Relationships Between Fatality Risk, Mass, and Footprint

February 25, 2011
Objective

• Estimate the effect on societal fatality rates of mass reduction without changing footprint
  ◆ “Societal” fatality rate: includes occupants of other vehicles and pedestrians
  ◆ Footprint = track width x wheelbase
How to change mass without changing footprint

• In the abstract
  † Add or remove sandbags in the trunk

• In actual practice to date – also tends to change the vehicle in other ways
  † Luxury features & powerful engines
  † Protective structure & padding

• Mostly in the future
  † Substitute lighter & stronger materials
Mass in collisions of 2 light vehicles (momentum)

- Mass reduction harms me and helps the other vehicle
- Relative mass of the 2 vehicles:
  - If mine is lighter, mass reduction harms me more than it helps you
  - If mine is heavier, mass reduction helps you more than it harms me
- Proportionate reductions in both vehicles: should have little net effect
Effects of mass on handling & stability

- Reduced stability if added mass raises the center of gravity
- Enhanced stability if it lowers cg
- Slower response to steering
  - Harmful if wise maneuver
  - Beneficial if inappropriate maneuver
Benefits of increased mass

- Knock down medium-sized trees or poles
- In collisions with
  - Medium-size trucks
  - Unoccupied parked cars
  - Deformable or movable objects
Benefits of increased size (footprint)

- Stability
- More crush space surrounding the occupants
Historical trend (since at least 1976)

• Heavier (and larger?) vehicles are better driven
  ♦ As evidenced by lower culpability in 2-vehicle crashes

• Is mass a cause, an effect, or neither?
2010 NHTSA Report

• Pages 464-542 of FRIA, March 2010
• Statistical analysis of fatality rates of MY 1991-1999 cars (2- & 4-door) and LTVs in CY 1995-2000

♦ By curb weight and footprint
♦ Societal fatality rate per billion VMT
  o Registration years from Polk
  o VMT per year from NASS (by vehicle type only)
2010 NHTSA Report

♦ Induced-exposure crashes from 8 States
  o Each crash assigned national weight-factors in registration years and VMT
  o Apportions the VMT by driver age & gender, rural/urban, etc.

♦ Logistic regressions for 6 crash types:
  o Rollovers
  o Collisions with fixed object, ped-bike-motorcycle, heavy truck, car, LTV
Independent variables

- Curb weight (2-piece linear)
- Footprint
- Driver age & gender
- Rural/urban, day/night, speed limit
- Frontal air bag, ABS, AWD
- Vehicle age, calendar year
<table>
<thead>
<tr>
<th>Violation Type</th>
<th>Fatality Increase per 100-pound Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cars &lt; 2,950 lbs</td>
<td>2.21%</td>
</tr>
<tr>
<td>Cars ≥ 2,950 lbs</td>
<td>0.90%</td>
</tr>
<tr>
<td>LTVs &lt; 3,870 lbs</td>
<td>0.17%</td>
</tr>
<tr>
<td>LTVs ≥ 3,870 lbs</td>
<td>-1.90%</td>
</tr>
</tbody>
</table>
Discussion

• Mass reduction harmful overall in light cars, beneficial in heavy LTVs
  ♦ Especially in collisions of 2 light vehicles
  ♦ Consistent with momentum considerations

• Footprint beneficial in all crashes, but especially rollover and fixed-object
Discussion

• Mass reduction beneficial or non-significant in rollover and fixed-object crashes

  ♦ Consistent with handling/stability considerations (lowers cg)

  ♦ Caveats about accuracy due to collinearity of mass and footprint
Discussion

- Slight tendency (3 of 4 vehicle groups, but only one significant): mass reduction harmful overall
  ♦ Consistent with the historical trend that heavier vehicles are better driven
2010 Conclusion

- If mass reduction in MY 2012-2016 emphasizes the heavier LTVs and maintains footprint
  - Fatalities will not increase significantly
  - May decrease
Status/Next Steps

• 2010 report peer-reviewed by:
  ◆ Charles Farmer, IIHS
  ◆ Paul Green, UMTRI
  ◆ Anders Lie, Swedish Transport Administration

• New study of MY 2000-2007 vehicles in CY 2002-2008 crashes underway
Great increase in crossover utility vehicles (CUV)

- LTVs with car-like structure and use patterns
- Lower rollover risk than past SUVs

Curb weights increased for all types of vehicles
Developments, 2000-2007

- **Major safety improvements**
  - Frontal air bags in all new vehicles
  - ESC will greatly reduce rollovers and fixed-object crashes
  - Increased belt use
  - Curtains and side air bags

- **Poor safety performers phased out**
  - New vehicles designed to IIHS offset test
Issues for new analysis

• CUVs
  ♦ Make separate vehicle category?
  ♦ Combine with cars? Keep with LTVs?

• Tools to address collinearity of curb weight and footprint

• Can analyses consider the mass of the “other” vehicle in 2-vehicle crashes?
Issues for new analysis

• More detailed VMT data
  ♦ Odometer readings by make and model

• New control variables
  ♦ ESC
  ♦ Side and curtain air bags
  ♦ IIHS test results

• Future effect of ESC on the number and distribution of fatalities
Limitations of historical, statistical analyses

• Cross-sectional analysis
  ♦ Compares fatality rates of light & heavy vehicles as they are
  ♦ Does not zero in on a specific mass reduction – before versus after

• Cannot control for all driver factors
  ♦ E.g., if more risky drivers select lighter and smaller vehicles
Limitations of historical, statistical analyses

- Historical analysis lags behind the latest vehicle developments
  - Intentional mass reduction by materials substitution not yet widespread in 2007, let alone 1999
  - Vehicles became lighter or heavier mostly for other reasons
    - E.g., to provide features that consumers desired