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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

Report prepared for the Office of Energy Efficiency and Renewable Energy,
US Department of Energy

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Executive Summary

This report recalculates the estimated relationship between vehicle mass and societal fatality risk, using alternative groupings by vehicle weight, to test whether the trend of decreasing fatality risk from mass reduction as case vehicle mass increases, holds over smaller increments of the range in case vehicle masses. The NHTSA baseline regression model estimates the relationship using for two weight groups for cars and light trucks; we re-estimated the mass reduction coefficients using four, six, and eight bins of vehicle mass. The estimated effect of mass reduction on societal fatality risk was not consistent over the range in vehicle masses in these weight bins. These results suggest that the relationship indicated by the NHTSA baseline model is a result of other, unmeasured attributes of the mix of vehicles in the lighter vs. heavier weight bins, and not necessarily the result of a correlation between mass reduction and societal fatality risk. An analysis of the average vehicle, driver, and crash characteristics across the various weight groupings did not reveal any strong trends that might explain the lack of a consistent trend of decreasing fatality risk from mass reduction in heavier vehicles.

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1. Introduction

In its recent 2016 updated report in support of the recent fuel economy/greenhouse gas emission standards, NHTSA used logistic regression models to estimate the effect of a 100-lb reduction in vehicle mass, or a 1-square foot reduction in vehicle footprint, on societal fatality risk per vehicle miles of travel, using data for model year 2003 to 2010 vehicles in calendar years 2005 through 2011 (Puckett and Kindelberger 2016, Wenzel 2016). Estimated coefficients were generated from 27 regression models, one each for three vehicle types (passenger cars; light duty trucks, i.e. pickups and SUVs; and car-based vehicles regulated as light-duty trucks, i.e. crossover utility vehicles, or CUVs, and minivans). For each vehicle type, a separate regression model was run for nine crash types. The estimated coefficients from each of the 27 regressions were reweighted by the expected number of fatalities in each type of crash after full adoption of electronic stability control technology (ESC).

In its baseline model, NHTSA used a two-piece linear variable for car and light truck mass, with the flex point for each vehicle type based on the median curb weight of each vehicle type (3,197 lbs for cars, 4,947 lbs for light trucks; because there were not enough fatalities involving case CUVs and minivans, a single variable for CUV/minivan weight was used). Of the five vehicle types (lighter- and heavier-than-average cars and light trucks, and CUVs/minivans), the estimated coefficients were statistically significant for only one, lighter-than-average cars. This report examines the sensitivity of NHTSA's results from its baseline regression model to using different groupings of cars and light trucks by curb weight. If societal fatality risk decreases as the curb weight of the case vehicle increases, we would expect to see increases in the estimated coefficients from mass reduction as the mass of the case vehicle increases.

2. Distributions of vehicle mass

Figure 1 shows the distribution of vehicle curb weight of the three vehicle types, using FARS records of vehicles involved in fatal crashes. The figure indicates that the weight distribution is not smooth for each vehicle type; for cars and CUVs/minivans, the distribution is bimodal, whereas the weight of light trucks has a wider distribution. Figures 2 though 4 show the weight distribution for sub-types of each vehicle type; Figure 2 indicates that the weight distribution of 2- and 4-door cars are nearly identical; Figure 3 indicates that the weight distributions of small pickups and SUVs are quite similar, but with little overlap with large pickups; and Figure 4 shows that the weight distributions of CUVs and minivans also have little overlap. Figures 3 and 4 suggest that, in future analyses, NHTSA should consider treating large pickups as a separate vehicle class from small pickups and SUVs, and CUVs as a separate vehicle class from minivans; however, because of small sample sizes, particularly for large pickups and CUVs, this may result in estimated mass effects that are not statistically-significant.

Figure 5 shows the cumulative weight distributions of the seven vehicle types. The figure indicates that about 77% of 2-door cars, and 52% of 4-door cars, have curb weights lower than 3,100 lbs, the approximate median weight NHTSA used in its baseline regression model. About 63% of small pickups and SUVs have curb weights lower than the 4,600 pound median weight NHTSA used in its baseline regression model; however, essentially all large pickups have a curb weight greater than 4,600 lbs.

Figure 1. Distribution of light-duty vehicle curb weights in FARs, by vehicle type

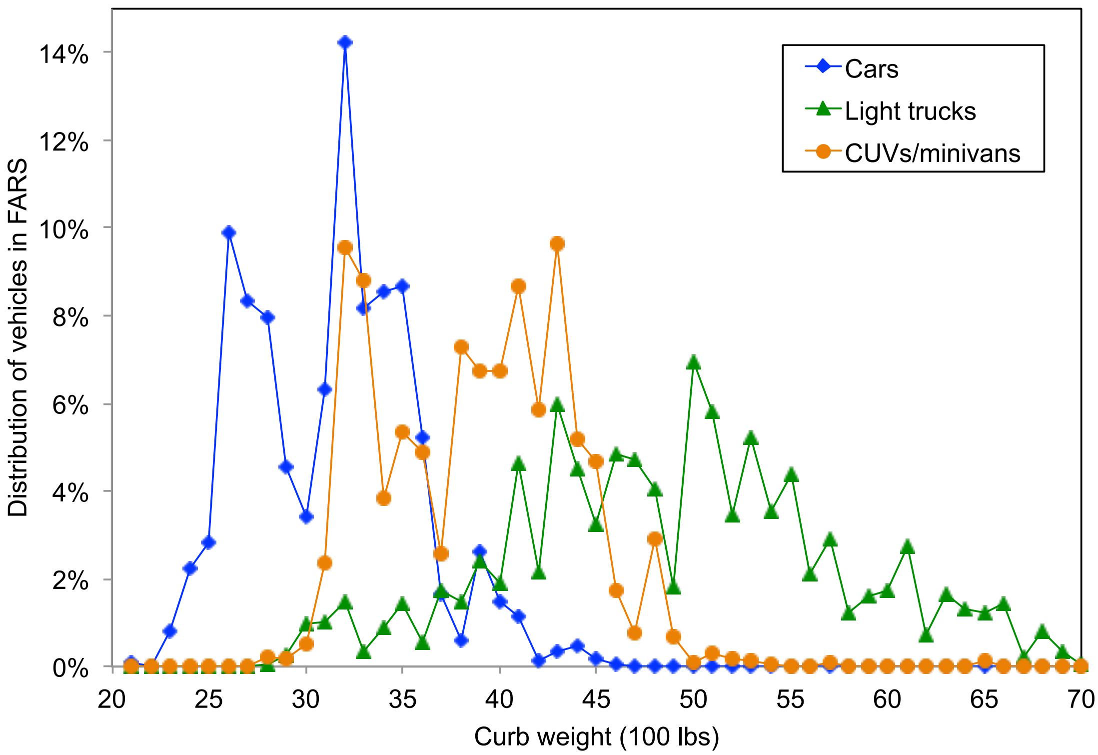


Figure 2. Distribution of car curb weights in FARs, by car type

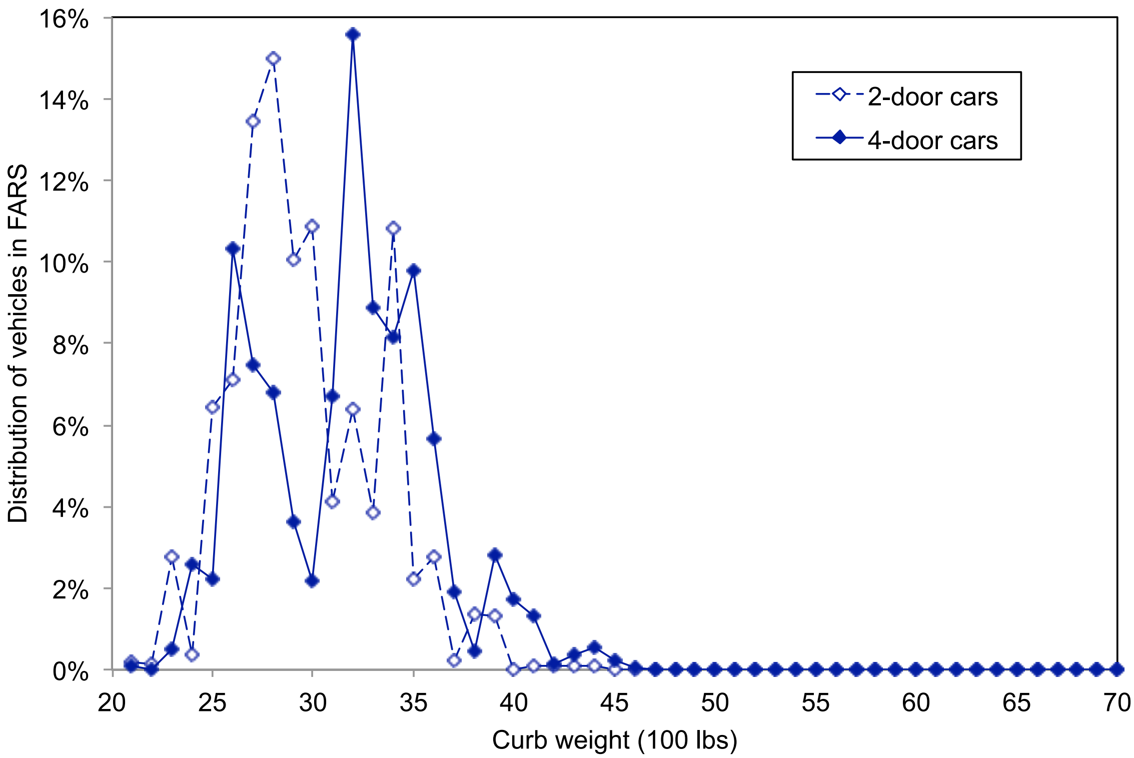


Figure 3. Distribution of light truck curb weights in FARs, by light truck type

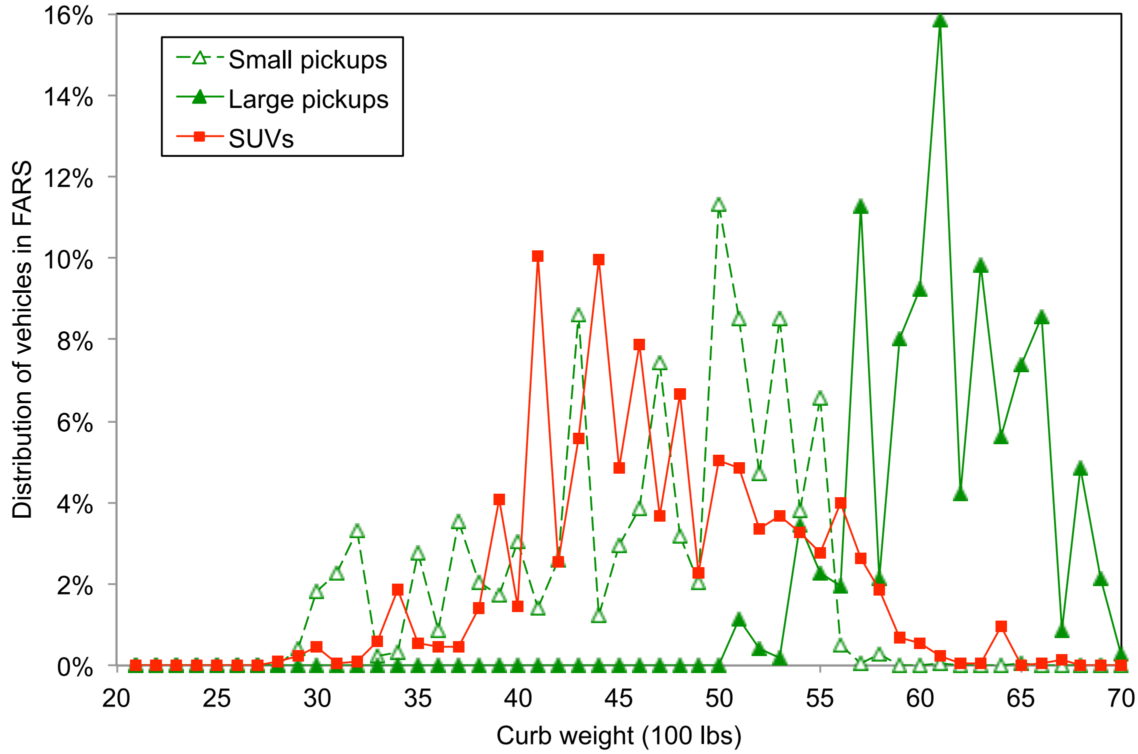


Figure 4. Distribution of CUV/minivan curb weights in FARs, by vehicle type

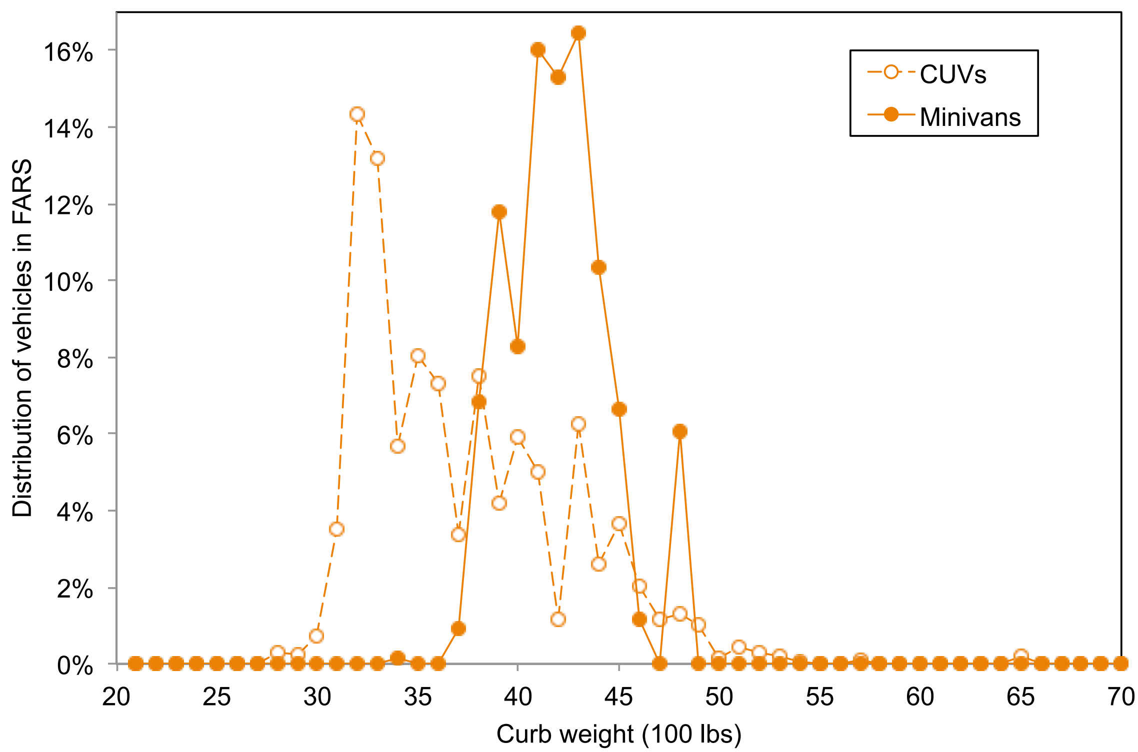
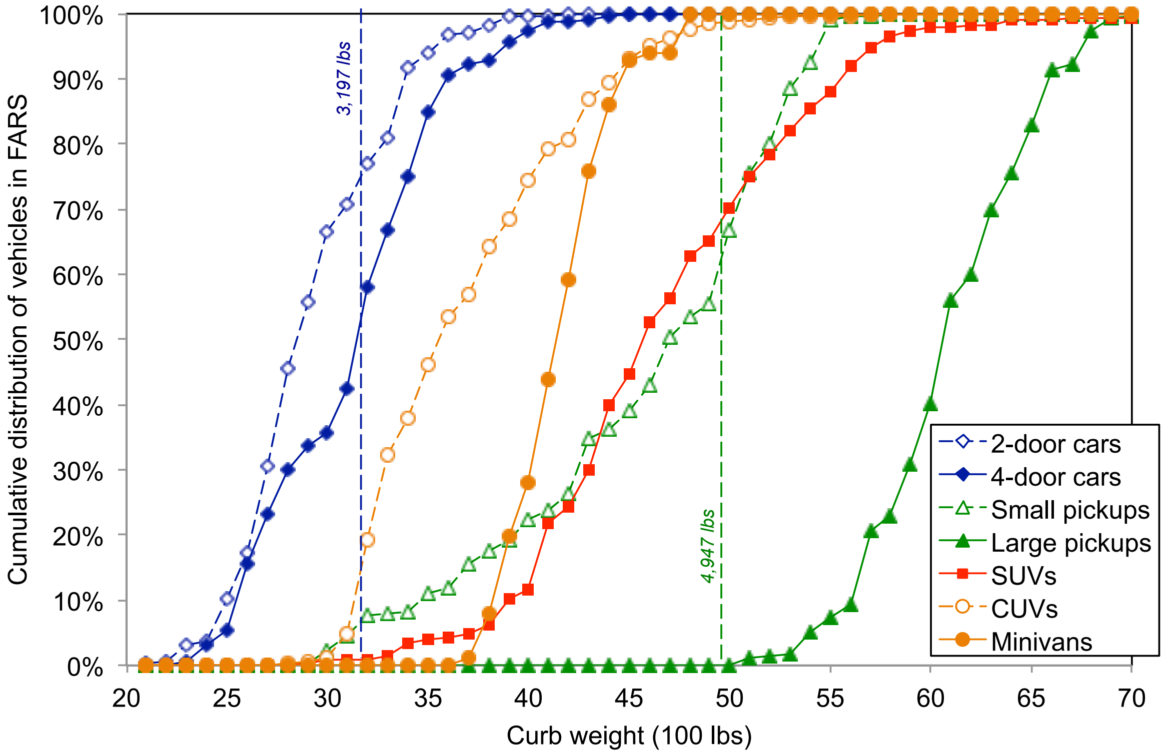


Figure 5. Cumulative distribution of curb weights in FARs, by vehicle type



3. Results

For this report we tested the sensitivity of the results from NHTSA's baseline model, which used a single flex point at the median vehicle weight, to seven alternative weight groupings:

- Alternative 1: one flex point, weight divided into quartiles;
- Alternative 2: one flex point, weight divided into sestiles;
- Alternative 3: one flex point, weight divided into octiles;
- Alternative 4: two flex points at the 25th and 75th weight percentile, weight divided into quartiles;
- Alternative 5: one flex point at the 75th percentile;
- Alternative 6: one flex point at the 25th percentile;
- Alternative 7: 2-dr cars treated separately from 4-dr cars, and small pickups/SUVs treated separately from large pickups.

Table 1 shows the number of vehicles, upper boundary level, and flex point (in hundreds of pounds) for each of the seven alternative weight groupings, for cars and light trucks. It is important to understand how the LBS100 value for a particular vehicle changes under each of the alternative weight groupings shown in Table 1; Table 2 shows how the weight group and value for LBS100 changes in each of the seven alternate weight groupings, for four sample vehicles. For example, because alternative Models 1 through 3 use the median mass as a single flex point, a 2,800-lb 2-door car would have the same value for LBS100 (-3.97), but would be in a different weight group in each model (the second lightest weight group in Models 1 and 2, but the third lightest weight group in Model 3). The mass of this car is in the second quartile, so it would be in weight group 2 in Models 4 and 6, with a LBS100 value of 0.41 (its mass less the median mass of lighter-than-average cars, or 28.00 – 27.59). However, in Model 5, it would be in the lighter of the two weight groups with a LBS100 value of -6.20 (28.00 – 34.20). Finally, in Model 7, it would be in the lighter-than-average weight group for 2-door cars, with a LBS100 value of -1.04 (28.00 – 29.04).

Table 1. Number of vehicles, upper boundary level and flex point (hundreds of pounds) for cars and light trucks in seven alternate weight groupings

		Number of vehicles		Mass upper boundary (lbs/100)		Flex point (lbs/100)	
	Percentile	Cars	LTs	Cars	LTs	Cars	LTs
1: Quartiles	25%	9,595	8,199	27.59	42.96	31.97	49.47
	50%	9,278	8,216	31.97	49.47	31.97	49.47
	75%	8,897	8,085	34.20	54.37	31.97	49.47
	100%	9,090	8,151	99.99	99.99	31.97	49.47
2: Sestiles	16.6%	6,224	5,702	26.58	41.15	31.97	49.47
	33.2%	6,102	5,254	28.90	44.98	31.97	49.47
	50.0%	6,547	5,459	31.97	49.47	31.97	49.47
	66.6%	5,749	5,437	33.25	52.51	31.97	49.47
	83.2%	6,290	5,478	35.10	57.11	31.97	49.47
	100%	5,948	5,321	99.99	99.99	31.97	49.47
3: Octiles	12.5%	5,025	4,092	26.23	39.44	31.97	49.47
	25.0%	4,570	4,107	27.59	42.96	31.97	49.47
	37.5%	4,240	4,154	29.84	46.12	31.97	49.47
	50.0%	5,038	4,062	31.97	49.47	31.97	49.47
	62.5%	4,228	4,001	32.84	51.23	31.97	49.47
	75.0%	4,669	4,084	34.20	54.37	31.97	49.47
	85.5%	3,768	3,426	35.36	58.28	31.97	49.47
	100%	5,322	4,725	99.99	99.99	31.97	49.47
4: Quartiles with two values for LBS100	25%	9,595	8,199	27.59	42.96	27.59	42.96
	50%	9,278	8,216	31.97	49.47	27.59	42.96
	75%	8,897	8,085	34.20	54.37	34.20	54.37
	100%	9,090	8,151	99.99	99.99	34.20	54.37
5: 75th percentile	75%	27,770	24,500	34.20	54.37	34.20	54.37
	100%	9,090	8,151	99.99	99.99	34.20	54.37
6: 25th percentile	25%	9,595	8,199	27.59	42.96	27.59	42.96
	100%	27,265	24,452	99.99	99.99	27.59	42.96
7: 2-dr cars and small PUs/SUVs	50%	2,673	13,650	29.04	47.00	29.04	47.00
	100%	2,666	13,635	99.99	99.99	29.04	47.00
7: 4-dr cars and large PUs	50%	16,133	2,692	32.09	60.97	32.09	60.97
	100%	15,388	2,674	99.99	99.99	32.09	60.97

Table 2. Weight group and value for LBS100 in each of seven alternate weight groupings, for four sample vehicles

Model	2,800-lb 2-dr car		3,500-lb 4-dr car		4,900-lb SUV		6,500-lb large PU	
	Group	LBS100	Group	LBS100	Group	LBS100	Group	LBS100
Baseline	1	-3.97	2	3.03	1	-0.47	2	15.53
1 (4 groups)	2	-3.97	4	3.03	2	-0.47	4	15.53
2 (6 groups)	2	-3.97	5	3.03	3	-0.47	6	15.53
3 (8 groups)	3	-3.97	7	3.03	4	-0.47	8	15.53
4 (4 groups)	2	0.41	4	0.80	2	6.04	4	10.63
5 (2 groups)	1	-6.20	2	0.80	1	-5.37	2	10.63
6 (2 groups)	2	0.41	2	7.41	2	6.04	2	22.04
7 (2 groups)	1	-1.04	2	2.91	2	2.00	2	4.03

Figures 6 and 7 show the estimated effect of mass reduction in the NHTSA baseline model (shown in orange) and alternative Models 1 through 6, for cars and light trucks, respectively. For simplicity, all of the results shown are for a single regression model across all crash types, and do not reweight the coefficients by crash type to account for full adoption of ESC technology. If mass reduction is consistently associated with an increase in risk, one would expect that the lightest and heaviest vehicles in alternative Models 1 (dark blue), 2 (dark green), and 3 (red), would have larger estimated effects of mass reduction than the vehicles closer to the median mass. However, we see that this is not the case; the estimated effect of mass reduction tends to be smallest, and usually not statistically-significant, in the lightest and heaviest vehicles, both for cars in Figure 6 and light trucks in Figure 7.

As indicated in Table 1, Model 4 uses the same weight groups as Model 1, but rather than calculating LBS100 for individual based on the median weight of all vehicles, for lighter-than-average vehicles it calculates LBS100 based on the median mass of the lightest 50% of vehicles (2,759 pounds for cars, 4,296 pounds for light trucks), and for heavier-than-average vehicles LBS100 is based on the median mass of the heaviest 50% of vehicles (3,420 pounds for cars, 5,437 pounds for light trucks). Figures 6 indicates that Model 4 (shown in purple) estimates that mass reduction in the lightest and heaviest cars is associated with very small decreases in fatality risk per VMT. This result is unexpected; if decreased mass is consistently associated with increasing risk, we would expect the lightest cars to be associated with the largest increase in risk. On the other hand, Model 4 does have the expected signs for light trucks in Figure 7, with mass reduction in the lighter light trucks in the two groups associated with increases in risk (0.44% and 1.41% increases in risk), and mass reduction in the heaver trucks in the two groups associated with decreases in risk (1.47% and 1.31% decreases in risk).

Model 5 uses only two weight groups, but sets the flex point for LBS100 at the 75th percentile weight for each type of vehicle. In this case, 75% of cars and trucks are included in the lighter vehicle group, while only 25% of vehicles are included in the heavier group. As indicated in Figure 6, Model 5 (shown in light blue) estimates, as expected, that mass reduction in the lightest 75% of cars is associated with a 1.31% increase in risk, while mass reduction in the heaviest 25% of cars is associated with essentially no change in risk. Figure 7 indicates that Model 5 also estimates in the expected direction for light trucks, with no change in risk for mass reduction in

Figure 6. Estimated effect of car mass reduction on US societal fatality risk per VMT, baseline model and six alternative weight groups

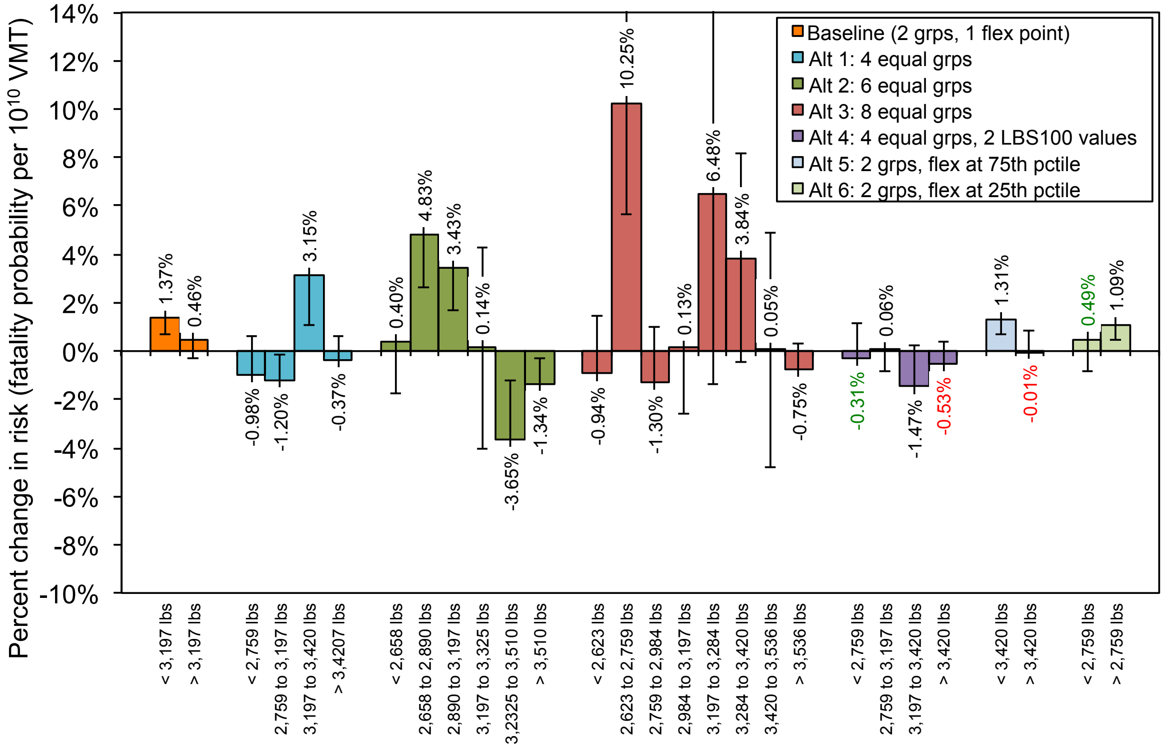
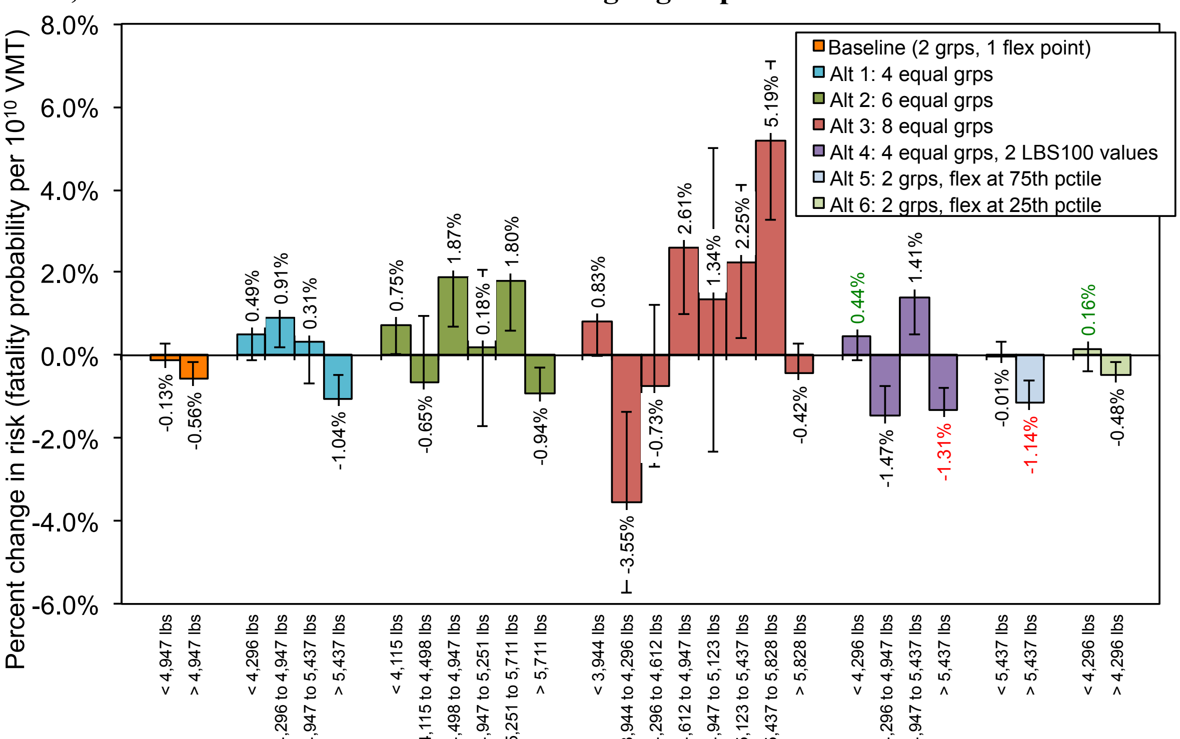


Figure 7. Estimated effect of light truck mass reduction on US societal fatality risk per VMT, baseline model and six alternative weight groups



the lightest 75% of light trucks, and an estimated 1.14% decrease in risk from mass reduction in the heaviest 25% of light trucks.

Model 6 is the opposite of Model 5, with the flex point set at the 25th percentile weight. The estimates of Model 6 (shown in light green in Figures 6 and 7) are in the unexpected direction, with mass reduction in the lightest 25% of cars associated with a small (0.49%) increase in risk, but mass reduction in the heaviest 75% of cars associated with a larger (1.09%) increase in risk. For light trucks, the estimated effect of mass reduction on risk in Model 6 is similar to that in the baseline model, with mass reduction in the lightest 25% of light trucks associated with a 0.16% increase in risk, and mass reduction in the heaviest 75% of light trucks associated with a 0.48% decrease in risk.

There are two cases where one of the vehicle weight groups is identical in two different alternative regression models: the first weight group in Models 4 and 6 (where the lightest quartile of vehicles are used, and LBS100 is calculated based on the weight of the 25th percentile of vehicles, 2,759 pounds for cars and 4,296 pounds for light trucks), and the last weight group in Models 4 and 5 (based on the heaviest quartile of vehicles, basing LBS100 on 3,420 pounds for cars and 5,437 pounds for light trucks), as shown in Table 1. The first of these comparisons is shown in green font in Table 1 and Figures 6 and 7, while the second is shown in red font. For cars, the estimated effect of mass reduction on fatality risk in these two weight groups have opposite signs depending on whether the other vehicles are included in one of the three remaining quartiles (Model 4, shown in purple in Figure 6) or the other vehicles are included in a single group (Models 5 and 6, shown in light blue and light green in Figure 6). For light trucks, the estimates of the same weight group in Model 4 are in the same direction as, but larger than, the estimates of that weight group in Models 5 and 6. This comparison indicates that the estimated effect of mass reduction on risk in a single weight group is sensitive to how the weights of other vehicles are grouped.

In Model 7 the relationship between mass reduction and risk in two-door cars is modeled separately from that in four-door cars, and the relationship in small trucks and SUVs is modeled separately from that in large pickups. Figure 8 compares the baseline estimates with those of two-door and four-door cars, while Figure 9 compares the baseline estimates with those of small pickups/SUVs and large pickups. In Figure 8, Model 7 estimates that mass reduction is associated with an increase in risk in lighter-than-average four-door cars and a slight decrease in risk in heavier-than-average four-door cars (shown in green), similar to the results from the baseline model (shown in orange). However, Model 7 estimates an unexpected result for two-door cars: mass reduction in lighter-than-average two-door cars is associated with a large decrease in risk, while mass reduction in heavier-than-average two-door cars is associated with a large increase in risk (shown in blue).

As shown in Figure 9, Model 7 estimates the same relationship for small pickups/SUVs as for all light-trucks combined in the baseline model (shown in orange): mass reduction in heavier-than-average trucks is associated with a slightly larger decrease in risk than mass reduction in lighter-than-average trucks (shown in blue). However, the relationship for small pickups/SUVs is smaller than in the baseline model. Model 7 shows an unexpected result when large pickups are modeled separately from small pickups/SUVS: here mass reduction in lighter-than-average large

Figure 8. Estimated effect of car mass reduction on US societal fatality risk per VMT, baseline model and treating 2-door cars separately from 4-door cars

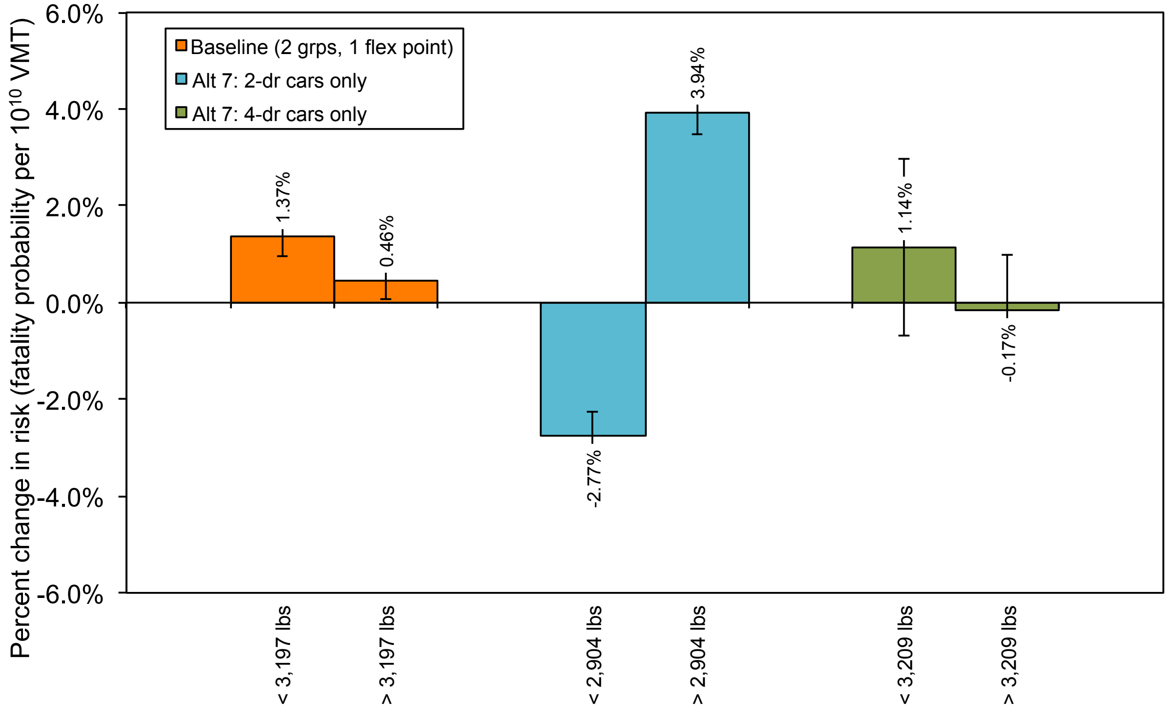
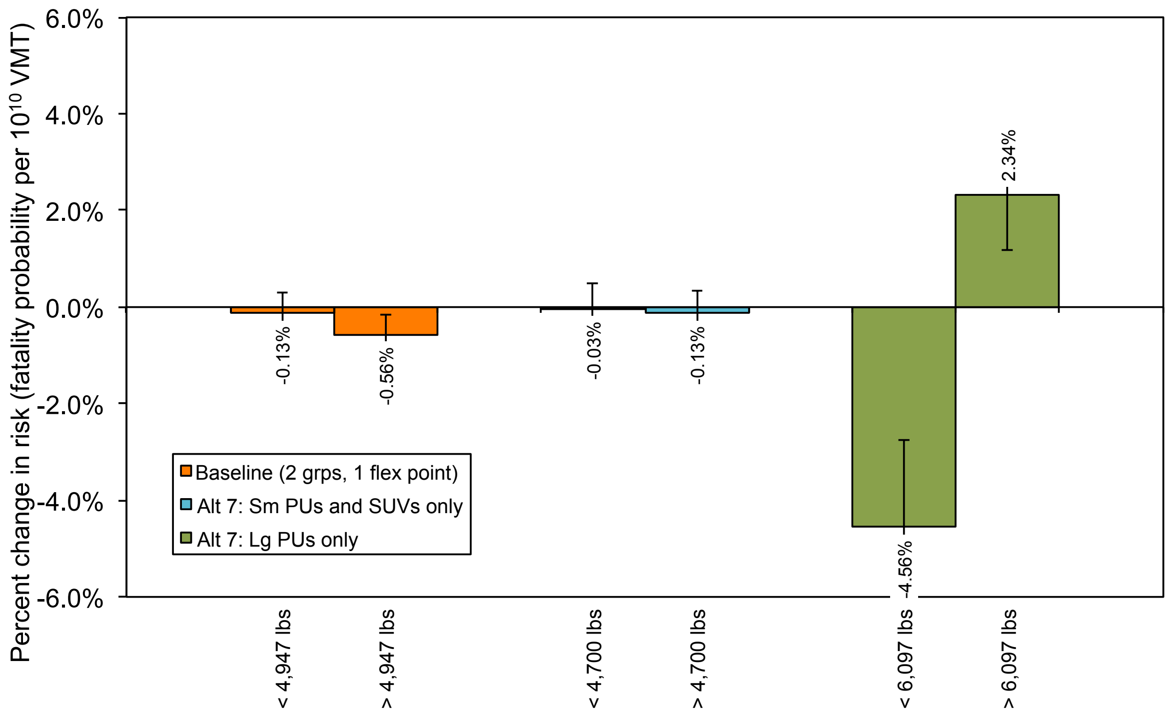


Figure 9. Estimated effect of light truck mass reduction on US societal fatality risk per VMT, baseline model and treating small pickups and SUVs separately from large pickups



pickups is associated with a large decrease in risk, while mass reduction in heavier-than-average large pickups is associated with a large increase in risk (shown in green). This unexpected result is similar to that obtained by Model 7 for two-door cars, shown in Figure 8.

In the NHTSA 2003 report, Kahane calculated the crossover weight at which mass reduction in light trucks shifted from an increase to a decrease in societal fatality risk. He estimated this crossover weight by using a quadratic, rather than a two-piece linear, equation for vehicle weight; i.e., he replaced the two variables UNDRWT00 and OVERWT00 in the baseline regression model with LBS100 and the square of LBS100 (LBS100SQRD).

Table 3 shows the estimated effect of two additional alternative regression models: Model 8 replaces the UNDRWT00 and OVERWT00 variables in the baseline regression model with a single mass variable, LBS100, while Model 9 replaces the two variables with LBS100 and the square of LBS100, LBS100SQRD. Models were run for all cars and all light trucks, and then for small pickups and SUVs only, and large pickups only. The estimated coefficients from comparable models reported in Kahane 2003 are also included in Table 3.

Table 3. Estimated effect of mass reduction on US societal fatality risk per VMT, using linear and quadratic weight variables, by vehicle type

	Model 8	Model 9	
Vehicle type	LBS100	LBS100	LBS100SQRD
Cars	0.0100	0.0404	-0.000481
Light trucks	-0.0034	0.0120	-0.000154
Small pickups/SUVs		0.0221	-0.000238
Large pickups		-0.4838	0.003880
Light trucks (2003)		0.0838	-0.000824

Note: estimates in red are statistically significant at the 95% level.

Figure 10 shows the estimated relationship between vehicle mass and societal fatality risk per VMT, from Kahane 2003 and for cars and light trucks from the updated database used in Puckett 2016. The figure indicates that the crossover weight for light trucks decreased from 5,085 pounds in 2003 to 3,896 pounds in 2016, and the 2016 crossover weight for cars is 4,200 pounds (and the crossover weight for cars is now higher than the crossover weight for light trucks). The analysis suggests that mass reduction in vehicles below the crossover weight will increase societal fatality risk, while mass reduction in vehicles above the crossover weight will decrease societal fatality risk. Note that the slope of the relationship between mass and risk for cars in 2016 is comparable to that for light trucks in 2003, although the intercept is less than half of the 2003 light truck intercept. On the other hand, the slope for light trucks in 2016 is much shallower than for light trucks in 2003.

Figure 10 also shows the 2016 relationship for small pickups and SUVs, separate from large pickups, in red. The 2016 crossover weight for small pickups and SUVs is 4,643 pounds, while the crossover weight for large pickups is 6,235 pounds. Note that the estimated societal fatality risk for large pickups is estimated to increase as mass increases.

Figure 10. Estimated effect of light truck mass reduction on US societal fatality risk per VMT, baseline model and treating small pickups and SUVs separately from large pickups

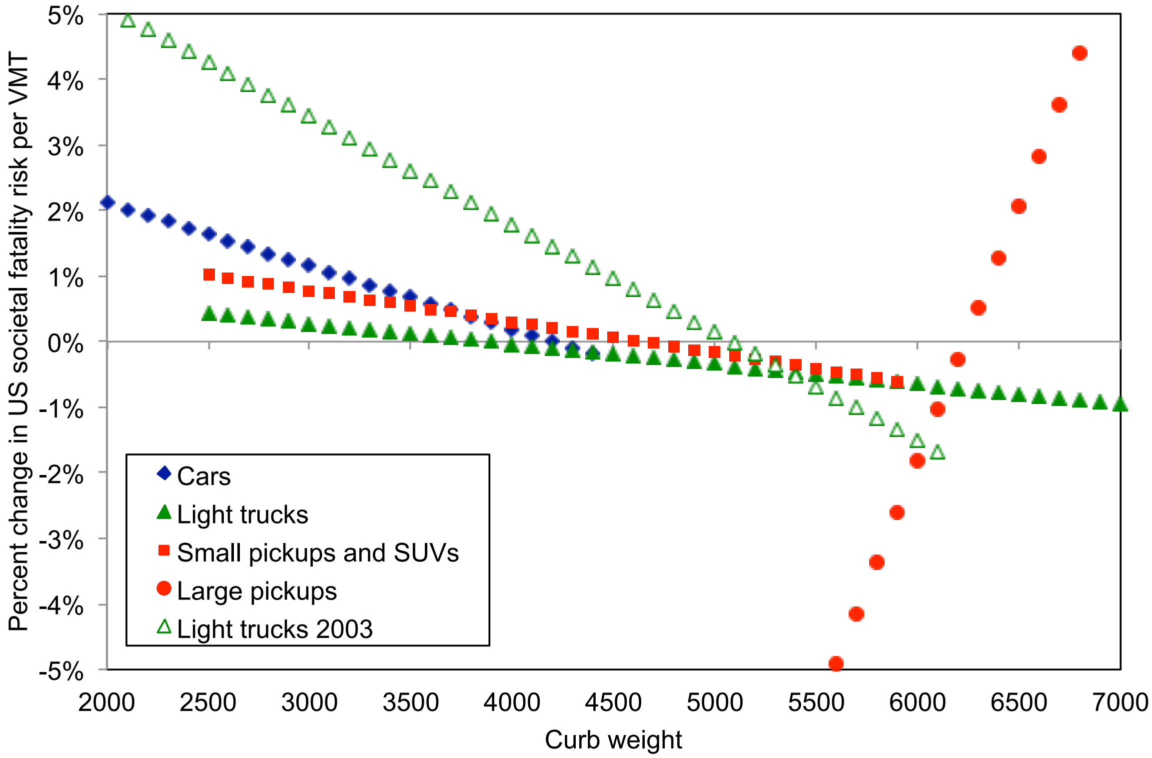
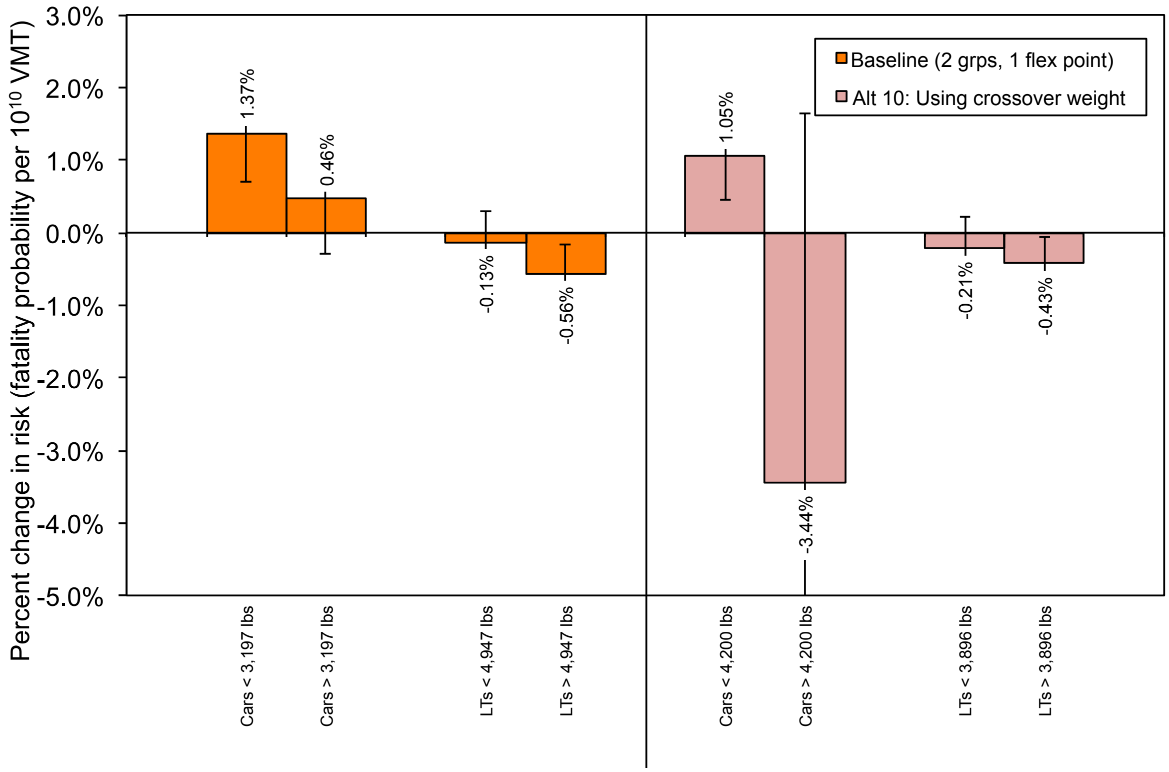


Figure 11 shows the estimated effect of mass reduction on societal fatality risk per VMT under alternative Model 10, which simply replaces the median curb weight for cars and light trucks (3,197 pounds and 4,947 pounds, respectively) with the crossover weights derived in Model 9 (4,200 pounds and 3,896 pounds, respectively). Figure 11 indicates that using the crossover weights estimates that mass reduction in heavier cars is associated with a large, but not statistically-significant, decrease in fatality risk, and reduces somewhat the estimated increase in risk for lighter cars, while the risk associated with mass reduction in light trucks is similar to that in the baseline model. Note that for cars the weight at which mass reduction on average becomes a benefit rather than a detriment occurs at 4,200 pounds, which is the 99th percentile of weight for cars (as indicated in Figure 5 above). The crossover weight for light trucks is 3,896 pounds, which is the 13th percentile weight for light trucks.

Figure 11. Estimated effect of mass reduction on US societal fatality risk per VMT, baseline model and alternative using crossover curb weights



4. Results using different method for vehicle weights

This section summarizes the changes in the estimated effect of mass reduction U.S. societal fatality risk per VMT, after revising the LBS100 values for alternative weight groups 1 through 3 using the method Kahane used for driver age groups. The LBS100 values for Models 1 through 3 described in Tables 1 and 2 were based on a single value for the different weight group variables, representing the difference in the curb weight of the subject vehicle from the median curb weight. For the revised LBS100 values, LBNL used the same method Kahane used for driver age groups: for the lightest vehicles, LBS100 values were calculated for all of the UNDRWT variables, while for the heaviest vehicles values were calculated for all of the OVERWT variables. For example, under Model 3, which used a separate weight variable for eight octiles of vehicle weight, a car 2,504 weighing pounds has the following values:

Table 4. LBS100 values for a 2,504-lb car, using eight weight groups

Variable	Weight group	Value
UNDRWT8A	< 2,623 lbs	-1.19
UNDRWT8B	2,623 to 2,759 lbs	-1.36
UNDRWT8C	2,759 to 2,984 lbs	-2.25
UNDRWT8D	2,984 to 3,197 lbs	-2.13

The sum of these values for the four UNDRWT variables is -6.93, the difference between the curb weight of the subject vehicle (2,504) and the median curb weight for cars (3,197). Tables 5 and 6 show the values used for the different weight variables used in Alternative Models 1 through 3, for cars and light trucks, respectively.

Table 5. LBS100 values for sample cars with different curb weights, under Baseline model and three alternative weight groupings

		LBS100 values for sample cars with different curb weights							
Model	Variable	25.04	26.63	29.77	31.79	32.06	33.82	35.14	38.05
Baseline	UNDRWT00	-6.93	-5.34	-2.2	-0.18	0	0	0	0
	OVERWT00	0	0	0	0	0.09	1.85	3.17	6.08
Alt. 1: 4 bins	UNDRWT4A	-2.55	-0.96	0	0	0	0	0	0
	UNDRWT4B	-4.38	-4.38	-2.2	-0.18	0	0	0	0
	OVERWT4C	0	0	0	0	0.09	1.85	2.23	2.23
	OVERWT4D	0	0	0	0	0	0	0.94	3.85
Alt 2: 6 bins	UNDRWT6A	-1.54	0	0	0	0	0	0	0
	UNDRWT6B	-2.32	-2.27	0	0	0	0	0	0
	UNDRWT6C	-3.07	-3.07	-2.2	-0.18	0	0	0	0
	OVERWT6D	0	0	0	0	0.09	1.28	1.28	1.28
	OVERWT6E	0	0	0	0	0	0.57	1.85	1.85
	OVERWT6F	0	0	0	0	0	0	0.04	2.95
Alt. 3: 8 bins	UNDRWT8A	-1.19	0	0	0	0	0	0	0
	UNDRWT8B	-1.36	-0.96	0	0	0	0	0	0
	UNDRWT8C	-2.25	-2.25	-0.07	0	0	0	0	0
	UNDRWT8D	-2.13	-2.13	-2.13	-0.18	0	0	0	0
	OVERWT8E	0	0	0	0	0.09	0.87	0.87	0.87
	OVERWT8F	0	0	0	0	0	0.98	1.36	1.36
	OVERWT8G	0	0	0	0	0	0	0.94	1.16
	OVERWT8H	0	0	0	0	0	0	0	2.69

Table 6. LBS100 values for sample light trucks with different curb weights, under Baseline model and three alternative weight groupings

Model	Variable	LBS100 values for sample light trucks with different curb weights							
		37.58	39.71	43.24	46.44	50.12	53.31	55.06	58.88
Baseline	UNDRWT00	-11.89	-9.76	-6.23	-3.03	0	0	0	0
	OVERWT00	0	0	0	0	0.65	3.84	5.59	9.41
Alt. 1: 4 bins	UNDRWT4A	-5.38	-3.25	0	0	0	0	0	0
	UNDRWT4B	-6.51	-6.51	-6.23	-3.03	0	0	0	0
	OVERWT4C	0	0	0	0	0.65	3.84	4.90	4.90
	OVERWT4D	0	0	0	0	0	0	0.69	4.51
Alt 2: 6 bins	UNDRWT6A	-3.57	-1.44	0	0	0	0	0	0
	UNDRWT6B	-3.83	-3.83	-1.74	0	0	0	0	0
	UNDRWT6C	-4.49	-4.49	-4.49	-3.03	0	0	0	0
	OVERWT6D	0	0	0	0	0.65	3.04	3.04	3.04
	OVERWT6E	0	0	0	0	0	0.80	2.55	4.60
	OVERWT6F	0	0	0	0	0	0	0	1.77
Alt. 3: 8 bins	UNDRWT8A	-1.86	0.00	0	0	0	0	0	0
	UNDRWT8B	-3.52	-3.25	0	0	0	0	0	0
	UNDRWT8C	-3.16	-3.16	-2.88	0	0	0	0	0
	UNDRWT8D	-3.35	-3.35	-3.35	-3.03	0	0	0	0
	OVERWT8E	0	0	0	0	0.65	1.76	1.76	1.76
	OVERWT8F	0	0	0	0	0	2.08	3.14	3.14
	OVERWT8G	0	0	0	0	0	0	0.69	3.91
	OVERWT8H	0	0	0	0	0	0	0	0.60

Figures 6 and 7 above used the original values for the alternative weight grouping variables. Figures 12 and 13 use the revised values, based on the method Chuck used for the driver age variables, for Alternative models 1 through 3. If fatality risk consistently decreases as vehicle mass increases, one would expect to see increases in risk from mass reduction at the lowest vehicle weights, and decreases in risk from mass reduction at the highest vehicle weights; that is, the detrimental effect of mass reduction would decrease from the lightest to the heaviest vehicles, or from left to right across weight groups under each alternative model. However, none of the figures show that trend under any of the alternative weight groupings, for either cars of light trucks.

Figure 12. Estimated effect of car mass reduction on US societal fatality risk per VMT, baseline model and six alternative weight groups, using Chuck method for Alt 1-3

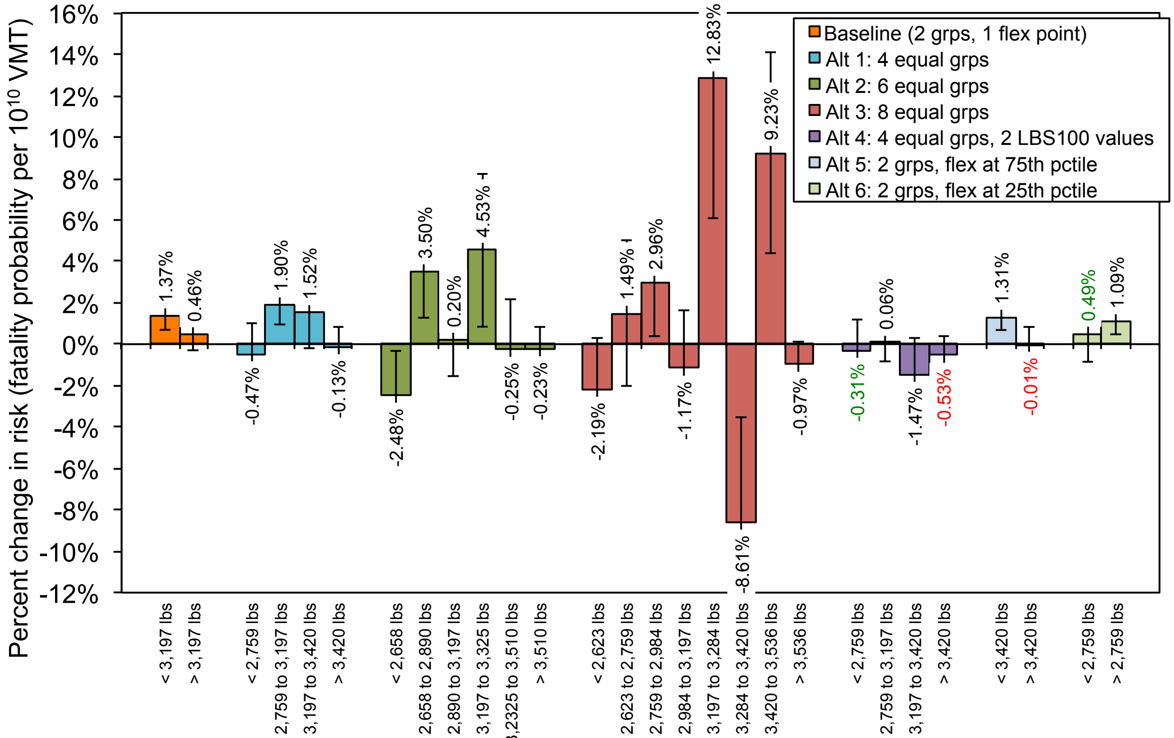
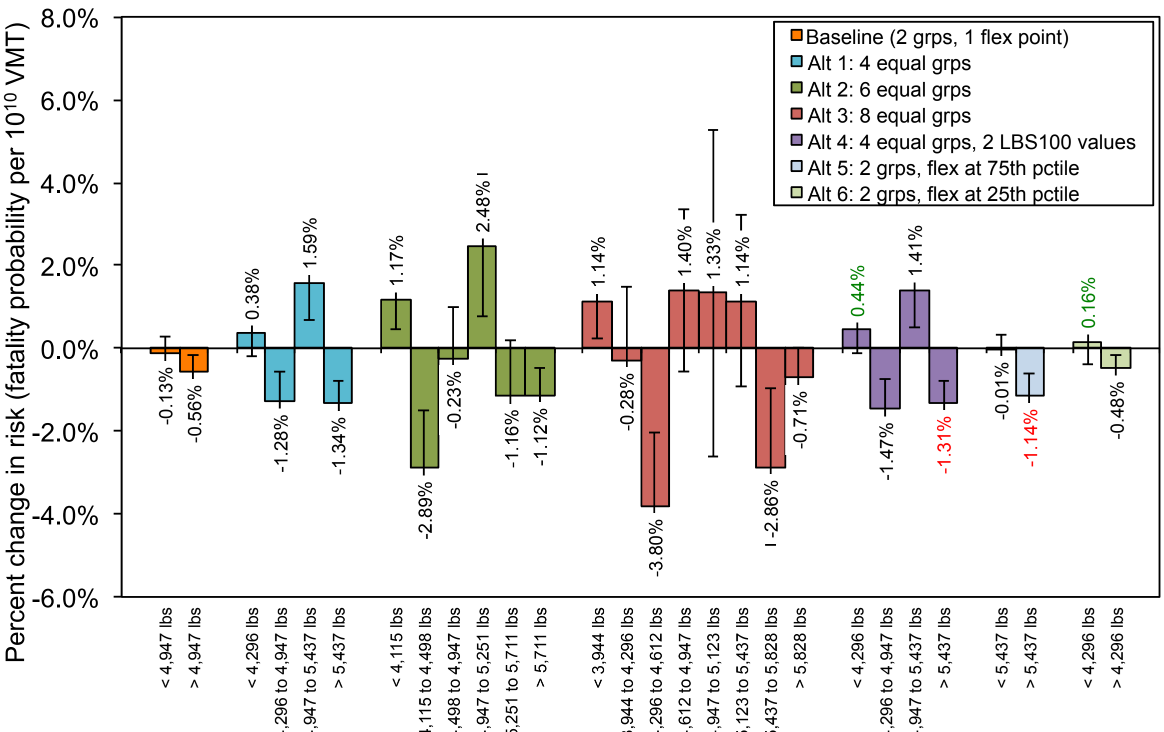


Figure 13. Estimated effect of light truck mass reduction on US societal fatality risk per VMT, baseline model and six alternative weight groups, using Chuck method for Alt 1-3



5. Car characteristics by subject car weight group

One possible explanation for the inconsistent trend in fatality risk over four, six and eight mass groups is that there are other differences among vehicles, drivers, or crash characteristics across the weight groups that are not controlled for by the independent variables in the logistic regression model. Tables 7 through 9 show the average values of vehicle, driver and crash characteristics across the four, six and eight weight groups, respectively, for cars; the weight group with the highest reduction in risk associated with mass reduction in Figure 12 are shown in green in each table, while the weight group with the highest increase in risk associated with mass reduction are shown in red in each table.

Both weight and footprint increase as the car weight group increases; however, the curb weight of the car's crash partner is very consistent across the different weight groups. The fraction of two-door cars decreases as car weight increases, while the fraction of cars equipped with side airbags, ABS, and ESC increases as car weight increases. The fraction of cars that are luxury cars is highest for the heaviest cars. The trends by manufacturer country of origin are not consistent, although lighter cars tend to be dominated by Japanese models while heavier cars tend to be dominated by U.S. models. Regarding driver characteristics, the heaviest vehicles tend to have the highest fraction of male drivers and old drivers, and the lowest fraction of young drivers; there is no consistent trend between the fraction of bad drivers, those that use safety restraints, and those that use alcohol or drugs as vehicle mass increases. The crash circumstances are also fairly similar across the different weight groups.

In summary, the average characteristics of vehicles, drivers, and crash circumstances by weight group do not appear to explain the lack of a consistent trend of decreasing fatality risk as mass increases.

Table 7. Average car, driver, and crash characteristics by four weight groups

Characteristic	Four weight groups < 2,759 lbs	2,759 to 3,197 lbs	3,197 to 3,420 lbs	> 3,420 lbs
Curb weight	2,604	2,992	3,292	3,661
Partner curb wt.	3,810	3,749	3,717	3,673
Footprint	41.27	43.71	45.56	48.03
2-door cars	19%	17%	8%	7%
Side airbags	36%	48%	65%	70%
ABS	37%	54%	77%	85%
ESC	6%	8%	26%	42%
US mfr	31%	39%	38%	64%
Japan mfr	52%	48%	43%	22%
European mfr	0%	5%	9%	9%
Korean mfr	13%	6%	9%	1%
Other mfr	3%	1%	1%	3%
Luxury brand	1%	0%	3%	22%
Low-risk models	48%	65%	72%	50%
High-risk models	30%	26%	21%	29%
Male driver	38%	39%	40%	49%
Young driver	45%	44%	31%	23%
Old driver	4.4%	3.9%	7.0%	11.2%
Bad driver	1.2%	1.2%	1.0%	1.1%
Restraint use	75%	74%	79%	78%
Alcohol/drug use	36%	40%	34%	36%
At night	19%	19%	17%	17%
Rural county	22%	23%	22%	23%
High-speed road	17%	17%	17%	18%
High fatality state	45%	45%	44%	45%

Table 8. Average car, driver, and crash characteristics by six weight groups

Characteristic	Six weight groups < 2,658 lbs	2,658 to 2,890 lbs	2,890 to 3,197 lbs	3,197 to 3,325 lbs	3,325 to 3,510 lbs	> 3,510 lbs
Curb weight	2,544	2,760	3,069	3,250	3,420	3,752
Partner curb wt.	3,809	3,800	3,734	3,725	3,687	3,674
Footprint	40.86	42.15	44.3	45.16	46.52	48.64
2-door cars	17%	19%	19%	4%	11%	8%
Side airbags	24%	52%	50%	67%	58%	77%
ABS	30%	50%	56%	75%	77%	91%
ESC	5%	6%	9%	22%	28%	51%
US mfr	31%	39%	36%	29%	58%	64%
Japan mfr	59%	42%	50%	49%	30%	19%
European mfr	0%	1%	7%	8%	9%	11%
Korean mfr	8%	14%	6%	12%	2%	2%
Other mfr	2%	4%	1%	2%	1%	4%
Luxury brand	0%	2%	0%	2%	9%	27%
Low-risk models	55%	49%	65%	74%	61%	48%
High-risk models	21%	38%	25%	21%	27%	27%
Male driver	38%	39%	39%	40%	42%	51%
Young driver	44%	46%	44%	31%	32%	19%
Old driver	4.5%	4.2%	3.8%	6.8%	7.1%	13.4%
Bad driver	1.2%	1.2%	1.3%	0.9%	1.2%	1.0%
Restraint use	76%	74%	74%	79%	76%	80%
Alcohol/drug use	35%	37%	41%	34%	37%	35%
At night	19%	19%	19%	17%	18%	16%
Rural county	21%	22%	24%	21%	24%	22%
High-speed road	17%	17%	17%	17%	17%	18%
High fatality state	45%	43%	46%	44%	44%	45%

Table 9. Average car, driver, and crash characteristics by eight weight groups

Characteristic	Eight weight groups < 2,623 lbs	2,623 to 2,759 lbs	2,759 to 2,984 lbs	2,984 to 3,197 lbs	3,197 to 3,284 lbs	3,284 to 3,420 lbs	3,420 to 3,536 lbs	> 3,536 lbs
Curb weight	2,524	2,698	2,848	3,105	3,230	3,352	3,484	3,780
Partner curb wt.	3,822	3,796	3,806	3,704	3,723	3,712	3,671	3,674
Footprint	40.84	41.78	42.46	44.68	44.89	46.19	46.81	48.84
2-door cars	15%	23%	20%	16%	3%	12%	7%	8%
Side airbags	24%	50%	54%	43%	69%	62%	58%	78%
ABS	31%	44%	58%	52%	76%	79%	76%	92%
ESC	6%	5%	7%	8%	20%	32%	28%	51%
US mfr	27%	37%	36%	42%	42%	23%	51%	60%
Japan mfr	61%	42%	49%	47%	47%	59%	27%	30%
European mfr	0%	0%	3%	7%	7%	9%	9%	8%
Korean mfr	10%	17%	9%	3%	3%	7%	11%	0%
Other mfr	2%	5%	2%	1%	1%	2%	1%	1%
Luxury brand	0%	1%	1%	0%	0%	2%	5%	12%
Low-risk models	51%	45%	56%	72%	72%	71%	57%	45%
High-risk models	23%	38%	37%	17%	22%	21%	28%	30%
Male driver	38%	39%	39%	39%	40%	41%	44%	52%
Young driver	44%	47%	45%	44%	31%	31%	30%	18%
Old driver	4.5%	4.2%	4.1%	3.8%	6.6%	7.4%	7.8%	13.6%
Bad driver	1.1%	1.4%	1.2%	1.2%	0.9%	1.0%	1.3%	1.0%
Restraint use	77%	73%	74%	74%	78%	79%	75%	80%
Alcohol/drug use	35%	38%	39%	40%	35%	34%	38%	35%
At night	19%	19%	19%	19%	17%	17%	18%	16%
Rural county	21%	22%	22%	24%	20%	24%	24%	22%
High-speed road	17%	17%	18%	17%	17%	17%	18%	17%
High fatality state	45%	44%	42%	47%	43%	45%	45%	45%

6. Estimated effect of mass reduction on risk by crash type

We next examined the estimated effect of mass reduction on societal fatality risk by crash type, using different weight groups. Table 10 compares the estimated effect of car mass reduction on risk for six types of crashes, using the two baseline weight groups and weight quartiles, sestiles, and octiles. Table 10 does not indicate any consistent trends of decreasing fatality risk with increasing car weight, for any crash type or using any of the alternative weight groups. For example, using the six weight groups, the lightest sestile of cars is estimated to have a larger decrease in societal fatality risk in rollovers for every 100-pound reduction in mass (an 10.2% decrease) as the heaviest sestile of cars (a 6.3% decrease). And the third heaviest octile of cars is estimated to have a higher increase in fatality risk in crashes with a stationary object (a 19% increase) as the second lightest octile of cars (a 15% increase), for every 100- pound reduction in mass.

Table 10. Estimated effect of mass reduction by crash type and weight group, cars

Weight groups	Range in curb weight	Six types of crashes: Rollovers	w/object	w/lgt car	w/hvy car	w/lgt LT	w/hvy LT
Baseline	< 3,197 lbs	-2.96%	-0.14%	-1.39%	2.44%	1.01%	2.78%
	> 3,197 lbs	-5.42%	-0.70%	0.12%	1.91%	-1.07%	1.94%
Quartiles	< 2,759 lbs	-9.84%	-3.20%	-5.89%	0.06%	-6.24%	0.03%
	2,759 to 3,197 lbs	-1.97%	0.30%	-4.91%	-1.35%	-4.61%	-0.84%
	3,197 to 3,420 lbs	9.52%	12.04%	3.53%	7.89%	-2.02%	-4.12%
	> 3,420 lbs	-3.37%	0.06%	-0.47%	2.11%	-3.72%	-1.62%
Sestiles	< 2,658 lbs	-10.16%	-2.45%	-1.14%	-0.80%	-4.12%	5.81%
	2,658 to 2,890 lbs	4.03%	3.86%	3.46%	4.30%	7.03%	12.90%
	2,890 to 3,197 lbs	4.68%	8.66%	0.93%	0.16%	0.81%	7.00%
	3,197 to 3,325 lbs	13.15%	5.25%	-6.09%	5.82%	0.82%	-14.78%
	3,325 to 3,510 lbs	-23.60%	-6.14%	-1.04%	-5.15%	-11.36%	-1.48%
	> 3,510 lbs	-6.26%	-2.28%	-0.55%	0.09%	-4.10%	-1.71%
Octiles	< 2,623 lbs	-8.49%	-1.57%	-1.76%	0.29%	-9.24%	-0.63%
	2,623 to 2,759 lbs	13.57%	15.25%	7.88%	17.79%	6.89%	4.07%
	2,759 to 2,984 lbs	3.30%	3.97%	-7.63%	0.83%	-6.74%	-2.50%
	2,984 to 3,197 lbs	-2.87%	1.28%	2.90%	2.95%	2.73%	-5.62%
	3,197 to 3,284 lbs	6.40%	0.31%	1.11%	14.30%	17.07%	-5.81%
	3,284 to 3,420 lbs	5.72%	19.26%	7.27%	9.52%	-14.22%	-5.64%
	3,420 to 3,536 lbs	-25.58%	-3.08%	2.32%	4.26%	-22.89%	7.59%
	> 3,536 lbs	-3.38%	-0.12%	0.10%	1.77%	-5.65%	-2.12%

Note: Effects that are statistically-significant at the 5% level are shown in red.

Table 11 repeats the estimates in Table 10, but only for fatalities in the subject vehicle (and not societal fatalities), for the four types of crashes between two light-duty vehicles. Again, there is no consistent decrease in fatality risk in a given type of crash as the weight of the subject vehicle increases. For example, in crashes with heavier-than-average cars, the second lightest octile of cars has a lower increase in fatality risk (a 23% increase) than the fourth heaviest octile of cars (a 39.0% increase).

Table 11. Estimated effect of mass reduction in subject vehicle in crashes between two vehicles, by crash type and weight group, cars

Weight groups	Range in curb weight	Four types of crashes between two vehicles w/lgt car	w/hvy car	w/lgt LT	w/hvy LT
Baseline	< 3,197 lbs	3.99%	6.32%	0.25%	2.85%
	> 3,197 lbs	5.66%	5.82%	-2.00%	2.84%
Quartiles	< 2,759 lbs	-1.42%	3.38%	-9.39%	-0.59%
	2,759 to 3,197 lbs	-4.81%	0.01%	-6.68%	-0.80%
	3,197 to 3,420 lbs	9.81%	9.36%	-6.87%	-4.03%
	> 3,420 lbs	3.37%	4.91%	-6.48%	-0.51%
Sestiles	< 2,658 lbs	3.27%	-0.03%	-5.48%	6.46%
	2,658 to 2,890 lbs	9.68%	4.72%	6.64%	15.60%
	2,890 to 3,197 lbs	3.57%	1.43%	-3.43%	5.98%
	3,197 to 3,325 lbs	8.94%	6.42%	-1.56%	-18.11%
	3,325 to 3,510 lbs	1.99%	1.11%	-7.97%	-1.23%
	> 3,510 lbs	2.35%	2.54%	-5.43%	-0.24%
Octiles	< 2,623 lbs	1.56%	-0.20%	-10.50%	0.09%
	2,623 to 2,759 lbs	22.03%	22.75%	4.93%	5.68%
	2,759 to 2,984 lbs	-8.00%	0.34%	-8.78%	-1.01%
	2,984 to 3,197 lbs	6.88%	1.34%	2.35%	-10.38%
	3,197 to 3,284 lbs	48.17%	39.30%	9.11%	-4.62%
	3,284 to 3,420 lbs	13.25%	14.05%	-22.72%	-3.37%
	3,420 to 3,536 lbs	14.67%	13.35%	-21.92%	11.09%
	> 3,536 lbs	3.33%	4.61%	-8.04%	0.00%

Note: Effects that are statistically-significant at the 5% level are shown in red.

7. Conclusions

The NHTSA baseline model uses the median curb weight to divide cars and light trucks into two weight groups each, to estimate the effect of mass reduction on societal fatality risk on lighter- and heavier-than-average cars and light trucks. The baseline model estimates that mass reduction in more detrimental in lighter-than-average cars and light trucks, and more beneficial in heavier-than-average cars and light trucks. In this report we recalculated the estimated relationship between vehicle mass and societal fatality risk, using alternative groupings by vehicle weight, to test whether the trend of decreasing fatality risk from mass reduction as the case vehicle mass increases, holds over smaller increments of the range in case vehicle masses. We re-estimated the mass reduction coefficients using four, six, and eight bins of vehicle mass; the estimated effect of mass reduction on societal fatality risk was not consistent over the range in vehicle masses. These results suggest that the relationship indicated by the NHTSA baseline model is a result of other, unmeasured attributes of the mix of vehicles in the lighter vs. heavier weight bins, and not necessarily the result of a correlation between mass reduction and societal fatality risk. An analysis of the average vehicle, driver, and crash characteristics across the various weight groupings did not reveal any strong trends that might explain the lack of a consistent trend of decreasing fatality risk from mass reduction in heavier vehicles.

8. References

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