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Do Automated Vehicle Crash Avoidance Technologies Keep Us Safe?

Media accounts of automated vehicle (AV) technology have given us glimpses of a futuristic world where robots will replace drivers (and all their faults) and self-driven vehicles will whisk us safely from one place to another as we work, read, eat, and so on. However, the gap between such visions and current reality is great. Huge challenges remain in many areas, including public safety. The push for AV development stems largely from the knowledge that driver actions contribute more to traffic crashes than all other factors combined. A national study found that driver errors (e.g., inattention, distraction, driving too fast, misjudging vehicle gaps and speeds, overcorrecting, poor steering, drowsiness, etc.) are the critical reason for about 94 percent of U.S. traffic crashes.

The need to eliminate such driver errors remains the chief motivation for AV technology, but safety concerns are also prominent in the minds of most Americans. A recent opinion survey regarding AVs found that over seven of every ten U.S. drivers are afraid to ride in a fully automated vehicle, and more than eight of every ten would not allow their children or loved ones to ride in one. Thus, hanging over the passenger-based AV industry is a simple question: How safe are these vehicles? Most research has found that, for specific crash types and conditions, they are significantly safer than human-operated vehicles. The Insurance Institute for Highway Safety's research arm, the Highway Loss Data Institute (HLDI), used insurance claims data from nearly fifty studies on individual AV systems to determine how well they prevent crashes and injuries. HLDI researchers grouped crash claims by specific crash types (e.g., rear-end crashes) and identified vehicles equipped with the specific AV technologies being studied.

In June 2019 HLDI posted an updated summary of their findings from these studies. This update reports that forward collision warning (FCW) alone reduced front-to-rear crashes by 27 percent (compared to controls) and reduced injury-related front-to-rear crashes by 20 percent. Vehicles that combined FCW and automatic emergency braking (AEB) showed reductions of 50 percent in front-to-rear crashes and 56 percent in injury-related front-to-rear crashes. Lane departure warning (LDW) reduced single-vehicle sideswipe and head-on crashes by 11 percent and injury-related crashes of the same types by 21 percent. Blind spot detection (BSD) reduced lane-change crashes by 14 percent and injury-related lane-change crashes by 23 percent. Finally, rear automatic braking (RAB) with rear-view camera and parking sensors reduced backing crashes by 78 percent. The only negative finding HLDI reported was that damage claims for insured AV-equipped vehicles averaged $104 higher compared to insured vehicles not equipped with these sensitive and expensive technologies.

In another recent study of the crash-prevention potential of AV technologies, the AAA Foundation for Traffic Safety reviewed the results from multiple studies of five crash-prevention systems and concluded that their crash-prevention potential was "substantial". Since these results varied greatly in size, the authors opted for another approach. They grouped 2016 crashes (from national crash databases) by crash types in order to estimate how many crashes, injuries, and deaths those five systems could have prevented or mitigated “if installed on all vehicles”. For each AV crash-prevention system in the study, they estimated how many related 2016 crashes could have been prevented or mitigated and how many could not have been prevented. For each crash-type, study authors subtracted cases where the relevant system would not have prevented or mitigated crashes from the total of crashes in that crash-type. Their results showed that FCW with AEB together could have prevented or mitigated 1,994,000 rear-end and pedestrian-bicyclist crashes that lead to 884,000 injuries and 4,738 deaths in 2016; that LDW and lane keeping assistance (LKA) combined could have prevented or mitigated 519,000 unintentional lane-departure crashes that lead to 187,000 injuries and 4,654 deaths; and, finally, that BSW could have prevented or mitigated 318,000 same-direction lane-change crashes that lead to 89,000 injuries and 274 deaths. The total number of crashes that these technologies could have prevented or mitigated in 2016 was 2,748,000, in turn leading to 1,128,000 fewer injuries and 9,496 fewer deaths. It is important to note that the crash-reduction estimates for these technologies decreased as crash severity increased.

These results are certainly promising, but some authors have offered important cautions. First, the comparison between current AV-equipped vehicles with current non-AV vehicles of the same models yields a portrait of AV safety that is highly uncertain. Both AV-equipped and non-AV vehicles are likely to improve a great deal over time, though AV-based safety systems are likely to develop at a much higher rate, thereby making current safety estimates not very useful except as proof-of-concept demonstrations.

Second, interactions between humans and advanced technology systems often yield a paradoxical outcome known as behavioral adaptation. This means, as a recent study puts it, that “Modifications of the driving task environment…will result in changes to a driver’s behavior that can complicate the net effect of any intended safety improvement.” In the case of AV technologies, the increasing range of driver-assistance technologies (tending toward complete vehicle control with no input from the driver), has increased driver disengagement from the driving task regardless of AV company warnings that drivers must be ready to take control of the vehicle under certain conditions.

A number of drivers just experiencing AV systems for the first time may disable driver-warning and driver-assist systems because they can produce annoying and persistent noises and create a sense of loss of control. On the other hand, many drivers adapt to these systems by improving their behaviors to avoid triggering the annoying or unnerving effects of driver-warning and driver-assistance. It has also been shown that increasing driver understanding of the functionality of their AV systems improves their use of these powerful safety technologies while minimizing the negative impacts of behavioral adaptation.

<u>Reference Summaries</u>:

American Automobile Association (2019). **Three in four Americans remain afraid of fully self-driving vehicles**. Fact Sheet – Automated Vehicle Survey – Phase IV. March, 2019. https://newsroom.aaa.com/2019/03/americans-fear-self-driving-cars-survey/

This fact sheet, the latest in a series that began in 2016, reports the findings from a January 2019 telephone survey (both land-line and cell phone) of U.S. adults 18 years of age or older. The survey was designed to represent the total nationwide adult population and was weighted to control for age, gender, geographic region, race/ethnicity, education, and landline vs. cell phone only. Results showed that 71 percent of U.S. drivers are still fearful of riding in fully self-driving vehicles and that only 19 percent of them would be willing to allow their children or loved ones to ride in one. On the other hand, 55 percent of U.S. drivers believe that by 2029, most passenger vehicles will be fully self-driving. Over half of drivers (53 percent) would be comfortable with fully self-driving vehicles being used for transporting people around airports and theme parks, and 44 percent would accept self-driving vehicles being used to deliver food or packages. Majorities of those drivers who don't believe that cars will be self-driving by 2029 explain that people "won't trust full self-driving cars" (53 percent) and "won't want to give up driving themselves" (52 percent).

Benson AJ, Tefft BC, Svancara AM, and Horrey WJ (2018). **Potential reductions in crashes, injuries, and deaths from large-scale deployment of advanced driver assistance systems** (research brief). Washington, DC: AAA Foundation for Traffic Safety. https://aaafoundation.org/wp-content/uploads/2018/09/18-0567_AAAFTS-ADAS-Potential-Benefits-Brief_v2.pdf

This research brief takes on the task of estimating how many total crashes, injuries, and deaths might have been prevented or mitigated in 2016 if five specific advanced driver assistance technologies had been fully deployed throughout the entire U.S. fleet that year. The authors created a synthetic method by compiling the results from numerous studies of the safety impacts of those five specific technologies – forward collision warning (FCW), automatic emergency braking (AEB), lane departure warning (LDW), lane keeping assist (LKA), and blind spot warning (BSW) – and then applying the grouped harm-reduction estimates for each AV technology to the corresponding crash types they are designed to prevent or mitigate. Using sequence-of-events fields from 2016 Fatality Analysis Reporting System (FARS) data and 2016 Crash Representative Sampling System (CRSS) data (weighted to generate nationwide estimates) for 2016, the AAA researchers identified and totaled the numbers of "crashes of the general type that each respective technology is designed to address." The variables of greatest interest for this purpose related to vehicles, drivers, crash geometrics, environmental conditions, and sequences of crash events. The authors then identified subsets of crashes that were unlikely to have been prevented or mitigated by these five subject AV technologies (e.g., in conditions of poor-visibility, when sensors and lenses would not function properly), and subtracted these "unlikely" crashes from their crash-type totals. In this way they estimated that FCW with AEB together could have prevented or mitigated 1,994,000 rear-end and pedestrian-bicyclist crashes that resulted in 884,000 injuries and 4,738 deaths in 2016; that the combination of LDW and LKA could have prevented or mitigated 519,000 unintentional lane-departure crashes that resulted in 187,000 injuries and 4,654 deaths; and, finally, that BSW could have prevented or mitigated 318,000 same-direction lane-change crashes that resulted in 89,000 injuries and 274 deaths. The total number of crashes that the ensemble of these technologies could have prevented or mitigated in 2016 was 2,748,000, which would then have led to 1,128,000 fewer injuries and 9,496 fewer deaths that year. It is noteworthy that the prevention/mitigation estimates for these technologies declined as crash severity increased, i.e., proportionately fewer deaths would have been prevented than crashes or injuries.

Coelingh E, Eidehall A, and Bengtsson M (2010). **Collision warning with full Auto Brake and Pedestrian Detection – practical example of Automatic Emergency Braking.** *13th International IEEE (Institute of Electrical and Electronics Engineers) Annual Conference on Intelligent Transportation Systems*: Madeira Island, Portugal, September 19-22, 2010: 155-160. https://s3.amazonaws.com/academia.edu.documents/44382845/Collision_Warning_with_Full_Auto_Brake_and_Pedestrian_Detection.pdf?response-content-disposition=inline percent3B percent20filename percent3DCollision_warning_with_full_auto_brake_a.pdf&X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Credential=AKIAIWOWYYGZ2Y53UL3A percent2F20190905 percent2Fus-east-1 percent2Fs3 percent2Faws4_request&X-Amz-Date=20190905T175151Z&X-Amz-Expires=3600&X-Amz-SignedHeaders=host&X-Amz-Signature=46d22c11cb4fc67fd2f58274fa27146e4b8fbbfe5cf00885ab3ebc80cc7c4057

In this article three technical experts with the Volvo Car Corporation's *Active Safety Functions Department* present their documentation of Volvo's then-latest iteration of their pedestrian crash avoidance technology, their Collision Warning with Full Auto Brake and Pedestrian Detection (CWAB-PD) system. Using a combination of long-range radar and a "forward-sensing wide-angle camera", this system was shown in testing to be very capable of detecting pedestrians and then averting pedestrian crashes altogether at vehicle speeds of up to 35 KPH (~22 MPH). The authors also claimed that "CWAB-PD is the only system on the market that automatically can avoid accidents with pedestrians." Interestingly, models in the 2018 Volvo XC series now feature a similar but upgraded technology with sensors and cameras for detecting and avoiding bicyclists and large animals as well as pedestrians. In all, these late-model Volvos also include more than a dozen additional automated technologies for preventing and mitigating crashes.

Cicchino JB and Luby DS (2019). **Characteristics of rear-end crashes involving passenger vehicles with automatic emergency braking.** *Traffic Injury Prevention*. 20:S112-S118. https://www.tandfonline.com/doi/pdf/10.1080/15389588.2019.1576172?needAccess=true

This study employed logistic regression analyses to analyze rear-end crash-involvement rates in 23 U.S. states between 2009 and 2016. The authors relied on HLDI's multi-year database, using VINs from police-reported rear-end crashes to create additional linkages for this study (this method of linkage is essentially the same method outlined in a 2018 paper by Cicchino, above). For this study, however, the authors used a novel method. Reasoning that since rear-end crashes typically occur when "2 passenger vehicles are proceeding in line, on a dry road, and at lower speeds" (S112), then if AEB-equipped vehicles are over-represented in rear-end crashes with unusual scenarios (compared to vehicles without AEB), AEB must perform exceptionally well at preventing more typical rear-end crashes. As predicted, regression analysis showed that AEB was more likely to be involved in crashes when striking vehicles in rear-end crashes were turning compared to when moving straight (OR 2.35, CI 1.76-3.13); when the struck vehicle was turning (OR 1.66; 95 percent CI, 1.25, 2.21) or changing lanes (OR 2.05; 95 percent CI, 1.13, 3.72) compared to when slowing or stopped; when the struck vehicle was not a passenger vehicle or was a special use vehicle relative to a car (OR 1.61; 95 percent CI, 1.01, 2.55); or when traveling on snowy or icy roads relative to dry roads (OR 1.83; 95 percent CI, 1.16, 2.86. Overall, 25.3 percent of crashes where the striking vehicle had AEB had at least one of these overrepresented characteristics, compared with 15.9 percent of strikes by vehicles without AEB. Therefore, the authors concluded, AEB must be especially useful for preventing more typical rear-end crashes.

Fraade-Blanar L, Blumenthal MS, Anderson JM, and Kalra N (2018). **Measuring automated vehicle safety – forging a framework**. Santa Monica, CA: RAND Corporation. https://www.rand.org/pubs/research_reports/RR2662.html?utm_source=WhatCountsEmail&utm_medium=NPA:2061:5036:Oct percent2010, percent202018 percent2012:57:22 percent20PM percent20PDT&utm_campaign=NPA:2061:5036:Oct percent2010, percent202018 percent2012:57:22 percent20PM percent20PDT

The authors of this report set out to "develop a framework for measuring safety in AVs that could be used broadly by companies, policymakers, and the public." They assert that the "meaning of safety in regard to AVs is surprisingly unclear – no standard definition exists," so they propose one: "[W]e define safety as the eliminating, minimizing, or managing of harm to the public (which can include people, animals, and property, but we focus on harm to people) ." They go on to point out that the AV industry "is more heterogeneous and dynamic than the conventional automotive industry with which it overlaps," featuring a central role for tech companies in developing and improving AV safety systems. Consequently, computer-based innovations central to AV technology consistently outstrip any regulatory efforts by state and federal legislators. Remarkably few applicable standards are yet in effect for AV technologies, including "premarket authorization" in the U.S., though this absence of laws has likely enhanced the rapid pace of AV development. Local jurisdictions, however, may sometimes be required to give explicit permission to drive on local roads – which some have revoked in the wake of well-publicized incidents. Those operational functions historically assigned to drivers are now being taken over by sensors, cameras, computer chips, and complex algorithms. The "fitness" of a computer system to operate a motor vehicle is a very different idea from our traditional-legal standards for defining driver fitness. The phased and stage approach to conceptualizing AV safety that these authors develop is reassuringly detailed, careful, and deliberate, with standards and safety metrics to be applied at every level and stage of technology development. They propose safety measures designed to be "flexible but rigorous." They acknowledge that huge amounts of uncertainty will persist for a very long time, but they urge that both AV technology developers and government policymakers work toward much more transparent communications with common citizens to promote "broad public dialogue about the safety of vehicles that are highly (and eventually fully) automated."

Highway Loss Data Institute (2018). **Compendium of HLDI collision avoidance research**. *HLDI Bulletin 35* (September 2018). Arlington, VA: Insurance Institute for Highway Safety. https://www.iihs.org/media/7560e1bf-fcc5-4540-aa16-07444f17d240/A25ptg/HLDI percent20Research/Collisions percent20avoidance percent20features/35.34-compendium.pdf

This report from the Insurance Institute for Highway Safety (IIHS) not only compiled all of the results from a number of separate analyses conducted by the IIHS but itemized the kinds of costs – crash, injury, and property loss claims stemming from those crashes in order to gauge the benefits accruing from the use of AV technologies. It outlines the methods used in these studies, which followed the IIHS's typical practice of using VINs in their client claims data to link VINs from their claims cases with VINs in the police-reported crashes associated with those claims. Results for the ensuing regression analysis were then summarized. In June 2019 the IIHS posted an updated summary-of-findings document, which showed that Forward collision warning (FCW) alone reduced front-to-rear crashes by 27 percent (compared to controls), injury-related front-to-rear crashes by 20 percent, claim-rates for damage to other vehicles by 9 percent, and claim-rates for injuries to occupants of other vehicles by 16 percent. For FCW-equipped vehicles that also included autobrake (AEB), reductions were even greater: 50 percent in front-to-rear crashes and 56 percent in injury-related front-to-rear crashes, 13 percent in claim-rates for damage to other vehicles and 23 percent in claim-rates for injuries to occupants of other vehicles. Lane departure warning (LDW) reduced single-vehicle sideswipe and head-on crashes by 11 percent, and injury-related crashes of the same types by 21 percent. Blind spot detection (BSD) reduced lane-change crashes by 14 percent, injury-related lane-change crashes by 23 percent, and claim-rates for these crashes by 7 percent and 8 percent respectively. Rear automatic braking (RAB) combined with rear-view camera and parking sensors reduced backing crashes by 78 percent, and claim-rates for damage to the insured vehicle and to other vehicles dropped by 12 percent and 30 percent respectively. The one negative finding reported in the document was that damage claims for insured AV technology-equipped vehicles were higher by an average of $104 compared to insured vehicles not equipped with these technologies. Updated findings (June 2019): https://www.iihs.org/media/259e5bbd-f859-42a7-bd54-3888f7a2d3ef/e9boUQ/Topics/ADVANCED%20DRIVER%20ASSISTANCE/IIHS-real-world-CA-benefits.pdf

Kalra N and Groves D (2017). **The enemy of good: estimating the cost of waiting for nearly perfect automated vehicles.** Santa Monica, CA: RAND Corporation https://www.rand.org/pubs/research_reports/RR2150.html

The authors of this study ask a deceptively simple question: How safe should highly-automated vehicles (HAVs) be before they're allowed to be operated by licensed drivers in traffic on public roads? They develop three different predictive models showing, first, likely outcomes when HAVs represent only a 10 percent improvement over conventional technology; second, likely outcomes when HAVs out-perform conventional vehicles by 75 percent; and third, when HAVs outperform conventional vehicles by 90 percent or more. A comparison of results after running these three predictive scenarios revealed that, in the long run, more crashes would be prevented and more lives would be saved under the 10 percent-improvement scenario than under the 75 percent-improvement or 90 percent-improvement scenarios, partly because reaching the higher-percentage targets will require a much longer period of time for sufficient fleet-saturation to occur.

McDonald A, Carney C, and McGehee DV (2018). **Vehicle owners' experiences with and reactions to Advanced Driver Assistance Systems**. Washington, DC: AAA Foundation for Traffic Safety (September 2019). https://aaafoundation.org/wp-content/uploads/2018/09/VehicleOwnersExperiencesWithADAS_TechnicalReport.pdf

This lengthy report presents the findings of a research study intended to find out about the experiences of drivers who own and operate certain 2016-2017 AVs with at least three of seven major AV technologies designed to either warn drivers about hazardous situations or to assist drivers with redressing them. The systems included forward collision warning (FCW), automatic emergency braking (AEB), lane departure warning (LDW), lane keeping assist (LKA), blind spot monitoring (BSW), rear cross-traffic alert (RCA), and adaptive cruise control (ACC). Nearly 1,400 registered owners (out of a total sample of 10,000 contacted) responded by taking an online survey regarding their knowledge of, experience with, and thoughts and feelings about the AV systems on their own vehicles. After excluding ineligible or inappropriate respondents, the authors analyzed a final sample of 1,212 surveys. Analysis of the results showed that most drivers of vehicles equipped with AV technologies generally like and trust those safety systems. Unfortunately, the survey also showed that many drivers are unaware of the limitations of their AV technologies, a condition which may increase their risks of crashing due to inattention or over-reliance on these systems. Many drivers indicated that they often engage in non-driving activities, which puts them at heightened risk of failing to respond in the event that they need to re-take control of the vehicle.

Rizzi M, Kullgren A, and Tingvall C (2014). **Injury crash reduction of low-speed autonomous emergency braking (AEB) on passenger cars.** *International Research Council on the Biomechanics of Injury*. Berlin, Germany: September 10-12, 2014. http://www.ircobi.org/wordpress/downloads/irc14/pdf_files/73.pdf

This study evaluated the role and effectiveness of AEB in preventing and mitigating police-reported two-car rear-end crashes in Sweden between 2010 and 2014, especially on urban roads. AEB-equipped Volvo passenger cars were evaluated against the same Volvo models without AEB as well as non-AEB vehicles from other manufacturers. Both AEB-equipped treatment vehicles and non-AEB control vehicles were of equivalent types and weights. The analysis focused on 3,922 crashes in which at least one person was injured and where at least one of these three study vehicle-categories was involved. The authors used an induced-exposure technique. The crash scenarios used to estimate exposure were ratios for striking and being struck in rear-end crashes, and striking and being struck in crossing crashes, for each of the three vehicle categories. Results for rear-end crashes showed that the striking/struck ratios for vehicles in the non-AEB categories were close to 1.0 (0.96 for Volvos and 0.90 for non-Volvos), while the corresponding ratio for the AEB-equipped Volvos was 0.42, signifying that they were significantly less involved in rear-end crashes than non-AEB vehicles. The authors concluded that “the risk of being the striking part in an injury rear-end crash could be halved by low-speed Autonomous Emergency Braking speed areas up to 50 km/h.”

Singh S (2015). **Critical reasons for crashes investigated in the National Motor Vehicle Crash Causation Survey**. DOT Report HS 812 115. Washington, DC: National Highway Traffic Safety Administration. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115

In 2005 Congress authorized NHTSA to conduct “a national survey to collect on-scene data pertaining to events and associated factors that possibly contributed to crash occurrence.” Accordingly, from July 2005 through December 2007, NHTSA generated a weighted sample of 5,470 U.S. crashes and thoroughly investigated each of them, specifically in order to ascertain the critical reason (CR) that each one happened. The author defines CR as “the immediate reason for the critical pre-crash event,” which is “often the last failure in the causal chain of events leading up to the crash.” After conducting this causal-chain analysis approach, the author concluded that roughly 94 percent of the critical reasons for these crashes were assigned to drivers, and 2 percent assigned to vehicles, environmental factors, and other unknown factors. Further analysis of the types of CRs involved determined that recognition errors (inattention, internal and external distractions, and inadequate surveillance) accounted for 41 percent of the CRs, while decision errors (driving too fast for conditions, going too fast for curves or turns, illegal maneuvers, misjudgment of gaps in traffic or other vehicles’ speeds) amounted to 33 percent of driver-related CRs. Performance errors (overcorrecting, poor vehicle-direction or lane-position control) made up around 11 percent of driver-related CRs, while the rest included nonperformance errors (such as falling asleep). Overall, driver errors constituted about 85 percent of all CRs initiating a crash.

Society of Automotive Engineers (SAE, 2018). **Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles** J3016_201806. Warrendale, PA: SAE International, (June 2018).
https://www.sae.org/standards/content/j3016_201806/

This brief piece outlines the Society of Automotive Engineers' (SAE) reasoning behind their latest revision to the original formulation of the levels of automation in car technologies. The SAE has created a six-level ranking for degrees of vehicle automation, ranging from Level 0, where the driver is fully responsible for all operational functions but may also benefit from driver-assist functions like forward collision warning (FCW), to Level 5 (where the vehicle takes full operational control). Most new vehicles fall somewhere between Level 0 and Level 2, and many now feature significant elements grouped under Advanced Driver Assistance Systems (ADAS). Prominent among these are driver-assist programs, like lane departure warning (LDW), a Level 0 technology that merely warns a driver if the vehicle drifts across a lane marker, and lane keep assist (LKA) and adaptive cruise control (ACC), Level 1 crash prevention and mitigation systems. Level 2 AV technologies can combine to enable vehicles to take over the jobs of steering the vehicle and controlling its speed. Level 3 AV technologies can assume complete control of speed-control, steering, and monitoring the traffic environment, but only when the vehicle is traveling on a limited-access road with no intersections, when posted speeds are moderate, and always with a driver ready to retake the controls as needed. Level 4 consists of Highly Automated Vehicles (HAVs), where the AV system completely controls vehicle actions and human beings are not required to be present. Currently, the Uber and Waymo companies are competing to be first in the race to bring commercial self-driving vehicles into the package delivery and rideshare businesses. At present, no Level 5 full-automation and all-condition vehicle systems exist. Ultimately, they will function within a technology framework where all vehicles are in nearly-constant communication with each other via an overarching system not unlike the internet.

Sullivan JM, Flannagan MJ, Pradhan AK, and Bao S (2016). **Literature review of behavioral adaptation to advanced driver assistance systems** (ADAS). Washington, DC: AAA Foundation for Traffic Safety (March 2016).
https://aaafoundation.org/wp-content/uploads/2017/12/BehavioralAdaptationADAS.pdf

The authors of this study develop the well-known concept of human behavioral adaptation to new technologies and then apply it to the special case of AV technologies. In principle, ADAS systems should benefit drivers and other road users "by providing relief from tedious tasks, alerting drivers about dangerous conditions, and intervening on drivers' behalf when physical limitations preclude an effective driver response." However, the anticipated safety gains of AV systems often shrink because "drivers change their behavior as they integrate these new support systems into their driving routine." Many drivers misunderstand the limitations of their AV technologies and thus may fail to re-engage when they need to. Specific examples of behavioral adaptation include failing to brake properly as a result of over-reliance on adaptive cruise control and failing to steer sufficiently on a curvy road after relying on a steering-assistance system. Owner's manual instructions are typically inadequate for fully informing drivers about their AV systems and thereby ensuring that they understand the limits of those systems. Initial experiences with AV systems that do not result in crashes or near-crashes may increase the drivers tendency to place too much trust in the system.

Yanagisawa M, Swanson ED, Azeredo P, and Najm W (2017). **Estimation of potential safety benefits for pedestrian crash avoidance/mitigation systems**. DOT Report HS 812 400. Washington, DC: National Highway Traffic Safety Administration. https://rosap.ntl.bts.gov/view/dot/12475

These researchers obtained and analyzed U.S. pedestrian injury data from the 2011-2012 national FARS and GES databases and then reduced that data to two specific pedestrian crash types that they defined as "PCAM-addressable," i.e., crashes where pedestrian crash prevention and mitigation systems (PCAMs) would clearly be operative for either preventing crashes or reducing their consequences. These two crash types combined to account for a majority of passenger vehicle-involved pedestrian crashes as well as a large percentage of fatalities and serious injuries resulting from those crashes: where a light vehicle is going straight and strikes a pedestrian crossing the road and where a light vehicle is going straight and strikes a pedestrian either in or along the roadway. The researchers then generated injury-probability estimate curves and vehicle-speed estimates from computer simulations based on sample data, and incorporated those estimates into a model for assessing PCAMs potential for reducing pedestrian crashes as well as their consequences. The authors then developed a method for evaluating the effectiveness of pedestrian crash prevention and mitigation systems for three different existing PCAM systems, procedures, and statistical techniques developed to speed up the evaluation process. The results of their analysis show that PCAM systems are likely to generate a 10 percent to 78 percent crash-avoidance rate, having the potential to prevent up to 5,000 total annual vehicle-pedestrian crashes and 810 fatal vehicle-pedestrian crashes.