



Relationships between Mass, Footprint, and Societal Fatality Risk in Recent Light-Duty Vehicles

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Methodology

- Starting in 2010, US DOE contracted with LBNL to conduct analyses of relationship between vehicle mass and risk, while holding footprint constant
 - Phase 1: Replicate NHTSA regression analysis of US societal fatality risk per vehicle mile of travel (VMT) (2011, 2012, 2016, 2018)
 - 2018 analysis: model year 2004 to 2011 vehicles in 2006 through 2012
 - Phase 2: Separate regression analysis of two components: crash frequency and risk per crash (2011, 2012, 2017)
- Logistic regression analysis for 27 combinations of vehicle and crash type
 - 3 vehicle types (car, light truck, CUV/minivan)
 - muscle, police, and AWD cars, as well as full vans, excluded
 - 9 crash types
 - two-piece mass variable for lighter- and heavier-than-average cars and light trucks
 - ~28 variables control for other vehicle (including footprint), driver, and crash characteristics
- Risk is societal, and includes:
 - All occupants of case vehicle
 - All occupants of any crash partner, including pedestrians/motorcyclists
- Coefficients by crash type reweighted by likely crash distribution after full adoption of ESC

- Use similar approach for crash-avoidance technologies as they penetrate market

Complicated procedure to estimate exposure to a crash

- 2.1 million non-culpable vehicles involved in two-vehicle crashes in 13 states
 - Gives characteristics of random sample of vehicle-driver combinations on road
- Assign sample weight to each vehicle to derive total US registrations
- Develop schedule of average annual VMT by vehicle age from 2009 National Household Travel Survey
- Use average odometer by make and model (from IHS Automotive/Carfax) to adjust annual VMT by make and model
- Regression model estimates the effect of 100-lb reduction in mass on societal fatalities per VMT, holding footprint and other vehicle, driver, and crash characteristics constant

1. Conclusions from 2018 LBNL Phase 1

- Baseline NHTSA results: Estimated effect of reduction in mass or footprint on societal risk is small
 - 100-lb reduction in mass associated with increases in risk only for lighterthan-average cars...
 - ... and decrease risk for heavierthan-average light trucks
 - Based on NHTSA jack-knife method, no estimates significant at 95% or 90% level
- 2018 results compared to 2012 results
 - Compared to 2012, 2018 societal risk from mass reduction declined for cars and light trucks, but increased slightly for CUVs/minivans ...
 - ... despite increase in mass disparity in two-vehicle crashes (increased 278 lbs for car v. LT crashes, and 200 lbs for LT v. LT crashes)
 - 2016 analysis mischaracterized some CUV models as SUVs (light trucks)



Control variables by vehicle type

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LBS100

FOOTPRNT

MINIVAN CURTAIN COMBO TORSO

ABS ESC

Vehicle

- Effect of mass or footprint • reduction is overwhelmed by other factors
 - Other vehicle characteristics nearly 10x larger
 - Driver gender up to 30x larger
 - Certain crash characteristics over 150x larger



A70 96 14_30

150

Driver

30

90 NITE RURAL SPDLIM55 VEHAGE BRANDNEW

Crash

CY2010 CY2012

CY2011

5

CY2006 CY2007 CY2008

Other

Light trucks •



Adjusted societal risk by vehicle model

- Adjusted risk is standardized for same driver and crash circumstances
- On average societal risk decreases with increasing mass ...
- ... but no correlation between risk and weight (or footprint) for most vehicle types
- Adjusted risk best correlated with curb weight in 4-door cars (R²=0.33)



Adjusted societal risk by car model

- Even for cars, risk varies substantially for models of similar weight, even after accounting for driver and crash variables
 - Fit, Prius, and Passat have lower risk than Neon, Cobalt, and G6
- Some light cars have lower adjusted risk than the heaviest cars
 - Fit, Prius, and Passat have much lower mass than much heavier Grand Marquis and Town Car



				Ν	lass reducti	on		Fo	otprint reduc	ction	
			Ca	ars	Light	trucks	CUV/		Light	CUV/	
	Mc	odel	<3201 lbs	≥3201 lbs	<5014 lbs	\geq 5014 lbs	minivan	Cars	trucks	minivan	
	Base	eline	1.20%	0.42%	0.31%	-0.61%	-0.25%	0.23%	0.08%	0.52%	
	isk n	1	1.06%	0.30%	0.38%	-0.61%	-0.48%	0.47%	0.21%	0.89%	
	e ri ioii	2	1.05%	0.30%	0.37%	-0.61%	-0.48%	0.47%	0.21%	0.88%	
	nat init	3	1.40%	0.61%	0.31%	-0.64%	-0.59%	0.26%	0.26%	1.12%	
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		6	1.36%	0.57%	0.40%	-0.57%	0.11%	1.18%	0.11%	0.23%	
	ol	7	2.09%	1.59%	1.14%	0.32%	0.00%	-0.13%	-0.82%	0.76%	
	ntro da1	8	2.26%	2.74%	1.15%	0.52%	-0.52%	-0.68%	-0.85%	1.38%	
	co or	9	1.10%	0.83%	0.05%	-0.83%	-1.00%	0.21%	0.14%	0.52%	
	ate les	10	0.26%	-0.07%	0.35%	-0.14%	-0.58%	1.03%	-0.02%	0.83%	
	ern iab	11	1.81%	1.13%	0.38%	-0.72%	-0.20%	0.01%	-0.03%	0.41%	
	Alt var	12	2.34%	1.62%	0.54%	-0.51%	-0.47%	0.18%	-0.13%	0.91%	
		13	1.01%	-0.21%	0.31%	-0.57%	-0.99%	1.01%	0.10%	1.12%	
		14	1.21%	0.55%	0.33%	-0.76%	-0.25%	0.16%	0.07%	0.52%	
	by s	15	1.32%	-0.17%	0.21%	-1.55%	-0.08%	0.88%	-0.19%	0.09%	
_	ted ver	16	0.66%	0.54%	-0.44%	-0.90%	-0.48%	—			
ᄂ	e e	17	0.73%	-0.02%	-0.77%	-1.91%	-0.18%				
	ug re	18	1.20%	0.42%	0.31%	-0.61%	0.04%	0.23%	0.08%	0.18%	LBNL baseline
	\mathbf{v}	19 20 ¹	0.99%	0.35%	0.36%	-0.50%	0.14%	0.41%	0.02%	0.09%	
		20	1.20%	0.42%	0.43%	-0.83%	-0.25%	0.23%	0.06%	0.52%	
		21	1.20%	0.42%	0.23%	-0.45%	-0.25%	0.23%	0.32%	0.52%	
	Ч	22	1.20%	0.42%	-3.07%	1./4%	-0.25%	0.23%	-0.19%	0.52%	
	/Ze	23	1.20%	0.42%	-3.52%	2.11%	-0.25%	0.23%	-1.43%	0.52%	
	aly t	24	1.05%	0.83%	0.31%	-0.61%	-0.25%	0.1/%	0.08%	0.52%	
	s ar por	25	1.37%	0.23%	0.31%	-0.61%	-0.25%	0.19%	0.08%	0.52%	
	ves	26	1.11%	0.25%	0.31%	-0.61%	-0.25%	0.46%	0.08%	0.52%	
	nati his	27	0.94%	0.59%	0.31%	-0.61%	-0.25%	0.40%	0.08%	0.52%	
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		302,5	0.65%	1.12%	-0.07%	-0.66%	1.25%	1.29%	0.94%	-0.91%	
		21	1.000/	0 410/	0.210/	0 (10/	-0.08%	-0.89%	-0.29%	0.52%	7
		31	1.20%	0.41%	0.31%	-0.61%	-0.26%	0.23%	0.08%	0.55%	LBNL baseline

2018 alternative estimates

- "DRI measures" reduces safety impact from mass reduction from NHTSA baseline
 - Use stopped instead of non-culpable vehicles as measure of exposure (Model 15)
 - Replace footprint with track width and wheelbase (Model 16)
- "LBNL baseline" has little additional effect on safety
 - DRI measures (Models 15 and 16) plus:
 - Reweight CUV/minivans by 2010 sales, weighted more towards CUVs (Model 18)
 - Remove kinks in VMT schedule by vehicle age, based on Texas odometer data (Model 31)



Vehicle type and curb weight (lbs)

Recommend that NHTSA/EPA conduct at least one additional run using alternative mass/safety coefficients

- Using NHTSA 2012 method, LBNL analyzed effect of different mass reduction scenarios
 - Eight scenarios of mass reductions spread across vehicle types
 - Using NHTSA, DRI, and LBNL baseline coefficients
- Most mass reduction scenarios result in small net increase in fatalities using NHTSA coefficients, but large net decrease in fatalities DRI or LBNL coefficients

		Percent mass reduction by vehicle type
	1. 100-lb	
Vehicle type	reduction	
Lgt car	3.61%	
Hvy car	2.88%	
Lgt LT	2.25%	
Hvy LT	1.80%	
CUV/Minivan	2.53%	

		Estimated change in societal fatalities						
Coefficients used	1. 100-lb reduction							1
NHTSA	87	_						_
DRI	-61							
LBNL	-39	ς,			- , - ,	,		_~_

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			Percent mass reduction by vehicle type
	1. 100-lb	2. Percent	
Vehicle type	reduction	reduction	
Lgt car	3.61%	2.80%	
Hvy car	2.88%	2.80%	
Lgt LT	2.25%	2.80%	
Hvy LT	1.80%	2.80%	
CUV/Minivan	2.53%	2.80%	

			Estimate	ed change in s	societal fatal	ities	
Coefficients used	1. 100-lb reduction	2. Percent reduction					:
NHTSA	87	65					_
DRI	-61	-112					
LBNL	-39	-87			- , - ,	,	 _~_

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			Percent m
			3. 2x
	1. 100-lb	2. Percent	reduction in
Vehicle type	reduction	reduction	heavy LTs
Lgt car	3.61%	2.80%	0.00%
Hvy car	2.88%	2.80%	2.80%
Lgt LT	2.25%	2.80%	2.80%
Hvy LT	1.80%	2.80%	5.60%
CUV/Minivan	2.53%	2.80%	2.80%

		Estimated change in societal fatalities								
			3. 2x							
Coefficients	1. 100-lb	2. Percent	reduction in							
used	reduction	reduction	heavy LTs							
NHTSA	87	65	0							
DRI	-61	-112	-248							
LBNL	-39	-87	-225		± , • ,	,				

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 - Eight scenarios of mass reductions spread across vehicle types
 - Using NHTSA, DRI, and LBNL baseline coefficients
- Most mass reduction scenarios result in small net increase in fatalities using NHTSA coefficients, but large net decrease in fatalities DRI or LBNL coefficients

		Percent mass reduction by vehicle type								
			3. 2x	6. 2015	-					
	1. 100-lb	2. Percent	reduction in	NRC	1					
Vehicle type	reduction	reduction	heavy LTs	report	_					
Lgt car	3.61%	2.80%	0.00%	5.0%						
Hvy car	2.88%	2.80%	2.80%	12.5%						
Lgt LT	2.25%	2.80%	2.80%	20.0%						
Hvy LT	1.80%	2.80%	5.60%	20.0%						
CUV/Minivan	2.53%	2.80%	2.80%	20.0%	_					

			Estimated	l change in societal fatalities				
			3. 2x	6. 2015				
Coefficients	1. 100-lb	2. Percent	reduction in			NRC		1
used	reduction	reduction	heavy LTs			report		
NHTSA	87	65	0			140		_
DRI	-61	-112	-248			-920		
LBNL	-39	-87	-225			-740		_~_

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			Percent m	ass reduction by vehicle t	type		
			3. 2x	-	6. 2015	7: EPA	8. EPA
	1. 100-lb	2. Percent	reduction in		NRC	estimate	estimate
Vehicle type	reduction	reduction	heavy LTs		report	in 2021	in 2025
Lgt car	3.61%	2.80%	0.00%		5.0%	0.0%	0.0%
Hvy car	2.88%	2.80%	2.80%		12.5%	4.4%	6.1%
Lgt LT	2.25%	2.80%	2.80%		20.0%	6.3%	8.0%
Hvy LT	1.80%	2.80%	5.60%		20.0%	4.7%	5.7%
CUV/Minivan	2.53%	2.80%	2.80%		20.0%	6.7%	10.6%

		Estimated change in societal fatalities								
			3. 2x	-		6. 2015	7: EPA	8. EPA		
Coefficients	1. 100-lb	2. Percent	reduction in			NRC	estimate	estimate		
used	reduction	reduction	heavy LTs			report	in 2021	in 2025		
NHTSA	87	65	0			140	29	40		
DRI	-61	-112	-248			-920	-242	-300		
LBNL	-39	-87	-225			-740	-181	-202		

2. 2017 LBNL Phase 2 analysis

- 2017 LBNL Phase 2 analysis
 - All data, including fatalities and casualties, from police-reported crashes in 13 states
 - Numerator: fatalities or casualties (fatalities + serious injuries)
 - Denominator: all crash-involved vehicles
 - Result: 13-state fatalities or casualties per crash
 - Analysis of two components of casualties per VMT:
 - Crash frequency: crashes per mile traveled, using NHTSA weights
 - Crashworthiness/compatibility: casualties per crash

<u>casualties</u> = <u>crashes</u> x <u>casualties</u> VMT VMT crash

- Drawbacks of Phase 2 analysis
 - Limited to 13 states that provide Vehicle Identification Number (VIN)
 - Does relationship between weight/size and risk vary by state?
 - Are 13 states representative of national relationship?
 - Not enough fatalities in 13 states to also get robust results for fatality risk

Results from 2017 LBNL Phase 2

- 13-state societal casualty risk per VMT vs. US fatality risk per VMT
 - Comparable for cars ...
 - ... but not for light trucks or CUVs/minivans, with mass reduction associated with increases in casualty risk per VMT, especially for CUVs/minivans
- Mass reduction increases crashes per VMT (crash frequency) but slightly reduces casualties per crash (crashworthiness/compatibility)
 - Contradicts belief that better handling and braking in lighter vehicles results in lower crash frequency
 - Results largely unchanged after accounting for:
 - Vehicle price, household income, driving record, alcohol/drug use, restraint use
 - Crash severity (by excluding crashes involving towed vehicles)



3. Effect of mass disparity over time on fatalities in two-vehicle crashes

- NAS 2015 recommended an analysis of the effect of mass disparity over time on fatalities in two-vehicle crashes
- Hypotheses
 - Standards immediately reduce mass in case vehicle, while mass in crash partner will increase over time (assuming same age) until it becomes subject to standards
 - In car-LT crashes, standards initially increase disparity (and fatalities)
 - In LT-car crashes, standards initially decrease disparity (and fatalities)
- Objective
 - What is net effect of standards, by crash type and overall, on annual fatalities when mass of crash partner is also eventually reduced because of standards?

Effect of mass disparity over time on total fatalities

- 1. Propose estimating relationship between relative masses of two vehicles and societal risk in two-vehicle crashes
 - NHTSA baseline only considers if case vehicle and crash partner are lighter or heavier than average
 - Relationship between risk and crash partner mass as percent of combined mass
 - Risk increases as mass disparity increases, especially for LT:LT crashes



- 2. Simulate mass of case vehicle and crash partner 25+ years into the future
- 3. Estimate change in fatalities by multiplying coefficients from regression models by simulated vehicle weights in each simulation year

Summary

- Mass reduction associated with a small increase in risk in lighterthan-average cars only, and small decrease in risk in heavier-thanaverage light trucks (Phase 1)
- Detrimental effect of mass reduction in lighter cars has declined in recent years
- Effect of mass reduction on risk is overwhelmed by other vehicle, driver, and crash characteristics
- Wide range in risk by vehicle models of similar mass, after accounting for vehicle, driver, and crash differences
- Accounting for vehicle design or driver behavior changes estimates depending on variables used
- Mass reduction associated with an increase in crash frequency, but a decrease in risk per crash (Phase 2)
- Mass disparity (rather than absolute difference) in two-vehicle crashes captures effect of changes in mass over time

Recommendations

- NHTSA method is most comprehensive statistical evaluation of relationship between mass/size reduction and societal safety
 - Allows for estimating impact of new crash avoidance technologies, by crash and vehicle type, over time
 - Allows assessment of different mass reduction scenarios by vehicle type
 - Recommend replacing absolute mass reduction with mass disparity in two vehicle crashes
- Statistical analysis uses real world data, and accounts for all crash configurations ...
 - ... but relates mass difference of different models to mass reduction in individual vehicle
- Computer aided engineering simulates the effect of specific mass reduction in specific vehicles and types of crashes ...
 - ... but does not account for all vehicle models and crash configurations experienced in real world
- Both methods helpful in predicting effect of mass reduction on safety

Publications and Presentations

- Wenzel, Tom. 2013. Relationships between Mass, Footprint, and Societal Risk in Recent Light-Duty Vehicles. Presentation to NRC Committee. <u>June</u>.
- Wenzel, Tom. 2015. Comments on NRC Committee report "Assessment of Technologies for Improving Fuel Economy of Light-Duty Vehicles, Phase 2". January.
- Wenzel, Tom. 2016. Sensitivity of Light-Duty Vehicle Crash Frequency per Vehicle Mile of Travel to Additional Vehicle and Driver Variables. February. <u>LBNL-1005831</u>.
- Wenzel, Tom. 2016. Effect of Accounting for Crash Severity on the Relationship between Mass Reduction and Crash Frequency and Risk per Crash. May. <u>LBNL-</u> <u>1005832</u>.
- Wenzel, Tom. 2016. Assessment of NHTSA's Report "Relationships Between Fatality Risk, Mass, and Footprint in Model Year 2003-2010 Passenger Cars and LTVs". <u>LBNL-1005177</u>.
- Wenzel, Tom. 2016. Effect of using Different Vehicle Weight Groups on the Estimated Relationship between Mass Reduction and U.S. Societal Fatality Risk per Vehicle Miles of Travel. August. <u>LBNL-1006317</u>.
- Wenzel, Tom. 2016. Comments on Docket No. NHTSA-2016-0068 and Docket ID No. EPA-HQ-OAR-2015- 0827, Draft Technical Assessment Report: Midterm Evaluation of Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2022-2025. <u>September</u>.
- Wenzel, Tom. 2018. An Analysis of the Relationship between Casualty Risk Per Crash and Vehicle Mass and Footprint for Model Year 2003-2010 Light-Duty Vehicles. January. <u>LBNL-2001092</u>.
- Wenzel, Tom. 2018. Assessment of NHTSA's Report "Relationships Between Fatality Risk, Mass, and Footprint in Model Year 2004-2011 Passenger Cars and LTVs". March. <u>LBNL-2001137</u>.

Supplemental slides

Separate regression model for each of nine crash types

- 1. First-event rollover
- 2. Crash with stationary object
- 3. Crash with pedestrian/bicycle/motorcycle
- 4. Crash with heavy-duty vehicle
- 5. Crash with car/CUV/minivan < 3,187 lbs
- 6. Crash with car/CUV/minivan \geq 3,187 lbs
- 7. Crash with light truck (pickup/SUV/van) < 4,360 lbs
- 8. Crash with light truck (pickup/SUV/van) \geq 4,360 lbs
- 9. Other (mostly crashes involving 3+ vehicles)
- Market saturation of electronic stability control (ESC) by 2017 assumed to reduce fatal crashes by:
 - Cars: rollovers by 60%, crashes with objects by 31%
 - Light trucks/CUVs/minivans: rollovers by 74%, crashes with objects by 45%
 - All other crashes by 7% in cars, 6% in light trucks/CUVs/minivans
- Coefficients by crash type reweighted by likely distribution after full adoption of ESC
 - Can use similar approach for crash-avoidance technologies as they penetrate market

Control variables

- Vehicle
 - UNDRWT00 (100 lbs < median mass; 3,201 lbs for cars, 5,014 lbs for LTs)
 - OVERWT00 (100 lbs ≥ median mass; 3,201 lbs for cars, 5,014 lbs for LTs)
 - LBS100 (in 100 lbs, for CUVs/minivans only)
 - FOOTPRINT (in square feet, wheelbase times track width)
 - Type: two-door car, SUV, heavy-duty (200/300 series) pickup, minivan
 - LT compatibility measure: bumper overlap, blocker beam
 - 5 side airbag variables: rollover curtain, curtain, torso, combo curtain/torso
 - Assisted braking system (ABS), electronic stability control (ESC), all-wheel drive (AWD), vehicle age, if a brand new vehicle
- Driver
 - 8 driver age/gender variables: years younger/older than 50 (for age groups 14-30, 30-50, 50-70, 70-90, for male and female)
- Crash
 - At night, in rural county (<250 pop/sq mile), on road with 55+ mph speed limit, in high-fatality rate state (25 southern/mountain states, plus KS and MO)
 - Crash occurred in 2006, 2007, 2008, 2010, 2011, or 2012
- Not all variables used for each vehicle or crash type

Method to estimate exposure, based on registration and VMT weights

- 2.1 million non-culpable vehicles involved in two-vehicle crashes in 13 states
 - 6 crash states (AL, FL, KS, KY, MO, WY) represent states with high fatality rates
 - 7 crash states (MD, MI, NE, NJ, PA, WA, WI) represent states with low fatality rates
 - DRI proposed using subset of 612,000 stopped vehicles in two-vehicle crashes
- Assign weight to each crash vehicle so that sum of weights equals total US vehicle registrations (from IHS Automotive/Polk), by MY and model
- Develop schedule of average annual VMT by vehicle age for cars and trucks, using 2009 National Household Travel Survey
- Use average odometer by make and model (from IHS Automotive/Carfax) to adjust annual VMT by make and model
- Regression model estimates the effect of 100-lb reduction in mass on societal fatalities per VMT, holding footprint constant

19 alternative regression models in 2012 LBNL report

• Alternative definitions of risk

- 1. Weighted by current distribution of fatalities (rather than after 100% ESC)
- 2. Single regression model across all crash types (rather by crash type)
- 3. Fatal crashes (rather than fatalities) per VMT
- 4. Fatalities per induced exposure crash (rather than VMT)
- 5. Fatalities per registered vehicle-year (rather than VMT)

• Alternative control variables/data

- 6. Allow footprint to vary with mass (and vice versa)
- 7. Account for 14 vehicle manufacturers
- 8. Account for 14 manufacturers + 5 additional luxury vehicle brands
- 9. Account for initial vehicle purchase price (based on Polk VIN decoder)
- 10. Exclude CY variables
- 11. Exclude crashes with alcohol/drugs
- 12. Exclude crashes with alcohol/drugs, and drivers with poor driving record
- 13. Account for median household income (based on vehicle zip code, from CA DMV data)
- 14. Include sports, police, and all-wheel drive cars, and full size vans

• Suggested by DRI and peer reviewers

- 15. Use stopped instead of non-culpable vehicles from 13-state crash data for induced exposure
- 16. Replace footprint with track width and wheelbase
- 17. Above two models combined
- 18. Reweight CUV/minivans by 2010 sales
- 19. Exclude non-significant control variables

12 additional regression models in 2016 and 2018 updates

• Different categories for light trucks

- 20. Exclude LTs over 10,000 GVWR (subject to HD truck rule)
- 21. Small pickups and SUVs analyzed separately from large pickups
- 22. Large pickups analyzed separately from small pickups and SUVs
- 23. Models 20 and 22 combined for large pickups

• Exclude certain types of cars

- 24. Include AWD cars, but not muscle or police cars
- 25. Include muscle and police cars, but not AWD cars
- 26. Exclude three high-risk car models
- 27. Include AWD cars, exclude three high-risk car models (Models 24 and 26)

• Two-piece variables

- 28. Use two-piece variable for CUV mass
- 29. Use two-piece variable for car and light truck footprint
- 30. Use two-piece variable for CUV mass, all footprint (Models 28 and 29)
- Changes to VMT weights
 - 31. Remove kinks in NHTSA VMT schedules

Effect of mass disparity over time on total fatalities

- 1. Estimate relationship between relative masses of two vehicles and societal risk
 - NHTSA baseline only considers if case vehicle and crash partner are lighter or heavier than average
 - Relationship between risk and crash partner mass as percent of combined mass
 - Risk increases as mass disparity increases, especially for LT:LT crashes



- 2. Simulate mass of case vehicle and crash partner 27 years into the future
 - Use current distribution of mass of case vehicles and crash partners, by age of each vehicle
 - Case vehicle mass is reduced in simulation year 1, to reflect effect of standards
 - NAS recommendations: light car 5%, heavy car 12.5%, light truck/CUV/minivan 20%
 - Crash partner mass is changed every year based on recent historical trends
 - 2.2% annual decrease between MY81 and MY87 for all vehicle types
 - 0.5% (cars, CUVs, minivans) or 2.2% (LTs) annual increase between MY88 and MY06
 - When a vehicle reaches MY07 assumed mass reduction from standards is applied
- 3. Estimate change in fatalities by multiplying coefficients from regression models by simulated vehicle weights in each simulation year

Simulated masses and mass differences over time

- Masses of two light trucks in two sample crashes
 - Mass of case vehicle decreases 20% in Year
 0 because of standards
 - Mass of crash partner decreases 2.2% annually until MY88, increases 2.2% annually until MY03
 - Mass of crash partner decreases 20% in MY04
 - Standards assumed to reduce LT mass by 20%, car mass by 5%
- Mass differences in two light trucks in two sample crashes
 - Crash with MY83 (21-yo) LT: mass difference decreases to 0 by Year 20, increases in year 21 when standards apply to crash partner (red)
 - Crash with MY93 (11-yo) LT: mass difference increases through Year 10, but decreases in Year 11 when standards apply to crash partner (blue)



Example simulation of mass disparity over time

- Simulated change in mass disparity (based on partner mass as a percent of combined mass)
- In Year 1 NAS-recommended mass reductions:
 - Increase mass disparity in crashes involving cars
 - Decrease mass disparity in crashes involving light trucks and CUVs/minivans
- By end of simulation period:
 - Crashes involving cars have slightly higher mass disparity
 - Crashes involving light trucks and CUVs/minivans have much lower mass disparity

