COMMENTS ON THE PRELIMINARY REGULATORY IMPACT ANALYSIS OF THE PROPOSED SAFER AFFORDABLE FUEL-EFFICIENT (SAFE) VEHICLES RULE FOR MODEL YEAR 2021 - 2026 PASSENGER CARS AND LIGHT TRUCKS

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R.M. Van Auken

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355 Van Ness Ave • Torrance • California 90501 • 310-212-5211 • Fax 310-212-5046 • www.dynres.com

ABOUT THE AUTHOR

Mr. Van Auken has been an engineer in the automotive and aerospace fields for nearly 40 years. He has a Bachelor of Science Degree in Aerospace Engineering from the University of Michigan, a Master of Science Degree in Aeronautical and Astronautical Engineering from Stanford University, and a post Masters Engineering Degree in Aeronautical and Astronautical Engineering from Stanford University.

Since joining Dynamic Research, Inc. in 1989 he has been involved in many multi-disciplinary research studies related to vehicle safety, and has authored or co-authored over 30 scientific and technical papers and numerous technical reports. The author's research activities have generally involved mathematical modeling, simulation, and analysis of man-machine systems. This included bio-mechanics, cost/benefit analysis, driver modeling, dynamics, feedback control, fleet systems modeling, frequency domain analysis, human factors, optimal estimation, regression analysis, ride quality, risk/benefit analysis, signal processing, sound data analysis, statistical analysis, tire math-modeling, and vehicle dynamics.

Mr. Van Auken has been involved in estimating the effects of vehicle mass and size on safety since the early 2000s. His results on the independent effects of mass and size on safety have been cited in previous regulatory evaluations of footprint based CAFE standards.

The opinions and conclusions in this report are the author's, and not necessarily those of Dynamic Research, Inc.

EXECUTIVE SUMMARY

A notice of proposed federal rulemaking (NPRM) entitled the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021–2026 Passenger Cars and Light Trucks was published in the Aug. 24, 2018 issue of the US Federal Register (83 FR 42986, NPRM, Ref 1). This NPRM presents several proposals to relax the greenhouse gas emissions and corporate average fuel economy (CAFE) standards for model years 2020 – 2026, with a leading proposal to roll back to the levels set for 2020. This rollback to 2020 is used for the purposes of this analysis. It would be a significant relaxation of the existing fuel economy standards for MY 2021, the existing greenhouse gas emissions standards, and the so-called "augural" standards for model years 2022 – 2026 (hereafter referred to collectively as the existing greenhouse gas emissions and existing CAFE standards).

This report reviews and comments on the estimated safety impacts of this NPRM and the corresponding Preliminary Regulatory Impact Analysis (PRIA, Ref 2). Emphasis is placed on the estimated effects of the existing and proposed CAFE and greenhouse gas emissions (CO_2) standards in terms of fatalities and costs at the 3% discount rate. Comments regarding the costs at the 3% discount rate are assumed to be generally applicable to costs at the 7% discount rate.

The key findings of this review are the following:

1. The estimated effect of mass reduction on CAFE attributable fatalities and fatality related costs is effectively zero. The CAFE model results based on NHTSA's preferred mass and size model using footprint and non-culpable vehicle induced-exposure indicated that the proposed standard slightly decreased fatalities, but the effect was small and statistically insignificant. The results based on five alternative mass and size models using wheelbase and track, or stopped-vehicle induced-exposure, were also small and statistically insignificant. Only

one of the five alternative model results for the change in CO2 standard had the same sign (i.e., a decrease in fatalities) as NHTSA's preferred model, and none of the five alternative model results for the change in CAFE standard had the same sign (i.e., the results had the opposite sign indicating an increase in fatalities). Therefore, the estimated effect of mass reduction on CAFE attributable fatalities and fatality related costs is effectively zero.

2. The fatality rate model described in the Safety Model section of the NPRM (pages 43135-43145) is incorrect because it does not account for changes in the fatality rate that occur over time (i.e., calendar year). For example, this model does not account for changes in human behavior such as increasing seat belt use over time, improvements in roadway design for safety, improvements in life saving emergency medical response and treatment, and improvements in the crash avoidance and crash compatibility of other vehicles on the road, which are not associated with vehicle model year and which over time (increasing calendar years) tend to improve overall safety and decrease the fatality risk. These improvements over time have occurred in the past and similar improvements over time can be expected in the future. As a result, the estimated effect of model year on fatality risk that is assumed in the current CAFE model are over estimated because they did not account for calendar year effects. For example, the model assumes that the fatality rate of 1985 model year vehicles is 23.8 fatalities per billion VMT. However, this estimate incorrectly includes risks that depend on calendar year, not model year. If this effect is properly accounted for then the change in the overall number of fatalities estimated by the CAFE model due to the proposed standard would be much less (e.g., by as much as 50% less).

3. It is unclear whether or not the fatalities being estimated by the CAFE model represent all road users (e.g., pedestrians, motorcyclists, and other collision partners) or just the subject vehicle occupants. The estimated number of fatalities should include all road users. It should

not under count or double count any fatalities. The methodology developed by Kahane (e.g., Ref 4) is an example of a method that counts all road users without double counting.

4. The uncertainty in the overall estimated fatality risk and related costs in the NPRM due to two sources of uncertainty were estimated to be approximately ±25% of the point estimates. The estimated uncertainty in the CAFE Model results would be larger if other sources of uncertainty, such as uncertainties in the estimated fleet size and VMT, and uncertainty in the costs of non-fatal injuries relative to the costs of fatal injuries, were also taken into account.

5. The sensitivity analysis results for the proposed CO2 standards reported in Table VII-95 of the NPRM are incorrect. They are the same as the results for the proposed CAFE standards reported in Table VII-94.

6. The sensitivity cases labeled "Fatalities Flat Earlier" and "Fatalities Flat Later" in the Sensitivity Analysis section of the NPRM (pages 43352-43367) are misleading. They represent the sensitivity to small changes in the fatality rates after the 2030 model year. The maximum percentage difference compared to the baseline fatality rate is less than 10%. These cases underrepresent the sensitivity of the results to the uncertainty in the fatality rate model, which is much larger. Furthermore, the results for "Fatalities Flat Later" without rebound in Tables VII-94 and VII-95 are incorrect because the CAFE model input parameter file for this case has a 20% rebound effect instead of 0%.

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INTRODUCTION

A notice of proposed federal rulemaking (NPRM) entitled the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021–2026 Passenger Cars and Light Trucks was published in the Aug. 24, 2018 issue of the US Federal Register (83 FR 42986, NPRM, Ref 1). This NPRM presents several proposals to relax the greenhouse gas emissions and corporate average fuel economy (CAFE) standards for model years 2020 – 2026, with a leading proposal to roll back to the levels set for 2020. This rollback to 2020 is used for the purposes of this analysis. It would be a significant relaxation of the existing fuel economy standards for MY 2021, the existing greenhouse gas emissions standards, and the so-called "augural" standards for model years 2022 – 2026 (hereafter referred to collectively as the existing greenhouse gas emissions and existing CAFE standards).

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A. BACKGROUND

In 2012 the US EPA and NHTSA (collectively referred to herein as the Agencies) issued a final rule for 2017 and later model year light duty vehicle greenhouse gas and fuel economy standards (77 FR 62624, Ref 3). This rule included "augural standards" for the 2022-2025 model years to be reviewed in a future mid-term evaluation.

In support of this rule making the NHTSA estimated the effects of vehicle weight and footprint on fatality risk based on 2000-2007 model year passenger cars and LTVs in 2002-2008 calendar year crashes (Ref 4). One of the main results from Ref 4 were estimated values for five "mass effect coefficients" that describe the percentage fatality increase per 100-pound mass reduction while holding vehicle footprint constant, which are unknown and assumed to depend only on the vehicle type and initial weight. Only one of the five mass effect coefficients based on NHTSA's preferred model and assumptions was statistically significant at the 0.05 level of significance, as indicated by point estimates in columns (B) and the 95% confidence intervals in (C) of Table 1.[1] These five estimated values were inputs to a CAFE Compliance and Effects Modeling System developed by the DOT Volpe National Transportation Systems Center to analyze potential CAFE standards, herein referred to as the "CAFE model".

As part of this rule making the Agencies sought comments on the relationships between fatality risk, mass, and footprint (docket NHTSA-2010-0152). Dynamic Research, Inc. (DRI), Lawrence Berkeley National Laboratory (LBNL), and others (e.g., Refs 5 and 6) provided comments and alternative estimates for the five CAFE model mass effect coefficients, which were listed in Table II-28 of the final rule.

In 2016 the EPA published a notice that the existing (augural) 2022-2025 standards were still appropriate and "*should not be amended to be either more or less stringent*" (81 FR 87927, Ref 7). The NHTSA and Volpe updated the estimated effects of vehicle weight and footprint on fatality risk based on 2003-2010 model year passenger cars and LTVs in 2005-2011 calendar year crashes (Ref 8) in support of this decision. This update is based on a 3 model year and 3 calendar year advance from the data used in Ref 4. None of the five mass effect coefficients in NHTSA's preferred model and assumptions were statistically significant, as indicated in columns (D) and (E) of Table 1. The estimated values were used as

[1] The point estimate represents the best estimate based on the assumptions and data. The confidence interval represents the uncertainty in the estimate. If the 95% confidence interval does not include zero (i.e., the limits are either both positive or both negative) then the result is considered to be statistically significant at the 0.05 probability level because, if the actual unknown value is 0 (i.e., a Null Hypothesis), then the probability of the estimated or larger magnitude value would be observed due to random chance is less than or equal to 1 in 20; therefore we can be reasonably certain that the true value is not 0. If the 95% confidence interval does include 0 (i.e., the lower bounds is negative and the upper bounds is positive), then the result is considered to be not statistically significant at the 0.05 probability level. See the discussion of statistical significance levels in Section I.D.

NHTSA's preferred inputs to the CAFE model. LBNL also provided alternative estimates suitable for input to the CAFE model (Ref 9).

In August 2018 the Agencies proposed new light duty vehicle greenhouse gas and fuel economy standards for the 2021-2026 model years that are less stringent than the existing standards (83 FR 42986, Ref 1). In support of this proposed rulemaking the CAFE model was changed to model the effects of the proposed standards on vehicle sales and scrappage, and rebound effects (Ref 10).

The estimated effects of vehicle weight and footprint on fatality risk were also updated based on 2004-2011 model year passenger cars and LTVs in 2006-2012 calendar year crashes. This update is a 1 year advance in the data compared to the data used in Ref 8. Again, as indicated in columns (F) and (G) of Table 1 none of the estimated mass effect coefficients based on NHTSA's preferred model and assumptions are statistically significant.

Table 1. Summary of Estimated Fataltity Increases due to Mass Reduction While Holding Footprint Constant based on NHTSA's Preferred Model and Assumptions in the Three Most Recent Evaluations

(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Estimated Fatality Increase Percent per 100-Pound Mass Reduction (NHTSA's preferred model and assumptions)					
	2012 (Ref 4)		2016 (Ref 8)		2018 (Ref 1, Table II-46)	
Model Years	2000-2007		2003-2010		2004-2011	
Calendar Years	2002-2008		2005-2011		2006-2012	
Vehicle Type	Point Estimate	95% Confidence Interval	Point Estimate	95% Confidence Interval	Point Estimate	95% Confidence Interval
Lighter Passenger Cars	**1.56**	**0.39 to 2.73**	1.49	-0.30 to 3.27	1.20	-0.35 to 2.75
Heavier Passenger Cars	0.51	-0.59 to 1.60	0.50	-0.59 to 1.60	0.42	-0.67 to 1.50
CUVs and minivans	-0.37	-1.55 to 0.81	-0.99	-2.17 to 0.19	-0.25	-1.55 to 1.04
Lighter Truck-based LTVs	0.52	-0.45 to 1.48	-0.10	-1.08 to 0.88	0.31	-0.51 to 1.13
Heavier Truck based LTVs	-0.34	-0.97 to 0.30	-0.72	-1.45 to 0.02	-0.61	-1.26 to 0.25

Note: **bold font** denotes a statistically significant estimate at the 0.05 level of significance.

B. OBJECTIVES

The objective of this study are to review and comment on the fatality effects and costs predicted by the CAFE model as reported in the NPRM and PRIA. Emphasis is placed on the estimated effects of the proposed CAFE and CO_2 rules with the 3% discount rate. It is assumed that the methods and results for the 7% discount rate are similar, and therefore the comments herein are also generally applicable.

C. OVERVIEW OF THE MAIN SAFETY IMPACT RESULTS IN THE NPRM

The NPRM presents estimated costs, benefits, and net benefits of the Agencies preferred alternative standards compared to the existing standards in Table I-4 on page 42998 of the NPRM. These estimates are for 1977 to 2029 model year vehicles inclusive over a 40 year lifetime (vehicles ages 0 to 39). The estimated net benefits in Table I-4 can be traced to more detailed cost and benefit results presented in line 21 of Tables II-25 through II-28 in the NPRM. These estimated net benefits and source tables are summarized in Table 2.

Table 2. Estimated Net Benefits of the Proposed Standard and Detailed Source Tables

(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Estimated Net Benefit of the Preferred Alternative Standards Compared to the Existing Standards, Cumulative for MY 1977-2029, CY 1977-2068 (Billions of 2016 $)					
	3% Discount Rate			7% Discount Rate		
	Estimate	NPRM Source		Estimate	NPRM Source	
		Page	Table (line 21)		Page	Table (line 21)
CAFE Standards	176.3	43063	II-25	131.5	43064	II-26
CO_2 Standards	200.7	43065	II-27	140.6	43066	II-28

Source: NPRM (Ref 1), page 42998, Table I-4.

Of particular interest for this review are the estimated benefits listed in lines 6 and 11 of Tables II-25 through II-28 in the NPRM. These estimated benefits can be traced to the estimated changes in the total societal costs for the Alternative 1 standard from the Existing Standards due to mass changes and sales impacts listed in Tables II-73, II-74, II-77 and II-78; as indicated in Table 3 and Table 4. Note that the estimated changes in the safety parameters are costs, which have the opposite sign of benefits.

Table 3. Estimated Benefits of the Proposed Standards due to Reduced Injuries and Fatalities from Higher Vehicle Weight and More Detailed Source Tables

(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Estimated Benefit of the Preferred Alternative Standards Compared to the Existing Standards due to Reduced Injuries and Fatalities from Higher Vehicle Weight, Cumulative for MY 1977-2029, CY 1977-2068 (Billions of 2016 $)					
	3% Discount Rate			7% Discount Rate		
	Estimated Benefit (-change in Costs)	NPRM Page & Table (line 6)	NPRM Page & Table (Alt 1, opposite sign)	Estimated Benefit (-change in Costs)	NPRM Page & Table (line 6)	NPRM Page & Table (Alt 1, opposite sign)
CAFE Standards	2.4	43062 II-25	43152 II-73	1.3	43064 II-26	43153 II-74
CO_2 Standards	7.5	43065 II-27	43157 II-77	4.4	43066 II-28	43158 II-78

Table 4. Estimated Benefits of the Proposed Standards due to Reduced Costs for Injuries and Property Damage Costs from Driving in Used Vehicles and More Detailed Source Tables

(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Estimated Benefit of the Preferred Alternative Standards Compared to the Existing Standards due to Reduced Costs for Injuries and Property Damage Costs from Driving in Used Vehicles, Cumulative for MY 1977-2029, CY 1977-2068 (Billions of 2016 $)					
	3% Discount Rate			7% Discount Rate		
	Estimated Benefit (-change in Costs)	NPRM Page & Table (line 11)	NPRM Page & Table (Alt 1, opposite sign)	Estimated Benefit (-change in Costs)	NPRM Page & Table (line 11)	NPRM Page & Table (Alt 1, opposite sign)
CAFE Standards	88.3	43062 II-25	43152 II-73	45.9	43064 II-26	43153 II-74
CO_2 Standards	111.0	43065 II-27	43157 II-77	56.7	43066 II-28	43158 II-78

Tables II-73 and II-77 of the NPRM are reproduced in Table 5 and Table 6. These tables are based on the raw CAFE model output files extracted from the `CAFE_Model/Central_Analysis/Central_Analysis.7z` file in the 2021-2026 CAFE NPRM FTP website (Ref 11). Table 5 and Table 6 also include additional rows for VMT results, compared to the original tables in the NPRM. Each row with numerical values is labeled with a number in parenthesis () for reference purposes. There are some gaps in the row label numbers in Table 5 and Table 6 in order to be consistent with identical or similar results in other tables in this report. The VMT and fatality results are from the annual_societal_effects_report.csv files located in three central analysis output folders, corresponding to three different CAFE model runs. The costs results are from the annual_societal_costs_report.csv files from the same three CAFE model runs and output folders. The total values listed in rows (7), (14), (21), (28) and (35) of Table 5 were calculated from the csv files in the `output_CAFE\CAFE_ss` folder. The subtotal values in rows (3), (10), (17), (24), and (31) were calculated from the csv files in the `output_CAFE\CAFE_ss_no_rebound` folder. The Sales Impact values in rows (2)[2], (9), (16), (23), and (30) were calculated from the csv files in the `output_CAFE\CAFE_ss_no_rebound_no_MR_Effect` folder. The values in Table 6 were calculated from similarly named csv files in the `output_CO2` folder. The mass change values in rows (1)[2], (8), (15), (22), and (29) were calculated by subtracting the sales impact results from the subtotal results (e.g., row (8)=row (10)–row (9)). Likewise the rebound effect values in rows (6), (13), (20), (27), and (34) were calculated by subtracting the subtotal values from the total values (e.g., row (13)=row (14)–row (10)). The total societal cost results in rows (29) through (35) are equal to the fatality costs in rows (15) through (21) plus the nonfatal costs in rows (22) through (28). The results in Table 5 and Table 6 are in close agreement with the results in Tables II-73 and II-77 of the NPRM, which appear to be rounded off.

Table 5 and Table 6 also includes rows for VMT results, which were not listed in the NPRM Tables II-73 and II-77. The results for the proposed CAFE rule in rows (3) and (7) of Table 5 agree with the rounded off values in reported Table VII-94 on page 43362 of the NPRM. The "CO2" results in Table VII-95 of the NPRM appear be incorrect because they are the same as the CAFE results in Table VII-94. Therefore the results for the proposed CO2 rule in (3) and (7) of Table 6 have no comparison in NPRM.

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[2] Row is not shown in Table 5.

Table 5. Change in Total Safety Parameter Values from Existing CAFE Standards, MY 1977-2029, CY 1977-2068, 3% Discount Rate

	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
Row	Safety Parameter	Change in Total Safety Parameter Values from Existing CAFE Standards, MY 1977 – 2029, CY 1977-2068, 3% Discount Rate							
		Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8
	VMT (Billion miles)								
(3)	Subtotal CAFE Atrb.	-692	-634	-587	-474	-350	-278	-106	-160
(6)	Rebound Effect	-776	-730	-688	-594	-442	-406	-267	-265
(7)	Total (Billion miles)	-1,468	-1,364	-1,275	-1,068	-792	-683	-372	-425
	Fatalities								
(8)	Mass Changes	-160	-147	-143	-172	-152	-72	-12	-30
(9)	Sales Impacts	-6,184	-5,680	-5,262	-4,284	-3,174	-2,553	-1,034	-1,485
(10)	Subtotal CAFE Atrb.	-6,344	-5,827	-5,405	-4,457	-3,326	-2,626	-1,046	-1,515
(13)	Rebound Effect	-6,335	-5,963	-5,625	-4,849	-3,610	-3,324	-2,198	-2,173
(14)	Total	-12,680	-11,790	-11,029	-9,305	-6,936	-5,950	-3,243	-3,688
	Fatalities Societal $B								
(15)	Mass Changes	-0.9	-0.9	-0.8	-1.1	-0.9	-0.4	-0.1	-0.2
(16)	Sales Impacts	-34.4	-31.6	-29.3	-23.9	-17.6	-14.4	-6.2	-8.3
(17)	Subtotal CAFE Atrb.	-35.4	-32.4	-30.1	-24.9	-18.5	-14.8	-6.2	-8.4
(20)	Rebound Effect	-41.7	-39.2	-37.0	-31.9	-23.7	-22.1	-14.8	-14.3
(21)	Total	-77.0	-71.6	-67.1	-56.9	-42.2	-36.9	-21.1	-22.8
	Nonfatal Societal $B								
(22)	Mass Changes	-1.5	-1.3	-1.3	-1.7	-1.5	-0.7	-0.1	-0.3
(23)	Sales Impacts	-53.8	-49.4	-45.8	-37.3	-27.5	-22.5	-9.7	-12.9
(24)	Subtotal CAFE Atrb.	-55.3	-50.7	-47.1	-39.0	-29.0	-23.2	-9.8	-13.2
(27)	Rebound Effect	-65.2	-61.3	-57.9	-50.0	-37.0	-34.6	-23.2	-22.4
(28)	Total	-120.5	-112.0	-105.0	-89.0	-66.0	-57.8	-33.0	-35.6
	Total Societal $B								
(29)	Mass Changes	-2.4	-2.2	-2.2	-2.7	-2.4	-1.1	-0.2	-0.5
(30)	Sales Impacts	-88.3	-80.9	-75.0	-61.2	-45.1	-36.9	-15.8	-21.2
(31)	Subtotal CAFE Atrb.	-90.7	-83.1	-77.2	-63.9	-47.5	-38.0	-16.0	-21.6
(34)	Rebound Effect	-106.8	-100.5	-94.9	-81.9	-60.7	-56.7	-38.0	-36.7
(35)	Total	-197.5	-183.6	-172.1	-145.8	-108.2	-94.7	-54.1	-58.3

Source: The summation for the 1977 - 2029 model years and 1977 - 2068 calendar years in:
Output_CAFE\CAFE_ss_no_rebound_no_MR_Effect\reports-csv\annual_societal_effects_report.csv
Output_CAFE\CAFE_ss_no_rebound_no_MR_Effect\reports-csv\annual_societal_costs_report.csv
Output_CAFE\CAFE_ss_no_rebound\reports-csv\annual_societal_effects_report.csv
Output_CAFE\CAFE_ss_no_rebound\reports-csv\annual_societal_costs_report.csv
Output_CAFE\CAFE_ss\reports-csv\annual_societal_effects_report.csv
Output_CAFE\CAFE_ss\reports-csv\annual_societal_costs_report.csv
Extracted from the Central_Analysis.7z file in Ref 11.

Table 6. Change in Total Safety Parameter Values from Existing CO_2 Standards, MY 1977-2029, CY 1977-2068, 3% Discount Rate

	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
Row	Safety Parameter	Change in Total Safety Parameter Values from Existing CO2 Standards, MY 1977 - 2029, CY 1977-2068, 3% Discount Rate							
		Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8
	VMT								
(3)	Subtotal CAFE Atrb.	-893	-862	-748	-614	-468	-360	-164	-232
(6)	Rebound Effect	-895	-849	-777	-643	-426	-399	-257	-246
(7)	Total (Billion miles)	-1,787	-1,711	-1,525	-1,257	-894	-759	-421	-478
	Fatalities								
(8)	Mass Changes	-468	-461	-411	-297	-219	-186	-111	-86
(9)	Sales Impacts	-7,878	-7,602	-6,633	-5,460	-4,148	-3,241	-1,531	-2,089
(10)	Subtotal CAFE Atrb.	-8,346	-8,063	-7,043	-5,757	-4,367	-3,427	-1,642	-2,174
(13)	Rebound Effect	-7,298	-6,929	-6,341	-5,253	-3,480	-3,263	-2,113	-2,013
(14)	Total	-15,644	-14,992	-13,385	-11,009	-7,848	-6,690	-3,755	-4,187
	Fatalities Societal $B								
(15)	Mass Changes	-2.9	-2.9	-2.6	-1.9	-1.4	-1.2	-0.7	-0.5
(16)	Sales Impacts	-43.3	-41.7	-36.6	-30.1	-22.5	-18.0	-8.9	-11.6
(17)	Subtotal CAFE Atrb.	-46.2	-44.6	-39.2	-32.0	-23.9	-19.2	-9.6	-12.1
(20)	Rebound Effect	-47.8	-45.3	-41.6	-34.4	-22.7	-21.5	-14.2	-13.3
(21)	Total	-94.0	-89.9	-80.8	-66.4	-46.6	-40.7	-23.8	-25.4
	Nonfatal Societal $B								
(22)	Mass Changes	-4.6	-4.5	-4.0	-2.9	-2.2	-1.9	-1.1	-0.8
(23)	Sales Impacts	-67.8	-65.2	-57.3	-47.1	-35.2	-28.2	-13.9	-18.1
(24)	Subtotal CAFE Atrb.	-72.3	-69.7	-61.3	-50.0	-37.3	-30.0	-15.1	-18.9
(27)	Rebound Effect	-74.7	-70.8	-65.0	-53.9	-35.6	-33.7	-22.1	-20.8
(28)	Total	-147.0	-140.6	-126.3	-103.9	-72.9	-63.7	-37.2	-39.7
	Total Societal $B								
(29)	Mass Changes	-7.5	-7.4	-6.6	-4.8	-3.5	-3.1	-1.9	-1.4
(30)	Sales Impacts	-111.1	-106.9	-93.9	-77.2	-57.6	-46.2	-22.9	-29.6
(31)	Subtotal CAFE Atrb.	-118.6	-114.3	-100.5	-82.0	-61.2	-49.2	-24.7	-31.0
(34)	Rebound Effect	-122.5	-116.1	-106.6	-88.3	-58.3	-55.2	-36.3	-34.0
(35)	Total	-241.1	-230.4	-207.1	-170.3	-119.5	-104.5	-61.0	-65.0

Source: The summation for the 1977 - 2029 model years and 1977 - 2068 calendar years in:
Output_CO2\CO2_no_rebound_no_MR_Effect\reports-csv\annual_societal_effects_report.csv
Output_CO2\CO2_no_rebound_no_MR_Effect\reports-csv\annual_societal_costs_report.csv
Output_CO2\CO2_no_rebound\reports-csv\annual_societal_effects_report.csv
Output_CO2\CO2_no_rebound\reports-csv\annual_societal_costs_report.csv
Output_CO2\CO2\reports-csv\annual_societal_effects_report.csv
Output_CO2\CO2\reports-csv\annual_societal_costs_report.csv
Extracted from the Central_Analysis.7z file in Ref 11.

D. STATISTICAL SIGNIFICANCE LEVEL AND CONFIDENCE INTERVALS

The NPRM reported on page 43111 the statistical significance of several results at the 85-percent confidence level, which is unusual. A 95-percent confidence interval, which corresponds to a 0.05 level of statistical significance, is more commonly used and widely accepted. Box et al (1978, Ref 12) states on page 109 that "*A series of conventional "critical" significance levels is in common use. These levels correspond to probabilities representing varying degrees of skepticism. When the probability that a discrepancy as large as that observed, or larger, might occur is smaller than one of these critical probabilities, the discrepancy between observation and hypothesis is said to be "significant" at that level. As a guide, it could be said that, when one's attitude is a priori "neutral" to a particular type of discrepancy, one begins to be slightly suspicious of a discrepancy at the 0.20 level, somewhat convinced of its reality at the 0.05 level, and fairly confident of it at the 0.01 level.*" Urdan (2006, Ref 13) states on page 62 that "*In the social sciences, the convention is to set that level at .05*" and "*The agreed-upon probability of .05 (symbolized as $\alpha = .05$) represents the Type I error rate that we, as researchers, are willing to accept before we conduct our statistical analysis.*" The 95% percent confidence interval is also the default value for many statistical software packages such as SAS and SPSS (see Allison (1999, Ref 14), p 32).

The 95% confidence interval is approximately $\pm$ 2 standard errors. Therefore the total range of the 95% confidence interval is approximately 4 times the standard error.

E. DEFINITIONS

CO2	An abbreviation for the greenhouse gas emission standard.
CAFE Model	The CAFE Compliance-and-Effects-Modeling-System model (Ref 10).
CI	Confidence interval (usually 95%). Assumed equal to PE$\pm$2xSE in this report, which is an approximation.

CUV	Crossover Utility Vehicle (as defined in Ref 4)
CY	Calendar Year
DRI	Dynamic Research, Inc.
IE	Induced-Exposure
LBNL	Lawrence Berkeley National Laboratory
LTV	Light Truck or Van (as defined in Ref 4)
MY	Model Year
NPRM	Notice of Proposed Rulemaking (Ref 1)
PC	Passenger Car
PE	Point Estimate
PRIA	Preliminary Regulatory Impact Analysis (Ref 2)
SE	Standard Error
VMT	Vehicle Miles Traveled
$\triangleq$	Defined equal

F. REPORT ORGANIZATION

Section II describes the functional relationship between the VMT and mass reduction and the resulting fatalities and fatality related costs predicted by the CAFE model.

Section III discusses the methods, assumptions and data used to estimate the effects of VMT and mass reduction on fatalities and fatality related costs.

Section IV summarizes the main results and comments of this review.

Appendix A describes the conditional uncertainty in the estimated fatalities and fatality related costs, given the predicted VMT and mass reduction effects. Only two sources of uncertainty are addressed.

Section II

FUNCTIONAL FORM OF THE FATALITY EFFECTS AND COSTS IN THE CAFE MODEL

This section describes the assumed relationships between the modeled VMT and mass reduction and the estimated fatalities and fatality related costs as implemented in the CAFE model (Ref 10). The modeled VMT values are reported in rows (1) through (7) in Table 5 and other related tables. The estimated numbers of fatalities are reported in rows (8) through (14) in the same tables. The estimated fatality related costs are reported in rows (15) through (35) of the same tables.

A. FATALITIES

The NPRM (Ref 1) indicates on page 43188 that the number of fatalities estimated by the CAFE model depends on the estimated VMT and mass reduction according to the following equation:

$$\text{Fatalities} = \frac{\text{VMT}}{1.0\text{e}9} \times \text{FatalityEstimate} \times \left(1 + \text{ChangePer100lbs} \times \frac{\Delta(\text{CurbWeight}, \text{Threshold})}{100 \text{ lbs}}\right) \quad (1)$$

In this equation the value for "ChangePer100lbs" is equal to one of the five mass effect coefficients listed in column (F) of Table 1 divided by 100%, depending on the vehicle type. According the NPRM and the corresponding equation in Ref 10, the value for ''FatalityEstimate'' is assumed to only depend on the model year.

The CAFE model was rerun with the values for the five mass effect coefficients (i.e., ChangePer100lbs) set to zero in order to elucidate and confirm the separate effects of mass reduction on the results.[3] The results of this comparison are listed in Table 7 and Table 8. The total safety parameter results for the Existing standards, the NPRM preferred alternative standards (Alternative 1), and the value for the Alternative 1 standard minus the value for the Existing standard are listed in columns (B), (C), and (D). These values were calculated by running the CAFE model

[3] The ChangePer100lbs mass effect coefficients in the CAFE model are specified in cells B8:B13 of the "Safety Values" worksheet in the parameters.xlsx input file. The "no mass reduction effect" was modeled setting these values to 0.

from the CAFE_Model\CAFE_model\cafe_model_2018-06-05.zip file with the inputs for the reference case in the CAFE_Model\Sensitivity_Analysis\Sensitivity_Analysis_Inputs.7z file in the 2021-2026 CAFE NPRM FTP website (Ref 11).[4] The corresponding results with the mass effect coefficients set to zero are in columns (E), (F), and (G).

As indicated in Section I the values in rows (2), (3), (7), (9), (10), and (14) in this table are calculated directly from the results of three separate CAFE model runs; and the values in rows (1), (6), (8), and (13) are derived from the values in the other rows. The results in rows (1) through (7) indicate that the estimated VMT does not depend on the five mass effect coefficients, as expected. Furthermore, the results in row (1) are 0 because there is no difference in the VMT results in rows (2) and (3). The results in row (8) indicate that the values for Fatalities due to Mass Changes are zero if the mass effect coefficients are zero, which is also expected. The results in row (9) indicate that the values for Fatalities due to Sales Impacts do not depend on the mass effect coefficients, which is also expected.

The results in row (13) indicate that the rebound effect does depend on the mass effect. Therefore two additional rows were added to this table to show the different components of the rebound effect. The results in row (12) show the rebound effect that does not depend on the mass effect. The values in this row were determined by a 4th CAFE Model run with zero values for the mass effect coefficients, but including any rebound effects. The values in row (12) are equal to the results from this model run minus the Sales Impact values in row (9). The values in row (11) are then equal to the values in row (13) minus the values in row (12).[5] As expected, the resulting values for row (11) are zero if the mass reduction

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[4] The results for the CO2 standard listed in column (D) of Table 8 are slightly different than the results listed in column (B) of Table 6 for unknown reasons. The results in Table 6 were calculated directly from the output files in the Central_Analysis.7z file in Ref 11. The results in Table 8 are in close agreement with the results calculated directly from the output files in the Sensitivity_Analysis\Outputs_CO2 folder in Ref 11.

[5] Likewise the values in row (5) are equal to the results from this model run minus the Sales Impact values in row (2), and the values in row (4) are then equal to the values in row (6) minus the values in row (5). By definition the results in rows (1) and (4) are always equal to 0, rows (2) and (3) are always equal, and rows (5) and (6) are always equal. Therefore rows (1), (2), (4), and (6) are not shown in any other tables in this report.

effect is zero, and the values in row (12) do not depend on the mass reduction effect.

Table 7. Effect of Mass Terms on the CAFE Standard Results in NPRM Table II-73

	(A)	(B)	(C)	(D)	(E)	(F)	(G)
Row	Safety Parameter	Change in Total Safety Parameter Values for Alt 1 from Existing CAFE Standards, MY 1977-2029, CY 1977-2068, 3% Discount Rate					
		Baseline Results (Table II-73)			No Mass Effect		
		Existing	Alternative 1	Alt 1-Existing	Existing	Alternative 1	Alt 1-Existing
	VMT (Billion miles)						
(1)	Mass Changes	0	0	0	0	0	0
(2)	Sales Impacts	126,771	126,079	-692	126,771	126,079	-692
(3)	Subtotal CAFE Atrb.	126,771	126,079	-692	126,771	126,079	-692
(4)	Rebound Effect (ME)	0	0	0	0	0	0
(5)	Rebound Effect (no ME)	-4,454	-5,230	-776	-4,454	-5,230	-776
(6)	Rebound Effect	-4,454	-5,230	-776	-4,454	-5,230	-776
(7)	Total (Billion miles)	122,317	120,849	-1,468	122,317	120,849	-1,468
	Fatalities						
(8)	Mass Changes	4,026	3,866	-160	0	0	0
(9)	Sales Impacts	1,716,834	1,710,650	-6,184	1,716,834	1,710,650	-6,184
(10)	Subtotal CAFE Atrb.	1,720,860	1,714,516	-6,344	1,716,834	1,710,650	-6,184
(11)	Rebound Effect (ME)	108	36	-72	0	0	0
(12)	Rebound Effect (no ME)	-69,178	-75,441	-6,264	-69,178	-75,441	-6,264
(13)	Rebound Effect	-69,070	-75,406	-6,335	-69,178	-75,441	-6,264
(14)	Total	1,651,790	1,639,110	-12,680	1,647,656	1,635,209	-12,447

Table 8. Effect of Mass Terms on the CO_2 Standard Results in NPRM Table II-77

	(A)	(B)	(C)	(D)	(E)	(F)	(G)
Row	Safety Parameter	Change in Total Safety Parameter Values for Alt 1 from Existing CO2 Standards, MY 1977-2029, CY 1977-2068, 3% Discount Rate					
		Baseline Results (Table II-77)			No Mass Effect		
		Existing	Alternative 1	Alt 1-Existing	Existing	Alternative 1	Alt 1-Existig
	VMT (Billion miles)						
(1)	Mass Changes	0	0	0	0	0	0
(2)	Sales Impacts	126,857	125,975	-883	126,857	125,975	-883
(3)	Subtotal CAFE Atrb.	126,857	125,975	-883	126,857	125,975	-883
(4)	Rebound Effect (ME)	0	0	0	0	0	0
(5)	Rebound Effect (no ME)	-4,498	-5,393	-896	-4,498	-5,393	-896
(6)	Rebound Effect	-4,498	-5,393	-896	-4,498	-5,393	-896
(7)	Total (Billion miles)	122,360	120,582	-1,778	122,360	120,582	-1,778
	Fatalities						
(8)	Mass Changes	4,097	3,630	-467	0	0	0
(9)	Sales Impacts	1,717,494	1,709,703	-7,791	1,717,494	1,709,703	-7,791
(10)	Subtotal CAFE Atrb.	1,721,591	1,713,333	-8,258	1,717,494	1,709,703	-7,791
(11)	Rebound Effect (ME)	101	21	-80	0	0	0
(12)	Rebound Effect (no ME)	-69,549	-76,768	-7,220	-69,549	-76,768	-7,220
(13)	Rebound Effect	-69,447	-76,747	-7,300	-69,549	-76,768	-7,220
(14)	Total	1,652,143	1,636,586	-15,558	1,647,946	1,632,935	-15,010

The $\mathrm{FatalityEstimate}$ term in Eqn (1) was confirmed to depend only on the model year. This was done by calculating the number of fatalities per VMT by model year in the CAFE model output, provided that the $\mathrm{ChangePer100lbs}$ values are set to 0, and comparing the results to the input values.[6] The nominal input and resulting output fatality rates per billion vehicle miles traveled versus model year is illustrated in Figure 1. The results appear to be identical to the results in Figure II-9 on page 43143 of the NPRM.

For comparison purposes the fatality rates indicated by Table II-67 on page 43138 are also shown. The nominal input and resulting output fatality rates are in

[6] The "Fixed Effect" input values in units of fatalities per billion vehicle miles traveled are located in cells C23:C98 in the "Safety Values" worksheet in the parameters.xlsx input file. The Fixed Effect input values are offset relative to 28.58895 fatalities per billion vehicle miles traveled, which is a "hard coded" value in the CAFE model.

close agreement with the results in Table II-67 for model years 1975 through 2006, but deviate for later model years. Note the total number of fatalities estimated by this model will depend on the distribution of VMT by model year.

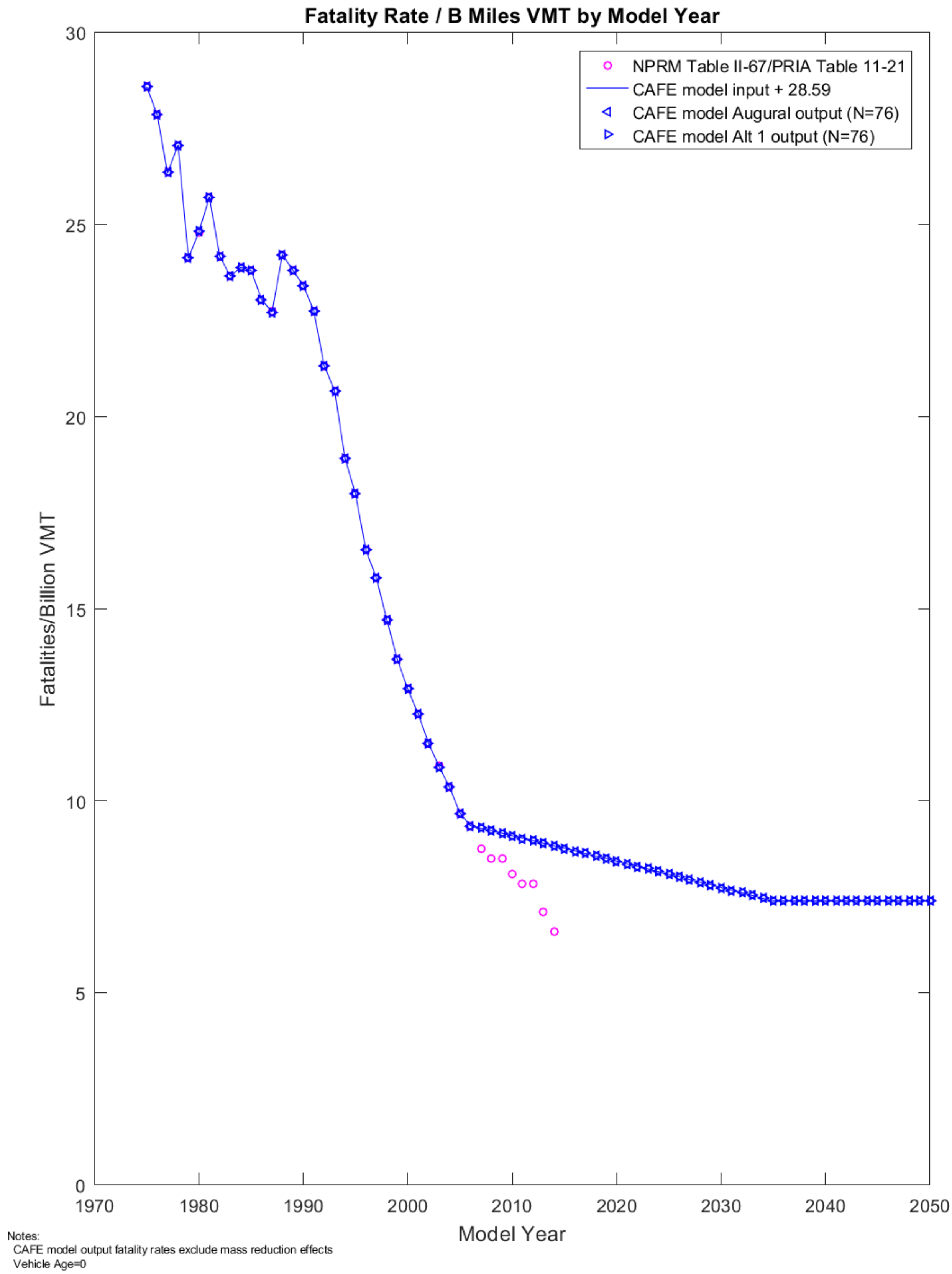


Figure 1. Modeled Fatality Rate verus Model Year

B. FATALITY COSTS

The modeled fatality costs (i.e., rows (15) to (21)) are assumed to be proportional to the corresponding estimated number of fatalities (rows (8) to (14)), which are discounted depending on the calendar year. If the costs were not discounted then the fatality costs would be $9,900,000 times the number of fatalities. The value of a statistical life used in the 3 most recent evaluations are summarized in Table 9. The value used in 2016$ is increasing over time. This assumed cost per fatality is an input to the CAFE model.

Table 9. The Value of a Statistical Life Used in Recent Evaluations

(A)	(B)	(C)
Evaluation	Value of a Statistical Life	
	Original $	2016$
June 2009	$5,500,000 (2000$)	$7,485,285
October 2012	$6,300,000 (2000$)	$8,574,053
August 2018	$9,900,000 (2016$)	$9,900,000

Sources: 77 FR 62624 (Ref 3), p 62938; 83 FR 42986 (Ref 1), p 43120; NIPA Table 1.1.9. Implicit Price Deflators for Gross Domestic Product (Ref 15).

C. NON-FATAL INJURY COSTS

The modeled non-fatal injury costs (i.e., rows (22) to (28)) are assumed to be proportional to the corresponding fatal injury costs (rows (15) to (21)). A proportional scaling factor of 1.5641 was used in the CAFE model, which is a model input parameter.

D. PROPERTY DAMAGE ONLY COSTS

Line 11 of the NPRM Tables II-25 through II-28 are labeled “*Reduced costs for injuries and property damage costs from driving in used vehicles*”, however the values for "`Accident Costs`"[7] estimated by the CAFE model are equal to 0. Therefore the CAFE model used in this NPRM does not estimate property damage costs.

E. TOTAL COSTS

The total modeled fatality and injury related costs reported (i.e., rows (29) to (35)) are equal to the sum of the corresponding fatal costs (i.e., rows (15) to (21)) and non-fatal injury costs (i.e., rows (22) to (28). These costs do not include any explicit property damage only costs. In effect the total costs are equal to 2.5641 times the fatality costs.

[7] See the list of CAFE model reported values listed Section B.3 of Ref 10.

Section III
DISCUSSION

This section discusses the data and assumptions implicit in the CAFE model related to the fatality rate and mass effect models used. As indicated in Section II, the CAFE model assumes that the number of fatalities is proportional to the VMT according to the following Equation on page 43188 of the NPRM

$$\text{Fatalities} = \frac{\text{VMT}}{1.0\text{e}9} \times \text{FatalityEstimate} \times \left(1 + \text{ChangePer100lbs} \times \frac{\Delta(\text{CurbWeight}, \text{Threshold})}{100\text{ lbs}}\right) \quad (2)$$

where

VMT is the number of vehicle miles traveled,
FatalityEstimate is the fatality rate per billion VMT,
ChangePer100lbs is the relative change in the fatality rates per 100 lb reduction in the vehicle mass, and the
$\Delta(\text{CurbWeight}, \text{Threshold})$ is the decrease in the vehicle mass.

The value for ChangePer100lbs depends on the vehicle type and the initial mass before any light weighting.

A. FATALITY RATE EFFECTS

Several concerns about the fatality rate model are now described.

1. Definition of Fatalities Estimated by the CAFE Model

It is unclear in the NPRM and PRIA what types of fatalities are being estimated by the CAFE model. Do "Fatalities" and "FatalityEstimate" in Eqn (1) include all fatalities associated with a given vehicle, including the collision partners (e.g., pedestrians and motorcyclist)? The NHTSA mass and size studies (e.g., Ref 4) addressed all fatalities in 9 different crash types: 1) first-event rollovers, 2) hit a fixed object, 3) hit a pedestrian, bicycle, or motorcycle, 4) hit a heavy truck or bus, 5) hit a lighter car, CUV or minivan, 6) hit a heavier car, CUV or minivan, 7) hit a lighter truck-based LTV, 8) Hit heavier truck-based LTV, or 9) other crash type.

2. Risk of Fatality versus VMT

Equation (1) assumes that the risk of fatality for a given model year vehicle, type, and curb weight, is on average, the same for each mile traveled. Therefore the assumed risk of fatality does not depend on numerous vehicle, driver, and environmental factors such as those factors that were controlled for in Refs 4 and 8. Nonetheless, VMT is useful and widely used measure of crash exposure.

3. Fatality Rate versus Model Year, Calendar Year, and Vehicle Age

In general we can assume that the fatality risk per VMT is, on average, a function of the vehicle model year, calendar year, and vehicle age.

i. Model Year

Newer model year vehicles are expected to have lower fatality rates than older model year vehicles due to improvements in the vehicle safety performance over time. These improvements may be the result of new or improved vehicle designs and design methods, and new or improved safety technologies, driven by more stringent vehicle safety regulations and consumer demand for improved safety ratings (e.g., the US New Car Assessment Program, Insurance Institute for Highway Safety, and Consumer Reports).

It can be assumed that similar vehicle specific safety improvements will continue in the future. Some methods to estimate the effectiveness and benefits of future crash avoidance safety technologies were developed and described in Refs 16 and 17. In general these methods involve identifying and developing technology relevant crash scenarios, developing and validating relevant models and simulations of the vehicle, technology, and driver behavior, and evaluation of the technology effectiveness and benefits.

Therefore the fatality rate should always tend to decrease versus the model year. This is in contrast to the fatality rates model in the NPRM (e.g., Figure II-9), which does not always have the expected downward trend.

ii. Calendar Year

Fatality rates for a given model year vehicle are also expected to decrease over time due to improved crash avoidance capabilities and crash compatibilities of collision partners in the vehicle fleet, as well as improved safety of roadway designs and infrastructure, human factors such increased seat belt use, and improvements in crash emergency notification, response, and medical treatment. For example, Ref 18 list a number of crash countermeasures that are not vehicle specific, such as roadside design improvement at curves, reduced left conflict intersections, traffic control improvements, and rumble strips. Ref 19 lists public safety campaigns and legislative countermeasures aimed at improving driver behavior. Ref 20 indicates on page 489 that a fatality rate index for all diseases (as a surrogate measure of emergency medical treatment) decreased from 88.9 in 1970 to 54.8 in 2010, a reduction of 38% over a 40 year period. It can be assumed that these non-vehicle specific traffic fatality rates will also continue to decrease in the future.

If the data illustrated in the NPRM Figure II-5 were estimated including calendar year terms, then the resulting curve for the model versus model year indicated in Figure II-11 might be in closer agreement with the result from Kahane. The modeled fatality rate versus calendar year would also be expected to decrease. For example, the results in Table A-2 of Ref 21 indicate that the fatality rate tends to decrease by 2.7% per calendar year.

iii. Vehicle Age

Fatality rates may also depend on the vehicle age (independent of model year and calendar year) due to differences in drivers, vehicle use, and vehicle maintenance as the vehicle gets older. However, any overall effect of vehicle age on fatality risk should not be sensitive to “sales impact” effects because the drivers and usage of the retained vehicles would not be expected to change.

Therefore the assumed on-average fatality risk per VMT should primarily be a function of model year and calendar year.

4. Fatality Rate versus Vehicle Type

The risk of fatality may also depend on whether the vehicle is a passenger car or LTV because they have historically had different safety regulations. For example, according to Tables 2-1 and 2-2 in Ref 20, frontal airbags were required in passenger cars by 1990, and LTVs by 1997. Therefore Ref 20 and other studies have estimated the fatality rates of these vehicle types separately.

5. Linear versus Logarithmic Fatality Rate Model

We also know that the fatality rate is always greater than or equal to 0. Therefore the following equation on page 43137 of the NPRM

$$\text{Fatalities per billion miles} = \beta_0 \times Age + \beta_1 \times Age^2 + \beta_2 \times Age^3 + \beta_3 \times Age^4 + \sum_i \beta_i \times MY_i \quad \text{for } i = \{1976, 1977, \ldots, 2014\} \tag{3}$$

is either incorrect or has limited domain-of-validity because it can potentially predict negative fatality rates. This equation is also incorrect because it does not have the intercept term indicated by Table II-67 of the NPRM. In contrast, a logarithmic fatality risk model (e.g., Refs 4, 21) would always predict a positive fatality rate. For example, a 2014 model year vehicle would be 34 years old in the 2048 calendar year, which is within the intended scope of the current CAFE model. The fatality rate for this 34 year old vehicle predicted by Eqn (3) plus the missing intercept term and using the estimated model coefficients indicated in the CAFE Model source code comments is -13.6 fatalities per billion VMT. This fatality rate is negative and therefore not possible.[8] The CAFE model limits the predicted fatality rates to values greater than or 2 fatalities per billion VMT, which prevents the calculation of negative values but does not appear to be supported by any data.

[8] Values for the coefficients indicated in the commented source code for the "`GetFatalityEstimate`" function were used because the coefficient in Table II-67 of the NPRM appeared to be rounded off. Therefore the following equation and coefficients were used: fatalities per billion vehicle miles = 28.58895 -3.626019*age +0.7556265*age^2 -0.03728426*age^3 + 0.0005200835*age^4 - 21.98, where age=34 and the "-21.98" is the relative term for the 2015 model year from Table II-67.

6. Other Concerns about the Fatality Rate Model

There are also a number of other concerns about the fatality rate model. These concerns are relatively minor in comparison to the aforementioned concerns. The statistical model described by Eqn (3) is numerically ill-conditioned because the range of the age polynomial terms vary from 40 to 40^4 = 2,560,000. As a result the reported values in the NPRM Table II-67 do not have the accuracy required to calculate the fatality rate. For example, the fatality rate for a 34 year old 2014 model year vehicle predicted by Eqn (3) plus the missing intercept term and using the values listed in Table II-67 is -142 fatalities per billion VMT. This fatality rate is also negative and therefore not possible, and also very different than the fatality rated based on the coefficients in the CAFE model source code comments. The signs of the age polynomial coefficients also suggest that the age polynomial is overparameterized, which is undesirable and can lead to coefficient instability.[9] Coefficient instability is the condition where the individual terms have nearly equal and opposite effects which tend to cancel out, and the coefficients are very sensitive to small changes in the data. The coefficients for the even-powered terms are positive and the odd-powered terms are negative.

One way to detect overparameterization in a liner regression model is to assess the RPRED statistic, which is similar to the regression R^2 statistic. Whereas the R^2 statistic is a measure of the regression model fit, the RPRED statistic is a measure of the fit and predictive capability of a model. The R^2 and RPRED statistics are defined according to the following equations:

$$R^2 = 1 - \frac{SS_{RES}}{SS_{TOT}} \tag{4}$$

$$RPRED = 1 - \frac{PRESS}{SS_{TOT}} \tag{5}$$

where

[9] Coefficient instability is an undesirable condition where the individual terms in a regression model have nearly equal and opposite effects that tend to cancel each other out. As a result the estimated coefficient values are very sensitive to small changes in the data and the resulting model has very little predictive value.

$$SS_{RES} = \sum_{k=1}^{n} \left(y_k - \hat{y}_k\right)^2 \tag{6}$$

$$PRESS = \sum_{k=1}^{n} \left(y_k - \hat{y}_{k,-k}\right)^2 \tag{7}$$

$$SS_{TOT} = \sum_{k=1}^{n} \left(y_k - \bar{y}\right)^2 \tag{8}$$

$$\bar{y} = \frac{1}{n} \sum_{k=1}^{n} y_k \tag{9}$$

and where

- y_k is the value of the k th data observation,
- $\hat{y}_k$ is the value of the k th data observation estimated by the model with all data observations,
- $\hat{y}_{k,-k}$ is the value of the k th data observation predicted by the model estimated with the k th data observation removed, and
- n is the number of observations.

The properties of these statistics are that $0 \le R^2 \le 1$ and $RPRED \le 1$, where $R^2 = 1$ represents and exact model fit and $RPRED = 1$ represents and exact model predictive fit. Therefore large values for R^2 and RPRED are desirable. The intermediate PRESS statistic is described on page 325 of Ref 22.

7. Revised Safety Parameter Estimates based on Alternative Fatality Risk Models

The previous subsections described several problems with the fatality risk model currently used in the NPRM. A fatality risk model that is a function of both model year and calendar year, such as the following more general equation:

$$\log\left(\text{Fatalities per billion vehicle miles}\right) = \beta_0 + \beta_1 \times \left(MY - 1975\right) + \beta_2 \times \left(CY - 2015\right) \tag{10}$$

would help to address these concerns. This is a parsimonious model that can describe the long term historical trends in the fatality risk vs model year and calendar year which can be used to predict future trends if we assume that the historical trends will continue into the future. The reference calendar year of 2015 was chosen because according to page 43140 the fatality rates were anchored to the 2015 fatality rates published by NHTSA.

Rough estimates for the β coefficients in Eqn (10) were calculated in two steps. First, the fatality rates for all of the model years and calendar years depicted in Figure II-5 of the NPRM were calculated using the equation and high precision versions of the coefficients on pages 43137-43139 of the NPRM. This step was necessary because we did not have the original data used to create Figure II-5 (as requested in Ref 23, Item 9). Then, the natural logarithms of the calculated fatality rates were fit the model year and calendar year to estimate the β values in Eqn (10). It was assumed that the model year and calendar year effects on fatality rate were equal, and therefore $\beta_1 = \beta_2$. This is based on the observation reported in Ref 20 that the overall reduction in the index for "everything else" (i.e., calendar year effects) was almost the same at the reduction in the vehicular risk index (i.e., model year effects). The resulting estimated model coefficients are listed in Table 10. These estimated values should be considered rough estimates because they were fit to the recreated data and not the original data. The standard errors are not reported for this reason as well. Note that the rough estimate of -0.02635 for the calendar year effect (β_2) is similar to the estimated value of -0.027 = (1-0.9730) found in Table A-2 of Ref 21.

Figure 1 shows a comparison of the fatality risk as a function of both model year and calendar year and the values used in the NPRM. The graph on the top shows the fatality risk versus model year, assuming that the calendar year is 2015. The graph on the bottom shows the relative change in the fatality risk due to calendar year. The new fatality risk curves reflects an assumption that the fatality risk will continue to decrease at a rate of 2.63% per model year and 2.63% per calendar year in the future based on the historical trends.

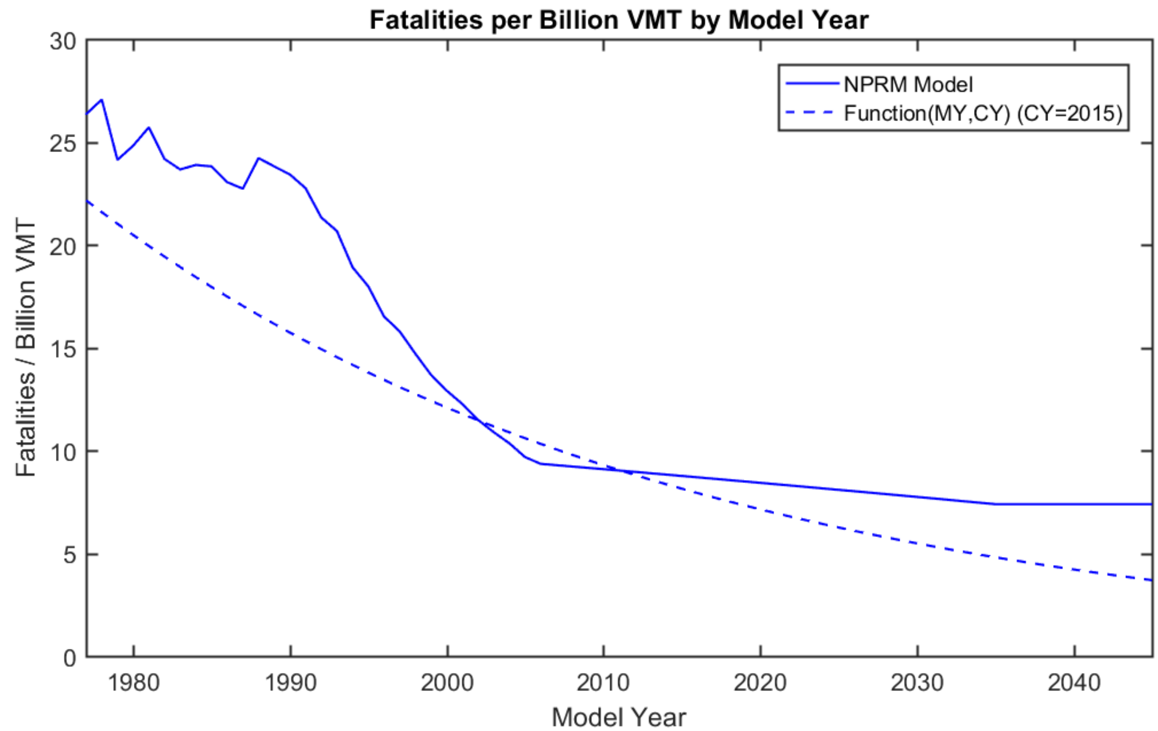
The graph on the bottom also includes data for "everything else" and "all diseases" versus calendar year from Ref 20, for comparison purposes. The "everything else" data does not include the effects of increased seat belt use over time and therefore tends to underestimate the calendar year effect. The new curve and the NPRM curve tend to bracket this data.

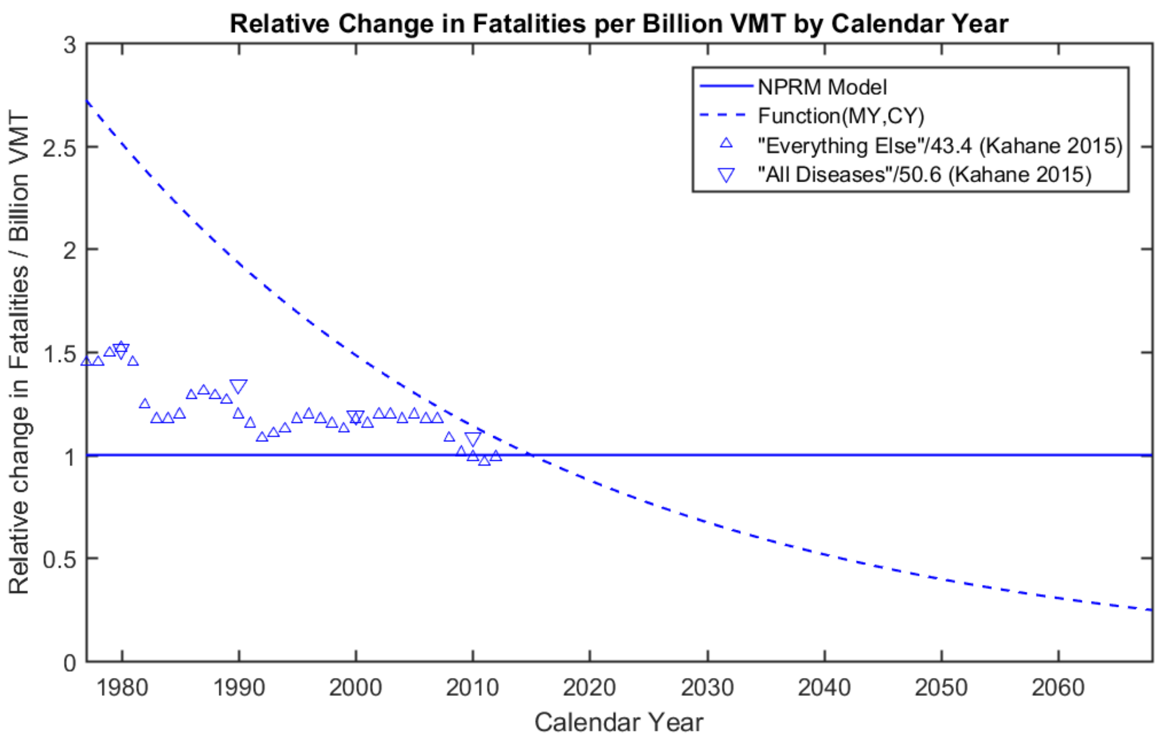
The CAFE model safety parameters were then estimated in two steps. First the fatality risks per billion miles for CY = 2015 were input the input to the CAFE model via the Parameters "Safety Values" worksheet.[10] The fatalities and fatality related costs including the calendar year effect were calculated by multiplying the CAFE model output by $\exp(\beta_2 \times (CY - 2015))$. The resulting safety parameters for the fatality risk based on both the model year and calendar year are listed in column (C) of Table 11 and Table 12. The corresponding safety parameters from the NPRM are also included in column (B) of this table for comparison. These results indicate that the estimated values for the fatality risk based on both model year and calendar year are approximately one half the estimated values reported in the NPRM. Therefore the safety parameter estimates based on a more accurate fatality rate model based on both model year and calendar year could be up to 50% less than estimates from a model, such as the current NPRM model, that does not properly account for safety improvements due to calendar year.

Table 10. Estimated Coefficients for the Logarithmic Fatality Rate Model versus MY and CY Model

Term	Coefficient	Rough Estimate
Log Fatality rate for MY 1975 and CY 2015	β_0	3.151
Log Fatality rate change versus MY	β_1	-0.02635
Log Fatality rate change versus CY	β_2	-0.02635

[10] Cells D23:D98 in the Safety Values worksheet were assigned the values $\text{Fixed Effect} = \exp(\beta_0 + \beta_1 \times (MY - 1975)) - 28.58895$.





Note: "Everything Else" does not include the effects of increased seat belt use over time.

Figure 2. Comparison of the Improved and NPRM Fataltiy Risk Models

Table 11. Comparison of the Change in Alternative 1 Safety Parameters from Existing CAFE Standards Using the Revised MY and CY Fatality Risk

	(A)	(B)	(C)
Row	Safety Parameter	Change in Total Safety Parameter Values for Alt 1 from Existing CAFE Standards, MY 1977-2029, CY 1977-2068, 3% Discount Rate	
		NPRM Point Estimate	Fatality Risk is a Function of Model Year and Calendar Year Point Estimate
	VMT (Billion miles)		
(3)	Subtotal CAFE Atrb.	-692	-692
(6)	Rebound Effect	-776	-776
(7)	Total (Billion miles)	-1,468	-1,468
	Fatalities		
(8)	Mass Changes	-160	-73
(9)	Sales Impacts	-6,184	-3,430
(10)	Subtotal CAFE Atrb.	-6,344	-3,503
(11)	Rebound Effect (ME)	-72	-36
(12)	Rebound Effect (no ME)	-6,264	-3,199
(13)	Rebound Effect	-6,335	-3,236
(14)	Total	-12,680	-6,738
	Fatalities Societal $B		
(15)	Mass Changes	-0.9	-0.4
(16)	Sales Impacts	-34.4	-20.8
(17)	Subtotal CAFE Atrb.	-35.4	-21.2
(18)	Rebound Effect (ME)	-0.5	-0.2
(19)	Rebound Effect (no ME)	-41.2	-21.8
(20)	Rebound Effect	-41.7	-22.0
(21)	Total	-77.0	-43.3
	Total Societal $B		
(29)	Mass Changes	-2.4	-1.1
(30)	Sales Impacts	-88.3	-53.3
(31)	Subtotal CAFE Atrb.	-90.7	-54.4
(32)	Rebound Effect (ME)	-1.2	-0.6
(33)	Rebound Effect (no ME)	-105.6	-55.9
(34)	Rebound Effect	-106.8	-56.5
(35)	Total	-197.5	-110.9

Note: The results for Nonfatal Societal Costs in rows (22) to (28) are not listed because they can be calculated from the Total Societal Costs in rows (29) to (35) – Fatalities Societal Costs in rows (15) to (21).

Table 12. Comparison of the Change in Alternative 1 Safety Parameters from Existing CO2 Standards Using the Revised MY and CY Fatality Risk

	(A)	(B)	(C)
Row	Safety Parameter	Change in Total Safety Parameter Values for Alt 1 from Existing CO2 Standards, MY 1977-2029, CY 1977-2068, 3% Discount Rate	
		NPRM Point Estimate	Fatality Risk is a Function of Model Year and Calendar Year Point Estimate
	VMT (Billion miles)		
(3)	Subtotal CAFE Atrb.	-883	-883
(6)	Rebound Effect	-896	-896
(7)	Total (Billion miles)	-1,778	-1,778
	Fatalities		
(8)	Mass Changes	-467	-227
(9)	Sales Impacts	-7,791	-4,176
(10)	Subtotal CAFE Atrb.	-8,258	-4,403
(11)	Rebound Effect (ME)	-80	-40
(12)	Rebound Effect (no ME)	-7,220	-3,661
(13)	Rebound Effect	-7,300	-3,701
(14)	Total	-15,558	-8,104
	Fatalities Societal $B		
(15)	Mass Changes	-2.9	-1.5
(16)	Sales Impacts	-42.9	-24.9
(17)	Subtotal CAFE Atrb.	-45.8	-26.4
(18)	Rebound Effect (ME)	-0.5	-0.3
(19)	Rebound Effect (no ME)	-47.3	-24.8
(20)	Rebound Effect	-47.8	-25.1
(21)	Total	-93.6	-51.4
	Total Societal $B		
(29)	Mass Changes	-7.5	-3.8
(30)	Sales Impacts	-109.9	-63.8
(31)	Subtotal CAFE Atrb.	-117.4	-67.6
(32)	Rebound Effect (ME)	-1.3	-0.7
(33)	Rebound Effect (no ME)	-121.2	-63.6
(34)	Rebound Effect	-122.5	-64.3
(35)	Total	-239.9	-131.9

Note: The results for Nonfatal Societal Costs in rows (22) to (28) are not listed because they can be calculated from the Total Societal Costs in rows (29) to (35) – Fatalities Societal Costs in rows (15) to (21).

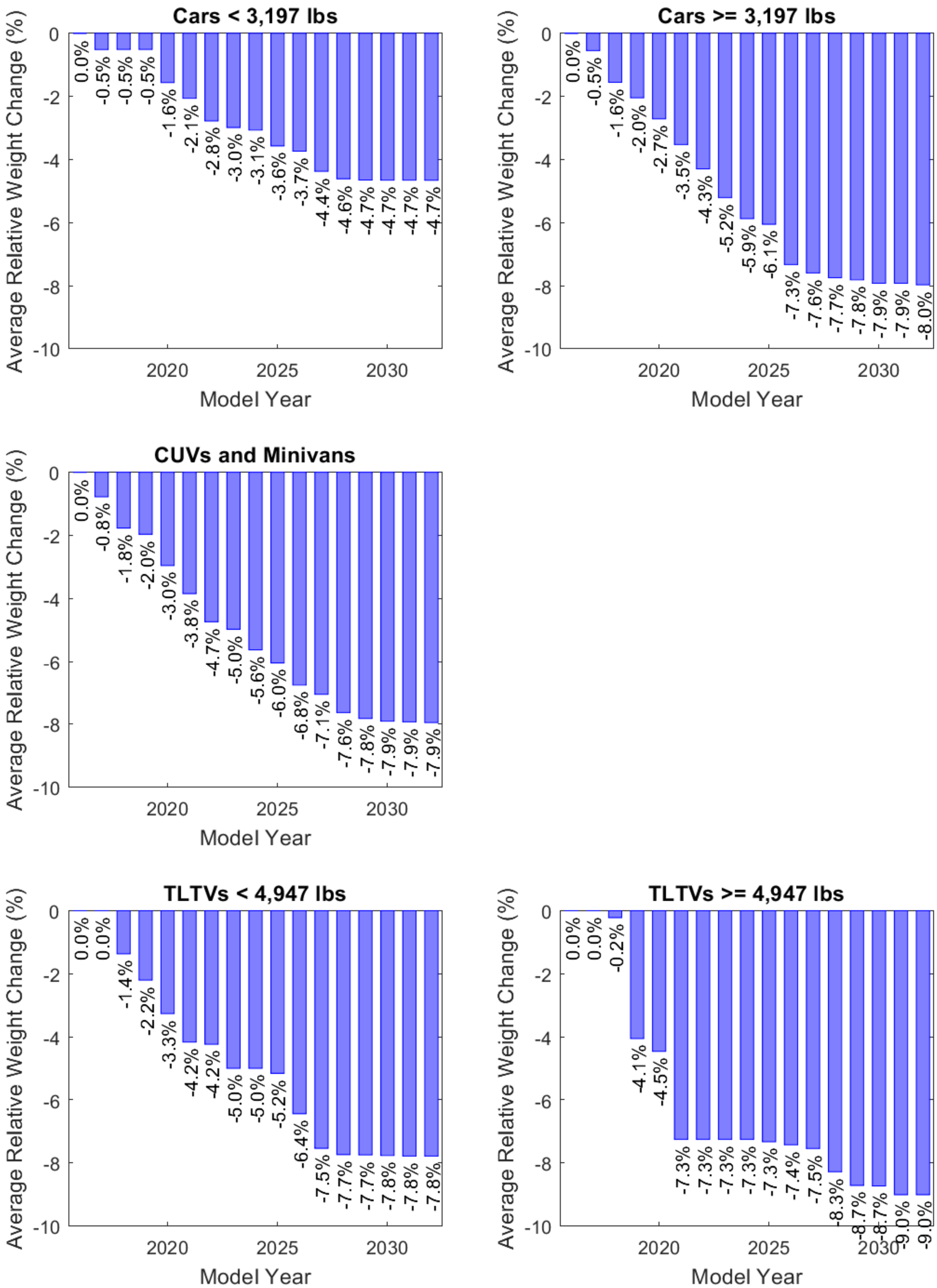
B. MASS REDUCTION EFFECTS

The estimated effect of mass reduction depends on the amount of mass reduction due to the CAFE or CO2 standards times the relative effect of mass on fatalities, as quantified by the $ChangePer100lbs$ term in Eqn (1). Both of these terms are now discussed separately.

8. Estimated Vehicle Mass Reduction

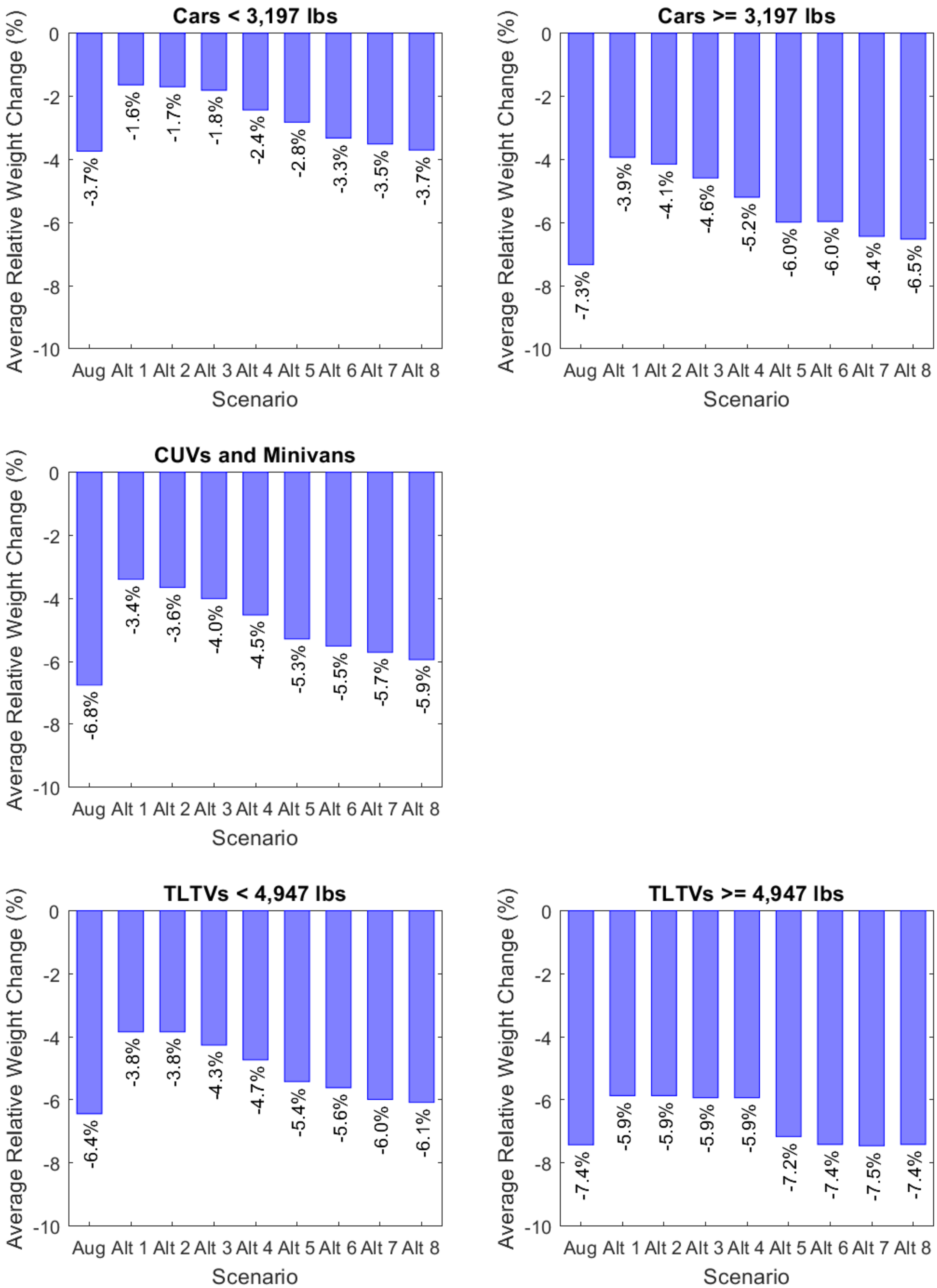
The estimated vehicle mass reductions predicted by the CAFE model for the Existing CO2 standards are illustrated in Figure 3 and Figure 4. Figure 3 shows the estimated mass reductions for the Existing CO2 Standards versus the model year from 2016 to 2032, for the five vehicle type and mass categories indicted in Table 1. This figure indicates that the estimated mass reductions are 0 for the 2016 MY and then increase until the 2026 MY and beyond. Figure 4 compares the estimated mass reductions in the 2026 MY for the Existing and proposed alternatives, for each of the five vehicle type and mass categories. This figure indicates that the estimated mass reductions are the largest for the Existing standards and the smallest for the proposed Alternative 1 standards. This figure shows that the heaviest truck based LTVs are predicted to have the largest percentage mass reductions and that the lightest passenger cars are predicted to have the smallest percentage mass reductions.

The mass reduction strategy can have an effect on the estimated number of fatalities (e.g., row 8). LBNL explored the effects of 8 different mass reduction scenarios, ranging from a 100-lb mass reduction in all vehicles, proportionate mass reduction in all vehicles, and various combinations of mass reductions by vehicle type and mass. The results of this analysis were summarized in Tables 6.1 and 6.2 of Ref (24). These results indicated that the overall estimated change in fatalities due to these 8 different mass reduction scenarios, using LBNL's baseline model, varied from a reduction of 39 fatalities if the masses of all vehicles were reduced by 100 lb, to a reduction of 1,737 fatalities if the masses of lighter- and heavier-than-average light trucks were reduced to the median mass values for lighter- and heavier-than-average passenger cars.



Source: D:CAFE\2021-2026_CAFE_NPRM\CAFE_Model\Central_Analysis\Central_Analysis\output_CO2\CO2\reports-csv\vehicles_report.csv (2018-06-05 14:51:21)

Figure 3. Estimated Vehicle Mass Reductions for the Existing CO2 Standards Predicted by the CAFE Model



Source: D:CAFE\2021-2026_CAFE_NPRM\CAFE_Model\Central_Analysis\Central_Analysis\output_CO2\CO2\reports-csv\vehicles_report.csv (2018-06-05 14:51:21)

Figure 4. Comparison of Estimated 2026 Model Year Mass Reductions for the Existing and Proposed Alternative CO2 Standards Predicted by the CAFE Model

9. Estimated Effects of Vehicle Mass Reduction on Fatalities

The numbers of fatalities are estimated by the CAFE model by multiplying the estimated mass reduction by the value for $ChangePer100lbs$ as indicated in Eqn (1). The estimated value for $ChangePer100lbs$ depends on the vehicle type and mass, as well as the modeling method, data, and assumptions. The point estimates and confidence intervals for NHTSA's preferred model using the most recent data are listed in the last two columns of Table 1. Estimates for these mass effect coefficients using several alternative models and the most recent data are listed in Table II-65 of the NPRM (page 43132) and Ref 24.

The estimated mass effect coefficients for these alternative models and the CAFE model results based on these values are listed in Table 13 and Table 14. The results in column (B) are the point estimates for NHTSA's preferred model. The results in column (C) are the standard errors for NHTSA's preferred model that were estimated in Appendix A. The point estimates in column (B) are considered to be statistically significant if the magnitude of the point estimate is greater than two times the standard error in column (C) (i.e., if $|PE| > 2xSE$). The results in column (D) are the point estimates with no mass effect, for reference purposes. The results in columns (E), (F), and (G) are the point estimates for three alternative models listed Table II-65 of the NPRM. The results in column (H) are the point estimates for the LBNL baseline model described on pages 86-87 of Ref 24.

The alternative models 2 and 5 were selected because they represent a single change in the model used to estimate the mass effect coefficients.

Alternative Model 2 replaces the footprint term in NHTSA's preferred model with wheelbase and track terms. The wheelbase and track are physical dimensions of the vehicle which were first proposed to control for vehicle size in the 2003 DRI study (Ref 25). The wheelbase and track directly relate to the pre-crash vehicle dynamics, which can affect the vehicle crash involvement. The wheelbase and track are also related to the length and width of the vehicle. Longer and wider vehicles may have increased crush space that can improve the vehicle crashworthiness and crash compatibility for a given impact condition, thus reducing the risk of occupant and collision partner injuries and fatalities. However the crush space available in front and rear of the passenger compartment tends to be much greater than the crush space available on the side. Therefore the wheelbase and track, and the corresponding length and width of the vehicle, can have different effects on fatality risk. The footprint is the product of wheelbase and track, which is used in the existing and proposed CAFE and CO_2 standards. The model preferred by NHTSA may misattribute some independent mass, wheelbase and track effects (i.e, long wheelbase and narrow track vs short wheelbase and wide track) into a combined mass and footprint effect. Therefore the model with wheelbase and track is preferred over the model with just footprint.

Alternative Model 5 uses “stopped vehicle” induced-exposure instead of “non-culpable vehicle” induced-exposure data. Induced-exposure data is used to compare and control for the effects of driver and environmental factors that are not available in vehicle registration and VMT data. These factors, such as driver age and driving at night, may affect the vehicle fatality risk and therefore were accounted for in the mass and size analysis. Stopped vehicle induced-exposure data was used in the 1997 NHTSA evaluation report (Ref 26). The NHTSA also used a “relaxed” version of induced-exposure data in Ref 27.

The results in Table 15 compare the induced-exposure data for twelve control variables that were used in a previous analysis of the effects of vehicle mass and size on fatalities (Refs 4-6). The data variables used in the analysis are listed in column (A) of the table. The VMT weighted average values for the non-culpable vehicle and stopped-vehicle induced-exposure data are listed in columns (B) and (C). The percentage difference is listed in column (D). The last 4 rows of Table 15 list the number of cases, the number of VMT weighted cases, the average VMT represented by each case, and the name of the source data file that was created by NHTSA. Note that the number of stopped-vehicle cases is approximately ¼ the number of non-culpable vehicle cases, and the average VMT per case is approximately 4 times higher. The smaller sample size of the stopped-vehicle induced exposure data may result in larger uncertainty in the estimated model coefficients, compared to the results based on the larger non-culpable vehicle dataset. The total numbers of VMT weighted cases are intentionally about the same.

Ideally the VMT weighted mean values in columns (B) and (C) of Table 15 would be the same for both of these types of induced-exposure data. However neither type of data is a perfect measure of exposure and so there are some differences in the data. One possible source of difference could be that safer cars and drivers may be better able to avoid a crash even if they are not culpable. As a result the safer cars and drivers may be under-represented in the non-culpable vehicle induced-exposure data. These differences and limitations then affect the overall estimates for the 5 mass effect coefficients listed at the top of Table 13 and Table 14. The differences in the results in columns (B) and (G) of these tables are indicative of the inherent uncertainty in the results due to the induced-exposure data.

The alternative model 3 and LBNL models include multiple changes compared to NHTSA's preferred model. Alternative model 3 includes both the wheelbase and track (Alternative model 2) and the stopped-vehicle induced exposure data (Alternative model 5). The LBNL model goes further by changing the assumed CUV to minivan sales ratio, and revised the VMT weights used by NHTSA.

These different mass effect models directly affect the results in rows (8) and (11) of Table 13 and Table 14. The alternative model point estimates for the change in fatalities due to mass effect and excluding rebound effects are in row (8). For comparison, the point estimate for NHTSA's preferred model in Table 13 is -160. On average, replacing the footprint in NHTSA's preferred model with wheelbase and track increases the estimated number of fatalities in row (8) by 563 fatalities. Using stopped-vehicle induced exposure data instead of non-culpable vehicle induced-exposure data further increases the estimated number of fatalities in row (8) by 173 fatalities. The changes for the LBNL model reduce the estimated number of fatalities from 576 in column (F) to 470 in column (H). As expected, the sales impact results in row (9) and the rebound effect not related to mass effect in row (12) do not depend on the mass effect model. All of the other fatality and fatality cost results in this table are related to the results in rows (8) and (11).

The uncertainties in the results for the alternative models can be assumed to be similar to the uncertainty in the NPRM results, based on the estimated mass effect results for similar but older data reported in Ref 28. Therefore all of the estimated effects of mass changes listed in row (8) of Table 13 and Table 14 are not statistically significant because their magnitudes are less than two times the standard error listed in column (C). For example the estimated 95% confidence interval based on NHTSA's preferred model is -160 $\pm$ 2x384, or -928 to 608, which is not statistically significant. Likewise the 95% confidence interval for the estimated mass changes based on Model 3 is approximately 576 $\pm$ 2x384, or -192 to 1,344, which is also not statistically significant.

Table 13. Sensitivity of the Estimated Safety Parameters for Alternative 1 from Existing CAFE Standards Reported in the NPRM to the Alternative Mass Effect Models

	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
Row	Safety Parameter	Change in Alternative 1 Safety Parameters from Existing CAFE Standards Baseline Total Fatalities, MY 1977-2029, CY 1977-2068, 3% Discount Rate						
		NPRM Table II-45		No Mass Effect	NPRM Table II-65 Alternative Model			LBNL Baseline
		NHTSA Preferred Model			Model 2 By track & wheelbase	Model 3 By track & Wheelbase, Stopped Vehicle IE	Model 5 Stopped Vehicle IE	
		PE	SE	PE	PE	PE	PE	PE
	Mass Effect Coefficient							
	Lighter PCs	1.20%	0.78%	0.00%	0.66%	0.73%	1.32%	0.74%
	Heavier PCs	0.42%	0.54%	0.00%	0.54%	-0.02%	-0.17%	0.03%
	CUVs and minivans	-0.25%	0.65%	0.00%	-0.48%	-0.18%	-0.08%	0.00%
	Lighter Truck-based LTVs	0.31%	0.41%	0.00%	-0.44%	-0.77%	0.21%	-0.78%
	Heavier Truck-based LTVs	-0.61%	0.43%	0.00%	-0.90%	-1.91%	-1.55%	-1.95%
	VMT (Billion miles)							
(3)	Subtotal CAFE Atrb.	-692	0	-692	-692	-692	-692	-692
(7)	Total (Billion miles)	-1,468	0	-1,468	-1,468	-1,468	-1,468	-1,468
	Fatalities							
(8)	Mass Changes	-160	384	0	393	576	3	470
(9)	Sales Impacts	-6,184	721	-6,184	-6,184	-6,184	-6,184	-6,184
(10)	Subtotal CAFE Atrb.	-6,344	818	-6,184	-5,791	-5,608	-6,181	-5,714
(11)	Rebound Effect (ME)	-72	32	0	17	-25	-126	-32
(12)	Rebound Effect (no ME)	-6,264	1,061	-6,264	-6,264	-6,264	-6,264	-6,264
(13)	Rebound Effect	-6,335	1,074	-6,264	-6,247	-6,288	-6,389	-6,295
(14)	Total	-12,680	1,459	-12,447	-12,038	-11,896	-12,570	-12,009
	Fatalities Societal $B							
(15)	Mass Changes	-0.9	2.4	0.0	2.6	3.9	0.2	3.2
(16)	Sales Impacts	-34.4	4.3	-34.4	-34.4	-34.4	-34.4	-34.4
(17)	Subtotal CAFE Atrb.	-35.4	4.9	-34.4	-31.8	-30.6	-34.2	-31.2
(18)	Rebound Effect (ME)	-0.5	0.2	0.0	0.1	-0.2	-0.8	-0.2
(19)	Rebound Effect (no ME)	-41.2	6.9	-41.2	-41.2	-41.2	-41.2	-41.2
(20)	Rebound Effect	-41.7	6.9	-41.2	-41.1	-41.4	-42.0	-41.4
(21)	Total	-77.0	8.6	-75.6	-72.9	-71.9	-76.2	-72.6
	Total Societal $B							

(29)	Mass Changes	-2.4	6.3	0.0	6.7	9.9	0.5	8.2
(30)	Sales Impacts	-88.3	11.0	-88.3	-88.3	-88.3	-88.3	-88.3
(31)	Subtotal CAFE Atrb.	-90.7	12.6	-88.3	-81.6	-78.4	-87.8	-80.1
(32)	Rebound Effect (ME)	-1.2	0.5	0.0	0.3	-0.4	-2.1	-0.5
(33)	Rebound Effect (no ME)	-105.6	17.6	-105.6	-105.6	-105.6	-105.6	-105.6
(34)	Rebound Effect	-106.8	17.8	-105.6	-105.4	-106.1	-107.7	-106.2
(35)	Total	-197.5	22.2	-193.9	-187.0	-184.4	-195.5	-186.3

Note: The results for Nonfatal Societal Costs in rows (22) to (28) are not listed because they can be calculated from the Total Societal Costs in rows (29) to (35) – Fatalities Societal Costs in rows (15) to (21).

Table 14. Sensitivity of the Estimated Safety Parameters for Alternative 1 from Existing CO2 Standards Reported in the NPRM to the Alternative Mass Effect Models

	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
Row	Safety Parameter	Change in Safety Parameters for Alternative 1 from Existing CO2 Standards Baseline Total Fatalities, MY 1977-2029, CY 1977-2068, 3% Discount Rate						
		NPRM Table II-45 NHTSA Preferred Model		No Mass Effect	NPRM Table II-65 Alternative Model			LBNL Baseline
					Model 2 By track & wheelbase	Model 3 By track & Wheelbase, Stopped Vehicle IE	Model 5 Stopped Vehicle IE	
		PE	SE	PE	PE	PE	PE	PE
	Mass Effect Coefficient							
	Lighter PCs	1.20%	0.78%	0.00%	0.66%	0.73%	1.32%	0.74%
	Heavier PCs	0.42%	0.54%	0.00%	0.54%	-0.02%	-0.17%	0.03%
	CUVs and minivans	-0.25%	0.65%	0.00%	-0.48%	-0.18%	-0.08%	0.00%
	Lighter Truck-based LTVs	0.31%	0.41%	0.00%	-0.44%	-0.77%	0.21%	-0.78%
	Heavier Truck-based LTVs	-0.61%	0.43%	0.00%	-0.90%	-1.91%	-1.55%	-1.95%
	VMT (Billion miles)							
(3)	Subtotal CAFE Atrb.	-883	0	-883	-883	-883	-883	-883
(7)	Total (Billion miles)	-1,778	0	-1,778	-1,778	-1,778	-1,778	-1,778
	Fatalities							
(8)	Mass Changes	-467	625	0	376	544	-314	365
(9)	Sales Impacts	-7,791	876	-7,791	-7,791	-7,791	-7,791	-7,791
(10)	Subtotal CAFE Atrb.	-8,258	1,092	-7,791	-7,414	-7,246	-8,105	-7,425
(11)	Rebound Effect (ME)	-80	38	0	30	-9	-137	-15
(12)	Rebound Effect (no ME)	-7,220	1,238	-7,220	-7,220	-7,220	-7,220	-7,220
(13)	Rebound Effect	-7,300	1,252	-7,220	-7,189	-7,229	-7,356	-7,235
(14)	Total	-15,558	1,891	-15,010	-14,604	-14,475	-15,461	-14,660
	Fatalities Societal $B							
(15)	Mass Changes	-2.9	4.0	0.0	2.4	3.5	-1.9	2.4
(16)	Sales Impacts	-42.9	5.0	-42.9	-42.9	-42.9	-42.9	-42.9
(17)	Subtotal CAFE Atrb.	-45.8	6.4	-42.9	-40.4	-39.3	-44.7	-40.5
(18)	Rebound Effect (ME)	-0.5	0.2	0.0	0.2	-0.1	-0.9	-0.1
(19)	Rebound Effect (no ME)	-47.3	7.9	-47.3	-47.3	-47.3	-47.3	-47.3
(20)	Rebound Effect	-47.8	8.0	-47.3	-47.1	-47.3	-48.2	-47.4
(21)	Total	-93.6	11.1	-90.1	-87.5	-86.7	-92.9	-87.8
	Total Societal $B							

(29)	Mass Changes	-7.5	10.2	0.0	6.2	9.1	-4.8	6.2
(30)	Sales Impacts	-109.9	12.9	-109.9	-109.9	-109.9	-109.9	-109.9
(31)	Subtotal CAFE Atrb.	-117.4	16.5	-109.9	-103.7	-100.8	-114.7	-103.8
(32)	Rebound Effect (ME)	-1.3	0.6	0.0	0.5	-0.2	-2.3	-0.3
(33)	Rebound Effect (no ME)	-121.2	20.4	-121.2	-121.2	-121.2	-121.2	-121.2
(34)	Rebound Effect	-122.5	20.6	-121.2	-120.7	-121.4	-123.5	-121.5
(35)	Total	-239.9	28.6	-231.1	-224.4	-222.2	-238.2	-225.2

Note: The results for Nonfatal Societal Costs in rows (22) to (28) are not listed because they can be calculated from the Total Societal Costs in rows (29) to (35) – Fatalities Societal Costs in rows (15) to (21).

Table 15. Comparison of Non-Culpable Vehicle and Stopped-Vehicle Induced-Exposure Data (2002 to 2008 Calendar Years)

(A)	(B)	(C)	(D)
Data Variable Variable	Mean VMT Weighted Value		Percent Difference
	Non-Culpable Vehicle Induced-Exposure	Stopped Vehicle Induced-Exposure	
DRVMALE	0.509	0.494	3.0%
M14_30	0.846	0.726	15.2%
M30_50	4.803	4.532	5.8%
M50_70	1.627	1.533	6.0%
M70PLUS	0.187	0.149	22.8%
F14_30	0.977	0.904	7.7%
F30_50	5.154	5.197	-0.8%
F50_70	1.166	1.102	5.6%
F70PLUS	0.112	0.086	25.8%
NITE	0.174	0.154	12.1%
RURAL	0.214	0.198	8.0%
SPDLIM55	0.168	0.123	31.4%
Number of cases	2,457,228	677,146	113.6%
VMT weighted	8,443,608,546,981	8,441,562,071,535	0.02%
Average VMT	3,436,233	12,466,384	-113.6%
File name	stcs2_6.sas7bdat	ststop_6.sas7bdat	-

Source: Ref 5, page 47, Table 7.

Section IV
SUMMARY

This section summarizes this evaluation of the CAFE model methods and results used to support the Notice of Proposed Rulemaking regarding CAFE and Greenhouse Gas standards for light duty passenger vehicles published in the US Federal Register (83 FR 42986, Ref 1) and it's accompanying Preliminary Regulatory Impact Analysis (Ref 2). The focus of this evaluation was on the estimated effects of the proposed rules on fatalities and fatality related costs that were predicted by the CAFE Model.

A. KEY FINDINGS

The key findings of this review are the following:

1. The estimated effect of mass reduction on CAFE attributable fatalities and fatality related costs is effectively zero. The CAFE model results based on NHTSA's preferred mass and size model using footprint and non-culpable vehicle induced-exposure indicated that the proposed standard slightly decreased fatalities, but the effect was small and statistically insignificant. The results based on five alternative mass and size models using wheelbase and track, or stopped-vehicle induced-exposure, were also small and statistically insignificant. Only one of the five alternative model results for the change in CO_2 standard had the same sign (i.e., a decrease in fatalities) as NHTSA's preferred model, and none of the five alternative model results for the change in CAFE standard had the same sign (i.e., the results had the opposite sign indicating an increase in fatalities). Therefore, the estimated effect of mass reduction on CAFE attributable fatalities and fatality related costs is effectively zero.

2. The fatality rate model described in the Safety Model section of the NPRM (pages 43135-43145) is incorrect because it does not account for changes in the fatality rate that occur over time (i.e., calendar year). For example, this

model does not account for changes in human behavior such as increasing seat belt use over time, improvements in roadway design for safety, improvements in life saving emergency medical response and treatment, and improvements in the crash avoidance and crash compatibility of other vehicles on the road, which are not associated with vehicle model year and which over time (increasing calendar years) tend to improve overall safety and decrease the fatality risk. These improvements over time have occurred in the past and similar improvements over time can be expected in the future. As a result, the estimated effect of model year on fatality risk that is assumed in the current CAFE model are over estimated because they did not account for calendar year effects. For example, the model assumes that the fatality rate of 1985 model year vehicles is 23.8 fatalities per billion VMT. However, this estimate incorrectly includes risks that depend on calendar year, not model year. If this effect is properly accounted for then the change in the overall number of fatalities estimated by the CAFE model due to the proposed standard would be much less (e.g., by as much as 50% less).

3. It is unclear whether or not the fatalities being estimated by the CAFE model represent all road users (e.g., pedestrians, motorcyclists, and other collision partners) or just the subject vehicle occupants. The estimated number of fatalities should include all road users. It should not under count or double count any fatalities. The methodology developed by Kahane (e.g., Ref 4) is an example of a method that counts all road users without double counting.

4. The uncertainty in the overall estimated fatality risk and related costs in the NPRM due to two sources of uncertainty were estimated to be approximately ±25% of the point estimates. The estimated uncertainty in the CAFE Model results would be larger if other sources of uncertainty, such as uncertainties in the estimated fleet size and VMT, and uncertainty in the costs of non-fatal injuries relative to the costs of fatal injuries, were also taken into account.

5. The sensitivity analysis results for the proposed CO2 standards reported in Table VII-95 of the NPRM are incorrect. They are the same as the results for the proposed CAFE standards reported in Table VII-94.

6. The sensitivity cases labeled "Fatalities Flat Earlier" and "Fatalities Flat Later" in the Sensitivity Analysis section of the NPRM (pages 43352-43367) are misleading. They represent the sensitivity to small changes in the fatality rates after the 2030 model year. The maximum percentage difference compared to the baseline fatality rate is less than 10%. These cases underrepresent the sensitivity of the results to the uncertainty in the fatality rate model, which is much larger. Furthermore, the results for "Fatalities Flat Later" without rebound in Tables VII-94 and VII-95 are incorrect because the CAFE model input parameter file for this case has a 20% rebound effect instead of 0%.

Based on these findings the

1) NPRM estimated mass effect results summarized in Table 3 are effectively zero.

2) NPRM estimated costs from driving in used vehicles summarized in Table 4 are over-estimated by up to a factor of 2 because the fatality rate model in the CAFE model did not account for improvements in safety that occur over time and are not associated with vehicle model year.

B. ESTIMATED FATALITIES AND FATALITY COSTS REPORTED IN THE NPRM

The results in Section II confirmed the basic model used to estimate fatalities and fatality related costs. The estimated fatalities are linearly related to the estimated vehicle miles traveled (VMT) predicted by the CAFE model. In turn the fatality related costs are linearly related to the estimated fatalities. Therefore many of the effects of the proposed rule on fatalities and fatality related costs predicted by the CAFE model can be traced to differences in the VMT predicted by the model.

The magnitudes of these effects are also dependent on the assumed fatality rates per VMT and to a lesser extent on the modeled changes in vehicle mass. As a result the estimated number of fatalities or fatality related costs can be decomposed into 4 components as indicted in Table 7:

- Fatalities or costs related to the standard:
    - Mass reduction related effects
    - Sales impact related effects
- Fatalities or costs due to rebound effects:
    - Mass reduction related effects
    - Non-mass reduction related effects.

The mass reduction related effects are equal to 0 if the assumed mass effect coefficients (e.g., Table 1) are equal to 0. The sales impact and non-mass reduction effects do not depend on the assumed values for mass effect coefficients. The mass reduction effects are small compared to the sales impact and non-mass reduction related effects.

C. UNCERTAINTIES IN THE ESTIMATED FATALITIES AND FATALITY COSTS REPORTED IN THE NPRM

The uncertainty in the CAFE Model fatality results were then investigated in Appendix A. Two sources of uncertainty were identified that could be quantified based on published uncertainties in the model inputs.

One is the uncertainty is due to the uncertainty in the assumed fatality rates per billion VMT reported in Table II-67 on page 43138 of the NPRM. Therefore the standard errors each of the safety parameters predicted by the CAFE model due to this effect can be calculated. For example, the estimated change in "subtotal" fatalities for the Alternative 1 – Existing standard is -6,344 fatalities. This value is rounded to -6,340 fatalities in Table II-73 of the NPRM. The standard error for this estimate due to this "F/VMT" source is 723 fatalities, as indicated in Table 20.

Another source of uncertainty is due to the uncertainty in the mass effect coefficients. Approximate standard errors were estimated by comparing the model output with all of the mass effect terms set to their lower and upper values for the 95% confidence interval. The resulting standard error for the -6,344 fatality estimate is 383 fatalities.

Assuming that these two sources of uncertainty are independent, the combined standard error is 818 fatalities. Therefore the 95% confidence interval for the estimated change in "subtotal" fatalities is -6,344 ± 2*818, which is -7,980 to -4,708. Using this approach, the change in the total societal cost that appears as a -88.3 $Billion cost in row (30) of Table 5 and a 88.3 $Billion benefit in Table 4 in has standard error of 11.0, or a 95% confidence interval of ±22.0.

These estimated standard errors do not include other sources of uncertainty in the model. These include uncertainty in the estimated vehicle sales, scrappage, and resulting vehicle population and VMT, the uncertainty in mass reduction and technology costs and the resulting use in new vehicles, uncertainty in energy and other vehicle operating costs, and uncertainty in the rebound effect.

D. LIMITATIONS OF THE CAFE MODEL

The Fatality model in the current CAFE model has a number of limitations. A major limitation is that it assumes that the fatality rate depends only on the vehicle model year. This ignores the safety benefits due to improvements in the crash compatibility and crash avoidance technologies of other vehicles on the roadway, improvements in roadway design, and improvements in emergency medical response that have occurred in the past and are expected to continue in the future. If the model is revised to address these factors, then the estimated differences in the existing and proposed standards are expected to substantially decrease.

Another limitation or concern is whether or not the fatalities include other road users such as pedestrians, bicyclists, or motorcyclist. The studies that estimated the effect of mass and size on fatalities (e.g., reported in Refs 4-6, etc.) used a methodology developed by Dr. Kahane that addressed all road users and avoided double counting. It also addressed different vehicle types.

The CAFE model does not currently account for the statistical uncertainty in the model inputs. The results in Refs 4 and 5, for example, estimated the 95% confidence intervals for the estimated effect using a jackknife method also developed by Dr. Kahane. This method might also be employed in the CAFE model.

E. RECOMMENDATIONS

The data used to develop the fatality risk versus VMT model should be made publicly available.

The fatality risk versus VMT model should be a function of both model year and calendar year. The model should also be parsimonious and should, in general, be a monotonically decreasing function of model year and calendar year.

The uncertainties in the CAFE model results should be evaluated using Monte Carlo or jackknife methods.

The reported sensitivity analysis for the CO2 standard needs to be corrected. CAFE model results for the Fatalities Flat Earlier sensitivity also needs to be corrected.

REFERENCES

1. 83 FR 42986, "The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021–2026 Passenger Cars and Light Trucks, Notice of Proposed Rulemaking," Federal Register, Vol. 83, No. 165, Washington, DC, August 24, 2018 (Docket Nos. EPA-HQ-OAR-2018-0283-0756 and NHTSA-2018-0067-2151).

2. PRIA, Preliminary Regulatory Impact Analysis, The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Year 2021 – 2026 Passenger Cars and Light Trucks, The National Highway Traffic Safety Administration, U.S. Department of Transportation, and the U.S. Environmental Protection Agency, Washington, DC, July 2018 (updated August 2018) (Docket Nos., NHTSA-2018-0067-1972 and EPA-HQ-OAR-2018-0283-0774).

3. 77 FR 62624, 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards, Final Rule, Federal Register, Vol. 77, No. 199, Washington, DC, October 15, 2012 (Docket Nos. EPA-HQ-OAR-2010-0799-12274 and NHTSA-2010-0131-0412).

4. Kahane, C.J., Relationships Between Fatality Risk, Mass, and Footprint in Model Year 2000-2007 Passenger Cars and LTVs, Final Report, DOT HS 811 665, National Highway Traffic Safety Administration, Washington, D.C., August 2012 (Docket No. NHTSA-2010-0152-0040).

5. Van Auken, R.M., and Zellner, J.W., Updated Analysis of the Effects of Passenger Vehicle Size and Weight On Safety, Phase II: Results Based on 2002 to 2008 Calendar Year Data for 2000 to 2007 Model Year Light Passenger Vehicles, DRI-TR-13-02, Dynamic Research, Inc., Torrance, CA, May 2013 (Docket No. NHTSA-2010-0152-0063).

6. Wenzel, T., An Analysis of the Relationship between Casualty Risk Per Crash and Vehicle Mass and Footprint for Model Year 2000-2007 Light-Duty Vehicles, LBNL-5697E, Lawrence Berkeley National Laboratory , Berkeley, CA, August 2012 (Docket No. NHTSA-2010-0152-0041).

7. 81 FR 87927, Proposed Determination on the Appropriateness of the Model Year 2022–2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards Under the Midterm Evaluation – Notice of Availability of a Proposed Order, Federal Register, Vol. 81, No. 234, Washington, DC, December 6, 2016.

8. Puckett, S.M., and Kindleberger, J.C., Relationships between Fatality Risk, Mass, and Footprint in Model Year 2003-2010 Passenger Cars and LTVs –

Preliminary Report, John A. Volpe National Transportation Systems Center for the National Highway Traffic Safety Administration, Washington, DC, June 2016 (Docket No. NHTSA-2016-0068-0012).

9. Wenzel, T., Assessment of NHTSA's Report "Relationships Between Fatality Risk, Mass, and Footprint in Model Year 2003-2010 Passenger Cars and LTVs", LBNL-1005177, Lawrence Berkeley National Laboratory , Berkeley, CA, June 2016 (Docket No. NHTSA-2016-0068-0006).

10. Shaulof, M., Bogard, D., Cooper, C., et al. Draft CAFE Model Documentation, John A. Volpe National Transportation Systems Center, Cambridge, MA, July 2018. (ftp://ftp.nhtsa.dot.gov/CAFE/2021-2026_CAFE_NPRM/CAFE_Model/CAFE_Model/CAFE_Model_Documentation_NPRM_2018.pdf, Accessed August 2018)

11. ftp://ftp.nhtsa.dot.gov/CAFE/2021-2016_CAFE_NPRM/

12. Box, B.E.P., Hunter, W.G., Hunter, 1.S., Statistics for Experimenters, John Wiley & Sons, New York, 1978.

13. Urdan, T.C., Statistics in Plain English, Second Edition, Lawrence Erlbaum Associates, Mahwah, NY, 2006.

14. Allison, P.D., Logistic Regression using SAS: Theory and Practice, SAS Institute, Cary, NC, 1999.

15. "National Accounts (NIPA), Table 1.1.9. Implicit Price Deflators for Gross Domestic Product," Bureau of Economic Analysis, Suitland, MD, https://apps.bea.gov/histdata/Releases/GDP_and_PI/2016/Q4/Third_March-30-2017/Section1all_xls.xls (accessed October 18, 2018).

16. Carter, A.A., Burgett, A., Srinivasan, G., and Ranganathan, R., "Safety Impact Methodology (SIM): Evaluation of Pre-Production Systems," Paper Number 09-0259, 21st International Technical Conference on the Enhanced Safety of Vehicles (ESV); Stuttgart, Germany, June 15-18, 2009.

17. Funke, J, Srinivasan, G, Ranganathan, R, and Burgett A., "Safety Impact Methodology (SIM): Application and Results of the Advanced Crash Avoidance Technologies (ACAT) Program," Paper Number 11-0367, 22nd International Technical Conference on the Enhanced Safety of Vehicles (ESV); Washington, DC, June 13-16, 2011.

18. "Proven Safety Countermeasures," https://safety.fhwa.dot.gov/provencountermeasures (Accessed 2018-09-19).

19. Richard, C.M., Magee, K., Bacon-Abdelmoteleb, P., and Brown, J.L., Countermeasures That Work: A Highway Safety Countermeasure Guide For State Highway Safety Offices, Ninth Edition, 2017, DOT HS 812 478, National Highway Traffic Safety Administration, Washington, DC, April 2018.

20. Kahane, C.J., Lives Saved by Vehicle Safety Technologies and Associated Federal Motor Vehicle Safety Standards, 1960 to 2012 – Passenger Cars and LTVs – With Reviews of 26 FMVSS and the Effectiveness of Their Associated Safety Technologies in Reducing Fatalities, Injuries, and Crashes, DOT HS 812 069, National Highway Traffic Safety Administration, Washington, DC, January 2015 (Docket No. NHTSA-2018-0067-0024).

21. Glassbrenner, D., An Analysis of Recent Improvements to Vehicle Safety, DOT HS 811 572, National Highway Traffic Safety Administration, Washington, DC, June 2012.

22. Draper, N.R., and Smith, H., Applied Regression Analysis, Second Edition, John Wiley & Sons, 1981.

23. Letter from Ellen Peter to Andrew Wheeler and Heidi King, "Re: Request for Documents ...," September 11, 2018 (Docket Nos. NHTSA-2017-0069-0487-2 and EPA-HQ-OAR-2018-0283-0883).

24. Wenzel, T., Assessment of NHTSA's Report "Relationships Between Fatality Risk, Mass, and Footprint in Model Year 2004-2011 Passenger Cars and LTVs", (LBNL Phase 1), LBNL-2001137, Lawrence Berkeley National Laboratory , Berkeley, CA, March 2018 (Docket No. EPA-HQ-OAR-2015-0827-11039-2).

25. Van Auken, R.M., and Zellner, J.W., A Further Assessment of the Effects of Vehicle Weight on Fatality Risk in Model Year 1985-98 Passenger Cars and 1985-97 Light Trucks, DRI-TR-03-01, Dynamic Research, Inc., Torrance, CA, January 2003 (Docket No. NHTSA-2003-16318-0003).

26. Kahane, C.J., Relationships Between Vehicle Size and Fatality Risk in Model Year 1985-93 Passenger Cars and Light Trucks, Technical Report No. DOT HS 808 570, National Highway Traffic Safety Administration, Washington, D.C., January 1997.

27. NHTSA, Motorcycle Antilock Braking Systems and Crash Risk Estimated from Case-Control, Comparisons, National Highway Traffic Safety Administration, Washington, D.C., July 7, 2010 (Docket No. NHTSA-2002-11950-0004).

28. Van Auken, R.M. and Zellner, J.W., "An Assessment of the Effects of Passenger Vehicle Weight and Size on Accident and Fatality Risk Based on

Data for 1991 through 2007 Model Year Vehicles," SAE Int. J. Trans. Safety 1(1):166-191, 2013, https://doi.org/10.4271/2013-01-0757.

APPENDIX A

STATISTICAL UNCERTAINTY IN THE ESTIMATED FATALITY EFFECTS AND COSTS

This appendix describes the uncertainty in the fatalities and fatality related costs estimated by the CAFE model due to two sources: the uncertainty in the assumed input fatality rate coefficients and the uncertainty in the mass reduction effect coefficients. This uncertainty is conditional on the assumption that the form of the fatality effects model described in Section I is correct, and that the VMT and vehicle mass reduction values are correct.

A. STATISTICAL SIGNIFICANCE LEVEL AND CONFIDENCE INTERVALS

The NPRM reported on page 43111 the statistical significance of several results at the 85-percent confidence level, which is unusual. A 95-percent confidence interval, which corresponds to a 0.05 level of statistical significance, is more commonly used and widely accepted. Box et al (1978, Ref 12) states on page 109 that *"A series of conventional "critical" significance levels is in common use. These levels correspond to probabilities representing varying degrees of skepticism. When the probability that a discrepancy as large as that observed, or larger, might occur is smaller than one of these critical probabilities, the discrepancy between observation and hypothesis is said to be "significant" at that level. As a guide, it could be said that, when one's attitude is a priori "neutral" to a particular type of discrepancy, one begins to be slightly suspicious of a discrepancy at the 0.20 level, somewhat convinced of its reality at the 0.05 level, and fairly confident of it at the 0.01 level."* Urdan (2006, Ref 13) states on page 62 that *"In the social sciences, the convention is to set that level at .05"* and *"The agreed-upon probability of .05 (symbolized as* $\alpha = .05$*) represents the Type I error rate that we, as researchers, are willing to accept before we conduct our statistical analysis."* The 95% percent confidence interval is also the default value for many statistical software packages such as SAS and SPSS (see Allison (1999, Ref 14), p 32).

The 95% confidence interval is approximately $\pm$ 2 standard errors. Therefore the total range of the 95% confidence interval is approximately 4 times the standard error.

B. UNCERTAINTY IN FATALITY RATE EFFECTS

One source of uncertainty in the number of fatalities estimated by the CAFE model is due to the uncertainty in the ''FatalityEstimate'' values in Eqn (1), which were assumed in the NPRM to only depend on the model year. This uncertainty can be estimated using the approach demonstrated by the example in Table 16. Each row in this table represents a model year indicated by column (A), except for the last row which is a total for all of the model years in the table. The range of model years is 1977 to 2029, which corresponds the range model years used in Tables I-4 and other related tables in the NPRM.

The values in columns (B) through (E) of Table 16 represent information that comes from Table II-67 on pages 43138-43139 of the NPRM. Columns (B) and (C) are model coefficient estimates and standard errors obtained directly from Table II-67. Table II-67 does not provide any information after the 2014 model year. The estimated fatality rate per billion VMT in column (D) are equal to the results in column (B) + 28.59, which is the intercept value also reported in Table II-67. The results in column (E) are the standard errors of the estimated fatality rates (C) divided by the point estimates (D), which is a relative measure of uncertainty in the estimates. It is assumed that values in column (E) after the 2014 model year are equal to the value for the 2014 model year, due to lack of other information. However the actual uncertainty in the fatality rate estimates for these years could be much larger.

The values in column (F) of Table 16 are based on the inputs to the CAFE model. Specifically these values are equal the "Fixed Effect" input values in the "Safety Values" worksheet plus 28.58895, which is a "hard coded" value in the CAFE model software. These values are identical to the values in column (D), to within the printed accuracy of Table II-67, for the 1977 to 2006 model years. The results then begin to diverge after the 2006 model year as illustrated in Figure 1. The results in column (G) = (E) * (F) represent the standard errors for the CAFE Model inputs. These values are also the same as the values in column (C) for the 1977 to 2006 model years, but then also diverge after the 2006 model year.

The values in columns (H) and (I) are the estimated differences between the Alternative 1 the Existing CAFE standards due to sales impacts. The results in column (H) are the differences in VMT, which for the purpose of this conditional analysis is assumed to be known. Note that while the differences in VMT are zero for model years 1977 to 1996, the modeled VMT values for the Alternative and Existing Standards are not zero. The differences in the estimated fatalities are listed in column (I), and the standard errors of the differences are listed in column (J). The values in these columns do not include any mass effects, so the results in column (I) = (F) * (H) according to Eqn (1). The standard errors in column (J) = (G) * abs(H). In general the results in column (J) = (E) * abs(I). This more general expression can be used when the results in column (I) include a relative mass effect.

The totals in columns (H) through (J) are calculated from the results for the individual model years. The total point estimates in columns (H) and (I) are equal the sum of the values for all of the model years. Assuming that the uncertainties for each model year are independent, then the total standard error in column (J) is equal to the square-root of the sum of the squared standard error values for each model year. The overall results for this example are that the change in the modeled VMT due to sales impacts for the Alternative 1 – Existing standard is -692 billion VMT, and the corresponding estimated net change in the fatalities due to sales impacts is -6,184 fatalities. The standard error of the estimated change in fatalities due to the uncertainties in the fatality rate coefficients is 721 fatalities. This result appears in row 10 of Table 20. The actual standard error due to this effect could be larger than 721 fatalities if the uncertainty in the 2014 model years is larger than the assumed values.

The results in Table 17 are similar to the results in Table 16 but for the CO2 standards.

Table 16. Example Calculation of the Uncertainty in the Estimated Change in Fatalities for the Alternative 1 CAFE Standard Compared to the Existing Standard

(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
Model Year	NPRM Table II-67 Information				CAFE Model Input		Alternative 1- Existing CAFE Sales Impact		
	Reported Value		Fatalities/B VMT		Fatalities/B VMT		Modeled B VMT	Estimated Fatalities	
	Esti-mate	Std. Error	PE	Relative SE	PE	SE	PE	PE	SE
1977	-2.24	3.425	26.35	0.1300	26.347	3.425	0.0	0.0	0.0
1978	-1.53	3.324	27.06	0.1228	27.063	3.324	0.0	0.0	0.0
1979	-4.46	3.268	24.13	0.1354	24.126	3.267	0.0	0.0	0.0
1980	-3.78	3.437	24.81	0.1385	24.813	3.437	0.0	0.0	0.0
1981	-2.88	3.380	25.71	0.1315	25.709	3.380	0.0	0.0	0.0
1982	-4.42	3.329	24.17	0.1377	24.171	3.329	0.0	0.0	0.0
1983	-4.93	3.236	23.66	0.1368	23.660	3.236	0.0	0.0	0.0
1984	-4.71	3.142	23.88	0.1316	23.879	3.142	0.0	0.0	0.0
1985	-4.78	3.113	23.81	0.1307	23.810	3.113	0.0	0.0	0.0
1986	-5.54	3.092	23.05	0.1341	23.045	3.091	0.0	0.0	0.0
1987	-5.86	3.086	22.73	0.1358	22.726	3.085	0.0	0.0	0.0
1988	-4.37	3.079	24.22	0.1271	24.216	3.078	0.0	0.0	0.0
1989	-4.78	3.074	23.81	0.1291	23.807	3.074	0.0	0.0	0.0
1990	-5.17	3.077	23.42	0.1314	23.418	3.077	0.0	0.0	0.0
1991	-5.84	3.072	22.75	0.1350	22.751	3.072	0.0	0.0	0.0
1992	-7.26	3.070	21.33	0.1439	21.327	3.070	0.0	0.0	0.0
1993	-7.92	3.062	20.67	0.1481	20.667	3.062	0.0	0.0	0.0
1994	-9.69	3.058	18.90	0.1618	18.904	3.059	0.0	0.0	0.0
1995	-10.61	3.053	17.98	0.1698	17.979	3.053	0.0	0.0	0.0
1996	-12.07	3.060	16.52	0.1852	16.519	3.060	0.0	0.0	0.0
1997	-12.80	3.056	15.79	0.1935	15.789	3.056	-0.1	-1.4	0.3
1998	-13.88	3.057	14.71	0.2078	14.709	3.057	-0.4	-6.4	1.3
1999	-14.91	3.055	13.68	0.2233	13.679	3.055	-1.1	-14.8	3.3
2000	-15.68	3.054	12.91	0.2366	12.909	3.054	-2.3	-30.1	7.1
2001	-16.33	3.059	12.26	0.2495	12.259	3.059	-3.8	-46.6	11.6
2002	-17.10	3.060	11.49	0.2663	11.489	3.060	-6.4	-73.6	19.6
2003	-17.70	3.065	10.89	0.2815	10.889	3.065	-9.0	-98.1	27.6
2004	-18.24	3.069	10.35	0.2965	10.349	3.069	-13.2	-136.2	40.4
2005	-18.91	3.074	9.68	0.3176	9.679	3.074	-17.4	-168.7	53.6
2006	-19.24	3.083	9.35	0.3297	9.349	3.083	-20.2	-188.4	62.1
2007	-19.85	3.090	8.74	0.3535	9.284	3.282	-24.8	-229.9	81.3
2008	-20.09	3.108	8.50	0.3656	9.220	3.371	-26.6	-245.3	89.7

2009	-20.11	3.170	8.48	0.3738	9.155	3.422	-20.7	-189.7	70.9
2010	-20.50	3.172	8.09	0.3921	9.090	3.564	-27.7	-251.5	98.6
2011	-20.74	3.196	7.85	0.4071	9.024	3.674	-33.1	-298.6	121.6
2012	-20.77	3.229	7.82	0.4129	8.959	3.699	-40.9	-366.0	151.1
2013	-21.49	3.294	7.10	0.4639	8.893	4.126	-49.8	-442.8	205.4
2014	-21.98	3.528	6.61	0.5337	8.827	4.711	-52.2	-460.7	245.9
2015	not available			0.5337	8.761	4.676	-55.4	-485.4	259.1
2016				0.5337	8.694	4.641	-51.9	-450.9	240.7
2017				0.5337	8.628	4.605	-50.9	-439.6	234.6
2018				0.5337	8.561	4.569	-46.3	-396.5	211.6
2019				0.5337	8.494	4.533	-44.1	-374.9	200.1
2020				0.5337	8.426	4.498	-40.0	-337.4	180.1
2021				0.5337	8.359	4.461	-32.1	-267.9	143.0
2022				0.5337	8.291	4.425	-23.8	-197.1	105.2
2023				0.5337	8.223	4.389	-17.1	-140.7	75.1
2024				0.5337	8.155	4.353	-6.6	-53.7	28.6
2025				0.5337	8.086	4.316	3.9	31.3	16.7
2026				0.5337	8.018	4.279	11.3	90.7	48.4
2027				0.5337	7.949	4.243	11.3	89.7	47.9
2028				0.5337	7.880	4.206	2.6	20.2	10.8
2029				0.5337	7.810	4.169	-2.9	-22.9	12.2
Total							**-691.7**	**-6183.7**	**721.0**

Note: CY 1977-2068

Table 17. Example Calculation of the Uncertainty in the Estimated Change in Fatalities for the Alternative 1 CO2 Standard Compared to the Existing Standard

(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
Model Year	NPRM Table II-67 Information				CAFE Model Input		Alternative 1- Existing CO2 Sales Impact		
	Reported Value		Fatalities/B VMT		Fatalities/B VMT		Modeled B VMT	Estimated Fatalities	
	Esti-mate	Std. Error	PE	Relative SE	PE	SE	PE	PE	SE
1977	-2.24	3.425	26.35	0.1300	26.347	3.425	0.0	0.0	0.0
1978	-1.53	3.324	27.06	0.1228	27.063	3.324	0.0	0.0	0.0
1979	-4.46	3.268	24.13	0.1354	24.126	3.267	0.0	0.0	0.0
1980	-3.78	3.437	24.81	0.1385	24.813	3.437	0.0	0.0	0.0
1981	-2.88	3.380	25.71	0.1315	25.709	3.380	0.0	0.0	0.0
1982	-4.42	3.329	24.17	0.1377	24.171	3.329	0.0	0.0	0.0
1983	-4.93	3.236	23.66	0.1368	23.660	3.236	0.0	0.0	0.0
1984	-4.71	3.142	23.88	0.1316	23.879	3.142	0.0	0.0	0.0
1985	-4.78	3.113	23.81	0.1307	23.810	3.113	0.0	0.0	0.0
1986	-5.54	3.092	23.05	0.1341	23.045	3.091	0.0	0.0	0.0
1987	-5.86	3.086	22.73	0.1358	22.726	3.085	0.0	0.0	0.0
1988	-4.37	3.079	24.22	0.1271	24.216	3.078	0.0	0.0	0.0
1989	-4.78	3.074	23.81	0.1291	23.807	3.074	0.0	0.0	0.0
1990	-5.17	3.077	23.42	0.1314	23.418	3.077	0.0	0.0	0.0
1991	-5.84	3.072	22.75	0.1350	22.751	3.072	0.0	0.0	0.0
1992	-7.26	3.070	21.33	0.1439	21.327	3.070	0.0	0.0	0.0
1993	-7.92	3.062	20.67	0.1481	20.667	3.062	0.0	0.0	0.0
1994	-9.69	3.058	18.90	0.1618	18.904	3.059	0.0	0.0	0.0
1995	-10.61	3.053	17.98	0.1698	17.979	3.053	0.0	0.0	0.0
1996	-12.07	3.060	16.52	0.1852	16.519	3.060	0.0	0.0	0.0
1997	-12.80	3.056	15.79	0.1935	15.789	3.056	-0.1	-1.0	0.2
1998	-13.88	3.057	14.71	0.2078	14.709	3.057	-0.4	-5.9	1.2
1999	-14.91	3.055	13.68	0.2233	13.679	3.055	-1.1	-14.7	3.3
2000	-15.68	3.054	12.91	0.2366	12.909	3.054	-2.4	-30.6	7.2
2001	-16.33	3.059	12.26	0.2495	12.259	3.059	-3.9	-47.2	11.8
2002	-17.10	3.060	11.49	0.2663	11.489	3.060	-6.5	-74.3	19.8
2003	-17.70	3.065	10.89	0.2815	10.889	3.065	-9.0	-98.5	27.7
2004	-18.24	3.069	10.35	0.2965	10.349	3.069	-13.4	-138.3	41.0
2005	-18.91	3.074	9.68	0.3176	9.679	3.074	-17.7	-171.7	54.5
2006	-19.24	3.083	9.35	0.3297	9.349	3.083	-20.7	-193.2	63.7
2007	-19.85	3.090	8.74	0.3535	9.284	3.282	-25.7	-238.2	84.2
2008	-20.09	3.108	8.50	0.3656	9.220	3.371	-28.0	-258.6	94.5

2009	-20.11	3.170	8.48	0.3738	9.155	3.422	-21.9	-200.7	75.0
2010	-20.50	3.172	8.09	0.3921	9.090	3.564	-30.0	-272.7	106.9
2011	-20.74	3.196	7.85	0.4071	9.024	3.674	-36.1	-325.5	132.5
2012	-20.77	3.229	7.82	0.4129	8.959	3.699	-44.5	-399.0	164.8
2013	-21.49	3.294	7.10	0.4639	8.893	4.126	-55.1	-489.8	227.2
2014	-21.98	3.528	6.61	0.5337	8.827	4.711	-59.1	-522.0	278.6
2015	not available			0.5337	8.761	4.676	-64.5	-564.8	301.5
2016				0.5337	8.694	4.641	-62.6	-544.6	290.7
2017				0.5337	8.628	4.605	-64.1	-552.9	295.1
2018				0.5337	8.561	4.569	-60.2	-515.5	275.1
2019				0.5337	8.494	4.533	-57.6	-489.5	261.3
2020				0.5337	8.426	4.498	-53.4	-449.8	240.1
2021				0.5337	8.359	4.461	-46.3	-386.8	206.5
2022				0.5337	8.291	4.425	-33.4	-276.6	147.7
2023				0.5337	8.223	4.389	-25.4	-208.9	111.5
2024				0.5337	8.155	4.353	-18.0	-147.0	78.5
2025				0.5337	8.086	4.316	-11.5	-93.1	49.7
2026				0.5337	8.018	4.279	-2.7	-21.6	11.5
2027				0.5337	7.949	4.243	-0.9	-6.8	3.6
2028				0.5337	7.880	4.206	-3.4	-27.2	14.5
2029				0.5337	7.810	4.169	-3.0	-23.4	12.5
Total							**-882.5**	**-7790.7**	**875.9**

Note: CY 1977-2068

C. UNCERTAINTY IN MASS REDUCTION EFFECTS

Another source of uncertainty in the number of fatalities estimated by the CAFE model is due to the uncertainty in the "ChangePer100lbs" value in Eqn (1). This mass effect coefficient depends on the vehicle type and mass. Columns (F) and (G) in Table 1 lists the point estimate and 95% confidence interval for the ChangePer100lbs values depending on the vehicle type and mass category. The total number of fatalities estimated by the CAFE model are based on a combination of all five of these mass effect coefficients. Therefore the total fatalities is an unknown linear combination of these five mass effect coefficients. Ideally we could estimate the uncertainty in the number of fatalities calculated by the CAFE model using the same "jackknife" confidence interval calculation method that was used to estimate the confidence intervals in column (G) of Table 1, however the needed information is not currently available.

Another approach is to estimate the standard errors based on the "safety coefficient" sensitivity cases reported on page 43363 of the NPRM. This approach assumes that the uncertainties in each of the five mass effect coefficients are independent and equally weighted. This approach also assumes that the 2½% and 97½% sensitivity cases reported in the NPRM are the most extreme combinations of mass effect coefficient values.[11]

The mass effect uncertainty calculation is illustrated by the example in Table 18. The results in column (B) are the baseline results for the difference between the Alternative 1 and Existing CAFE standards, e.g., Table 5 and Table 7. These results are based on the mass effect coefficients listed in the first five rows of the table, which are inputs to the CAFE model. The results in columns (C) and (D) are based on the mass effect coefficients at the 2½% and 97½% values reported in Table II-45 on page 43111 of the NPRM. Therefore the results for rows (10) and (14) in columns (C) and (D) also appear in the table on page 43363 of the NPRM.

Column (E) lists the range of the results in columns (C) and (D). This value is equal to the absolute value of (D)−(C).

The number of independent terms that contribute to the range in column (E) is listed in column (F). The value each of the input terms is 1 because each term is independent of the others. The values for the model output terms is 5 because they results are based on a combination of the 5 input terms.

Finally, the estimated standard error is listed in column (G). This value is equal to the range in column (E) divided by 4 times the square root of number of independent terms in column (F). If there is only 1 independent term then the total range of the 95% confidence interval is approximately 4 times the standard error. If there are 5 equally weighted and independent mass effect terms, then the standard error of the combined result is $\sqrt{5}$ times the standard error of the individual terms. However the estimates in columns (C) and (D) were obtained by setting all of the

[11] The lower and upper bounds of the 95% confidence interval are incorrectly labeled as the "Safety Coefficient at 5th Percentile" and "Safety Coefficient at 95th Percentile" in the Tables on pages 43363 and 43365. The correct labels are the "Safety Coefficient at 2½th Percentile" and "Safety Coefficient at 97½th Percentile", which represent a 95% confidence interval.

input values to their lower and upper bound values that the same time. Therefore the standard error of the combined result is 5 times the standard error of the individual terms. Therefore the standard error of the estimate is approximately $\sqrt{5}/(5\times 4)$ times the values in column (E).

The example results in Table 19 are similar to the example results in Table 18 but for the CO2 standards.

Table 18. Example Calculation of the Uncertainty in the CAFE Model CAFE Standard Results due to Uncertainty in the Estimated Mass Effect Coefficients

	(A)	(B)	(C)	(D)	(E)	(F)	(G)
Row	Safety Parameter	Change in Total Safety Parameter Values for Alt 1 from Existing CAFE Standards, MY 1977-2029, CY 1977-2068, 3% Discount Rate					
		Baseline	2.5%	97.5%	Range = |(D)-(C)|	No. Indep. Terms	SE
	Mass Effect Coefficient						
	Lighter PCs	1.20%	-0.35%	2.75%	3.10%	1	0.78%
	Heavier PCs	0.42%	-0.67%	1.50%	2.17%	1	0.54%
	CUVs and minivans	-0.25%	-1.55%	1.04%	2.59%	1	0.65%
	Lighter Truck-based LTVs	0.31%	-0.51%	1.13%	1.64%	1	0.41%
	Heavier Truck-based LTVs	-0.61%	-1.46%	0.25%	1.71%	1	0.43%
	VMT (Billion miles)						
(3)	Subtotal CAFE Atrb.	-692	-692	-692	0	5	0
(6)	Rebound Effect	-776	-776	-776	0	5	0
(7)	Total (Billion miles)	-1,468	-1,468	-1,468	0	5	0
	Fatalities						
(8)	Mass Changes	-160	1,554	-1,870	3424	5	383
(9)	Sales Impacts	-6,184	-6,184	-6,184	0	5	0
(10)	Subtotal CAFE Atrb.	-6,344	-4,629	-8,054	3424	5	383
(11)	Rebound Effect (ME)	-72	60	-204	263	5	29
(12)	Rebound Effect (no ME)	-6,264	-6,264	-6,264	0	5	0
(13)	Rebound Effect	-6,335	-6,204	-6,467	263	5	29
(14)	Total	-12,680	-10,833	-14,521	3688	5	412
	Fatalities Societal $B						
(15)	Mass Changes	-0.9	10.0	-11.8	21.8	5	2.4
(16)	Sales Impacts	-34.4	-34.4	-34.4	0.0	5	0.0
(17)	Subtotal CAFE Atrb.	-35.4	-24.4	-46.3	21.8	5	2.4
(18)	Rebound Effect (ME)	-0.5	0.4	-1.3	1.7	5	0.2
(19)	Rebound Effect (no ME)	-41.2	-41.2	-41.2	0.0	5	0.0
(20)	Rebound Effect	-41.7	-40.8	-42.5	1.7	5	0.2
(21)	Total	-77.0	-65.2	-88.8	23.5	5	2.6

Table 19. Example Calculation of the Uncertainty in the CAFE Model CO2 Standard Results due to Uncertainty in the Estimated Mass Effect Coefficients

	(A)	(B)	(C)	(D)	(E)	(F)	(G)
Row	Safety Parameter	Change in Total Safety Parameter Values for Alt 1 from Existing CO2 Standards, MY 1977-2029, CY 1977-2068, 3% Discount Rate					
		Baseline	2.5%	97.5%	Range = |(D)-(C)|	No. Indep. Terms	SE
	Mass Effect Coefficient						
	Lighter PCs	1.20%	-0.35%	2.75%	3.10%	1	0.78%
	Heavier PCs	0.42%	-0.67%	1.50%	2.17%	1	0.54%
	CUVs and minivans	-0.25%	-1.55%	1.04%	2.59%	1	0.65%
	Lighter Truck-based LTVs	0.31%	-0.51%	1.13%	1.64%	1	0.41%
	Heavier Truck-based LTVs	-0.61%	-1.46%	0.25%	1.71%	1	0.43%
	VMT (Billion miles)						
(3)	Subtotal CAFE Atrb.	-883	-883	-883	0	5	0
(6)	Rebound Effect	-896	-896	-896	0	5	0
(7)	Total (Billion miles)	-1,778	-1,778	-1,778	0	5	0
	Fatalities						
(8)	Mass Changes	-467	2,312	-3,235	5547	5	620
(9)	Sales Impacts	-7,791	-7,791	-7,791	0	5	0
(10)	Subtotal CAFE Atrb.	-8,258	-5,479	-11,026	5547	5	620
(11)	Rebound Effect (ME)	-80	76	-237	313	5	35
(12)	Rebound Effect (no ME)	-7,220	-7,220	-7,220	0	5	0
(13)	Rebound Effect	-7,300	-7,143	-7,456	313	5	35
(14)	Total	-15,558	-12,622	-18,482	5860	5	655
	Fatalities Societal $B						
(15)	Mass Changes	-2.9	14.8	-20.6	35.4	5	4.0
(16)	Sales Impacts	-42.9	-42.9	-42.9	0.0	5	0.0
(17)	Subtotal CAFE Atrb.	-45.8	-28.0	-63.4	35.4	5	4.0
(18)	Rebound Effect (ME)	-0.5	0.5	-1.5	2.0	5	0.2
(19)	Rebound Effect (no ME)	-47.3	-47.3	-47.3	0.0	5	0.0
(20)	Rebound Effect	-47.8	-46.8	-48.8	2.0	5	0.2
(21)	Total	-93.6	-74.8	-112.2	37.4	5	4.2

D. COMBINED CONDITIONAL UNCERTAINTY

The conditional uncertainty results are summarized in Table 20 and Table 21. Columns (B) and (C) list the point estimates for the Existing and Alternative 1 standards, and column (D) the difference between columns (C) and (B). The last three columns list the standard errors for the difference between the two standards. Column (E) lists the standard error due to the uncertainty in the estimated model year fatality rates. The value in row (9) of Table 20 is directly from the total row of Table 16. Likewise the corresponding value in Table 21 is directly from the total row of Table 17. Column (F) lists the standard error due to the uncertainty in the mass effect coefficients. The values in column (F) of Table 20 are directly from column (G) of Table 18. Likewise the values in column (F) of Table 21 are directly from Table 19. Column (G) of Table 20 and Table 21 lists the combined standard error estimate for these two sources of uncertainty. The values are equal to the standard the square root of the sum-of-squares of the results in columns (E) and (F). These estimates based on the assumption that there are no other sources of uncertainty, including any uncertainty in the modeled VMT.

Table 20. Conditional Uncertainty in the CAFE Model CAFE Standard Results Due to Uncertainty in the Fatality Rate and Mass Effect Coefficients

	(A)	(B)	(C)	(D)	(E)	(F)	(G)
Row	Safety Parameter	Comparison of Safety Parameters for Existing and Alternative 1 CAFE Standards for MY 1977-2029 and CY 1977-2068					
		Existing	Alt 1	Alternative 1 - Existing			
		Point Estimate	Point Estimate	Point Estimate	Standard Error		
					F/VMT	ME	Combined
	VMT (Billion miles)						
(3)	Subtotal CAFE Atrb.	126,771	126,079	-692	0	0	0
(7)	Total (Billion miles)	122,317	120,849	-1,468	0	0	0
	Fatalities						
(8)	Mass Changes	4,026	3,866	-160	30	383	384
(9)	Sales Impacts	1,716,834	1,710,650	-6,184	721	0	721
(10)	Subtotal CAFE Atrb.	1,720,860	1,714,516	-6,344	723	383	818
(11)	Rebound Effect (ME)	108	36	-72	12	29	32
(12)	Rebound Effect (no ME)	-69,178	-75,441	-6,264	1,061	0	1,061
(13)	Rebound Effect	-69,070	-75,406	-6,335	1,073	29	1,074
(14)	Total	1,651,790	1,639,110	-12,680	1,399	412	1,459
	Fatalities Societal $B						
(15)	Mass Changes	28.0	27.1	-0.9	0.2	2.4	2.4
(16)	Sales Impacts	15,773.1	15,738.6	-34.4	4.3	0.0	4.3
(17)	Subtotal CAFE Atrb.	15,801.1	15,765.7	-35.4	4.3	2.4	4.9
(18)	Rebound Effect (ME)	0.7	0.2	-0.5	0.1	0.2	0.2
(19)	Rebound Effect (no ME)	-691.3	-732.5	-41.2	6.9	0.0	6.9
(20)	Rebound Effect	-690.6	-732.2	-41.7	6.9	0.2	6.9
(21)	Total	15,110.5	15,033.5	-77.0	8.2	2.6	8.6
	Total Societal $B						
(29)	Mass Changes	71.9	69.5	-2.4	0.5	6.3	6.3
(30)	Sales Impacts	40,443.7	40,355.5	-88.3	11.0	0.0	11.0
(31)	Subtotal CAFE Atrb.	40,515.6	40,424.9	-90.7	11.0	6.3	12.6
(32)	Rebound Effect (ME)	1.8	0.6	-1.2	0.2	0.5	0.5
(33)	Rebound Effect (no ME)	-1,772.5	-1,878.1	-105.6	17.6	0.0	17.6
(34)	Rebound Effect	-1,770.7	-1,877.5	-106.8	17.8	0.5	17.8
(35)	Total	38,744.9	38,547.4	-197.5	21.1	6.7	22.2

Note: The results for Nonfatal Societal Costs in rows (22) to (28) are not listed because they can be calculated from the Total Societal Costs in rows (29) to (35) – Fatalities Societal Costs in rows (15) to (21).

Table 21. Conditional Uncertainty in the CAFE Model CO2 Standard Results Due to Uncertainty in the Fatality Rate and Mass Effect Coefficients

	(A)	(B)	(C)	(D)	(E)	(F)	(G)
Row	Safety Parameter	Comparison of Safety Parameters for Existing and Alternative 1 CAFE Standards for MY 1977-2029 and CY 1977-2068					
		Existing	Alt 1	Alternative 1 - Existing			
		Point	Point	Point	Standard Error		
		Estimate	Estimate	Estimate	F/VMT	ME	Combined
	VMT (Billion miles)						
(7)	Total (Billion miles)	122,360	120,582	-1,778	0	0	0
	Fatalities						
(8)	Mass Changes	4,097	3,630	-467	80	620	625
(9)	Sales Impacts	1,717,494	1,709,703	-7,791	876	0	876
(10)	Subtotal CAFE Atrb.	1,721,591	1,713,333	-8,258	899	620	1,092
(11)	Rebound Effect (ME)	101	21	-80	14	35	38
(12)	Rebound Effect (no ME)	-69,549	-76,768	-7,220	1,238	0	1,238
(13)	Rebound Effect	-69,447	-76,747	-7,300	1,252	35	1,252
(14)	Total	1,652,143	1,636,586	-15,558	1,774	655	1,891
	Fatalities Societal $B						
(15)	Mass Changes	28.4	25.5	-2.9	0.5	4.0	4.0
(16)	Sales Impacts	15,775.9	15,733.1	-42.9	5.0	0.0	5.0
(17)	Subtotal CAFE Atrb.	15,804.3	15,758.6	-45.8	5.1	4.0	6.4
(18)	Rebound Effect (ME)	0.7	0.1	-0.5	0.1	0.2	0.2
(19)	Rebound Effect (no ME)	-694.2	-741.5	-47.3	7.9	0.0	7.9
(20)	Rebound Effect	-693.5	-741.3	-47.8	8.0	0.2	8.0
(21)	Total	15,110.8	15,017.2	-93.6	10.3	4.2	11.1
	Total Societal $B						
(29)	Mass Changes	72.9	65.4	-7.5	1.3	10.1	10.2
(30)	Sales Impacts	40,451.1	40,341.2	-109.9	12.9	0.0	12.9
(31)	Subtotal CAFE Atrb.	40,523.9	40,406.6	-117.4	13.0	10.1	16.5
(32)	Rebound Effect (ME)	1.7	0.4	-1.3	0.2	0.6	0.6
(33)	Rebound Effect (no ME)	-1,780.0	-1,901.2	-121.2	20.4	0.0	20.4
(34)	Rebound Effect	-1,778.3	-1,900.9	-122.5	20.6	0.6	20.6
(35)	Total	38,745.6	38,505.7	-239.9	26.5	10.7	28.6

Note: The results for Nonfatal Societal Costs in rows (22) to (28) are not listed because they can be calculated from the Total Societal Costs in rows (29) to (35) – Fatalities Societal Costs in rows (15) to (21).