Traffic21 Policy Brief

Driver Warning Technologies and Partial Vehicle Automation

Save Lives and Money

By Stan Caldwell, Corey Harper, Chris Hendrickson and Constantine Samaras

Traffic21
A transportation research institute of Carnegie Mellon University

Carnegie Mellon University

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Executive Summary

Nearly all motor vehicle manufacturers now offer driver warning technologies and partial automation systems to avoid and mitigate vehicle crashes. With a few exceptions, adoption and use of these driver assistance technologies is voluntary rather than regulatory-driven. We assessed these systems and conclude that they provide both private and societal benefits far exceeding the cost of the technology. While net benefits per vehicle are modest (about $300 per year), the benefit of equipping the entire vehicle fleet with forward collision warning, lane departure warning, and blind spot warning driver warning systems would amount to billions of dollars in annual savings in societal and private costs, with even larger benefits possible with the deployment of active braking systems. These systems also help avoid fatalities, with an estimated 40 deaths avoided in 2018, which would be substantially higher with greater market penetration. According to the Insurance Institute for Highway Safety (IIHS) about 2% of registered vehicles in 2018 were equipped with forward collision warning systems. Listed below, we conclude with policy suggestions for research and measures to encourage faster deployment of these technologies.

1. Adopt a common nomenclature for driver assistance technologies.
2. Encourage vehicle manufacturers to continue to offer driver assistance standard packages, through either inducement or regulatory action.
3. Continue to monitor the market penetration and effectiveness of specific driver assistance technologies.
4. Conduct research on improving the performance of driver assistance technologies, particularly human-computer interfaces and behavioral adoption.
5. Conduct research on improving the societal benefits of driver assistance technologies. For example, adaptive cruise control could be designed to reduce energy consumption and mitigate stop and go driving.
6. Conduct research on cooperative driver assistance technologies through vehicle-to-vehicle or vehicle-to-infrastructure connectivity.
7. Incorporate more detailed technology specific information on automation systems into national crash datasets.


SELF-DRIVING MODE
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Introduction

Over the past few decades, numerous vehicle manufacturers have offered a variety of driver warning technologies as well as partial automation systems to avoid or mitigate crashes. Driver warning systems provide information to the driver when a potentially dangerous situation is detected, and requires no vehicle automation, while partial automation systems take action (e.g., steering and/or braking) to avoid a collision without driver direction or interaction. Both are often called driver assistance technologies (DAT) (NHTSA, 2020).

Some of these DATs are offered as options while some have become ubiquitous, such as the required rear backup cameras. Despite additional costs, these technologies reduce crash frequencies and crash severity. As we document in this policy brief, these technologies are saving lives and money for both drivers and society. However, these are only DATs, and drivers need to be actively aware of their surroundings and prepare to react to driving events.

Driver warning technologies are offered on numerous new vehicles but are often called by different names by vehicle manufacturers (AAA, 2019; Consumer Reports, 2020b). The technologies may be standard or options available for an additional charge. In many cases, manufacturers offer a suite of warning technologies as a package. Major warning technologies are shown in Table 1.

Partial automation can take many forms, including aiding regular driving. Here, we focus on automation for crash avoidance. Table 2 lists the most common partial automation systems for crash avoidance. These systems are also offered on numerous new vehicles as single options or packages of features.

More and more new vehicles for sale have driver warning technologies and partial automation for crash avoidance (Consumer Reports, 2020b). While new vehicles are entering the vehicle fleet with these systems, many older vehicles are not equipped with these safety systems. In 2018, 93% of new vehicles for sale had all or some of these technologies, but it will be a decade before the majority of the vehicle fleet in use is equipped (AAA, 2019). Capital turnover in the vehicle fleet takes a long time, as vehicles can stay on the road for 15-20 years or more. Frontal airbags were first introduced in 1984, and most vehicles for sale were required to have airbags by 2000. Yet an estimated 13 percent of the vehicle fleet did not have airbags in 2010 (HLDI, 2012c). The slow diffusion of safety technologies through the vehicle fleet presents a safety, policy, and equity challenge since higher cost vehicles in the fleet tend to incorporate safety technologies first. Federal mandates or voluntary agreements could speed up the diffusion of technologies throughout the light-duty vehicle fleet making crash avoidance systems more widely available to all consumers (HLDI, 2019).

In the next sections, we first review empirical data on changes in crash frequency and severity with driver warning technologies and partial automation. We then provide estimates of benefits, costs and lives saved. Finally, we conclude with policy recommendations.

TABLE 1 MAJOR DRIVER WARNING TECHNOLOGIES

WARNING TECHNOLOGY	ACTION
Forward Collision Warning	Warns of impending obstacle collision while moving forward.
Lane Departure Warning	Warns of departure from marked lanes.
Blind Spot Warning	Warns of vehicles to the rear or side in adjacent lanes.
Rear Cross Traffic Warning	Warns of vehicles coming from the side while traveling in reverse.
Parking Obstruction Warning	Warns of obstacles in a parking space (a rear-view camera is one simple form of such technology).
Pedestrian Detection	Warns of pedestrians to the front or side of a vehicle.
Driver Monitoring	Warns of driver drowsiness or lack of attention.
Night Vision	Projects enhanced forward views.

TABLE 2 COMMON PARTIAL AUTOMATION SYSTEMS TO AID CRASH AVOIDANCE

FEATURE	ACTION
Forward Automatic Emergency Braking	Detects obstacles ahead and applies brakes during forward travel.
Reverse Automatic Emergency Braking	Detects obstacles behind and applies brakes during reverse travel.
Automatic Emergency Steering	Detects potential collision and automatically steers to avoid.
Anti-Lock Brakes	Pumps brakes automatically to avoid locking during skids.
Adaptive Cruise Control	Slows or speeds vehicles to ensure safe following distances.
Lane Keeping Assistance	Automatically maintains vehicles within a marked lane.
Automatic High Beams	Adjusts high beams to avoid glare.
Electronic Stability Control	Aids vehicle stability in extreme maneuvers to avoid roll over.

Cost Benefit Analysis

In order to assess the economic feasibility of fleet-wide deployment of forward collision warning (FCW), lane departure warning (LDW), and blind spot warning (BSW) driver warning systems, a cost-benefit analysis was conducted using observed insurance data on changes in crash frequency and severity for vehicles with these systems from the Insurance Institute for Highway Safety (IIHS) (HLDI, 2011-2015) and crash data from the National Highway Traffic Safety Administration (NHTSA) (NHTSA, 2015). Analysis details can be found in Harper et al. (2016) and Khan et al. (2019).

TOTAL ANNUAL COSTS

The total cost of equipping all light-duty vehicles (LDVs) with driver warning technologies are the technology purchasing costs associated with purchasing FCW, LDW, and BSW systems (Khan et al. 2019). This cost is annualized over the average lifespan of a vehicle in order to compare annual fleet-wide costs and benefits. The authors used the median price offering of Toyota Safety Sense (TSS) of $575 (Lienert, 2015) in 2015 to equip a new vehicle with the three technologies. While many manufacturers offered these systems at a higher price tag, the authors assume that other manufacturers will eventually reduce their price to remain competitive in the market. In order to annualize the technology purchasing costs, the authors assumed an average vehicle lifespan of 11.5 years (Walsworth, 2016) and an average car loan interest rate of 4.63% (Zabritski, 2015). The total annual cost assumes these systems will be equipped on new vehicles and the cost to purchase these technologies will be spread over the lifetime of the vehicle on the road.

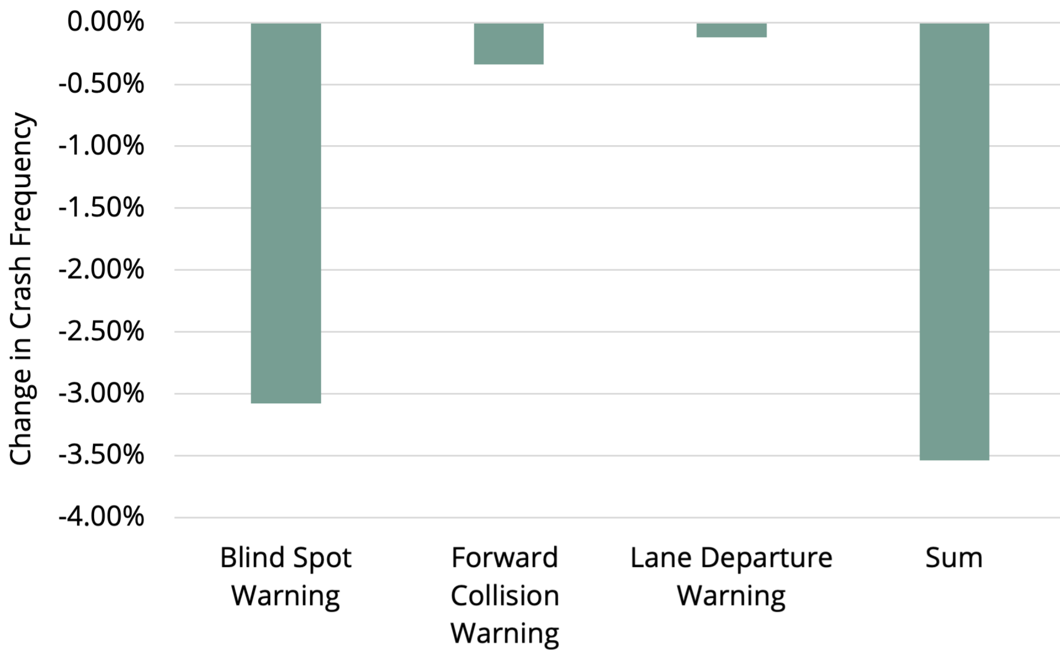
In 2015, the total number of registered vehicles in the national fleet was 243 million, which only includes LDVs (Bureau of Transportation Statistics, 2015). The total annual cost of equipping all LDVs with the three driver warning technologies is about $16 billion, assuming that the total cost to equip each vehicle with FCW, LDW, and BSW systems is $575.

TOTAL ANNUAL BENEFITS

Changes in Crash Frequency and Severity with Driver Warning Technology and Partial Vehicle Automation

The authors gathered observed insurance data on changes in collision claim frequency and collision claim severity published by the IIHS Highway Loss Data Institute (HLDI) for major automakers between 2011 and 2015. Vehicles with BSW had the greatest reduction in collision frequency and severity, by 3% and $45, respectively. This was followed by forward collision warning (FCW), which lowers the claim frequency by 0.34% but increases the claim amount by $165. Lastly, LDW has the lowest reduction in claim frequency and similarly to FCW increases claim severity. LDW lowers collision claim frequency by about 0.12% and increased claim amounts $40. Combined, we see that the three technologies lower collision claim frequency by about 3.54% but increases crash costs by $160. The higher crash costs can be attributed to the mix of vehicle make and models assessed in this study. In particular, some of the manufacturers in this study paired expensive headlights (that are vulnerable to damage when a crash occurs) with FCW sensors, which contributed to the increase in collision claim severity. Although there is an increased claim cost, this paper demonstrates a net cost savings when considering societal costs. Figure 1 and Figure 2 summarizes these changes in crash frequency and severity for each of the three technologies.

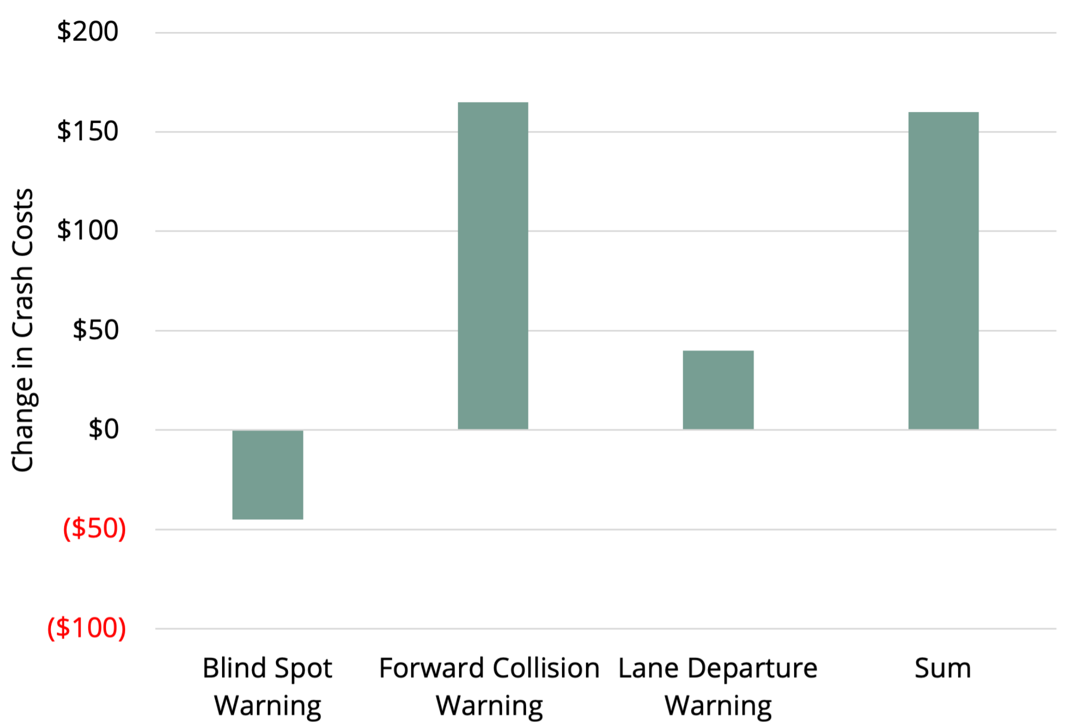
FIGURE 1 OBSERVED CHANGES IN CRASH FREQUENCY BY DRIVER WARNING TECHNOLOGY FROM INSURANCE REPORTS (2011 – 15)



Source: Collection of Collision Avoidance Features Reports published for Volvo, Mercedes, Acura, Buick, Honda, Mazda, and Subaru (HLDI, 2011-2015).

Note: Forward collision warning estimates do not include vehicles equipped with automatic emergency braking (AEB).

FIGURE 2 OBSERVED CHANGES IN CRASH COSTS ($2015) BY DRIVER WARNING TECHNOLOGY FROM INSURANCE REPORTS (2011 – 15)



Source: Collection of Collision Avoidance Features Reports published for Volvo, Mercedes, Acura, Buick, Honda, Mazda, and Subaru (HLDI, 2011-2015)

Note: Forward collision warning estimates do not include vehicles equipped with automatic emergency braking (AEB).

Number of Crashes Addressed by Each Technology

The annual societal benefits of fleet-wide deployment of the three technologies comes from a reduction in crash frequency and severity. Using the 2015 FARS and GES datasets the authors have estimated the upper bound number of crashes that could be avoided or made less severe by the three driver warning technologies, given system limitations (shown in Figure 3, Figure 4, and Figure 5). The authors estimated that approximately 25% of the 6.3 million police reported crashes are relevant to at least one of the three technologies. With 100% deployment, the combination of all three technologies could prevent or reduce the severity of as many as 1.6 million crashes including 7,200 fatal crashes. The largest number of non-fatal crashes occurs due to front-end collisions, followed by lane change and lane departure collisions. For the fatal crashes, the authors see that LDW could prevent or reduce the severity of the highest number of those crashes out of all three technologies, followed by FCW and BSW, respectively.

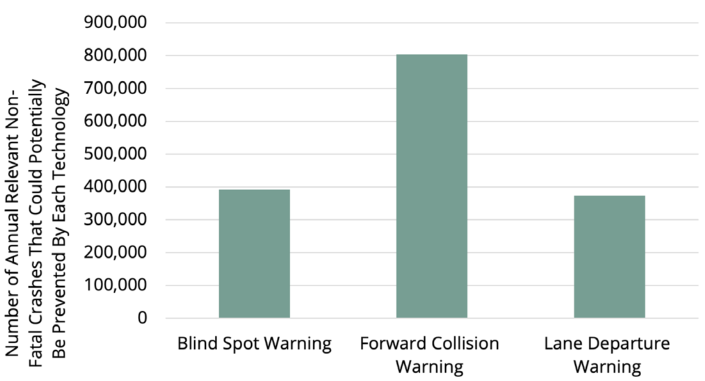


FIGURE 3 RELEVANT NON-FATAL CRASHES FROM 2015 GES AND FARS DATA REPRESENTING THE UPPER BOUND THAT CAN POTENTIALLY BE PREVENTED OR BECOME LESS SEVERE ANNUALLY BY DRIVER WARNING TECHNOLOGIES

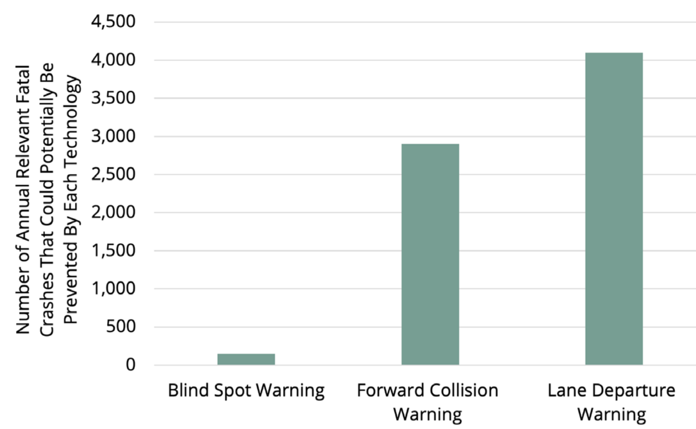


FIGURE 4 RELEVANT FATAL CRASHES FROM 2015 GES AND FARS DATA REPRESENTING THE UPPER BOUND THAT CAN POTENTIALLY BE PREVENTED OR BECOME LESS SEVERE ANNUALLY BY DRIVER WARNING TECHNOLOGIES

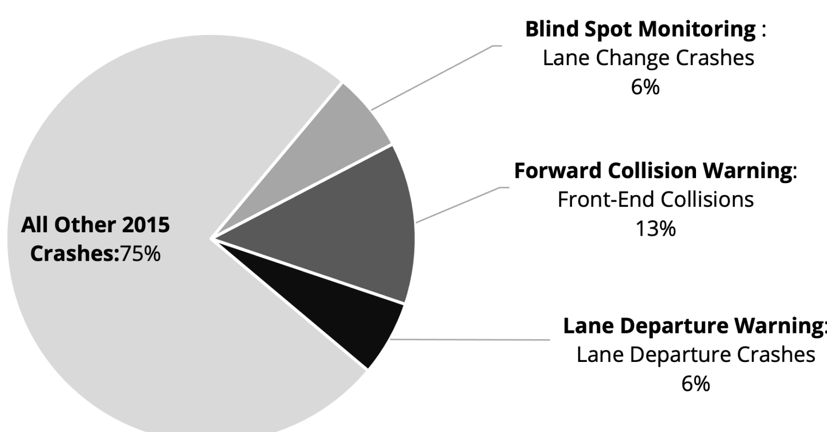
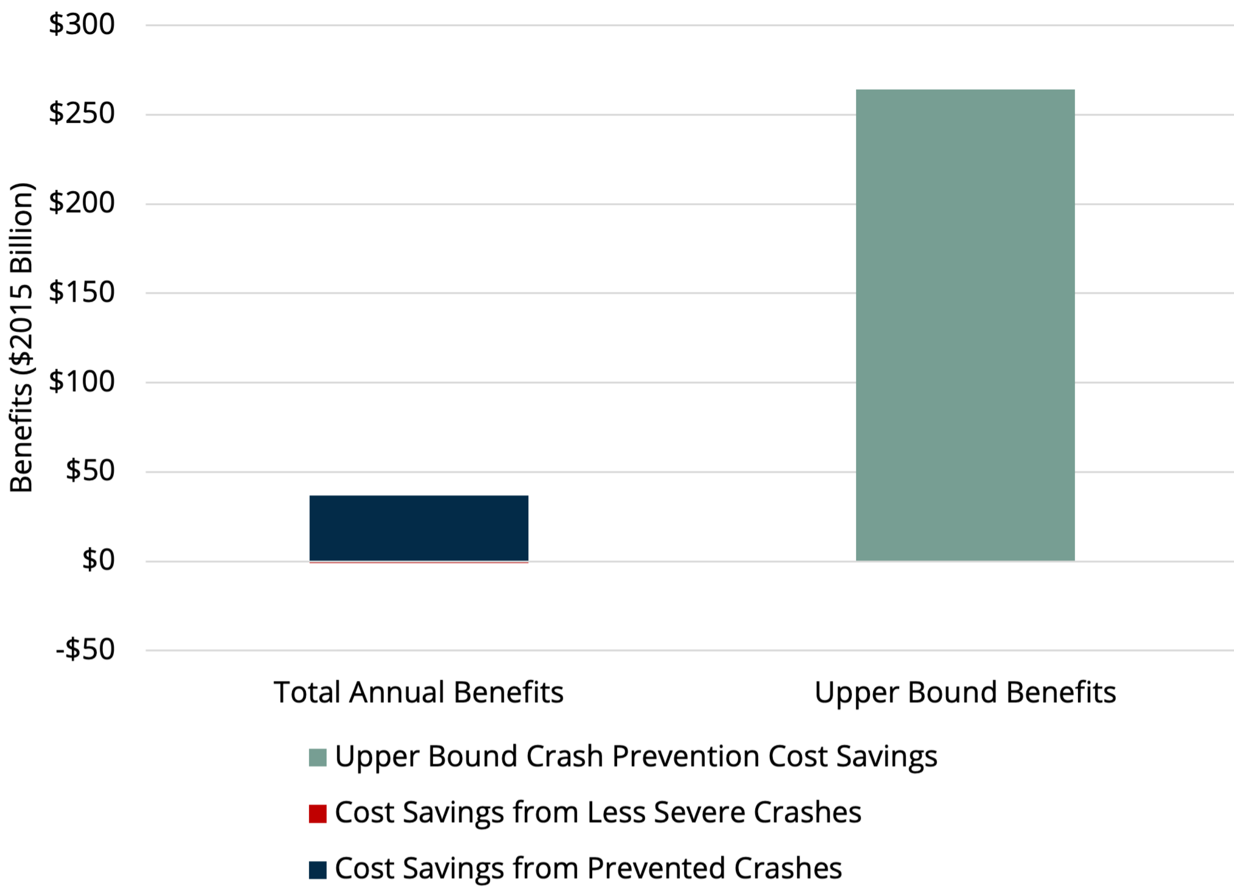


FIGURE 5 PERCENTAGE OF TOTAL CRASHES THAT COULD POTENTIALLY BE AVOIDED OR MADE LESS SEVERE ANNUALLY BY EACH TECHNOLOGY

Total Annual Benefits

Figure 6 shows the estimated annual benefits in 2015 of vehicles equipped with driver assistance, with the net benefits roughly $40B. If all vehicles were equipped with these technologies, the net benefits would exceed $250B.

FIGURE 6 ESTIMATES OF TOTAL ANNUAL BENEFIT AND UPPER BOUND BENEFITS OF FLEET-WIDE DEPLOYMENT OF DRIVER WARNING TECHNOLOGIES IN LIGHT-DUTY VEHICLE FLEET



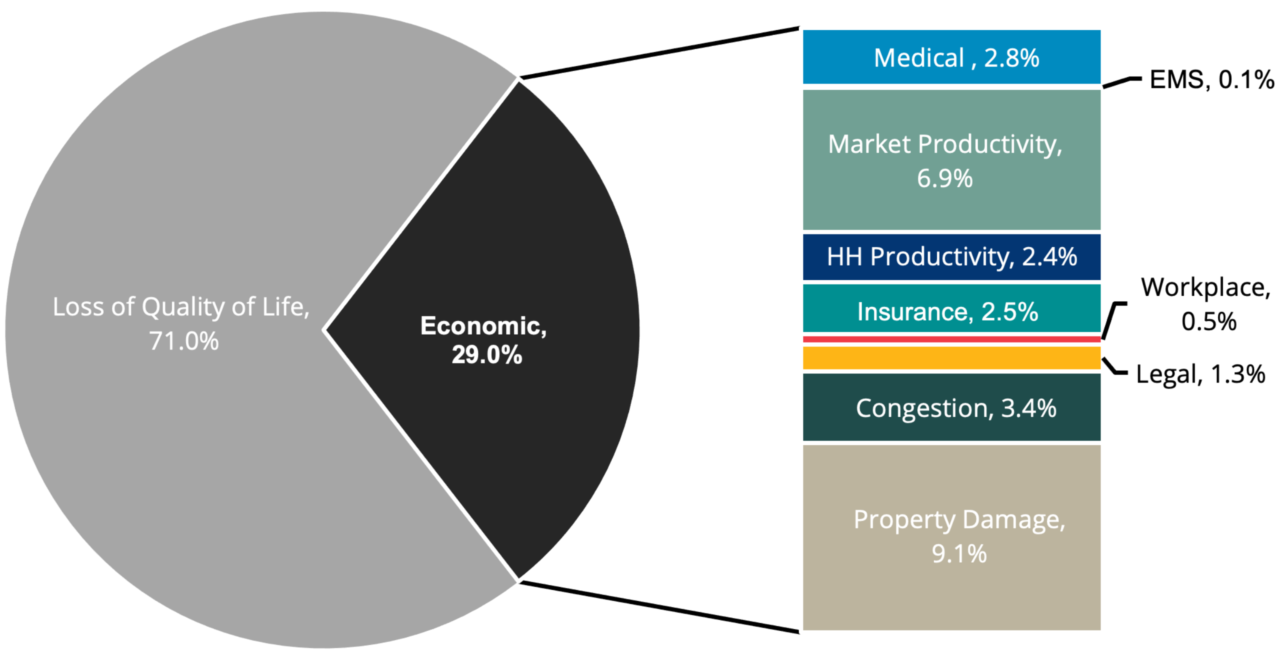
Note: Total annual benefits are based on observed effectiveness of driver warning technologies in preventing crashes and reducing crash severity

Note: Upper bound benefits assume that technologies are 100% effective in preventing all relevant crashes

Cost Components of a Crash

The value of societal harm from motor vehicle crashes includes the economic costs that are mostly the monetary outflows, and the remaining share is attributed to the valuation for quality-of-life. Lost quality-of-life represents 71% of the societal cost and the remaining 29% consists of economic costs, as shown in Figure 7. The societal cost consists of the indirect and intangible cost of Quality of Life Adjusted Years (QALYs.) However, the societal and economic costs are a mixture of direct and indirect monetary costs that are paid from four major sources: government, private insurers, individual crash victims, and other third parties. In order of incidence, private insurers incur more than half of all economic costs by being the primary source for medical care costs, insurance administration, legal costs, and property damage. Individual crash victims contribute a modest portion of medical care costs but absorb considerable portions of property damage as well as market and household productivity losses. Third parties absorb all costs related to workplace and congestion. Lastly, tax dollars cover a significant portion of medical care, lost market productivity and the entire cost of emergency medical service (EMS).

FIGURE 7 COMPOSITION OF THE SOCIETAL COST OF MOTOR VEHICLE CRASHES INTO QUALITY-ADJUSTED-LIFE-YEARS (QALYS) AND ECONOMIC COSTS INCLUDING ITS NINE COST COMPONENTS

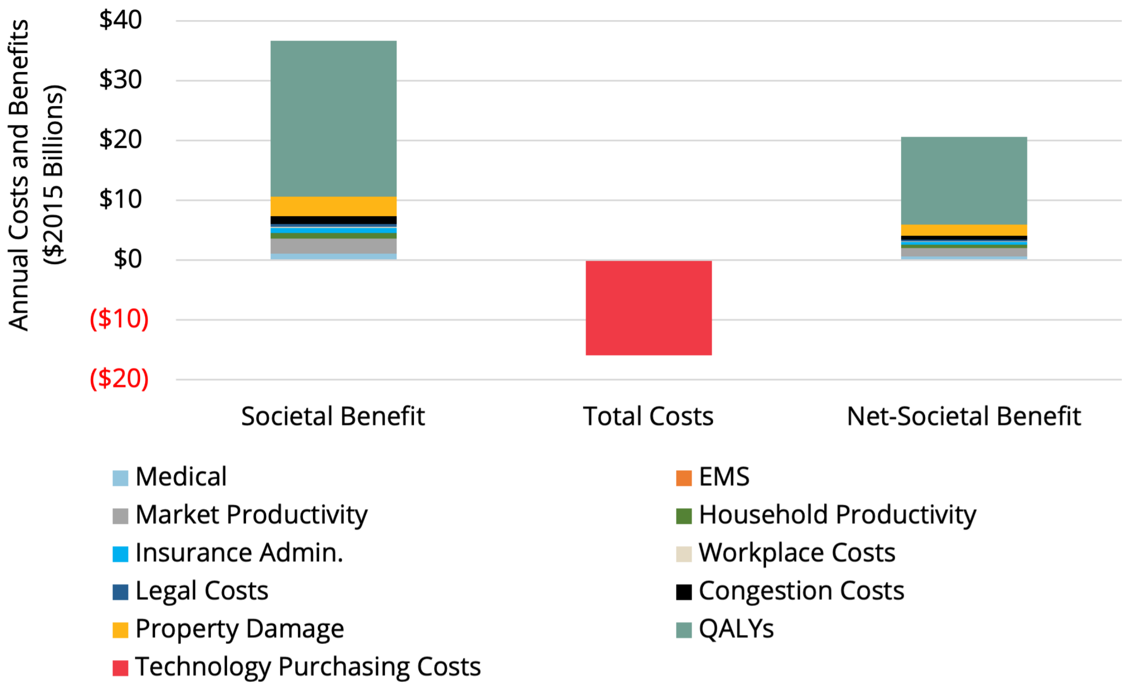


Source: Adopted from NHTSA's Econo Source: Adopted from NHTSA's Economic and Societal Impact of Motor Vehicle Crashes (Blincoe, et al., 2015) mic and Societal Impact of Motor Vehicle Crashes (Blincoe, et al., 2015)

Net-Societal Benefits

The total annual societal benefits are the benefits that the authors estimate from crash prevention and reduced crash severity every year. The total cost of equipping the technology on 100% fleet of light duty vehicles in the U.S. with this cost annualized over the life of the vehicle is the total cost. Net-Societal benefit is the difference between the societal benefits ($36 billion) and total costs ($16 billion). The net-societal benefit of equipping light-duty vehicles with the BSW, LDW, and FCW systems is about $20 billion as shown in Figure 8. On a per-vehicle basis, this amount translates to an approximate net benefit of $362 for each light-duty vehicle.

FIGURE 8 ANNUAL SOCIETAL NET-BENEFITS FROM FLEET-WIDE DEPLOYMENT OF DRIVER WARNING TECHNOLOGIES IN LIGHT-DUTY VEHICLE FLEET



Net-Private Benefits

A distinction can be made between costs borne by private individuals and the public. Private costs are those that are borne by private individuals and consist of direct costs as a result of fatal and non-fatal crashes. For this analysis, private costs are those costs to individual crash victims as well as to private insurers. Public costs are primarily intangible and indirect costs that arise from lost market productivity, congestion, and emergency medical services (EMS) costs. For this analysis, costs to government entities and third parties (e.g., uninvolved motorists) are considered public costs. A summary of definitions for private, public, and societal costs is shown in Table 3.

Using Blincoe et al.'s (2015) distribution of source of payment for economic costs by component, which shows the portion of related crash costs borne by private insurers, governmental sources, individual crash victims, and other sources, the economic cost of a crash can be disaggregated into public and private benefit categories. To allocate the cost of QALYs into public and private costs, the authors have used Blincoe et al.'s (2015) relative incidence crash scenarios to establish a 10% share of public costs from the overall comprehensive costs. Therefore, QALYs are allocated 90% to private vehicle occupants since 10% of all societal harm are incurred by bicycle or pedestrian crashes (Blincoe, et al., 2015). As shown in Figure 9, private costs comprise about 86% of the societal cost of a crash, while public costs make up only about 14%.

The net-societal benefit of equipping light-duty vehicles with the BSW, LDW, and FCW systems is about $16 billion as shown in Figure 10. On a per-vehicle basis, this amount translates to an approximate net benefit of $362 per light-duty vehicle. The net-private benefit is the difference between your private benefits ($32 billion) and total costs ($16 billion).

TABLE 3 DEFINITIONS FOR CRASH COSTS CATEGORIES

CATEGORY OF BENEFIT	DEFINITION
Societal Costs	The comprehensive cost of a crash that includes both economic and valuation for lost quality-of-life.
Private Costs	Costs borne by private individuals and consist of direct costs as a result of fatal and non-fatal crashes.
Public Costs	Primarily intangible and indirect costs that arise from lost market productivity, congestion, and emergency medical services (EMS).

FIGURE 9 DISTRIBUTION OF ANNUAL TOTAL PRIVATE AND PUBLIC COSTS FOR FLEET-WIDE DEPLOYMENT OF FORWARD COLLISION WARNING, LANE DEPARTURE WARNING, AND BLIND SPOT WARNING

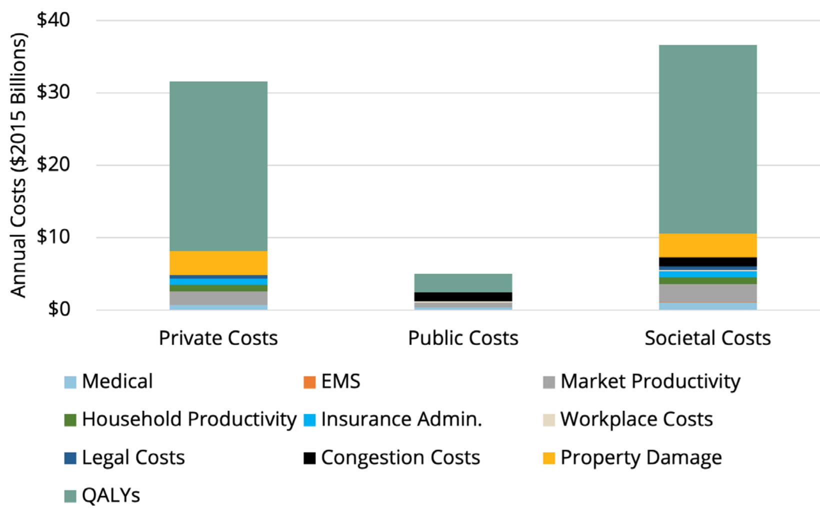
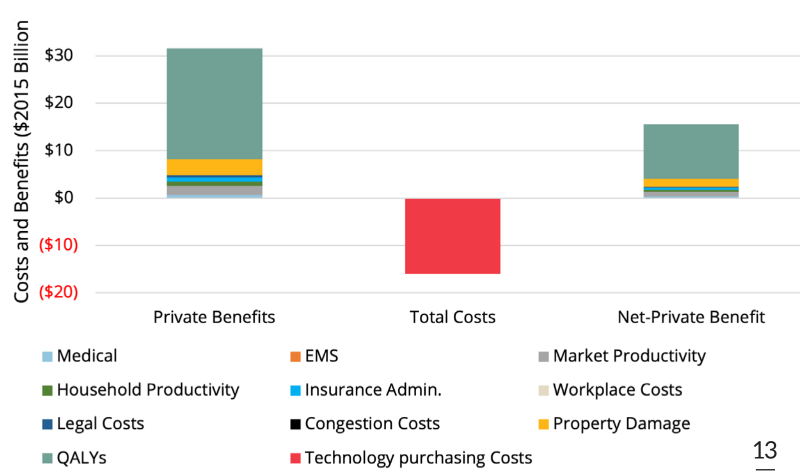


FIGURE 10 ANNUAL PRIVATE NET-BENEFIT FROM FLEET-WIDE DEPLOYMENT OF DRIVER WARNING TECHNOLOGIES IN LIGHT-DUTY VEHICLE FLEET



Lives Saved

A major benefit of crash avoidance systems are saved lives. Using the effectiveness figures from the "Total Annual Benefits" section of the paper along, crash data from FARS, and data on crash avoidance availability by car make and model (Consumer Reports, 2020b), we estimate that collectively, BSW, FCW, and LDW saved 43 lives in 2018 (see Table 4). Specifically, for each technology combination, we multiply the total number of crashes by the change in collision claim frequency and the expected number of fatalities per crash. This estimate is based on current market penetration, which is relatively low, and driver warning effectiveness measures. As the market penetration increases and technology efficacy improves, the number of lives saved will increase.

TABLE 4. ESTIMATED NUMBER OF LIVES SAVED IN 2018 BY DRIVER WARNING TECHNOLOGY

TECHNOLOGY COMBINATION	NUMBER OF LIVES SAVED
FCW Alone	20
LDW Alone	4
BSW Alone	2
FCW+LDW	10
FCW+BSW	4
LDW+BSW	1
FCW+BSW+LDW	2
TOTAL	**43**

Societal Benefits with Partial Automation

The base case analysis presented in this report assesses the societal benefits of FCW alone and separated insurance statistics of vehicles that had FCW with automatic emergency braking (AEB) (i.e., a paired system) from the initial analysis. FCW with AEB has proven to be more effective than FCW alone (Cicchino, 2017) and as a result the authors consider two separate scenarios. The first scenario is the analysis conducted earlier, where all light-duty vehicles are assumed to have FCW, LDW, and BSW, without any associated automated features. A second scenario, that should be considered, is where AEB, a Level 1 automated feature as defined by the Society of Automotive Engineers (SAE) (SAE, 2018), is introduced to the light-duty vehicle fleet in addition to the warning systems. If the same methodology is followed, the introduction of AEB would lower collision claim frequency from -3.54% to -7.17%, increasing the annual societal benefits by about 62%, from $36.6 billion to $59.2 billion (see Table 5).

TABLE 5. ANNUAL SOCIETAL BENEFITS WITH PARTIAL AUTOMATION SYSTEMS

SCENARIO 1: SOCIETAL BENEFITS FCW ALONE ($BILLION)	SCENARIO 2: SOCIETAL BENEFITS FCW WITH AEB ($BILLION)	% IMPROVEMENT WITH AEB
$36.6	$59.2	62%

Note: Each scenario assumes that FCW alone or FCW with AEB are paired with LDW and BSW systems.


RACING

Policy Implications

A variety of policy and research initiatives could accelerate the adoption and improve the performance and impact of driver assistance technologies. We suggest several below.

1. ADOPT A COMMON NOMENCLATURE FOR DRIVER ASSISTANCE TECHNOLOGIES

Currently, companies and observers use a variety of terms for these technologies. This has caused confusion for consumers/drivers, which can result in unrealistic expectation and over reliance of the driver assistance technology.

In August 2020 AAA, Consumer Reports, J.D. Power, the National Safety Council, Partners for Autonomous Vehicle Education (PAVE), and SAE International jointly released a list of 20 defined terms in "CLEARING THE CONFUSION: Recommended Common Naming for Advanced Driver Assistance Technologies" (CR 2020a):

"Advanced Driver Assistance Systems (ADAS) have become increasingly prevalent on new vehicles, but the terminology used by automakers to describe them varies widely and so far has focused on marketing strategies.

The common naming outlined is simple, specific and based on system functionality.

The list is meant to aid in reducing driver confusion and define the functions of ADAS in a consistent manner. This is critical to ensure that drivers are aware these systems are designed to assist, not replace an engaged driver.

The list is not meant to replace automaker proprietary system or package names, but rather help identify key functions within those packages and provide clarity to consumers. The list will be continually refined as we work with other stakeholders and as new systems are developed."

Regulatory authorities should consider voluntary compliance or regulatory means to guarantee the automotive industry adoption of this common naming. Public education efforts should be pursued to ensure appropriate consumer understanding and realistic expectation of these technologies and tracked for effectiveness.

2. ENCOURAGE VEHICLE MANUFACTURERS TO CONTINUE TO OFFER DRIVER ASSISTANCE STANDARD PACKAGES, THROUGH EITHER INDUCEMENT OR REGULATORY ACTION.

HLDI data of market penetration for the three driver assistance technologies highlighted in this report predict that is will require ten years (2025 - 2035) to grow adoption from 40% to 80% of registered vehicles. One example of policy speeding up adoption is the voluntary agreement with 20 automakers to equip all new passenger vehicles by September 1, 2022, with a low speed AEB (NHTSA, 2017). By 2025, IIHS estimates this commitment will prevent 28,000 crashes and 12,000 injuries (NHTSA, 2017). Accelerating the rate of adoption for these and other driver assistance technologies will save more lives and increase both private and societal benefits as demonstrated in this report.

Policy Implications

3. CONTINUE TO MONITOR THE MARKET PENETRATION AND EFFECTIVENESS OF SPECIFIC DRIVER ASSISTANCE TECHNOLOGIES.

As indicated in the previous recommendation, safety and cost outcomes are based on predictions of individual driver assistance technologies and their adoption. Monitoring market penetration will help guide regulatory agencies on the effectiveness of industry efforts if more agency intervention is warranted.

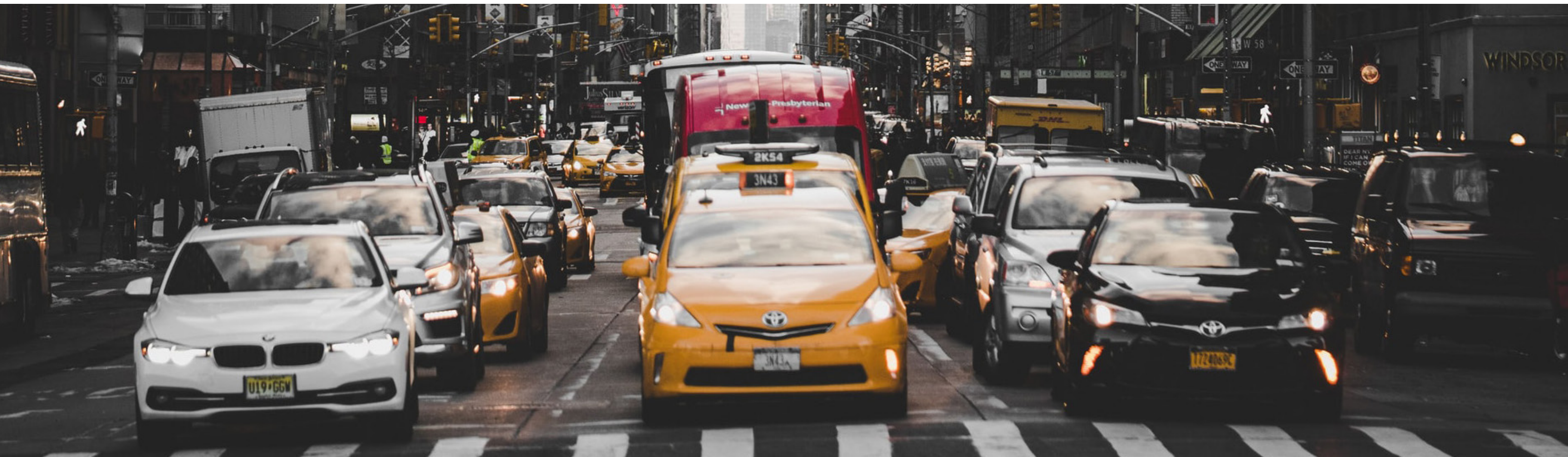
Tracking the effectiveness of individual and collectively deployed driver assistance technologies in reducing the frequency or severity of crashes will help target effort to accelerate the most effective individual or combination of technologies.

4. CONDUCT RESEARCH ON IMPROVING THE PERFORMANCE OF DRIVER ASSISTANCE TECHNOLOGIES, PARTICULARLY HUMAN-COMPUTER INTERFACES AND BEHAVIORAL ADOPTION.

In addition to the level of adoption, it is important to understand the level and quality of human-computer interface. Even if vehicles are equipped with a driver assistance technology, how many drivers disengage or ignore warning systems? Do drivers have realistic expectations of technology limitations and do not become over reliant? How good is the on-road performance of driver assistance technologies in sensing, warning, and avoiding pedestrians, cyclists, other vehicles, and objects, in different types of roadway facilities and weather conditions and over time? These research questions are imperative to achieve a true and accurate level of driver adoption. This research can lead to improved human computer interfaces, effectiveness of the systems and increased safety and private and societal benefit.

5. CONDUCT RESEARCH ON IMPROVING THE SOCIETAL BENEFITS OF DRIVER ASSISTANCE TECHNOLOGIES. FOR EXAMPLE, ADAPTIVE CRUISE CONTROL COULD BE DESIGNED TO REDUCE ENERGY CONSUMPTION AND MITIGATE STOP AND GO DRIVING.

Research in this report is limited to the safety and individual and societal economic benefits outlined above. However, there are potentially significant benefits from reduction in energy, emissions, and congestion that should be further explored. This research could look further into impacts from individual and combined driver assistance technologies.



6. CONDUCT RESEARCH ON COOPERATIVE DRIVER ASSISTANCE TECHNOLOGIES THROUGH VEHICLE-TO-VEHICLE OR VEHICLE-TO-INFRASTRUCTURE CONNECTIVITY.

As connected vehicle technology evolves in parallel with driver assistance technologies it is important to understand how these technologies can interface and augment each other in applications such as cooperative automation. Effectiveness of driver assistance technologies may be significantly increased through communications with other vehicles and the infrastructure to further improve safety, efficiency, cost and environment.

7. INCORPORATE MORE DETAILED TECHNOLOGY SPECIFIC INFORMATION ON AUTOMATION SYSTEMS INTO NATIONAL CRASH DATASETS.

National crash datasets provide information on the presence of automation systems in vehicles that were involved in crashes. However, they do not provide technology specific information for the automation systems present in the vehicle (e.g., Automatic Emergency Braking) but instead only describes the highest level of automation present in the vehicle (e.g., Level 1 or Level 2). Including more technology specific information into crash datasets will make it easier for researchers, policymakers, and engineers to assess how specific technologies are affecting crash and fatality rates.

References

American Automobile Association, 2019. 'Advanced Driver Assistance Technology Names,' https://www.aaa.com/AAA/common/AAR/files/ADAS-Technology-Names-Research-Report.pdf (accessed 8.25.20).

Blincoe, L., Miller, T. R., Zaloshnja, E., & Lawrence, B. A. (2015). The economic and societal impact of motor vehicle crashes, 2010 (Revised) (No. DOT HS 812 013).

Bureau of Labor Statistics, 2020. CPI Inflation Calculator. https://data.bls.gov/cgi-bin/cpicalc.pl (accessed 3.9.17).

Bureau of Transportation Statistics, 2015. Table 1-11: Number of U.S. Aircraft, Vehicles, Vessels, and Other Conveyances. https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_01_11.html (accessed 9.2.17).

Cicchino, J.B., 2017. Effectiveness of forward collision warning and autonomous emergency braking systems in reducing front-to-rear crash rates. Accident Analysis and Prevention. 99, 142–152. doi:10.1016/j.aap.2016.11.009

Consumer Reports, 2020a. Clearing the Confusion. https://advocacy.consumerreports.org/wp-content/uploads/2018/10/Clearing-the-Confusion-ADAS-Nomenclature-one-pager-8-3-20-FINAL.pdf (accessed 11.15.20).

AAA. (2019, January 25). Advanced Driver Assistance Technology Names. AAA Newsroom. https://www.aaa.com/AAA/common/AAR/files/ADAS-Technology-Names-Research-Report.pdf

Harper, C. D., Hendrickson, C. T., & Samaras, C. (2016). Cost and benefit estimates of partially-automated vehicle collision avoidance technologies. Accident Analysis & Prevention, 95, 104-115.

Highway Loss Data Institute, 2011a. Highway Loss Data Institute. Acura collision avoidance features: initial results. Bulletin Vol. 28, No. 21. Insurance Institute for Highway Safety, Arlington, VA.

Highway Loss Data Institute, 2011b. Highway Loss Data Institute. Buick collision avoidance features: initial results. Bulletin Vol. 28, No. 22. Insurance Institute for Highway Safety, Arlington, VA.

Highway Loss Data Institute, 2012a. Highway Loss Data Institute. Mercedes-Benz collision avoidance features: initial results. Bulletin Vol. 29, No. 7. Insurance Institute for Highway Safety, Arlington, VA.

Highway Loss Data Institute, 2012b. Highway Loss Data Institute. Volvo collision avoidance features: initial results. Bulletin Vol. 29, No. 5. Insurance Institute for Highway Safety, Arlington, VA.

Highway Loss Data Institute, 2012c. Highway Loss Data Institute. Predicted availability of safety features on registered vehicles. Bulletin Vol. 28, No. 26. Insurance Institute for Highway Safety, Arlington, VA.

Highway Loss Data Institute, 2015a. Highway Loss Data Institute. Subaru collision avoidance features: an update. Bulletin Vol. 32, No. 8. Insurance Institute for Highway Safety, Arlington, VA.

Highway Loss Data Institute, 2015a. Predicted availability of safety features on registered vehicles. Bulletin Vol. 32, No. 16. Insurance Institute for Highway Safety, Arlington, VA.

Highway Loss Data Institute, 2015b. Highway Loss Data Institute. Honda Accord collision avoidance features.

Bulletin Vol. 32, No. 7. Insurance Institute for Highway Safety, Arlington, VA.

Highway Loss Data Institute, 2015c. Highway Loss Data Institute. Mazda collision avoidance features. Bulletin Vol. 32, No. 22. Insurance Institute for Highway Safety, Arlington, VA.

Highway Loss Data Institute, 2019. Predicted availability and fitment of safety features on registered vehicles — a 2019 update. Bulletin Vol. 32, No. 16. Insurance Institute for Highway Safety, Arlington, VA.

Highway Loss Data Institute, 2019b. Predicted availability and fitment of safety features on registered vehicles — a 2019 update. Bulletin Vol. 36, No. 23. Insurance Institute for Highway Safety, Arlington, VA.

Khan, A., Harper, C. D., Hendrickson, C. T., & Samaras, C. (2019). Net-societal and net-private benefits of some existing vehicle crash avoidance technologies. Accident Analysis & Prevention, 125, 207-216.

Lienert, A., 2015. Toyota Safety Sense, Lexus Safety System+ Pricing Announced. https://www.edmunds.com/car-news/toyota-safety-sense-lexus-safety-system-pricing-announced.html (accessed 8.25.17).

NHTSA. (2015). Traffic Safety Facts 2015. United States Department of Transportation.

NHTSA, 2017. NHTSA-IIHS Announcement on AEB. https://www.nhtsa.gov/press-releases/nhtsa-iihs-announcement-aeb (accessed 11.23.20).

NHTSA, 2020. Driver Assistance Technologies. https://www.nhtsa.gov/equipment/driver-assistance-technologies. (accessed 11.23.20)

SAE, 2018. Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles (No. J3016).

Toyota, 2016. Lexus and Toyota Will Make Automated Braking Standard on Nearly Every Model and Trim Level by End of 2017. http://corporatenews.pressroom.toyota.com/releases/lexus+toyota+automated+braking+standard+2017.htm (accessed 8.29.17).

Walsworth, J., 2016. Average age of vehicles on road hits 11.6 years. http://www.autonews.com/article/20161122/RETAIL05/161129973/average-age-of-vehicles-on-road-hits-11.6-years (accessed 8.15.17).

Webb, C. N. Estimating lives saved by electronic stability control, 2011–2015. Washington (DC): NHTSA, US Dept. of Transportation; 2017. Traffic Safety Facts Research Note DOT HS, 812, 391.

Zabritski, M., 2015. State of the Automotive Finance Market. https://www.experian.com/assets/automotive/quarterly-webinars/2017-q3-safm-recording.pdf (accessed 8.29.17).

Traffic21
A transportation research institute of Carnegie Mellon University

Carnegie Mellon University

Heinz College
Carnegie Mellon University
5000 Forbes Ave.
Pittsburgh, PA 15213
412-268-9505
traffic21.heinz.cmu.edu

Carnegie Mellon University
5000 Forbes Ave.
Pittsburgh, PA 15213

412-268-2000
cmu.edu

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