Prediction Algorithm

Crash Severity
Crash direction
Belt status
1 or 2 events
Vehicle Type
Age
Gender

Model → Predicted risk of serious injury
Automatic Collision Notification and the Injury Severity Prediction Algorithm

Current work:

1. Refine algorithm to use details of the crash pulse to improve prediction
2. Focus prediction algorithm only on injuries for which timing is critical
3. Determine additional sensors that might enhance algorithm performance (e.g., more occupant sensors, occupant weight sensors, crush sensors in siderails, etc.)
Final Comments

• Injury data are essential to improving safety at both the policy and technology levels.

• Injury is an increasing focus of safety efforts as fatalities drop, but datasets must support development of safety technology and assessment of benefits.

• Data linkage between state crash and medical outcome datasets would significantly improve sample sizes and analysis results (linkage to EDR reports would make datasets even better!)
Thanks for your attention.

University of Michigan Transportation Research Institute (UMTRI)
Benefits Assessment for Crash Mitigation Technology

Simulation

• Identify crash-relevant situations in driving data
• Simulate driver non-response and play out until “crash” occurs
• Simulate effect of safety technology

Example: Collision Mitigation Braking in Heavy Trucks
Track Testing
Benefits Assessment for Crash Avoidance Technology

Collision Mitigation Braking in Heavy Trucks Simulation

1) Use real-world braking scenarios and simulate out-of-the-loop truck driver to create “crashes” where none actually happened
2) Model injury potential of simulated crashes
3) Simulate effect of technology (based on track tests)
4) Model reductions in injury
Results….injury reductions

Injury Reductions for CMB (LV Decel and Stopped):

<table>
<thead>
<tr>
<th>Percent Reduction in Injuries</th>
<th>Killed</th>
<th>Serious Injury</th>
<th>Moderate Injury</th>
<th>Minor Injury</th>
<th>Property Damage Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMB1</td>
<td>6.7%</td>
<td>5.8%</td>
<td>4.1%</td>
<td>1.9%</td>
<td>-1.6%</td>
</tr>
<tr>
<td>CMB3</td>
<td>53.9%</td>
<td>52.7%</td>
<td>50.5%</td>
<td>46.1%</td>
<td>14.0%</td>
</tr>
</tbody>
</table>