Relationships Between Fatality Risk, Mass, and Footprint in Model Year 2000-2007 and in Future Passenger Cars and LTVs

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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 reduce mass without changing footprint

- **Substitute with lighter materials**
- **Substitute with stronger materials but use less of them**
- **Downsize engine and powertrain**
- **Use light-weighted features**
- **Reduce overhang outside the wheels**

Predictable effects of mass reduction

- **Conservation-of-momentum factors**
  - ♦ **In collisions of two light vehicles**
    - o **Depends how mass reduction is applied across the light-vehicle fleet**
  - ♦ **Slightly higher risk in a collision with a movable object or a heavy vehicle**
- **Improved braking and steering**
- **Less roof crush in rollovers**

Conservation of momentum in collisions of 2 light vehicles

- **Mass reduction in my vehicle harms me and helps the other vehicle**
- **Societal effect depends on 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**

Conservation of momentum in collisions of 2 light vehicles

- **Proportionate reductions in <u>both</u> vehicles: no net effect**
- **Increasing fleet-wide mass disparities will increase societal risk**
- **Reducing disparities will reduce societal risk**

Unpredictable effects of future mass reduction

- **Will heavier and larger vehicles continue to be better driven?**
  - ♦ **Historical trend since 1976**
- **Will material substitution change force/deflection properties of vehicles?**

Harmful effects of reducing footprint

- **More rollover-prone**
- **Reduced directional stability**
- **Less crush space around the occupants**

2012 NHTSA Report

- **Issued September 17, 2012**
- **Report available at www-nrd.nhtsa.dot.gov/Pubs/811665.PDF**
- **Databases available at www.nhtsa.gov/fuel-economy**
- **Earlier reports in 2011, 2010, 2003, 1997, 1991**

Analysis Method

- **Statistical analysis of fatality rates of MY 2000-2007 cars and LTVs in CY 2002-2008**
  - **By curb weight and footprint**
  - **Societal fatality rate per billion VMT**
    - **VMT apportioned by driver age & gender, rural/urban, etc., based on induced-exposure crash data**
  - **Logistic regressions for 9 crash types**

Independent variables

- Curb weight (2-piece linear)
- Footprint
- Driver age & gender
- Rural/urban, day/night, speed limit
- ESC, ABS, AWD, side air bag, blocker beam
- IIHS offset-frontal test ratings
- Vehicle age, calendar year

Fatality increase per 100-pound reduction (holding footprint constant)

Cars < 3,106 lbs	1.56 %	Statistically significant
Cars ≥ 3,106 lbs	.51 %	Not significant
CUVs & minivans	- .37 %	Not significant
LTVs < 4,594 lbs	.52 %	Not significant
LTVs ≥ 4,594 lbs	- .34 %	Not significant

Discussion

- **Only significant effect: cars < 3,106 pounds**
- **Mass reduction more harmful in lighter vehicles, more beneficial in heavier vehicles**
  - **Consistent with momentum considerations**

Sensitivity tests: plausible alternative models

- **Reviewers suggested 13 alternatives:**
  - ♦ **Delete some control variables**
  - ♦ **Add new control variables:**
    - o **Track width, wheelbase instead of footprint**
    - o **Driver income (based on ZIP)**
    - o **Vehicle manufacturer, nameplate, price**
  - ♦ **Apportion VMT based on stopped-vehicle crash involvements**
  - ♦ **Limit to sober drivers or good drivers**

Sensitivity tests: range of estimated effect on fatalities per year

Scenario: reduce mass by 14 pounds (light cars) to 247 pounds (big LTVs)

- **Effect in NHTSA baseline model:**
  - ♦ **Point estimate: ZERO (safety neutral)**
  - ♦ **Confidence bounds: ± 240 fatalities/year**
- **13 alternative models:**
  - ♦ **Point estimates ranging from -321 to +276 fatalities**

Conclusions

- **If mass reduction in MY 2017-2025 emphasizes the heavier LTVs and maintains footprint:**
  - ♦ **Fatalities will not increase significantly**
  - ♦ **May decrease**
- **Confidence bounds, sensitivity tests show limitations of estimating future effects from historical data**

Comparison of MY 2000-2007 with MY 1991-1999 results

	2000-07	1991-99
Lighter cars	1.56 %	2.21 %
Heavier cars	.51 %	.90 %
CUVs/ minivans	- .37%	with LTVs
Lighter LTVs	.52 %	.17 %
Heavier LTVs	- .34 %	- 1.90 %

Comparison of MY 2000-2007 with MY 1991-1999 results

- **Directionally similar**
- **2000-07 results lower magnitude**
  - ♦ **Lighter cars: from 2.21% to 1.56%**
  - ♦ **Heavier LTVs: from -1.90% to -.34%**

Possible explanations for smaller effects (2000-2007 developments in vehicles)

- **Light vehicles up-sized or phased out**
  - ♦ **Trend might not continue after 2007**
- **Older designs with poor safety performance phased out**
  - ♦ **Many of these were the lighter vehicles**
- **Compatibility improved in heavy LTVs**
- **Diminishing tendency of small/light vehicles to be driven poorly**

Lessons for the future

- **Laws of physics stay the same**
  - ♦ Conservation-of-momentum effects
  - ♦ Mass reduction and braking/steering
- **Other things can change year to year**
  - ♦ Mass distribution of new-vehicle fleet
  - ♦ Safety equipment
  - ♦ Vehicle use patterns
  - ♦ Who selects what type of vehicle

Next Steps

- **Revisit analyses circa 2015 (interim CAFE review)**
  - ♦ **Crash data may be available up to MY 2011 and CY 2012**
- **Consider revisions to the model**
  - ♦ **Techniques in the alternative models**
  - ♦ **New ideas to address changes in the crash environment**