# NHTSA
# Mass-Size-Safety Symposium

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# Background

- About 60% of fatalities in automotive accidents are the result of MVAs; 50% are front-to-front crashes between light vehicles
- Mass and size effects are closely related to *vehicle compatibility*
- More than 25 years of research by NHTSA and other institutions to address *vehicle compatibility* issues:
  - ***Mass compatibility***
    - LTVs are on average 900 lbs heavier than passenger cars (Kahane, 1997)
  - ***Stiffness compatibility***
    - LTV's frontal structures are stiffer than passenger cars
  - ***Geometric compatibility***
    - LTV's ride higher than passenger cars (bumper height)

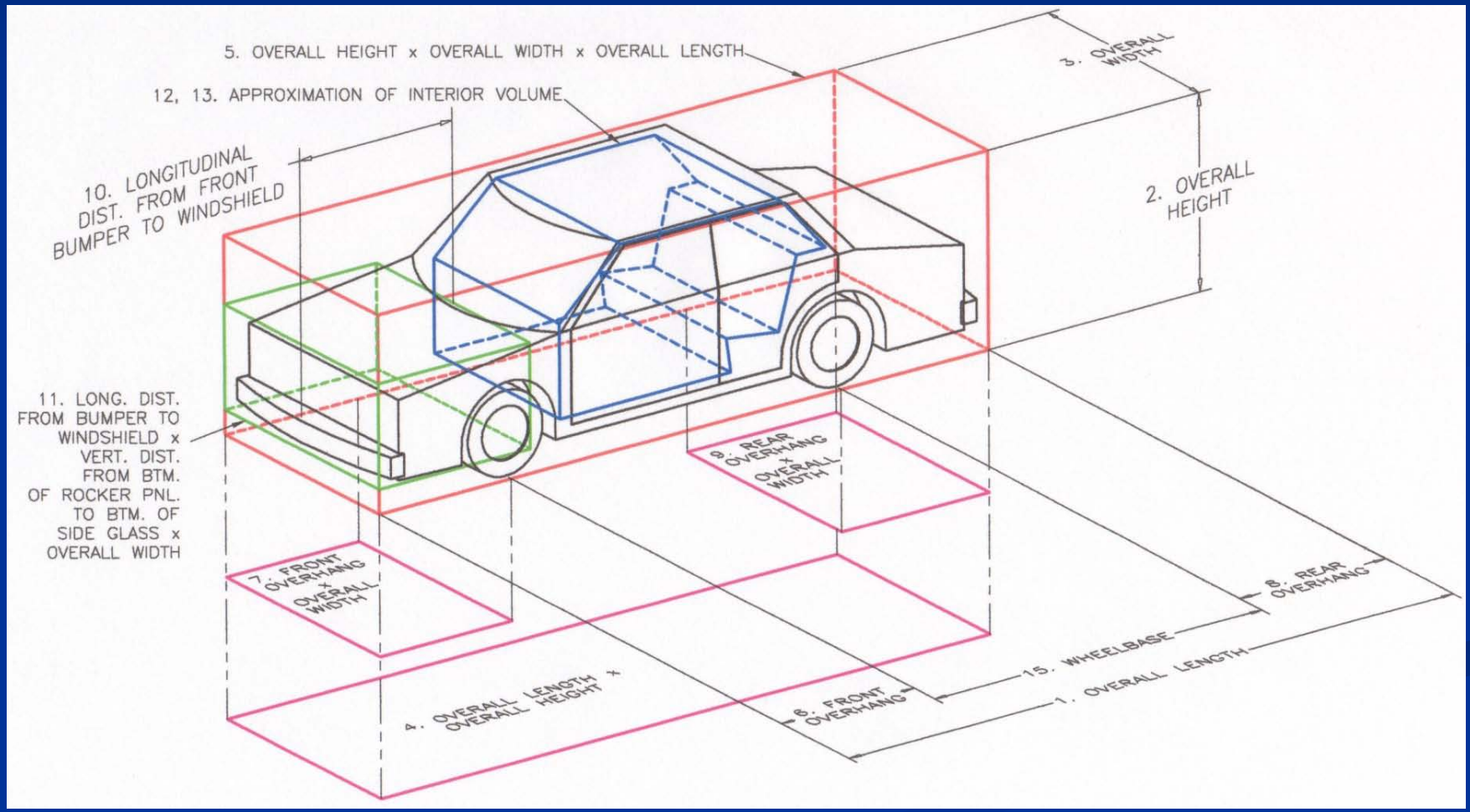
# Background

- JP Research conducted a 6 phase study (2001-2009) to address:
  - Effects of vehicle *mass* on the odds of driver fatality in frontal/side impact crashes
  - Identify vehicle size parameters that influence driver odds of fatality
- Estimate the societal effect associated with vehicle *weight reduction*, compare the results to other studies.

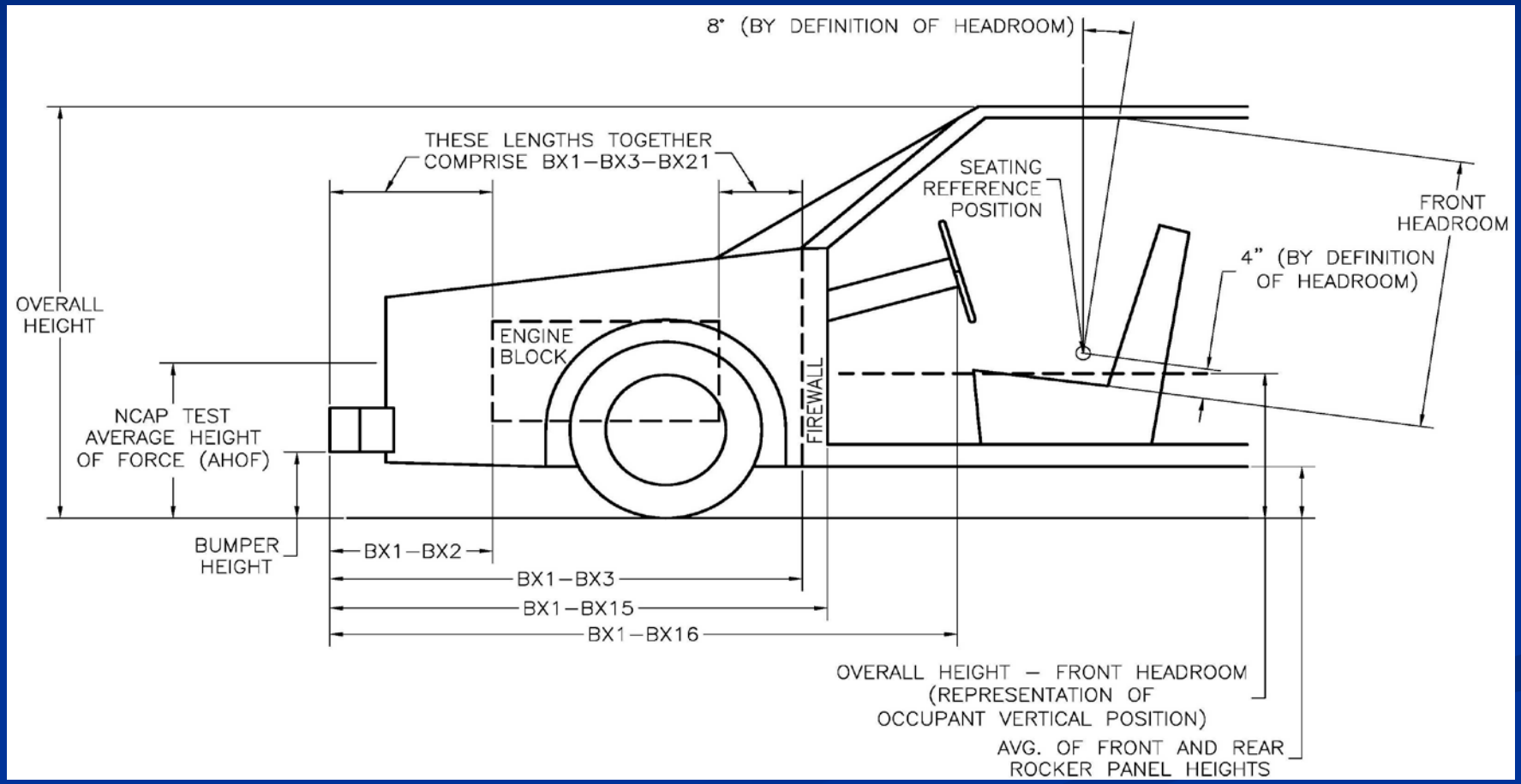
# Background

- Examined:
  - Over 40 vehicle parameters (mass ratio, stiffness, bumper height, AHOF, wheelbase, distance from axle to windshield etc)
  - Over 1,500 vehicle groupings (primarily domestic, 1981-2003 model years)
  - Car-to-car; light truck-to-car crashes (front, left, right)
  - Logistic models predicting “Odds of Fatality”

# Initial Vehicle Dimension Metrics Illustrated



# Additional Metrics: Illustrated



# Data Sources

- Vehicle Parameter Data from various sources
  - AAMA, Kelly Blue Book, EPA, NCAP tests, websites, Gas Truck Index, Industry Sources
- FARS Data/State Accident Data (7 states)
- Frontal stiffness Data:
  - NHTSA's NCAP tests and "KW400"
  - Three types (Ke1, Ke2 and Ke3 = energy equivalent) of stiffness data from the industry
- NASS/CDS Data

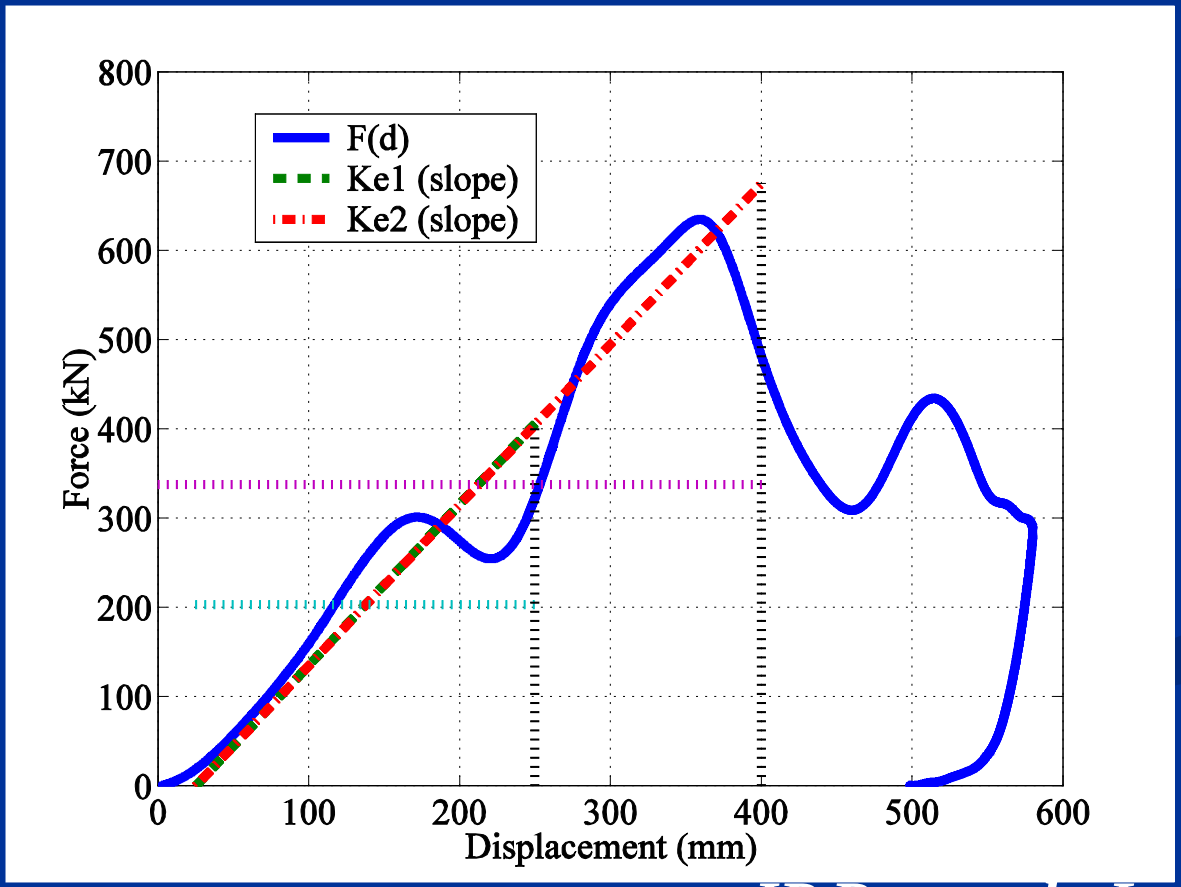
# Definitions of “Stiffness”

## Energy Equivalent Stiffness

Average F(d)*2/d

Ke1: [25 250]

Ke2: [25 400]



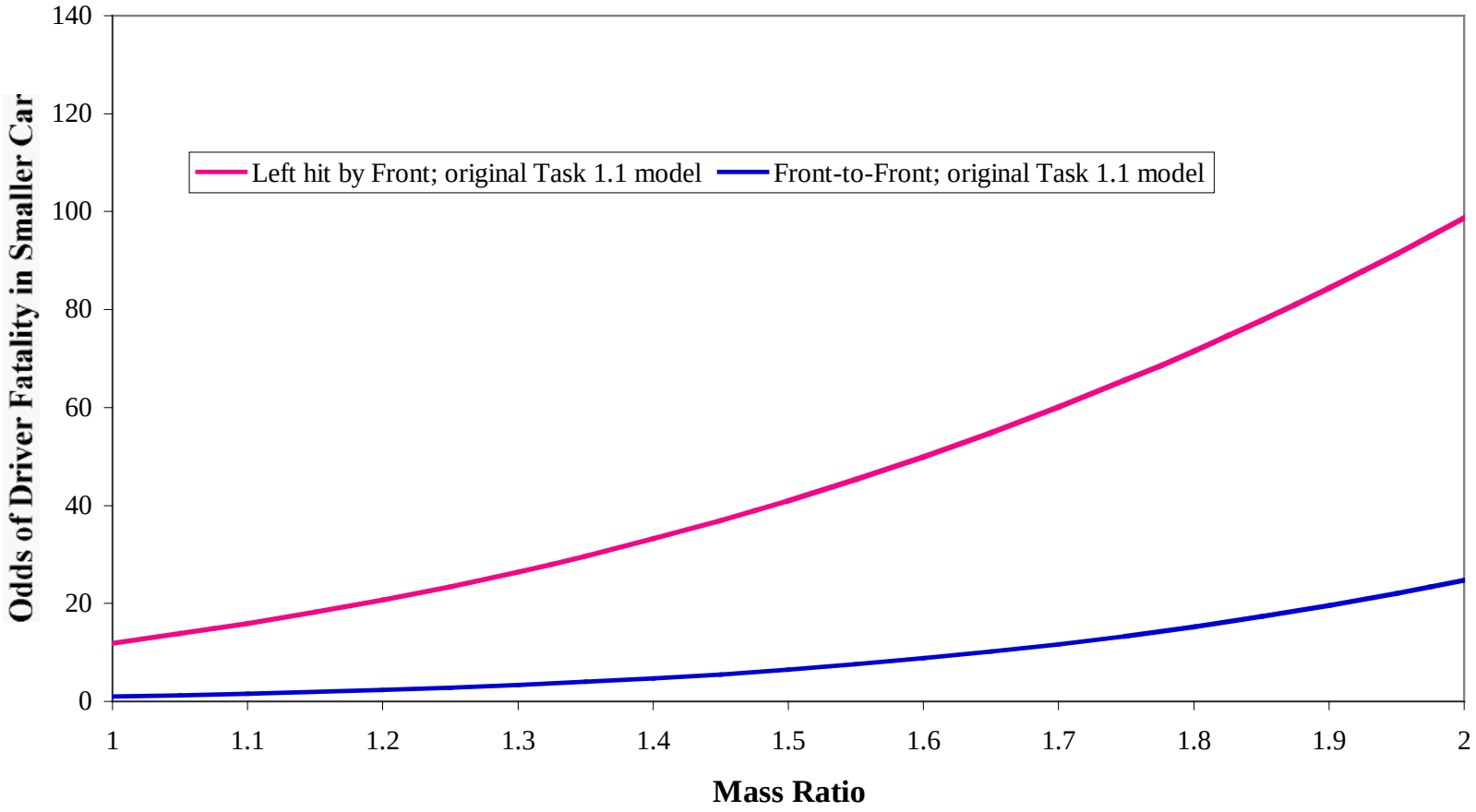
# Definitions of “Stiffness”

## Global Linear Energy Equivalent Stiffness

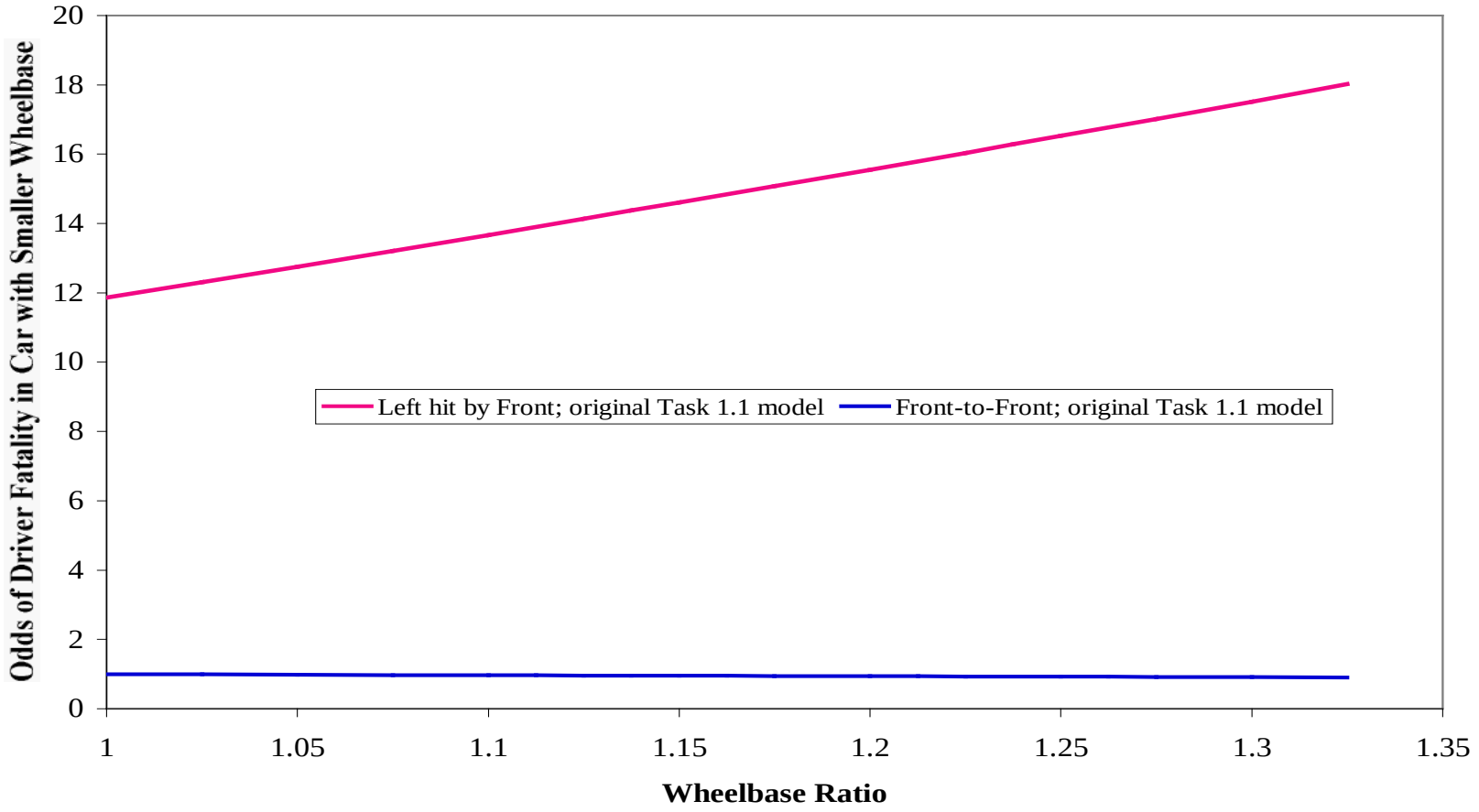
$$Ke3 = \frac{mv^2}{x^2}$$

where **m** = **mass**
**v** = **velocity**
**x** = **crush**

# Repeat of Evan's Study
# Effect of *Mass Ratio* for Car-to-Car



# Effect of *Wheelbase Ratio* for Car-to-Car



# Coefficients of Log (Mass Ratio) Predicting Drivers Odds of fatality

| | Front-Front | Front-Left (Struck Left) | Front-Right (Struck Right) |
|---|---|---|---|
| **Car-to-Car** | 3.87 - 5.4 | 4.35 | 4.04 |
| **Car-to-Truck** | 5.89 - 6.1 | 3.49 | 3.85 |

**MASS ratio is the most important vehicle factor predicting driver odds of fatality.**

# Results
# Car-to-Car Crashes

| | Data Used | Crash Configuration | Significant Vehicle Parameters for Frontals |
|---|---|---|---|
| Phase 1 and Phase 2 | FARS/States | Front, left, right | Mass ratio, FAW (Front Axle to Windshield Distance) |
| Phase 3 | FARS/States | Front, left | Mass Ratio, FAW, Stiffness (Struck Vehicle) |
| Phase 4 | FARS | Frontal | Mass Ratio, FAW, Stiffness * Bumper Height Ratio |
| Phase 5 and Phase 6 | FARS/States | Frontal | Mass ratio, FAW |

Driver age/belt use are highly significant driver factors predicting fatality odds.

# Results
# Truck-to-Car Crashes

| | Data Used | Crash Configuration | Significant Vehicle Parameters for Frontals |
|---|---|---|---|
| Phase 1 And Phase 2 | FARS/States | Front, left, right | Mass Ratio, Vehicle Height Ratio FAW (striking) |
| Phase 3 | FARS/States | Front, left | Mass Ratio Stiffness (Striking & Struck), FAW (Striking & Struck), Bumper Height Difference, Overall Height (Struck) |
| Phase 4 | FARS | Frontal | Mass Ratio, Stiffness * Bumper Height Ratio |
| Phase 5 and Phase 6 | FARS/States | Frontal | Mass ratio, FAW, Stiffness * Bumper Height Ratio |

# Results (Frontal Crashes)

- Car-to-Car:
  - Mass ratio, vehicle stiffness, and FAW (front axle to windshield distance) are significant predictors.
  - Ke3 (global linear energy equivalent stiffness measure*) was the best stiffness predictor of fatality odds.
- Light Truck-to-Car:
  - Mass ratio, vehicle stiffness, FAW and bumper height ratio are significant.
  - Ke3 was the best stiffness predictor.

# Weight or Wheelbase?

- System Identification Errors
  - Correlation – *Weight* and *wheelbase* are highly correlated (0.9)
- Using *weight* and *wheelbase* in logistic model distorts the estimates, resulting in:
  - Inflated variance
  - *Wrong signs and magnitudes*
- Our size parameter of choice: *FAW* (front axle to windshield distance)
  - Weak interaction with the *weight* (about 0.4)
  - Provides better model fit than the *wheelbase*
- Physical Interpretation

# Other Vehicle Parameters

- Stiffness
  - Second order effect (explains 1% of variation while mass ratio explains 20% of variation in fatality odds)
  - Energy equivalent stiffness parameter (Ke3) is the best stiffness predictor
- Bumper Height Ratio
  - More Significant for truck-to-car frontals when combined with stiffness
  - Significant when “bumper height difference” is used as a separate variable-indicates vehicle compatibility
- Front axle to windshield (FAW) distance
  - Very significant for car-to-car and truck-to-car crashes

# Societal Effect* of Reducing Mass by 100 lbs for *Passenger Cars* in US Fleet

| Crash Type | Kahane 1997 | Kahane 2003 | Van Auken 2005 | JP Research Study |
|---|---|---|---|---|
| Car-to-Car | -0.6% (n.s.) | N/A | -6.7% | +0.4% |
| Truck-to-Car | +2.6% | +4.3% | -0.2% (n.s.) | +3.4% |

*Change in the annual number of fatalities

# Societal Effect of Reducing Mass by 100 lbs for *Light Trucks* in US Fleet

| Crash Type | Kahane 1997 | Kahane 2003 | Van Auken 2005 | JP Research Study |
|---|---|---|---|---|
| Truck-to-Car | -1.4% | -0.2% (n.s.) | +0.6% (n.s.) | -2.1% |

# Conclusions

- *Vehicle Mass Ratio* is the most influential vehicle parameter
- FAW, *Frontal stiffness and bumper height ratio* (second order of effect compared to *weight)*
- Societal effect of *reducing vehicle weight* by 100 lbs for truck-to-car crashes:
  - Reducing passenger cars: 3.4% increase in fatalities
  - Reducing light trucks: 2.1% decrease in fatalities