Mass Change, Complexity and Fleet Impact Response

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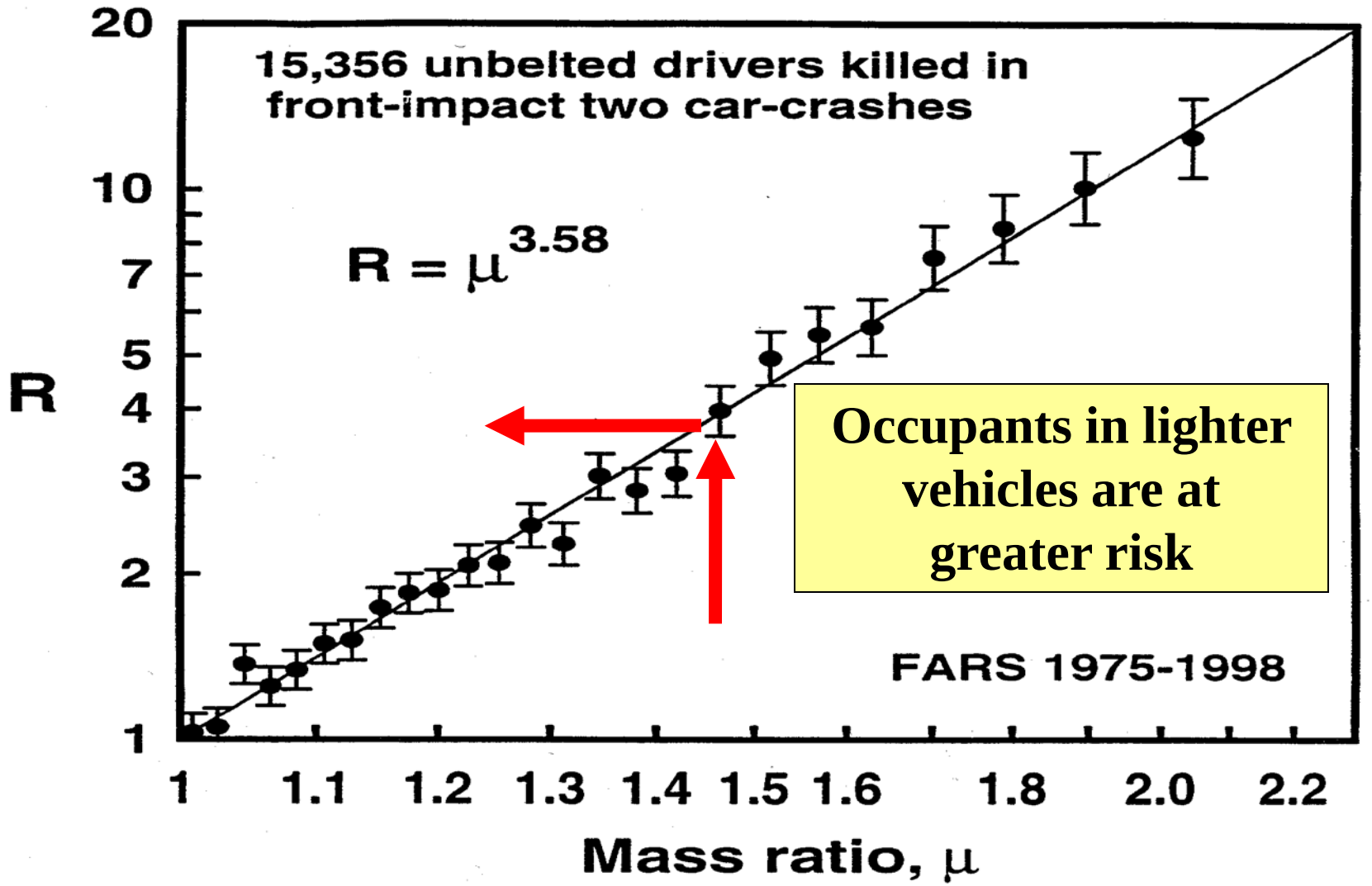
Overview

- Review of historical mass/fatalities studies
- Elaborating on complexity of mass reduction
- Description of fleet model
- Results of fleet model

Mass Effect History

- Evans: $R_1/R_2 = (\mathbf{M_2/M_1})^{\mathbf{3.58}}$
- Kahane 2003: mass was the dominant parameter, stiffness plays significantly less of a role and geometry has no statistically significant contribution.
- Padmanaban: Mass is the most significant vehicle parameter determining relative fatality outcome.

Effect of Mass Ratio on Relative Fatality Risk

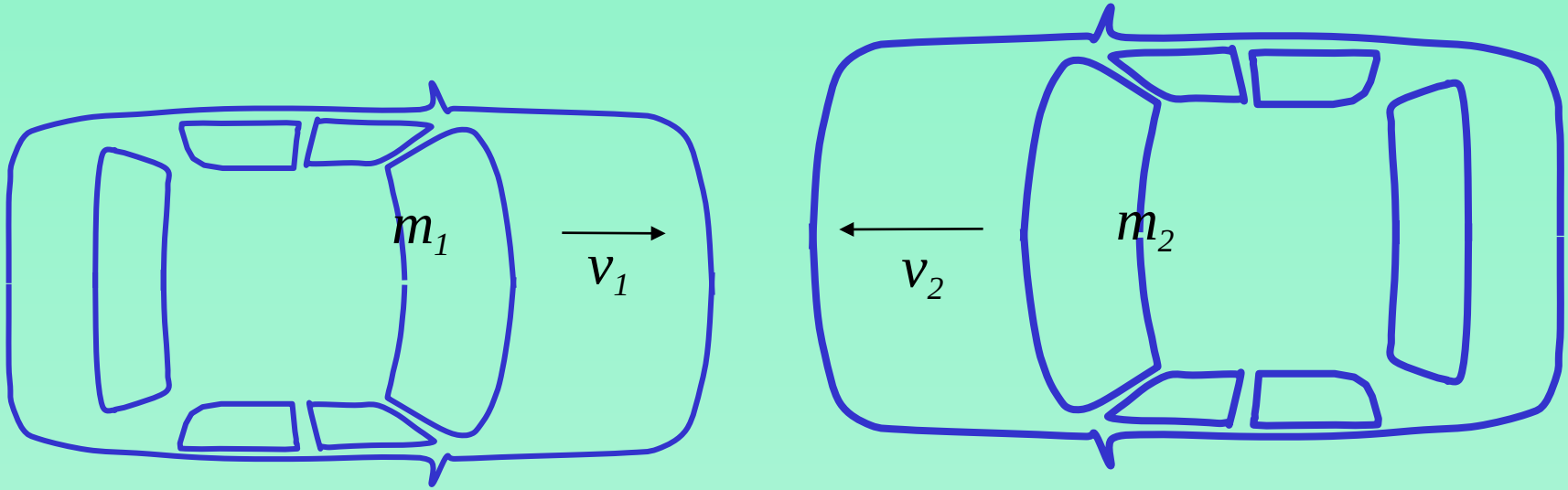


R : driver fatalities in lighter car / driver fatalities in heavier car

μ : mass of the heavier car / mass of the lighter car

L. Evans, February 2000

Effect of Mass on Velocity Change

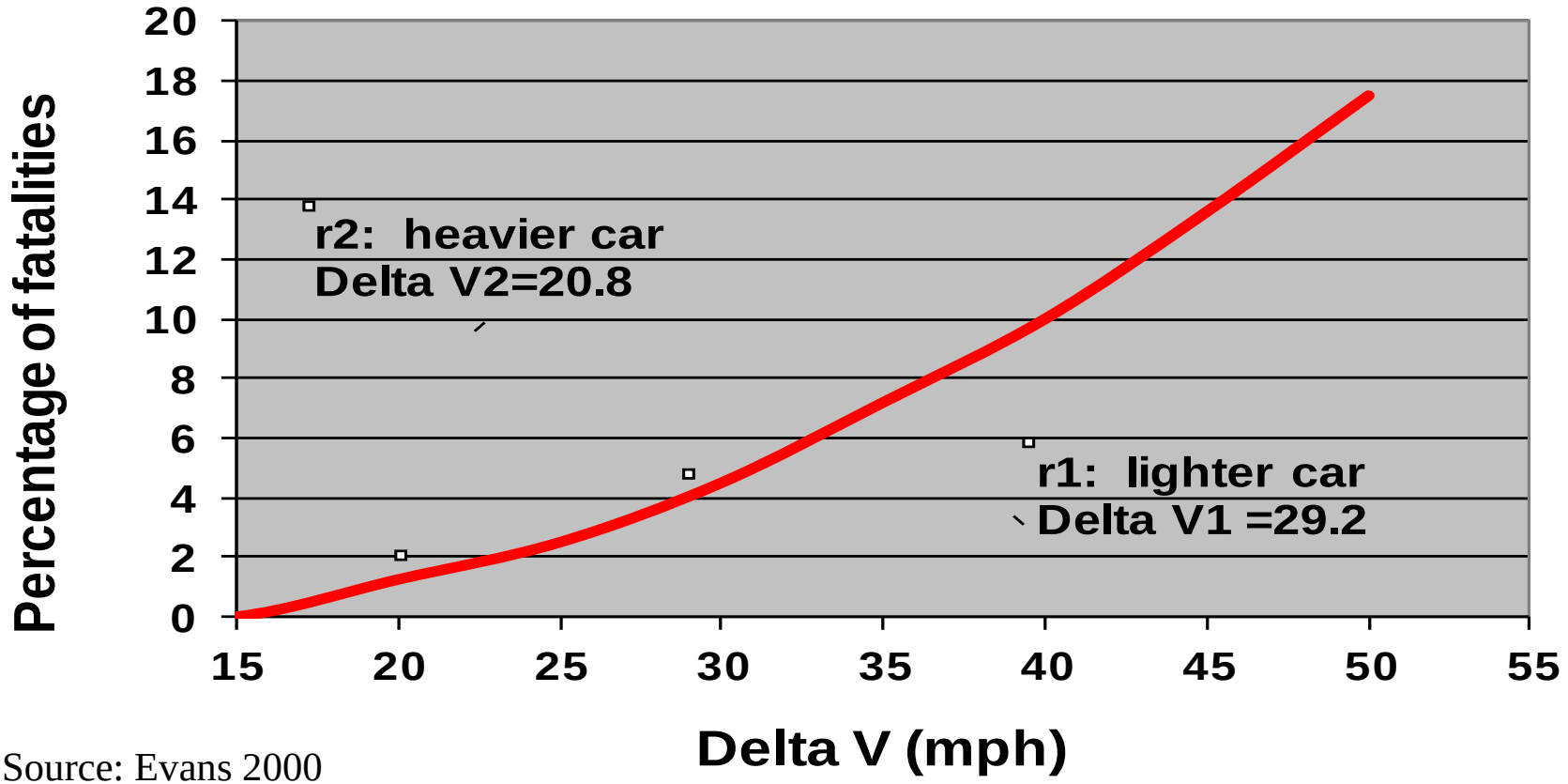


$$|\Delta v_1| = \frac{m_2}{m_1 + m_2}(|v_1| + |v_2|) \qquad |\Delta v_2| = \frac{m_1}{m_1 + m_2}(|v_1| + |v_2|)$$

For $m_1 = 2500\,lb$, $m_2 = 3500\,lb$, and $|v_1| + |v_2| = 50\,mph$,

$\Delta v_1 = 29.2\,mph$, $\Delta v_2 = 20.8\,mph.$

Effect of Velocity Change on Fatality

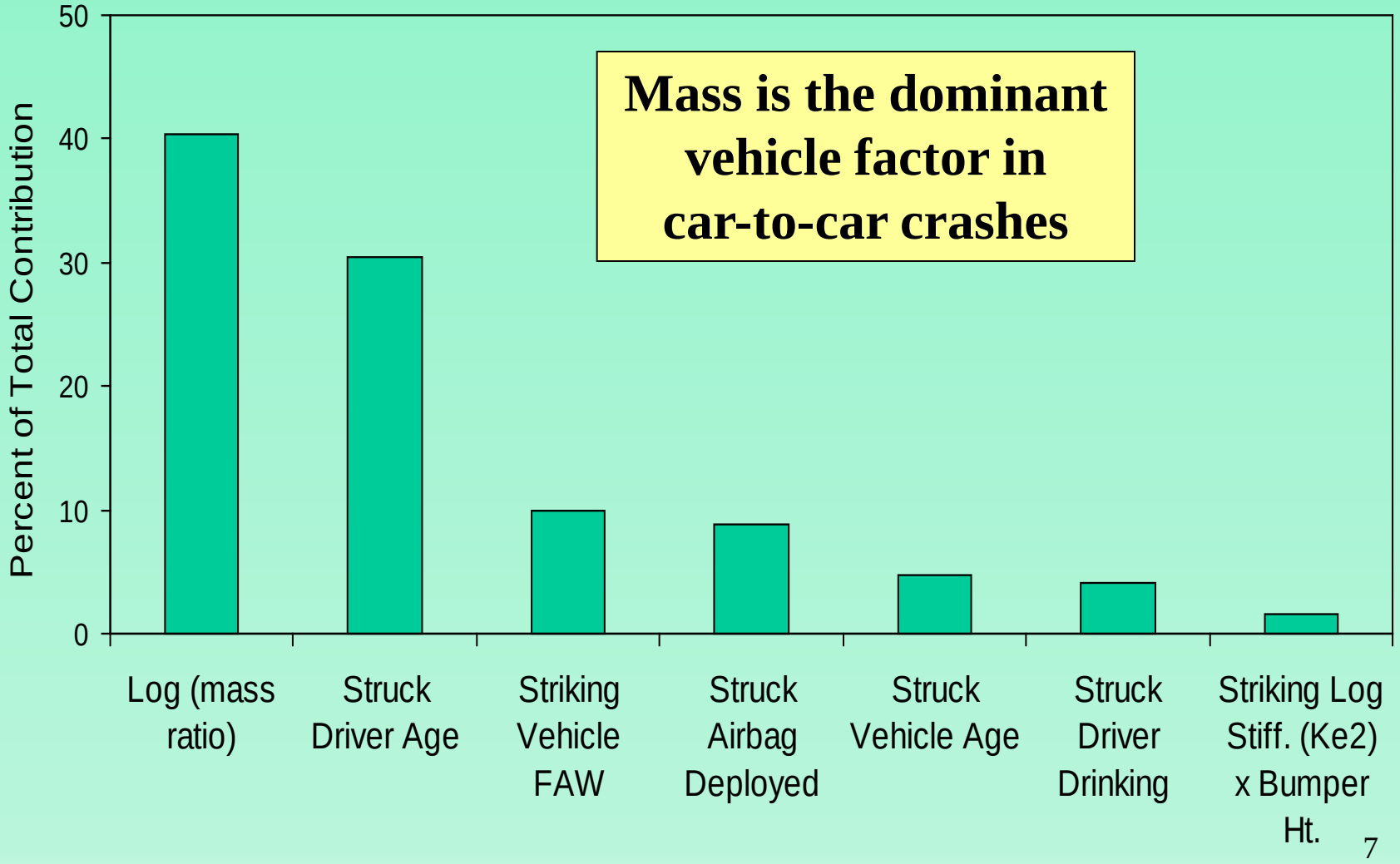


Source: Evans 2000

Ratio of fatality risk ~ 4%/1.5%=2.7

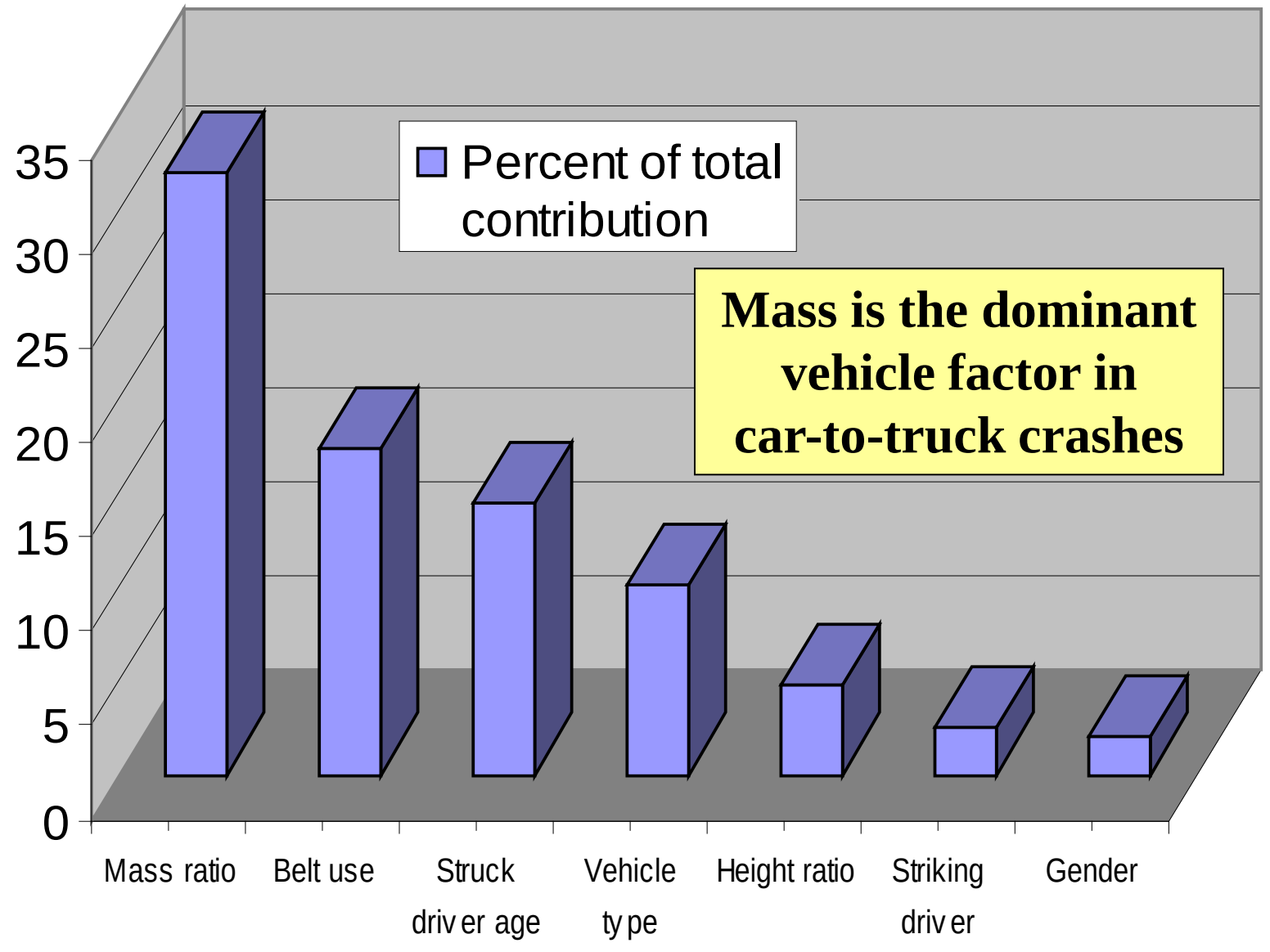
Occupants in the lighter vehicle are at 2.7 times greater risk

Relative Contribution of Variables to Odds of Fatality Car-to-Car, Frontal Crashes



Source: Padmanaban 2003

Relative Contribution of Variables to Odds of Fatality Car-to-Truck, Frontal Crashes



Fleet Model

- Analyze and understand the general effects of a set of different vehicle and behavioral attributes on overall crash outcome.
- Attributes considered are: mass, stiffness, crush, intrusion, pulse shape, seatbelt usage, velocity distribution, etc.

Original 2003 Model

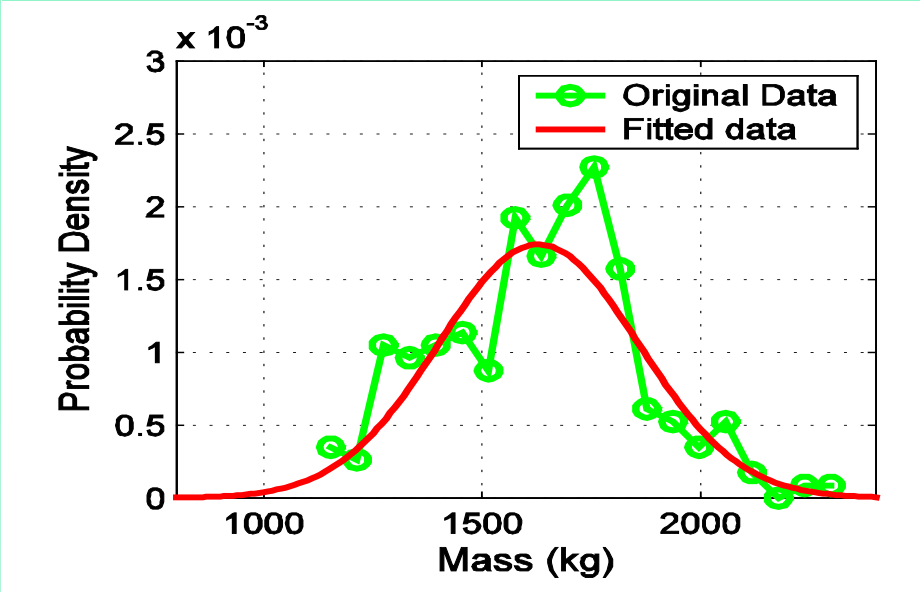
- Data-based fleet model
  - Original version:
    - Investigate the effect of mass and size
    - Fleet samples created based on 22 NCAP tests.
    - Pulse: Two-step, Linear and Linear/Plastic
    - Average acceleration is used to estimate the fatality risk.

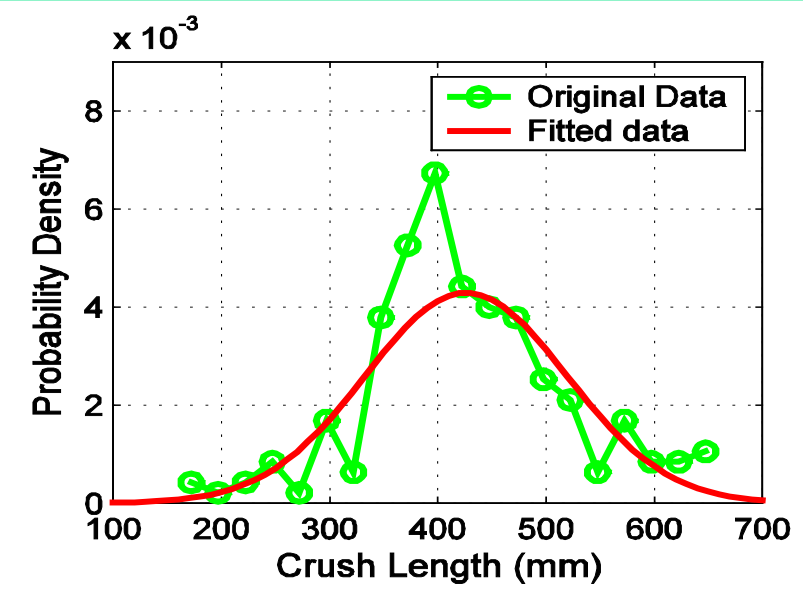
Source: Nusholtz SAE 2003-01-0905

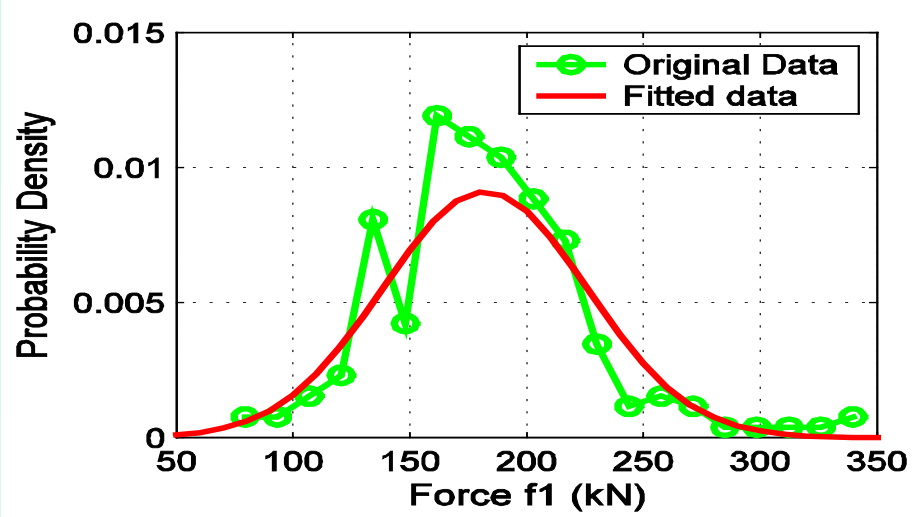
Updated Current Model

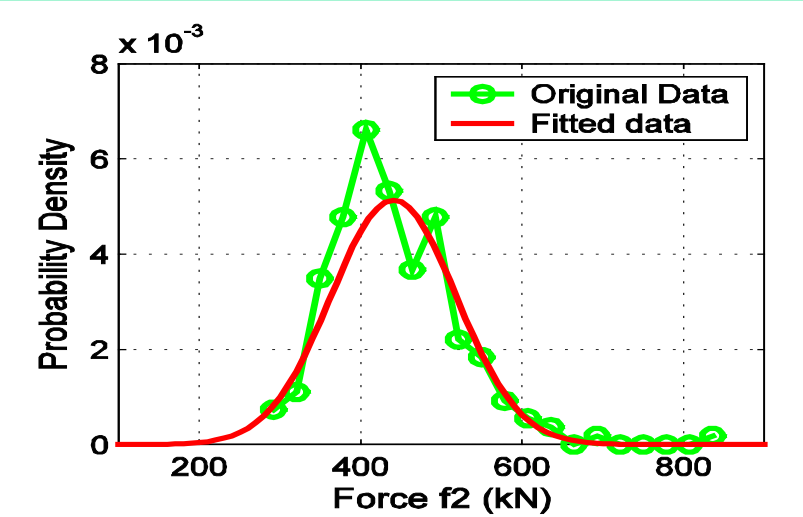
- Data-based fleet model
  - Introduced a significant number of new variables (intrusion, belt use, airbag, driver behavior, etc.)
  - Fleet samples created based on over 300 NCAP tests (1993~2010).
  - Non-NCAP response included: Car to Car, offset, lower velocity impacts, etc.
  - Pulse: Linear, Piece-wise Linear, Non-linear and NCAP
  - Average acceleration is used to estimate the fatality risk (no change).

Examples of Data Input to Model



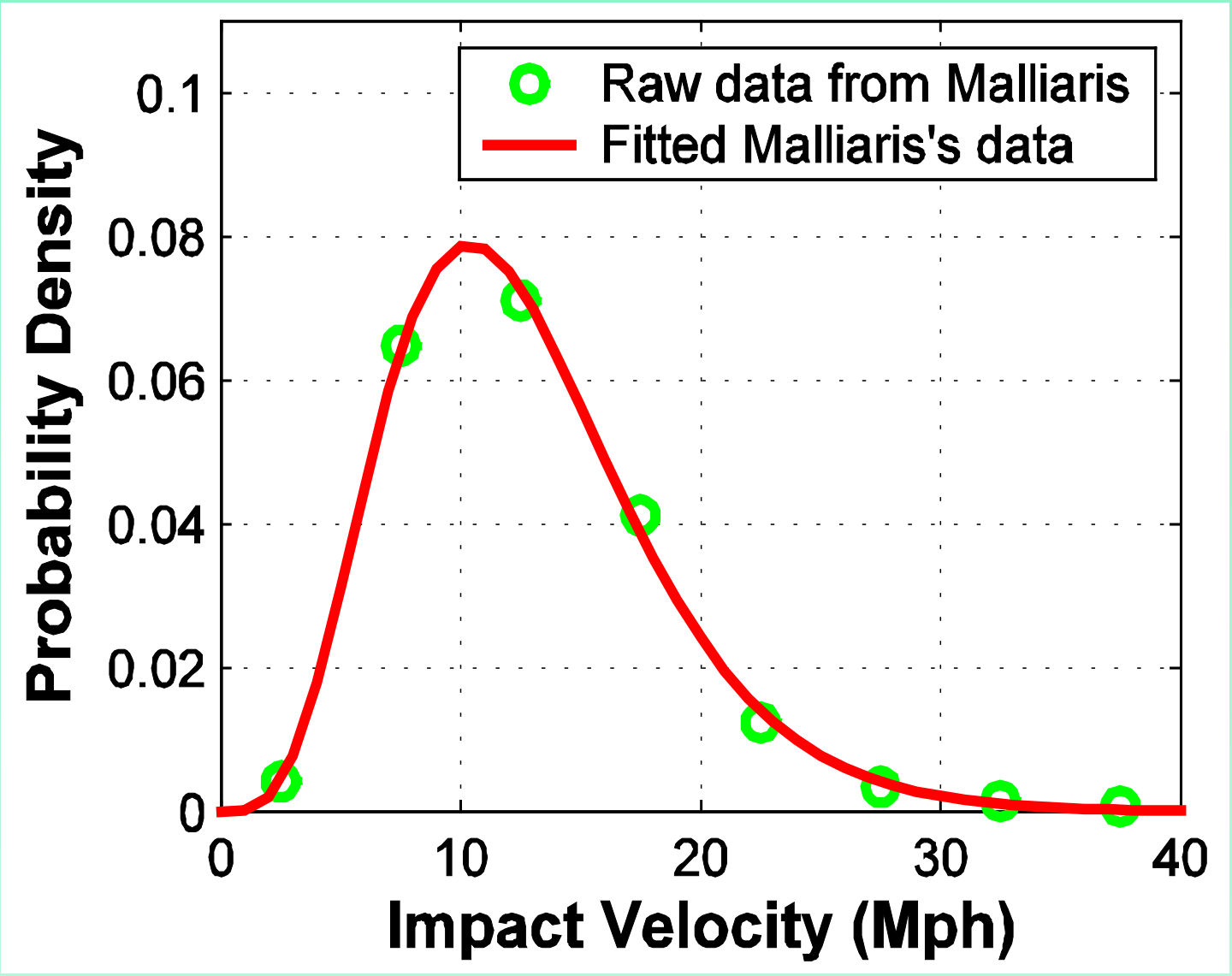






Data source: NCAP (35 MPH)

Data Input: Initial Velocity Spectrum



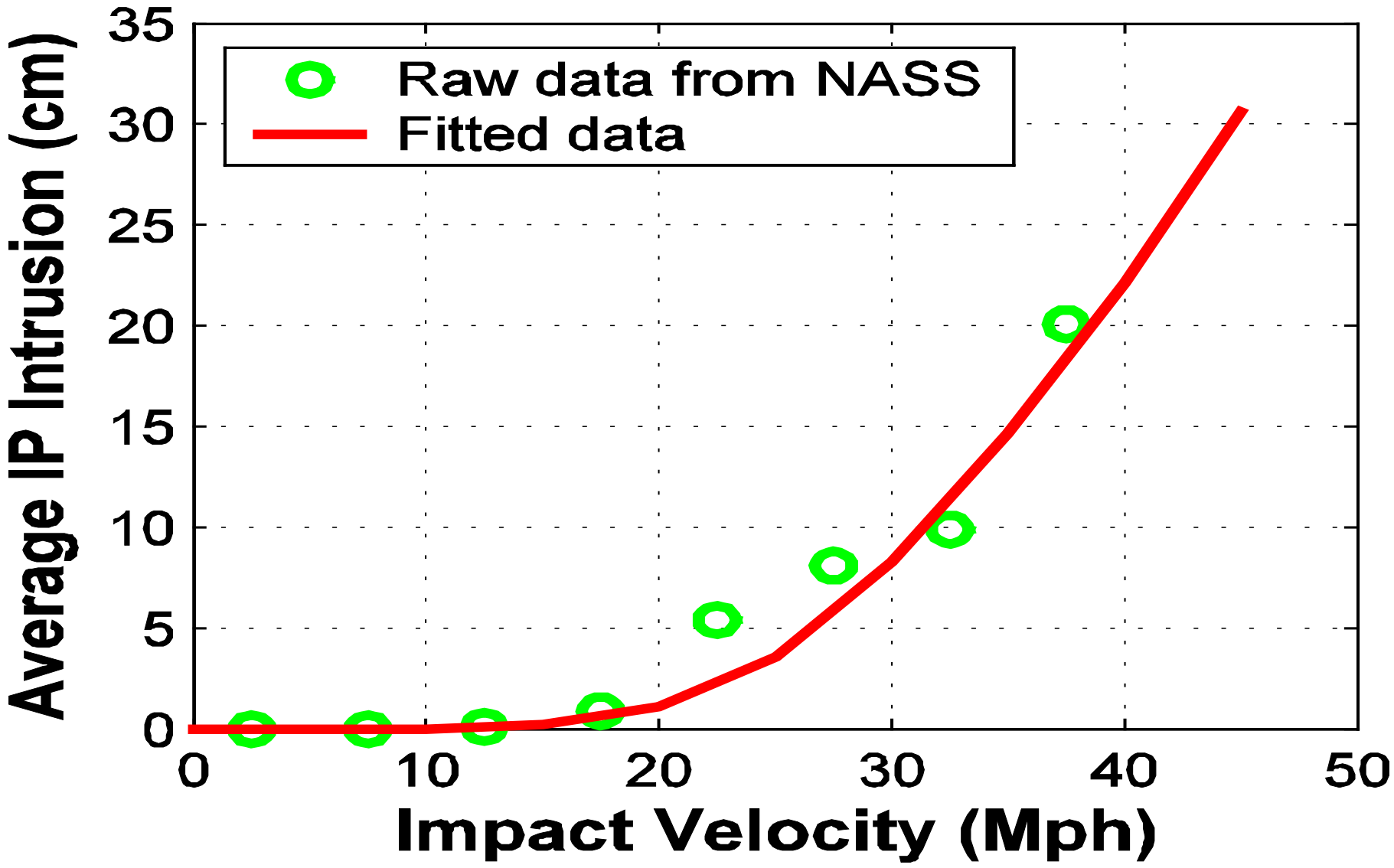
$\alpha = 5.37$

$\beta = 2.38$

$\mu = 12.76$

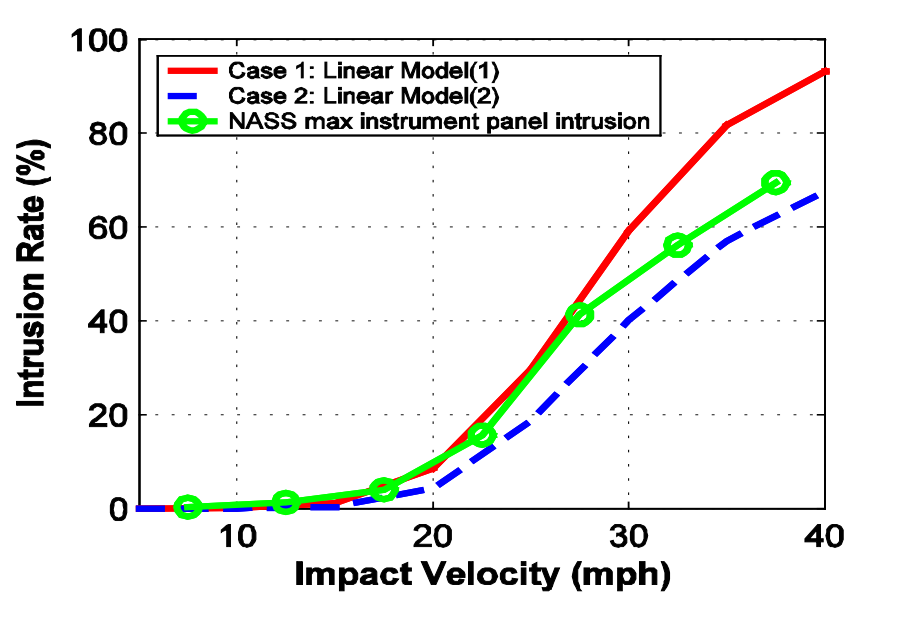
$\sigma = 5.51$

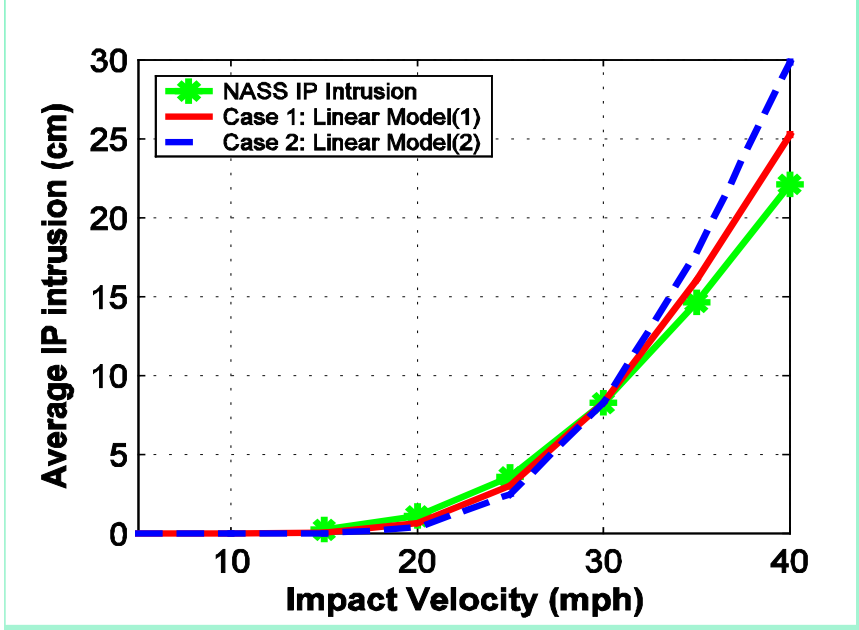
Data Input: Intrusion

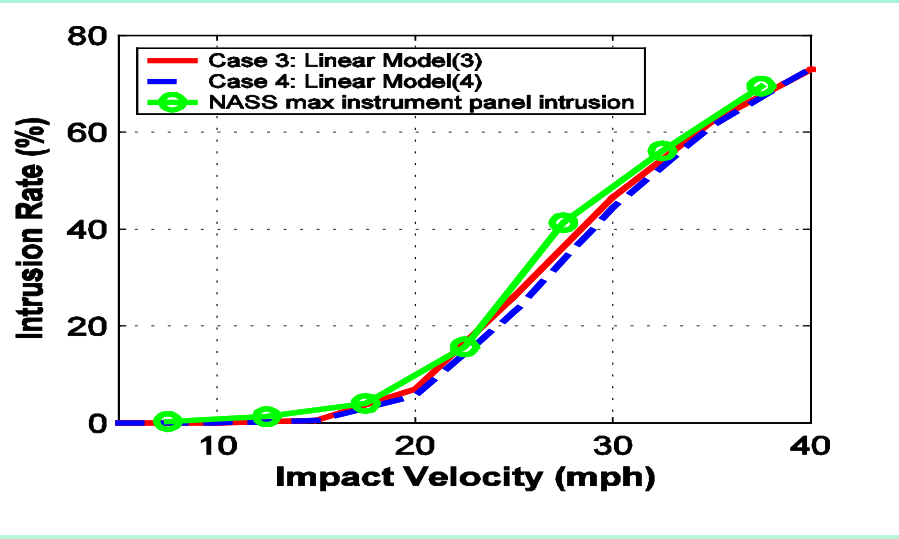


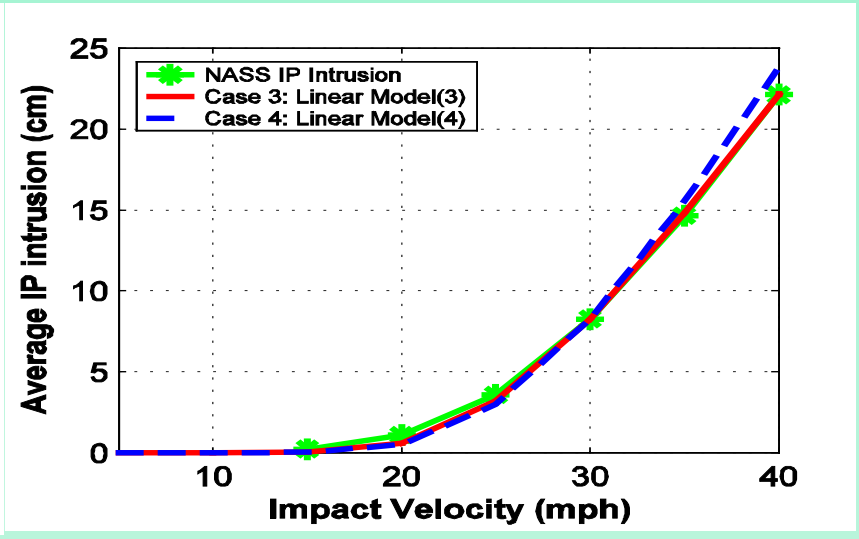
Data source: Nusholtz SAE 2006-01-1134

Model Validation: Intrusion

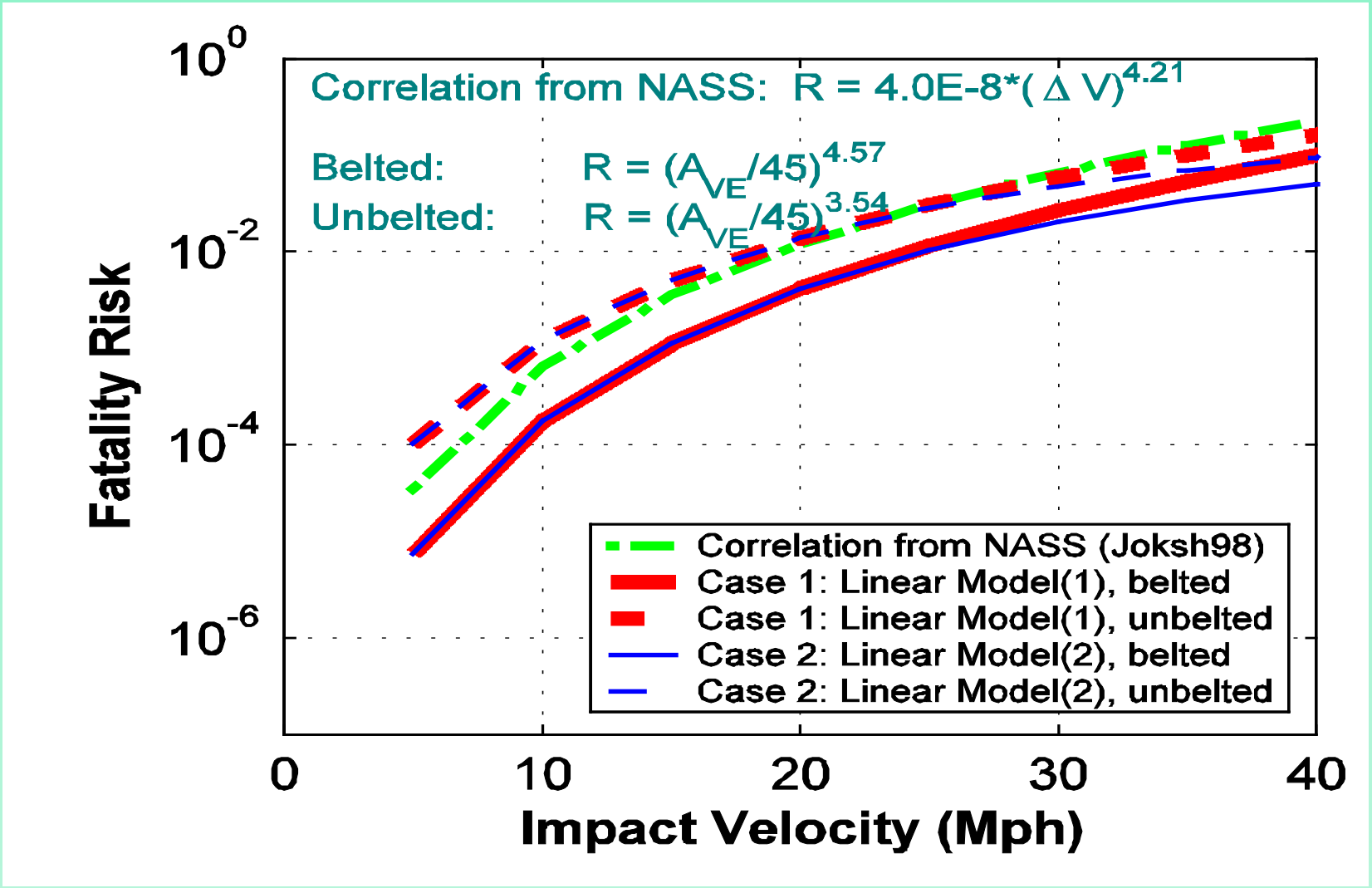








Model Validation: Fatality Risk



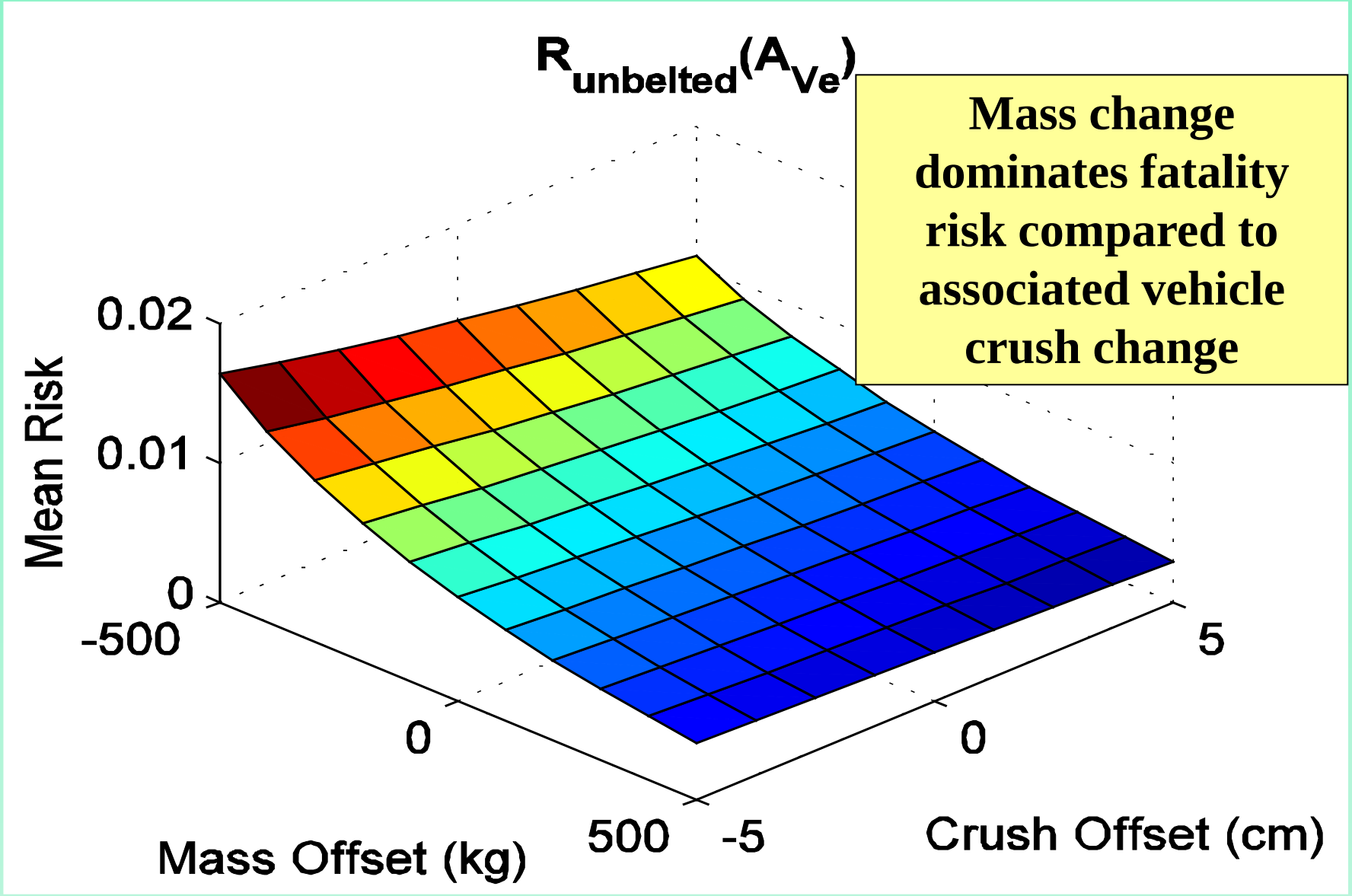
Model Assumptions (1 of 3)

- 70% belted.
- No behavioral changes.
- Front Impacts: car to car, truck to truck and truck to car.
- Risk is monotonically increasing with velocity change (all other conditions fixed).
- Risk is a function of velocity change and the average rate of velocity change (all other conditions fixed).

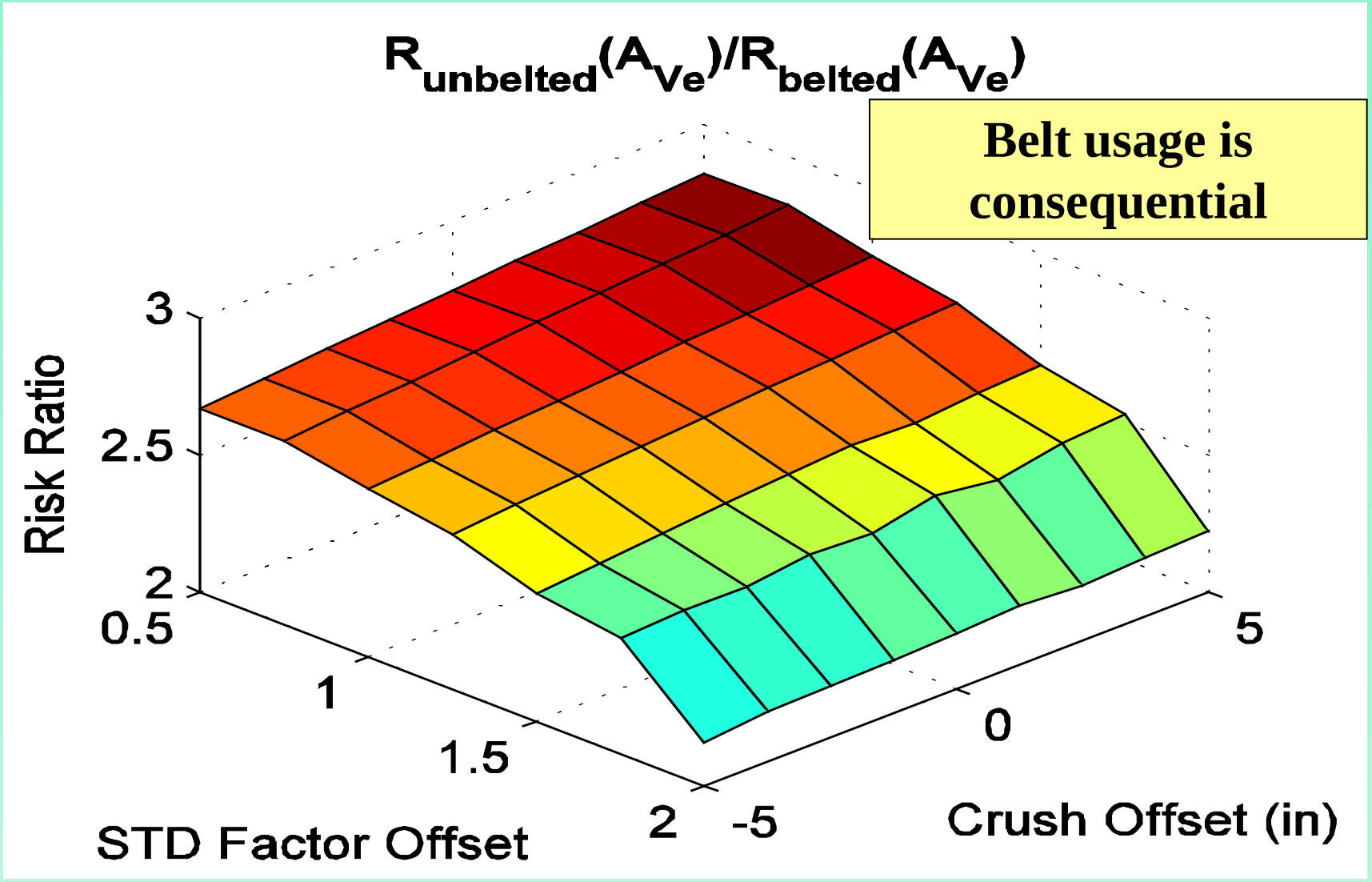
Model Assumptions (3 of 3)

- Fleet turn over at a constant rate with complete turn over in 20 years.
- The national and state accident data bases are an accurate representation of the real world.
- Scaling laws apply during down massing and stiffening and adding crush space.

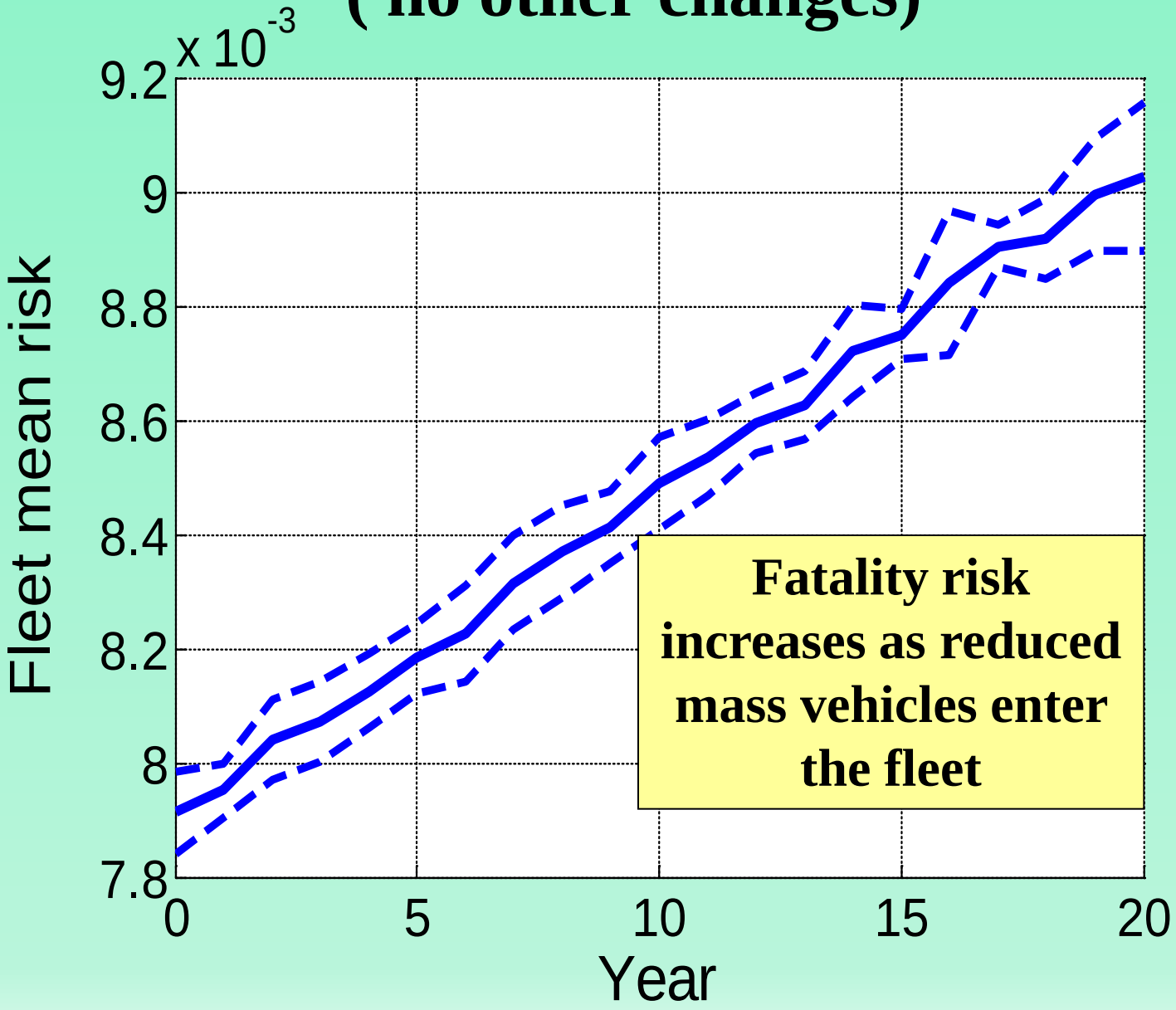
Effect of Mean Mass and Mean Crush Change



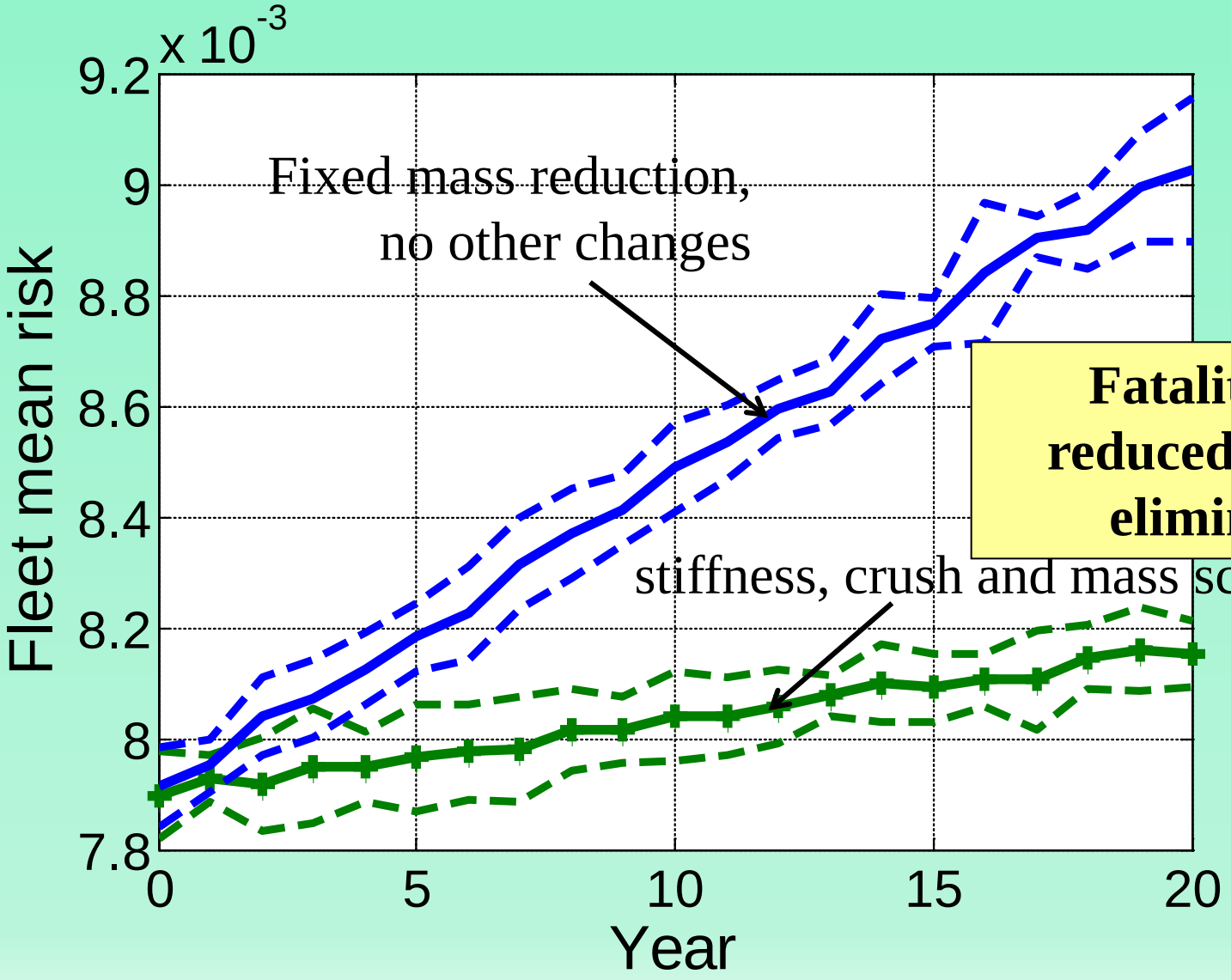
Complexity Effect of Belted vs. Unbelted



Fixed 200 lb. Mass Reduction (no other changes)



Scaled Stiffness, Mass, and Crush (intrusion held constant)



Fatality risk reduced but not eliminated

Conclusions

- The following conclusions are based on the assumptions used to construct the fleet model.

Conclusion for Fixed 200 lb. Mass Reduction

- **A constant 200lb. mass reduction across the fleet with no other changes (average stiffness, crush, vehicle size, functional aspects and impact force deflection characteristics stay the same) results in increased risk of fatality.**

Conclusion for Scaled Mass and Stiffness Reductions

- A 3/2 power law scaled mass reduction (heavier vehicles have a greater amount of mass removed across the fleet)
- Scaled reductions based on known impact response
- An average stiffness reduction, proportional to the mass with a comparative force deflection modification
- Crush increase obtained from downsizing components as a result of mass reduction while holding vehicle size and intrusion constant
- **Risk of fatality slowed compared to constant mass reduction, but fuel economy improvement is not as significant and fatality risk still increases as reduced mass vehicles enter the fleet.**

Thank you!