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FOR HIGHWAY SAFETY

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# The Relative Safety of Large and Small Passenger Vehicles

NHTSA Mass-Size Safety Symposium  
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# Overview

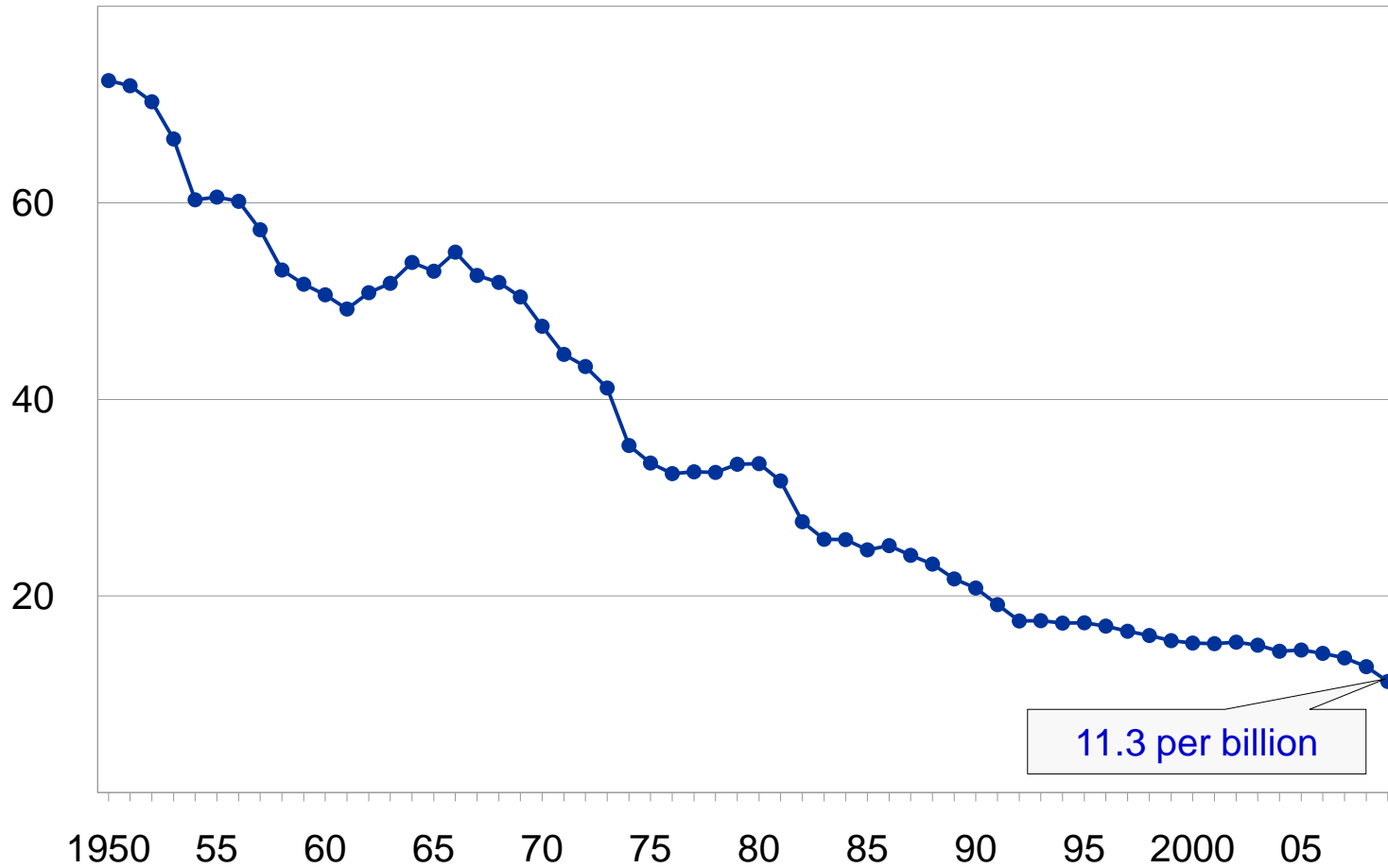
- What is the history of motor vehicle crash safety by size and mass? *Historical trends*
- Can down-weighting of vehicles occur without safety consequences if size is held constant? *Physics of injury*
- What does the future hold?



# Historical trends

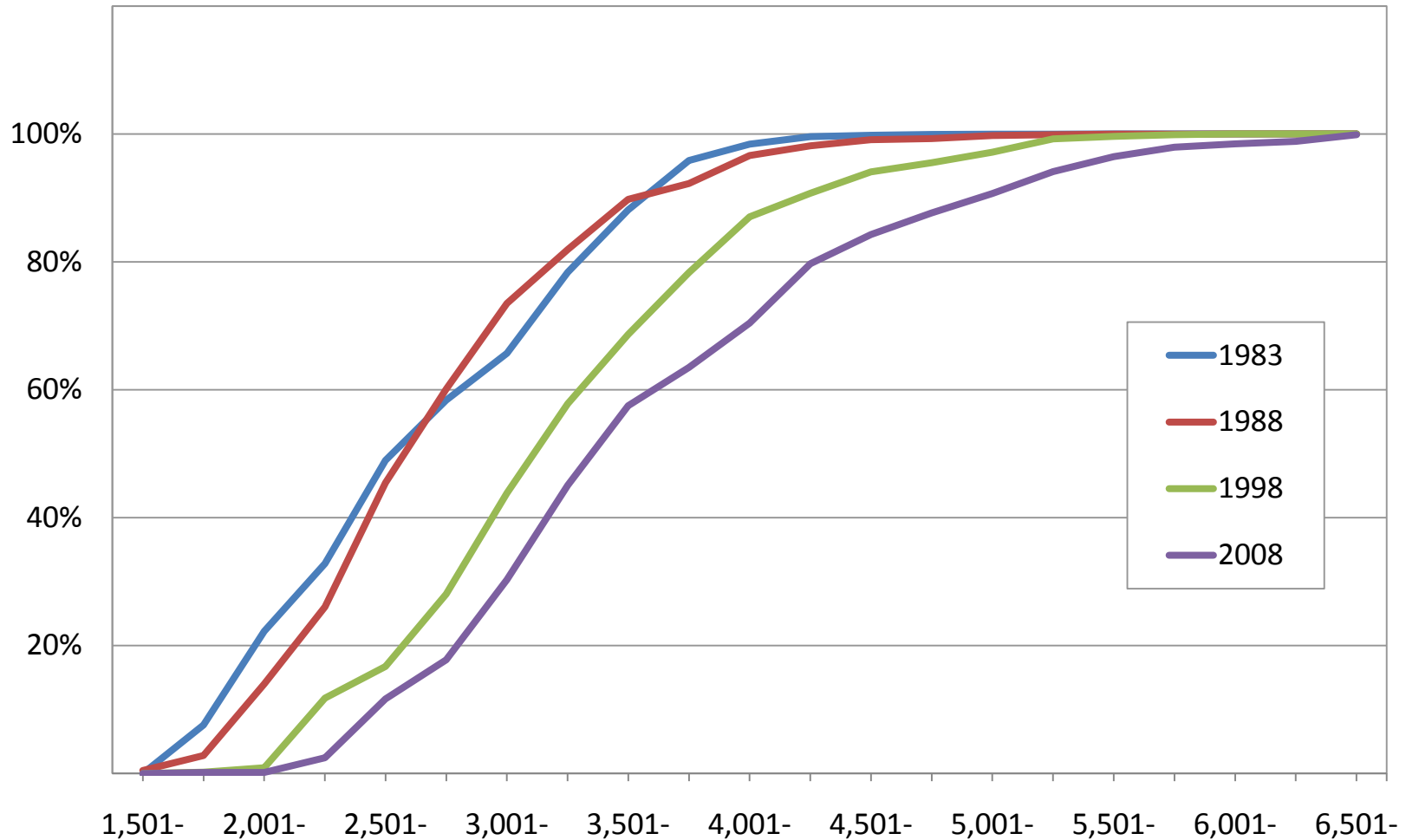
# Motor vehicle crash deaths per billion miles traveled

1950-2009



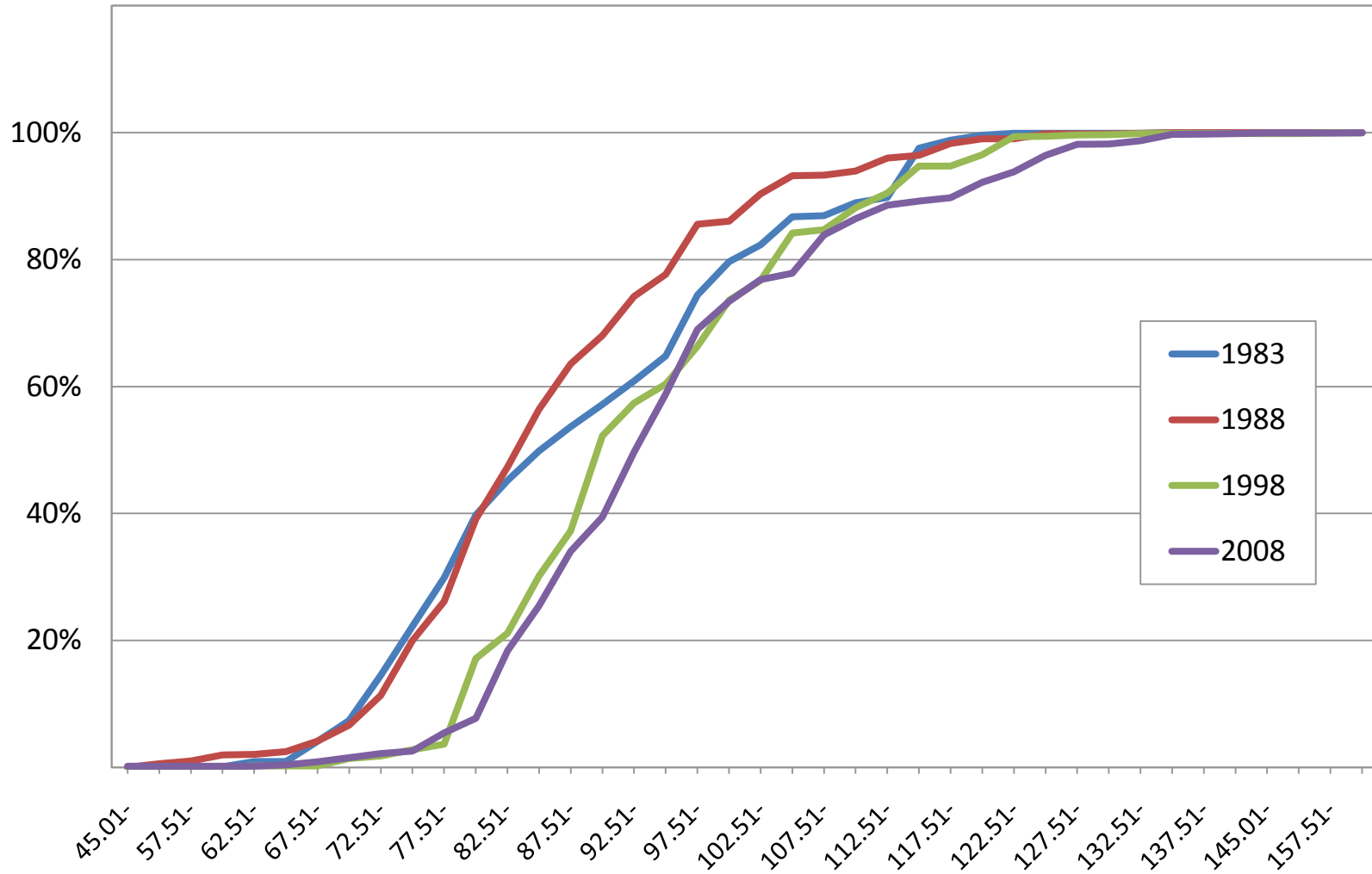
# Cumulative percentage of passenger vehicles

By model year and curb weight (lbs)



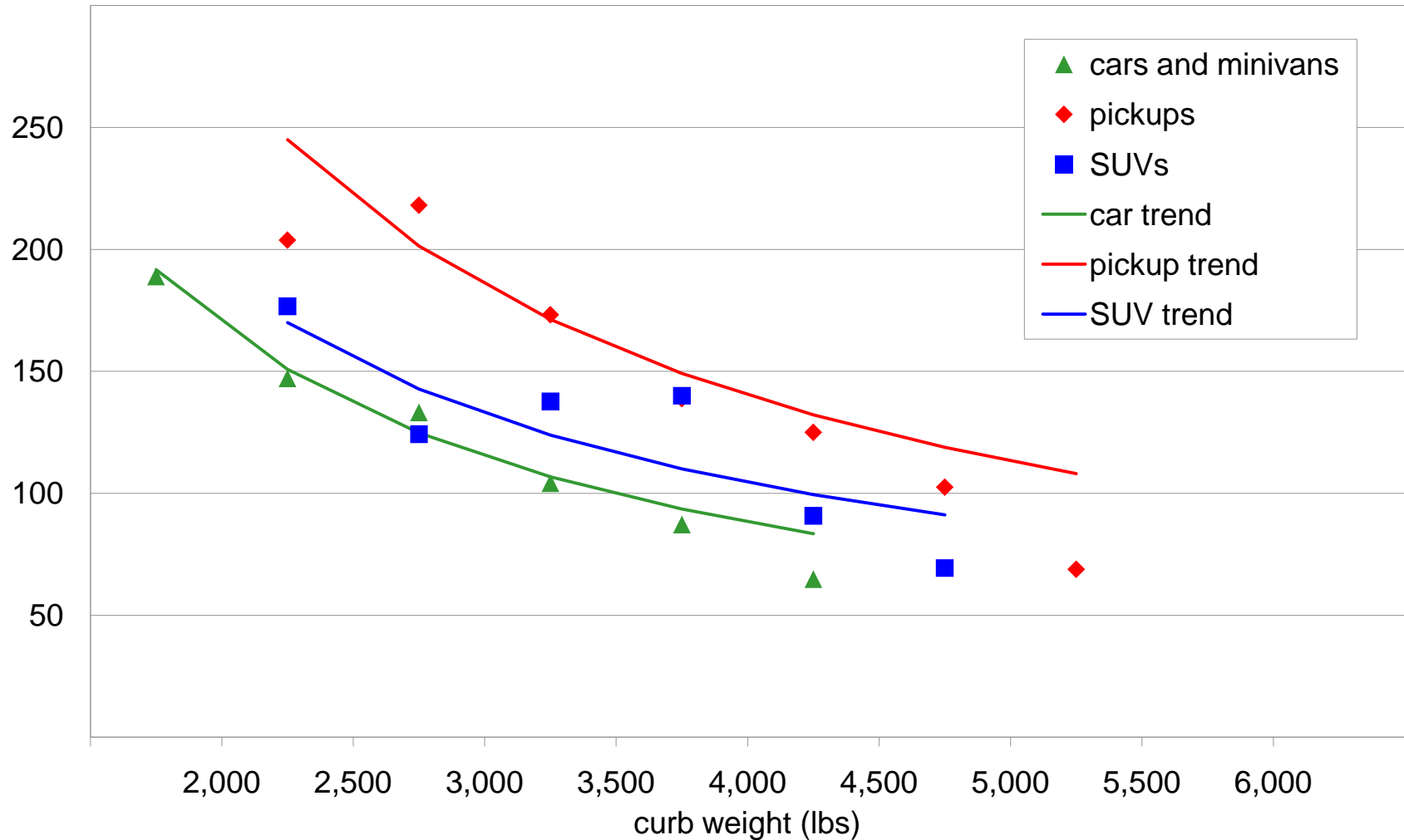
# Cumulative percentage of passenger vehicles

By model year and shadow (sq ft)



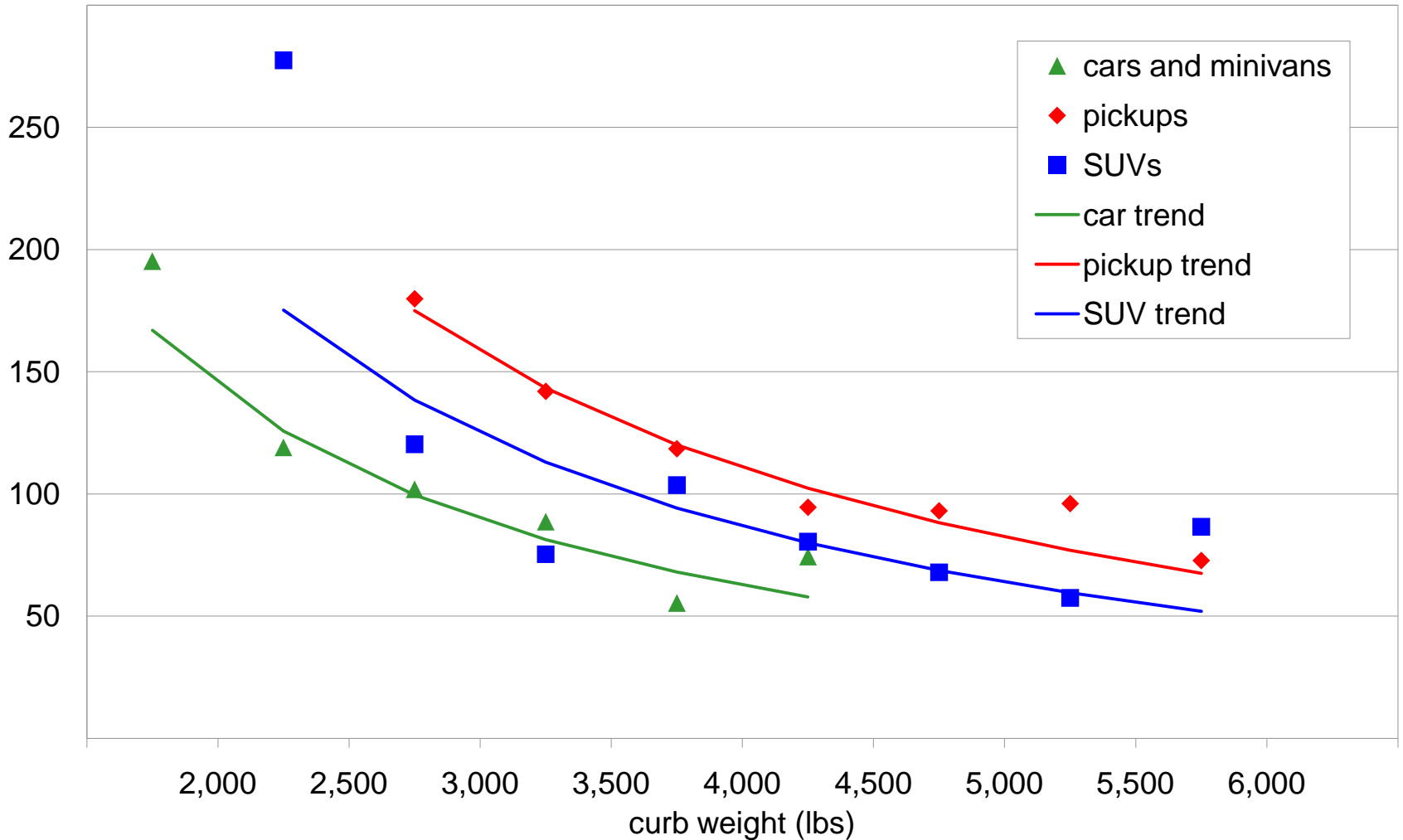
# Driver deaths per million vehicle registrations

1985-88 models during 1986-89, trend based on 1/weight



# Driver deaths per million vehicle registrations

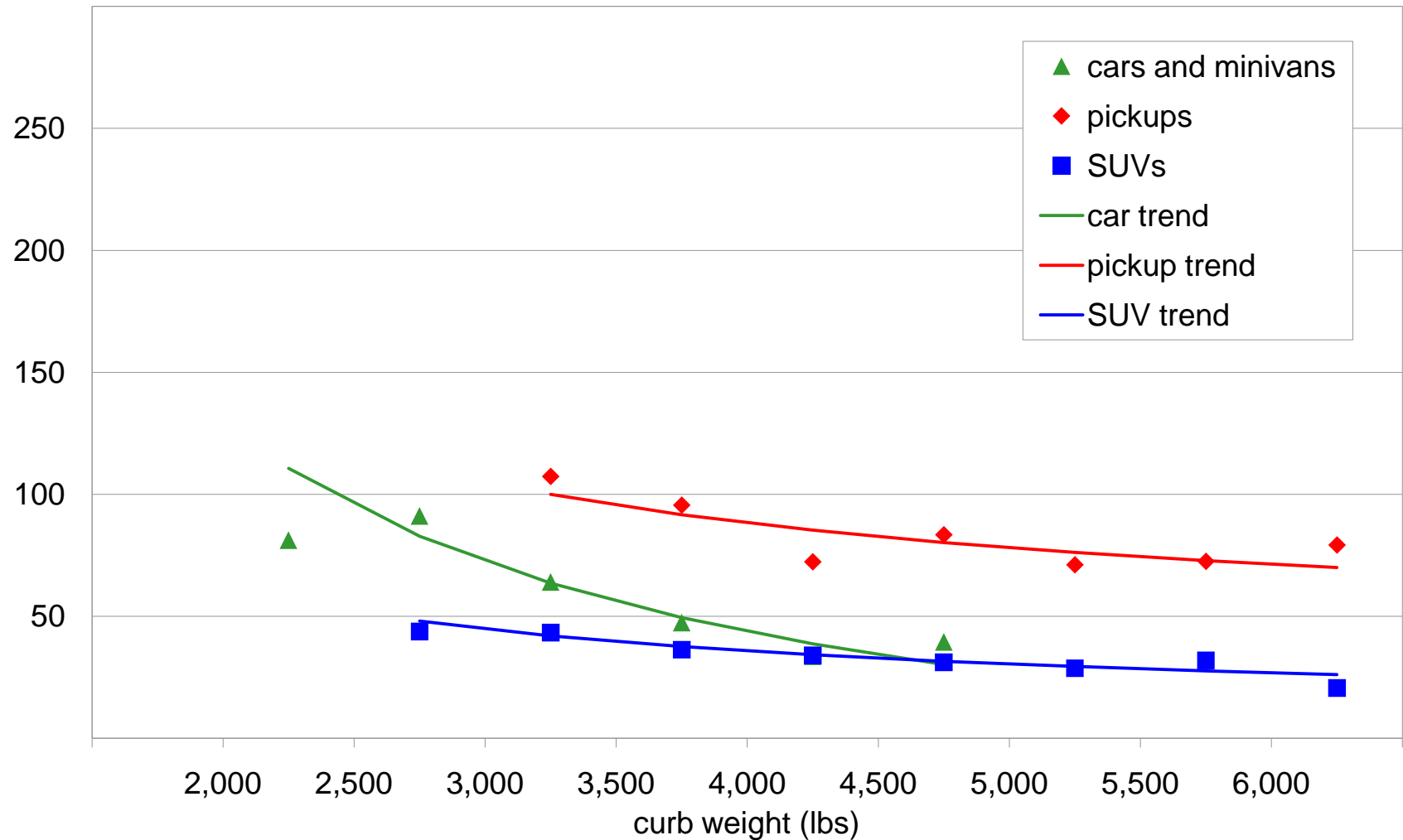
1995-98 models during 1996-99, trend based on 1/weight





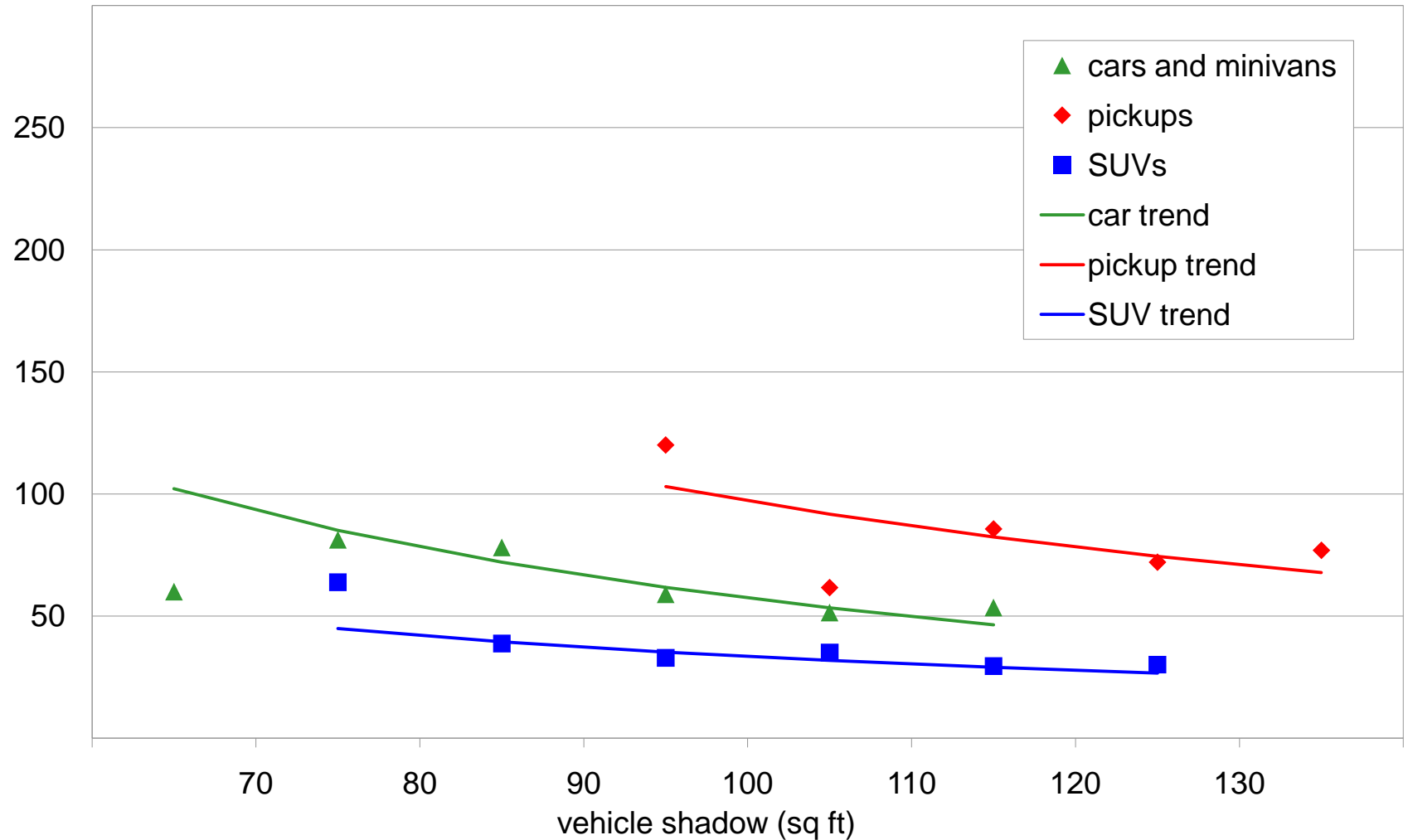
# Driver deaths per million vehicle registrations

2005-08 models during 2006-09, trend based on 1/weight

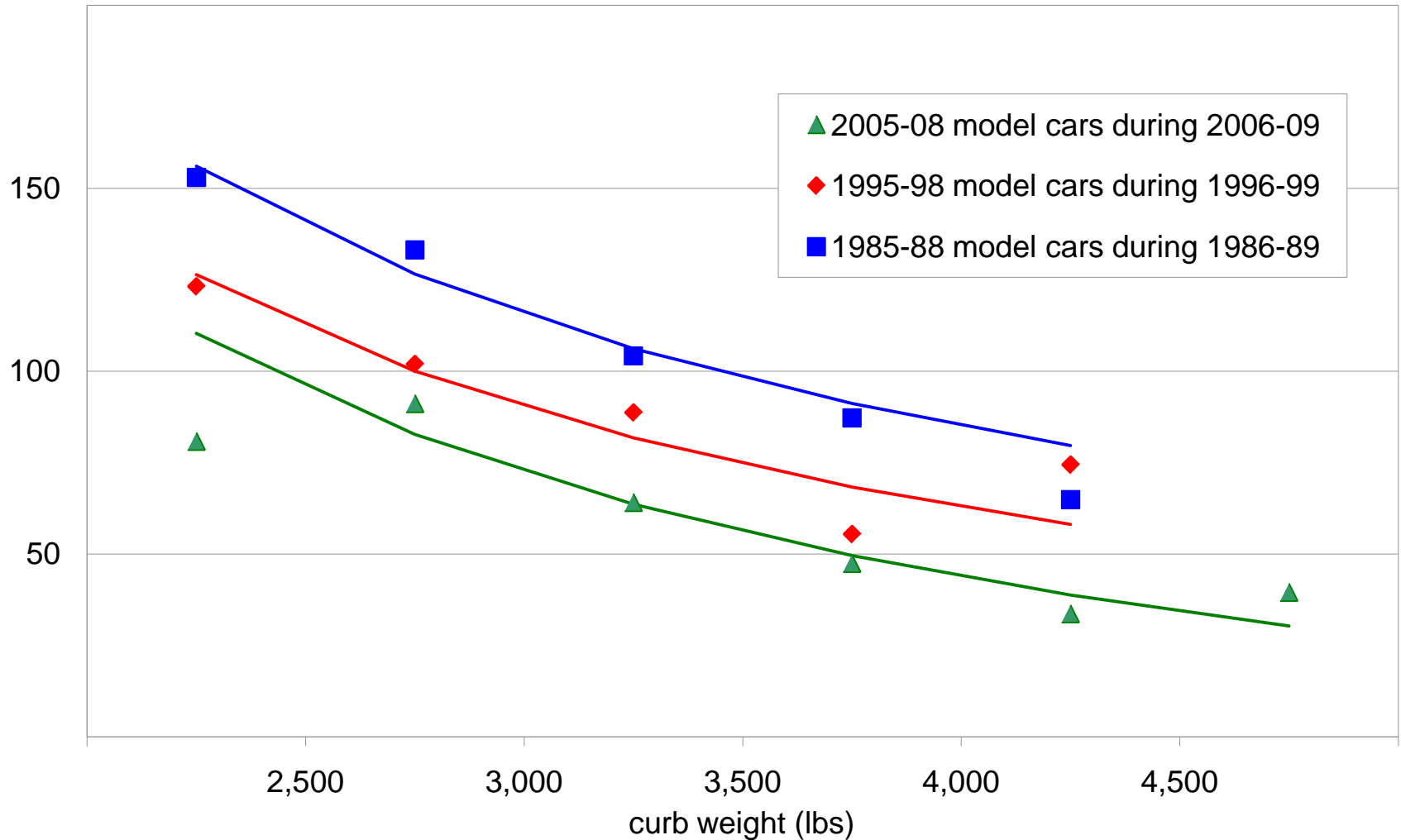


# Driver deaths per million vehicle registrations

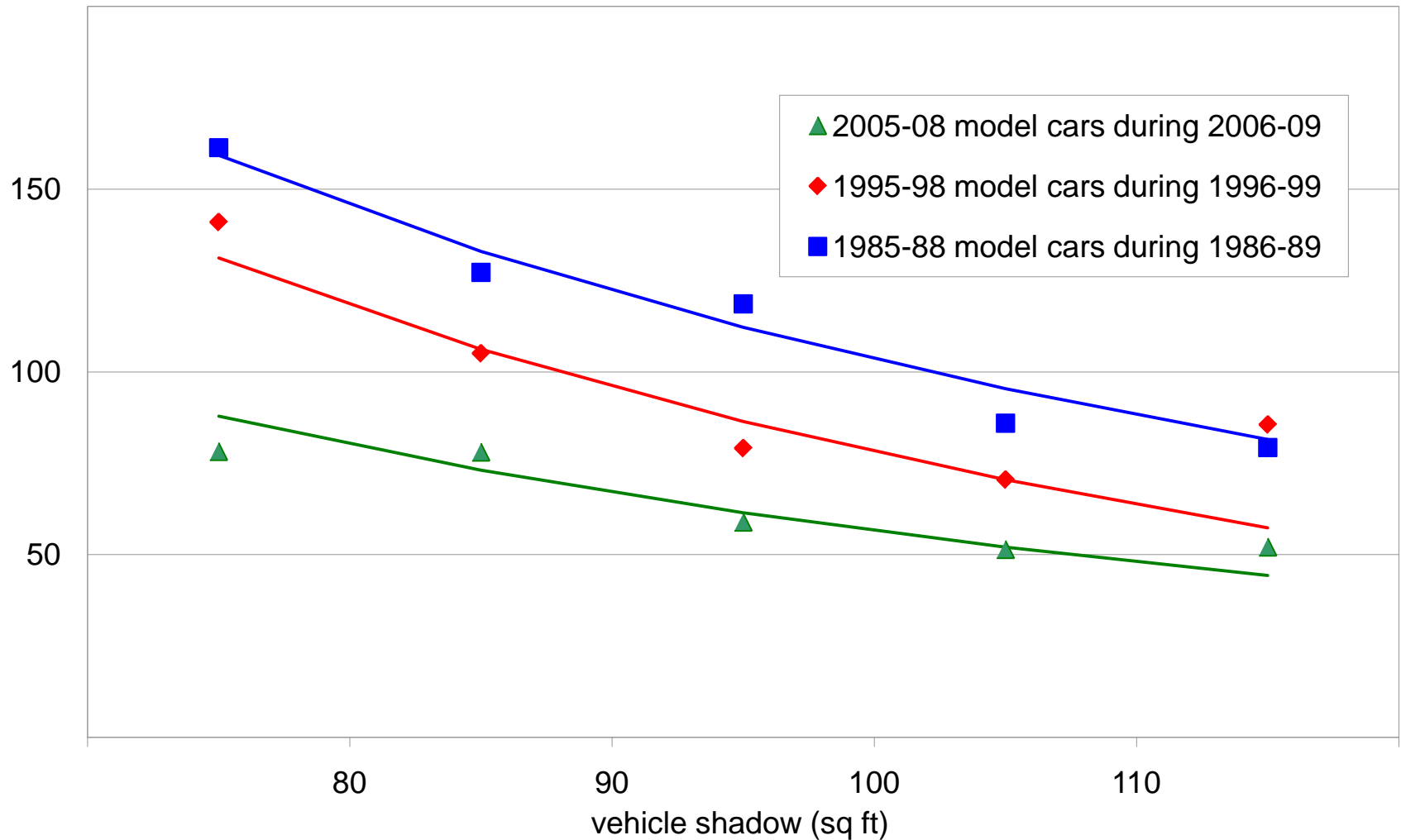
2005-08 models during 2006-09, trend based on 1/shadow



# Driver deaths per million vehicle registrations per year, by model year and curb weight (lbs)



# Driver deaths per million vehicle registrations per year, by model year and shadow (sq ft)



# Historical conclusions

- Passenger vehicles of all types and sizes provide their occupants with greater protection today than just a decade ago and much greater protection than two decades ago
- Occupants of the smallest and/or lightest vehicles still have death rates about twice as high as occupants of the largest and/or heaviest vehicles



**Mass and Size –  
Physics predicts independent  
effects on occupant injury risk**

# What is the source of injury in motor vehicle crashes?

“...in the highway safety area the problem is almost exclusively one of mechanical energy reaching people at rates that involve forces in excess of their injury thresholds.”

– William Haddon, Jr., MD, *American Journal of Public Health*, 1968

First head of what is now NHTSA (1967-68)

President of IIHS from 1969-1985

# What affects forces experienced by occupants in crashes?

- In a simple model of frontal crashes, forces act on the occupant to bring his or her pre-crash velocity to its post-crash velocity
- The longer the distance over which the occupant's velocity change occurs, the lower the average force experienced by the occupant
  - Change in occupant energy state  $\approx$  Force \* Distance<sub>preV to postV</sub>
- The occupant's stopping distance is a combination of
  - The space between the occupants and stiff parts of the compartment in front of them
    - Given that drivers generally seat themselves similarly in different cars to optimize vehicle control, restraint system design and usage is the primary determinant of this factor's relevance
  - The effective crush distance of the car in front of the occupant compartment
    - Occupants of longer vehicles typically will have greater effective crush distance
  - The distance which the car's momentum carries forward or is reversed by the momentum of the crash partner (car, tree, pole, wall) during the crash
    - Occupants of heavier vehicles typically will benefit from greater effective momentum



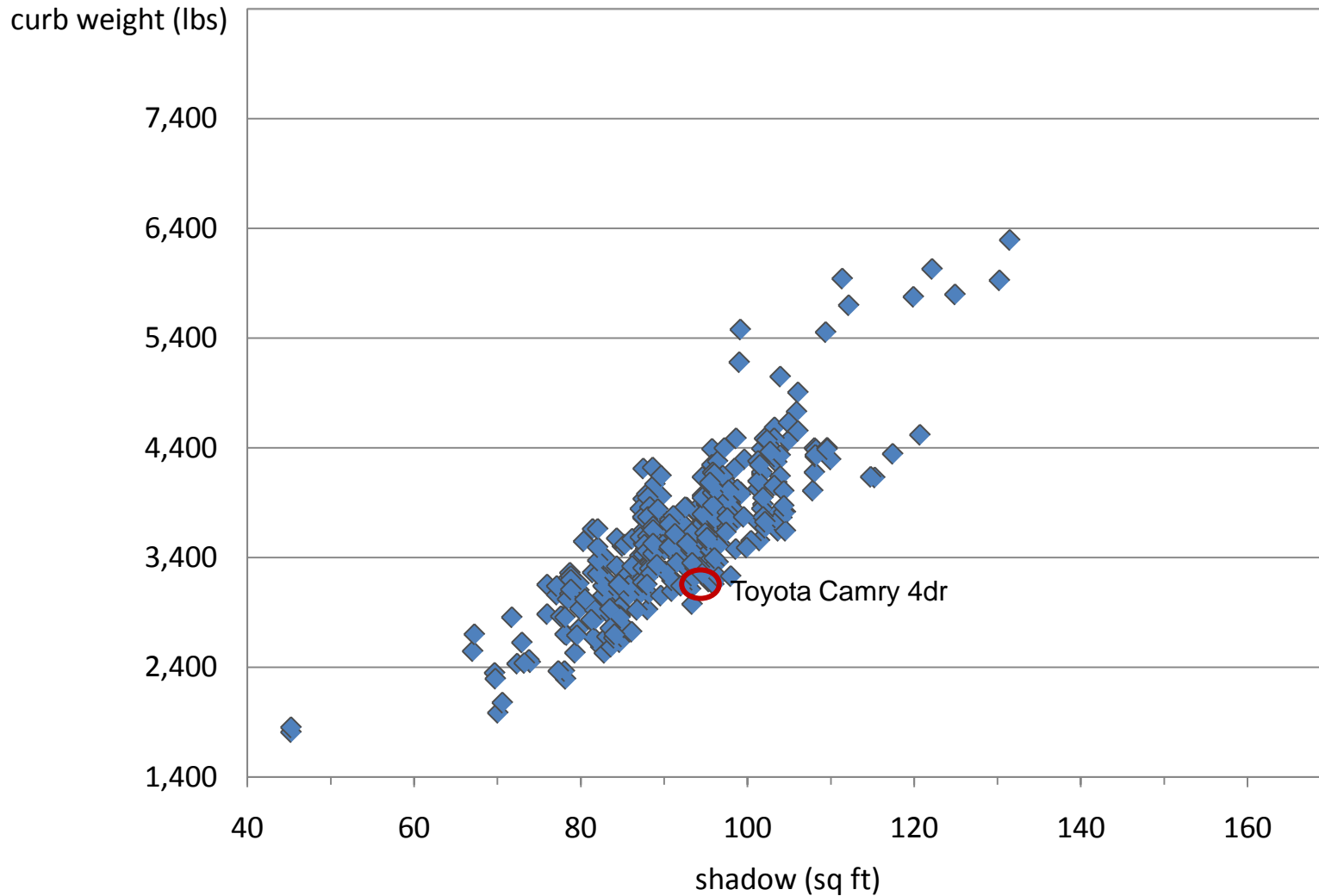
# Car size and weight are separate physical factors influencing the stopping distance of an occupant

How well can their effects be quantified in vehicle crash experience?

- Vehicle size and weight tend to vary together in actual cars
- Car size and weight can influence crash likelihood, including the likelihood of different types of crashes
  - Rollover risk decreases with size and weight but injury risk given a rollover increases with size and weight
  - Smaller vehicles are involved in more crashes (not fewer, as some have hypothesized)
- Many other vehicle characteristics that can affect crash likelihood and severity are confounded with size and weight
  - Heavier cars for a given size often have larger engines, 4-wheel drive, or are convertibles

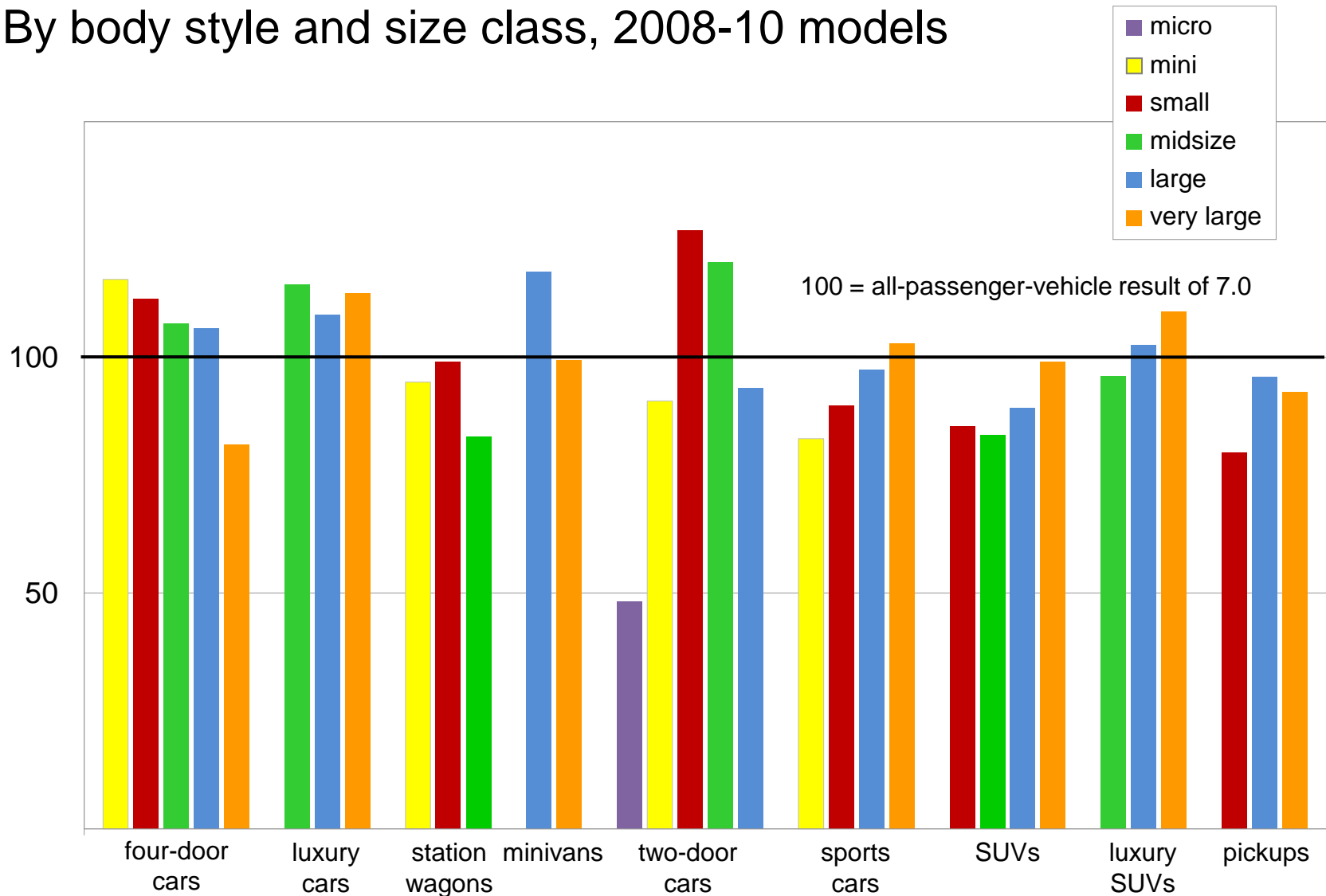
# Curb weight vs. shadow, by make and series

Model year 2008 cars and minivans ( $r^2= 0.70$ )



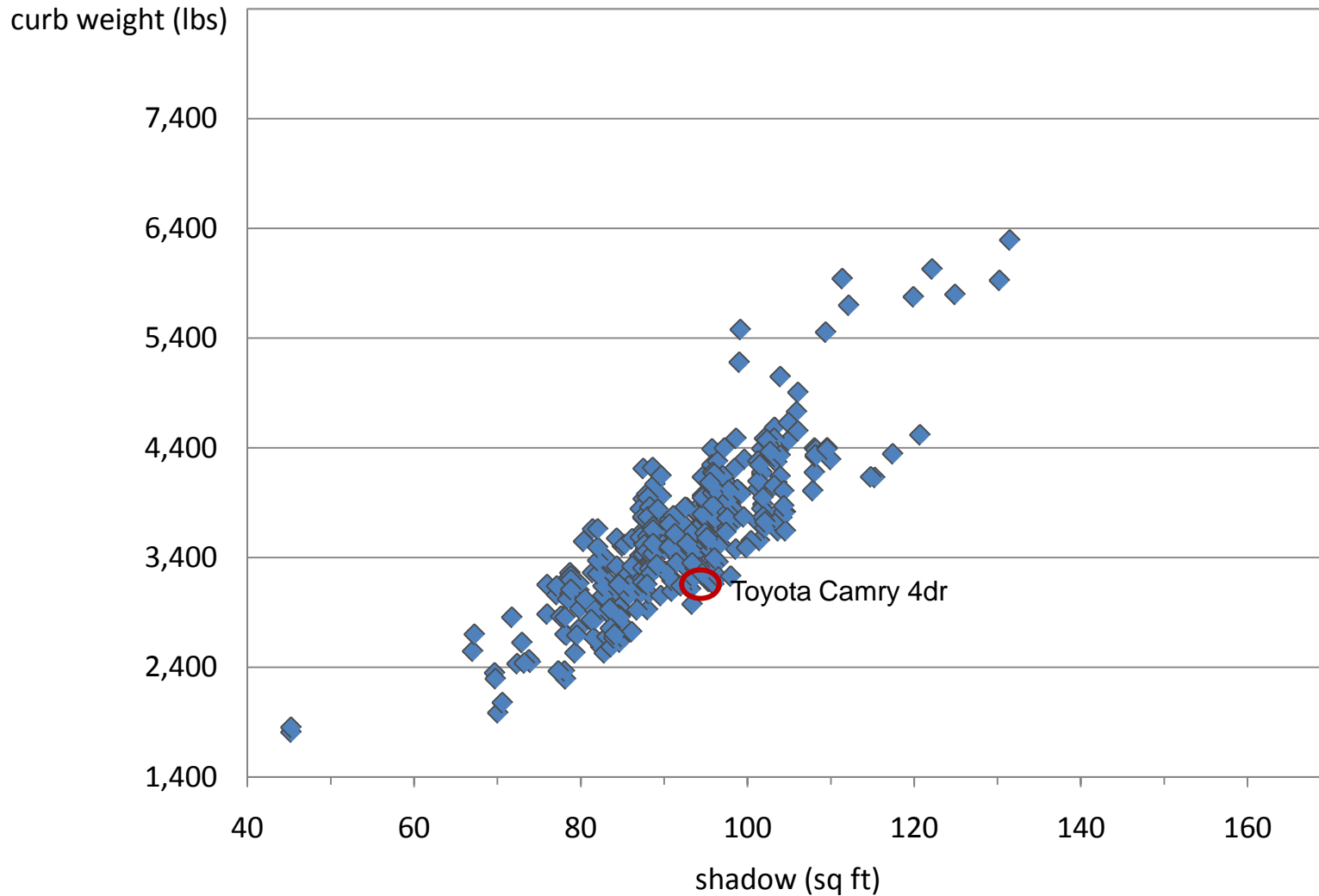
# Relative collision claim frequencies

By body style and size class, 2008-10 models



# Curb weight vs. shadow, by make and series

Model year 2008 cars and minivans ( $r^2= 0.70$ )



# Variation in weight among 2008 model year cars of similar size (93-95 sq. ft) to Toyota Camry

make	series	Shadow in sq. ft.	Weight in lb.
Nissan	Altima 4D	93.2	3,112
Ford	Fusion 4D 2WD	95.4	3,181
Toyota	Camry Solara 2D	95.6	3,185
Toyota	Camry 4D 2WD	94.2	3,263
Volkswagen	Passat 4D 2WD	93.7	3,305
Chrysler	Sebring 4D	94.2	3,310
Ford	Fusion 4D 4WD	95.4	3,325
Dodge	Avenger 4D 2WD	95.2	3,355
Chevrolet	Malibu 4D (new)	93.6	3,415
Lincoln	Zephyr/MKZ 4D	95.5	3,469
Volkswagen	Passat SW 2WD	93.6	3,512
Chevrolet	Malibu Hybrid 4D	93.6	3,537
Toyota	Camry Solara Conv	95.6	3,615
Lincoln	MKZ 4D 4WD	95.5	3,672
Toyota	Camry Hybrid 4D	94.2	3,680
Chrysler	Sebring 4D 4WD	94.2	3,699
Dodge	Avenger 4D 4WD	95.2	3,738
Volkswagen	Passat SW 4WD	93.7	3,819
Volkswagen	Passat 4D 4WD	93.7	3,829

# Conclusions about size, mass, and safety

- Mass and size have separate, inverse relationships with occupant injury risk in crashes predicted by physics
- Quantifying those separate effects in the real world of a car fleet, however, is complicated by
  - The high correlation between size and mass in real world vehicles, and
  - the fact that, even after controlling for things like driver age and gender, there are important other confounding variables that covary with size and weight and have their own separate effects on injury risk
- Failure to find the separate effects indicates a failure to adequately account for the confounds, not that physical laws have been repealed



# Size, mass, and safety of future vehicles

# Predictions

- Vehicles will get lighter **and** smaller as fuel prices increase

One benefit of size-indexed CAFE is to keep larger, safer cars affordable longer for all income brackets

- The sky will not fall as the fleet downsizes

We will not see an increase in absolute injury risk because smaller cars will become increasingly protective of their occupants

- However, some people will die in motor vehicle crashes that would have survived without the downsizing

– Large cars still will have fatality rates half as large as smaller cars and the smaller (on average) fleet that results will not be as safe as it could be

- Those of us whose mission is highway safety will have to adapt our strategies to the reality created by consumer choices

We will be ok if we let data on what works – not wishful thinking – guide our strategies



# Smart Fortwo frontal offset test



# Smart Fortwo into Mercedes C class



# Minitruck into Ford Ranger





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