Strategies to Improve Traffic Safety in the United States and Comments on Safety Impacts of Potential Rollback of Vehicle Efficiency Standards

David R. Ragland, PhD, MPH

Safe Transportation Research and Education Center (SafeTREC)

University of California, Berkeley

October 23, 2018

Professional Experience:

In 2000 I founded the UC Berkeley Traffic Safety Center, now called the Safe Transportation Research and Education Center (SafeTREC), which conducts research on transportation practices, evaluates new technologies for road safety, and analyzes transportation policy (https://safetrec.berkeley.edu/). I have been the Principle Investigator on numerous projects funded at SafeTREC (more than $30M since 2000), and have authored or co-authored more than 100 technical reports and peer-reviewed publications in the traffic safety arena (SafeTREC Publications). I have also advised state and federal transportation agencies on issues of transportation safety, including collision analysis, data collection, and safety for vulnerable populations such as pedestrians and bicyclists. I also co-teach two graduate level courses: (i) Injury Prevention and Control (Injury Prevention and Control (SPH) , which examines traffic safety from a public health viewpoint, and (ii) Traffic Safety and Injury Control (Traffic Safety (CE), which investigates traffic safety from an engineering perspective. Through our courses and seminars, and via student involvement in research, we have introduced several hundred students to various aspects of traffic safety. Many are now working in transportation-related professions in universities, transportation agencies, or consulting firms.

Work Performed to Reach Conclusions in the Following Comments

Original analysis involving statistical modeling of the relationships between emission and fuel efficiency standards and safety is beyond the scope of this report. Instead, the report represents my conclusions after reviewing existing agency documents and the extensive literature describing relevant research, including the following:

(i) (EPA and NHTSA, *The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021–2026 Passenger Cars and Light Trucks* (August 24, 2018) volume 83, No. 165, Federal Register. <https://www.federalregister.gov/documents/2018/08/24/2018-18418/the-safer-affordable-fuel-efficient-safe-vehicles-rule-for-model-years-2021-2026-passenger-cars-and>)

(ii) Other documents prepared by NHTSA and/or EPA in conjunction with the domain of emission and fuel efficiency standards from 2012 up to the August 24, 2018 document.

(iii) Governmental reports from NHTSA, FHWA, CDC, and elsewhere on topics pertaining to the impacts of fuel efficiency and emission standards.

(iv) Peer reviewed publications related to impacts of fuel efficiency and emission standards and safety.

Documents and reports reviewed are referenced in the report, and online links to these reports are provided in the References section. Although the opinions and conclusions in the report are mine, I was assisted in the review by SafeTREC staff, particularly Aditya Medury and Katherine Chen, research associates at SafeTREC.

Table of Contents

Executive Summary

The existing greenhouse gas emissions and existing corporate average fuel economy (CAFE) standards for passenger cars and light trucks, negotiated in 2012 (EPA and NHTSA, 2012), as part of a harmonized program, reduce fuel costs for consumers, reduce overall fuel use in the U.S., and reduce CO2 and other tailpipe emissions. The National Highway Traffic Safety Administration (NHTSA) and the Environmental Protection Agency (EPA) (the Agencies) issued the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks in August 2018, which proposes to roll back existing CAFE standards for model years (MYs) 2021-2026.[1] A rationale for the federal proposal is the assertion that existing CAFE standards would increase roadway fatalities after 2020 compared with freezing standards at 2020 levels.

This purpose of this report is to:

- Describe strategies that are currently or could be implemented and/or accelerated to increase safety benefits that far outweigh any potential adverse impacts of existing CAFE standards.
- Measure these strategies against the Agencies' assertions of increased fatalities under existing CAFE standards, and describe a potential increase in horsepower under a MPG rollback that may increase fatalities.

Policies/Countermeasures to Increase Traffic Safety Going Forward

An underlying theme in road safety is the move toward a system in which deaths and injuries are prevented entirely. The means for achieving this goal tends to revolve around three general strategies (e.g., Ecola, 2018, Hakkert & Gitelman, 2014), which, if pursued vigorously, hold tremendous promise in reducing traffic fatalities and injuries and possibly eliminating them within the foreseeable future:

1. Promote Accelerated Implementation of Proven Countermeasures
2. Support Advanced Technology
3. Promote Safe System/Toward Zero Deaths Policies

1. Promote Accelerated Implementation of Proven Countermeasures

Numerous factors have contributed to the dramatic increase in road safety over the past century (NHTSA, 2018a). These include seat belts, alcohol-related legislation such as 0.08 Blood Alcohol Concentration (BAC) levels, minimum drinking age laws, lower speed limits, High Visibility Enforcement, and roadway engineering treatments to reduce speeding, such as roundabouts. Detailed descriptions of these and many other countermeasures are maintained by NHTSA (Richard et al., 2018), the Federal Highway Administration (FHWA) (FHWA, 2017), and the Centers for Disease Control and Prevention (CDC) (CDC, 2017). Despite historic gains, major safety challenges remain, including impaired driving (10,497 deaths in 2016, 28% of the total), speeding (10,111 deaths, 27% of the total), and unrestrained passengers (10,428 deaths, 44% of the total in passenger vehicles) (NCSA, 2018a). Substantial safety

[1] EPA and NHTSA (2018). The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021–2026 Passenger Cars and Light Trucks. Federal Register / Vol. 83, No. 165 / Friday, August 24, 2018 / Proposed Rules. Hereafter, this report focuses on the CAFE standards proposed in the SAFE Vehicles Rule as compared to the existing standards for model year 2021 and the so-called "augural" standards for model years beginning in 2022, referred to as the existing or current fuel economy standards.

gains could be achieved with continued application of proven countermeasures for these and other factors.

2. Support Advanced Technology

We are heading into an era of major innovations in vehicle and infrastructure technology, such as partial or full automation of vehicles and infrastructure. These innovations will almost certainly have a significant impact on safety. Automated technologies have the potential to mitigate human error, which NHTSA reports is a leading factor in 94 percent of serious crashes (NHTSA, 2018b), thus saving many lives. Some have expressed caution about the emergence of automated driving technology (Litman, 2018), including safety hazards resulting from having both autonomous and non-autonomous vehicles on the road, system failure or hacking, possible increased risk taking, and potential for increased traffic. It is clear that automation will require dependable vehicle/infrastructure connectivity, which, in turn, will require collaboration among manufacturers and agencies responsible for vehicle and highway regulations. In Vision Safety 2.0, NHTSA (2017a) outlines an updated policy framework to help guide safe deployment of automated vehicles with the following policy goals:

- Encouraging new entrants and ideas that deliver safer vehicles.
- Streamlining Department regulatory processes to match the pace of private sector innovation.
- Supporting industry innovation and encouraging open communication with the public and stakeholders.

Although the pace of innovation is uncertain, there is broad consensus that technology, including but not limited to autonomous vehicles, will improve safety and mobility dramatically over the coming years.

3. Adopt Safe System/Toward Zero Deaths Policies

The "Safe System" approach is a holistic view of transportation network safety that was developed in Australia and which strives to build a system in which no road user can be severely or fatality injured. It is aligned with earlier concepts such as the Swedish Vision Zero and Dutch Sustainable Safety approaches, which have been credited with the rapid progress in road safety in those countries. In a study of 53 countries, "those that have taken a 'Safe System' based approach have achieved both the lowest rates of fatalities per 100,000 inhabitants and the greatest reduction in fatality levels over the past 20 years." (Welle, et al., 2018). Two major principles underlie a Safe System model. The first is acceptance that road user error or poor judgement is inevitable, and that the system (including vehicle and infrastructure) should be designed to protect or "forgive" the road user when this occurs. The second, and related, principle is that no death or serious injury is acceptable—that the occurrence of a fatality or serious injury represents a system failure. The approach incorporates established countermeasures in a systematic manner and includes safe vehicles, roadways, and road user behavior. NHTSA and other federal agencies, and many state and local transportation agencies have begun to embrace this approach (NHTSA, 2017b; FHWA, 2018a). NHTSA (2017b), for example, has documented progress toward zero deaths on a state-by-state basis.

Summary

Each of these three strategies alone—accelerating implementation of proven countermeasures, supporting advanced technology, and adopting a Safe Systems approach—can be effective in improving traffic safety. Together, their combined impact should lead to a new era of road safety in which we can see an end to traffic fatalities and injuries. Evolution of these strategies will require the cooperation and collaboration of multiple stakeholders, including federal, state, and local transportation agencies, private firms involved in vehicle design and highway infrastructure design, and non-governmental organizations with vested interests in road safety.

Comments on Impact of Potential Rollback of Vehicle Efficiency Standards on Safety

The existing greenhouse gas emissions and existing CAFE standards would continue to reduce fuel costs for consumers, reduce overall fuel use in the U.S., and reduce CO2 and other tailpipe emissions. However, the rationale proposed by the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks is that they also contribute to fatalities, and that rolling back the standards would reduce these fatalities. Three assertions are made by the federal proposal: (i) decreased mass necessary to meet higher Miles per Gallon (MPG) standards would reduce safety of occupants in the event of a crash; (ii) increased vehicle costs for meeting the MPG standards would result in delayed purchase of new vehicles, reduced turnover, and an older, less safe fleet; and (iii) lower fuel costs would lead to increased miles of driving, which would increase crash risk.

Based on a review of the extensive relevant body of literature, this report considers aspects of these three arguments, adds another consideration based on projected horsepower under a rollback, and concludes that the adverse impact of current MPG standards has likely been overestimated in the federal proposal. The four considerations are as follows:

1. Mass reduction: Statistical uncertainty regarding method of estimating fatalities, and failure to consider the distribution of crash types
2. Fleet turnover: Failure to account for all relevant factors in assessing impacts of fleet turnover
3. Rebound effect: Failure to account for relevant factors in calculating impact of rebound effect
4. Horsepower: Failure to account for potential increased horsepower under the federal proposal

1. Mass Reduction: Statistical uncertainty regarding method of estimating fatalities, and failure to consider the distribution of crash types

The federal proposal asserts that mass reduction required to meet current MPG mandates from 2021 through 2026 would lead to excess traffic fatalities over the number expected with a rollback to 2020 MPG requirements. However, the degree to which mass reduction would be used to increase efficiency is not clear and is one source of uncertainty. Two issues arise concerning the calculation of mass reduction on safety used by the Agencies. First, it is not clear whether steps were taken to assure the statistical significance of parameters linking mass and fatality. In particular, some parameters were included in the estimation of impact of mass reduction on fatalities that had wide confidence intervals and were not significantly different from being interpreted as having zero impact for a given crash type (Puckett & Kindelberger, 2016). These issues increase the uncertainty about projections based on the modelling. Second, is the assumption put forth in the federal proposal that reducing the mass of passenger vehicles would lead to an increase in fatalities in crashes involving vulnerable road users. In contrast, reduction in mass of light trucks is expected to reduce fatalities in crashes involving vulnerable road users. Given the substantive difference in masses of cars/trucks and pedestrians/bicycles/

motorcycles, these contradictory findings for passenger vehicles and light trucks are non-intuitive (Evans, 2004). This issue is further compounded by the fact that the proportion of pedestrian and bicyclist fatalities has been increasing (NCSA, 2018b; NCSA, 2018b), and is likely to increase further given promotion of active transportation (walking and bicycling) modes of travel. Based on these considerations, the projected impact of possible mass reduction on fatalities is both more uncertain and likely overestimated in the Agencies' analyses.

2. Fleet Turnover: Failure to account for all relevant factors in assessing impacts of fleet turnover

The analyses in the federal proposal assert that allowing existing CAFE standards to increase for MYs 2021-2026 would lead to increased vehicle prices, resulting in slowed purchase of new vehicles, and therefore slower transition to newer, safer vehicles. However, the analyses fail to account for several relevant factors. Vehicle prices can increase not just because of efficiency improvements, but for many other factors as well, including increased number of safety features. In addition, during recent periods of higher fuel economy, vehicle sales have increased (CFA, 2018). The federal proposal states that "fatality rates have declined significantly because of technological safety improvements as well as behavior shifts such as increased seat belt use." In fact, seat belt use has risen dramatically over the past few decades independently of vehicle costs (NHTSA, 2017c). Estimates of crash risk of older vehicles depend on considerations other than age of vehicle. For example, older vehicles may be driven more by younger drivers, or in rural areas where fatalities per mile driven are higher (Zwerling et al., 2005). It is not clear whether the Agencies considered this and other variables in calculating the change in risk associated with model year.

3. Rebound Effect: Failure to account for relevant factors in calculating impact of rebound effect

The 2018 federal proposal asserts that existing CAFE standards would lead to decreased cost per mile of travel, leading to increased VMT, or a "rebound effect" whereby some of the savings in fuel is offset by increased driving. The federal proposal contends that this increase would lead to a rise in fatalities. Existing CAFE standards assume a rebound of 10 percent, while the federal proposal assumes a rebound of 20 percent. Recent analyses (e.g., Tierney and Hibbard, 2018) which exclude data from non-U.S. countries and include estimates that rely on odometer readings as opposed to self-report, suggest that the rebound effect is closer to 10 percent. For whatever value of rebound effect used, a calculation of VMT by risk per mile yields an estimate of an increase in fatalities proportionate to the rise in VMT. The federal analyses fail to account for relevant factors, including three of particular importance. First, (i) higher MPG vehicles will be newer and therefore have more safety features, reducing the risk per mile driven; (ii) a person who purchases a new and more efficient vehicle may also differ in driving habits; (iii) individuals who drive more have lower risk per mile (Janke, 1991; Antin et al., 2017). Any of these possibilities would reduce the impact of an increase in miles driven and therefore reduce the rebound effect. In summary, (i) a rebound effect in terms of extra miles traveled is likely closer to 10 percent than to the 20 percent assumed by the federal proposal because of the mitigating factors described above, and (ii) estimates of increased mortality based on a linear calculation of VMT by risk per mile are uncertain and likely to be overestimates. Therefore, fatalities due to a rebound effect are almost certainly exaggerated in the Agencies' calculations.

4. Horsepower: Failure to Account for Potential Increased Horsepower Under Federal Proposal

Although both MPG and horsepower have increased over the years, there is ultimately a tradeoff between them, with a lower MPG mandate facilitating the option of greater horsepower (HP). The federal proposal would allow or might even encourage increased hp/lb (EPA Trends, 2018), depending on how much manufacturers take advantage of reduced MPG goals and how much consumers value more HP. A similar effect occurred from 1985 to the early 2000s (EPA Trends, 2018). IIHS (2008) reports that "a 3-unit increase in horsepower per 100 pounds of vehicle weight was associated with a 38 percent increase in the likelihood of a vehicle exceeding the speed limit by more than 10 mph." Speed, in turn, remains a major factor in fatalities (NHTSA, 2016; NHTSA, 2018c), as well as in injuries and insurance costs (IIHS, 2008). Therefore, freezing MPG standards may increase fatalities and injuries through increased speed.

Summary

The Agencies' projections of increased fatality based on mass reduction, rebound effect, and fleet turnover under existing greenhouse gas emissions and existing CAFE standards are less certain than those being proposed, and, in some cases, may actually have the opposite impact asserted in the federal proposal. Implications for increased HP under a rollback of MPG standards, not considered by the Agencies, are that fatalities could actually increase compared with maintenance of existing standards.

Conclusions

Traffic fatality (and injury) rates have been declining throughout the entire history of the automobile, including during periods of improved fuel efficiency. The mileage death rate (MDR, or fatalities per 100 million vehicle miles), has decreased steadily at a rate of about 2 percent per year, from just over 24 in 1921 to just above 1 in 2016 (NHTSA, 2018d). Very substantial improvements in traffic safety continued even after the establishment of CAFE standards in 1975 (NHTSA, 2018d). Review of traffic safety strategies and impacts of existing greenhouse gas emissions and existing CAFE standards yields two conclusions. First, there are very promising strategies going forward for reducing traffic fatality and injury. Accelerating implementation of current proven safety countermeasures, supporting advanced emerging technology, and adopting Safe Systems/Toward Zero Deaths will, without doubt, hasten the decline in traffic deaths and injuries. Second, based on review of the extensive literature on the relationship between emission and fuel efficiency standards and safety, the Agencies' projections regarding fatalities under current efficiency mandates have a higher level of uncertainty than presented and likely overestimate the impact. In some respects, existing CAFE standards may actually yield more safety going forward.

Safety, in terms of risk per mile driven, increased substantially over previous periods of increased fuel efficiency. As observed from multiple perspectives, there does not appear to be an incompatibility of efficiency and safety.

Introduction

The federal proposal is the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks. It is cited as 83 Fed. Reg. 42,986 (Aug. 24, 2018). It presents several proposals to relax the greenhouse gas emissions and corporate average fuel economy (CAFE) standards for model years 2021 - 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).

The existing greenhouse gas emissions and existing CAFE standards, negotiated in 2012 (EPA and NHTSA, 2012), would reduce fuel costs for consumers, reduce overall fuel use in the U.S., and reduce CO2 and other tailpipe emissions.[2] However, a rationale for the federal proposal post-2020 is the assertion that existing CAFE standards would add 12,700 fatalities[3] over the lifetimes of vehicles through MY 2029.

This purpose of this report is to:

- Describe strategies that are currently or could be implemented and/or accelerated to increase safety benefits that far outweigh any potential adverse impacts of existing CAFE standards.
- Measure these strategies against the Agencies' assertions of increased fatalities under existing CAFE standards, and describe a potential increase in horsepower under a MPG rollback that may increase fatalities.

Increasing Traffic Safety in the United States—the Way Forward

Traffic Safety in the United States—1921 to the Present

Great strides have been made in reducing traffic fatality and injury over the past century. In the nearly 100 years since 1921, vehicle miles travelled (VMT) increased exponentially, while fatalities have fluctuated from a high of 55,600 in 1972 to 37,461 in 2016.[4] In addition, the mileage death rate (MDR, or fatalities per 100 million vehicle miles), has decreased steadily at a rate of about 2 percent per year, from just over 24 in 1921 to just above 1 in 2016 9 (NHTSA, 2018d). Very substantial improvements in traffic safety continued even after the establishment of CAFE standards in 1975 (NHTSA, 2018d). The Centers for Disease Control and Prevention (CDC) has identified improvement in traffic safety as one of the top ten public health successes of the 20th century (CDC, 1999).

---

[2] The federal proposal considers existing CAFE standards and tailpipe emission to be closely linked. Most of the discussion in the federal proposal about safety was linked to existing CAFE standards, and this report will direct its intentions accordingly.
[3] This report will focus on fatalities, with the understanding that the number of injuries is much greater, but generally parallel to fatalities.
[4] A recent low number of fatalities was reached in 2011, at 32,367. That low may have been brought about partly because of the recession starting in 2008, and the current increase may be partly driven by the economic recovery (He, 2016).

The increase in road safety over the past 100 years has saved a very large number of lives and reduced serious injury. However, challenges remain. First, despite steady improvement, 37,461 people were killed and an estimated 3,144,000 people were injured as a result of traffic crashes in 2016 (NCSA, 2018d). NHTSA estimated that in 2010 the direct economic cost of motor vehicle crashes was $242 billion. When quality of life factors were included, total estimated value of societal harm from motor vehicle crashes in the United States totaled $836 billion (Blincoe et al., 2015). Second, many developed countries have surpassed the U.S. in reducing road fatalities over the past several decades (Evans, 2014). In the early 1970s, the U.S. had the lowest number of deaths per number of registered vehicles as well as the lowest number of deaths per VMT out of 25 developed nations. By early 2010, the U.S. was 19th out of 26 developed countries in deaths per registered vehicles, and 13th out of 19 in the number of deaths per VMT. Although various factors among these countries (e.g., percentage of rural driving, population density) differ from the U.S. (Kahane, 2016), the relative change from 1970 is a cause for concern.

Policies/Countermeasures to Increase Traffic Safety Going Forward

An underlying theme in road safety is the move toward a system in which deaths and injuries are prevented entirely. The means for achieving this goal tends to revolve around three general strategies (e.g., Ecola, 2018, Hakkert & Gitelman, 2014), which, if pursued vigorously, hold tremendous promise in reducing traffic fatalities and injuries and possibly eliminating them within the foreseeable future:

1. Promote Accelerated Implementation of Proven Countermeasures
2. Support Advanced Technology
3. Promote Safe System/Toward Zero Deaths Policies

Table 1. Strategies for Improving Traffic Safety Going Forward

Strategy	Description
Promote Accelerated Implementation of Proven Countermeasures	A very large number of proven countermeasures addressing road user and infrastructure factors have been documented by NHTSA, FHWA, and CDC. Accelerating implementation would have a major impact on safety going forward.
Support Advanced Technology	Rapidly advancing technology for crash warning and crash avoidance for vehicles, infrastructure, and their interaction will greatly increase safety.
Promote Safe System/Toward Zero Deaths Policies	Adopting a framework of road safety with an emphasis on system design that accounts for, and mitigates, the role of road user behavior and susceptibility while promoting the principal that no death is acceptable should help direct and motivate efforts toward road safety.

1. Promote Accelerated Implementation of Proven Countermeasures

Numerous factors have contributed to the dramatic increase in road safety through the decades, including changes in road user factors, improved vehicle features, and roadway improvements. Road user factors include increased seat belt use and reduced impaired driving. Highway improvements include updated signal systems and signage, limited access highways, intersection upgrades, and roundabouts. Vehicle factors include early changes such as shatterproof glass, rear view mirrors, and installation of seat belts. Later changes included energy-absorbing design, advanced braking systems, and rear mounted taillights. More recently, vehicles have been equipped with crash warning systems, and crash avoidance systems. These changes represent a small fraction of the improvements that have improved safety over time. A historic view of traffic safety improvements is provided by NHTSA (2018a). Numerous examples of effective countermeasures are documented in published reports. For example, NHTSA (2017c) calculated that in 2016 alone 14,688 lives were saved by seat belts in passenger vehicles (occupants 5 years and older). An additional 2,456 lives would have been saved with 100-percent compliance.

Overall, alcohol-impaired driving dropped steadily from 1982 to about the year 2000. Much of the improvement was attributed to alcohol-related legislation during that time period, including 1.0 and then .08 blood alcohol content (BAC) limits, administrative license revocation, and minimum drinking age laws (Deng, 2008). During this same time, there was also a marked decline in the percentage of drivers who were found to be positive for alcohol impairment at roadside surveys (Berning et al., 2015). The percentage of drivers with BrACs of .08 and higher decreased from 7.5 percent in 1973 to 1.5 percent in 2013 - 2014. Comparable decreases were observed for the percentage of drivers from .005 - .049 and 0.50 - .079. There was also increased awareness of the issue of impaired driving, which was promoted by grassroots organizations such as Mothers Against Drunk Driving. In conjunction with the cumulative research on the risk of impaired driving, there was a strong movement of Federal and State laws and funding. A National Transportation Safety Board (NTSB) report (NHSB, 2013) describes the potential benefits of accelerating efforts to reduce impaired driving, including reducing 0.08 BAC limits to 0.05, increased high visibility enforcement, increased penalties for repeat offenders, and other related measures.

Following is list of strategic areas along with examples of specific laws or programs that have been evaluated. Studies vary with respect to effectiveness, cost, and confidence in findings. Detail on each of these can be found in an NHTSA guide summarizing available evidence on effectiveness and cost of a large array of countermeasures (Richard et al, 2018).

- Deterrence: Laws (e.g., open container laws, high BAC sanctions, BAC test refusal penalties, publicized sobriety checkpoints, high-visibility saturation patrols, preliminary breath test devices [PBTs], passive alcohol sensors, integrated enforcement)
- Deterrence: Prosecution and Adjudication (e.g., DWI courts, limits on diversion & plea agreements, court monitoring)
- Deterrence: DWI Offender Treatment, Monitoring, and Control (e.g., alcohol problem assessment and treatment, alcohol ignition interlocks, vehicle and license plate sanctions, DWI offender monitoring, 4.5 lower BAC limit for repeat offenders)
- Prevention, Intervention, Communications and Outreach (e.g., alcohol screening and brief intervention, mass-media campaigns, responsible beverage service, alternative transportation, designated drivers)
- Underage Drinking and Drinking and Driving (e.g., minimum drinking age 21 laws, zero-tolerance law enforcement, alcohol vendor compliance checks, other minimum legal drinking age 21 law enforcement)
- Drug-Impaired Driving (e.g., enforcement of drug-impaired driving)

The percentage of traffic fatalities in which one driver was speeding dropped from 32 percent in 2007 to 27 percent in 2016. Reducing vehicle speeds sharply decreases the probability of both fatalities and injuries (Richard et al., 2018). Enforcement-related countermeasures that are effective in reducing speed include lower speed limits, automated speed enforcement, and high visibility enforcement (Richard et al., 2018). A wide and varied range of highway engineering features are also effective in speed management, including surface treatments, dynamic and static signage, and roundabouts (FHWA, 2018b). Highway engineering features that are effective in speed management include:

- Vertical Deflections Within the Roadway (e.g., speed bumps)
- Horizontal Deflections/Roadway Narrowing (e.g., bulb outs, chicanes, center islands, lane narrowing)
- Surface Treatments and Markings (e.g., rumble strips, transverse bars)
- Vertical Delineation (e.g., landscaped medians)
- Dynamic Signing (e.g., speed activated speed limit signs, speed activated warning signs)
- Static Signing (chevron signs)
- Intersection Treatments (roundabouts)
- Gateway Entrance Treatments (to reduce entry speed into communities)

These examples are just a few of the proven countermeasures too numerous to be listed in this report. However, detailed descriptions of these countermeasures are maintained by NHTSA, FHWA, and CDC (Table 2). The sources listed in Table 2 describe conditions under which various countermeasures might be deployed and ratings of expected effectiveness. Crash modification factors (CMF) (i.e., percentage of crashes reduced with implementation), are listed for many of the countermeasures, and such factors can be used to calculate cost-benefit estimates. The documents demonstrate unequivocally that continued application of currently available proven countermeasures can extend the decades-long trends toward greater road safety.

There are few universal estimates of cost savings if sets of countermeasures were administered on a national scale—however, AAFTS issued a report in 2017 (AAAFTS, 2017) that projects the costs and benefits of meeting current infrastructure needs on a nationwide basis:

> "Cost-effective infrastructure investments (i.e., those for which the benefits exceed the costs) represent an opportunity to improve safety on U.S. highways and streets. This report makes a conservative estimate of such current infrastructure improvement needs. The estimates developed in this report indicate that current infrastructure improvement needs in the U.S. for the roadway types and functional classes listed above would cost $146 billion to address. If all of these needs were addressed, the present value of the 20-year safety benefits would be $348 billion, with a benefit-cost ratio of 2.4. In other words, benefits of $2.40 could be achieved for every $1.00 spent on infrastructure improvement. Addressing these needs could reduce 63,700 fatalities and more than 350,000 serious injuries over 20 years." (AAAFTS, 2017, Page 2).

Table 2. Documentation of Proven Countermeasures by NHTSA, FHWA, and CDC

Countermeasure Documentation	Brief Description
Countermeasures that work: A highway safety countermeasure guide for State Highway Safety Offices. National Highway Traffic Safety Administration (NHTSA). (Richard et al., 2018). Web Link: NHTSA Countermeasures that Work	The guide is a basic reference to assist State Highway Safety Offices (SHSOs) in selecting effective, evidence based countermeasures for traffic safety problem areas. "The guide describes major strategies and countermeasures that are relevant to SHSOs; summarizes strategy/countermeasure use, effectiveness, costs, and implementation time; and provides references to the most important research summaries and individual studies."
Crash Modification Clearinghouse (University of North Carolina) Web Link: CMF Clearinghouse	"The CMF Clearinghouse User Guide provides information about crash modification factor (CMF) basics for those unfamiliar with CMFs and guidance on how to conduct searches on the CMF Clearinghouse. It also provides advanced tips and functionality for more experienced users."
Office of Safety: Proven Safety Countermeasures, Federal Highway Administration (FHWA, 2017). Web Link: FHWA Proven Countermeasures	"This list of Proven Safety Countermeasures has now reached a total of 20 treatments and strategies that practitioners can implement to successfully address roadway departure, intersection, and pedestrian and bicycle crashes. Among the 20 Proven Safety Countermeasures are several crosscutting strategies that address multiple safety focus areas."
Motor Vehicle Safety Web Site, Centers for Disease Control (CDC). Web Link: CDC Motor Vehicle Safety	This web site provides statistics and countermeasures for a number of topic areas, including Child Passenger Safety, Seat Belts, Teen Drivers, Older Adult Drivers, Impaired Driving, Distracted Driving, Pedestrian Safety, Tribal Road Safety, Motorcycle Safety, Bicycle Safety

2. Support Advanced Technology

We are heading into an era of improved vehicle and infrastructure technology. The exact trajectory of this era cannot be charted precisely; however, there will almost certainly be major impacts on safety. Partial or full automation is a feature of much of this technology. According to a NHTSA website describing automation:

> "The safety benefits of automated vehicles are paramount. Automated vehicles' potential to save lives and reduce injuries is rooted in one critical and tragic fact: 94 percent of serious crashes are due to human error. Automated vehicles have the potential to remove human error from the crash equation, which will help protect drivers and passengers, as well as bicyclists and pedestrians. When you consider more than 35,092 people died in motor vehicle-related crashes in the U.S. in 2015, you begin to grasp the lifesaving benefits of driver assistance technologies." (NHTSA, 2018b).

A considerable amount of research is beginning to describe the safety benefits of various levels of emerging technology. For example, a recent AAAFTS report (Benson et al., 2018) examines the potential impacts of forward collision warning (FCW), automatic emergency braking (AEB), lane departure warning (LDW), lane keeping assistance (LKA), and blind spot warning (BSW) systems. The report does not attempt to specifically estimate the *number* of crashes that would be prevented if these technologies were implemented, but provides estimates of the *types* of crashes, injuries, and fatalities that potentially could be prevented based on the profile of crash types in 2016.

In the meantime, some reports have expressed caution about the emergence of automated driving technology (e.g., Litman, 2018). Concerns include safety hazards of traffic combining autonomous and non-autonomous vehicles, possible hardware or software failure, potential for hacking autonomous systems, and possible increased risk taking, among others. Other considerations include the potential for increased traffic (as a result of increased travelling convenience) and increased costs. It is clear that increased vehicle/infrastructure technology, including steps toward automation, will require collaboration among manufacturers and agencies responsible for vehicle and highway regulations. In Vision Safety 2.0, NHTSA (2017a) outlines an updated policy framework to help guide safety deployment of automated vehicles with the following policy goals:

- Encouraging new entrants and ideas that deliver safer vehicles.
- Streamlining Department regulatory processes to match the pace of private sector innovation.
- Supporting industry innovation and encouraging open communication with the public and stakeholders.

The exact trajectory of advanced technology, including autonomous vehicles is uncertain. However, there is wide consensus, that, in the coming decades, technology—including autonomous vehicles—will improve safety and mobility dramatically.

3. Adopt Safe System/Toward Zero Deaths Policies

The "Safe System" approach, is a holistic view of transportation network safety that was developed in Australia and which strives to build a system on which no road user can be severely or fatality injured. It is aligned with earlier concepts such as the Swedish Vision Zero, and the Dutch Sustainable Safety approaches, which have been credited with the rapid progress in road safety in those countries. In a study of 53 countries, "those that have taken a 'Safe System' based approach have achieved both the lowest rates of fatalities per 100,000 inhabitants and the greatest reduction in fatality levels over the past 20 years." (Welle, et al., 2018). Two major principles underlie a Safe System model. The first principle is acceptance that road user error or poor judgement is inevitable, and that the system (including vehicle and infrastructure) should be designed to protect or "forgive" the road user when this occurs. The second, and related, principle is that no death or serious injury is acceptable—that the occurrence of a fatality or serious injury represents a system failure.

The approach incorporates established countermeasures in a systematic manner and includes safe vehicles, safe roadways, and until these are accomplished, safer road user behavior. While the U.S. has been somewhat late in adopting Safe System/Vision Zero strategies, in recent years NHTSA and many state and local transportation agencies have begun to embrace various versions of this approach (NHTSA, 2017b; FHWA, 2018a). NHTSA (2018b), for example, has documented progress toward zero deaths on a state-by-state basis. US DOT, NHTSA, FHWA, FMCSA are all part of a Road to Zero coalition focused on strategies to end vehicle fatalities by 2050 (TZD, 2014).

A complementary approach is termed by FHWA a "systemic approach" to deploying highway improvements (FHWA, 2018c):

> "Agencies design highway safety improvement projects to improve safety by minimizing or eliminating risk to roadway users. Rather than managing risk at certain locations, a systemic approach takes a broader view and evaluates risk across an entire roadway system. A system-based approach acknowledges crashes alone are not always sufficient to determine what countermeasures to implement, particularly on low volume local and rural roadways where crash densities are lower, and in many urban areas where there are conflicts between vehicles and vulnerable road users (pedestrians, bicyclists, and motorcyclists)."

The approach is proactive, compared with the "hot spot" method which addresses locations only after the occurrence of a collision or series of collision.

Several federal programs mandated at the state level provide an organizational context for deployment of proven countermeasures and for supporting the principles of a Safe Systems/Toward Zero Deaths approach. A major example is the Strategic Highway Safety Plan (SHSP). Each state is required to develop a coordinated plan for reducing fatalities and serious injuries on public roads. The SHSP for each state convenes the major stakeholders for that state and develops a plan for coordination of efforts in the areas deemed most critical for that state. The SHSP is a requirement of the Highway Safety Improvement Program (HSIP) (23 U.S.C. § 148). Concurrently, states must also set safety targets for a set of performance measures to support the HSIP. A full description and relevant resources can be found at the FHWA SHSP web site: https://safety.fhwa.dot.gov/shsp/

Summary

Each of the three strategies alone—accelerating implementation of proven countermeasures, supporting technology, and adopting a Safe Systems approach—can be effective in improving traffic safety. Together, if coordinated and managed carefully, they should lead to a new era of road safety in which we can see an end to traffic fatalities and injuries. Evolution of these strategies will require the cooperation and collaboration of multiple stakeholders, including federal, state, and local transportation agencies, private firms involved in vehicle design and highway infrastructure design, and non-governmental organizations with vested interests in road safety.

Comments on Impact of Potential Rollback of Vehicle Efficiency Standards on Safety

Introduction

It is clear that maintaining existing greenhouse gas emissions and existing CAFE standards would accomplish the following:

- Reduce fuel costs for drivers
- Reduce fuel consumption in the U.S.
- Reduce tail pipe emissions, including CO2

However, the rationale proposed by the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks for rolling back CAFE standards post-2020 is that it would reduce highway fatalities that would allegedly result from continuation of the existing standards, based on the following three arguments: (i) decreased mass necessary to meet higher MPG will impact safety by reducing safety to occupants in the event of a crash; (ii) increase costs for higher MPH will increase cost of vehicles leading to reduced turnover and an older, less safe fleet; and (iii) lower fuel costs will result in increased miles driven which will increase crash risk.

Four Considerations Based on the NPRM Assertions

This report considers aspects of the three arguments above. In addition, the report addresses another consideration based on projected horsepower under a rollback. The four areas we examined are shown in Table 3.

Table 3. Four Considerations Based on the NPRM Assertions

Scenario	NPRM Assertion
Mass Reduction	The federal proposal asserts that mass reduction required to meet current MPG mandates from 2021 through 2026 would lead to excess traffic fatalities over the number expected with a rollback to 2020 MPG requirements.
Fleet Turnover	In the proposal, the Agencies assert that allowing CAFE standards to increase for MYs 2021-2026 would lead to increased vehicle prices, resulting in slowed purchase of new vehicles, and therefore slower transition to newer, safer vehicles.
Rebound Effect	The federal proposal asserts that current CAFE standards would lead to decreased cost per mile, leading to increased VMT, or a "rebound effect" whereby some of the savings in fuel is offset by increased driving, and in turn, that increased driving leads to increased fatalities.
Horsepower	Because of the tradeoff between MPG and HP, a lower MPG mandate under a rollback of existing standards would allow/encourage increased hp/lb. Increase hp/lb is associated with increased speed which in turn would yield increased fatalities.

Issues pertaining to each of the four areas are listed below and described in detail in the following sections.

- Mass reduction: Statistical uncertainty regarding method of estimating fatalities, and failure to consider the distribution of crash types
- Fleet turnover: Failure to account for all relevant factors in assessing impacts of fleet turnover
- Rebound effect: Failure to account for relevant factors in calculating impact of rebound effect
- Horsepower: Failure to account for potential increased horsepower under the federal proposal

Based on these issues, the report concludes that the impact of increased MPG standards has been overestimated in the federal proposal.

1. Mass Reduction: Statistical uncertainty regarding method of estimating fatalities, and failure to consider the distribution of crash types

In the federal proposal, the Agencies assert that mass reduction required to meet current MPG mandates from 2021 through 2026 would lead to excess traffic fatalities over the number expected with a rollback to 2020 MPG requirements. Reducing mass is one strategy among many potential strategies for increasing efficiency, although the degree to which mass reduction would be used to meet MPG mandates is not clear. However, it is important to consider how potential mass reduction would impact safety. In considering the rationale presented in the federal proposal, which proceed from different assumptions about mass and mass reduction, we comment on two key components of the fatality estimation:

- The statistical uncertainty in the method of estimating fatalities in the federal proposal
- Failure to consider the distribution of fatalities across crash types

Fatality estimates due to mass reduction given a crash type for a given vehicle class:

The fatality estimates for a given crash type and vehicle class are derived from a binary logistic regression (Kahane, 2012; Puckett and Kindelberger, 2016), which compares crashes from Fatality Analysis Reporting System (FARS) data that correspond to the given crash type and involve the vehicle class of interest with a crash dataset of non-fatal crashes obtained from 13 states (from which an indirect measure of exposure, referred to as induced exposure, is derived). One problem is in regards to the appropriateness of the induced exposure method used to generate the parameters. Since the suitability of this method relies on a set of assumptions to hold true (Jiang and Lyles, 2010), based on the best practices pertaining to induced exposure method as identified in the traffic safety literature (Jiang et al., 2011a and b; Jiang et al., 2014; Keall and Newstead, 2009), it is not clear whether steps were taken to assure the statistical significance of parameters linking mass and fatality in the Agencies' estimates. In particular, some parameters were included in the estimation of impact of mass reduction on fatalities which had wide confidence intervals and were thus not significantly different from being interpreted as having zero impact for a given crash type (Puckett & Kindelberger, 2016).

In addition, for crashes involving vulnerable road users (in particular, pedestrians, but also including bicyclists and motorcyclists), the logistic regression indicates that reducing the mass of passenger vehicles would lead to an increase in fatalities. However, from a physical standpoint, reducing the mass of the colliding vehicle with a pedestrian should, if anything, reduce the likelihood of a fatality (Evans, 2004). In relevant research, Kahane (2012) and Puckett and Kindelberger (2016) do not provide any justification for why an increase in fatalities due to mass reduction in passenger vehicles is valid, and not just a statistical manifestation owing to insufficient control variables and/or inappropriate exposure metrics when evaluating crashes involving pedestrians. Both of these concerns increase the uncertainty about projections based on the modelling.

Distribution of crash types for each vehicle class:
In order to obtain a combined estimate of the impact of mass reductions on fatality for a given vehicle class, prior relevant research (Kahane, 2012; Puckett and Kindelberger, 2016) computed a combined estimate by weighting the coefficients from each regression model by the fraction of fatalities associated with the given crash type and vehicle class. However, the proportion of traffic fatalities involving vulnerable road users has increased (NCSA, 2018b; NCSA, 2018c), and, with promotion of walking and biking (PBIC, 2018), may increase even more. Puckett and Kindelberger's 2016 model accounts for pedestrian, bicycles, and motorcycle collisions as one of nine crash types. However, their model only examined FARS data through 2011. Between 2011 and 2016, pedestrian, bicycle, and motorcycle fatalities increased 24.0 percent, while all other fatalities only increased 11.6 percent (FARS, 2018). Thus, the impact of vehicle mass reductions in the future must accommodate potential scenarios in which the crash mix may trend toward or away from the consistent increase in pedestrian/bicycle/motorcycle fatalities.

In summary, (i) questions about the modeling process used by the Agencies to generate estimates for model/crash type combinations introduce a large degree of uncertainty into the projected safety impacts of reduced mass, and (ii) the assumption that reduced mass increases fatalities for pedestrians overestimates the societal impact of potential impact of mass reduction. Therefore, calculated estimates of fatality via reduced mass are likely to be both less clear and more exaggerated in the federal proposal analyses.

2. Fleet turnover: Failure to account for all relevant factors in assessing impacts of fleet turnover

The federal proposal analyses assert that allowing existing CAFE standards to increase for MYs 2021-2026 would lead to increased vehicle prices, resulting in slowed purchase of new vehicles, and therefore slower transition to newer, safer vehicles. However, the analyses fail to account for several relevant factors. Vehicle prices can increase not just because of efficiency improvements, but for many other factors as well, including increased number of safety features. In addition, during recent periods of increased fuel economy vehicle sales have, in fact, increased (CFA, 2018). In the federal proposal, the Agencies state that "fatality rates have declined significantly because of technological safety improvements as well as behavior shifts such as increase seat belt use." However, seat belt use has increased dramatically over the past few decades independently of vehicle costs (NHTSA, 2017c). Estimates of crash risk of older vehicles may depend on factors other than age. For example, older vehicles may be driven more by younger drivers, or in rural areas where fatalities per mile driven are higher (Zwerling et al., 2005). A report by NHTSA (NHTSA, 2018f) found a relationship between vehicle age and fatality, but wasn't able to control for vehicle maintenance or driver behavior. Similarly, Blows, et al. (2013), studied vehicle age and injury using self-reported information, but the authors were not able to control for variables such as risk-taking behavior or socioeconomic status. It is not clear whether the Agencies have taken these variables into account in calculating the change in risk associated with model year in the federal proposal. The PRIA (NHTSA and EPA (2018) discusses demographic and driver behavior factors but does not include them in the analyses.

3. Rebound Effect: Failure to account for relevant factors in calculating impact of the rebound effect

In the federal proposal, the Agencies assert that existing CAFE standards would lead to decreased cost per mile, leading to increased VMT, or a "rebound effect" whereby some of the savings in fuel is offset by increased driving. And in turn, the increase driving would lead to increased fatalities.

In actual fact, cost per mile due to fuel expense is a relatively small fraction of the total cost per mile driven, approximately 20 percent. Nevertheless, there is evidence that increased efficiency can lead to increased miles driven. The existing CAFE standards assume a rebound of 10 percent and the federal proposal assumes 20 percent. While it is not the objective of the present study to review literature on the magnitude of the rebound effect, the size of the effect depends on the data used to generate an estimate. Recent analyses (e.g., Tierney and Hibbard, 2018) which exclude data from non-U.S. sources and include estimates that rely on odometer readings as opposed to self-report, suggest that the rebound effect is closer to 10 percent. The difference between 10 and 20 percent yields a considerable difference in exposure, and therefore in fatality estimates based on increased exposure.

For whatever value of rebound effect that is used, a linear calculation of VMT by risk per mile yields an estimate for an increase in fatalities proportionate to the increase in VMT. There are, however, several potential caveats. The federal agencies' analyses fail to account for three important factors when assessing the rebound effect. First, (i) higher MPG vehicles will be newer and therefore have more safety features, reducing the risk per mile driven; (ii) a person who purchases a new and more efficient vehicle may also differ in driving habits; and (iii) individuals who drive more have lower risk per mile (Janke, 1991; Antin et al., 2017). Any of these possibilities would reduce the impact of increase miles driven and therefore reduce the rebound effect.

In summary, (i) the rebound effect in terms of additional miles traveled with increased efficiency is likely to be closer to 10 percent than to the 20 percent assumed by the Agencies in the federal proposal, and (ii) estimates of increased mortality based on a linear calculation of VMT by risk per mile are uncertain and likely to be overestimates. Therefore, fatalities due to a rebound effect are almost certainly exaggerated in the federal proposal calculations.

4. Horsepower: Failure to account for potential increased horsepower under federal proposal

Although both MPG and horsepower have increased over the years, there is ultimately a tradeoff between them, with a lower MPG mandate facilitating the option of greater horsepower. The federal proposal would allow or even encourage increased hp/lb (EPA Trends, 2018), depending on how much manufacturers take advantage of reduced MPG goals and how much consumers value more HP. Such an effect occurred from 1985 to the early 2000s (EPA Trends, 2018)

The increase in HP could be viewed as an advantage of the revised MPG mandate. However, increased HP/lb is associated with increased speed (IIHS, 2016). For example, one analysis (IIHS, 2008) reports that "a 3-unit increase in horsepower per 100 pounds of vehicle weight was associated with a 38 percent increase in the likelihood of a vehicle exceeding the speed limit by more than 10 mph." Speed remains one of the most prevalent contributing factors in roadway fatalities (NHTSA, 2016; NHTSA, 2018c), and is also associated with crashes of all severity levels (NHTSA, 2016) as well as with increased insurance costs (IIHS, 2008). Therefore, lower MPG standards may increase fatalities and injuries through increased speed.

In summary, freezing the MPG mandate at the 2020 levels will potentially lead to increasing hp/lb, resulting in increased speeding, leading to increased fatality, injury, and insurance costs.

Summary

Projections of increased fatality based on vehicle mass reduction, the rebound effect, and fleet turnover are less certain than presented in the federal proposal, in some cases may actually be exaggerated, and in other cases may actually exert the opposite impact. Implications for increased HP under a rollback of MPG standards, not considered by the federal proposal, are that fatalities could actually increase compared with maintenance of existing standards.

Overall Conclusions

Overall traffic fatality (and injury) rates have been declining throughout the entire history of the automobile, including during periods of improved fuel efficiency. There are two primary conclusions from our review of road safety strategies and safety impacts in relation to efficiency rollbacks in the federal proposal.

First, there are very promising strategies going forward for reducing traffic fatality and injury. NHTSA, FHWA, CDC and others have identified many effective and economical countermeasures. Although most of these are already being implemented, more vigorous application of these countermeasures in the future will prevent additional traffic deaths and injuries. Emerging advanced technologies, such as autonomous vehicles, are likely to have a very positive impact on traffic safety. Finally, adoption of a Safe Systems/Toward Zero Deaths approach should help consolidate safety efforts under a comprehensive framework.

Second, based on review of the extensive relevant literature on the relationship between emission and efficiency standards and safety, the Agencies' calculations regarding increased fatalities under current efficiency mandates are more uncertain than presented, because they fail to account for all relevant factors that affect fatality rates, and likely overestimate fatality risk of existing CAFE standards. Overall, safety, in terms of risk per mile driven, increased substantially over a previous period of increased fuel efficiency. Therefore, observed from multiple perspectives, there does not appear to be an incompatibility of efficiency and safety. This past data suggests that the shortcomings in the federal analyses are fundamental and that conclusions presented in the federal proposal fail to demonstrate that the existing standards would decrease safety.

References

(Antin, et al., *A Validation of the Low Mileage Bias Using Naturalistic Driving Study Data* (2017) 63 Journal of Safety Research 115-120. <https://www.sciencedirect.com/science/article/pii/S0022437516303279?via%3Dihub> [as of October 9, 2018])

(Benson, et al., *Potential Reductions in Crashes, Injuries, and Deaths from Large-Scale Deployment of Advanced Driver Assistance Systems* (2018) <http://aaafoundation.org/wp-content/uploads/2018/09/18-0567_AAAFTS-ADAS-Potential-Benefits-Brief_v2.pdf> [as of October 9, 2018])

(Berning, et al., *Results of the 2013–2014 National Roadside Survey of alcohol and drug use by drivers* (2015) <https://trid.trb.org/view/1343065> [as of October 5, 2018])

(Blincoe, et al., *The economic and societal impact of motor vehicle crashes, 2010* (2015) <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812013> [as of October 7, 2018])

(Blows, et al., *Vehicle Year and the Risk of Car Crash Injury* (2003) volume 9, Issue 4, Injury Prevention. 353-356. <https://injuryprevention.bmj.com/content/injuryprev/9/4/353.full.pdf> [as of October 6, 2018])

(CDC, *Achievements in Public Health, 1900-1999 Motor-Vehicle Safety: A 20th Century Public Health Achievement* (1999) volume 48, No. 18, Morbidity and Mortality Weekly Report. 369-374. <https://www.cdc.gov/mmwr/preview/mmwrhtml/mm4818a1.htm> [as of October 9, 2018])

(Centers for Disease Control (CDC) *Motor Vehicle Safety Web Site* (n.d.). <https://www.cdc.gov/motorvehiclesafety/> [as of October 8, 2018])

(Chandraratna & Stamatiadis, *Quasi-induced exposure method: evaluation of not-at-fault assumption* (2009) volume 41, No. 2, Accident Analysis & Prevention. 308-313. <https://www.sciencedirect.com/science/article/pii/S000145750800239X?via%3Dihub> [as of October 7, 2018])

(Consumer Federation of America (CFA), *Fuel Economy Standards: There is No Tradeoff with Safety, Cost and Fleet Turnover* (2018) <https://consumerfed.org/press_release/study-cars-are-safer-and-sell-better-as-fuel-efficiency-improves/> [as of October 9, 2018])

(Dang, *Statistical Analysis of Alcohol-Related Driving Trends, 1982-2005* (2008) <https://trid.trb.org/view/860402> [as of October 6, 2018])

(Ecola, et al., *The Road to Zero: A Vision for Achieving Zero Roadway Deaths by 2050* (2018) <https://www.rand.org/pubs/research_reports/RR2333.html> [as of October 5, 2018])

(Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2017* (2018) <https://www.epa.gov/fuel-economy-trends> [as of October 7, 2018])

(EPA and NHTSA, *2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards* (October 15, 2012) volume 77, No. 199, Federal Register. <https://www.federalregister.gov/documents/2012/11/15/C1-2012-21972/2017-and-later-model-year-light-duty-vehicle-greenhouse-gas-emissions-and-corporate-average-fuel> [as of October 9, 2018])

(EPA and NHTSA, *The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021–2026 Passenger Cars and Light Trucks* (August 24, 2018) volume 83, No. 165, Federal Register. <https://www.federalregister.gov/documents/2018/08/24/2018-18418/the-safer-affordable-fuel-efficient-safe-vehicles-rule-for-model-years-2021-2026-passenger-cars-and https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812580> [as of October 9, 2018])

(Evans, Traffic Fatality Reductions: United States Compared With 25 Other Countries (2014) volume 104, No. 8, American Journal of Public Health. 1501-1507. <https://ajph.aphapublications.org/doi/abs/10.2105/AJPH.2014.301922> [as of October 6, 2018])

(*Fatality Analysis Reporting System* (FAR), <https://www.nhtsa.gov/research-data/fatality-analysis-reporting-system-fars> [as of October 9, 2018])

(FHWA, *A Systemic Approach to Safety* (2018c) <https://safety.fhwa.dot.gov/systemic/index.cfm>[as of October 7, 2018])<https://safety.fhwa.dot.gov/systemic/index.cfm>[as of October 7, 2018])

(FHWA, *Crash Modification Factors Clearinghouse* (2018b) <http://www.cmfclearinghouse.org/resources_analysis.cfm> [as of October 9, 2018])

(FHWA, *Office of Safety: Proven Safety Countermeasures* (2017) <https://safety.fhwa.dot.gov/provencountermeasures/> [as of October 7, 2018])

(FHWA, *Safety Culture and the Zero Deaths Vision* (2018a) <https://safety.fhwa.dot.gov/zerodeaths/> [as of October 6, 2018])

(Hakkert & Gitelman, *Thinking about the history of road safety research: Past achievements and future challenges* (2014) volume 25, Part B, Issue 0, Transportation Research Part F: Traffic Psychology and Behaviour, 137-149 <http://www.sciencedirect.com/science/article/pii/S1369847814000187> [as of October 8, 2018])

(Harwood, et al., *Safety Benefits of Highway Infrastructure Investments* (2017) <http://aaafoundation.org/safety-benefits-of-highway-infrastructure-investments/> [as of October 5, 2018])

(He, D*riving through the Great Recession: Why does motor vehicle fatality decrease when the economy slows down?* (2016) volume 155, Social Science and Medicine. 1-11. <https://trid.trb.org/view/1405278> [as of October 5, 2018])

(IIHS, *Insurance losses rise as automakers rev up horsepower* (2008) volume 43, No. 1, Status Report. <https://www.iihs.org/iihs/sr/statusreport/article/43/1/6> [as of October 7, 2018])

(IIHS, *Vehicles are packing more horsepower, and that pushes up travel speeds* (2016) volume 51, No. 5, Status Report. <https://www.iihs.org/iihs/sr/statusreport/article/51/5/2> [as of October 6, 2018])

(Janke, *Accidents, Mileage, and the Exaggeration of Risk (*1991) volume 23, Issue 2/3, Accident Analysis & Prevention. 183-188. <https://trid.trb.org/view/354244> [as of October 9, 2018])

(Jiang & Lyles, *A review of the validity of the underlying assumptions of quasi-induced exposure* (2010) volume 42, No. 4, Accident Analysis & Prevention. 1352-1358. <https://ac.els-cdn.com/S0001457510000618/1-s2.0-S0001457510000618-main.pdf?_tid=67205e40-1583-40a0-9ed7-d16d5fd2b553&acdnat=1537301139_72406813300737a6481a3bd45ae5db00> [as of October 5, 2018])

(Jiang, et al., *US National Household Travel Survey Used to Validate Exposure Estimates by the Quasi-Induced Exposure Technique* (2011b) 2237(1) Transportation Research Record. 152-159. <https://trrjournalonline.trb.org/doi/10.3141/2237-17> [as of October 9, 2018])

(Jiang, et al., *Using Complimentary Set Analysis to Validate the Underlying Assumptions of Quasi-induced Exposure* (2011a) In 3rd International Conference on Road Safety and Simulation Purdue University Transportation Research Board <https://pdfs.semanticscholar.org/5798/acd329058d87d9f8b9c7290095c6d8858e31.pdf?_ga=2.92348573.146341504.1540094302-242404177.1540094302 >[as of October 10, 2018])

(Kahane, *Comparison of 2013 VMT fatality rates in U.S. States and in high-income countries* (2016) <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812340> [as of October 9, 2018])

(Kahane, *Relationships Between Fatality Risk, Mass, and Footprint in Model Year 2000-2007 Passenger Cars and LTVs – Final Report* (2012) <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811665> [as of October 6, 2018])

(Keall & Newstead, *Selection of comparison crash types for quasi-induced exposure risk estimation* (2009) volume 10, No. 1, Traffic Injury Prevention. 23-29. <https://www.tandfonline.com/doi/abs/10.1080/15389580802383125?casa_token=9S73Fbx9d8QAAAAA:lmaDNLVh0UJLOrOrUjpUZHO0CS56rYyzpkIwLCHsD_tTrzQIxhUnI1CZ5PGtWOzUtEqsnsOPps8w> [as of October 5, 2018])

(Litman, *Autonomous Vehicle Implementation Predictions Implications for Transport Planning* (2018) <https://www.vtpi.org/avip.pdf> [as of October 9, 2018])

(National Center for Statistics and Analysis (NCSA), *Bicyclists and other cyclists: 2016 data* (2018c) <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812507> [as of October 6, 2018])

(National Center for Statistics and Analysis (NCSA), *Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System* (2018d) <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812554> [as of October 8, 2018])

(National Center for Statistics and Analysis (NCSA), *Pedestrians: 2016 data* (2018b) <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812493> [as of October 9, 2018])

(National Center for Statistics and Analysis (NCSA), *Summary of motor vehicle crashes: 2016 data* (2018a) <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812580> [as of October 7, 2018])

(National Transportation Safety Board (NTSB), *Reaching Zero: Actions to Eliminate Alcohol-Impaired Driving* (2013) <https://www.ntsb.gov/safety/safety-studies/Pages/SR1301.aspx> [as of October 5, 2018])

(*NHTSA and EPA, The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Year 2021 – 2026 Passenger Cars and Light Trucks* (2018) <https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ld-cafe-co2-nhtsa-2127-al76-epa-pria-180823.pdf> [as of October 5, 2018])

(NHTSA, *A Comparative Analysis of State Traffic Safety Countermeasures and Implications for Progress "Toward Zero Deaths" in the United States* (2017b) <https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/812392_rn-usprogresstowardzerodeathscomparativeanalysis_0.pdf> [as of October 6, 2018])

(NHTSA, *A Drive Through Time* (2018a) <https://one.nhtsa.gov/nhtsa/timeline/index.html> [as of October 7, 2018])

(NHTSA, *Automated Driving Systems 2.0.* (2017a) <https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf> [as of October 9, 2018])

(NHTSA, *How Vehicle Age and Model Year Relate to Driver Injury Severity in Fatal Crashes* (2018e) <http://www-nrd.nhtsa.dot.gov/Pubs/811825.pdf> [as of October 9, 2018])

(NHTSA, Lives Saved in 2016 by Restraint Use and Minimum-Drinking-Age Laws (2017c) <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812454> [as of October 9, 2018])

(NHTSA, *Motor Vehicle Traffic Fatalities and Fatality Rates, 1899-2016* (2018d) <https://cdan.nhtsa.gov/tsftables/Fatalities%20and%20Fatality%20Rates.pdf> [as of October 9, 2018])

(NHTSA, *Speeding, 2016* (2016) <https://www.nhtsa.gov/risky-driving/speeding> [as of October 5, 2018])

(NHTSA, *Speeding: 2016 Data* (2018c). <https://crashstats.nhtsa.dot.gov/Api/Public/Publication/812480> [as of October 6, 2018])

(NHTSA, *The Evolution of Automated Safety Technologies* (2018b) <https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety#issue-road-self-driving> [as of October 7, 2018])

(Pedestrian and Bicycle Information Center (PBIC), Promote Walking and Bicycling Accessed October 2018. <http://www.pedbikeinfo.org/programs/promote.cfm> [as of October 18, 2018])

(Puckett & Kindelberger, *Relationships between Fatality Risk, Mass, and Footprint in Model Year 2003-2010 Passenger Cars and LTVs – Preliminary Report* (2016) <https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/2016-prelim-relationship-fatalityrisk-mass-footprint-2003-10.pdf> [as of October 8, 2018])

(Richard, et al., *Countermeasures that work: A highway safety countermeasure guide for State Highway Safety Offices, Ninth edition* (2018) <https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/812478_countermeasures-that-work-a-highway-safety-countermeasures-guide-9thedition-2017v2_0.pdf> [as of October 6, 2018])

(Sung, et al., *A Comparative Analysis of State Traffic Safety Countermeasures and Implications for Progress "Toward Zero Deaths" in the United States* (2017) <https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/812392_rn-usprogresstowardzerodeathscomparativeanalysis_0.pdf> [as of October 8, 2018])

(Tierney & Hibbard, *Vehicle Fuel-Economy and Air-Pollution Standards: A Literature Review of the Rebound Effect* (2018) <http://www.analysisgroup.com/uploadedfiles/content/insights/publishing/ag_fuel_economy_rebound_effect_june_2018.pdf> [as of October 9, 2018])

(TZD Org, *Toward Zero Deaths: A National Strategy on Highway Safety* (2014) <https://www.towardzerodeaths.org/wp-content/uploads/TZD_Strategy_12_1_2014.pdf> [as of October 6, 2018])

(University of North Carolina, *CMF Clearinghouse* (n.d.) <http://www.cmfclearinghouse.org/notice.cfm> [as of October 7, 2018])

(Welle, et al., *Sustainable and Safe: A Vision and Guidance for Zero Road Deaths* (2018) <https://www.wri.org/publication/sustainable-and-safe-vision-and-guidance-zero-road-deaths> [as of October 8, 2018])

(Wenzel & Fujita, *Elasticity of Vehicle Miles of Travel to Changes in the Price of Gasoline and the Cost of Driving in Texas* (2018) <https://eln.lbl.gov/publications/elasticity-vehicle-miles-travel> [as of October 9, 2018])

(Zwerling, et al., *Fatal Motor Vehicle Crashes in Rural and Urban Areas: Decomposing Rates into Contributing Factors* (2005) volume 11, Issue 1, Injury Prevention. 24-28. <https://injuryprevention.bmj.com/content/11/1/24> [as of October 8, 2018])